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राष्ट्रीय भवन निर्माण मानक 2026
NATIONAL BUILDING CONSTRUCTION STANDARDS 2026

खण्ड 2 / VOLUME 2

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 1 LIGHTING AND NATURAL VENTILATION

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part D/Section 1) covers the lighting and natural ventilation requirements in buildings. Thermal comfort conditions for the building occupants and illumination levels for different tasks are recommended to be achieved either by daylighting or artificial lighting or a combination of both. This section, read together with Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS, adequately covers the thermal comfort conditions for naturally ventilated buildings and mixed mode operation buildings, and the illumination levels required and methods of achieving the same.

Ventilation requirements to maintain air quality, control body odours and pollutants in terms of air changes per hour and to ensure thermal comfort and heat balance of body are laid for different occupancies and the methods of achieving the same by natural means or mixed mode operations means are covered in this Section. The provisions on mechanical ventilation are covered in Part D 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of this NBCS.

Climatic factors which normally help in deciding the orientation of the buildings to get desirable benefits of lighting and natural ventilation inside the buildings are also covered in this section.

This section was first published in 1970 as a part of National Building Code of India. The first revision of the section was brought out in 1983. In the second revision of 2005, some provisions were updated based on the information given in the SP 41 : 1987 'Handbook on functional requirements of buildings (other than industrial buildings)'; other major changes in the 2005 revision included rationalization of definitions and inclusion of definitions for some more terms; inclusion of climatic classification map of India based on a new criteria; updating of data on total solar radiations incident on various surfaces of buildings for summer and winter seasons; inclusion of design guidelines for natural ventilation; reference to Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code for guidelines on mechanical ventilation, made, where these provisions were covered exhaustively; inclusion of rationalized method for estimation of desired capacity of ceiling fans and their optimum height above the floor for rooms of different sizes; incorporation of design sky illuminance values for different climatic zones of India, etc. Energy efficiency was another important aspect which was considered. Accordingly, the relevant requirements for energy efficient system for lighting and natural ventilation were duly included in the concerned provisions under the section.

In third revision of the Code in 2016, the changes that were incorporated include; elaboration of the calculation for solar load, and inclusion of 'Method of calculating solar load on vertical surfaces in different orientation' in Annex A; inclusion of provisions on sky component calculation procedure along with examples in Annex B; inclusion of reference to SP 41 : 1987 for obtaining coefficient utilization for determination of luminous flux; updation of provisions relating to efficient artificial light source and luminaires; inclusion of modern lighting techniques such as LED and induction light in comparison with their energy consumption; updation of provisions relating to photocontrols for artificial lights; inclusion of definitions and enabling provision for lighting shelves and light pipes; elaboration of the provisions related to thermal comfort including indices such as effective temperature, adaptive thermal comfort along with elaborations on tropical summer index; elaboration of design guidelines for natural ventilation with illustrations; elaboration of provisions related to determination of rate of ventilation particularly on combined effect of wind and thermal actions; and inclusion of provision on colour rendering in line with that in SP 72 : 2010 'National Lighting Code 2010'.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

As a result of experience gained since the implementation of the 2016 version of this NBCS and feedback received as well as revisions of Indian Standards on which this Section was based, a need was felt to revise this Section. The significant changes incorporated in this revision include the following:

a) Terminology clause has been updated with new terms and definitions;

b) Orientation of building clause has been renamed to site planning and building placement; and

c) The clause on aspects of daylighting has been updated;

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d) Provisions for spatial and environmental consideration in building design; and operable windows and UV exposure have been added;

e) The aims of good lighting clause has been updated;

f) Table 6 for illuminance and lighting performance parameters have been updated;

g) Provisions for planning and design guidelines for circadian lighting including supplementary artificial circadian lighting have been introduced;

h) Planning and design guidelines for outdoor lighting and its energy efficiency aspects have been introduced;

j) Detailed provisions on design charts for natural ventilation and acceptable air temperature with the increase in the air speed have been added;

k) Provisions of the adaptive thermal comfort mode of ventilation have been reviewed and updated;

The provisions of this Section are without prejudice to the various acts, Rules and Regulations including the *Factories Act*, 1948 and Rules and Regulations framed thereunder.

The information contained in this Section is largely based on the following Indian Standards/Special Publications:

IS 2440 : 1975	Guide for daylighting of buildings (*second revision*)
IS 3103 : 1975	Code of practice for industrial ventilation (*first revision*)
IS 3362 : 1977	Code of practice for natural ventilation of residential buildings (*first revision*)
IS 3646 (Part 1) : 2025	Interior illumination — Code of practice: Part 1 General requirements and recommendations for working interiors (*second revision*)
IS 7662 (Part 1) : 1974	Recommendations for orientation of buildings: Part 1 Nonindustrial buildings
IS 11907 : 1986	Recommendations for calculation of solar radiation on buildings
SP 32 : 1986	Handbook on functional requirements of industrial buildings (lighting and ventilation)
SP 41 : 1987	Handbook on functional requirements of buildings other than industrial buildings

Provisions given in National Lighting Code of India, 'SP 72 : 2025' (*first revision*) may also be referred.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

Assistance has been taken from the following documents in the revision of this Section:

'Report on Energy Conservation in Buildings', submitted to Department of Power, Ministry of Energy by CSIR-Central Building Research Institute, Roorkee.

'Adaptive thermal comfort model based on fields studies in five climate zones across India', Building and Environment, Volume 219, 1 July 2022 by Rawal, R., Shukla, Y., Vardhan, V., et al. (2022)

'Field studies of thermal comfort across multiple climate zones for the subcontinent: India Model for Adaptive Comfort (IMAC)', *Building and Environment*, 98 (March 2106), (pp. 55–70) by Manu, S., Shukla, Y., Rawal, R., Thomas, L. E., and De Dear, R. (2016)

'Low Energy Cooling and Ventilation for Indian Residences: Design Guide', Loughborough University, UK and CEPT Research and Development Foundation (CRDF), India by Cook, M., Shukla, Y., Rawal, R., Loveday, D., Faria, L. C., and Angelopoulos, C. (2020).

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As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **"accepted standard"** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/ Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practices [D-1(1)] refers to the Indian Standard(s) give at serial number (1) of the list of standards given at the end of this Part D/Section 1, that is, IS 7662 (Part 1) : 1974 'Recommendations for orientation of buildings: Part 1 Non-industrial buildings'

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 1 LIGHTING AND NATURAL VENTILATION

1 SCOPE

1.1 This NBCS (Part D/Section 1) covers requirements and methods for lighting and natural ventilation of buildings.

1.2 For all buildings and facilities open to and used by the public, including all forms of public housing by the government/civic bodies and private developers, adequate lighting and natural ventilation for barrier-free access and movement within and around buildings by elderly and persons with disabilities and of different age groups shall be ensured. The ventilation through the building envelope elements such as windows, skylights, ventilators for thermal comfort and better air quality requirements are included in this section.

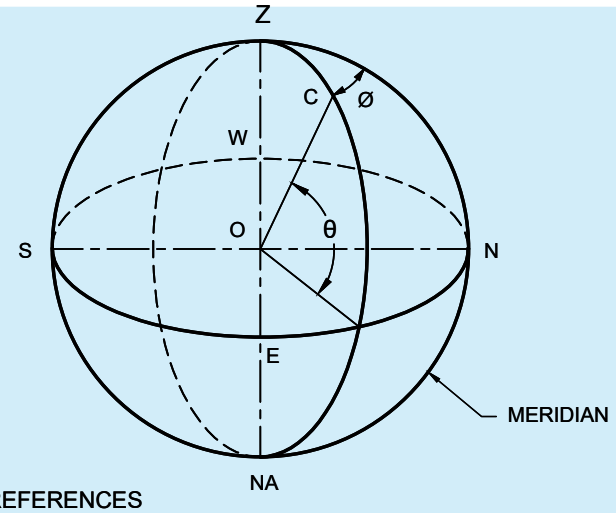
2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

2.1 Lighting

2.1.1 *Altitude* (θ) — The angular distance of any point of celestial sphere, measured from the horizon, on the great circle passing through the body and the zenith (*see* Fig. 1).

2.1.2 *Azimuth* (Φ) — The angle measured between meridians passing through the north point and the point in question (point C in Fig. 1).



REFERENCES

O - Observer's station	*S* - Geographical south
C - Celestial body	*E* - Geographical east
Z - Zenith	*W* - Geographical west
NA - Nadir	*N* - Geographical north

FIG. 1 ALTITUDE AND AZIMUTH OF A CELESTIAL BODY

2.1.3 *Brightness Ratio or Contrast* — The variations or contrast in brightness of the details of a visual task, such as white print on blackboard.

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2.1.4 *Candela* (*cd*) — The SI unit of luminous intensity.

Candela = 1 lumen per steradian

2.1.5 *Central Field* — The area of circle around the point of fixation and its diameter, subtending an angle of about 2 degrees at the eye. Objects within this area are most critically seen in both their details and colour.

2.1.6 *Clear Design Sky* — The distribution of luminance of such a sky is non-uniform; the horizon can be brighter than the zenith depending on the sun position, and when L_z is the brightness at zenith, the brightness at an altitude (θ) in the region away from the sun, is given by the expression:

$$L_\theta = L_z \operatorname{cosec} \theta \ (\text{for } 15^o < \theta \leq 90^o)$$

$$L_\theta = L_z \operatorname{cosec} 15^o \ (\text{for } 0^o \leq \theta \leq 15^o) = 3.863\ 7\ L_z$$

2.1.7 *Circadian Lighting* — A lighting means that uses electric lights in a way that supports natural sleep and wake cycle of humans. This is done by changing how bright the light is and what colour it is throughout the day, so it matches what the body expects from natural daylight and night time.

2.1.8 *Colour Rendering Index* (*CRI*) — Measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

2.1.9 *Correlated Colour Temperature* (*CCT*) (*K*) — The temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions.

2.1.10 *Daylighting* — The strategic use of natural optical radiation from the sun and sky to illuminate interior spaces, enhancing visual comfort and supporting human circadian regulation. In this context, daylight encompasses the portion of solar radiation within the visible spectrum, typically between 380 nm and 780 nm. Effective daylighting design aims to maximize natural light penetration, minimize reliance on electric lighting, and promote occupant health and well-being.

2.1.11 *Daylight Area* — The portion of an interior space where the working plane receives natural light at or above a specified daylight factor or meets a defined minimum illuminance threshold. This area is typically delineated by a daylight factor contour, representing zones with adequate daylight levels for visual tasks.

2.1.12 *Daylight Factor* — The ratio, expressed as a percentage, of the illuminance at a specific point on a given plane indoors to the simultaneous illuminance on a horizontal plane outdoors under an overcast sky. This factor measures the amount of daylight reaching the indoor point relative to outdoor conditions, providing an indication of natural light availability in interior spaces.

2.1.13 *Daylight Penetration* — The maximum distance to which a given daylight factor contour penetrates into a room.

2.1.14 *Direct Solar Illuminance* — The illuminance from the sun without taking into account the light from the sky.

2.1.15 *External Reflected Component* (*ERC*) — Daylight illuminance at a point which is received by direct reflection from external surfaces.

2.1.16 *Glare* — A condition of vision in which there is discomfort or a reduction in the ability to see significant objects or both due to an unsuitable distribution or range of luminance or due to extreme contrasts in space.

2.1.17 *Illuminance* — At a point on a surface, the ratio of the luminous flux incident on an infinitesimal element of the surface containing the point under consideration to the area of the element.

NOTE — The unit of illuminance (the measurement of illumination) is lux which is 1 lumen per m^2.

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2.1.18 *Indoor Artificial Lighting* — Artificial lighting powered by electricity, designed to enhance visual comfort, task performance, and occupant well-being in indoor environments. Its effectiveness is assessed using several key parameters:

a) *Spectral power density* (*SPD*) — Describes the relative power of a light source at each wavelength across the visible spectrum. SPD influences colour rendering, visual perception and biological effects, including circadian response;

b) *Colour tuning* — The capability to dynamically adjust the correlated colour temperature (*CCT*) and spectral content of the light source, allowing adaptation to user preferences, visual tasks, or time-of-day considerations to support circadian health;

c) *Light flicker* — Rapid fluctuations in luminous intensity that may be visible or invisible to the human eye. Flicker can cause visual fatigue, headaches, or reduced task performance. The P_{st}^{LM} value (short-term flicker severity measured by the light flickermeter method) is used to quantify flicker in lighting systems; and

d) *Unified glare rating* (*UGR*) — A standardized metric that quantifies discomfort glare in indoor spaces. Lower UGR values indicate better visual comfort and help prevent visual strain without reducing task visibility.

2.1.19 *Internal Reflected Component* (*IRC*) — Daylight illuminance at a point in a given plane which is received by direct reflection or inter-reflection from the internal surfaces.

2.1.20 *Light Output Ratio* (*LOR*) *or Efficiency* (η) — The ratio of the luminous flux emitted from the luminaire to that emitted from the lamp(s) (nominal luminous flux). It is expressed in percent.

2.1.21 *Light Pipe* — A conduit made of a highly reflective material, which is capable of channelling light from one end to the other through successive internal reflections. Such a pipe may be flexible or rigid.

2.1.22 *Light Shelf* — A daylighting system based on sun path geometry used to bounce the light off a ceiling, project it deeper into a space, distribute it from above and diffuse it to produce a uniform light level below.

2.1.23 *Lumen* (*lm*) — SI unit of luminous flux. The luminous flux emitted within unit solid angle (one steradian) by a point source having a uniform intensity of one candela.

2.1.24 *Luminance* (*at a Point of a Surface in a Given Direction*) (*Brightness*) — The quotient of the luminous intensity in the given direction of an infinitesimal element of the surface containing the point under consideration by the orthogonally projected area of the element on a plane perpendicular to the given direction. The unit is candela per square metre (cd/m^2).

2.1.25 *Luminous Flux* (ϕ) — The quantity characteristic of radiant flux which expresses its capacity to produce visual sensation evaluated according to the values of relative luminous efficiency for the light adapted eye:

a) *Effective luminous flux* (ϕ_n) — Total luminous flux which reaches the working plane; and

b) *Nominal luminous flux* (ϕ_o) — Total luminous flux of the light sources in the interior.

2.1.26 *Maintenance Factor* (*d*) — The ratio of the average illuminance on the working plane after a certain period of use of a lighting installation to the average illuminance obtained under the same conditions for a new installation.

2.1.27 *Meridian* — It is the great circle passing through the zenith and nadir for a given point of observation.

2.1.28 *North and South Points* — The point in the respective directions where the meridian cuts the horizon.

2.1.29 *Orientation of Buildings* — In the case of non-square buildings, orientation refers to the direction of the normal to the long axis. For example, if the length of the building is east-west, its orientation is north-south.

2.1.30 *Outdoor Artificial Lighting* — Lighting systems specifically designed for exterior environments, intended to enhance visibility, safety and security during nighttime hours while minimizing adverse environmental and ecological impacts. Key considerations include:

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a) *Fully shielded* — Luminaire designs that emit light only in the downward direction, preventing upward light emissions. This helps control glare and limits contributions to light pollution;

b) *Full cut-off* — A luminaire classification where zero light is emitted at or above the horizontal plane of the fixture. This design minimizes sky glow and enhances lighting efficiency by directing light only where it is needed;

c) *Light trespass* — The unintended or intrusive illumination of areas beyond the target zone, such as neighbouring properties, streets, or natural habitats. Light trespass can lead to discomfort, sleep disruption and privacy issues; and

d) *Sky glow* — The diffuse illumination of the night sky caused by artificial lighting, particularly from urban areas. Sky glow reduces the visibility of stars, interferes with astronomical observations and disrupts nocturnal ecosystems.

2.1.31 *Peripheral Field* — It is the rest of the visual field which enables the observer to be aware of the spatial framework surrounding the object seen.

NOTE — A central part of the peripheral field, subtending an angle of about 30º on either side of the point of fixation, is chiefly involved in the perception of glare.

2.1.32 *Reflected Glare* — The adverse impact on visual comfort and efficiency caused by unwanted reflections in the task area, which can hinder the ability to see clearly or cause discomfort, regardless of the source of the glare.

2.1.33 *Surface Reflectance* (*Reflectance*) — The ratio of the luminous flux reflected by an opaque surface (with or without diffusion) to the flux it receives. Here the term is used for lighting. Some symbols used for surface reflectance of common indoor surfaces are:

r_c = reflection factor of ceiling.

r_w = reflection factor of parts of the wall between the working surface and the luminaires.

r_f = reflection factor of floor.

2.1.34 *Reveal* — The side of an opening for a window.

2.1.35 *Room Index* (k_r) — An index relating to the shape of a rectangular interior, according to the formula:

$$k_r = \frac{L \times W}{(L + W)\, H_m}$$

where

L and W = length and width respectively of the interior; and

H_m = mounting height, that is, height of the fittings above the working plane.

NOTES

1 For rooms where the length exceeds 5 times the width, L shall be taken as $L = 5W$.

2 If the surface reflectance of the upper stretch of the walls is less than half the surface reflectance of the ceiling, for indirect or for the greater part of indirect lighting, the value H_m is measured between the ceiling and the working plane.

2.1.36 *Sky Component* (*SC*) — Daylight illuminance at a point on a given plane which is received directly from the sky.

2.1.37 *Solar Load* — The amount of heat received into a building due to solar radiation which is affected by orientation, materials of construction and reflection of external finishes and colour.

2.1.38 *Utilization Factor* (*Coefficient of Utilization*) (μ) — The ratio of the total luminous flux which reaches the working plane (effective luminous flux, ϕ_n) to the total luminous flux of the light sources in the interior (nominal luminous flux, ϕ_o).

2.1.39 *UV-A* — Ultraviolet radiation with wavelengths between 315 and 400 nm. UV-A penetrates the skin more deeply than UV-B and contributes to photoaging, oxidative stress, and potential DNA damage through indirect

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mechanisms. While it plays a role in skin ageing and long-term health effects, UV-A is significantly less effective for germicidal and disinfection purposes due to its lower energy.

2.1.40 *UV-B* — Ultraviolet radiation with wavelengths between 280 nm and 315 nm. UV-B plays a critical role in the synthesis of pre-vitamin D3 in the human skin upon exposure. It has higher biological activity than UV-A and can also cause sunburn and DNA damage with excessive exposure.

2.1.41 *Visual Field* — The visual field in the binocular which includes an area approximately 120º vertically and 160º horizontally centering on the point to which the eyes are directed. The line joining the point of fixation and the centre of the pupil of each eye is called its primary line of sight.

2.1.42 *Working Plane* — A horizontal plane at a level at which work will normally be done (*see* **4.1.4.4** and **4.1.4.5**).

2.2 Ventilation

2.2.1 *Air Change per Hour* — The amount of air leakage into or out of a building or room in terms of the number of building volume or room volume exchanged.

2.2.2 *Axial Flow Fan* — A fan having a casing in which the air enters and leaves the impeller in a direction substantially parallel to its axis.

2.2.3 *Centrifugal Fan* — A fan in which the air leaves the impeller in a direction substantially at right angles to its axis.

2.2.4 *Contaminants* — Dusts, fumes, gases, mists, vapours and such other substances present in air that are likely to be injurious or offensive to the occupants.

2.2.5 *Dilution Ventilation* — Supply of outside air to reduce the airborne concentration of contaminants in the building.

2.2.6 *Dry Bulb Temperature* — The temperature of the air, read on a thermometer, taken in such a way so as to avoid errors due to radiation.

2.2.7 *Effective Temperature* (*ET*) — An arbitrary index which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body and its numerical value is that of the temperature of still saturated air which would induce an identical sensation.

2.2.8 *Exhaust of Air* — Removal of air from a building or a room and its disposal outside by means of a mechanical device, such as a fan.

2.2.9 *Fresh Air or Outside Air* — Air of that quality, which meets the criteria of Table 1 and in addition shall be such that the concentration of any contaminant in the air is limited to within one-tenth the threshold limit value (TLV) of that contaminant.

NOTES

1 Where it is reasonably believed that the air of quality is not expected as indicated above, sampling and analysis shall be carried out by a competent authority having jurisdiction and if the outside air of the specified quality is not available, filtration and other treatment devices shall be used to bring its quality to or above the levels mentioned in Table 1. Odour is to be essentially unobjectionable.

2 The above list of contaminants is not exhaustive and available special literature may be referred for data on other contaminants.

2.2.10 *General Ventilation* — Ventilation, either natural or mechanical or both, so as to improve the general environment of the building, as opposed to local exhaust ventilation for contamination control.

2.2.11 *Globe Temperature* — The temperature measured by a thermometer whose bulb is enclosed in a matt black painted thin copper globe of 150 mm diameter. It combines the influence of air temperature and thermal radiations received or emitted by the bounding surfaces.

2.2.12 *Humidification* — The process whereby the absolute humidity of the air in a building is maintained at a higher level than that of outside air or at a level higher than that which would prevail naturally.

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Table 1 Maximum Allowable Contaminant Concentrations for Ventilation Air

(*Clause* 2.2.9)

Sl No.	Contaminants	Annual Average (Arithmetic Mean)	Short Term Level (Not to Exceed More than Once a Year)	Averaging Period
		µg/m^3	µg/m^3	h
(1)	(2)	(3)	(4)	(5)
i)	Suspended particulates	60	150	24
ii)	Sulphur oxides	80	400	24
iii)	Carbon monoxide	20 000	30 000	8
iv)	Photochemical oxidant	100	500	1
v)	Hydrocarbons (not including methanes)	1 800	4 000	3
vi)	Nitrogen oxide	200	500	24

2.2.13 *Humidity*, *Absolute* — The mass of water vapour per unit volume.

2.2.14 *Humidity*, *Relative* — The ratio of the partial pressure or density of the water vapour in the air to the saturated pressure or density respectively of water vapour at the same temperature.

2.2.15 *Local Exhaust Ventilation* — Ventilation effected by exhaust of air through an exhaust appliance, such as a hood with or without fan located as closely as possible to the point at which contaminants are released, so as to capture effectively the contaminants and convey them through ducts to a safe point of discharge.

2.2.16 *Make-up Air* — Outside air supplied into a building to replace the indoor air.

2.2.17 *Mechanical Ventilation* — Supply of outside air either by positive ventilation or by infiltration by reduction of pressure inside due to exhaust of air, or by a combination of positive ventilation and exhaust of air.

2.2.18 *Natural Ventilation* — Supply of outside air into a building through window or other openings due to wind outside and convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building.

2.2.19 *Positive Ventilation* — The supply of outside air by means of a mechanical device, such as a fan.

2.2.20 *Propeller Fan* — A fan in which the air leaves the impeller in a direction substantially parallel to its axis designed to operate normally under free inlet and outlet conditions.

2.2.21 *Spray-Head System* — A system of atomizing water so as to introduce free moisture directly into a building.

2.2.22 *Stack Effect* — Convection effect arising from temperature or vapour pressure difference (or both) between outside and inside of the room and the difference of height between the outlet and inlet openings.

2.2.23 *Tropical Summer Index* (*TSI*) — The temperature of calm air at 50 percent relative humidity which imparts the same thermal sensation as the given environment.

2.2.24 *Threshold Limit Value* (*TLV*) **—** Refers to air-borne concentration of contaminants currently accepted by the American Conference of Governmental Industrial Hygienists and represents conditions under which it is believed that nearly all occupants may be repeatedly exposed, day after day, without adverse effect.

2.2.25 *Velocity*, *Capture* — Air velocity at any point in front of the exhaust hood necessary to overcome opposing air currents and to capture the contaminants in air at that point by causing the air to flow into the exhaust hood.

2.2.26 *Ventilation* — Supply of outside air into, or the removal of inside air from an enclosed space.

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2.2.27 *Wet Bulb Temperature* — The steady temperature finally given by a thermometer having its bulb covered with gauze or muslin moistened with distilled water and placed in an air stream of not less than 4.5 m/s.

3 SITE PLANNING AND BUILDING PLACEMENT

3.1 The aim of site planning and building placement for optimum building orientation is to provide physically and psychologically comfortable living inside the building by creating conditions which suitably and successfully ward off the undesirable effects of severe weather to a considerable extent by judicious use of the recommendations and knowledge of climatic factors.

3.2 Climate Zones

3.2.1 For the purpose of design of buildings, the country may be divided into the major climatic zones as given in Table 2, which also gives the basis of this classification.

Table 2 Classification of Climate

(*Clause* 3.2.1)

Sl No.	Climatic Zone	Mean Monthly Maximum Temperature °C	Mean Monthly Relative Humidity Percent
(1)	(2)	(3)	(4)
i)	Hot-dry	Above 30	Below 55
ii)	Warm-humid	Above 30	Above 55
		Above 25	Above 75
iii)	Temperate	25 to 30	Below 75
iv)	Cold	Below 25	All values
v)	Composite	*See* **3.2.2**	*See* **3.2.2**

The climatic classification map of India is shown in Fig. 2.

3.2.2 Each climatic zone does not have same climate for the whole year; it has a particular season for more than six months and may experience other seasons for the remaining period. A climatic zone that does not have any season for more than six months may be called as composite zone.

3.3 Climatic Factors

From the point of view of lighting and natural ventilation, the following climatic factors influence the optimum orientation of the building:

a) Solar radiation and temperature;

b) Relative humidity; and

c) Prevailing winds.

3.4 Solar Radiation

3.4.1 The best orientation from a solar point of view requires that the building as a whole should receive the maximum solar radiation in winter and the minimum in summer. For practical evaluation, it is necessary to know the duration of sunshine and hourly solar intensity on the various external surfaces on representative days of the seasons. The total direct plus diffused diurnal solar loads per unit area on the vertical surface facing different directions are given in Table 3 for two days in the year, that is, 22 June and 22 December, representative of summer and winter, for latitudes corresponding to some important cities all over India. From Table 3, the total heat intake can be calculated for all possible orientations of the building for these extreme days of summer and winter. Solar load on vertical surfaces of different orientations can be calculated as per the method given in Annex A.

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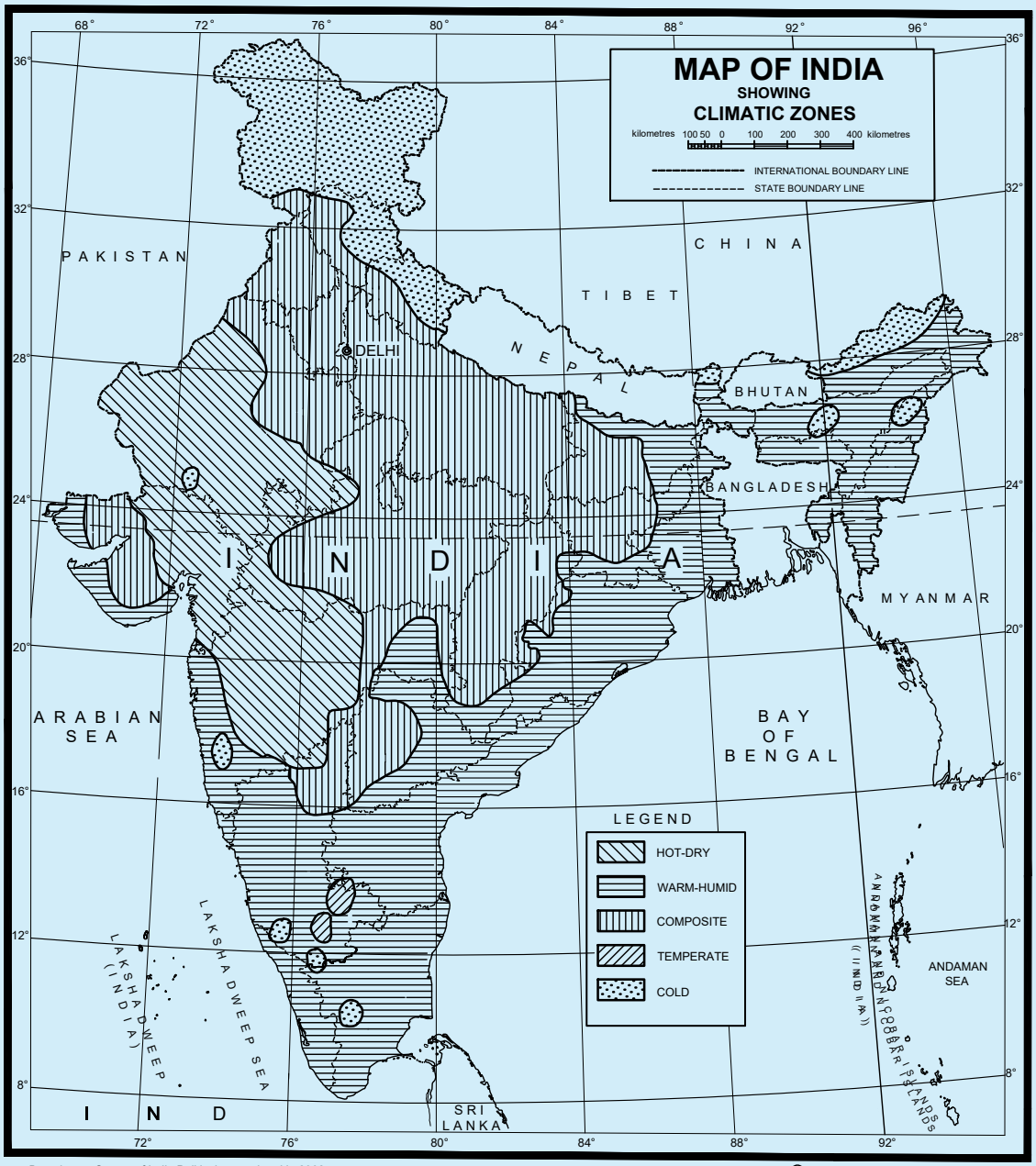

Based upon Survey of India Political map printed in 2002.

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate baseline.

The interstate boundaries between Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the North-Eastern Areas (Reorganization) Act, 1971, but have yet to be verified.

The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India.

The responsibility for the correctness of internal details rest with the publisher.

FIG. 2 MAP OF INDIA SHOWING CLIMATIC ZONES

3.4.1.1 Except in cold climatic zone, suitable sun-breakers have to be provided to cut off the incursion of direct sunlight to prevent heat radiation and to avoid glare. A location (latitude) and weather specific approach to sizing of shading devices should consider the annual start and end date of the summer season for the building. Table 3

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shows irradiation (W/m^2) received per unit of the facade area in each orientation. Irradiation values maybe used for prioritizing shading devices and other measures of solar protection (for example, planting of vegetation).

Table 3 Total Solar Radiation (Direct Plus Diffused) Incident on Various Surfaces of Buildings, in W/m^2/day, for Summer and for Winter Seasons

(*Clause* 3.4.1, 3.4.1.1 *and* A-2.1.3)

Sl No.	Orientation	Season	Latitude					
			9° N	13° N	17° N	21° N	25° N	29° N
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	North	Summer	1 494	1 251	2 102	1 775	2 173	1 927
		Winter	873	859	840	825	802	765
ii)	North-East	Summer	2 836	2 717	3 144	3 092	3 294	3 189
		Winter	1 240	1 158	1 068	1 001	912	835
iii)	East	Summer	3 344	3 361	3 475	3 598	3 703	3 794
		Winter	2 800	2 673	2 525	2 409	2 211	2 055
iv)	South-East	Summer	2 492	2 660	2 393	2 629	2 586	2 735
		Winter	3 936	3 980	3 980	3 995	3 892	3 818
v)	South	Summer	1 009	1 185	1 035	1 117	1 112	1 350
		Winter	4 674	4 847	4 958	5 059	4 942	4 981
vi)	South-West	Summer	2 492	2 660	2 393	2 629	2 586	2 735
		Winter	3 936	3 980	3 980	3 995	3 892	3 818
vii)	West	Summer	3 341	3 361	3 475	3 598	3 703	3 794
		Winter	2 800	2 673	2 525	2 409	2 211	2 055
viii)	North-West	Summer	2 836	2 717	3 144	3 092	3 294	3 189
		Winter	1 240	1 158	1 068	1 001	912	835
ix)	Horizontal	Summer	8 107	8 139	8 379	8 553	8 817	8 863
		Winter	6 409	6 040	5 615	5 231	4 748	4 281

3.5 Relative Humidity and Prevailing Winds

3.5.1 The discomfort due to high relative humidity in air when temperatures are also high can be counteracted, to a great extent, by circulation of air with electric fans or by ventilation. In the past, simultaneously with heavy construction and surrounding *Verandahs* to counter the effect of sun's radiation, there was also an over emphasis on prevailing winds to minimise the adverse effects of high humidity with high temperatures. With the introduction of electric fan to effectively circulate air and owing to taking into account the rise in cost of construction of buildings, emphasis should be on protection from solar radiation where temperatures are very high. When, however, there is less diurnal variation between morning and mean maximum temperatures along with high humidity, as in coastal areas, the emphasis should be on prevailing winds.

3.5.1.1 For the purpose of orientation, it is necessary to study the velocity and direction of the wind at each hour and in each month instead of relying on generalizations of a month or a period or for the year as a whole. This helps to spot the right winds for a particular period of day or night.

3.5.1.2 It is generally found that variation up to 30° with respect to the prevalent wind direction does not materially affect indoor ventilation (average indoor air speed) inside the building.

3.5.2 In hot-dry climate, advantage can be taken of evaporative cooling in summer to cool the air before introducing it into the building. But in warm humid climate, it is desirable either to regulate the rate of air movement with the aid of electric fans or to take advantage of prevailing winds.

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3.6 Aspects of Daylighting

The clear design sky concept accounts for the worst-case scenario, making building orientation less critical, except for the need to avoid direct sunlight and glare. However, mutual shading effects from opposite facades and significant vegetation elements shall be considered to maintain effective daylighting. For glare control reference may be made from relevant guidelines/best practices ('Handbook on Sustainability in Buildings'). Daylighting design is supported by three key pillars: daylight availability, sun control, and glare control, all of which are essential to ensure optimal visual comfort and energy efficiency within buildings.

3.7 Spatial and Environmental Considerations in Building Design

Sustainable building design focuses on optimizing the use of natural resources, improving energy efficiency and ensuring occupant well-being. Integrating natural elements such as vegetation and considering the spatial relationships between buildings play a crucial role in enhancing daylight access, ventilation, and thermal comfort, while promoting ecological balance.

The following considerations should guide the integration of these elements into building design:

a) It is suggested to plant tall trees or plants at least as tall as the building around new buildings. This can make the area look aesthetic and help the environment by giving shade, cleaning the air and making the place cooler. It is also better to use plants that naturally grow in the area;

b) Adequate spacing between a building and neighbouring structures is essential for ensuring access to natural light, ventilation, and privacy. The distance between buildings should be planned to minimize overshadowing, reduce light trespass and promote natural airflow, enhancing the overall livability of the area;

c) The orientation of building facades relative to cardinal directions should be planned to optimize solar gain, energy efficiency, and occupant comfort. Facades should maximize natural light while minimizing glare and overheating, contributing to overall energy efficiency and improving thermal performance; and

d) Tree planting in open spaces and streets should be carefully planned to provide shade during the summer season, allow intermittent or seasonal sunlight access, without obstructing natural winds or compromising daylight access. The selected trees should reduce glare, create cool microclimates, and improve air quality. Deciduous trees that shed leaves in winter and retain thick foliage in summer are especially advantageous, particularly for southern and western exposures, allowing maximum sunlight in winter and providing effective shading in summer. Trees with high-density foliage and low gap percentages (for example, *Ashoka*, *Asopalav*) should be placed at a distance proportional to their mature height to avoid obstructing light and airflow. Less dense or deciduous trees (for example, *Gulmohar*, *Amaltas*, *Neem*) may be planted with considerations beyond daylight access, including aesthetics and ecological benefits. In addition, it is recommended that native species of trees be preferred, as identified by the respective state environmental departments, to support region-specific environmental planning.

3.8 Operable Windows and UV Exposure

Operable windows should be provided in habitable spaces to allow for natural ventilation and daylighting. Most glazing types (single pane or double pane) block the UV part of the solar radiation to avoid over-exposure of interiors and occupants to damaging effects of UV radiation. However, some UV exposure has health benefits (UV-B for vitamin D3 production) that occupants can only access if the glass windows are operable. Operable windows should be designed for maximum accessibility to building occupants and direct sun access on facades that receive direct sun, operable windows should be preferred from healthy daylight access point-of-view.

3.9 For detailed information regarding orientation of buildings and recommendations for various climatic zones of country, reference may be made to good practice [D-1(1)].

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4 LIGHTING

4.1 Principles of Lighting

4.1.1 *Aims of Good Lighting*

Good lighting is an essential element of building design, serving both visual and non-visual functions to promote occupant comfort, safety and well-being. It should ensure a visually comfortable and functional environment that enhances task performance, supports safe movement and complements the architectural and interior design of spaces. Beyond meeting visual requirements, lighting should also address non-visual impacts by supporting healthy circadian rhythms and aiding in proper eye development, particularly in children. Effective control of glare is critical, as poorly managed glare can lead to visual discomfort, eye strain and headaches. Proper glare management not only improves visual comfort and productivity but also contributes significantly to occupant satisfaction and overall quality of life in buildings.

4.1.1.1 Realization of these aims involves the following:

a) Careful planning of the brightness and colour pattern within both the working areas and the surroundings so that attention is drawn naturally to the important areas, detail is seen quickly and accurately and the room is free from any sense of gloom or monotony (*see* **4.1.4**);

b) Using directional lighting where appropriate to assist perception of task detail and to give good modelling;

c) Controlling direct and reflected glare from light sources to eliminate visual discomfort;

d) In artificial lighting installations, minimizing flicker from certain types of lamps and paying attention to the colour rendering properties of the light;

e) Correlating lighting throughout the building to prevent excessive differences between adjacent areas so as to reduce the risk of accidents; and

f) Installing emergency lighting systems, where necessary.

4.1.2 *Planning the Brightness Pattern*

The brightness pattern seen within an interior may be considered as composed of three main parts – the task itself, immediate background of the task and the general surroundings of walls, ceiling, floor, equipment and furnishings.

The illuminance requirements given in good practice [D-1(2)] for elders and persons with disabilities, shall be complied with in addition to the requirements specified in this Section.

4.1.2.1 In occupations where the visual demands are small, the levels of illumination derived from a criterion of visual performance alone may be too low to satisfy the other requirements. For such situations, therefore, illuminance recommendations are based on standards of welfare, safety and amenity judged appropriate to the occupations; they are also sufficient to give these tasks brightness which ensures that the visual performance exceeds the specified minimum.

4.1.2.2 Where work takes place over the whole utilizable area of room, the illumination over that area should be reasonably uniform and it is recommended that the uniformity ratio (minimum illuminance divided by average illuminance levels) should be not less than 0.7 for the working area.

4.1.2.3 To ensure visual comfort and minimize strain, the illuminance levels within a space should be carefully balanced. Large spatial variations in illuminance around the task or activity area shall be avoided, as they can lead to visual stress and discomfort. The illuminance of the immediate surrounding area shall be related to that of the task area or activity area, ensuring a well-balanced luminance distribution within the visual field. This immediate surrounding area shall be defined as a band with a minimum width of 0.5 m around the task area. While the illuminance of this surrounding area may be lower than that of the task area, it shall not fall below the minimum values specified in Table 4. Additionally, the size and position of the immediate surrounding area shall be clearly stated and documented in the lighting design specifications. Proper planning of these illuminance levels contributes to a visually comfortable and efficient built environment.

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Table 4 Relationship of Average Illuminances on Immediate Surrounding to the Average Illuminance on the Task Area or Activity Area

(*Clause* 4.1.2.3)

Sl No.	Average Illuminance on the Task Area or Activity Area	Average Illuminance on Immediate Surrounding Areas
	lx	lx
(1)	(2)	(3)
i)	≥750	500
ii)	500	300
iii)	300	200
iv)	200	150
v)	≤150	equal to task area

4.1.2.4 In indoor workplaces, particularly those devoid of daylight, ensuring adequate illumination beyond the immediate task surroundings is essential for visual comfort and spatial perception. A large area outside the immediate surrounding area, referred to as the background area, shall be illuminated to maintain a well-balanced visual environment. The background area is a horizontal surface at floor level, adjacent to the immediate surrounding area within the limits of the space. It shall have a maintained average illuminance of at least one-third of the illuminance value of the immediate surrounding area. In larger rooms, this background area shall have a minimum width of 3 m to ensure uniformity in lighting. Proper illumination of the background area may help in reducing visual fatigue and enhancing overall workplace efficiency.

4.1.2.5 In case of all buildings and facilities open to and used by the public, including all forms of public housing by the government/civic bodies and private developers, the requirements for visual contrast as given in good practice [D-1(2)] shall also be complied with for ensuring visual comfort for elders and persons with disabilities.

4.1.3 *Glare*

Excessive contrast or abrupt and large changes in brightness produce the effect of glare. When glare is present, the efficiency of vision is reduced and small details or subtle changes in scene cannot be perceived. It may be,

a) direct glare due to light sources within the field of vision;

b) reflected glare due to reflections from light sources or surfaces of excessive brightness; and

c) veiling glare where the peripheral field is comparatively very bright.

4.1.3.1 An example of glare sources in daylighting is the view of the bright sky through a window or skylight, especially when the surrounding wall or ceiling is comparatively dark or weakly illuminated. Glare can be minimized in this case either by shielding the open sky from direct sight by louvers, external hoods or deep reveals, curtains or other shading devices or by cross lighting the surroundings to a comparable level. A gradual transition of brightness from one portion to the other within the field of vision always avoids or minimizes the discomfort from glare.

For electric lamps the minimum shielding angles for lamp luminance shall not be less than the values given in the table below:

Sl No.	*Lamp Luminance*	*Minimum Shielding Angle*
	kcd/m^2	Degrees
(1)	(2)	(3)
i)	1 to 20	10
ii)	20 to 50	15
iii)	50 to 500	20
iv)	≥500	30

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The above mentioned shielding angle should not be applied to luminaries who do not appear in the field of view of a worker during usual work and/or do not give the worker any noticeable disability glare

Table 6 also gives recommended value of quality class of direct glare limitation for different tasks. These are numbers assigned to qualitative limits of direct glare; high, medium and low quality as 1, 2 and 3, respectively. For more details, reference may be made to good practice [D–1(3)].

4.1.4 *Recommended Values of Illuminance*

Table 6 gives the illuminance and lighting performance parameters commensurate with the general standards of lighting described in this Section and related to many occupations and buildings. These are valid under most of the conditions whether the illumination is by daylighting, artificial lighting or a combination of the two. The great variety of visual tasks makes it impossible to list them all and those given should be regarded as representing types of tasks.

The illuminance shall comply with the requirements given in good practice [D-1(2)] for persons with disabilities, in addition to the requirements specified in Table 6.

For comprehending and applying Table 6, reference may be made to **4.1.4.1** to **4.1.7**.

4.1.4.1 *Composition of Table* 6

a) Column (2) lists the reference number for each task area or activity area;

b) Column (3) lists those tasks areas or activities areas, for which specific requirements are given. If the particular task or activity is not listed, the values given for a similar, comparable situation should be adopted. Task areas or activity areas can also be a room, for example, a corridor or resting room;

c) Column (4) gives the required maintained average illuminance $\bar{E}_m$ on the reference surface (*see* **4.1.7**) for the interior (area) in which the task or activity from column (3) is performed;

d) Column (5) gives the minimum illuminance uniformity U_o on the reference surface for the maintained average illuminance $\bar{E}_m$ chosen according to **5**;

e) Column (6) gives the minimum colour rendering indices (R_a) (*see* **4.1.8**) for the situation listed in col (3);

f) Column (7) gives the unified glare rating limits (UGR limits, R_{UGL}) that are applicable to the situation listed in col (3) (*see* **4.1.3**);

g) Column (8) gives the maintained cylindrical illuminance $\bar{E}_{m,z}$ for the recognition of object and people;

h) Column (9) gives the maintained average illuminance on walls $\bar{E}_{m,wall}$; and

j) Column (10) gives the maintained average illuminance on ceilings $\bar{E}_{m,ceiling}$.

4.1.4.2 Indicative list detailing the different locations and tasks are grouped as per the following:

Sl No.	*Location*	*Tasks/Specific Location*
(1)	(2)	(3)
i)	Traffic zones inside buildings	–
ii)	General areas inside buildings	Rest, sanitation and first aid rooms Control rooms Store rooms, cold stores
iii)	Logistics and warehouses	–

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Table (*Concluded*)

Sl No.	*Location*	*Tasks/Specific Location*
(1)	(2)	(3)
iv)	Industrial activities and crafts	Agriculture Bakeries Cement, cement goods, concrete, bricks Ceramics, tiles, glass, glassware Chemical, plastics and rubber industry Electrical and electronic industry Food stuffs and luxury food industry Foundries and metal casting Hair dressers Jewellery manufacturing Laundries and dry cleaning Leather and leather goods Metal working and processing Paper and paper goods Power stations Printers Rolling mills, iron and steel works Textile manufacture and processing Vehicle construction and repair Wood working and processing
v)	Offices	–
vi)	Retail premises	–
vii)	Places of public assembly	General areas Restaurants and hotels Theatres, concert halls, cinemas, places for entertainment Trade fairs, exhibition halls Museums Libraries Car parks (indoor)
viii)	Educational premises	Nursery school, play school Educational buildings
ix)	Health care premises	Rooms for general use Staff rooms Wards, maternity wards Examination rooms (general) Eye examination rooms Ear examination rooms Scanner rooms Delivery rooms Treatment rooms (general) Operating areas Intensive care unit Dental clinics/units Laboratories and pharmacies Decontamination rooms Autopsy rooms and mortuaries
x)	Transportation areas	Airports Railway installations

4.1.4.3 The illumination levels recommended in Table 6 are those to be maintained at all time on the task. As circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or

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activity instead of a single value of illuminance. Each range consists of three successive steps of the recommended scale of illuminances. They represent good practice and should be regarded as giving order of illumination commonly required rather than as having some absolute significance. For working interiors, the middle value of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.

4.1.4.3.1 The higher value of the range should be used when,

a) unusually low reflectances or contrasts are present in the task;

b) errors are costly to rectify;

c) visual work is critical;

d) accuracy or higher productivity is of great importance; and

e) visual capacity of the worker makes it necessary.

4.1.4.3.2 The lower value of the range may be used when,

a) reflectances or contrast are unusually high;

b) speed and accuracy is not important; and

c) the task is executed only occasionally.

4.1.4.4 Where a visual task is required to be carried out throughout an interior, general illumination level to the recommended value on the working plane is necessary; where the precise height and location of the task are not known or cannot be easily specified, the recommended value is that on horizontal plane 850 mm above floor level.

NOTE — For an industrial task, working plane for the purpose of general illumination levels is that on a work place which is generally 750 mm above the floor level. For certain purposes, such as viewing the objects of arts, the illumination levels recommended are for the vertical plane at which the art pieces are placed.

4.1.4.5 Where the task is localized, the recommended value is that for the task only; it need not, and sometimes should not, be the general level of illumination used throughout the interior. Some processes, such as industrial inspection process, call for lighting of specialized design, in which case the level of illumination is only one of the several factors to be taken into account.

4.1.4.6 In case of all buildings and facilities open to and used by the public, including all forms of public housing by the government/civic bodies and private developers, the minimum illuminance level as given in good practice [D-1(2)] shall also be complied with for ensuring sufficient lighting for accessibility by elders and persons with disabilities.

4.1.5 *Lighting for Movement about a Building*

Most buildings are complexes of working areas and other areas, such as passages, corridors, stairways, lobbies and entrances. The lighting of all these areas shall be properly correlated to give safe movement within the building at all times. In case of all buildings and facilities open to and used by the public, including all forms of public housing by the government/civic bodies and private developers, the illuminance in these areas shall comply with the requirements given in good practice [D-1(2)].

4.1.5.1 *Corridors, passages and stairways*

Transitions from brightly lit work areas to dimly lit corridors, passages, or stairways can pose safety risks, as the human eye requires time to adapt to significant changes in luminance. To mitigate these risks, such transitional spaces should be illuminated uniformly and adequately to ensure clear visibility and safe movement. In areas that are used intermittently, occupancy or motion-sensing lighting controls may be used to conserve energy while ensuring illumination is provided when the space is occupied. Stairways should be designed to prevent direct glare from luminaires and to eliminate harsh shadows that can obscure steps. Tread lighting or integrated step-strip lighting can be used to delineate step edges, especially in low-light environments or emergency egress paths. For outdoor applications, such as industrial catwalks and stairways, lighting should be robust, weather-resistant, and positioned to provide uniform coverage without creating glare. These strategies collectively enhance visual guidance, reduce fall hazards, and improve overall safety in circulation spaces.

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4.1.5.2 *Entrances*

The problems of correctly grading the lighting within a building to allow adequate time for adaptation when passing from one area to another area are particularly acute at building entrances. These are given below:

a) By day, people entering a building will be adapted to the very high levels of brightness usually present outdoors and there is risk of accident if entrance areas, particularly any steps, are poorly lighted. This problem may often be overcome by arranging windows to give adequate natural lighting at the immediate entrance, grading to lower levels further inside the entrance area. Where this cannot be done, supplementary artificial lighting should be installed to raise the level of illumination to an appropriate value; and

b) At night it is desirable to light entrance halls and lobbies so that the illumination level reduces towards the exit and so that no bright fittings are in the line of sight of people leaving the building. Any entrance steps to the building should be well-lighted by correctly screened fittings.

4.1.6 *Brightness Appearance of Rooms*

To enhance the brightness appearance and visual comfort of rooms, it is important to define the task or activity areas within the space and assess the type of visual tasks performed. Appropriate lighting criteria, such as maintained average illuminance ($\bar{E}_m$), uniformity ratio (U_o), colour rendering index (R_a) and unified glare rating limit (R_{UGL}), should be selected based on the most demanding tasks. Key room surfaces, including walls and ceilings, should be illuminated to contribute to the perception of brightness. Higher illuminance levels in task areas may be considered to support better visual performance, while the illumination of objects and room surfaces, such as walls ($\bar{E}_{m,wall}$) and ceilings ($\bar{E}_{m,ceiling}$), should be optimized. In spaces with high ceilings or in industrial settings where ceiling lighting is less critical, a lower ceiling illuminance may be acceptable. Table 5 shows the assignment of columns to requirements, as given in **4.1.4.1**.

4.1.7 *Lighting Requirements for Task Areas*, *Activity Areas*, *Room and Space Brightness*

The requirements for task areas and activity areas are given in Table 5. The requirements for the specific tasks and activities are given by $\bar{E}_m$, U_o, R_a and R_{UGL}. The requirements for the space in which the task(s) or activities are carried out are given by $\bar{E}_{m,z}$ for the perception of objects and people within this space and $\bar{E}_{m,wall}$ and $\bar{E}_{m,ceiling}$ for room brightness. The latter are used for designing the room and the space including R_{UGL}. Glare (by R_{UGL}) is dedicated to the space in which a task is carried out.

The first four columns are used for of task area or activity area design and more than one of these areas can occur within one space.

Table 5 Assignment of Columns in Table 6 to Requirements

(*Clauses* 4.1.6 *and* 4.1.7)

Sl No.	**Task Area or Activity Area Design**				**Room or Space Design Requirements**		
(1)	(2)				(3)		
i)	Task or activity related requirements				Brightness appearance of rooms (**4.1.6**)		
ii)	$\bar{E}_m$ lux	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lux	$\bar{E}_{m,wall}$ lux	$\bar{E}_{m,ceiling}$ lux

where

$\bar{E}_m$ = minimum average illuminance level at defined area;
U_o = uniformity ratio (minimum illuminance/average illuminance);
R_a = colour rendering properties of a light source;
R_{UGL} = unified glare rating limit value;
$\bar{E}_{m,z}$ = maintained average cylindrical illuminance;
$\bar{E}_{m,wall}$ = average illuminance level at wall(s); and
$\bar{E}_{m,ceiling}$ = average illuminance level at ceiling.

In all enclosed places the maintained illuminances on the major surfaces shall have the values specified in Table 6.

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Table 6 Illuminance and Lighting Performance Parameters

(*Foreword*, *Clauses* 4.1.3.1, 4.1.4, 4.1.4.1, 4.1.4.3, 4.1.7, 4.3.2, 4.3.2.1 *and* 4.4.8)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	**1**	**Areas Inside Buildings**							
	1.1	Corridors and circulation areas	75-100-150	0.40	70	28	–	–	–
	1.2	Stairs, escalators, moving walks	75-100-150	0.40	70	25	–	–	–
	1.3	Lifts	75-100-150	0.40	70	25	–	–	–
	1.4	Area in front of lifts and escalators	150-200-300	0.40	70	25	–	–	–
	1.5	Loading ramps/bays	100-150-200	0.40	70	25	–	–	–
	1.6	Building entrance with canopy	20-30-50	0.40	–	–	–	–	–
	1.7	Gangways: manned	100-150-200	0.40	70	25	–	–	–
ii)	**2**	**General Areas Inside Buildings-Rest, Sanitation and First Aid Rooms**							
	2.1	Canteens and break areas	150-200-300	0.40	80	22	–	–	–
	2.2	Resting rooms	75-100-150	0.40	80	22	–	–	–
	2.3	Rooms for physical exercise	200-300-500	0.40	80	22	–	–	–
	2.4	Cloakroom (area), washrooms, bathrooms, dressing, lockers, shower, sink and toilet areas	150-200-300	0.40	80	25	–	–	–
	2.5	Facial lighting in front of mirrors	150-200-300	0.40	80	–	–	–	–
	2.6	Sick bay	300-500-750	0.60	80	19	–	–	–
	2.7	Rooms for medical attention	300-500-750	0.60	90	19	–	–	–
	2.8	General cleaning	75-100-150	0.40	–	–	–	–	–

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$ lx	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
iii)	**3**	**General Areas Inside Buildings-Control Rooms**							
	3.1	Plant rooms, switch gear rooms	150-200-300	0.40	80	25	50	50	–
	3.2	Post sorting, switchboard	300-500-750	0.60	80	19	150	150	–
	3.3	Surveillance station	200-300-500	0.60	80	19	100	100	–
iv)	**4**	**General Areas Inside Buildings-Store Rooms, Cold Stores**							
	4.1	Store and stockrooms	75-100-150	0.40	80	25	–	–	–
	4.2	Dispatch packing handling areas	200-300-500	0.60	80	25	–	–	–
	4.3	Larder (large storage space for food)	150-200-300	0.40	80	25	–	–	–
v)	**5**	**Logistics and Warehouses**							
	5.1	Unloading/loading area	150-200-300	0.40	80	25	50	–	–
	5.2	Packing/grouping area	200-300-500	0.50	80	25	100	–	–
	5.3	Configuration and rehandling	500-750-1 000	0.60	80	22	150	–	–
	5.4	Open goods storage	150-200-300	0.40	80	25	50	–	–
	5.5	Rack storage floor	100-150-200	0.50	80	25	–	–	–
	5.6	Rack storage rack face	50-75-100	0.40	80	–	–	–	–
	5.7	Central logistics corridor (heavy traffic)	200-300-500	0.60	80	25	100	–	–
	5.8	Automated zones (unmanned)	50-75-100	0.40	80	25	–	–	–
vi)	**6**	**Industrial Activities and Crafts-Agriculture**							
	6.1	Loading and operating of goods, handling equipment and machinery	150-200-300	0.40	80	25	–	–	–
	6.2	Buildings for livestock	30-50-75	0.40	70	-	–	–	–
	6.3	Sick animal pens; calving stalls	150-200-300	0.60	80	25	–	–	–
	6.4	Feed preparation; dairy; utensil washing	150-200-300	0.60	80	25	–	–	–

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
vii)	**7**	**Industrial Activities and Crafts–Bakeries**							
	7.1	Preparation and baking	200-300-500	0.60	80	22	75	–	–
	7.2	Finishing, glazing, decorating	300-500-750	0.70	80	22	100	–	–
viii)	**8**	**Industrial Activities and Crafts-Cement, Cement Goods, Concrete, Bricks**							
	8.1	Drying	30-50-75	0.40	70	28	–	–	–
	8.2	Preparation of materials; work on kilns and mixers	150-200-300	0.40	70	28	50	–	–
	8.3	General machine work	200-300-500	0.60	80	25	100	–	–
	8.4	Rough forms	200-300-500	0.60	80	25	100	–	–
ix)	**9**	**Industrial Activities and Crafts-Ceramics, Tiles, Glass, Glassware**							
	9.1	Drying	30-50-75	0.40	70	28	–	–	–
	9.2	Preparation, general machine work	200-300-500	0.60	80	25	100	–	–
	9.3	Enamelling, rolling, pressing, shaping simple parts, glazing, glass blowing	200-300-500	0.60	80	25	100	–	–
	9.4	Grinding, engraving, glass polishing, shaping precision parts, manufacture of glass instruments	500-750-1 000	0.70	80	19	150	75	50
	9.5	Grinding of optical glass, crystal, hand grinding and engraving	500-750-1 000	0.70	80	19	150	75	50
	9.6	Precision work, for example, decorative grinding, hand painting	750-1 000-1 000	0.70	90	19	150	75	50
	9.7	Manufacture of synthetic precious stones	1 000-1 500-2 000	0.70	90	19	150	75	50

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
x)	**10**	**Industrial Activities and Crafts-Chemical, Plastics and Rubber Industry**							
	10.1	Remote operated processing installations	30-50-75	0.40	70	–	–	–	–
	10.2	Processing installations with limited manual intervention	100-150-200	0.40	70	28	50	–	–
	10.3	Constantly manned work stations in processing installations	200-300-500	0.60	80	25	100	–	–
	10.4	Precision measuring rooms, laboratories	300-500-750	0.60	80	19	150	75	50
	10.5	Pharmaceutical production	300-500-750	0.60	80	22	150	–	–
	10.6	Tyre production	300-500-750	0.60	80	22	150	–	–
	10.7	Colour inspection	750-1 000-1 500	0.70	90	19	150	75	50
	10.8	Cutting, finishing, inspection	500-750-1 000	0.70	80	19	150	75	50
xi)	**11**	**Industrial Activities and Crafts-Electrical and Electronic Industry**							
	11.1	Cable and wire manufacture	200-300-500	0.60	80	25	100	–	–
	11.2	Winding-large coils	200-300-500	0.60	80	25	100	–	–
	11.3	Winding-medium-sized coils	300-500-750	0.60	80	22	150	–	–
	11.4	Winding-small coils	500-750-1000	0.70	80	19	150	75	50
	11.5	Coil impregnating	200-300-500	0.60	80	25	100	–	–
	11.6	Galvanizing	200-300-500	0.60	80	25	100	–	–
	11.7	Assembly work:- rough, for example, large transformers	200-300-500	0.60	80	25	100	–	–
	11.8	Assembly work: Medium, for example, switchboards	300-500-750	0.60	80	22	150	–	–

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	11.9	Assembly work: Fine, for example, telephones, radios, IT equipment (computers)	500-750-1 000	0.70	80	19	150	75	50
	11.10	Assembly work: Precision, for example, measuring equipment, printed circuit boards	750-1 000-1 500	0.70	80	19	150	75	50
	11.11	Electronic workshops, testing, adjusting	1 000-1 500-2 000	0.70	80	19	150	75	50
xii)	**12**	**Industrial Activities and Crafts-Food Stuffs and Luxury Food Industry**							
	12.1	Work stations	150-200-300	0.40	80	25	50	–	–
	12.2	Sorting and washing of products, milling, mixing, packing	200-300-500	0.60	80	25	100	–	–
	12.3	Work stations and critical zones in slaughter houses, butchers, dairies, mills, on filtering floor in sugar refineries	300-500-750	0.60	80	25	150	–	–
	12.4	Cutting and sorting of fruit and vegetables	200-300-500	0.60	80	25	100	–	–
	12.5	Manufacture of delicatessen foods,	300-500-750	0.60	80	22	150	–	–
	12.6	Inspection of glasses and bottles, product control, trimming, sorting, decoration	300-500-750	0.60	80	22	150	–	–
	12.7	Laboratories	300-500-750	0.60	80	19	150	75	50
	12.8	Colour inspection	750-1 000-1 500	0.70	90	19	150	75	50

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
xiii)	**13**	**Industrial Activities and Crafts-Foundries and Metal Casting**							
	13.1	Man-size underfloor tunnels, cellars, etc	30-50-75	0.40	70	–	–	–	–
	13.2	Platforms	75-100-150	0.40	70	25	50	–	–
	13.3	Sand preparation	150-200-300	0.40	80	25	50	–	–
	13.4	Dressing	150-200-300	0.40	80	25	50	–	–
	13.5	Work stations at cupola and mixer	150-200-300	0.40	80	25	50	–	–
	13.6	Casting bay	150-200-300	0.40	80	25	50	–	–
	13.7	Shake out areas	150-200-300	0.40	80	25	50	–	–
	13.8	Machine moulding	150-200-300	0.40	80	25	50	–	–
	13.9	Hand and core moulding	200-300-500	0.60	80	25	100	–	–
	13.10	Die casting	200- 300-500	0.60	80	25	100	–	–
	13.11	Model building	300-500-750	0.60	80	22	150	–	–
xiv)	**14**	**Industrial Activities and Crafts-Hairdressers**							
	14.1	Hairdressing	300-500-750	0.60	90	19	150	75	50
xv)	**15**	**Industrial Activities and Crafts-Jewellery Manufacturing**							
	15.1	Working with precious stones	1 000-1 500-2 000	0.70	90	19	150	75	50
	15.2	Manufacture of jewellery	750-1 000-1 500	0.70	90	19	150	75	50
	15.3	Watch making (manual)	1 000-1 500-2 000	0.70	80	19	150	75	50
	15.4	Watch making (automatic)	300-500-750	0.60	80	19	150	75	50
xvi)	**16**	**Industrial Activities and Crafts-Laundries and Dry Cleaning**							
	16.1	Goods in, marking and sorting	200-300-500	0.60	80	25	100	–	–
	16.2	Washing and dry cleaning	200-300-500	0.60	80	25	100	–	–

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	16.3	Ironing, pressing	200-300-500	0.60	80	25	100	–	–
	16.4	Inspection and repairs	500-750–1 000	0.70	80	19	150	75	50
xvii)	**17**	**Industrial Activities and Crafts-Leather and Leather Goods**							
	17.1	Work on vats, barrels, pits	150-200-300	0.40	80	25	75	–	–
	17.2	Fleshing, skiving, rubbing, tumbling of skins	200-300-500	0.40	80	25	100	–	–
	17.3	Saddlery work, shoe manufacture: stitching, sewing, polishing, shaping, cutting, punching	300-500-750	0.60	80	22	150	–	–
	17.4	Sorting	300-500-750	0.60	90	22	150	–	–
	17.5	Leather dyeing (machine)	300-500-750	0.60	80	22	150	–	–
	17.6	Quality control	750-1 000-1 500	0.70	80	19	150	75	50
	17.7	Colour inspection	750-1 000-1 500	0.70	90	19	150	75	50
	17.8	Shoe making	300-500-750	0.60	80	22	150	–	–
	17.9	Glove making	300-500-750	0.60	80	22	150	–	–
xviii)	**18**	**Industrial Activities and Crafts-Metal Working and Processing**							
	18.1	Open die forging	150-200-300	0.60	80	25	50	–	–
	18.2	Drop forging	200-300-500	0.60	80	25	75	–	–
	18.3	Welding	200-300-500	0.60	80	25	75	–	–
	18.4	Rough and average machining: Tolerances ≥ 0.1 mm	200-300-500	0.60	80	22	75	–	–
	18.5	Precision machining; grinding: Tolerances < 0.1 mm	300-500-750	0.70	80	19	150	75	50
	18.6	Scribing; inspection	500-750-1 000	0.70	80	19	150	75	50

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$ lx	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx	$\bar{E}_{m,wall}$ lx	$\bar{E}_{m,ceiling}$ lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	18.7	Wire and pipe drawing shops; cold forming	200-300-500	0.60	80	25	75	–	–
	18.8	Plate machining: Thickness ≥ 5 mm	150-200-300	0.60	80	25	50	–	–
	18.9	Sheet metalwork: Thickness < 5 mm	200-300-500	0.60	80	22	75	–	–
	18.10	Tool making, cutting equipment manufacture	500-750-1 000	0.70	80	19	150	–	–
	18.11	Assembly:						–	–
		1) Rough	150-200-300	0.60	60	25	50	–	–
		2) Medium	200-300-500	0.60	80	25	75	–	–
		3) Fine	300-500-750	0.60	80	22	150	–	–
		4) Precision	500-750-1 000	0.70	80	19	150	75	50
	18.12	Galvanizing	200-300-500	0.60	80	25	75	–	–
	18.13	Surface preparation and painting	500-750-1 000	0.70	80	25	150	–	–
	18.14	Tool, template and jig making, precision mechanics, micro- mechanics	750-1 000-1 500	0.70	80	19	150	75	50
xix)	**19**	**Industrial Activities and Crafts-Paper and Paper Goods**							
	19.1	Edge runners, pulp mills	150-200-300	0.40	80	25	50	–	–
	19.2	Paper manufacture and processing, paper and corrugating machines, cardboard manufacture	200-300-500	0.60	80	25	75	–	–
	19.3	Standard bookbinding work, for example, folding, sorting, gluing, cutting, embossing, sewing	300-500-750	0.60	80	22	150	–	–
xx)	**20**	**Industrial Activities and Crafts-Power Stations**							
	a) 20.1	Fuel supply plant	30-50-75	0.40	70	–	–	–	–

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	20.2	Boiler house	75-100-150	0.40	70	28	50	–	–
	20.3	Machine halls	150-200-300	0.40	80	25	50	–	–
	20.4	Side rooms, for example pump rooms, condenser rooms, etc; switchboards (inside buildings)	150-200-300	0.40	80	25	50	–	–
	20.5	Control rooms	300-500-750	0.70	80	19	150	75	50
xxi)	**21**	**Industrial Activities and Crafts-Printers**							
	21.1	Cutting, gilding, embossing, block engraving, work on	300-500-750	0.60	80	19	150	75	50
	21.2	Paper sorting and hand printing	300-500-750	0.60	80	19	150	75	50
	21.3	Type setting, retouching, lithography	750-1 000-1 500	0.70	80	19	150	75	50
	21.4	Colour inspection in multicoloured printing	1 000-1 500-2 000	0.70	90	19	150	75	50
	21.5	Steel and copper engraving	1 500-2 000-3 000	0.70	80	19	150	75	50
xxii)	**22**	**Industrial Activities and Crafts-Rolling Mills, Iron and Steel Works**							
	22.1	Production plants without manual operation	30-50-75	0.40	70	–	–	–	–
	22.2	Production plants with occasional manual operation	100-150-200	0.40	70	28	50	–	–
	22.3	Production plants with continuous manual operation	150-200-300	0.60	80	25	50	–	–
	22.4	Slab store	30-50-75	0.40	70	–	–	–	–
	22.8	Furnaces	150-200-300	0.40	70	25	50	–	–
	22.9	Mill train; coiler; shear line	200-300-500	0.60	70	25	75	–	–
	22.10	Control platforms; control panels	200-300-500	0.60	80	22	75	–	–

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	22.11	Test, measurement and inspection	300-500-750	0.60	80	22	150	–	–
	22.12	Underfloor man-sized tunnels; belt sections, cellars, etc	30-50-75	0.40	70	–	–	–	–
xxiii)	**23**	**Industrial Activities and Crafts-Textile Manufacture and Processing**							
	23.1	Work stations and zones in baths, bale opening	150-200-300	0.60	70	25	50	–	–
	23.2	Carding, washing, ironing, devilling machine work, drawing, combing, sizing, card cutting, pre-spinning, jute and hemp spinning	200-300-500	0.60	70	22	100	–	–
	23.3	Spinning, plying, reeling, winding	300-500-750	0.60	70	22	150	–	–
	23.4	Warping, weaving, braiding, knitting	300-500-750	0.60	70	22	150	–	–
	23.5	Sewing, fine knitting, taking up stitches	500-750-1 000	0.70	80	22	150	–	–
	23.6	Manual design, drawing patterns	500-750-1 000	0.70	90	22	150	–	–
	23.7	Finishing, dyeing	300-500-750	0.60	80	22	150	–	–
	23.8	Drying room	75-100-150	0.40	60	28	50	–	–
	23.9	Automatic fabric printing	300-500-750	0.60	90	25	100	–	–
	23.10	Burling, picking, trimming	750-1 000-1 500	0.70	80	19	150	75	50
	23.11	Colour inspection; fabric control	750-1 000-1 500	0.70	90	19	150	75	50
	23.12	Invisible mending	1 250-1 500-2 000	0.70	90	19	150	75	50
	23.13	Hat manufacturing	300-500-750	0.60	80	22	150	–	–
xxiv)	**24**	**Industrial Activities and Crafts-Vehicle Construction and Repair**							
	24.1	Press shop - Large parts	200-300-500	0.60	80	25	100	–	–
	24.2	Press shop - Visual inspection	300-500-750	0.60	80	22	150	–	–

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Table 6 (*Continued*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	24.3	Body work and assembly-Automatic line	200-300-500	0.60	80	25	100	–	–
	24.4	Body work and assembly- Manual welding	300-500-750	0.60	80	22	150	–	–
	24.5	Painting, spraying chamber, polishing chamber	500-750-1 000	0.70	80	22	150	–	–
	24.6	Painting, inspection, touch- up and polishing	750-1 000-1 500	0.70	90	19	150	75	50
	24.7	Upholstery manufacture (manual)	750-1 000-1 500	0.70	80	19	150	75	50
	24.8	Detailing: Subparts assembly (doors, dashboard, upholstery), under chassis assembly, motor and mechanical assembly, final assembly conveyor line	500-750-1 000	0.70	80	22	150	–	–
	24.9	Detailing - Work with electronics	500-750-1 000	0.60	90	22	150	–	–
	24.10	Final inspection	750-1 000-1 500	0.70	90	19	150	75	50
	24.11	General vehicle services, repair and testing	300-500-750	0.60	80	22	100	–	–
xxv)	**25**	**Industrial Activities and Crafts-Wood Working and Processing**							
	25.1	Automatic processing, for example, drying, plywood manufacturing	30-50-75	0.40	70	28	–	–	–
	25.2	Steam pits	100-150-200	0,40	70	28	50	–	–
	25.3	Saw frame	200-300-500	0.60	70	25	100	–	–
	25.4	Work at joiner's bench, gluing, assembly	200-300-500	0.60	80	25	100	–	–
	25.5	Polishing, painting, fancy joinery	500-750-1 000	0.70	80	22	150	–	–
	25.6	Work on wood working machines, for example, turning, fluting, dressing,	300-500-750	0.60	80	19	150	75	50

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Table 6 (*Continued*)

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		rebating, grooving, cutting, sawing, sinking							
	25.7	Selection of veneer woods	500-750-1 000	0.90	70	22	150	–	–
	25.8	Marquetry, inlay work	500-750-1 000	0.90	70	22	150	–	–
	25.9	Quality control, inspection	750-1 000-1 500	0.90	70	19	150	75	50
xxvi)	**26**	**Offices**							
	26.1	Filing, copying, etc	200-300-500	0.40	80	19	100	75	50
	26.2	General office area - Writing, typing, reading, data processing	300-500-750	0.60	80	19	150	75	50
	26.3	Private cabins	300-500-750	0.70	80	19	150	75	50
	26.4	CAD work stations	300-500-750	0.60	80	19	150	75	50
	26.5	Huddle/breakout area	200-300-500	0.60	80	19	150	75	50
	26.6	Conference and meeting rooms	300-500-750	0.60	80	19	150	75	50
	26.7	Light on presenter	150-200-300		80	19			
	26.8	Reception desk	200-300 -500	0.60	80	22	100	75	50
	26.9	Archiving	150-200-300	0.40	80	25	75	–	–
	26.10	Canteens and break out areas	150-200-300	0.60	80	22	–	–	–
	26.11	Resting rooms	75-100-200	0.40	80	22	–	–	–
	26.12	Rooms for physical exercise	200-300-500	0.40	80	22	–	–	–
	26.13	Cloakroom (area), wash room	150-200-300	0.40	80	25	100	75	50
	26.14	Facial lighting in front of mirrors	200-300-500	0.40	80	–	–	–	–
	26.15	Sick bay	300-500-750	0.60	80	19	100	75	50
	26.16	Rooms for medical attention	300-500-750	0.40	90	19	100	75	50
	26.17	General cleaning	75-100-150	0.40	80	–	–	–	–

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Table 6 (*Continued*)

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	26.18	Corridors and circulation areas	75 -100-150	0.40	70	28	–	–	–
	26.19	Stairs, escalators, travelators	75-100-150	0.40	70	25	–	–	–
	26.20	Lifts	75-100-150	0.40	70	25	–	–	–
	26.21	Area in front of lifts and escalators	150-200-300	0.40	70	25	–	75	50
	26.22	Auditorium, training hall, town hall, amphitheater	300-500-750	0.60	80	19	75	50	–
xxvii)	**27**	**Retail Premises**							
	27.1	General sales area	200-300-500	0.40	80	22	75	–	–
	27.2	Till area	300-500 -750	0.60	80	19	100	75	50
	27.3	Wrapper table	300-500-750	0.60	80	22	100	–	–
	27.4	Storage area	200-300-500	0.40	80	25	50	–	–
	27.5	Dressing/fitting room	200-300-500	0.4	90	–	–	–	–
xxviii)	**28**	**Places of Public Assembly General Areas**							
	28.1	Entrance halls	75-100-150	0.40	80	22	50	–	–
	28.2	Cloakrooms	150-200-300	0.40	80	25	75	–	–
	28.3	Lounges	150-200-300	0.40	80	22	75	–	–
	28.4	Ticket offices	200-300-500	0.60	80	22	75	–	–
xxix)	**29**	**Places of Public Assembly- Restaurants and Hotels**							
	29.1	Reception/cashier desk, porters desk	200-300-500	0.60	80	22	100	–	–
	29.2	Kitchen	300-500-750	0.60	80	22	100	–	–
	29.3	Restaurant, dining room, function room	–	–	80	–	–	–	–
	29.4	Self-service restaurant	150-200-300	0.40	80	22	75	–	–
	29.5	Buffet	200-300-500	0.60	80	22	75	–	–

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Table 6 (*Continued*)

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	29.6	Conference rooms	300-500-750	0.60	80	19	150	75	50
	29.7	Corridors	75-100-150	0.40	80	25	50		
xxx)	**30**	**Places of Public Assembly-Theatres, Concert Halls, Cinemas, Places for Entertainment**							
	30.1	Practice rooms	200-300-500	0.60	80	22	100	–	–
	30.2	Dressing rooms	200-300-500	0.60	90	22	100	–	–
	30.3	Seating areas-maintenance, cleaning	150-200-300	0.40	80	22	50	–	–
	30.4	Stage area rigging	200-300-500	0.40	80	25	75	–	–
xxxi)	**31**	**Places of Public Assembly-Trade Fairs, Exhibition Halls**							
	31.1	General lighting	200-300-500	0.40	80	22	50	–	–
xxxii)	**32**	**Places of Public Assembly-Museums**							
	32.1	Exhibits, insensitive to light	–	–	80	–	–	–	–
	32.2	Exhibits sensitive to light	–	–	80	–	–	–	–
xxxiii)	**33**	**Places of Public Assembly-Libraries**							
	33.1	Bookshelves	150-200-300	0.40	80	19	–	–	–
	33.2	Reading area	300-500-750	0.60	80	19	100	75	50
	33.3	Counters	300-500-750	0.60	80	19	150	75	50
	33.4	General lighting	200-300-500	0.40	80	22	75	–	–
xxxiv)	**34**	**Places of Public Assembly-Car Parks (Indoor)**							
	34.1	Entry/exit ramps (during daylight hours)	200-300-500	0.40	70	25	75	–	–
	34.2	Entry/exit ramps (at night)	50-75-100	0.40	70	25	50	–	–

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	34.3	Traffic lanes, internal ramps and pedestrian paths	50-75-100	0.40	70	25	50	–	–
	34.4	Parking areas - Not open to public	50-75-100	0.25	70	–	50	–	–
	34.5	Parking areas - Open to public with a large number of users for example, shopping centres, arenas	100-150-200	0.40	70	–	50	–	–
	34.6	Ticket office	200-300-500	0.60	80	19	75	75	50
xxxv)	**35**	**Educational Premises-Nursery School, Play School**							
	35.1	Play room	200-300-500	0.40	80	22	100	75	50
	35.2	Nursery	200-300-500	0.40	80	22	100	75	50
	35.3	Handicraft room	200-300-500	0.60	80	19	100	75	50
xxxvi)	**36**	**Educational Premises-Educational Buildings**							
	36.1	Classroom-General activities	300-500-750	0.60	80	19	150	75	50
	36.2	Auditorium, lecture halls	300-500-750	0.60	80	19	150	75	50
	36.3	Attending lecture in seating areas in auditoriums and lecture halls	150-200-300	0.60	80	19	75	75	50
	36.4	Black, green and white boards	300-500-750	0.70	80	19	–	–	–
	36.5	Black, green and white boards in auditorium and lecture halls	300-500-750	0.60	80	19	–	–	–
	36.6	Projector and smartboard presentation	–	–	–	–	–	–	–
	36.7	Display board	150-200-300	0.60	80	19	–	–	–
	36.8	Demonstration table in auditoriums and lecture halls	500-750-1 000	0.70	80	19	–	–	–
	36.9	Light on teacher/presenter	–	–	80	–	150	–	–
	36.10	Light on podium area	200-300-500	0.70	80	–	–	–	–

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Table 6 (*Continued*)

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	36.11	Computer work only	200-300-500	0.60	80	19	100	75	50
	36.12	Art rooms in art schools	500-750-1 000	0.70	90	19	150	75	50
	36.13	Technical drawing rooms	500-750-1 000	0.60	80	19	150	75	50
	36.14	Practical rooms and laboratories	300-500-750	0.60	80	19	150	75	50
	36.15	Handcraft rooms	300-500-750	0.60	80	19	150	75	50
	36.16	Teaching workshop	300-500-750	0.60	80	19	150	75	50
	36.17	Preparation rooms and workshops	300-500-750	0.60	80	22	150	–	–
	36.18	Entrance halls	150-200-300	0.40	80	22	75	–	–
	36.19	Circulation areas, corridors	75-100-150	0.40	80	25	50	–	–
	36.20	Stairs	100-150-200	0.40	80	25	50	–	–
	36.21	Student common rooms and assembly halls	150-200-300	0.40	80	22	75	–	–
	36.22	Teachers rooms	200-300-500	0.60	80	19	100	75	50
	36.23	Library – Bookshelves	150-200-300	0.60	80	19	75	75	50
	36.24	Library - Reading areas	300-500-750	0.60	80	19	100	75	50
	36.25	Stock rooms for teaching materials	75–100-150	0.40	80	25	50	–	–
	36.26	Sports halls, gymnasiums, swimming pools	200–300–500	0.60	80	22	100	–	–
	36.27	School canteens	150-200-300	0.40	80	22	75	–	–
	36.28	Kitchen	300–500-750	0.60	80	22	100	–	–
xxxvii)	**37**	**Health Care Premises-Rooms for General Use**							
	37.1	Waiting rooms	150-200-300	0.40	80	22	75	75	30
	37.2	Corridors: During the day	75-100-150	0.40	80	22	50	50	30
	37.3	Corridors: Cleaning	75-100-150	0.40	80	22	50	50	30

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	37.4	Corridors: During the night	30-50-75	0.40	80	22	–	–	–
	37.5	Corridors with multi-purpose use (for example, pre-examination of patients)	150-200-300	0.60	80	22	75	75	50
	37.6	Day rooms	200-300-500	0.60	80	22	75	75	50
	37.7	Lifts for persons and visitors	75-100-150	0.60	80	22	50	50	30
	37.8	Service lifts	150-200-300	0.60	80	22	75	75	50
xxxviii)	**38**	**Health Care Premises-Staff Rooms**							
	38.1	Staff office	300-500-750	0.60	80	19	150	75	50
	38.2	Staff rooms	200-300-500	0.60	80	19	100	75	50
xxxix)	**39**	**Health Care Premises-Wards, Maternity Wards**							
	39.1	General lighting	75-100-150	0.70	80	19	50	50	30
	39.2	Reading lighting	200-300-500	0.70	80	19	100	75	50
	39.3	Wards-simple examinations	200-300-500	0.70	80	19	100	75	50
	39.4	Examination and treatment	750-1 000-1 500	0.70	90	19	150	75	50
	39.5	Night lighting, observation lighting	5	–	80	–	–	–	–
	39.6	Bathrooms and toilets for patients	150-200-300	0.70	90	22	75	75	50
xl)	**40**	**Health Care Premises-Examination Rooms (General)**							
	40.1	General lighting	300-500-750	0.60	90	19	150	75	50
	40.2	Examination and treatment	750-1 000-1 500	0.70	90	19	150	75	50
xli)	**41**	**Health Care Premises-Eye Examination Rooms**							
	41.1	General lighting	300-500-750	0.60	90	19	150	75	50
	41.2	Examination of the outer eye	750-1 000-1 500	–	90	–	150	75	50

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Table 6 (*Continued*)

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	41.3	Reading and colour vision tests with vision charts	300-500-750	0.70	90	19	150	75	50
xlii)	**42**	**Health Care Premises-Ear Examination Rooms**							
	42.1	General lighting	300-500-750	0.60	90	19	150	75	50
	42.2	Ear examination	750-1 000-1 500	–	90	–	150	75	50
xliii)	**43**	**Health Care Premises-Scanner Rooms**							
	43.1	General lighting	200-300-500	0.60	80	19	100	75	50
	43.2	Scanners with image enhancers and television systems	30-50-75	–	80	19	–	–	–
xliv)	**44**	**Health Care Premises-Delivery Rooms**							
	44.1	General lighting	200-300-500	0.60	90	19	100	75	50
	44.2	Examination and treatment	750-1 000-1 500	0.70	90	19	150	75	50
xlv)	**45**	**Health Care Premises-Treatment Rooms (General)**							
	45.1	Dialysis	300-500-750	0.60	80	19	150	75	50
	45.2	Dermatology	300-500-750	0.60	90	19	150	75	50
	45.3	Endoscopy	200-300-500	0.60	80	19	100	75	50
	45.4	Plastering	300-500-750	0.60	80	19	150	75	50
	45.5	Medical baths	200-300-500	0.60	80	19	100	75	50
	45.6	Massage and radiotherapy	200-300-500	0.60	80	19	100	75	50
xlvi)	**46**	**Health Care Premises-Operating Areas**							
	46.1	Pre-op and recovery rooms	500-750-1 000	0.60	90	19	150	75	50
	46.2	Operating cavity surround	750-1 000-1 500	0.60	90	19	150	75	50
	46.3	Operating theatre	750-100-1 500	0.60	90	19	–	–	–

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	46.4	Operating cavity	–	–	90	–	–	–	–
xlvii)	**47**	**Health Care Premises-Intensive Care Unit**							
	47.1	General lighting	200-300-500	0.60	90	19	50	50	30
	47.2	Simple examinations	300-500-750	0.60	90	19	100	75	50
	47.3	Examination and treatment	1 000-1 250 -1 500	0.70	90	19	150	75	50
	47.4	Night watch	20	–	90	19	–	–	–
xlviii)	**48**	**Health Care Premises-Dental Clinics/Units**							
	48.1	General lighting	300-500-750	0.60	90	19	150	75	50
	48.2	At the patient	750-1 000-1 500	0.70	90	–	150	75	50
	48.3	Operating cavity	–	–	–	–	–	–	–
	48.4	White teeth matching	–	–	–	–	–	–	–
xlix)	**49**	**Health Care Premises-Laboratories and Pharmacies**							
	49.1	General lighting	300-500-750	0.60	80	19	150	75	50
	49.2	Colour inspection	750-1 000- 1 500	0.70	90	19	150	75	50
l)	**50**	**Health Care Premises-Decontamination Rooms**							
	50.1	Sterilization	300-500-750	0.60	80	22	100	75	50
	50.2	Disinfection	300-500-750	0.60	80	22	100	75	50
li)	**51**	**Health Care Premises-Autopsy Rooms and Mortuaries**							
	51.1	General lighting	300-500-750	0.60	90	19	150	75	50
	51.2	Autopsy table and dissecting table	500-7500	0.70	90	–	150	75	50

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
lii)	**52**	**Transportation Areas-Airports**							
	52.1	Arrival and departure halls, baggage claim areas	150-200-300	0.40	80	22	75	–	–
	52.2	Connecting areas	100-150-200	0.40	80	22	50	–	–
	52.3	Information desks, check-in desks	300-500-750	0.70	80	19	150	–	–
	52.4	Customs and passport control desks	300-500-750	0.70	80	19	150	–	–
	52.5	Waiting areas	150-200-300	0.40	80	22	50	–	–
	52.6	Luggage storage rooms	150-200-300	0.40	80	25	50	–	–
	52.7	Security check areas	200-300-500	0.60	80	19	100	–	–
	52.8	Air traffic control tower	300-500-750	0.60	80	19	50	75	50
	52.9	Tasks in hangars: Testing and repair areas, engine test areas, measuring areas	300-500-750	0.60	80	22	50	–	–
liii)	**53**	**Transportation Areas-Railway Installations**							
	53.1	Fully enclosed platforms: Small number of passengers	30-50-75	0.30	80	–	–	–	–
	53.2	Fully enclosed platforms: Medium number of passengers	75-100-150	0.40	80	–	–	–	–
	53.3	Fully enclosed platforms: Large number of passengers	150-200-300	0.50	80	–	–	–	–
	53.4	Fully enclosed passenger subways (underpasses): Small number of passengers	30-50-75	0.30	80	–	–	–	–
	53.5	Fully enclosed passenger subways (underpasses): Medium number of passengers	75-100-150	0.40	80	–	–	–	–

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			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	53.6	Fully enclosed passenger subways (underpasses): Large number of passengers	150-200-300	0.50	80	–	–	–	–
	53.7	Stairs, escalators: Small number of passengers	30-50-75	0.30	80	–	–	–	–
	53.8	Stairs, escalators: Medium number of passengers	75-100-150	0.40	80	–	–	–	–
	53.9	Stairs, escalators: Large number of passengers	150-200-300	0.50	80	–	–	–	–
	53.10	Ticket hall and concourse	150-200-300	0.50	80	28	75	–	–
	53.11	Ticket counters and luggage offices	200-300-500	0.50	80	19	100	75	50
	53.12	Waiting rooms	150-200-300	0.40	80	22	75	–	–
	53.13	Entrance halls, station halls	150-200-300	0.40	80	–	75	–	–
	53.14	Switch and plant rooms	150-200-300	0.50	80	28	50	–	–
	53.15	Railway control centre (area of dispatcher)	150-200-300	0.50	80	19	–	–	–
	53.16	Access tunnels	30-50-75	0.40	20	–	–	–	–
	53.17	Assembly work in maintenance sheds - Rough	150-200-300	0.40	80	–	–	–	–
	53.18	Assembly work in maintenance sheds - Medium	200-300-500	0.50	80	–	–	–	–
	53.19	Assembly work in maintenance sheds - Fine	300-500 -750	0.60	80	–	–	–	–
	53.20	Assembly work in maintenance sheds precision	500-750-1 000	0.70	80	–	–	–	–

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Table 6 (*Concluded*)

Sl No.	Ref No.	Type of Task/Activity Area	$\bar{E}_m$	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$	$\bar{E}_{m,wall}$	$\bar{E}_{m,ceiling}$
			lx				lx	lx	lx
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	53.21	Circulation areas for maintenance halls for railway vehicles (without additional vehicular traffic)	75-100-150	0.25	80	–	–	–	–
	53.22	Circulation areas for maintenance halls for railway vehicles (with additional vehicular traffic)	100-150-200	0.40	80	–	–	–	–

NOTES

1 For 33.1, illuminance level mentioned is vertical at bookshelves.

2 For 36.4, 36.7 and 36.23, illuminance level mentioned is vertical illuminance.

3 For 40.1 and 40.2, preferred colour temperature should be 4 000 K to 5 000 K.

4 For 41.1, preferred colour temperature should be 4 000 K to 5 000 K.

5 For 41.2 and 41.3, preferred colour temperature should be 4 000 K to 6 500 K.

6 For 46.1, 46.2, 46.3 and 46.4, additional local lighting to be provided to achieve 10 000 lux to 50 000 lux.

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4.1.8 *Colour Rendering*

The colour appearance of light and its colour rendering capability are different aspects of the light sources. A faithful reproduction of an object colour depends on the colour rendering capability of the light source. In 1965, International Commission on Illumination (CIE) developed a quantitative method of assignment of colour rendering property and is denoted as Colour Rendering Index (CRI).

CRI is arrived at by a test by which a number of specified samples are tested under a standard or reference light source and the chromaticity coordinate are plotted on the IE triangle as given in Fig. 7 of Part 2 'Physics of Light, Section 3 Colour' of good practice [D-1(3)]. The same test is repeated under the source under test and corresponding chromaticity coordinate are plotted on the same plot. The difference between the position of each sample for test and standard source is measured to scale. The general colour rendering index (R_a) is obtained by the average value for eight samples {*see* Fig. 8 of Part 2 'Physics of Light, Section 3 Colour' of good practice [D-1(3)]}. For perfect agreement of colour, the R1 value should be 100. In general:

$$R_a = 1/(R1 + R2 + R3 + R4 + \ldots\ldots + R8)$$

The specific colour rendering index for an individual sample is given by:

$$R_i = 100 - 4.6\Delta E_i$$

where

ΔE_i = chromaticity shift on the CIE chromaticity diagram for each sample.

From the obtained value of R_a, as calculated above, the colour rendering shall be evaluated as mentioned in the following table:

Sl No.	*Colour Rendering Evaluated*	R_a (*General Colour Rendering Index*)
(1)	(2)	(3)
i)	Excellent	$90 \leq R_a < 100$
ii)	Good	$80 \leq R_a < 90$
iii)	Moderate	$70 \leq R_a < 80$

4.1.9 For detailed information regarding principles of good lighting, reference may be made to good practice [D-1(4)].

4.2 Daylighting

While the sun is the primary source of natural light, the daylight received at the Earth's surface comprises two components: direct solar illuminance and sky illuminance (diffused light from the sky dome). For effective daylighting design in buildings, direct solar illuminance is typically excluded due to the potential for glare, excessive contrast and thermal discomfort (overheating). Glare from direct sun exposure in occupied zones should be mitigated through appropriate window orientation, sizing and external/internal shading strategies. Accordingly, daylighting strategies should emphasize sky illuminance, which provides diffused uniform light conducive to visual comfort and energy efficiency. By relying on sky illuminance, daylighting design achieves balanced illumination, reduces glare and cooling loads, and supports both visual comfort and sustainable building performance.

4.2.1 The relative amount of sky illuminance at a given point-in-time depends on the position of the sun defined by its altitude, which in turn, varies with the latitude of the locality, the day of the year and the time of the day, as indicated in Table 7.

4.2.2 The external available horizontal sky illuminance (diffuse illuminance) values which are exceeded for about 90 percent of the daytime working hours may be taken as outdoor design illuminance values for ensuring adequacy of daylighting design. The outdoor design sky illuminance varies for different climatic regions of the country. The recommended design sky illuminance values are 6 800 lux for cold climate, 8 000 lux for composite climate,

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9 000 lux for warm humid climate, 9 000 lux for temperate climate and 10 500 lux for hot-dry climate. For integration with the artificial lighting during daytime working hours an increase of 500 lux in the recommended sky design illuminance for daylighting is suggested.

4.2.3 The daylight factor is dependent on the sky luminance distribution, which varies with atmospheric conditions. A clear design sky with its non-uniform distribution of luminance is adopted for the purposes of design in this section.

4.2.4 *Components of Daylight Factor*

Daylight factor is the sum of all the daylight reaching on an indoor reference point from the following sources:

a) Direct sky visible from the point;

b) External surfaces reflecting light directly (*see* Note 1) to the point; and

c) Internal surfaces reflecting and inter-reflecting light to the point.

NOTES

1 External surface reflection may be computed approximately only for points at the centre of the room, and for detailed analysis the procedures are complicated and these may be ignored for actual calculations.

2 Each of the three components, when expressed as a ratio or percent of the simultaneous external illuminance on the horizontal plane, defines respectively the sky component (SC), the external reflected component (ERC) and the internal reflected component (IRC) of the daylight factor.

4.2.4.1 The daylight factors on the horizontal plane only are usually taken, as the working plane in a room is generally horizontal; however, the factors in vertical planes should also be considered when specifying daylighting values for special cases, such as daylighting on classrooms, blackboards, pictures and paintings hung on walls.

4.2.5 *Sky Component* (*SC*)

Sky component for a window of any size is computed by the use of the appropriate Table 20, Table 21 and Table 22 of Annex B.

The recommended sky component level should be ensured generally on the working plane at the following positions:

a) At a distance of 3 m to 3.75 m from the window along the central line perpendicular to the window;

b) At the centre of the room if more appropriate; and

c) At fixed locations, such as school desks, black-boards and office tables.

The daylight area of the prescribed sky component should not normally be less than half the total area of the room.

4.2.5.1 The values obtainable from the tables are for rectangular, open unglazed windows, with no external obstructions. The values shall be corrected for the presence of window bars, glazing and external obstructions, if any. This assumes the maintenance of a regular cleaning schedule.

4.2.5.2 *Corrections for window bars*

The corrections for window bars shall be made by multiplying the values read from tables in Annex B by a factor equal to the ratio of the clear opening to the overall opening.

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Table 7 Solar Altitudes (to the Nearest Degree) for Indian Latitudes

(*Clause* 4.2.1)

Sl No.	Period of Year	22 June						21 March and 23 September						22 December					
	Hours of Day (Sun or Solar) → / Latitude ↓	07 00	08 00	09 00	10 00	11 00	12 00	07 00	08 00	09 00	10 00	11 00	12 00	07 00	08 00	09 00	10 00	11 00	12 00
		17 00	16 00	15 00	14 00	13 00	-	17 00	16 00	15 00	14 00	13 00	-	17 00	16 00	15 00	14 00	13 00	-
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
i)	10ÁN	18	31	45	58	70	77	15	30	44	59	72	80	9	23	35	46	53	57
ii)	13ÁN	19	32	46	60	72	80	15	29	44	58	70	77	8	21	33	43	51	54
iii)	16ÁN	20	33	47	61	74	83	14	29	43	56	68	74	7	19	31	41	48	51
iv)	19ÁN	21	34	48	62	75	86	14	28	42	55	66	71	5	18	29	48	45	48
v)	22ÁN	22	35	49	62	75	89	14	28	41	53	64	68	4	16	27	36	42	45
vi)	25ÁN	23	36	49	63	76	88	13	27	40	52	61	65	3	14	25	34	39	42
vii)	28ÁN	23	36	49	63	76	86	13	26	39	50	59	62	1	13	23	31	37	39
viii)	31ÁN	24	37	50	62	75	82	13	25	37	48	56	56	–	11	21	28	34	36
ix)	34ÁN	25	37	49	62	73	79	12	25	36	46	53	56	–	9	18	26	31	33

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4.2.5.3 *Correction for glazing*

Where windows are glazed, the sky components obtained from Annex B shall be reduced by 10 percent to 20 percent, provided the panes are of clear and clean glass. Where glass is of the frosted (ground) type, the sky components read from Annex A may be reduced by 15 percent to 30 percent. In case of tinted or reflective glass the reduction is about 50 percent. Higher indicated correction corresponds to larger windows and/or near reference points. In the case of openings and glazings which are not vertical, suitable correction shall be taken into account.

4.2.5.4 *Correction for external obstructions*

There is no separate correction, except that the values from tables in Annex B shall be read only for the unobstructed portions of the window.

4.2.6 *External Reflected Component* (*ERC*)

The value of the sky component corresponding to the portion of the window obstructed by the external obstructions may be found by the use of methods described in Annex C of good practice [D-1(5)].

These values when multiplied by the correction factors, corresponding to the mean elevation of obstruction from the point in question as given in Table 8, can be taken as the external reflected components for that point.

For method of calculating ERC, reference may be made to accepted standard {*see* examples given in Annex B of good practice [D-1(5)]}.

Table 8 Correction Factor for ERC

(*Clause* 4.2.6)

Sl No.	Mean Angle of Elevation	Correction Factor
(1)	(2)	(3)
i)	5°	0.086
ii)	15°	0.086
iii)	25°	0.142
iv)	35°	0.192
v)	45°	0.226
vi)	55°	0.274
vii)	65°	0.304
viii)	75°	0.324
ix)	85°	0.334

4.2.7 *Internal Reflected Component* (*IRC*)

The component of daylight factor contributed by reflection from the inside surfaces varies directly as the window area and inversely as the total area of internal surfaces and depends on the reflection factor of the floor, wall and roof surfaces inside and of the ground outside. For rooms white-washed on walls and ceiling and windows of normal sizes, the IRC will have sizeable value even at points far away from the window. External obstructions, when present, will proportionately reduce IRC. Where accurate values of IRC are desired, the same may be done in accordance with the good practice [D-1(5)].

4.2.8 *General Principles of Openings to Afford Good Lighting*

4.2.8.1 Generally, while taller openings give greater penetrations, broader openings give better distribution of light. It is preferable that some area of the sky at an altitude of 20º to 25º should light up the working plane.

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4.2.8.2 Broader openings may also be equally or more efficient, provided their sills are raised by 300 mm to 600 mm above the working plane.

NOTE — It is to be noted that while placing window with a high sill level might help natural lighting, this is likely to reduce ventilation at work levels. While designing the opening for ventilation also, a compromise may be made by providing the sill level about 150 mm below the head level of workers.

4.2.8.3 For a given penetration, a number of small openings properly positioned along the same, adjacent or opposite walls will give better distribution of illumination than a single large opening. The sky component at any point, due to a number of openings may be easily determined from the corresponding sky component contour charts appropriately superposed. The sum of the individual sky component for each opening at the point gives the overall component due to all the openings. The same charts may also facilitate easy drawing of sky component contours due to multiple openings.

4.2.8.4 Unilateral lighting from side openings will, in general, be unsatisfactory if the effective width of the room is more than 2 to 2.5 times the distance from the floor to the top of the opening. In such cases provision of light shelves is always advantageous.

4.2.8.5 Openings on two opposite sides will give greater uniformity of internal daylight illumination, especially when the room is 7 m or more across. They also minimize glare by illuminating the wall surrounding each of the opposing openings. Side openings on one side and clerestory openings on the opposite side may be provided where the situation so requires.

4.2.8.6 Cross-lighting with openings on adjacent walls tends to increase the diffused lighting within a room.

4.2.8.7 Openings in deep reveals tend to minimize glare effects.

4.2.8.8 Openings shall be provided with *Chajjahs*, louvers, baffles or other shading devices to exclude, as far as possible, direct sunlight entering the room. *Chajjahs*, louvers, etc, reduce the effective height of the opening for which due allowance shall be made. Broad and low openings are, in general, much easier to shade against sunlight entry. Direct sunlight, when it enters, increases the inside illuminance very considerably. Glare will result if it falls on walls at low angles, more so than when it falls on floors, especially when the floors are dark coloured or less reflective.

4.2.8.9 Light control media, such as translucent glass panes (opal or matt) surfaced by grinding, etching or sandblasting, configurated or corrugated glass, certain types of prismatic glass, tinted glass and glass blasts are often used. They should be provided, either fixed or movable outside or inside, especially in the upper portions of the openings. The lower portions are usually left clear to afford desirable view. The chief purpose of such fixtures is to reflect part of the light on to the roof and thereby increase the diffuse lighting within, light up the farther areas in the room and thereby produce a more uniform illumination throughout. They will also prevent the opening causing serious glare discomfort to the occupants but will provide some glare when illuminated by direct sunlight.

4.2.9 *Availability of Daylight in Multistoreyed Block*

Proper planning and layout of building can add appreciably to daylighting illumination inside. Certain dispositions of building masses offer much less mutual obstruction to daylight than others and have a significant relevance, especially when intensive site planning is undertaken. As guidance, the relative availability of daylight in multi-storeyed blocks (up to 4 storeys) of different relative orientations may be taken as given in Table 9.

4.2.10 For specified requirements for daylighting of special occupancies and areas, reference may be made to good practice [D-1(6)]. For using annual climate-based daylight assessment of design, a reference may be made to specialist literature (*see* Note). It also presents a computer simulation-based approach for assessment of adequacy of daylight in indoor spaces.

NOTE — The specialist literature may be Chapter 5 of Energy Conservation and Sustainable Building Code 2024.

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Table 9 Relative Availability of Daylight on the Window Plane at Ground Level in Four-Storeyed Building Blocks (Clear Design-Sky as Basis, Daylight Availability Taken as Unity on an Unobstructed Facade, Values are for the Centre of the Blocks)

(*Clause* 4.2.9)

Sl No.	Distance of Separation Between Blocks	Infinitely Long Parallel Blocks	Parallel Blocks Facing Each Other (Length = 2 × Height)	Parallel Blocks facing Gaps Between Opposite Blocks (Length = 2 × Height)
(1)	(2)	(3)	(4)	(5)
i)	0.5 Ht	0.15	0.15	0.25
ii)	1.0 Ht	0.30	0.32	0.38
iii)	1.5 Ht	0.40	0.50	0.55
iv)	2.0 Ht	0.50	0.60	0.68

NOTE — Ht = Height of the building.

4.3 Artificial Lighting

4.3.1 Artificial lighting may have to be provided,

a) Where the recommended illumination levels have to be obtained by artificial lighting only;

b) To supplement daylighting when the level of illumination falls below the recommended value; and

c) Where visual task may demand a higher level of illumination.

4.3.2 *Artificial Lighting Design for Interiors*

For general lighting purposes, the recommended practice is to design for a level of illumination on the working plane on the basis of the recommended levels for visual tasks given in Table 6 by a method called 'Lumen method'. In order to make the necessary detailed calculations concerning the type and quantity of lighting equipment necessary, advance information on the surface reflectances of walls, ceilings and floors is required. Similarly, calculations concerning the brightness ratio in the interior call for details of the interior décor and furnishing. Stepwise guidance regarding designing the interior lighting systems for a building using the 'Lumen method' is given in **4.3.2.1** to **4.3.2.4**.

4.3.2.1 *Determination of the illumination level*

Recommended value of illumination shall be taken from Table 6, depending upon the type of work to be carried out in the location in question and the visual tasks involved.

4.3.2.2 *Selection of the light sources and luminaires*

The selection of light sources and luminaires depends on the choice of lighting system, namely, general lighting, directional lighting and localized or local lighting.

4.3.2.3 *Determination of the luminous flux*

a) The luminous flux (ϕ) reaching the working plane depends upon the following:

1) Lumen output of the lamps;

2) Type of luminaire;

3) Proportion of the room (room index) (k_r);

4) Reflectance of internal surfaces of the room;

5) Depreciation in the lumen output of the lamps after burning their rated life; and

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6) Depreciation due to dirt collection on luminaires and room surface.

b) Coefficient of utilization or utilization factor;

1) The compilation of tables for the utilization factor requires a considerable amount of calculations, especially if these tables have to cover a wide range of lighting practices. For every luminaire, the exact light distribution has to be measured in the laboratory and their efficiencies have to be calculated and measured exactly. These measurements comprise,

i) the luminous flux radiated by the luminaires directly to the measuring surface;

ii) the luminous flux reflected and re-reflected by the ceiling and the walls to the measuring surface; and

iii) the inter-reflections between the ceiling and wall which result in the measuring surface receiving additional luminous flux.

All these measurements have to be made for different reflection factors of the ceiling and the walls for all necessary room indices. These tables have also to indicate the maintenance factor to be taken for the luminous flux depreciation throughout the life of an installation due to ageing of the lamp and owing to the deposition of dirt on the lamps and luminaires and room surfaces.

2) The values of the reflection factor of the ceiling and of the wall are as follows:

White and very light colours	0.7
Light colours	0.5
Middle tints	0.3
Dark colours	0.1

For the walls this should be estimated, taking into account the influence of the windows without curtains, shelves, *Almirahs* and doors with different colours, etc.

c) Calculation for determining the luminous flux {see Table 22 of accepted standard [D-1(7)]}

$$E_{\text{av}} = \frac{\mu . \phi}{A}$$

or, $\phi = \frac{E_a A}{\mu}$, for new condition, and

$\phi = \frac{E\text{av}.A}{\mu . d}$, for working condition.

where

E_{av} = average illumination level required on the working plane, in lux;

μ = utilization factor in new conditions;

ϕ = total luminous flux of the light sources installed in the room, in lumens;

A = area of the working plane, in m^2; and

d = maintenance factor.

In practice, it is easier to calculate straightaway the number of lamps or luminaires from:

$$N_{lamp} = \frac{E_{av} . A}{\mu . d . \phi_{lamp}}$$

$$N_{luminaries} = \frac{E_{av} . A}{\mu . d . \phi_{luminaries}}$$

where

N_{lamp} = total number of lamps;

ϕ_{lamp} = luminous flux of each lamp, in lumens;

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$N_{luminaires}$ = total number of luminaires; and

$\phi_{luminaries}$ = luminous flux of each luminaire, in lumens.

4.3.2.4 *Arrangement of the luminaires*

This is done to achieve better uniformly distributed illumination. The location of the luminaires has an important effect on the utilization factor:

a) In general, luminaires are spaced 'x' metre apart in either direction, while the distance of the end luminaire from the wall is '0.5 x' metre. The distance 'x' is more or less equal to the mounting height 'H_m' between the luminaire and the working plane. The utilization factor tables are calculated for this arrangement of luminaires {*see* Table 22 of the accepted standard [D-1(7)]}.

b) For small rooms where the room index (k_r) is less than 1, the distance 'x' should always be less than H_m, since otherwise luminaires cannot be properly located. In most cases of such rooms, four or two luminaires are placed for good general lighting. If, however, in such rooms only one luminaire is installed in the middle, higher utilization factors are obtained, but the uniformity of distribution is poor. For such cases, references should be made to the additional tables for k_r = 0.6 to 1.25 for luminaires located centrally.

4.3.3 *Artificial Lighting to Supplement Daylighting*

4.3.3.1 The need for general supplementary artificial lighting arises due to diminution of daylighting beyond design hours, that is, for solar altitude below 15° or when dark cloudy conditions occur.

4.3.3.2 The need may also arise for providing artificial lighting during the day in the innermost parts of the building which cannot be adequately provided with daylighting, or when the outside windows are not of adequate size or when there are unavoidable external obstructions to the incoming daylighting.

4.3.3.3 The need for supplementary lighting during the day arises, particularly when the daylighting on the working plane falls below 100 lux and the surrounding luminance drops below 19 cd/m^2.

4.3.3.4 The requirement of supplementary artificial lighting increases with the decrease in daylighting availability. Therefore, conditions near sunset or sunrise or equivalent conditions due to clouds or obstructions, etc, represent the worst conditions when the supplementary lighting is most needed.

4.3.3.5 The requirement of supplementary artificial lighting when daylighting availability becomes poor may be determined from Fig. 3 for an assumed ceiling height of 3.0 m, depending upon floor area, fenestration percentage and room surface reflectance. Cool daylight fluorescent tubes are recommended with semi-direct luminaires. To ensure a good distribution of illumination, the mounting height should be between 1.5 m and 2.0 m above the work plane for a separation of 2.0 m to 3.0 m between the luminaires. Also, the number of lamps should preferably be more in the rear half of the room than in the vicinity of windows. The following steps may be followed for using Fig. 3 for determining the number of fluorescent tubes required for supplementary daylighting:

a) Determine fenestration percentage of the floor area, that is:

$$\frac{Window\ area}{Floor\ area} \times 100$$

b) In Fig. 3, refer to the curve corresponding to the percent fenestration determined above and the set of reflectances of ceiling, walls and floor actually provided; and

c) For the referred curve of Fig. 3 read, along the ordinate, the number of 40 W fluorescent tubes required, corresponding to the given floor area on the abscissa.

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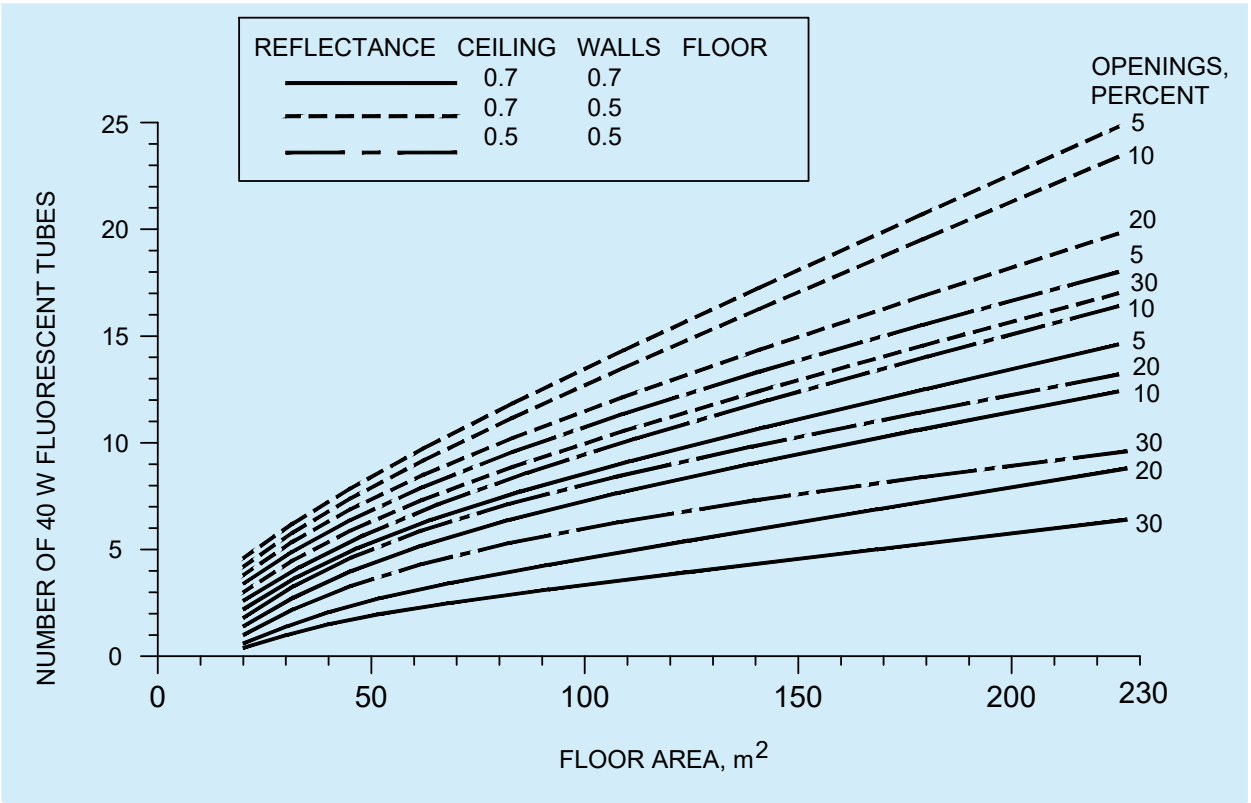

FIG. 3 SUPPLEMENTARY ARTIFICIAL LIGHTING FOR 40 W FLUORESCENT TUBES

4.3.4 For detailed information on the design aspects and principles of artificial lighting, reference may be made to good practice [D-1(4)].

4.3.5 For specific requirements for lighting of special occupancies and areas, reference may be made to good practice [D-1(8)].

4.3.6 Electrical installation aspect for artificial lighting should be in accordance with Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS.

4.4 Energy Conservation in Lighting

4.4.1 A substantial portion of the energy consumed on lighting may be saved by utilization of daylight and rational design of supplementary artificial lights.

4.4.2 Daytime use of artificial lights may be minimized by proper design of windows for adequate daylight indoors. Daylighting design should be according to **4.2**.

4.4.3 Fenestration expressed as percentage of floor area required for satisfactory visual performance of a few tasks for different separation to height (S/H) ratio of external obstructions such as opposite buildings may be obtained from the design nomogram (*see* Fig. 4). The obstructions at a distance of three times their height or more ($S/H > 3$) from a window facade are not significant and a window facing such an obstruction may be regarded as a case of unobstructed window.

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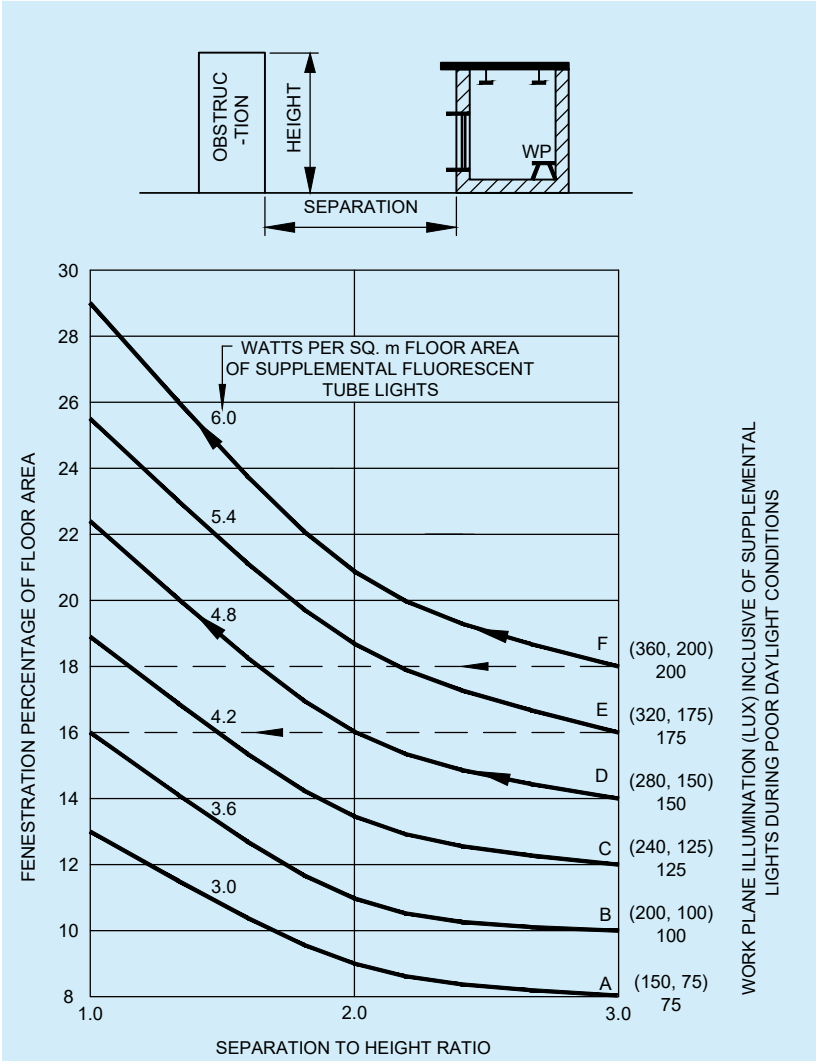

FIG. 4 NOMOGRAPH FOR DAYLIGHTING AND SUPPLEMENTAL LIGHTING DESIGN OF BUILDINGS

4.4.3.1 The nomogram consists of horizontal lines indicating fenestration percentage of floor area and vertical lines indicating the separation to height ratio of external obstructions such as opposite buildings. Any vertical line for separation to height ratio other than already shown in the nomogram (1.0, 2.0 and 3.0) may be drawn by designer, if required. For cases where there is no obstruction, the ordinate corresponding to the value 3.0 may be used. The value of percentage fenestration and separation to height ratio are marked on left hand ordinate and abscissa respectively. The illumination levels are marked on the right hand ordinate. The values given within brackets are the illumination levels on the work plane at centre and rear of the room. The wattage of fluorescent tubes required per square metre of the floor area for different illumination levels is shown on each curve.

4.4.3.2 Following assumptions have been made in the construction of the nomogram:

a) An average interior finish with ceiling white, walls off white and floor grey has been assumed;

b) Ceiling height of 3 m, room depths up to 10 m and floor area between 30 m^2 and 50 m^2 have been assumed. For floor area beyond 50 m^2 and less than 30 m^2, the values of percent fenestration as well as wattage/m^2 should be multiplied by a factor of 0.85 and 1.15, respectively;

c) It is assumed that windows are of metallic sashes with louvers of width up to 600 mm or a *Chhajja* (balcony projection) at ceiling level of width up to 2.0 m. For wooden sashes, the window area should be increased by a factor of about 1.1; and

d) Luminaires emanating more light in the downward direction than upward direction (such as reflectors with or without diffusing plastics) and mounted at a height of 1.5 m to 2.0 m above the work plane have been considered.

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4.4.3.3 *Method of use*

The following steps shall be followed for the use of nomogram:

a) *Step* 1 — Decide the desired illumination level depending upon the task illumination requirement in the proposed room and read the value of watt per square metre on the curve corresponding to the required illumination level;

b) *Step* 2 — Fix the vertical line corresponding to the given separation to height ratio of opposite buildings on the abscissa. From the point of intersection of this vertical line and the above curve move along horizontal and read the value of fenestration percent on the left-hand ordinate; and

c) *Step* 3 — If the floor area is greater than 50 m^2 or if it is less than 30 m^2, the value of watt/m^2 as well as fenestration percent may be easily determined for adequate daylighting and supplemental artificial lighting for design purposes. However, if the fenestration provided is less than the required value, the wattage of supplementary artificial lights should be increased proportionately to make up for the deficiency of natural illumination.

4.4.4 For good distribution of day light on the working plane in a room, window height, window width and height of sill should be chosen in accordance with the following recommendations:

a) In office buildings windows of height 1.2 m or more in the centre of a bay with sill level at 1.0 to 1.2 m above floor and in residential buildings windows of height 1.0 m to 1.1 m with sill height as 0.9 m to 0.7 m above floor are recommended for good distribution of daylight indoors. Window width can accordingly be adjusted depending upon the required fenestration percentage of the floor area;

b) If the room depth is more than 10 m, windows should be provided on opposite sides for bilateral lighting; and

c) It is desirable to have a white finish for ceiling and off white (light colour) to white for walls. There is about 7 percent improvement in lighting levels in changing the finish of walls from moderate to white.

4.4.5 For good distribution and integration of daylight with artificial lights the following guidelines are recommended:

a) Employ cool daylight fluorescent tubes for supplementary artificial lighting;

b) Distribute luminaries with a separation of 2 m to 3 m in each bay of 3 m to 4 m width; and

c) Provide more supplementary lights such as twin tube luminaries in work areas where daylight is expected to be poor for example in the rear region of a room having single window and in the central region of a room having windows on opposite walls. In the vicinity of windows only single tube luminaries should be provided.

4.4.6 *Artificial Lighting*

Energy conservation in lighting is affected by reducing wastage and using energy effective lamps and luminaires without sacrificing lighting quality. Measures to be followed comprise utilization of daylight, energy effective artificial lighting design by providing required illumination where needed, turning off artificial lights when not needed, maintaining lighter finishes of ceiling, walls and furnishings, and implementing periodic schedule for cleaning of luminaires and group replacement of lamps at suitable intervals. Choice of light sources with higher luminous efficacy and luminaires with appropriate light distribution is the most effective means of energy saving in lighting. However, choice of light sources also depends on the other lighting quality parameters like colour rendering index and colour temperature or appearance. The choice of light sources type also depends on the desired mounting height in the interiors.

4.4.6.1 *Efficient artificial light sources and luminaires*

Luminous efficacies of some of the lamps used in lighting of buildings are given in Table 10 along with average life in burning hours, colour rendering index and colour temperature. Given the high luminous efficacy that can be achieved with most LED lighting, energy efficiency in lighting can be achieved via space appropriate zoning, identifying the application type (task versus ambient) and careful consideration of lighting quality requirements.

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Table 10 Luminous Efficacy, Life, Lumen Maintenance and Colour Rendition of Light Sources

(*Clause* 4.4.6.1)

Sl No.	Light Source	Wattage Range	Efficacy	Average Life	Lumen Maintenance	Colour Rendition
		W	Lm/W	h		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Incandescent lamps	15 to 200	12 to 20	500 to 1 000	Fair to good	Very good
ii)	Tungsten halogen	300 to 1 500	20 to 27	200 to 2 000	Good to very good	Very good
iii)	Slim line fluorescent	18 to 58	57 to 67	5 000	Fair to good	Good
iv)	High pressure mercury vapour lamps	60 to 1 000	50 to 65	5 000	Very low to fair	Federate
v)	Blended-light lamps	160 to 250	20 to 30	5 000	Low to fair	Federate
vi)	High pressure sodium vapour lamps	50 to 1 000	90 to 125	10 000 to 15 000	Fair to good	Low to good
vii)	Metal halide lamps	35 to 2 000	80 to 95	4 000 to 10 000	Very low	Very good
viii)	Low pressure sodium	10 to 180	100 to 200	10 000 to 20 000	Good to very good	Poor
ix)	LED	0.5 to 2.0	60 to 100	10 000	Very good	Good for white LED

NOTES

1 This includes lamps and wattages currently in use in buildings in India.

2 Luminous efficacy varies with the wattage of the lamp.

3 Average life values are from available Indian Standards. Where Indian Standard is not available, values given are only indicative.

4 For exact values, it is advisable to contact manufacturers.

4.4.6.2 For the same lumen output, it is possible to save 50 percent to 70 percent energy if CFL lamps are replaced with induction lighting, and 40 percent to 60 percent if replaced with LED lamps. Similar energy effective solutions are to be chosen for every application area.

Similarly, with white fluorescent tubes recommended for corridors and staircases, the electrical consumption reduces to 1/4.5 of the energy consumption with incandescent lamps.

4.4.6.3 Efficient luminaire also plays an important role in energy conservation in lighting. The choice of a luminaire should be such that it is efficient not only initially but also throughout its life. Following luminaries are recommended for different locations:

a) For offices semi-direct type of luminaries are recommended so that both the work plane illumination and surround luminance can be effectively enhanced;

b) For corridors and stair cases direct type of luminaries with wide spread of light distributions are recommended; and

c) In residential buildings, glare free wide spread of light distributions are recommended.

4.4.7 *Cleaning Schedule for Window Panes and Luminaires*

Adequate schedule for cleaning of window panes and luminaries will result in significant advantage of enhanced daylight and lumen output from luminaries. Frequent cleaning of windows will tend to reduce the duration over

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which artificial lights will be used and minimize the wastage of energy. Depending upon the location of the building a cleaning interval of three to six months is recommended for cleaning of luminaires.

4.4.8 *Photocontrols for Artificial Lights*

There is a considerable wastage of electrical energy in lighting of buildings due to carelessness in switching off lights even when sufficient daylight is available indoors. In offices and commercial buildings, occupants may switch on lights in the morning and keep them on throughout the day. When sufficient daylight is available inside, suitable photocontrols can be employed to switch off the artificial lights and thus prevent the wastage of energy.

The photocontrol should have the following features:

a) An integrated photocontrol system continually measures the amount of visible light under the lighting fixture and maintains the lux levels as referred in Table 6;

b) An integrated photocontrol system should maintain six daylighting scenarios that can be adjusted by the user namely; daytime occupied, daytime unoccupied, sunset occupied, sunset unoccupied, night time occupied and night time unoccupied;

c) The photocontrol sensor should have a 60° cone of reference to measure the amount of light on the work surface;

d) Photocontrol, along with supporting lighting based on influx of natural light, should have controls for intelligent 'occupancy based shut-off' system to control which areas need lighting at any moment; and

e) The controls should maintain a decent standard of 'ease of use' for occupants as well as building staff.

4.4.9 *Solar Photovoltaic Systems* (*SPV*)

Solar photovoltaic system enables direct conversion of sunlight into electricity and is viable option for lighting purpose in remote non grid areas. The common SPV lighting systems are:

a) Solar lantern;

b) Fixed type solar home lighting system; and

c) Street lighting system.

4.4.9.1 SPV lighting system should preferably be provided with CFL for energy efficiency.

4.4.9.2 Invertors used in buildings for supplying electricity during the power cut period should be charged through SPV system.

4.4.9.3 Regular maintenance of SPV system is necessary for its satisfactory functioning.

4.4.10 Lighting shelves and light pipes may be explored for utilization and integration in the lighting design.

4.5 Circadian Lighting

Light is fundamental to human health and well-being, extending beyond its role in vision. It is the principal regulator of our circadian rhythm, profoundly influencing visual experience, physiological processes and emotional state. Thus, human-centric lighting, designed for human health and well-being, is essential.

Human physiology is evolved under natural sunlight. Ideally, we would experience abundant daylight exposure, gradually decreasing in the evening, with minimal light at night. Modern indoor lifestyles disrupt this natural rhythm. Optimizing indoor environments to emulate this 24 h light-dark cycle can significantly improve sleep quality and promote rejuvenation, with the added benefit of naturally sustained energy.

The influence of light on human health stems from its role in regulating the internal clock of the body. The circadian rhythm governs diverse physiological functions, from sleep-wake cycles and mood to overall health. This system is orchestrated by the suprachiasmatic nucleus (SCN) in the brain, which relies on consistent light-dark patterns, reflecting our attunement to the diurnal and seasonal rhythms of daylight availability.

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The melanopic daylight efficacy ratio (melanopic DER) and melanopic equivalent daylight illuminance (melanopic EDI) provide metrics for assessing light's efficacy in supporting our biological rhythms.

In practice, morning light acts as a critical entraining cue, signalling the body to transition to a state of wakefulness and activity. Exposure to bright light during the day further strengthens the circadian rhythm, which plays a vital role in regulating sleep-wake cycles, daytime engagement, and mood. Conversely, darkness at night-time is essential for promoting restorative sleep, a process crucial for overall health and well-being.

NOTE — The early 2 000 s saw the discovery of specialized retinal light-sensitive cells, peaking at around 480 nm (cyan), leading to the concepts of 'biologically active' or 'circadian light'.

4.5.1 *Need for Supplementary Artificial Circadian Lighting*

Artificial circadian lighting is advised in spaces where permanent day-active occupants spend more than 4 h between sunrise and sunset and do not have a direct line of sight to any external windows from their general working area.

In spaces where artificial circadian lighting cannot be incorporated due to functional considerations (for example, museums, movie theatres), break rooms for day-active permanent occupants may be equipped with circadian lighting.

4.5.2 *Characteristics of Supplementary Artificial Circadian Lighting*

In spaces where supplementary artificial circadian lighting is implemented, it should have the following features:

a) The lighting system shall include dynamic controls that enable gradual changes in light intensity and colour temperature to mimic natural daylight cycles; and

b) Lux levels (vertical illuminance at the occupant positions) shall be modulated based on time of day to ensure sufficient light exposure during the day and reduced exposure in the evening time following the best-practice for circadian lighting design.

4.6 Outdoor Lighting

Outdoor lighting plays a crucial role in ensuring safety, security and functionality in various environments, while contributing to energy conservation and minimizing environmental impacts. To achieve these objectives, outdoor lighting should be designed and managed in accordance with the good practice [D-1(3)], focussing on energy efficiency and minimizing light pollution.

4.6.1 *Lighting Design and Light Zones*

Outdoor lighting designs should adhere to energy efficiency measures and address the requirements of different light zones, as per the good practice [D-1(3)]. The following guidelines should be considered for the design in various zone:

a) *Urban zones* — Lighting intensity should be optimized for high activity areas, using energy-efficient technologies such as LEDs and lighting controls to ensure energy savings;

b) *Suburban zones* — Lighting should be designed for moderate activity areas with an emphasis on reducing unnecessary energy consumption, utilizing dimming controls or motion sensors; and

c) *Rural zones* — Lighting should be kept minimal, ensuring safety while limiting light pollution. Energy-efficient, low-intensity lighting should be implemented.

These zones should serve as guidelines and lighting levels should align with the specific needs of the location while minimizing energy consumption as required by specialist literature.

NOTE — The specialist literature may be Energy Conservation and Sustainable Building Code 2024.

4.6.2 *Energy Efficiency and Light Pollution Mitigation*

To comply with the good practice [D-1(3)] and reduce light pollution, outdoor lighting systems should incorporate the following:

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a) *Energy-efficient light sources* — Use of LEDs or other high-efficiency light sources with appropriate lumen output to reduce energy consumption;

b) *Fully shielded and full cut-off fixtures* — These should be implemented to prevent upward light emission and sky glow, focusing light where needed to minimize spill over and improve energy use;

c) *Lighting controls* — The good practice [D-1(3)] compliant controls, such as timers, dimmers, and motion sensors, should be employed to reduce lighting during periods of low activity, contributing to energy savings; and

d) *Luminaire efficacy* — All outdoor lighting luminaires should meet the minimum efficacy requirements as specified in the good practice [D-1(3)] for energy conservation and reduced power consumption.

4.6.3 *Effects of Light Pollution on Life*

Excessive outdoor lighting, if not properly controlled, may have adverse effects on human, animal and plant life:

a) *Human health* — Exposure to artificial light at night can disrupt circadian rhythms, leading to potential health risks such as sleep disorders and increased stress. Lighting design should prioritize human well-being by controlling glare and unnecessary brightness;

b) *Animal life* — Wildlife, particularly nocturnal species, may experience disruptions in natural behaviours, such as feeding and mating, due to poorly managed artificial lighting. The good practice [D-1(3)] compliant lighting should minimize impact on ecosystems; and

c) *Plant life* — Artificial lighting may affect plant growth cycles, leading to ecological imbalance. Properly designed lighting should reduce this risk by controlling light spill and adhering to the lighting recommendations of good practice [D-1(3)].

5 VENTILATION

5.1 General

Natural ventilation of buildings is required to supply outdoor air for the respiration of occupants, to remove any products of combustion or other contaminants in the air and to provide such thermal environments as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to the health of the occupants. The natural ventilation through building envelope elements such as operable windows, skylights and ventilators help maintain the desired quality of air and thermal comfort conditions when outdoor air and thermal environments are conducive to the cause.

5.2 Design Considerations

5.2.1 *Respiration*

Supply of fresh air to provide oxygen for the human body for elimination of waste products and to maintain carbon dioxide concentration in the air within safe limits rarely calls for special attention as enough outside air for this purpose normally enters the areas of occupancy through crevices and other openings.

In normal habitable rooms devoid of smoke generating source, the content of carbon dioxide in air rarely exceeds 0.5 percent to 1 percent and is, therefore, incapable of producing any ill effect. The amount of air required to keep the concentration down to 1 percent is very small. The change in oxygen content is also too small under normal conditions to have any ill effects; the oxygen content may vary quite appreciably without noticeable effect, if the carbon dioxide concentration is unchanged.

5.2.2 *Vitiation by Body Odours*

Where no products of combustion or other contaminants are to be removed from air, the amount of fresh air required for dilution of inside air to prevent vitiation of air by body odours, depends on the air space available per person and the degree of physical activity; the amount of air decreases as the air space available per person increases, and it may vary from 20 m^3 to 30 m^3 per person per hour. In rooms occupied by only a small number of persons such an air change will automatically be attained in cool weather by normal leakage around windows and other openings and this may easily be secured in warm weather by keeping the openings open.

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No standards have been laid down under the *Factories Act*, 1948 as regards the amount of fresh air required per worker or the number of air changes per hour. Section 16 of the *Factories Act*, 1948 relating to over-crowding requires that at least 14 m^3 to 16 m^3 of space shall be provided for every worker and for the purpose of that section no account shall be taken of any space in a work room which is more than 4.25 m above the floor level.

NOTE — Vitiation of the atmosphere can also occur in factories by odours given off due to contaminants of the product itself, say for example, from tobacco processing in a '*Beedi'* factory. Here the ventilation will have to be augmented to keep odours within unobjectionable levels.

5.2.2.1 *Recommended values for air changes*

The standards of general ventilation are recommended/based on maintenance of required oxygen, carbon dioxide and other air quality levels and for the control of body odours when no products of combustion or other contaminants are present in the air; the values of air changes should be as follows:

Sl No.	*Application*	*Air Change per Hour*
(1)	(2)	(3)
i)	Assembly rooms	4 to 8
ii)	Bakeries	20 to 30
iii)	Banks/building societies	4 to 8
iv)	Bathrooms	6 to 10
v)	Bedrooms	2 to 4
vi)	Billiard rooms	6 to 8
vii)	Boiler rooms	*See* Note 2
viii)	Cafes and coffee bars	10 to 12
ix)	Canteens	8 to 12
x)	Cellars	3 to 10
xi)	Changing rooms	6 to 10
xii)	Churches	1 to 3
xiii)	Cinemas and theatres	10 to 15
xiv)	Club rooms	12, *Min*
xv)	Compressor rooms	10 to 12
xvi)	Conference rooms	8 to 12
xvii)	Corridors	5 to 10
xviii)	Dairies	8 to 12
xix)	Dance halls	12, *Min*
xx)	Dye works	20 to 30
xxi)	Electroplating shops	10 to 12
xxii)	Engine rooms/DG Rooms/GG Rooms	*See* Note 2
xxiii)	Entrance halls	3 to 5
xxiv)	Factories and work shops	8 to 10
xxv)	Foundries	15 to 30
xxvi)	Garages	6 to 8
xxvii)	Glass houses	25 to 60
xxviii)	Gymnasium	6, *Min*

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Table (*Concluded*)

Sl No.	*Application*	*Air Change per Hour*
(1)	(2)	(3)
xxix)	Hair dressing saloon	10 to 15
xxx)	Hospitals sterilising	15 to 25
xxxi)	Hospital wards	6 to 8
xxxii)	Hospital domestic	15 to 20
xxxiii)	Laboratories	6 to 15
xxxiv)	Launderettes	10 to 15
xxxv)	Laundries	10 to 30
xxxvi)	Lavatories	6 to 15
xxxvii)	Lecture theatres	5 to 8
xxxviii)	Libraries	3 to 5
xxxix)	Lift cars	20, *Min*
xl)	Living rooms	3 to 6
xli)	Mushroom houses	6 to 10
xlii)	Offices	6 to 10
xliii)	Paint shops (not cellulose)	10 to 20
xliv)	Photo and X-ray dark room	10 to 15
xlv)	Public house bars	12, *Min*
xlvi)	Recording control rooms	15 to 25
xlvii)	Recording studios	10 to 12
xlviii)	Restaurants	8 to 12
xlix)	Schoolrooms	5 to 7
l)	Shops and supermarkets	8 to 15
li)	Shower baths	15 to 20
lii)	Stores and warehouses	3 to 6
liii)	STP rooms	30, *Min*
liv)	Squash courts	4, *Min*
lv)	Swimming baths	10 to 15
lvi)	Toilets	6 to 10
lvii)	Underground vehicle parking	6, *Min*
lviii)	Utility rooms	15 to 30
lix)	Welding shops	15 to 30

NOTES

1 The ventilation rates may be increased by 50 percent where heavy smoking occurs or if the room is below the ground.

2 The ventilation rate shall be as per **14.2.1** of Part D 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of this NBCS.

5.2.3 *Heat Balance of Body*

Especially in hot weather, when the thermal environment inside the room is worsened by the heat given off by machinery, occupants and other sources, the prime need for ventilation is to provide such a thermal environment

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as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to health. Excess of heat either from increased metabolism due to physical activity of persons or gains from a hot environment has to be offset to maintain normal body temperature (approximately 37 °C). Heat exchange of the human body with respect to the surroundings is determined by the temperature and humidity gradient between the skin and the surroundings and other factors, such as the age of person, clothing, etc and the latter depends on air temperature (dry bulb temperature), relative humidity, radiation from the solid surroundings and rate of air movement. The volume of outside air to be circulated through the room is, therefore, governed by the physical considerations of controlling the temperature, air distribution or air movement. Air movement and air distribution may, however, be achieved by recirculation of the inside air rather than bringing in all outside air. However, fresh air supply or the circulated air will reduce heat stress by dissipating heat from the body by evaporation of the sweat, particularly when the relative humidity is high and the air temperature is near body temperature.

5.2.3.1 *Indices of thermal comfort*

Thermal comfort is that condition of a thermal environment under which a person can maintain a body heat balance at normal body temperature and without perceptible sweating. Limits of comfort vary considerably according to studies carried out in India and abroad.

The thermal indices which find applications for Indian climate are as follows:

a) Effective temperature (ET);

b) Tropical summer index (TSI); and

c) Operative temperature based adaptive thermal comfort.

5.2.3.1.1 *Effective temperature* (*ET*)

Effective temperature is defined as the temperature of still, saturated air which has the same general effect upon comfort as the atmosphere under investigation. Combinations of temperature, humidity and wind velocity producing the same thermal sensation in an individual are taken to have the same effective temperature.

Initially two scales were developed, one of which referred to men stripped to the waist and called the basic scale. The other applies to men fully clad in indoor clothing and called the normal scale of effective temperature. Bedfort (1946) proposed the use of globe temperature reading instead of the air temperature reading to make allowance for the radiant heat. This scale is known as the corrected effective temperature (CET) scale. No allowance, however, was made for the different rates of energy expenditure. The scale was compiled only for men either seated or engaged in light activity.

Figure 5 represents the corrected effective temperature nomogram. The CET can be obtained by connecting the appropriate points representing the dry bulb (or globe) and wet bulb temperatures and reading the CET value at the intersection of this line with the relevant air velocity curve from the family of curves for various air velocities running diagonally upwards from left to right.

The effective temperature scale may be considered to be reasonably accurate in warm climates where the heat stress is not high but it may be misleading at high levels of heat stress. There appears to be an inherent error in this scale if used as an index of physiological strain, the error increasing with the severity of the environmental conditions. For low and moderate degrees of heat stress, the effective temperature scales appear to assess climatic heat stress with an accuracy which is acceptable for most practical purposes.

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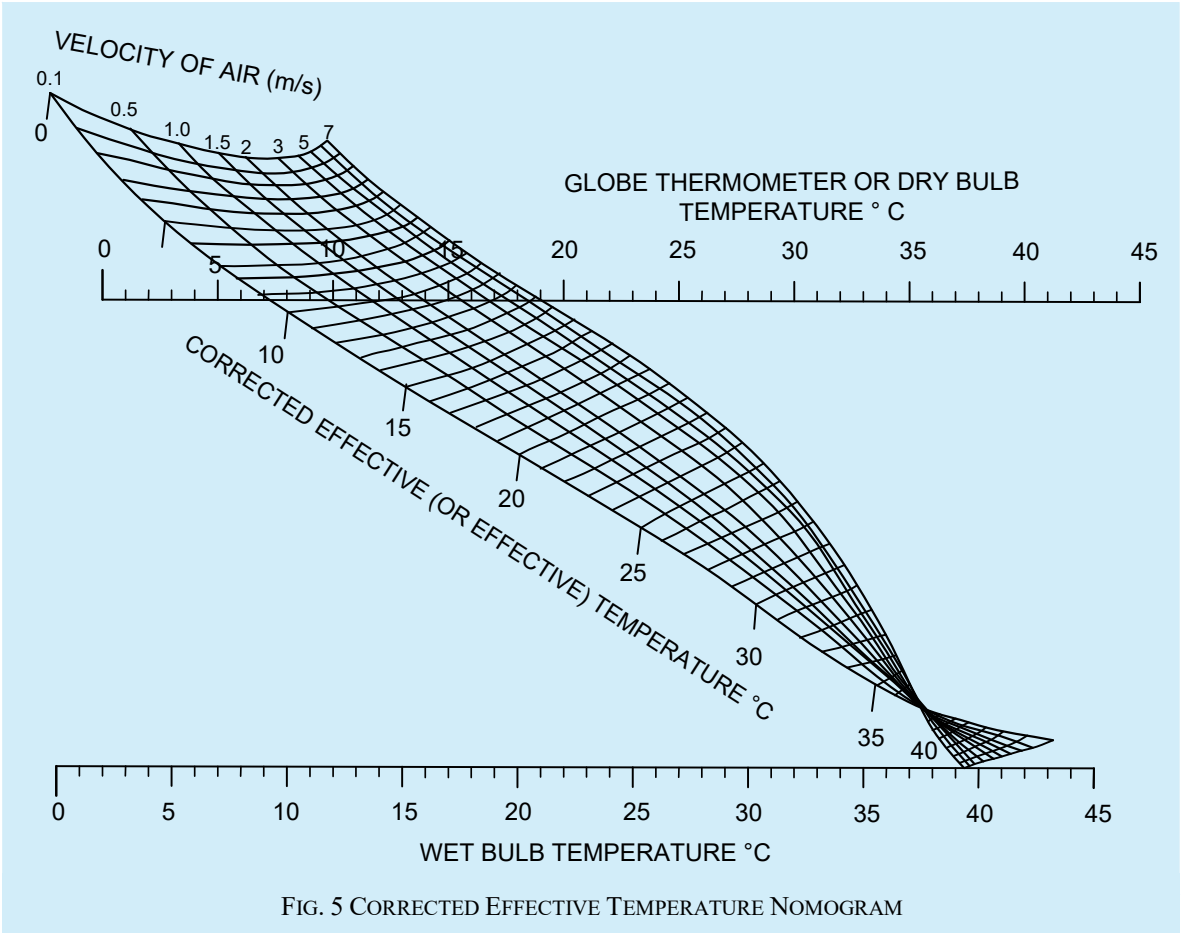

FIG. 5 CORRECTED EFFECTIVE TEMPERATURE NOMOGRAM

5.2.3.1.2 *Tropical Summer Index* (*TSI*)

The TSI is defined as the temperature of calm air, at 50 percent relative humidity which imparts the same thermal sensation as the given environment. The 50 percent level of relative humidity is chosen for this index as it is a reasonable intermediate value for the prevailing humidity conditions. Mathematically, TSI (°C) is expressed as:

$$\text{TSI} = 0.745t_g + 0.308t_w\text{-}2.06\sqrt{v + 0.841}$$

where

t_w = wet bulb temperature, in °C;
t_g = globe temperature, in °C; and
v = air speed, in m/s.

The thermal comfort of a person lies between TSI values of 25 °C and 30 °C with optimum condition at 27.5 °C. Air movement is necessary in hot and humid weather for body cooling. A certain minimum desirable wind speed is needed for achieving thermal comfort at different temperatures and relative humidity. Such wind speeds are given in Table 11. These are applicable to sedentary work in offices and other places having no noticeable sources of heat gain. Where somewhat warmer conditions are prevalent, such as in godowns and machine shops and work is of lighter intensity, and higher temperatures can be tolerated without much discomfort, minimum wind speeds for just acceptable warm conditions are given in Table 12. For obtaining values of indoor wind speed above 2.0 m/s, mechanical means of ventilation may have to be adopted (*see also* Part D 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of this NBCS).

The warmth of the environment was found tolerable between 30 °C and 34 °C (TSI), and too hot above this limit. On the lower side, the coolness of the environment was found tolerable between 19 °C and 25 °C (TSI) and below 19 °C (TSI), it was found too cold.

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Table 11 Desirable Wind Speeds (m/s) for Thermal Comfort Conditions

(*Clause* 5.2.3.1.2)

Sl No.	Dry Bulb Temperature, °C	Relative Humidity, percent						
		30	40	50	60	70	80	90
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	28	[1]	[1]	[1]	[1]	[1]	[1]	[1]
ii)	29	[1]	[1]	[1]	[1]	[1]	0.06	0.19
iii)	30	[1]	[1]	[1]	0.06	0.24	0.53	0.85
iv)	31	[1]	0.06	0.24	0.53	1.04	1.47	2.10
v)	32	0.20	0.46	0.94	1.59	2.26	3.04	[2]
vi)	33	0.77	1.36	2.12	3.00	[2]	[2]	[2]
vii)	34	1.85	2.72	[2]	[2]	[2]	[2]	[2]
viii)	35	3.20	[2]	[2]	[2]	[2]	[2]	[2]

Table 12 Minimum Wind Speeds (m/s) for Just Acceptable Warm Conditions

(*Clause* 5.2.3.1.2)

Sl No.	Dry Bulb Temperature, °C	Relative Humidity, percent						
		30	40	50	60	70	80	90
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	28	[1]	[1]	[1]	[1]	[1]	[1]	[1]
ii)	29	[1]	[1]	[1]	[1]	[1]	[1]	[1]
iii)	30	[1]	[1]	[1]	[1]	[1]	[1]	[1]
iv)	31	[1]	[1]	[1]	[1]	[1]	0.06	0.23
v)	32	[1]	[1]	[1]	0.09	0.29	0.60	0.94
vi)	33	[1]	0.04	0.24	0.60	1.04	1.85	2.10
vii)	34	0.15	0.46	0.94	1.60	2.26	3.05	[2]
viii)	35	0.68	1.36	2.10	3.05	[2]	[2]	[2]
ix)	36	1.72	2.70	[2]	[2]	[2]	[2]	[2]

5.2.4 *Design of Indoor Conditions as per Adaptive Thermal Comfort Model*

Air conditioning systems for interior spaces intended for human occupancy should be sized for not more than 26 °C for cooling and for not less than 18 °C for heating at an occupied level. Design based on an adaptive thermal comfort model can play a major role in reducing energy use whilst maintaining the comfort, productivity and well-being of occupants. This approach recognizes that people's thermal comfort needs depend on their past and present context and that these needs vary with the outdoor environmental conditions of their location.

People living year-round in air-conditioned spaces are likely to develop high expectations for homogeneity and cool temperatures and may become quite critical if thermal conditions deviate from the centre of the comfort zone

[1] None.

[2] Higher than those acceptable in practice.

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they have come to expect. In contrast, people who live or work in naturally ventilated buildings, can control their immediate interior spaces and get accustomed to variable indoor thermal conditions that reflect local patterns of daily and seasonal climate changes. Their thermal perceptions, preferences, as well as tolerances, are likely to extend over a wider range of temperatures. It allows buildings to operate within broader temperature bands. The specification of a broader comfort band suited to the Indian context has the potential to reduce the use of energy-intensive space cooling for buildings in India. The provisions here deal with the adaptive thermal comfort model, which differentiates the thermal response of occupants in air-conditioned and naturally ventilated buildings. It is imperative to specify indoor comfort conditions separately for buildings depending upon their operation, namely, air-conditioned buildings as well as naturally ventilated buildings:

a) Operative temperature is a more suitable index to measure thermal comfort in a building having low indoor air velocities since the index also accounts for the impact of building surface temperatures (radiant temperatures) on human comfort. Indoor operative temperature, for sedentary activities, can be approximated as an arithmetic mean of indoor air and radiant temperatures. For operating an air conditioning system based on operative temperature, the prevalent conditions along with the historical outdoor trend can be used to derive suitable operative temperature limits. Typical climatic conditions of various Indian cities are in the public domain; and

b) In case of buildings having higher indoor air velocity (more than 0.5 m/s), an effective temperature-based approach is recommended since, in addition to all factors considered in operative temperature, it also takes into account heat dissipation from the human body through convective heat transfer. High air velocity can allow keeping higher air temperature without compromising thermal comfort. However, it is also suggested to keep in consideration noise and other effects of high indoor air velocity. For annual indoor design conditions as per the adaptive model, for Indian cities, reference may be made to Annex A of Part D 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of this NBCS. These are indicative, simplified values. They have been derived using typical meteorological year (TMY) files. More accurate design conditions can be derived using the following equations.

5.2.4.1 *Design Conditions for Commercial Buildings*

It is recommended to use the below-mentioned set of adaptive thermal comfort equations for commercial buildings. Equations (a) to (b) are best suited for the 30 day outdoor running mean temperatures between 13 °C and 38.5 °C:

a) For naturally ventilated (NV) commercial buildings — The following equation should be used for the design and operation of naturally ventilated (NV) buildings. It indicates that occupants in NV buildings thermally adapt to the outdoor temperature of their location:

$$Indoor\ operative\ temperature = (0.54 \times Outdoor\ temperature) + 12.83$$

where, indoor operative temperature (in °C) is the neutral temperature, and outdoor temperature is the 30 day outdoor running mean air temperature (in °C). The 90 percent acceptability range for naturally ventilated buildings is ± 2.38 °C.

b) For mixed-mode (MM) operation commercial buildings — Mixed-mode buildings, where HVAC is operated only during extreme outdoor conditions, are becoming prevalent in India. The occupants in mixed-mode buildings are more adaptive when compared to those in air conditioned buildings and somewhat less adaptive compared to occupants in naturally ventilated buildings:

$$Indoor\ operative\ temperature = (0.28 \times Outdoor\ temperature) + 17.87$$

where, indoor operative temperature (in °C) is the neutral temperature, and outdoor temperature is the 30 day outdoor running mean air temperature (in °C). The 90 percent acceptability range for mixed-mode buildings is ± 3.46 °C.

5.2.4.2 *Design Conditions for Residential Buildings*

The following equation should be used for determining adaptive thermal comfort in residential buildings, applicable for outdoor running mean temperatures between 7 °C and 33 °C. It is recommended to use the below-

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mentioned adaptive thermal comfort equation for residential buildings, for all operation modes:

$$Indoor\ operative\ temperature = (0.42 * Outdoor\ temperature) + 17.45$$

where, indoor operative temperature (in °C) is neutral temperature, and outdoor temperature is the 30 day outdoor running mean air temperature (in °C). The 90 percent acceptability range for conditioned buildings is ± 2.15 °C.

The adaptive comfort values derived using equations given in 5.2.4.1 for commercial, and the equation given in 5.2.4.2 for residential buildings are best suited for indoor relative humidity conditions (RH in percentage) between 25 percent and 75 percent.

5.2.5 *Minimum Outside Fresh Air*

Minimum outside fresh air applicable to only fully air-conditioned buildings. Table 13 prescribes minimum supply rates of acceptable outdoor air required for acceptable indoor air quality. These requirements for ventilation of health care facilities (hospitals, nursing and convalescent homes) are separately covered in Table 14. These values have been prescribed to dilute human bio effluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels. The values prescribed in the table should be used in conjunction with the accompanying notes. Naturally ventilated spaces and mixed mode spaces, while operating in naturally ventilated mode, will have to rely on outdoor air using fenestration systems. The quantity and distribution of introduced fresh air should take into account the natural infiltration of the building. The proportion of fresh air introduced into air conditioned building may be varied to achieve economical and efficient operation. When the fresh air can provide a useful cooling effect, the quantity should be controlled through an air-side economizer to balance the cooling demand. However, when the air is too warm or humid the quantity may be reduced to a minimum to reduce the cooling load.

5.2.5.1 *Air class characteristic*

The following are the characteristics of the four air classes:

a) Class 1 — Air with low contaminant concentration, low sensory-irritation intensity and inoffensive odour;

b) Class 2 — Air with moderate contaminant concentration, mild sensory-irritation intensity, or mildly offensive odours. This air also includes air that is not necessarily harmful or objectionable but that is inappropriate for transfer or recirculation to spaces used for different purposes;

c) Class 3 — Air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odour; and

d) Class 4 — Air with highly objectionable fumes or gases or with potentially dangerous particles, bio aerosols, or gases, at concentrations high enough to be considered harmful.

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Table 13 Minimum Ventilation Rates in Breathing Zone

(*Clauses* 5.2.5)

(This table is not valid in isolation; it shall be used in conjunction with the accompanying notes.)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s/person	l/s/m^2		persons per 100 m^2	l/s/person	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	**Correctional facilities:**						
	a) Cell	2.5	0.6	–	25	4.9	2
	b) Dayroom	2.5	0.3	–	30	3.5	1
	c) Guard stations	2.5	0.3	–	15	4.5	1
	d) Booking/waiting	3.8	0.3	–	50	4.4	2
ii)	**Educational facilities:**						
	a) Daycare (through age 4)	5	0.9	–	25	8.6	2
	b) Daycare sickroom	5	0.9	–	25	8.6	3
	c) Classrooms (age 5 to 8)	5	0.6	–	25	7.4	1
	d) Classrooms (age 9 plus)	5	0.6	–	35	6.7	1
	e) Lecture classroom	3.8	0.3	–	65	4.3	1
	f) Lecture hall (fixed seats)	3.8	0.3	–	150	4.0	1
	g) Art classroom	5	0.9	–	20	9.5	2
	h) Science laboratories	5	0.9	–	25	8.6	2
	j) University/college laboratories	5	0.9	–	25	8.6	2

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Table 13 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s/person	l/s/m^2		persons per 100 m^2	l/s/person	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	k) Wood/metal shop	5	0.9	–	20	9.5	2
	m) Computer lab	5	0.6	–	25	7.4	1
	n) Media centre	5	0.6	*See* Note 6	25	7.4	1
	p) Music/theatre/dance	5	0.3	–	35	5.9	1
	q) Multi-use assembly	3.8	0.3	–	100	4.1	1
iii)	**Food and beverage service:**						
	a) Restaurant dining rooms	3.8	0.9	–	70	5.1	2
	b) Cafeteria/fast-food dining	3.8	0.9	–	100	4.7	2
	c) Bars, cocktail lounges	3.8	0.9	–	100	4.7	2
iv)	**General:**						
	a) Break rooms	2.5	0.3	–	25	5.1	1
	b) Coffee stations	2.5	0.3	–	20	5.5	1
	c) Conference/meeting rooms	2.5	0.3	–	50	3.1	1
	d) Corridors	–	0.3	–	–	–	1
	e) Storage rooms	–	0.6	*See* Note 7	–	–	1

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Table 13 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s/person	l/s/m^2		persons per 100 m^2	l/s/person	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
v)	**Hotels, motels, resorts, dormitories:**						
	a) Bedroom/living room	2.5	0.3	–	10	5.5	1
	b) Barracks sleeping areas	2.5	0.3	–	20	4.0	1
	c) Laundry rooms, central	2.5	0.6	–	10	8.5	2
	d) Laundry rooms within dwelling units	2.5	0.6	–	10	8.5	1
	e) Lobbies/pre-function	3.8	0.3	–	30	4.8	1
	f) Multipurpose assembly	2.5	0.3	–	120	2.8	1
vi)	**Office buildings:**						
	a) Office space	2.5	0.3	–	5	8.5	1
	b) Reception Areas	2.5	0.3	–	30	3.5	1
	c) Telephone/data entry	2.5	0.3	–	60	3.0	1
	d) Main entry lobbies	2.5	0.3	–	10	5.5	1
				–			
vii)	**Miscellaneous spaces**:						
	a) Bank vaults/safe deposit	2.5	0.3	–	5	8.5	2
	b) Computer (not printing)	2.5	0.3	–	4	10.0	1

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Table 13 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s/person	l/s/m^2		persons per 100 m^2	l/s/person	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	c) Electrical equipment rooms	–	0.3	*See* Note 7	–	–	1
	d) Elevator machine rooms	–	0.6	*See* Note 7	–	–	1
	e) Pharmacy (preparation area)	2.5	0.9	–	10	11.5	2
	f) Photo studios	2.5	0.6	–	10	8.5	1
	g) Shipping/receiving	–	0.6	*See* Note 7	–	–	1
	h) Telephone closets	–	0.0	–	–	–	1
	j) Transportation waiting	3.8	0.3	–	100	4.1	1
	k) Warehouses	–	0.3	*See* Note 7	–	–	2
viii)	**Public assembly spaces:**						
	a) Auditorium seating area	2.5	0.3	–	150	2.7	1
	b) Places of religious worship	2.5	0.3	–	120	2.8	1
	c) Courtrooms	2.5	0.3	–	70	2.9	1
	d) Legislative chambers	2.5	0.3	–	50	3.1	1
	e) Libraries	2.5	0.6	–	10	8.5	1
	f) Lobbies	2.5	0.3	–	150	2.7	1
	g) Museums (children's)	3.8	0.6	–	40	5.3	1

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Table 13 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s/person	l/s/m^2		persons per 100 m^2	l/s/person	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	h) Museums/galleries	3.8	0.3	–	40	4.6	1
ix)	**Residential:**						
	a) Dwelling unit	2.5	0.3	*See* Notes 8 and 9	*See* Note 8	–	1
	b) Common corridors	–	0.3	–	–	–	1
x)	**Retail:**						
	a) Sales (except as below)	3.8	0.6	–	15	7.8	2
	b) Mall common areas	3.8	0.3	–	40	4.6	1
	c) Barber shop	3.8	0.3	–	25	5.0	2
	d) Beauty and nail salons	10	0.6	–	25	12.4	2
	e) Pet shops (animal areas)	3.8	0.9	–	10	12.8	2
	f) Supermarket	3.8	0.3	–	8	7.6	1
	g) Coin-operated laundries	3.8	0.3	–	20	5.3	2
xi)	**Sports and entertainment:**						
	a) Sports arena (play area)	–	1.5	*See* Note 10	–	–	1
	b) Gym, stadium (play area)	–	1.5	–	30	–	2
	c) Spectator areas	3.8	0.3	–	150	4.0	1

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Table 13 (*Concluded*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s/person	l/s/m^2		persons per 100 m^2	l/s/person	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	d) Swimming (pool and deck)	-	2.4	*See* Note 11	–	–	2
	e) Disco/dance floors	10	0.3	–	100	10.3	1
	f) Health club/aerobics room	10	0.3	–	40	10.8	2
	g) Health club/weight rooms	10	0.3	–	10	13.0	2
	h) Bowling alley (seating)	5	0.6	–	40	6.5	1
	j) Casinos	3.8	0.9	–	120	4.6	1
	k) Game arcades	3.8	0.9	–	20	8.3	1
	m) Stages, studios	5	0.3	*See* Note 12	70	5.4	1

NOTES

1 The rates in this table are based on all other applicable requirements being met.

2 This table applies to no-smoking areas only. Rates for smoking-permitted spaces shall be determined using other methods.

3 Volumetric airflow rates are based on an air density of 1.2 kg of dry air/m^3, which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 21 °C. Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.

4 Actual occupant density should be considered, the default occupant density shall be used only when actual occupant density is not known. Default combined outdoor air (per person) rate is based on the default occupant density.

5 If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.

6 For high school and college libraries, use values shown for public assembly spaces-libraries.

7 The prescribed value may not be sufficient when stored materials include those having potentially harmful emissions.

8 Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.

9 Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

10 When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.

11 The prescribed value does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.

12 The prescribed value does not include special exhaust for stage effects, for example, dry ice vapours, smoke.

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Table 14 Outdoor Air Requirements for Ventilation of Health Care Facilities

(*Clause* 5.2.5)

Sl No.	Application	Estimated Maximum Occupancy[1)]	Outdoor Air Requirements		Remarks
		persons/100 m²	l/s per person	l/s per m²	
(1)	(2)	(3)	(4)	(5)	(6)
i)	Patient rooms	10	13	–	Special requirements and pressure relationships may determine minimum ventilation rates and filter efficiency. Procedures generating contaminants may require higher rates.
ii)	Medical procedure	20	8	–	
iii)	Operating rooms	20	15	–	
iv)	Recovery and ICU	20	8	–	
v)	Autopsy rooms	20	–	2.5	Air shall not be recirculated into other spaces.
vi)	Physical therapy	20	8	–	

[1)] Net occupiable space.

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5.2.6 There will be a limit of heat tolerance when air temperatures are excessive and the degree of physical activity is high. This limit is determined when the bodily heat balance is upset, that is, when the bodily heat gain due to conduction, convection and the radiation from the surroundings exceeds the bodily heat loss, which is mostly by evaporation of sweat from the surface of the body. The limits of heat tolerance for Indian workers are based on the study conducted by the Chief Adviser Factories, Government of India, Ministry of Labour and are given in his report on Thermal Stress in Textile Industry (Report No. 17) issued in 1956. According to this report, where workers in industrial buildings wearing light clothing are expected to do work of moderate severity with the energy expenditure in the range 273 W to 284 W, the maximum wet bulb temperature shall not exceed 29 °C and adequate air movement subject to a minimum air velocity of 30 m/min shall be provided, and in relation to the dry bulb temperature, the wet bulb temperature of air in the work room, as far as practicable, shall not exceed that given in Table 15.

Table 15 Maximum Permissible Wet Bulb Temperatures for Given Dry Bulb Temperatures

(*Clause* 5.2.6)

Sl No.	Dry Bulb Temperature °C	Maximum Wet-Bulb Temperature °C
(1)	(2)	(3)
i)	30	29.0
ii)	35	28.5
iii)	40	28.0
iv)	45	27.5
v)	50	27.0

NOTES

1 These are limits beyond which the industry should not allow the thermal conditions to go for more than 1 h continuously. The limits are based on a series of studies conducted on Indian subjects in psychrometric chamber and on other data on heat casualties in earlier studies conducted in Kolar Gold Fields and elsewhere.

2 Figures given in this table are not intended to convey that human efficiency at 50 °C will remain the same as at 30 °C, provided appropriate wet bulb temperatures are maintained. Efficiency decreases with a rise in the dry bulb temperature as well, as much as possible. Long exposures to temperatures of 50 °C dry bulb/27 °C wet bulb may prove dangerous.

3 Refrigeration or some other method of cooling is recommended in all cases where conditions would be worse than those shown in this table.

5.3 Methods of Ventilation

General ventilation involves providing a building with relatively large quantities of outside air in order to improve general environment of the building. This may be achieved in one of the following ways:

a) Natural supply and natural exhaust of air;

b) Natural supply and mechanical exhaust of air;

c) Mechanical supply and natural exhaust of air; and

d) Mechanical supply and mechanical exhaust of air.

5.3.1 *Control of Heat*

Although it is recognized that general ventilation is one of the most effective methods of improving thermal environmental conditions in factories, in many situations, the application of ventilation should be preceded by and considered along with some of the following other methods of control. This would facilitate better design of buildings for general ventilation, either natural or mechanical or both and also reduce their cost.

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5.3.1.1 *Isolation*

Sometimes it is possible to locate heat producing equipment, such as furnaces in such a position as would expose only a small number of workers to hot environment. As far as practicable, such sources of heat in factories should be isolated.

In situations where relatively few people are exposed to severe heat stress and their activities are confined to limited areas as in the case of rolling mill operators and crane operators, it may be possible to enclose the work areas and provide spot cooling or supply conditioned air to such enclosures.

5.3.1.2 *Insulation*

A considerable portion of heat in many factories is due to the solar radiation falling on the roof surfaces, which, in turn, radiate heat inside the building. In such situations, insulations of the roof or providing a false ceiling or double roofing would be very effective in controlling heat. Some reduction can also be achieved by painting the roof in heat reflective shades.

Hot surfaces of equipment, such as pipes, vessels, etc, in the building should also be insulated to reduce their surface temperature.

5.3.1.3 *Substitution*

Sometimes, it is possible to substitute a hot process by a method that involves application of localized or more efficiently controlled method of heating, examples include induction hardening instead of conventional heat treatment, cold riveting or spot welding instead of hot riveting, etc.

5.3.1.4 *Radiant shielding*

Hot surfaces, such as layers of molten metal emanate radiant heat, which can best be controlled by placing a shield having a highly reflecting surface between the source of heat and the worker, so that a major portion of the heat falling on the shield is reflected back to the source. Surfaces such as of tin and aluminium have been used as materials for shields. The efficiency of the shield does not depend on its thickness, but on the reflectivity and emissivity of its surface. Care should be taken to see that the shield is not heated up by conduction and for this purpose adequate provision should be made for the free flow upwards of the heated air between the hot surface and the shield by leaving the necessary air space and providing opening at the top and the bottom of the sides.

5.3.2 *Volume of Air Required*

The volume of air required shall be calculated by using both the sensible heat and latent heat gain as the basis. The larger of the two values obtained should be used in actual practice.

In places without sufficient wind speeds and/or in buildings where effective cross ventilation is not possible due to the design of the interior, the indoor air may be exhausted by a fan, with outdoor air entering the building through the open windows.

5.3.2.1 *Volume of air required for removing sensible heat*

When the amount of sensible heat given off by different sources, namely, the sun, the manufacturing processes, machinery, occupants and other sources, is known and a suitable value for the allowable temperature rise is assumed, the volume of outside air to be provided for removing the sensible heat may be calculated from:

$$Q_1 = \frac{2.976\ 8\ K_s}{t}$$

where

Q_1 = quantity of air, in m^3/h;

K_s = sensible heat gained, in W; and

t = allowable temperature rise, in °C.

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5.3.2.2 Temperature rise refers mainly to the difference between the air temperatures at the outlet (roof exit) and at the inlet openings for outside air. As very little data exist on allowable temperature rise values for supply of outside air in summer months, the values given in Table 16 related to industrial buildings may be used for general guidance.

Table 16 Allowable Temperature Rise Values

(*Clause* 5.3.2.2)

Sl No.	Height of Outlet Opening	Temperature Rise
	m	°C
(1)	(2)	(3)
i)	6	3 to 4.5
ii)	9	4.5 to 6.5
iii)	12	6.5 to 11

NOTES

1 The conditions are limited to light or medium heavy manufacturing processes, freedom from radiant heat and inlet openings not more than 3 m to 4.5 m above floor level.

2 At the working zone between floor level and 1.5 m above floor level, the recommended maximum allowable temperature rise for air is 2 °C to 3 °C above the air temperature at the inlet openings.

5.3.2.3 *Volume of air required for removing latent heat*

If the latent heat gained from the manufacturing processes and occupants is also known and a suitable value for the allowable rise in the vapour pressure is assumed, the volume of air to be provided to remove the latent heat may be calculated from:

$$Q_2 = \frac{4\ 127.26\ K_1}{h}$$

where

Q_2 = quantity of air, in m^3/h;

K_1 = latent heat gained, in W; and

h = allowable vapour pressure difference, in mm of mercury.

NOTE — In majority of the cases, the sensible heat gain will far exceed the latent heat gain, so that the amount of outside air to be drawn by ventilating equipment can be calculated on the basis of the equation given in **5.3.2.1**.

5.3.2.4 Ventilation is also expressed as $m^3/h/m^2$ of floor area. This relationship fails to evaluate the actual heat relief provided by a ventilation system, but it does give a relationship which is independent of building height. This is a more rational approach, because, with the same internal load, the same amount of ventilation air, properly applied to the work zone with adequate velocity, will provide the desired heat relief quite independently of the ceiling height of the space, with few exceptions. Ventilation rates of 30 $m^3/h/m^2$ to 60 $m^3/h/m^2$ have been found to give good results in many plants.

5.4 Natural Ventilation

The rate of ventilation by natural means through windows or other openings depends on,

a) direction and velocity of wind outside and sizes and disposition of openings (wind action); and

b) convection effects arising from temperature of vapour pressure difference (or both) between inside and outside the room and the difference of height between the outlet and inlet openings (stack effect).

5.4.1 *Ventilation of Non-Industrial Buildings*

Ventilation in non-industrial buildings due to stack effect, unless there is a significant internal load, could be neglected, except in cold regions and wind action may be assumed to be predominant.

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5.4.1.1 In hot dry regions, the main problem in summer is to provide protection from sun's heat so as to keep the indoor temperature lower than those outside under the sun. For this purpose, windows and other openings are generally kept closed during day time and only minimum ventilation is provided for the control of odours or for removal of products of combustion.

5.4.1.2 In warm humid regions, the problem in the design of non-industrial buildings is to provide free passage of air to keep the indoor temperature as near to those outside in the shade as possible, and for this purpose the buildings are oriented to face the direction of prevailing winds and windows and other openings are kept open on both windward and leeward sides.

5.4.1.3 In winter months in cold regions, the windows and other openings are generally kept shut, particularly during night; and ventilation necessary for the control of odours and for the removal of products of combustion can be achieved either by stack action or by some infiltration of outside air due to wind action.

5.4.2 *Ventilation of Industrial Buildings*

In providing natural ventilation of all industrial buildings having significant internal heat loads due to manufacturing process, proper consideration should be given to the size and distribution of windows and other inlet openings in relation to outlet openings so as to give, with due regard to orientation, prevailing winds, size and configuration of the building and manufacturing processes carried on, maximum possible control of thermal environment.

5.4.2.1 In the case of industrial buildings wider than 30 m, the ventilation through windows may be augmented by roof ventilation.

5.4.3 *Design Guidelines for Natural Ventilation*

5.4.3.1 *By wind action*

a) A building need not necessarily be oriented perpendicular to the prevailing outdoor wind; it may be oriented at any convenient angle between 0° and 30° without losing any beneficial aspect of the breeze. If the prevailing wind is from east or west, building may be oriented at 45° to the incident wind so as to diminish the solar heat without much reduction in air motion indoors;

b) Inlet openings in the buildings should be well distributed and should be located on the windward side at a low level, and outlet openings should be located on the leeward side. Inlet and outlet openings at high levels may only clear the top air at that level without producing air movement at the level of occupancy;

c) Maximum air movement at a particular plane is achieved by keeping the sill height of the opening at 85 percent of the critical height (such as head level) for the following recommended levels of occupancy:

   1) For sitting on chair 0.75 m;

   2) For sitting on bed 0.60 m; and

   3) For sitting on floor 0.40 m.

d) Inlet openings should not as far as possible be obstructed by adjoining buildings, trees, sign boards or other obstructions or by partitions inside in the path of air flow;

e) In rooms of normal size having identical windows on opposite walls the average indoor air speed increases rapidly by increasing the width of window up to two-third of the wall width; beyond that the increase is in much smaller proportion than the increase of the window width. The air motion in the working zone is maximum when window height is 1.1 m. Further increase in window height promotes air motion at higher level of window, but does not contribute additional benefits as regards air motion in the occupancy zones in buildings;

f) Greatest flow per unit area of openings is obtained by using inlet and outlet openings of nearby equal areas at the same level;

g) For a total area of openings (inlet and outlet) of 20 percent to 30 percent of floor area, the average indoor wind velocity is around 30 percent of outdoor velocity. Further increase in window size increases the available velocity but not in the same proportion as shown in Fig. 6. In fact, even under most favourable conditions the maximum average indoor wind speed does not exceed 40 percent of outdoor velocity;

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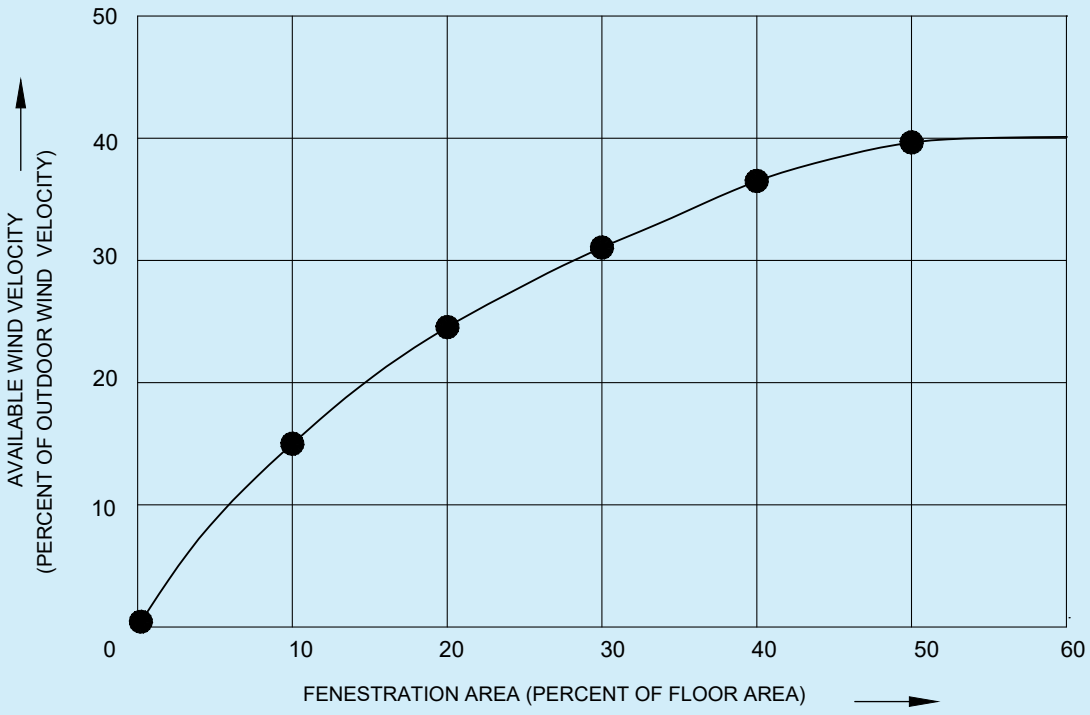

FIG. 6 EFFECT OF AREA OF OPENING ON AVERAGE INDOOR WIND VELOCITY

h) Where the direction of wind is quite constant and dependable, the size of the inlet should be kept within 30 percent to 50 percent of the total area of openings and the building should be oriented perpendicular to the incident wind. Where direction of the wind is quite variable the openings may be arranged so that as far as possible there is approximately equal area on all sides. Thus, no matter what the wind direction be, there would be some openings directly exposed to wind pressure and others to air suction and effective air movement through the building would be assured;

j) Windows of living rooms should open directly to an open space. In places where building sites are restricted, open space may have to be created in the buildings by providing adequate courtyards;

k) In the case of rooms with only one wall exposed to outside, provision of two windows on that wall is preferred to that of a single window;

m) Windows located diagonally opposite to each other with the windward window near the upstream corner give better performance than other window arrangements for most of the building orientations;

n) Horizontal louvers, that is, sunshades atop windows deflect the incident wind upward and reduce air motion in the zone of occupancy. A horizontal slot between the wall and horizontal louver prevents upward deflection of air in the interior of rooms. Provision of inverted L type (Γ) louver increases the room air motion provided that the vertical projection does not obstruct the incident wind (*see* Fig. 7);

p) Provision of horizontal sashes inclined at an angle of 45° in appropriate direction helps to promote the indoor air motion. Sashes projecting outward are more effective than projecting inward;

q) Air motion at working plane 0.4 m above the floor can be enhanced by 30 percent using a pelmet type wind deflector (*see* Fig. 8);

r) Roof overhangs help promoting air motion in the working zone inside buildings;

s) In case of room with windows on one wall, with single window, the room wind velocity inside the room on the windward side is 10 percent of outdoor velocity at points up to a distance one-sixth of room width from the window and then decreases rapidly and hardly any air movement is produced in the leeward half portion of the room. The average indoor wind velocity is generally less than 10 percent of outdoor velocity. When two windows are provided and wind impinges obliquely on them, the inside velocity increases up to 15 percent of the outdoor velocity;

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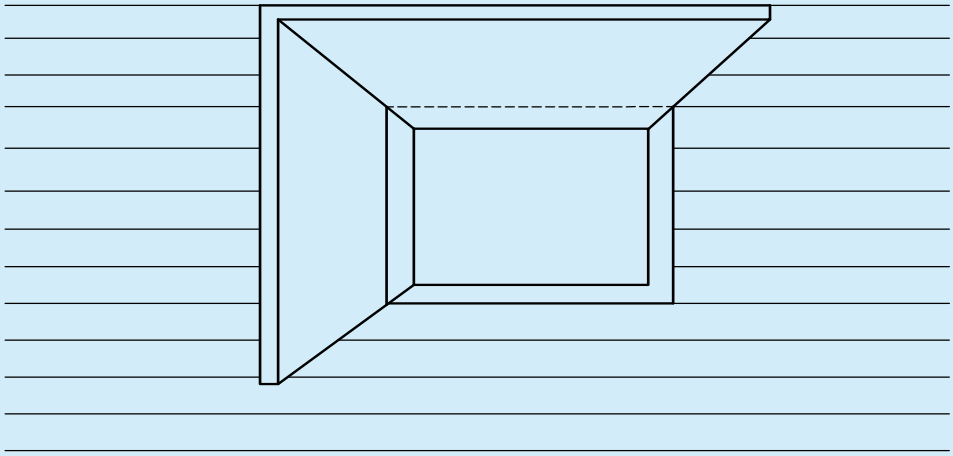

FIG. 7 L-TYPE LOUVER

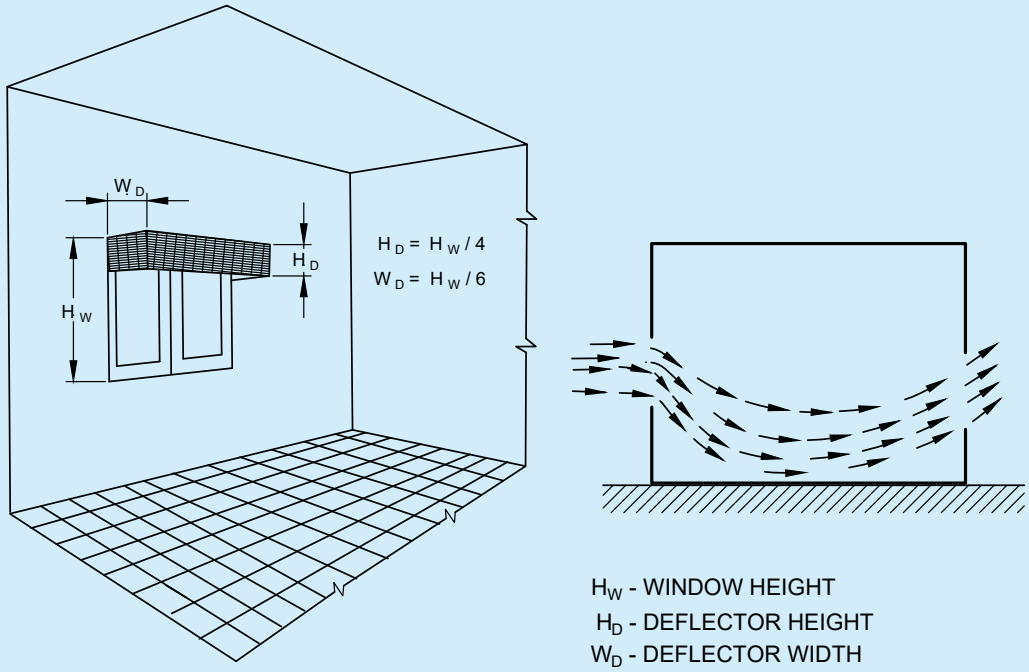

FIG. 8 SKETCH OF A PELMET TYPE WIND DEFLECTOR

t) Cross ventilation can be obtained through one side of the building to the other, in case of narrow buildings with the width common in the multistoreyed type by the provision of large and suitably placed windows or combination of windows and wall ventilators for the inflow and outflow of air;

u) *Verandah* open on three sides is to be preferred since it causes an increase in the room air motion for most of the orientations of the building with respect to the outdoor wind;

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v) A partition placed parallel to the incident wind has little influence on the pattern of the air flow, but when located perpendicular to the main flow, the same partition creates a wind shadow. Provision of a partition with spacing of 0.3 m underneath helps augmenting air motion near floor level in the leeward compartment of wide span buildings;

w) Air motion in a building unit having windows tangential to the incident wind is accelerated when another unit is located at end-on position on downstream side (s*ee* Fig. 9);

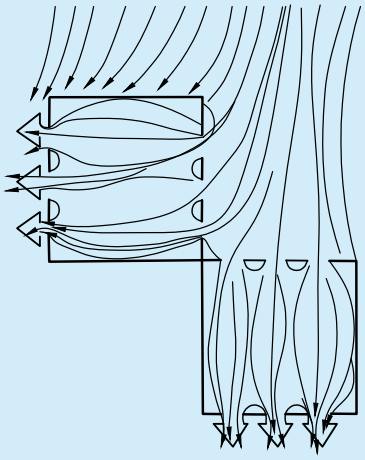

FIG. 9 TWO UNITS LOCATED AT THE END-ON POSITION

y) Air motion in two wings oriented parallel to the prevailing breeze is promoted by connecting them with a block on downstream side;

z) Air motion in a building is not affected by constructing another building of equal or smaller height on the leeward side; but it is slightly reduced if the leeward building is taller than the windward block;

aa) Air motion in a shielded building is less than that in an unobstructed building. To minimize shielding effect, the distances between two rows should be 8 H for semi-detached houses and 10 H for long rows houses. However, for smaller spacing the shielding effect is also diminished by raising the height of the shielded building;

bb) Hedges and shrubs deflect the air away from the inlet openings and cause a reduction in indoor air motion. These elements should not be planted at a distance of about 8 m from the building because the induced air motion is reduced to minimum in that case. However, air motion in the leeward part of the building can be enhanced by planting a low hedge at a distance of 2 m from the building;

cc) Trees with large foliage mass having trunk bare of branches up to the top level of window, deflect the outdoor wind downwards and promotes air motion in the leeward portion of buildings;

dd) Ventilation conditions indoors can be ameliorated by constructing buildings on earth mound having a slant surface with a slope of 10° on upstream side;

ee) In case of industrial buildings, the window height should be about 1.6 m and width about two-third of wall width. These should be located at a height of 1.1 m above the floor. In addition to this, openings around 0.9 m high should be provided over two-third length of the glazed area in the roof lights;

ff) Height of industrial buildings, although determined by the requirements of industrial processes involved, are generally kept large enough to protect the workers against hot stagnant air below the ceiling as also to dilute the concentration of contaminant inside. However, if high level openings in roof or walls are provided, building height can be reduced to 4 m without in any way impairing the ventilation performance; and

gg) The maximum width up to which buildings of height usually found in factories, being effectively ventilated by natural means by wind action, is 30 m, beyond which sufficient reliance cannot be placed

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on prevailing winds. Approximately half the ventilating area of openings should be between floor level and a height of 2.25 m from the floor.

NOTE — For data on outdoor wind speeds at a place, reference may be made to 'The Climatic Data Handbook prepared by Central Building Research Institute, Roorkee, 1999'.

5.4.3.2 *By stack effect*

Natural ventilation by stack effect occurs when air inside a building is at a different temperature than air outside. Thus, in heated buildings or in buildings wherein hot processes are carried on and in ordinary buildings during summer nights and during pre-monsoon periods, the inside temperature is higher than that of outside, cool outside air will tend to enter through openings at low level and warm air will tend to leave through openings at high level. It would, therefore, be advantageous to provide ventilators as close to ceilings as possible. Ventilators can also be provided in roofs as, for example, cowl, vent pipe, covered roof and ridge vent.

5.4.4 *Design Charts for Natural Ventilation*

Openings for natural ventilation can be sized without the need for complex and expensive computer simulation methods using analytical techniques. The design charts (DCs) provided hereunder can be used to assist in the sizing of ventilation openings to deliver natural ventilation.

The design charts are derived from analytical techniques. They provide either the geometrical free area (A_f) of openings to deliver a recommended air flow rate, or the achieved flow rate for a given free area.

Based on information for inside-outside air temperature difference (ΔT), wind speed (U) and wind pressure co-efficient (ΔC_p), the DCs are applicable for a wide range of weather conditions and parameters appropriate for residential buildings located in the selected Indian climatic zones.

These are considered to be the most common configurations encountered in practice in Indian residences. The corresponding DCs are:

a) DC-01 — Buoyancy-driven flow; single-sided ventilation with one opening (Fig. 10A and Fig. 11);

b) DC-02 — Buoyancy-driven flow; cross-ventilation with multiple openings (Fig. 10B and Fig. 12);

c) DC-03 — Wind-driven flow; single-sided ventilation with one opening (Fig. 10C and Fig. 13); and

d) DC-04 — Wind-driven flow; cross-ventilation with multiple openings (Fig. 10D and Fig. 14).

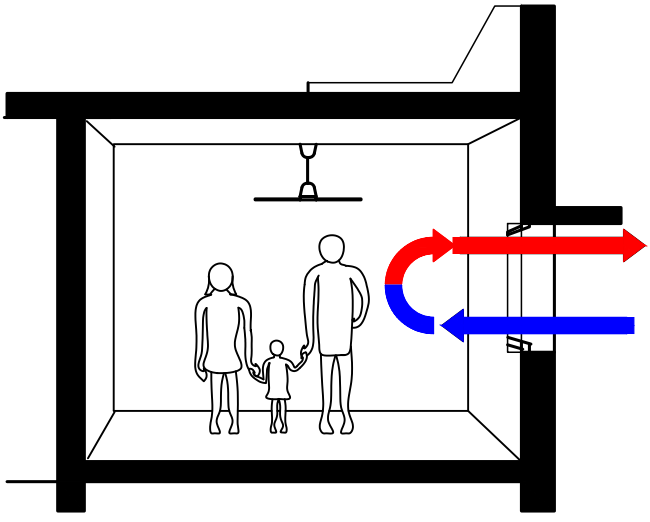

FIG. 10A DC-01

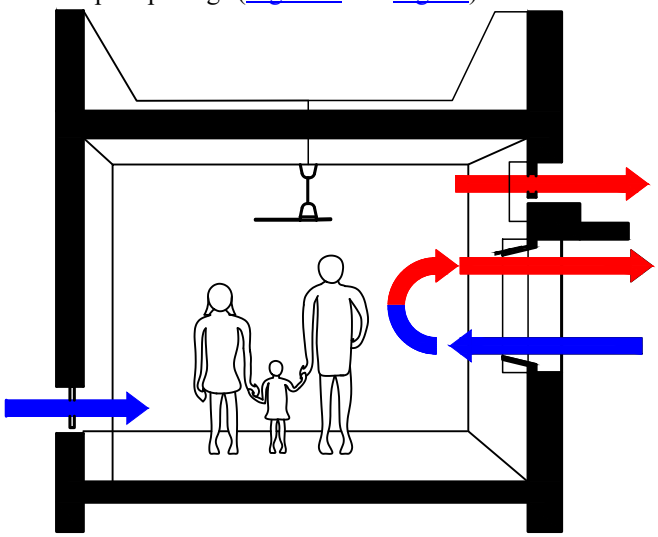

FIG. 10B DC-02

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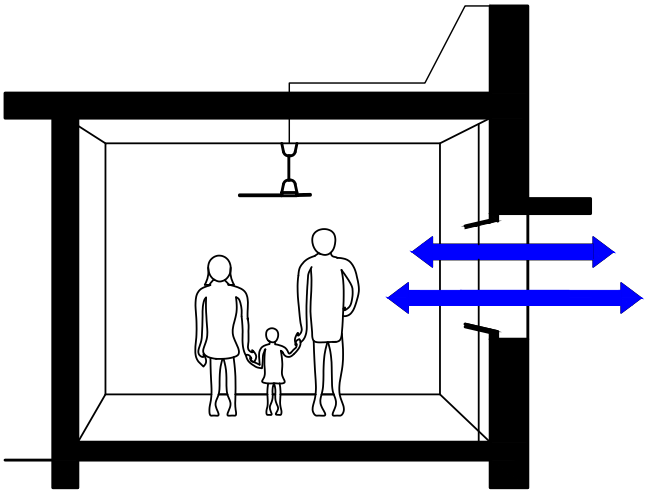

FIG. 10C DC-03

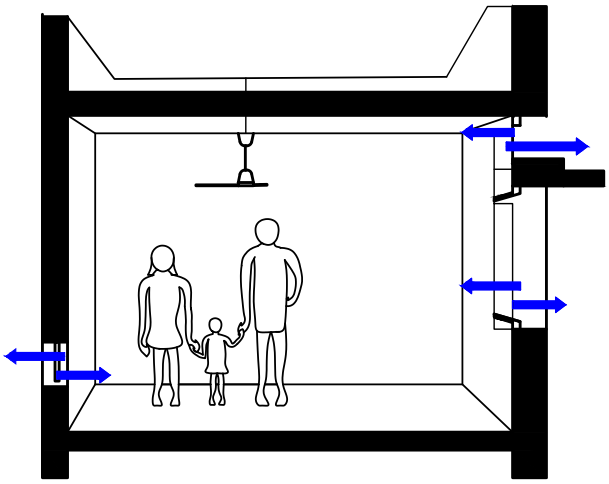

FIG. 10D DC-04

FIG. 10 CROSS-SECTION SKETCHES OF THE DRIVING FORCES FOR THE NATURAL VENTILATION SYSTEMS PRESENTED IN THE FOUR DESIGN CHARTS

5.4.4.1 *Design charts for natural ventilation — by stack effect*

a) DC-01 — Buoyancy-driven flow; single-sided ventilation with one opening;

The DC-01 is derived from the equation below (*see also* Fig. 11). For single opening, the value for C_d adopted is 0.25:

$$A_f = \frac{q_{rec}}{C_d}\sqrt{\frac{(T_{inside}+273)}{g\,h_a \Delta T_{inside\text{-}outside}}}$$ (*see also* **C-1.2.1**)

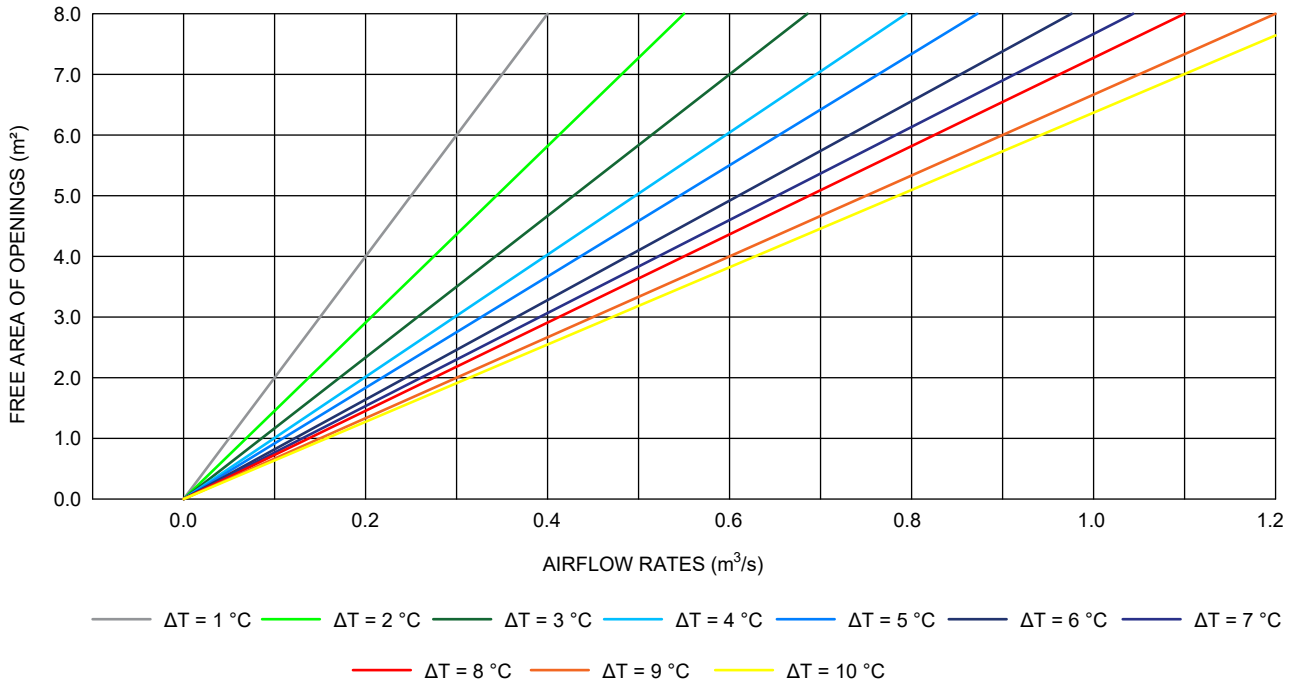

FIG. 11 DESIGN CHART DC-01 FOR SINGLE-SIDED SINGLE OPENING BUOYANCY DRIVEN FLOW

b) DC-02 — buoyancy-driven flow; cross-ventilation;

The DC-02 is also derived from the equation below (*see also* Fig. 12). Conversely, for multiple openings, the value for C_d adopted is 0.61:

$$V_z = V_{ref}\, k\, z^{\alpha}(m/s)$$ (*see also* **C-1.2.3.1**)

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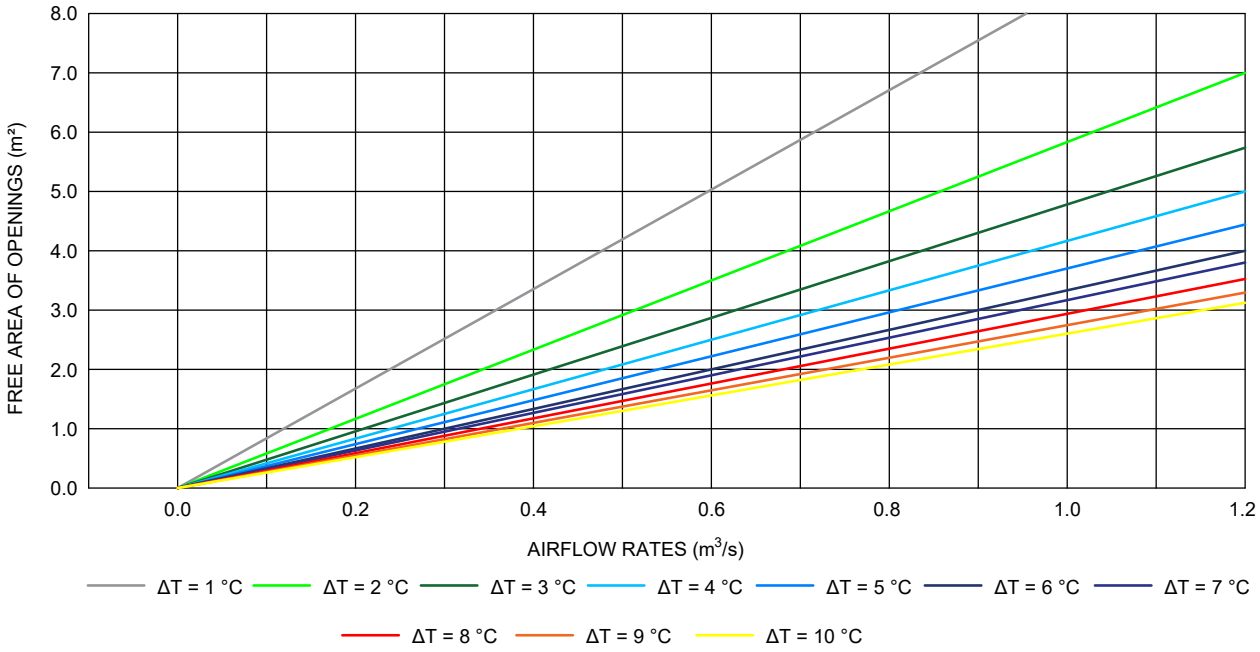

FIG. 12 DESIGN CHART DC-02 FOR MULTIPLE OPENINGS AND BUOYANCY-DRIVEN FLOW

5.4.4.2 *Design charts for natural ventilation — by wind effect*

a) DC-03 — Wind-driven flow; single-sided ventilation with one opening;

The DC-03 is derived from the following equation (*see also* Fig. 13):

$$A_f = {}^{q_{rec}}/_{C\,V_z}$$ (*see also* **C-1.2.3**)

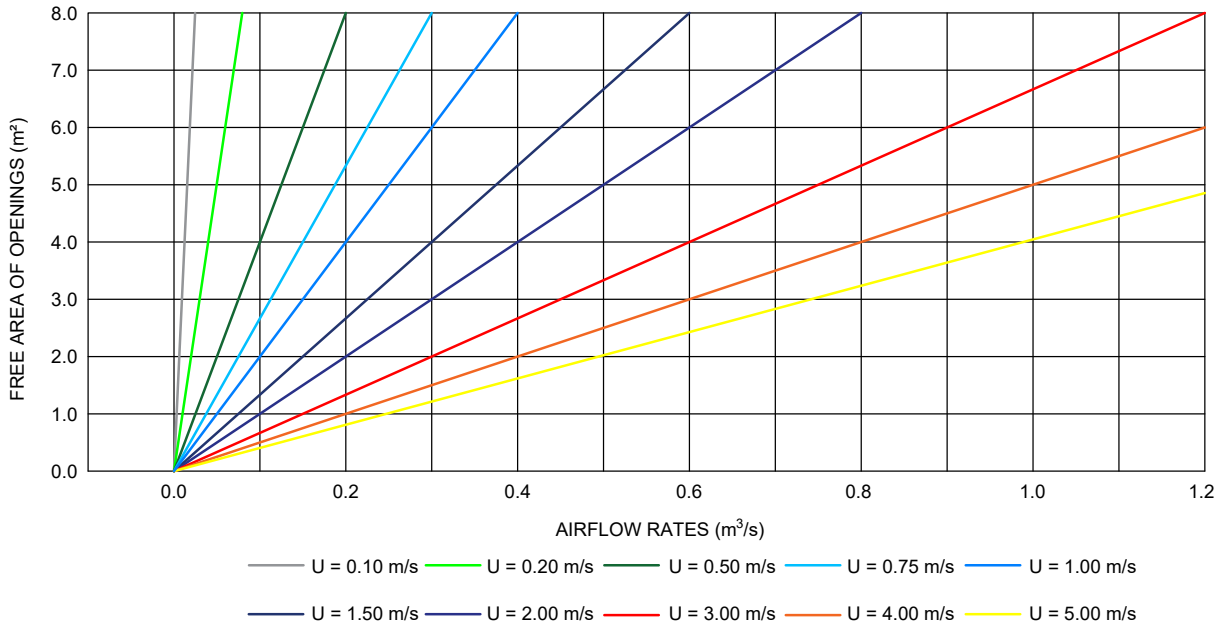

FIG. 13 DESIGN CHART DC-03 FOR SINGLE-SIDED SINGLE OPENINGS AND WIND-DRIVEN FLOW

b) DC-04 — Wind-driven flow; cross-ventilation with multiple openings;

The DC-04 is derived from the following equation (*see also* Fig. 14):

$$A_f = q_{ref}\left(C_d V_z \sqrt{\frac{\Delta C_p}{2}}\right)^{-1}$$ (*see also* **C-1.2.4**)

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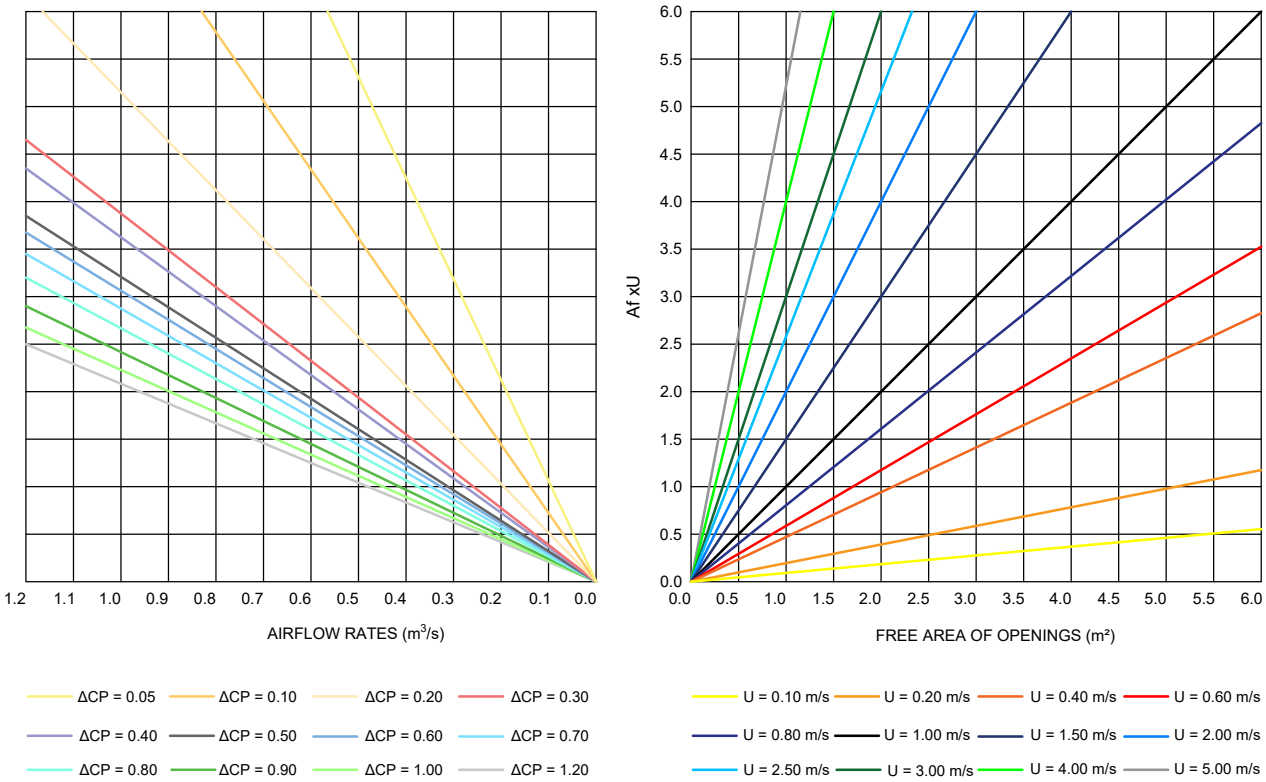

FIG. 14 DESIGN CHART DC-04 FOR MULTIPLE OPENINGS AND WIND-DRIVEN FLOW

5.4.4.3 For detailed application and use of the design charts for natural ventilation, reference may be made to Annex C.

5.5 Mechanical Ventilation

The requirements of mechanical ventilation should be in accordance with Part D 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of this NBCS.

5.6 Determining Rate of Ventilation

5.6.1 *Natural Ventilation*

This is difficult to measure as it varies from time to time. The amount of outside air through windows and other openings depends on the direction and velocity of wind outside (wind action) and/or convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building (stack effect).

5.6.1.1 *Wind action*

For determining the rate of ventilation based on wind action the wind may be assumed to come from any direction within 45° of the direction of prevailing wind. Ventilation due to external wind is given by the following formula:

$$Q_w = K \times A \times V$$

where

Q_w = rate of air flow, in m^3/h;

K = coefficient of effectiveness, which may be taken as 0.6 for wind perpendicular to openings and 0.3 for wind at an angle less than 45° to the openings;

A = free area of inlet openings, in m^2; and

V = wind speed, in m/h.

NOTE — For wind data at a place, the local Meteorological Department may be consulted.

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5.6.1.2 *Stack effect* (*thermal action*)

Ventilation due to convection effects arising from temperature difference between inside and outside is given by:

$$Q_T = 7.0\, A \sqrt{h\,(t_r - t_o)}$$

where

Q_T = rate of air flow, in m^3/h;

A = free area of inlet openings, in m^2;

h = vertical distance between inlets and outlets, in m;

t_r = average temperature of indoor air at height h, in °C; and

t_o = temperature of outdoor air, in °C.

NOTE — The equation is based on 0.65 times the effectiveness of openings. This should be reduced to 0.50 if conditions are not favourable.

5.6.1.3 When areas of inlet and outlet openings are unequal, the value of A may be calculated using the equation:

$$\frac{2}{A^2} = \frac{1}{A_{\text{inlet}}^2} + \frac{1}{A_{\text{outlet}}^2}$$

5.6.1.4 *Combined effect of wind and thermal action*

When both forces (wind and thermal) act together in the same direction, even without interference, the resulting air flow is not equal to the two flows estimated separately.

When acting simultaneously, the rate of air flow through the building may be computed by the following equation:

$$Q^2 = Q_w{}^2 + Q_t{}^2$$

where

Q = resultant volume of air flow, in m^3/min;

Q_w = volume of air flow due to wind force, in m^3/min; and

Q_t = volume of air flow due to thermal force, in m^3/min.

Wind velocity and direction, outdoor temperature, and indoor distribution cannot be predicted with certainty, and refinement in calculation is not justified. A simple method is to calculate the sum of the flows produced by each force separately. Then using the ratio of the flow produced by thermal forces to the aforementioned sum, the actual flow due to the combined forces can be approximated from Fig. 15. When the two flows are equal, the actual flow is about 30 percent greater than the flow caused by either force acting independently (*see* Fig. 15).

Judgment is necessary for proper location of openings in a building specially in the roof, where heat, smoke and fumes are to be removed. Usually, windward monitor openings should be closed, but if wind is so slight that temperature head can overcome it, all openings may be opened.

5.6.1.5 For method for determining the rate of ventilation based on probable indoor wind speed with typical illustrative example for residential building, reference may be made to **A-4** of good practice [D-1(9)].

5.6.2 *Mechanical Ventilation*

The determination of rate of ventilation in case of mechanical ventilation shall be done in accordance with Part D 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of this NBCS.

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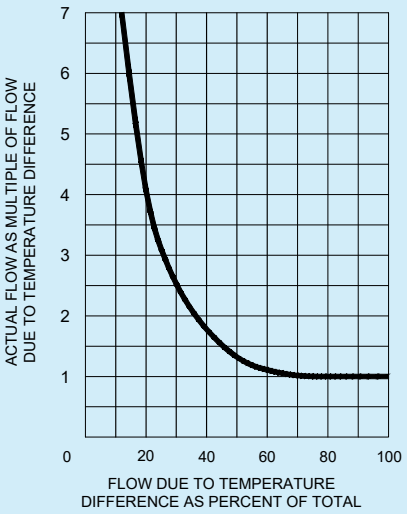

FIG. 15 DETERMINATION OF FLOW CAUSED BY COMBINED FORCES OF WIND AND TEMPERATURE DIFFERENCE

5.6.3 *Combined effect of Different Methods of Ventilation*

When combination of two or more methods of general ventilation is used, the total rate of ventilation shall be reckoned as the highest of the following three, and this rule shall be followed until an exact formula is established by research:

a) 1.25 times the rate of natural ventilation;

b) Rate of positive ventilation; and

c) Rate of exhaust of air.

5.6.4 *Measurement of Air Movement*

The rate of air movement of turbulent type at the working zone shall be measured either with a Kata thermometer (dry silvered type) or heated thermometer or properly calibrated thermocouple anemometer. Whereas anemometer gives the air velocity directly, the Kata thermometer and heated thermometer give cooling power of air and the rate of air movement is found by reference to a suitable nomogram using the ambient temperature.

5.7 Energy Conservation in Ventilation System

5.7.1 Maximum possible use should be made of wind induced natural ventilation. This may be accomplished by following the design guidelines given in **5.7.1.1**.

5.7.1.1 Adequate number of circulating fans should be installed to serve all interior working areas during summer months in the hot dry and warm humid regions to provide necessary air movement at times when ventilation due to wind action alone does not afford sufficient relief.

5.7.1.1.1 The capacity of a ceiling fan to meet the requirement of a room with the longer dimension *D* metre should be about 55 D m^3/min.

5.7.1.1.2 The height of fan blades above the floor should be (3 *H* + *W*)/4, where *H* is the height of the room and *W* is the height of work plane.

5.7.1.1.3 The minimum distance between fan blades and the ceiling should be about 0.3 m.

5.7.2 Electronic regulators should be used instead of resistance type regulators for controlling the speed of fans.

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5.7.3 When actual ventilated zone does not cover the entire room area, then optimum size of ceiling fan should be chosen based on the actual usable area of room, rather than the total floor area of the room. Thus, smaller size of fan can be employed and energy saving could be achieved.

5.7.4 Power consumption by larger fans is obviously higher, but their power consumption per square metre of floor area is less and service value higher. Evidently, improper use of fans irrespective of the rooms' dimensions is likely to result in higher power consumption. From the point of view of energy consumption, the number of fans and the optimum sizes for rooms of different dimensions are given in Table 17.

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Table 17 Optimum Size and Number of Fans for Rooms of Different Sizes

(*Clause* 5.7.4)

Sl No.	Room Width m	Optimum Size (mm)/Number of Fans, For Room Length										
		4 m	5 m	6 m	7 m	8 m	9 m	10 m	11 m	12 m	14 m	16 m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	3	1 200/1	1 400/1	1 500/1	1 050/2	1 200/2	1 400/2	1 400/2	1 400/2	1 200/3	1 400/3	1 400/3
ii)	4	1 200/1	1 400/1	1 200/2	1 200/2	1 200/2	1 400/2	1 400/2	1 500/2	1 200/3	1 400/3	1 500/3
iii)	5	1 400/1	1 400/1	1 400/2	1 400/2	1 400/2	1 400/2	1 400/2	1 500/2	1 400/3	1 400/3	1 500/3
iv)	6	1 200/2	1 400/2	900/4	1 050/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
v)	7	1 200/2	1 400/2	1 050/4	1 050/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
vi)	8	1 200/2	1 400/2	1 200/4	1 200/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
vii)	9	1 400/2	1 400/2	1 400/4	1 400/4	1 400/4	1 400/4	1 400/4	1 500/4	1 400/6	1 400/6	1 500/6
viii)	10	1 400/2	1 400/2	1 400/4	1 400/4	1 400/4	1 400/4	1 400/4	1 500/4	1 400/6	1 400/6	1 500/6
ix)	11	1 500/2	1 500/2	1 500/4	1 500/4	1 500/4	1 500/4	1 500/4	1 500/4	1 500/6	1 500/6	1 500/6
x)	12	1 200/3	1 400/3	1 200/6	1 200/6	1 200/6	1 400/6	1 400/6	1 500/6	1 200/7	1 400/9	1 400/9
xi)	13	1 400/3	1 400/3	1 200/6	1 200/6	1 200/6	1 400/6	1 400/6	1 500/6	1 400/9	1 400/9	1 500/9
xii)	14	1 400/3	1 400/3	1 400/6	1 400/6	1 400/6	1 400/6	1 400/6	1 500/6	1 400/9	1 400/9	1 500/9

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5.7.5 *Acceptable Air Temperature with the Increase in the Air Speed*

The natural ventilation (NV) – mixed mode (MM) solutions combine designed openings for natural ventilation with the simultaneous use of mechanical ceiling fans to deliver thermal comfort with minimal use of energy. The air movement induced by the fan allows a rise in the acceptable operative temperature which is proportional to the increase in the air speed. This combination will be referred to as NV-MM solutions for 'enhanced natural ventilation (NV+).

The total number of hours of the year for which the outdoor conditions are feasible for natural ventilation, calculated as per the adaptive thermal comfort model for India-mixed mode building, and estimated with the NV-MM solutions for NV+, are shown in Fig. 16 for each of the eight Indian cities. This estimation utilizes the values for the corresponding rise in the acceptable air temperature with the increase in the air speed shown in Table 18 for the scenario with $T_{radiant} = T_{air}$ (as in specialist literature) and applies to clothing insulation values (in clo) ranging from 0.50 clo to 0.70 clo and to metabolic rates (in met) ranging from 1.00 met ranging from 0.50 clo to 0.70 clo and to metabolic rates (in met) ranging from 1.00 met to 1.30 met.

NOTE — Specialist literature may be ASHRAE 2010.

This scenario is considered likely to occur in a typical residential environment during daytime and in summer season, with NV operating and without any mechanical cooling source (a radiant cooling panel). This scenario yields more conservative values than the scenario when occupants have some control over the local environment (as per specialist literature).

NOTE — Specialist literature may be ASHRAE 2017.

Table 18 Corresponding Rise in the Acceptable Air Temperature with the Increase in the Air Speed

(*Clause* 5.7.5)

Sl No.	Fan Speed Mode	Air Speed m/s	Corresponding Rise in Temperature °C		
			Applying: 0.50 clo to 0.70 clo; 1.00 met to 1.30 met		Applying: 0.50 clo to 1.00 clo; 1.10 met
			$T_{radiant} - T_{air} = -10$	$T_{radiant} - T_{air} = 0$	
(1)	(2)	(3)	(4)	(5)	(6)
i)	OFF	0.1	–	–	–
ii)	I	0.6	1.20	2.00	2.80
iii)	II	0.9	1.80	2.70	3.40
iv)	III	1.2	2.20	3.30	3.75
v)	IV	1.5	2.50	3.60	4.00

5.7.6 *Mixed-Mode Principles*

Buildings that are designed with a mixed-mode ventilation strategy rely on natural ventilation for much of the occupied hours but also have integrated mechanical ventilation and cooling systems that are used in certain climatic or internal heat gain conditions. Mixed-Mode (MM) systems include naturally ventilated buildings that are designed using one of the following approaches:

a) Concurrent mixed-mode (*see* Fig. 17A) — Where both systems operate at the same space at the same time. The mechanical system operates as supplementary ventilation or cooling while the occupants are free to operate the windows based on their personal preference. This strategy is the most common form of mixed mode ventilation strategy typically employed for open-plan offices and residential buildings;

b) Change-over mixed-mode (*see* Fig. 17B and Fig. 17C) — Where the mechanical systems and natural ventilation operate in the same space at different times of the day or year. This approach requires an automated control system to determine which mode should be used at a particular point in time. The selection is based on a variety of input parameters such as outdoor conditions and occupancy. The

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system operating as change-over MM in a residence can either run automatically or inform the occupants to open or close the windows and switch on/off HVAC systems; and

c) Zoned mixed-mode (*see* Fig. 17D) — Where the mechanical cooling and natural ventilation operate at the same time but in different spaces of the building. This ventilation strategy is suitable for large office buildings where some offices could use natural ventilation by operating the windows whereas other rooms such as conference rooms may require a mechanical system for fresh air distribution.

Mixed-mode ventilation presents an energy efficient alternative to full air conditioning by capitalizing on the potential for natural ventilation when conditions permit.

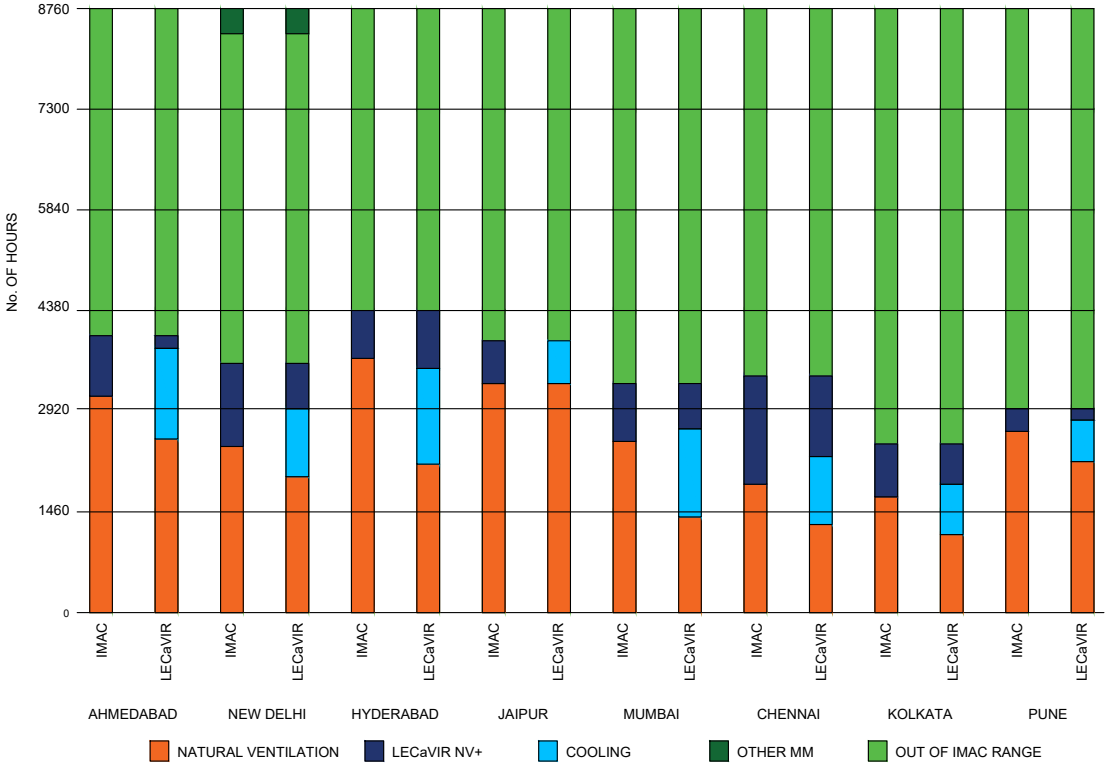

FIG. 16 NUMBER OF HOURS IN A YEAR USING 'NATURAL VENTILATION, MECHANICAL COOLING AND OTHER MM', FROM THE ADAPTIVE THERMAL COMFORT MODEL FOR INDIA-MIXED MODE BUILDINGS, AND USING 'NATURAL VENTILATION, ENHANCED NATURAL VENTILATION (NV+), MECHANICAL COOLING AND OTHER MM', FROM NV-MM SOLUTIONS FOR NV+ FOR EIGHT INDIAN CITIES

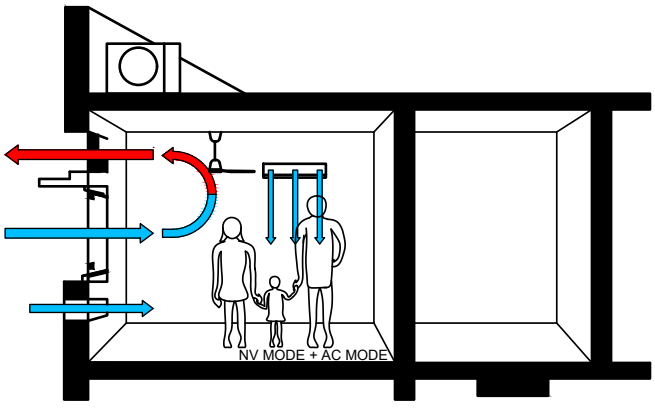

FIG. 17A CONCURRENT MIXED-MODE SYSTEM

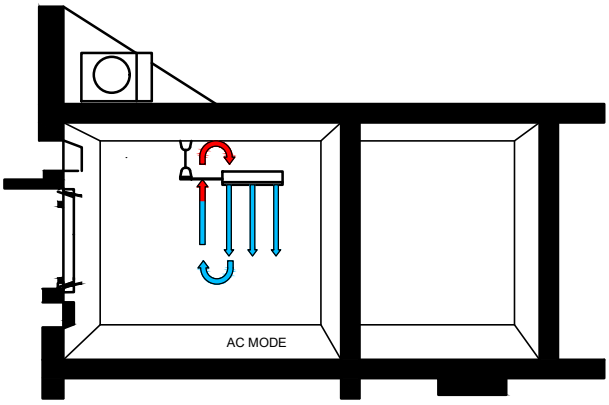

FIG. 17B CHANGE-OVER MIXED-MODE SYSTEM (AC MODE)

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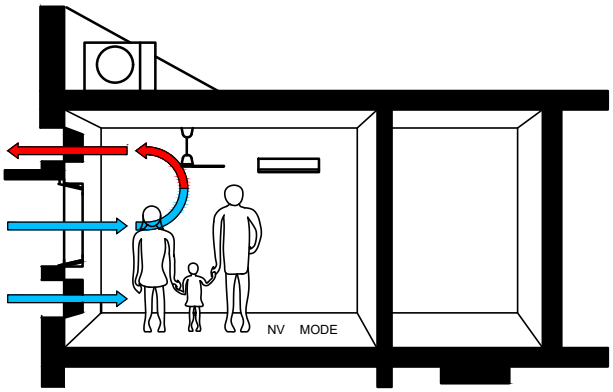

FIG. 17C CHANGE-OVER MIXED-MODE SYSTEM (NV MODE)

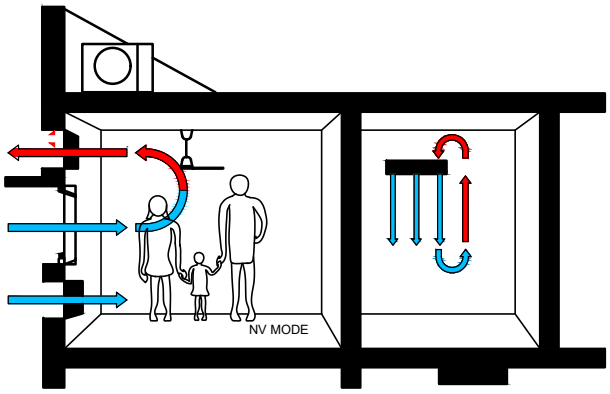

FIG. 17D ZONED MIXED-MODE SYSTEM FOR HOT DAY

FIG. 17 CLASSIFICATION OF MIXED-MODE SYSTEMS

ANNEX A

(*Clauses* 3.4.1 *and* 4.2.5.3)

METHOD OF CALCULATING SOLAR LOAD ON VERTICAL SURFACES OF DIFFERENT ORIENTATION

A-1 DETAILS OF CALCULATION

A-1.1 The solar energy above the earth's atmosphere is constant and the amount incident on unit area normal to sun's rays is called solar constant (1.360 8 kWm^{-2} or 2 $cal/cm^2/min$). This energy, in reaching the earth's surface, is depleted in, the atmosphere due to scattering by air molecules, water vapour, dust particles, and absorption by water vapour and ozone. The depletion varies with varying atmospheric conditions. Another important cause of depletion is the length of path traversed by sun's rays through the atmosphere. This path is the shortest when sun is at the zenith and, as the altitude of the sun decreases, the length of path in the atmosphere increases. Fig. 18 gives the computed incident solar energy/hour on unit surface area normal to the rays under standard atmospheric conditions (*see* Note below) for different altitudes of the sun.

NOTE — The standard atmospheric conditions assumed for this computation are: cloud-free, 300 dust particles per cm^3, 15 mm of precipitable water, 2.5 mm of ozone, at sea level.

A-1.2 In order to calculate the solar energy on any surface other than normal to the rays, the altitude of the sun at that time should be known. The corresponding value of direct solar radiation (I_N) should then be found with the help of Fig. 19. The solar radiation incident on any surface (I_S) is given by:

$$I_S = I_N \left(\sin \beta \sin \phi + \cos \beta \cos \alpha \cos \phi\right)$$

where

β = solar altitude;

ϕ = angle tilt of the surface from the vertical (*see* Fig. 19); and

α = wall solar azimuth angle.

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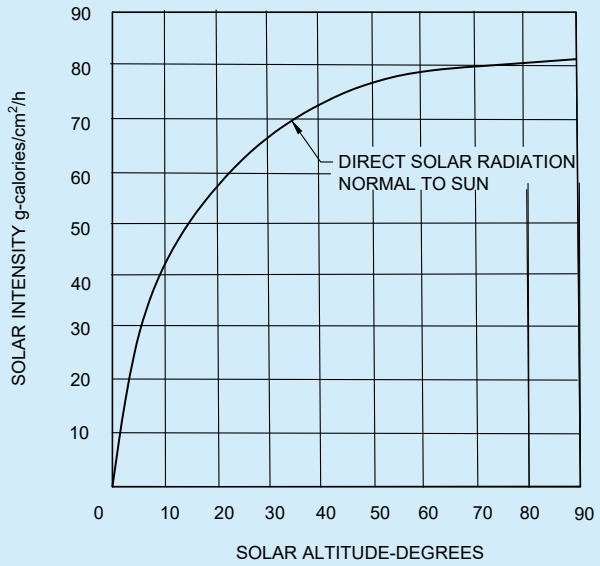

FIG. 18 DIRECT SOLAR INTENSITIES NORMAL TO SUN AT SEA LEVEL FOR STANDARD CONDITION (COMPUTED)

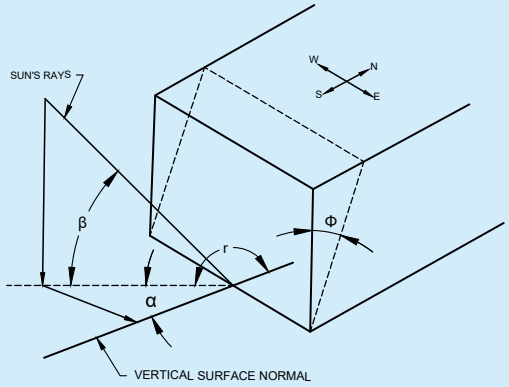

FIG. 19 DEFINITION OF SOLAR ANGLES

A-2 EXAMPLE TO FIND OUT ORIENTATION ON THE BASIS OF SOLAR LOAD

A-2.1 Example

A-2.1.1 As an example, a simple building with flat roof, 10 m × 20 m and 4 m high is dealt with below. For the sake of generalization, no shading device or verandah is taken.

A-2.1.2 As the roof is horizontal, it will receive the same solar heat in any orientation.

A-2.1.3 The area of the vertical surfaces are 4 m × 10 m = *A* (say) and 4 m × 20 m = 2*A*. Since, the external wall surfaces are not in shade except when the sun is not shining on them, the total solar load in a day on a surface can be obtained by multiplying the total load per unit area per day (*see* Table 3) by the area of the surface. For four principal orientations of the building, the total solar load on the building is worked out in Table 19.

A-2.1.4 From Table 19, it can be seen that for the above type of building, orientation 3 (longer surface facing North and South) is appropriate as it affords maximum solar heat gain in winter and in summer. This is true for all places of India from the point of solar heat gain. By further increasing the length to breadth ratio, the advantage

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of this orientation will be more pronounced. It may also be noted that in higher altitudes, the relative merit of this orientation is more.

A-2.1.5 It is also seen that the total solar heat on the building is the same for orientation 2 and 4. But if the site considerations require a choice between these two, orientation 2 should be preferred at places north of latitude 23° N and orientation 4 at southern places. This is so because the total solar load per unit area in summer on the north western wall decreases with the increase in latitude and that on the south western wall increases. It would, therefore, be advantageous to face only smaller surface of the building to greater solar load in the summer afternoons, when the air temperature also is higher.

A-2.1.6 At hill stations, winter season cause more discomfort and so sole criterion for optimum orientation should be based on receiving maximum solar energy on building in winter.

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Table 19 Solar Heat Gained Due to Orientation of Buildings

(*Clauses* A-2.1.3 *and* A-2.1.4)

Sl No.	Orientation	Solar Heat Gained							
		8° N THIRUVANANTHAPURAM		13° N CHENNAI		19° N MUMBAI		23° N KOLKATA	
		May 16	Dec 22	May 16	Dec 22	May 16	Dec 22	May 16	Dec 22
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	North	2 177 × A = 2 177A	–	1 625 × A = 1 625A	–	962 × A = 962A	–	741 × A = 741A	–
	East	2 618 × 2A = 5 236A	2 177 × 2A = 4 354A	2 697 × 2A = 5 394A	2 019 × 2A = 4 038A	2 795 × 2A = 5 590A	1 830 × 2A = 3 660A	2 871 × 2A = 5 742A	1 703 × 2A = 3 406A
	South	–	4 164 × A = 4 164A	–	4 385 × A = 4 385A	–	4 574 × A = 4 574A	205 × A = 205A	4 637 × A = 4 637A
	West	2 618 × 2A = 5 236A	2 177 × 2A = 4 354A	2 697 × 2A = 5 394A	2 019 × 2A = 4 038A	2 795 × 2A = 5 590A	1 830 × 2A = 3 660A	2 871 × 2A = 5 742A	1 703 × 2A = 3 406A
	Total	12 649A	12 872A	12 413A	12 461A	12 142A	11 894A	12 430A	11 449A
ii)	NE	2 650 × A = 2 650A	410 × A = 410A	2 492 × A = 2 492A	315 × A = 315A	2 255 × A = 2 255A	237 × A = 237A	2 192 × A = 2 192A	173 × A = 173A
	SE	1 167 × 2A = 2 334A	3 391 × 2A = 6 782A	1 341 × 2A = 2 682A	3 423 × 2A = 6 846A	1 640 × 2A = 3 280A	3 438 × 2A = 6 876A	1 845 × 2A = 3 690A	3 454 × 2A = 6 908A
	SW	1 167 × 2A = 2 334A	3 391 × A = 3 391A	1 341 × A = 1 341A	3 423 × A = 3 423A	1 640 × A = 1 640A	3 438 × A = 3 438A	1 845 × A = 1 845A	3 454 × A = 3 454A
	NW	2 650 × 2A = 5 300A	410 × 2A = 820A	2 492 × A = 4 984A	315 × 2A = 630A	2 255 × 2A = 4 510A	237 × 2A = 474A	2 192 × 2A = 4 384A	173 × 2A = 346A
	Total	12 618A	11 403A	11 499A	11 214A	11 685A	11 025A	12 111A	10 881A
iii)	North	2 177 × 2A = 4 354A	–	1 625 × 2A = 3 250A	–	962 × 2A = 1 924A	–	741 × 2A = 1 482A	–
	East	2 618 × A = 2 618A	2 177 × A = 2 177A	2 697 × A = 2 697A	2 019 × A = 2 019A	2 795 × A = 2 795A	1 830 × A = 1 830A	2 871 × A = 2 871A	1 703 × A = 1 703A
	South	–	4 164 × 2A = 8 328A	–	4 385 × 2A = 8 770A	–	4 574 × 2A = 9 148A	205 × 2A = 410A	4 637 × 2A = 9 274A
	West	2 618 × A = 2 618A	2 177 × A = 2 177A	2 697 × A = 2 697A	2 019 × A = 2 019A	2 795 × A = 2 795A	1 830 × A = 1 830A	2 871 × A = 2 871A	1 703 × A = 1 703A
	Total	9 590A	12 602A	8 644A	12 808A	7 514A	12 808A	7 634A	12 680A
iv)	NE	2 650 × 2A = 5 300A	–	2 492 × A = 4 984A	315 × 2A = 630A	2 255 × 2A = 4 510A	237 × 2A = 474A	2 192 × 2A = 4 384A	173 × 2A = 346A
	SE	1 167 × A = 1 167A	2 177 × A = 2 177A	1 341 × A = 1 341A	3 423 × A = 3 423A	1 640 × A = 1 640A	3 438 × A = 3 438A	1 845 × A = 1 845A	3 454 × A = 3 454A
	SW	1 167 × 2A = 2 334A	4 164 × 2A = 8 328A	1 341 × 2A = 2 682A	3 423 × 2A = 6 846A	1 640 × 2A = 3 280A	3 438 × 2A = 6 876A	1 845 × 2A = 3 690A	3 454 × 2A = 6 908A
	NW	2 650 × A = 2 650A	2 177 × A = 2 177A	2 492 × A = 2 492A	315 × A = 315A	2 255 × A = 2 255A	237 × A = 237A	2 192 × A = 2 192A	173 × A = 173A
	Total	11 451A	12 682A	11 499A	11 214A	11 685A	11 025A	12 111A	10 881A

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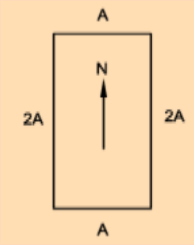
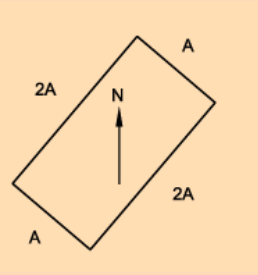
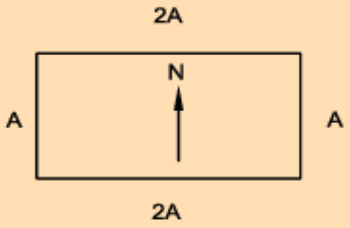
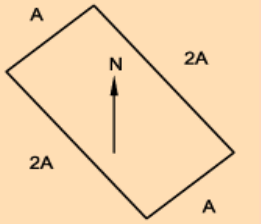
		29° N DELHI		
		May 16	Dec 22	
i)	North	536 × A = 536A	–	 ORIENTATION 1
	East	2 950 × 2A = 5 900A	1 467 × 2A = 2 934A	
	South	741 × A = 741A	4 543 × A = 4 543A	
	West	2 950 × 2A = 5 900A	1 467 × 2A = 2 934A	
	Total	13 077A	10 411A	
ii)	NE	2 098 × A = 2 098A	110 × A = 110A	 ORIENTATION 2
	SE	2 192 × 2A = 4 384A	3 265 × 2A = 6 530A	
	SW	2 192 × A = 2 192A	3 265 × A = 3 265A	
	NW	2 098 × 2A = 4 196A	110 × 2A = 220A	
	Total	12 870A	10 125A	
iii)	North	536 × 2A = 1 072A	–	 ORIENTATION 3
	East	2 950 × A = 2 950A	1 467 × A = 1 467A	
	South	741 × 2A = 1 482A	4 543 × 2A = 9 086A	
	West	2 950 × A = 2 950A	1 467 × A = 1 467A	
	Total	8 454A	12 020A	
iv)	NE	2 098 × 2A = 4 196A	110 × 2A = 220A	 ORIENTATION 4
	SE	2 192 × A = 2 192A	3 265 × A = 3 265A	
	SW	2 192 × 2A = 4 384A	3 265 × 2A = 6 530A	
	NW	2 098 × A = 4 196A	110 × A = 110A	
	Total	12 870A	10 125A	

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ANNEX B

(*Clauses* 4.2.5, 4.2.5.2, 4.2.5.3, 4.2.5.4 *and* 4.2.6)

SKY COMPONENT TABLES

B-1 DESCRIPTION OF TABLES

B-1.1 The three sky component tables are as given below:

a) Table 20 — Percentage sky components on the horizontal plane due to a vertical rectangular opening for the clear design sky;

b) Table 21 — Percentage sky components on the vertical plane perpendicular to a vertical rectangular opening for the clear design sky; and

c) Table 22 — Percentage sky components on the vertical plane parallel to a vertical rectangular opening for the clear design sky.

B-1.2 All the Table 20, Table 21 and Table 22 are for an unglazed opening illuminated by the clear design sky.

B-1.3 The values tabulated are the components at a point *P* distant from the opening on a line perpendicular to the plane of the opening through one of its lower corners, and *l* and *h* are the width and height respectively of the rectangular opening (*see* Fig. 20).

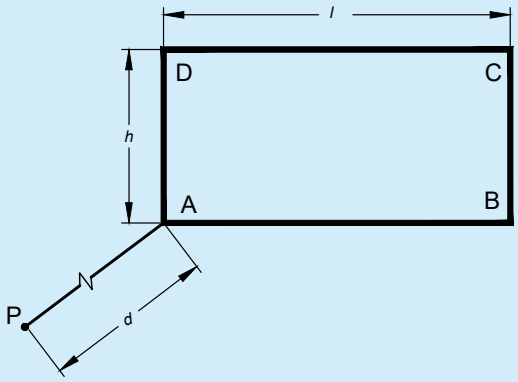

FIG. 20 DEPICTION OF OBSERVATIN POINT ' P '

B-1.4 Sky component for different *h*/*d* and *l*/*d* values are tabulated, that is, for windows of different size and for different distances of the point *P* from the window.

B-1.5 By suitable combination of the values obtained from the Table 20, Table 21 and Table 22, for a given point for a given window, the sky component in any plane passing through the point may be obtained.

B-1.6 Method of Using the Tables

B-1.6.1 Method of using the Table 20, Table 21 and Table 22 to get the sky component at given point is explained with help of the following example.

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B-1.6.2 *Example*

It is desired to calculate the sky component (F) due to a vertical window ABCD with width 1.8 m and height 1.5 m at a point P on a horizontal plane 3.0 m from the window wall located as shown in the Fig. 21. Foot of the perpendicular N is 0.6 m below the sill and 0.9 m to the left of AD.

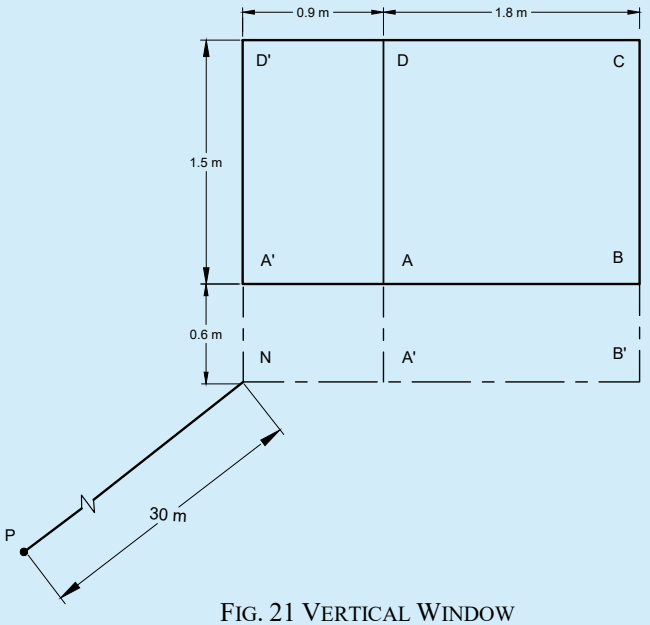

FIG. 21 VERTICAL WINDOW

Consider ABCD extended to NB'CD'

a) For NB'CD'

l/d = (1.8 + 0.9)/3 = 0.9

h/d = (1.5 + 0.6)/3 = 0.7

F_1 = 5.708 percent (from Table 20)

b) For NA'DD'

l/d = 0.9/ 3 = 0.3

h/d = (1.5 + 0.6)/3 = 0.7

F_2 = 2.441 percent (from Table 20)

c) For NB'BA'

l/d = (1.8 + 0.9)/3 = 0.9

h/d = 0.6/3 = 0.2

F_3 = 0.878 percent (from Table 20)

d) For NA'AA'

l/d = 0.9/3 = 0.3

h/d = 0.6/3 = 0.2

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F_4 = 0.40 3 percent (from Table 20)

Since ABCD = NB'CD' – NA'DD' – NB'BA' + NA'AA'

Sky component, F = $F_1 – F_2 – F_3 + F_4$
= 5.708 – 2.441 – 0.878 + 0.403
= 2.792

B-2 GENERAL INSTRUCTIONS

B-2.1 For irregular obstructions like row of trees parallel to the plane of the window, equivalent straight boundaries horizontal and vertical, maybe drawn.

B-2.2 Waldram diagrams are an effective early-stage design tool for planning daylight and direct solar illuminance for extremely irregular obstructions or obstructions not in a plane parallel to the window. Fig. 22 and Fig. 23 show two possible massing schemes for a site located at 17° N latitude, while Fig. 24 and Fig. 25 illustrate the corresponding Waldram diagrams drawn from the central open area of the site. The white area above the shadow silhouettes in Fig. 24 and Fig. 25 indicate unobstructed sky (48 percent sky view in case of Fig. 24 and 65 percent sky view in case of Fig. 25). The yellow lines in Fig. 24 and Fig. 25 indicate the annual sun path as seen from the middle of the central open area of the site, aiding in evaluating sky visibility and optimizing site layouts for improved daylight performance.

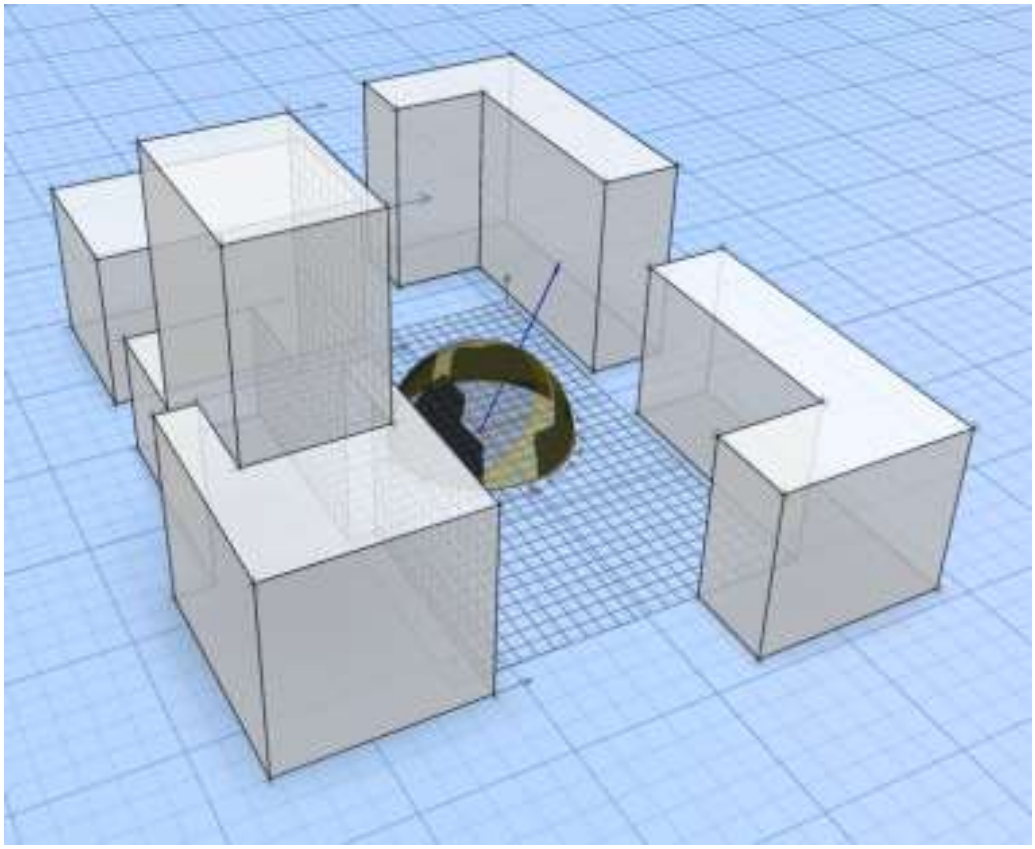

FIG. 22 MASSING SCHEME A

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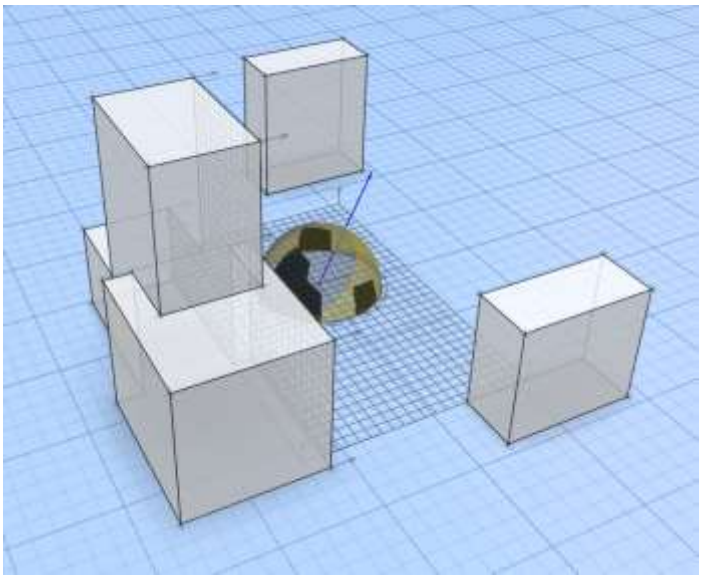

FIG. 23 MASSING SCHEME B

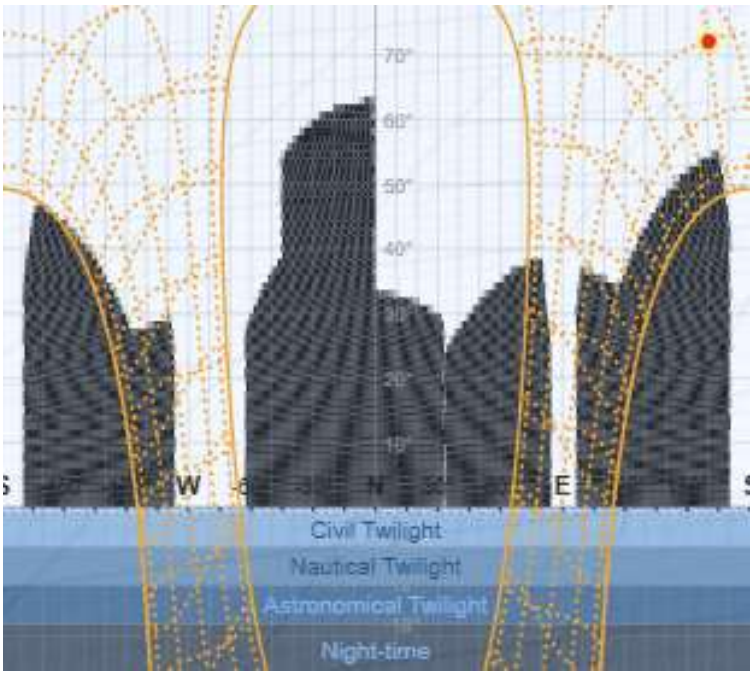

FIG. 24 WALDRAM DIAGRAM A

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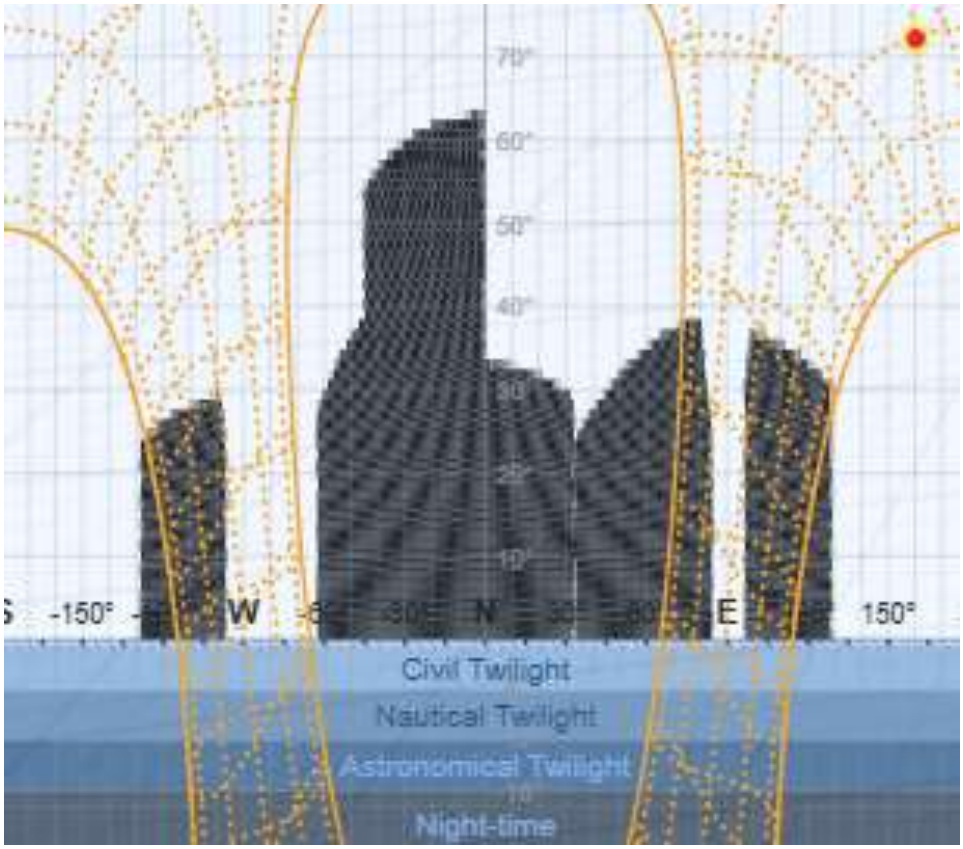

FIG. 25 WALDRAM DIAGRAM B

B-2.3 For bay windows, dormer windows or corner windows the effective dimensions of window opening computed should be taken when using the Table 20, Table 21 and Table 22 to find the sky components.

B-3 CALCULATION OF INTERNAL REFLECTED COMPONENT

B-3.1 The internal reflected component (IRC) is a variable quantity which varies from point to point in a room depending upon the interior finish. IRC value is maximum at the centre of the room and decreases elsewhere in all directions. For processing calculations of IRC at any given point of the room, special techniques have to be made out. The internal reflected component may be calculated by using the formula:

$$IRC = \frac{0.85W}{A(1\text{-R})} \ (CR_{fw} + 10R_{cw})$$

where

W = window area;

C = constant of value 78 when there is no external obstruction but it has different values as shown in the following table when there are obstructions;

R_{fw} = average reflection factor of the floor and those parts of the wall below the plane of the mid-height of the window (excluding the window wall);

R_{cw} = average reflection factor of the ceiling and those parts of the wall above the plane of the mid-height of the window (excluding the window wall);

A = area of all the surfaces in the room (ceiling walls, floor and windows); and

R = average reflection factor of all surfaces in the room (ceiling, walls, floor and windows) expressed as a decimal part of unity.

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Sl No.	*Angle of Obstruction*	*Sky + External Obstruction*
	Degree	C
(1)	(2)	(3)
i)	5	68.9
ii)	15	50.6
iii)	25	36.2
iv)	35	26.7
v)	45	20.1
vi)	55	15.8
vii)	65	12.9
viii)	75	11.1
ix)	85	10.36

B-3.2 Example

Consider two rooms of dimensions:

Room *X* = 6 m (*l*) × 5 m (*w*) × 3 m (*ht*)

Room *Y* = 3.7 m × 3 m × 3 m

Let the window area be 15 percent of the floor area and be glazed.

Window size in room *X* = 2.5 m × 1.8 m

Window size in room *Y* = 3.7 m × 3 m

The windows are on the 6 m × 3 m side in room *X* and 3.7 m × 3 m side in room *Y,* and the sill heights are 0.9 m from floor level.

Reflection coefficients of:

walls and ceiling = 70 percent

floor = 20 percent

glazing = 15 percent

a) <u>Value of IRC in room *X*:</u>

1) Total interior area, $A = 2\ (30 + 18 + 15) = 126\ m^2$;

2) Average reflection factor of interior:

$$R = \frac{(61.5 \times 0.7) + (30 \times 0.7) + (30 \times 0.2) + (4.5 \times 0.15)}{(61.5 + 30 + 30 + 4.5)} = 0.56$$

3) $1 - R = 0.44$;

4) Mid-height of window is 1.83 m from floor, average reflection factor of room below 1.83 m level excluding the wall containing the window:

$$R_{fw} = \frac{(29.28 \times 0.7) + (30 \times 0.2)}{(29.28 + 30)} = 0.45$$

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5) Average reflection factor of room above 1.83 m level excluding the wall containing the window:

$$R_{cw} = \frac{(18.72 \times 0.7) + (30 \times 0.7)}{(18.72 + 30)} = 0.7$$

6) IRC = $\frac{0.85 \times 4.5}{126 \times 0.44}$ $[(78 \times 0.45) + (10 \times 0.7)] = 2.904$.

b) Value of IRC in room Y:

1) Total interior area:

$$A = 2[(3.7 \times 3) + (3.7 \times 3) + (3 \times 3)] = 62.4 \text{ m}^2$$

2) Average reflection factor:

$$R = \frac{(38 \times 55 \times 0.7 \times 3 \times 0.7) + (3.7 \times 3 \times 0.2) + (1.5 \times 1.1 \times 0.15)}{(38.55 + 11.1 + 11.1 + 1.65)} = 0.596$$

3) Mid-height of window from floor = 1.46 m;

4) Average reflection factor below 1.46 m level:

$$R_{fw} = \frac{(3.7 \times 3 \times 0.7) + (1.54 \times 9.7 \times 0.7)}{(11.1 + 14.94)} = 0.48$$

5) Average reflection factor above 1.46 m level:

$$R_{cw} = \frac{(3.7 \times 3 \times 0.7) + (1.54 \times 9.7 \times 0.7)}{(11.1 + 14.94)} = 0.7$$

6) IRC = $\frac{0.85 \times 1.65}{62.4 \times 0.404}$ $[(78 \times 0.48) + (10 \times 0.7)] = 2.472$.

B-4 GENERAL NOTE ON DAYLIGHTING OF BUILDING

B-4.1 The main aim of day lighting design is how to admit enough light for good visibility without setting up uncomfortable glare. No simple solution may be given as the sky varies so much in its brightness from hour to hour, and from season to season.

B-4.2 Different visual tasks need differing amounts of lights for the same visual efficiency. The correct amount of light for any task is determined by the following:

a) *Characteristics of the tasks* — Size of significant detail, contrast of detail with background and how close it is to the eyes;

b) *Sight of the worker* — For example, old people need more light;

c) Speed and accuracy necessary in the performance of work. If no errors are permissible, much more light is needed; and

d) *Ease and comfort of working* — Long and sustained tasks should be done easily whereas workers can make a special effort for tasks of very short duration.

These factors have been made the subject of careful analysis as a result of which tables of necessary levels of illumination have been draw up.

B-4.3 Levels of lighting determined analytically shall be translated into levels of daylight and then into size of window opening or vice versa for checking the size of window assumed for required levels of daylight.

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B-4.4 One of the many important factors involved in the translation is the lightness of the room surface. The illumination levels in a given room with a finite window will be higher when the walls are light coloured than when these are dark coloured. It is necessary, therefore, at an early stage to consider the colouring of the rooms of the building and not to leave this until later. Lighting is not merely a matter of window openings and quite half the eventual level of lighting may be dependent on the decoration in the room. Whatever may be the colour the occupant wants to use, it is most desirable to maintain proper values of reflectance factors for ceiling, wall and floors so that the level of daylight illumination is maintained.

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Table 20 Percentage Sky Components on the Horizontal Plane Due to a Vertical Rectangular Opening for the Clear Design Sky

(*Clauses* 4.2.5, B-1.1, B-1.2, B-1.5, B-1.6.1, B-1.6.2, *and* B-2.3)

Sl No.	*l/d*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
	h/d												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	0.1	0.036	0.071	0.104	0.133	0.158	0.179	0.198	0.213	0.225	0.235	0.243	0.250
ii)	0.2	0.141	0.277	0.403	0.516	0.614	0.699	0.770	0.829	0.878	0.918	0.950	0.977
iii)	0.3	0.300	0.589	0.859	1.102	1.315	1.499	1.653	1.782	1.888	1.976	2.048	2.108
iv)	0.4	0.460	0.905	1.322	1.702	2.041	2.337	2.590	2.804	2.984	3.134	3.258	3.361
v)	0.5	0.604	1.189	1.741	2.247	2.700	3.099	3.444	3.740	3.992	4.204	3.383	4.553
vi)	0.6	0.732	1.443	2.114	2.732	3.289	3.781	4.211	4.582	4.900	5.171	5.401	5.596
vii)	0.7	0.844	1.665	2.441	3.159	3.808	4.385	4.891	5.330	5.708	6.034	6.311	6.548
viii)	0.8	0.942	1.858	2.727	3.532	4.262	4.914	5.488	5.989	6.423	6.798	7.119	7.395
ix)	0.9	1.026	2.025	2.974	3.855	4.657	5.375	6.011	6.567	7.051	7.470	7.832	8.144
x)	1.0	1.099	2.169	3.188	4.135	5.000	5.776	6.465	7.071	7.600	8.060	8.458	8.803
xi)	1.1	1.161	2.294	3.372	4.377	5.296	6.124	6.861	7.510	8.079	8.576	9.008	9.383
xii)	1.2	1.215	2.401	3.531	4.586	5.553	6.425	7.204	7.893	8.498	9.027	9.489	9.892
xiii)	1.3	1.262	2.493	3.668	4.767	5.775	6.687	7.503	8.226	8.863	9.422	9.912	10.339
xiv)	1.4	1.302	2.573	3.787	4.924	5.968	6.915	7.764	8.517	9.183	9.769	10.283	10.733
xv)	1.5	1.337	2.643	3.891	5.060	6.136	7.114	7.991	8.772	9.664	10.073	10.609	11.080
xvi)	1.6	1.367	2.703	3.981	5.179	6.283	7.287	8.190	8.996	9.710	10.341	10.897	11.386
xvii)	1.7	1.394	2.756	4.060	5.283	6.412	7.440	8.366	9.192	9.927	10.577	11.151	11.657
xviii)	1.8	1.417	2.803	4.129	5.375	6.526	7.574	8.520	9.366	10.119	10.786	11.376	11.898
xix)	1.9	1.438	2.844	4.190	5.456	6.626	7.693	8.656	9.520	10.289	10.972	11.577	12.112
xx)	2.0	1.456	2.880	4.244	5.527	6.714	7.798	8.778	9.656	10.440	11.137	11.755	12.303
xxi)	3.0	1.559	3.087	4.553	5.937	7.223	8.403	9.478	10.448	11.321	12.103	12.804	13.431
xxii)	4.0	1.600	3.168	4.676	6.100	7.426	8.646	9.759	10.768	11.678	12.498	13.235	13.897
xxiii)	5.0	1.620	3.208	4.735	6.179	7.525	8.765	9.897	10.925	11.854	12.693	13.448	14.128
xxiv)	10.0	1.648	3.263	4.818	6.289	7.662	8.930	10.089	11.144	12.100	12.965	13.747	14.454
xxv)	INF	1.657	3.282	4.846	6.327	7.710	8.986	10.155	11.220	12.186	13.060	13.851	14.567

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Table 20 (*Concluded*)

Sl No.	*l/d* *h/d*	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
(1)	(2)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
i)	0.1	0.256	0.261	0.264	0.268	0.270	0.272	0.274	0.276	0.284	0.286	0.287	0.288	0.288
ii)	0.2	0.999	1.018	1.033	1.046	1.056	1.065	1.072	1.079	1.110	1.118	1.122	1.125	1.125
iii)	0.3	2.157	2.197	2.231	2.259	2.282	2.302	2.318	2.333	2.401	2.421	2.429	2.436	2.437
iv)	0.4	3.446	3.516	3.574	3.623	3.664	3.699	3.728	3.753	3.873	3.909	3.922	3.935	3.937
v)	0.5	4.659	4.765	4.853	4.928	4.990	5.043	5.088	5.126	5.312	5.366	5.387	5.408	5.410
vi)	0.6	5.761	5.901	6.020	6.121	6.208	6.281	6.344	6.397	6.661	6.739	6.769	6.798	6.802
vii)	0.7	6.751	6.924	7.071	7.198	7.307	7.400	7.481	7.551	7.902	8.006	8.047	8.087	8.092
viii)	0.8	7.632	7.836	8.011	8.162	8.292	8.405	8.502	8.587	9.029	9.164	9.217	9.268	9.276
ix)	0.9	8.413	8.645	8.846	9.019	9.170	9.301	9.415	9.515	10.045	10.214	10.280	10.345	10.355
x)	1.0	9.102	9.361	9.585	9.780	9.950	10.098	10.228	10.343	10.957	11.162	11.243	11.323	11.335
xi)	1.1	9.709	9.992	10.239	10.454	10.642	10.806	10.951	11.078	11.776	12.017	12.114	12.209	12.224
xii)	1.2	10.243	10.549	10.816	11.050	11.254	11.434	11.593	11.732	12.509	12.786	12.900	13.013	13.030
xiii)	1.3	10.713	11.040	11.326	11.577	11.797	11.992	12.163	12.314	13.167	13.478	13.609	13.742	13.762
xiv)	1.4	11.127	11.473	11.777	12.044	12.279	12.487	12.670	12.833	13.758	14.102	14.251	14.404	14.427
xv)	1.5	11.493	11.857	12.176	12.458	12.707	12.927	13.122	13.295	14.289	14.666	14.832	15.006	15.033
xvi)	1.6	11.817	12.196	12.531	12.826	13.088	13.319	13.525	13.708	14.768	15.176	15.359	15.555	15.585
xvii)	1.7	12.104	12.498	12.846	13.154	13.427	13.669	13.885	14.078	15.199	15.638	15.838	16.056	16.091
xviii)	1.8	12.359	12.766	13.127	13.446	13.730	13.983	14.208	14.409	15.590	16.058	16.274	16.516	16.554
xix)	1.9	12.587	13.006	13.378	13.708	14.002	14.264	14.498	14.707	15.944	16.441	16.673	16.937	16.980
xx)	2.0	12.789	13.220	13.603	13.943	14.246	14.516	14.758	14.975	16.265	16.790	17.037	17.325	17.372
xxi)	3.0	13.993	14.496	14.947	15.353	15.718	16.048	16.346	16.676	18.301	19.051	19.432	19.943	20.046
xxii)	4.0	14.493	15.030	15.514	15.951	16.347	16.706	17.033	17.330	19.241	20.142	20.623	21.322	21.495
xxiii)	5.0	14.742	15.296	15.798	16.252	16.664	17.040	17.382	17.695	19.740	20.740	21.293	22.148	22.393
xxiv)	10.0	15.094	15.674	16.201	16.681	17.118	17.518	17.885	18.222	20.491	21.681	22.390	23.676	24.238
xxv)	INF	15.217	15.806	16.342	16.831	17.278	17.688	18.064	18.410	20.770	22.046	22.838	24.463	26.111

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Table 21 Percentage Sky Components on the Vertical Plane Perpendicular to a Vertical Rectangular Opening for the Clear Design Sky

(*Clause* 4.2.5, B-1.1, B-1.2, B-1.5, B-1.6.1 *and* B-2.3)

Sl No.	*l/d*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2
	h/d												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	0.1	0.036	0.141	0.303	0.506	0.734	0.971	1.207	1.432	1.643	2.836	1.011	2.168
ii)	0.2	0.071	0.277	0.594	0.993	1.442	1.910	2.374	2.820	3.236	3.618	3.964	4.276
iii)	0.3	0.103	0.401	0.863	1.445	2.100	2.793	3.475	4.180	4.743	5.306	5.818	6.278
iv)	0.4	0.126	0.491	1.059	1.779	2.597	3.460	4.326	5.166	5.958	6.691	7.359	7.967
v)	0.5	0.142	0.554	1.197	2.015	2.947	3.937	4.938	5.914	6.842	7.707	8.503	9.228
vi)	0.6	0.154	0.600	1.298	2.187	3.204	4.288	5.389	6.468	7.498	8.464	9.358	10.177
vii)	0.7	0.162	0.634	1.372	2.316	3.397	4.552	5.729	6.887	7.997	9.042	10.013	10.907
viii)	0.8	0.169	0.660	1.429	2.413	3.543	4.754	5.990	7.209	8.382	9.490	10.523	11.476
ix)	0.9	0.174	0.680	1.472	2.487	3.655	4.909	6.192	7.460	8.683	9.841	10.924	11.926
x)	1.0	0.178	0.695	1.505	2.545	3.743	5.030	6.350	7.657	8.921	10.120	11.243	12.284
xi)	1.1	0.181	0.707	1.532	2.591	3.812	5.126	6.475	7.814	9.110	10.342	11.498	12.573
xii)	1.2	0.183	0.716	1.552	2.626	3.866	5.202	6.575	7.939	9.261	10.521	11.705	12.807
xiii)	1.3	0.185	0.723	1.568	2.655	3.910	5.263	6.655	8.040	9.384	10.666	11.873	12.998
xiv)	1.4	0.186	0.729	1.582	2.678	3.945	5.312	6.720	8.122	9.484	10.785	12.011	13.155
xv)	1.5	0.188	0.734	1.592	2.697	3.973	5.352	6.773	8.189	9.566	10.883	12.124	13.285
xvi)	1.6	0.189	0.738	1.601	2.712	3.996	5.385	6.816	8.244	9.634	10.963	12.219	13.394
xvii)	1.7	0.189	0.741	1.608	2.724	4.016	5.412	6.852	8.290	9.690	11.031	12.298	13.484
xviii)	1.8	0.190	0.744	1.614	2.735	4.032	5.434	6.882	8.328	9.737	11.087	12.364	13.561
xix)	1.9	0.191	0.746	1.619	2.743	4.045	5.453	6.908	8.360	9.777	11.135	12.420	13.625
xx)	2.0	0.191	0.748	1.623	2.751	4.056	5.469	6.929	8.387	9.811	11.175	12.468	13.680
xxi)	3.0	0.193	0.756	1.642	2.785	4.109	5.544	7.030	8.517	9.972	11.371	12.699	13.950
xxii)	4.0	0.194	0.759	1.648	2.794	4.124	5.566	7.058	8.540	10.018	11.427	12.767	14.029
xxiii)	5.0	0.194	0.760	1.650	2.798	4.129	5.574	7.069	8.568	10.036	11.449	12.793	14.060
xxiv)	10.0	0.194	0.761	1.652	2.801	4.135	5.581	7.080	8.582	10.053	11.470	12.818	14.095
xxv)	INF	0.194	0.761	1.652	2.802	4.136	5.582	7.081	8.584	10.056	11.473	12.822	14.095

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Table 21 (*Concluded*)

Sl No.	*l/d* *h/d*	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
(1)	(2)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
i)	0.1	2.308	2.433	2.544	2.642	2.730	2.808	2.878	2.940	3.309	3.461	3.536	3.641	3.678
ii)	0.2	4.554	4.802	5.022	5.219	5.393	5.549	5.688	5.812	6.547	6.850	7.000	7.211	7.284
iii)	0.3	6.690	7.058	7.385	7.677	7.936	8.168	8.375	8.560	9.657	10.110	10.335	10.651	10.760
iv)	0.4	8.507	8.900	9.420	9.804	10.146	10.451	10.724	10.968	12.421	13.024	13.323	13.743	13.889
v)	0.5	9.883	10.472	10.999	11.476	11.897	12.273	12.610	12.912	14.712	15.462	15.835	16.360	16.542
vi)	0.6	10.922	11.596	12.204	12.752	13.244	13.686	14.084	14.441	16.583	17.478	17.924	18.552	18.771
vii)	0.7	11.723	12.465	13.138	13.746	14.296	14.793	15.241	15.646	18.111	19.148	19.665	20.397	20.653
viii)	0.8	12.350	13.147	13.873	14.531	15.129	15.670	16.161	16.606	19.361	20.538	21.127	21.961	22.253
ix)	0.9	12.847	13.690	14.459	15.159	15.796	16.375	16.902	17.381	20.387	21.701	22.360	23.397	23.625
x)	1.0	13.245	14.126	14.931	15.666	16.337	16.948	17.504	18.012	21.237	22.680	23.408	24.446	24.810
xi)	1.1	13.356	14.478	15.314	16.079	16.778	17.416	17.999	18.531	21.946	23.508	24.303	25.441	25.841
xii)	1.2	13.827	14.766	15.628	16.418	17.141	17.802	18.407	18.961	22.543	24.208	25.072	26.309	26.745
xiii)	1.3	14.041	15.003	15.887	16.698	17.442	18.123	18.747	19.320	23.049	24.809	25.735	27.070	27.542
xiv)	1.4	14.217	15.198	16.101	16.931	17.692	18.391	19.032	19.621	23.480	25.326	26.308	27.441	28.249
xv)	1.5	14.364	15.361	16.280	17.125	17.902	18.616	19.272	19.875	23.850	25.772	26.808	28.336	28.880
xvi)	1.6	14.486	15.497	16.430	17.289	18.079	18.806	19.475	20.090	24.169	26.161	27.245	28.866	29.445
xvii)	1.7	14.589	15.511	16.556	17.427	18.229	18.968	19.648	20.274	24.444	26.501	27.629	29.340	29.955
xviii)	1.8	14.675	15.708	16.663	17.545	18.357	19.105	19.795	20.431	24.684	26.799	27.969	29.765	30.416
xix)	1.9	14.749	15.791	16.755	17.645	18.466	19.224	19.922	20.567	24.893	27.062	28.270	30.149	30.835
xx)	2.0	14.811	15.861	16.833	17.731	18.560	19.325	20.031	20.684	25.077	27.294	28.537	30.496	31.217
xxi)	3.0	15.120	16.211	17.224	18.164	19.036	19.844	20.594	21.289	26.082	28.619	30.108	32.676	32.742
xxii)	4.0	15.212	16.316	17.343	18.298	19.185	20.008	20.772	21.483	26.439	29.128	30.745	33.687	35.064
xxiii)	5.0	15.248	16.357	17.390	18.351	19.243	20.073	20.844	21.562	26.592	29.359	31.049	34.232	35.872
xxiv)	10.0	15.283	16.398	17.436	18.403	19.302	20.138	20.917	21.641	26.758	29.624	31.419	35.049	37.513
xxv)	INF	15.288	16.404	17.443	18.411	19.311	20.148	20.928	21.654	26.785	29.672	31.490	35.274	39.172

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Table 22 Percentage Sky Components on the Vertical Plane Parallel to a Vertical Rectangular Opening for the Clear Design Sky

(*Clauses* 4.2.5, B-1.1, B-1.2, B-1.5, B-1.6.1 *and* B-2.3)

Sl No.	***l/d*** ***h/d***	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
i)	0.1	0.728	1.429	2.078	2.600	3.167	3.660	3.964	4.265	4.513	4.717	4.883	5.020	5.132
ii)	0.2	1.429	2.803	4.007	5.221	6.220	7.073	7.790	8.385	8.876	9.278	9.609	9.880	10.103
iii)	0.3	2.068	4.061	5.913	7.580	9.040	10.285	11.337	12.212	12.934	13.528	14.016	14.417	14.747
iv)	0.4	2.529	4.970	7.249	9.312	11.133	12.707	14.042	15.164	16.097	16.870	17.507	18.025	18.458
v)	0.5	2.852	5.608	8.186	10.529	12.606	14.401	15.952	17.256	18.350	19.262	20.021	20.652	21.177
vi)	0.6	3.086	6.070	8.867	11.415	13.681	15.656	17.353	18.793	20.008	21.027	21.879	22.592	23.189
vii)	0.7	3.259	6.413	9.373	12.074	14.482	16.588	18.402	19.949	21.257	22.359	23.285	24.063	24.716
viii)	0.8	3.389	6.672	9.755	12.573	15.090	17.296	19.201	20.830	22.212	23.380	24.365	25.195	25.895
ix)	0.9	3.489	6.869	10.046	12.955	15.556	17.840	19.817	21.511	22.952	24.173	25.206	26.078	26.816
x)	1.0	3.565	7.024	10.272	13.250	15.917	18.263	20.297	22.043	23.531	24.795	25.866	26.773	27.542
xi)	1.1	3.625	7.139	10.447	13.481	16.200	18.594	20.674	22.462	23.989	25.288	26.391	27.326	28.121
xii)	1.2	3.672	7.233	10.586	13.663	16.423	18.857	20.973	22.795	24.353	25.681	26.810	27.770	28.587
xiii)	1.3	3.709	7.307	10.696	13.807	16.602	19.067	21.213	23.062	24.646	25.998	27.148	28.128	28.963
xiv)	1.4	3.739	7.366	10.784	13.924	16.745	19.236	21.406	23.278	24.884	26.255	27.424	28.420	29.271
xv)	1.5	3.763	7.414	10.856	14.018	16.861	19.373	21.563	23.454	25.077	26.465	27.649	28.660	29.523
xvi)	1.6	3.783	7.453	10.914	14.095	16.956	19.485	21.692	23.599	25.236	26.638	27.835	28.857	29.732
xvii)	1.7	3.799	7.485	10.962	14.158	17.034	19.578	21.798	23.718	25.368	26.781	27.989	29.022	29.906
xviii)	1.8	3.812	7.512	11.002	14.211	17.099	19.655	21.886	23.817	25.478	26.900	28.118	29.160	30.052
xix)	1.9	3.824	7.534	11.035	14.254	17.153	19.719	21.960	23.900	25.570	27.001	28.226	26.276	30.175
xx)	2.0	3.833	7.553	11.062	14.291	17.199	19.773	22.022	23.970	25.647	27.086	28.318	29.374	31.279
xxi)	3.0	3.876	7.639	11.192	14.463	17.412	20.027	22.316	24.302	26.016	27.491	28.757	29.846	30.783
xxii)	4.0	3.888	7.663	11.228	14.511	17.471	20.098	22.398	24.398	26.121	27.606	28.884	29.983	30.930
xxiii)	5.0	3.893	7.672	11.241	14.529	17.494	20.125	22.430	24.432	26.161	27.650	28.932	30.035	30.986
xxiv)	10.0	3.897	7681	11.254	14.546	17.515	20.150	22.459	24.466	26.199	27.693	28.978	30.085	31.041
xxv)	INF	3.898	7.682	11.256	44.548	17.518	20.154	22.464	24.471	26.205	27.699	28.985	30.093	31.049

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Table 22 (*Concluded*)

Sl No.	*l/d* *h/d*	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
(1)	(2)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
i)	0.1	5.225	5.301	5.365	5.418	5.463	5.501	5.533	5.687	5.733	5.749	5.765	5.766
ii)	0.2	10.286	10.439	10.565	10.671	10.760	10.835	10.899	11.207	11.296	11.330	11.362	11.365
iii)	0.3	15.020	15.246	15.434	15.591	15.724	15.836	15.931	16.390	16.523	16.574	16.623	16.627
iv)	0.4	18.816	19.113	19.360	19.568	19.742	19.890	20.015	20.624	20.801	20.868	20.933	20.939
v)	0.5	21.613	21.978	22.275	22.530	22.746	22.923	23.082	23.836	24.056	24.140	24.222	24.229
vi)	0.6	23.689	24.109	24.462	24.761	25.014	25.229	25.412	26.229	26.561	26.662	26.759	26.768
vii)	0.7	25.267	25.731	26.124	26.458	26.742	26.984	27.192	28.214	28.517	28.634	28.748	28.758
viii)	0.8	26.486	26.987	27.412	27.775	28.084	28.350	28.578	29.720	30.065	30.198	30.327	30.339
ix)	0.9	27.441	27.972	28.424	28.810	29.141	29.426	29.672	30.927	31.303	31.451	31.596	31.610
x)	1.0	28.196	28.572	29.226	29.633	29.982	30.283	30.544	31.889	32.302	32.467	32.627	32.643
xi)	1.1	28.798	29.375	29.869	30.293	30.658	30.973	31.246	32.670	33.117	33.297	33.473	33.491
xii)	1.2	29.283	29.878	30.388	30.826	31.204	31.532	31.816	33.309	33.796	33.981	34.173	34.193
xiii)	1.3	29.676	30.286	30.810	31.261	31.651	31.989	32.283	33.836	34.350	34.550	34.756	34.779
xiv)	1.4	29.998	30.621	31.157	31.618	32.018	32.365	32.667	34.374	34.813	35.035	35.247	35.271
xv)	1.5	30.262	30.897	31.443	31.914	32.322	32.677	32.986	34.641	35.202	35.436	35.663	35.689
xvi)	1.6	30.482	31.226	31.680	32.160	32.575	32.937	33.253	34.950	35.532	35.776	36.017	36.046
xvii)	1.7	30.665	31.317	31.879	32.366	32.888	33.156	33.477	35.211	35.812	36.067	36.321	36.352
xviii)	1.8	30.818	31.477	32.046	32.539	32.967	33.340	33.666	35.435	36.052	36.316	36.584	36.617
xix)	1.9	30.948	31.613	32.188	32.686	33.119	33.497	33.828	35.626	35.259	36.532	36.812	36.847
xx)	2.0	31.058	31.728	32.308	32.811	33.249	33.631	33.965	35.791	36.438	36.719	37.011	37.048
xxi)	3.0	31.592	32.291	32.898	33.427	33.889	34.294	34.551	36.640	37.380	37.715	38.107	38.157
xxii)	4.0	31.748	32.457	33.074	33.611	34.082	34.496	34.860	36.915	37.699	38.063	38.510	38.579
xxiii)	5.0	31.808	32.521	33.142	33.683	34.157	34.574	34.943	37.028	37.834	38.214	38.696	38.781
xxiv)	10.0	31.867	32.584	33.208	33.753	34.231	34.652	35.024	37.144	37.978	38.382	38.927	39.057
xxv)	INF	31.876	32.593	33.218	33.764	34.243	34.664	35.037	37.162	38.003	38.411	38.978	39.172

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ANNEX C

(*Clauses* 4.2.6 *and* 5.4.4.3)

USE OF DESIGN CHARTS FOR NATURAL VENTILATION

C-1 APPLICATION OF THE DESIGN CHARTS

C-1.1 The application of the design charts for natural ventilation (NV) is demonstrated here. The openings for the master-bedroom of the apartment two BHK case in Fig. 26 are sized to deliver the recommended airflow rates for two scenarios of input parameters.

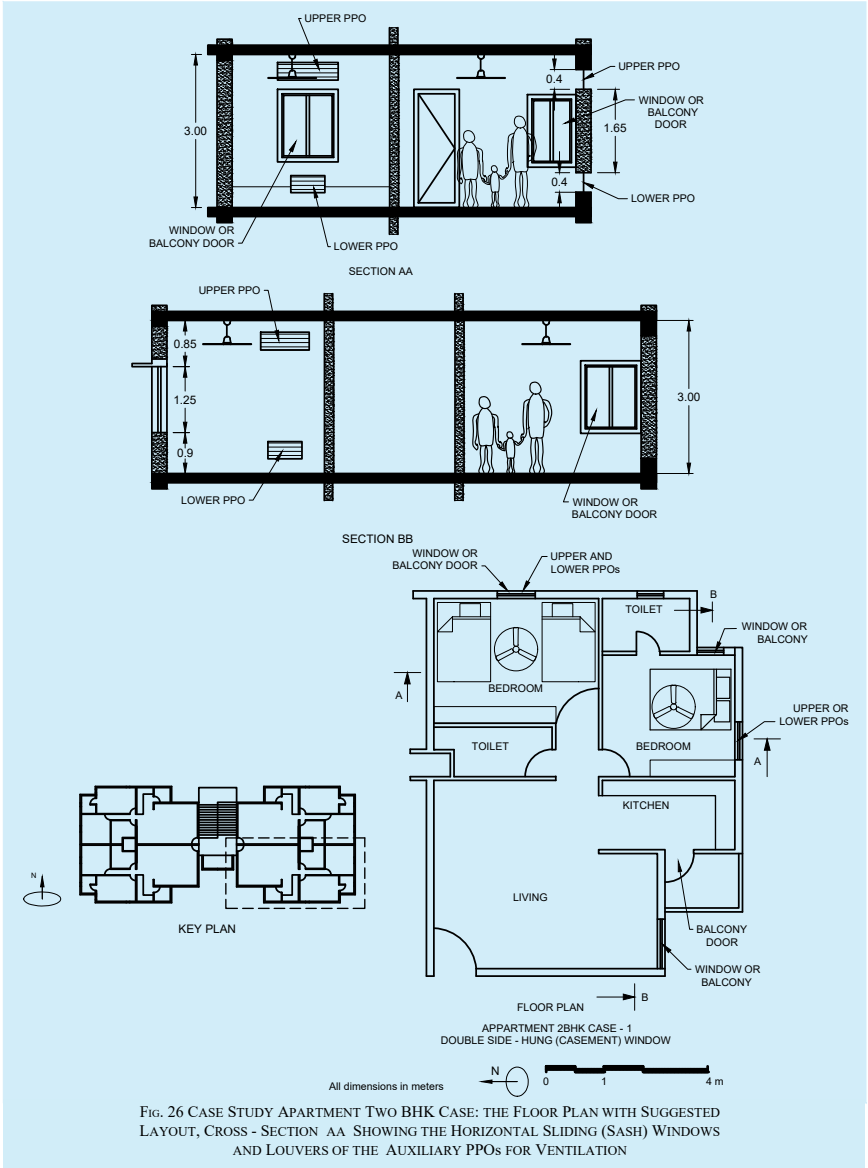

FIG. 26 CASE STUDY APARTMENT TWO BHK CASE: THE FLOOR PLAN WITH SUGGESTED LAYOUT, CROSS - SECTION AA SHOWING THE HORIZONTAL SLIDING (SASH) WINDOWS AND LOUVERS OF THE AUXILIARY PPOs FOR VENTILATION

C-1.2 The input parameters used for the demonstration of the design charts are shown in Table 23. The demonstration is shown for DC-01 in Fig. 26, for DC-02 in Fig. 27, for DC-03 in Fig. 28 and for DC-04 in Fig. 29. The free area for the openings A_f calculated with the DCs are shown in Table 25.

C-1.2.1 *DC*-01 — *Buoyancy-Driven Flow*; *Single-Sided Ventilation with One Opening*

$$A_f = \frac{q_{rec}}{C_d}\sqrt{\frac{(T_{inside}+273)}{g\,h_a \Delta T_{inside\text{-}outside}}}$$

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where

A_f = free area of the openings for NV, m^2;

C_d = discharge coefficient [-];

q_{rec} = ventilation rate achieved, m^3/s;

T_{inside} = temperature inside, °C;

g = acceleration due to gravity, m/s^2;

h_a = vertical distance between the centres of the openings, m; and

$\Delta T_{inside\text{-}outside}$ = [temperature inside (°C) - temperature outside (°C)].

DC-01 is derived from the equation given in **C-1.2.1**. For single openings, the value for C_d adopted is 0.25. The demonstration of the application of this DC for two scenarios (a set of values) and for the input parameters as per Table 23 is shown in Fig. 27.

C-1.2.2 *DC*-02 — *Buoyancy-Driven Flow*; *Cross-Ventilation with Multiple Openings Shown in Fig. 28*

The DC-02 is also derived from the equation given in **C-1.2.3.1**. Conversely, for multiple openings, the value for C_d adopted is 0.61. The demonstration of the application of this DC for two scenarios (a set of values) and for the input parameters shown in Table 23 is shown in Fig. 28.

C-1.2.3 *DC*-03 — *Wind-Driven Flow*; *Single-Sided Ventilation with One Opening Shown in Fig. 29*

DC-03 is derived from the following equation:

$$A_f = q_{rec} / CV_z$$

where

A_f = free area of the openings for NV, m^2;

q_{rec} = ventilation rate achieved, m^3/s;

C = opening shape coefficient, [-]; and

V_z = wind speed at height 'Z', m/s.

C-1.2.3.1 The wind speed is calculated based on the height of the opening and the wind profile adjusted according to the terrain roughness. The equation below defines the wind speed (V_z) at height 'Z' based on the mean wind velocity at 10 m height (V_{ref}) and the characteristics of the roughness of the terrain, employed as an exponent of this power law. For this demonstration 'city terrain' is adopted in the calculations of V_z (input parameters and calculated values are shown in Table 23 and Table 24).

$$V_z = V_{ref}\, k\, z^{\alpha} (m/s)$$

where

V_z = wind speed at height 'Z', m/s;

V_{ref} = mean wind velocity, m/s;

k = terrain-roughness coefficient;

z = height above ground level, m; and

α = terrain roughness exponent.

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Table 23 Input Parameters Used for the Demonstration of the Design Charts

(*Clauses* C-1.2, C-1.2.1, C-1.2.2, C-1.2.3.1, C-1.2.3.2, C-1.2.4.1 *and* C-1.2.5)

Sl No.	Input Parameters	Scenario 1	Scenario 2
(1)	(2)	(3)	(4)
i)	q_{rec} (m/s)	0.18	0.35
ii)	ΔT (°C)	3.4	2.6
iii)	T_{inside} (°C)	31.3	31
iv)	$T_{outside}$ (°C)	27.9	28.4
v)	V_{ref} (m/s)	1.8	2.03
vi)	V_r (m/s)	0.98	1.10
vii)	ΔC_p	0.36	0.36
viii)	C_d for single openings	0.25	0.25
ix)	C_d for multiple openings	0.61	0.61
x)	C for single openings	0.05	0.05
xi)	h_a (m)	1.20	1.20
xii)	z (m)	18.00	18.00
xiii)	α	0.33	0.33
xiv)	k	0.21	0.21

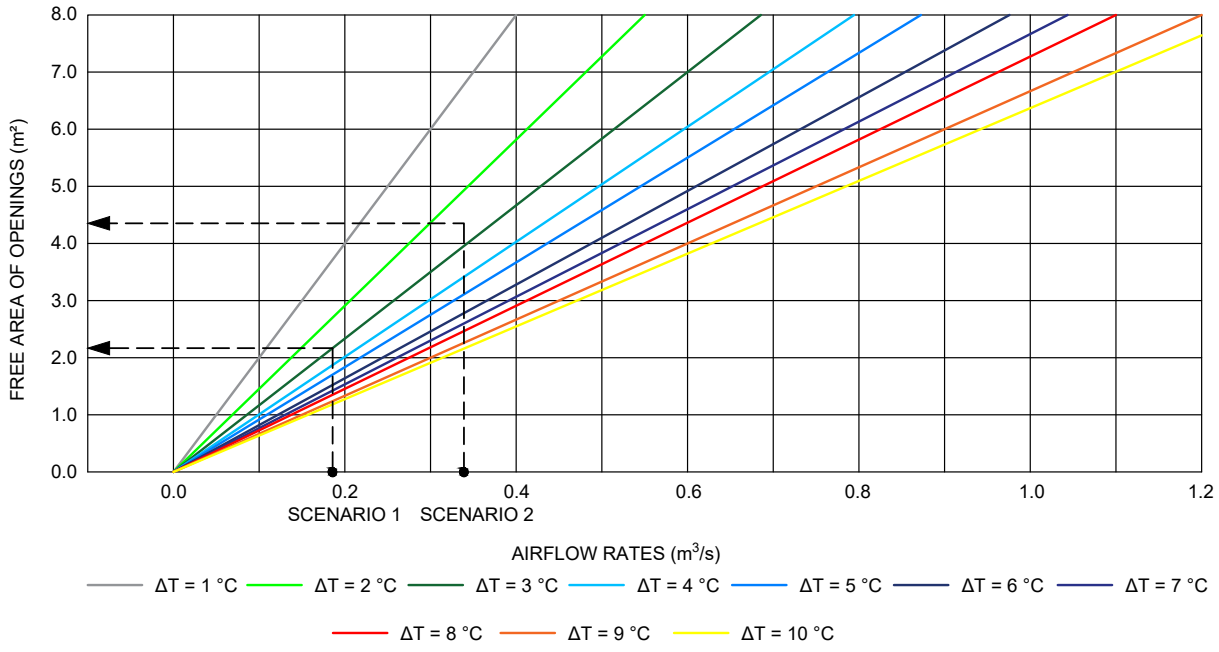

FIG. 27 DEMONSTRATION OF THE APPLICATION OF THE DC-01 (BUOYANCY-DRIVEN FLOW; SINGLE-SIDED VENTILATION WITH ONE OPENING) FOR BOTH SCENARIOS OF INDIAN CITIES

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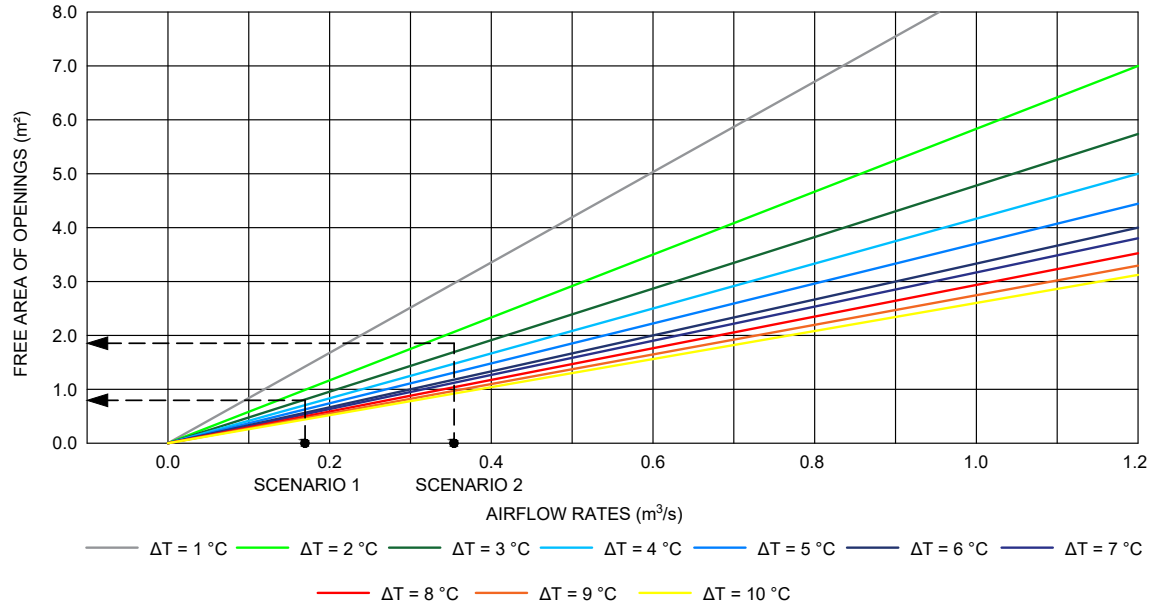

FIG. 28 DEMONSTRATION OF THE APPLICATION OF THE DC-02 (BUOYANCY-DRIVEN FLOW; CROSS-VENTILATION WITH MULTIPLE OPENINGS) FOR BOTH SCENARIOS OF INDIAN CITIES

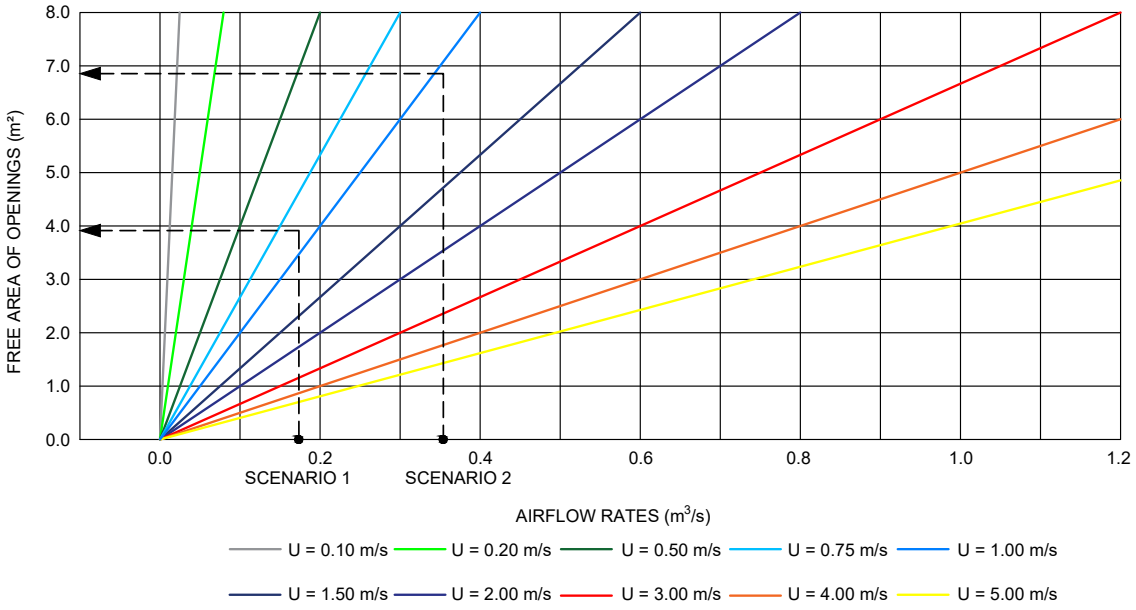

FIG. 29 DEMONSTRATION OF THE APPLICATION OF THE DC-03 (WIND-DRIVEN FLOW; SINGLE-SIDED VENTILATION WITH ONE OPENING) FOR BOTH SCENARIOS OF INDIAN CITIES

Table 24 Exponent Values Based on the Terrain Roughness

(*Clause* C-1.2.3.1)

Sl No.	Terrain Roughness	α	k
(1)	(2)	(3)	(4)
i)	Open country	0.17	0.68
ii)	Few blockages	0.20	0.52
iii)	Urban	0.25	0.35
iv)	City	0.33	0.21

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C-1.2.3.2 The demonstration of the application of this DC for both scenarios of Indian cities and for the input parameters shown in Table 23 is shown in Fig. 29.

C-1.2.4 *DC*-04 — *Wind-Driven Flow*; *Cross-Ventilation with Multiple Openings is Derived from the Equation:*

$$A_f = q_{rec}\left(C_d V_z \sqrt{\frac{\Delta C_p}{2}}\right)^{-1}$$

C-1.2.4.1 For orthogonal wind and for the floor plan presented in Fig. 26 for the two bedroom, kitchen and hall, apartment block a pressure coefficient difference (ΔC_p) between inlets and outlets of 0.36 is adopted for this application demonstration (*see* Table 23).

C-1.2.5 The free areas of the openings calculated utilizing the four design charts provided in this design guide for the recommended airflow rates presented in Table 23 and for two scenarios of Indian cities, are given in Table 25.

Table 25 Free Areas of the Openings Calculated Utilizing the Design Charts for Both Scenarios of Indian Cities

(*Clauses* C-1.2 *and* C-1.2.5)

Sl No.	Design Chart	Scenario 1 m^2	Scenario 2 m^2
(1)	(2)	(3)	(4)
i)	DC-01	2.03	4.36
ii)	DC-02	0.83	1.79
iii)	DC-03	4.02	6.90
iv)	DC-04	0.78	1.33

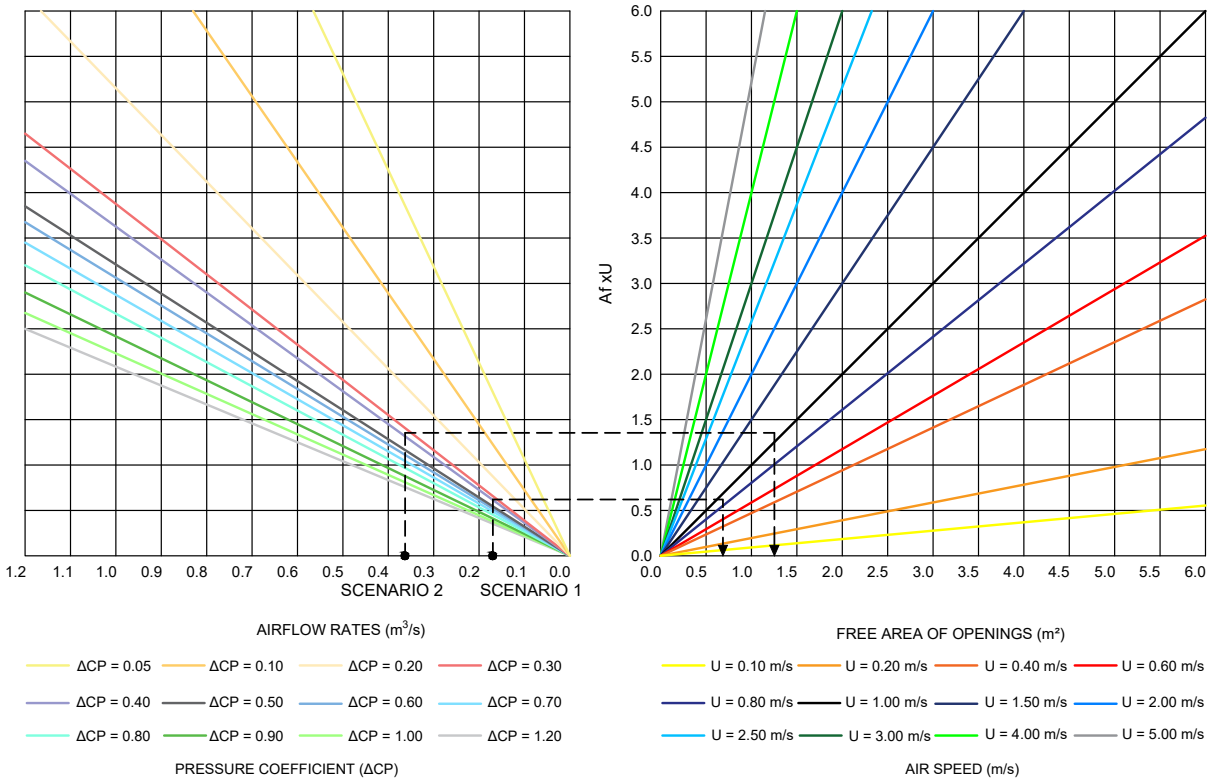

FIG. 30 DEMONSTRATION OF THE APPLICATION OF THE DC-04 (WIND-DRIVEN FLOW; CROSS-VENTILATION WITH MULTIPLE OPENINGS) FOR BOTH SCENARIOS OF INDIAN CITIES

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used as a guide in conformance with the requirements of the referred clauses in this NBCS.

	IS No.	*Title*
(1)	IS 7662 (Part 1) : 1974	Recommendations for orientation of buildings: Part 1 Nonindustrial buildings
(2)	IS 4963 : 2025	Accessibility in built environment for older adults and persons with disabilities — Requirements (*second revision*)
(3)	SP 72 : 2025	National Lighting Code of India 2025 (*first revision*)
(4)	IS 3646 (Part 1) : 2025	Interior illumination — Code of practice: Part 1 General requirements and recommendations for working interiors (*second revision*)
(5)	IS 2440 : 1975	Guide for daylighting of buildings (*second revision*)
(6)	IS 6060 : 1971	Code of practice for daylighting of factory buildings
	IS 7942 : 1976	Code of practice for daylighting of educational buildings
(7)	SP 41 (S&T) : 1987	Handbook on functional requirements of buildings (other than industrial buildings)
(8)	IS 1944	Code of practice for lighting of public thoroughfares:
	(Parts 1 and 2) : 1970	Part 1 General Principles and Part 2 Lighting for traffic routes (Groups A1, A2, B1 and B2) (*first revision*)
	(Part 6) : 1981	Lighting for town and city centres and areas of civic importance (Group E)
	IS 2672 : 1966	Code of practice for library lighting
	IS 4347 : 1967	Code of practice for hospital lighting
	IS 6074 : 1971	Code of practice for functional requirements of hotels, restaurants and other food service establishments
	IS 6665 : 1972	Code of practice for industrial lighting
	IS 10894 : 1984	Code of practice for lighting of educational institutions
	IS 10947 : 1984	Code of practice for lighting for ports and harbours
(9)	IS 3362 : 1977	Code of practice for natural ventilation of residential buildings (*first revision*)

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 2 ELECTRICAL AND ALLIED INSTALLATIONS

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part D/Section 2) covers the general requirements for electrical and allied installations in buildings. For more details, it is essential to refer to the relevant Indian Standards on the subject.

This Section was first published in 1970 as part of the National Building Code of India and was subsequently revised in 1983, 2005 and 2016. In the first revision in 1983, general guidance for electrical wiring installation in industrial location where voltage supply normally exceeds 650 V was included. This Section was also updated based on the existing version of the Indian Standards. The importance of pre-planning and exchange of information among all concerned agencies from the earlier stages of building work was emphasized.

In the second revision of 2005, the title of this Section was modified from the erstwhile 'Electrical Installations' to 'Electrical and Allied Installations' to reflect the provisions included on certain allied installations. The significant changes incorporated in this revision included, thorough change in the risk assessment procedure for lightning including some other changes in the provision of lightning protection of building; alignment of some of the provisions of wiring with the practices prevalent at that time; modification of definitions in line with terminologies used at national and international levels and addition of some new definitions; incorporation of provisions on installation of distribution transformer inside the multistoreyed buildings; introduction of concept of energy conservation in lighting and introduction of concept of various types of earthing in building installations.

In the third revision in 2016, various updates were made including: location and other requirements relating to layout, environmental and safety aspects for different substation apparatus/equipment and generating sets were reviewed and updated; location of compact substations was included; requirements for electrical supply system for life and safety services were included; provisions relating to reception and distribution of supply and wiring installations were updated; installation best practices of energy meters were updated; discrimination, cascading and limitation concepts for the coordination of protective devices in electrical circuits were introduced; socket outlets with suitable circuit breakers, conforming to Indian Standards were recommended for industrial and commercial applications, either indoors or outdoors; provisions relating to earthing/grounding were substantially revised and updated; provisions relating to lightning protection of buildings were revamped based on the national and international developments then; provisions relating to renewable energy sources for building, such as solar PV system, aviation obstacle lights, electrical supply for electric vehicle charging and car park management, etc, were included; provisions relating to electrical installations for construction sites and demolition sites were included; provisions relating to protection of human beings from electrical hazards and protection against fire in the building due to leakage current were included; typical formats for checklists for handing over and commissioning of substation equipment and earthing pit were included; and the terminologies updated.

In this revision, the publication has been renamed as National Building Construction Standards (NBCS).

All electrical installations in India come under the purview of *The Indian Electricity Act*, 2003 and the rules and regulations framed thereunder. In the context of the buildings, both buildings (the structure itself) and the building services (not just the electrical services, but all other services that use electricity or have an interface with the electrical system) are required to follow these. The erstwhile *Indian Electricity Rules*, 1956 were modified by various Central Electricity Authority Regulations. While revising the provisions of this Section of the NBCS, care has been taken to align the same with the provisions of the relevant regulations, particularly, *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023. In this revision, in addition to above, the following major modifications have been incorporated:

a) Various terms and their definitions have been reviewed based on current developments at national and international level. In addition, few more definitions have been added for more clarity and better understanding;

b) Voltage categorization for building has been made considering revision in voltage norms by CEA, Indian Standards and various State Electricity Boards;

c) Provisions relating to location and other requirements relating to layout, environmental and safety aspects for different substation apparatus/equipment and generating sets have been reviewed and updated;

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d) Requirements for electrical supply system for life and safety services have been reviewed;

e) Provisions relating to reception and distribution of supply and wiring installations have been updated with due cognizance to Indian Standards formulated for various wiring systems;

f) Provisions relating to installation of energy meters have been updated;

g) Discrimination, cascading and limitation concepts for the coordination of protective devices in electrical circuits have been updated;

h) Socket-outlets with suitable circuit breakers, conforming to IS 1293 : 2019 'Plugs and socket-outlets for household and similar purposes of rated voltage up to and including 250 V and rated current up to and including 16 A — Specification (*fourth revision*)' have been recommended for industrial and commercial applications, either indoors or outdoors.

j) Provisions relating to earthing/grounding have been substantially revised and updated;

k) Provisions relating to lightning protection of buildings have been reviewed and updated based on the current national and international developments;

m) Provisions relating to renewable energy sources for building, such as rooftop solar photovoltaic (PV) system has been updated and building integrated photovoltaic (BIPV) system and solar water heating system have been included;

n) Provisions relating to electrical installations for construction sites and demolition sites have been reviewed and updated;

p) Provisions related to electric vehicles (EV) charging have been updated as per present norms;

q) Provisions relating to protection of human beings from electrical hazards and protection against fire in the building due to leakage current have been reviewed and updated;

r) Provisions on building management systems (BMS) have been updated in **10.4**; and

s) Provisions on power fence (electrical fence) system has been included in **10.11**.

This Section has to be read together with Part D 'Building Services, Section 1 Lighting and Natural Ventilation' of this NBCS for making provision for the desired levels of illumination as well as ventilation for different locations in different occupancies; Part D 'Building Services, Section 6 Information and Communication Enabled Installations'; Part F 'Fire and Life Safety' of this NBCS for list of emergency fire and life safety services and other sections of Part D 'Building Services' and Part E 'Plumbing Services' for electricity related requirements and integration thereof. Utmost importance should be given in the installation of electrical wiring to prevent short circuiting and the hazards associated therewith.

Notwithstanding the provisions given in this Section and the National Electrical Code 2023, the provisions of the *Central Electrical Authority* regulations framed under the *Indian Electricity Act*, 2003 as amended up to date have to be necessarily complied with.

The information contained in this section is largely based on the following Indian Standards/Special Publications:

IS 732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
IS 3043 : 2018	Code of practice for earthing (*second revision*)
IS 4648 : 1968	Guide for electrical layout in residential buildings
IS 19127 : 2025	Graphical symbols for diagrams in the field of electrotechnology
IS/IEC 62305-1 : 2010	Protection against lightning: Part 1 General principles
IS/IEC 62305-2 : 2010	Protection against lightning: Part 2 Risk management
IS/IEC 62305-3 : 2010	Protection against lightning: Part 3 Physical damage to structures and life hazard

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IS/IEC 62305-4 : 2010	Protection against lightning: Part 4 Electrical and electronic systems within structures
IS 17017-1 : 2018	Electric vehicle conductive charging system: Part 1 General requirement
IS 17017-2 : 2020	Electric vehicle conductive charging system: Part 2 Plugs, socket-outlets, vehicle connectors, and vehicle inlets (*all sections*)
IS 18925 : 2025 (Parts 1 to 8)	Lightning protection system components
SP 30 : 2023	National Electrical Code of India, 2023 (*second revision*)

It may be noted that some of the above standards are currently under revision. The revised version when available should be referred.

Considerable assistance has also been drawn from following International Standards while formulating this Section:

IEC 62305 : 2024	Protection against lightning:
(Part 1) : 2024	General principles
(Part 2) : 2024	Risk management
(Part 3) : 2024	Physical damage to structures and life hazard
(Part 4) : 2024	Electrical and electronic systems within structures
IEC 60335-2-76 : 2018	Household and similar electrical appliances — Safety — Part 2-76: Particular requirements for electric fence energizers
IEC 60364-4-41 : 2005	Low-voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock
IEC 60364-4-43 : 2023	Low-voltage electrical installations — Part 4-43: Protection for safety — Protection against overcurrent
IEC 60364-4-44 : 2007	Low-voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances
IEC 60364-5-51 : 2005	Electrical installations of buildings — Part 5-51: Selection and erection of electrical equipment – Common rules
IEC 60364-5-54 : 2011	Low-voltage electrical installations — Part 5-54: Selection and erection of electrical equipment — Earthing arrangements and protective conductors
IEC 60364-7 series	Low-voltage electrical installations — Part 7: Requirements for special installations or locations
IEC 61439-1 : 2020	Low-voltage switchgear and controlgear assemblies — Part 1: General rules
IEC 61439-2 : 2020	Low-voltage switchgear and controlgear assemblies — Part 2: Power switchgear and controlgear assemblies
IEC 61439-6 : 2012	Low-voltage switchgear and controlgear assemblies — Part 6: Busbar trunking systems (busways)

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The

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implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section of the NBCS.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **'accepted standard'** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [D-2(1)] refers to the Indian Standard/Special Publication given at serial number (1) of the List of Standards given at the end of this Part D/Section 2, that is, SP 30 : 2023, 'National Electrical Code of India, 2023 (*second revision*)'

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NATIONAL BUILDING COSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 2 ELECTRICAL AND ALLIED INSTALLATIONS

1 SCOPE

This NBCS (Part D/Section 2) covers the essential requirements for electrical installations in buildings to ensure efficient use of electricity including safety from fire and shock, reliability and sustainability. This Section also includes general requirements relating to renewable energy sources, EV charging, lightning protection of buildings and brief provisions on allied installations.

2 TERMINOLOGY AND CONVENTIONAL SYMBOLS

2.1 For the purpose of this Section, the following definitions shall apply. For definition of other terms, reference may be made to good practice [D-2(1)] and accepted standard [D-2(2)].

2.1.1 *Accessory* — A device, other than current using equipment, associated with such equipment or with the wiring of an installation.

2.1.2 *Apparatus* — Electrical apparatus including all machines, appliances and fittings in which conductors are used or of which they form a part.

2.1.3 *Appliance* — An item of current using equipment other than a luminaire or an independent motor.

2.1.4 *Back-up Protection* — Protection which is intended to operate when a system fault is not cleared or abnormal condition not detected in the required time, because of failure or inability of other protection to operate or failure of appropriate circuit-breaker to trip.

2.1.5 *Barrier* — A part providing a defined degree of protection against contact with live parts, from any usual direction of access.

2.1.6 *Basic Protection* — Protection against electric shock under fault-free condition.

NOTE — For low voltage installations, systems and equipment, basic protection generally corresponds to protection against direct contact that is ‘contact of persons or live parts’.

2.1.7 *Battery Energy Storage System* (*BESS*) — Electrical energy storage system with an accumulation subsystem based on batteries fitted with secondary cells.

2.1.8 *Bonding Conductor* — A protective conductor providing equipotential bonding.

2.1.9 *Bonding Ring Conductor* (*BRC*) — A bus earthing conductor in the form of a closed ring.

NOTE — Normally the bonding ring conductor, as part of the bonding network, has multiple connections to the common bonding network (CBN) that improves its performance.

2.1.10 *Branch Switch* — A miniature circuit breaker that protects a specific branch circuit within a larger power distribution circuit, such as a house or building. It acts as a safety device, automatically interrupting the flow of electricity in the event of an overload or short circuit, preventing damage to wiring and appliances.

2.1.11 *Bunched* — Cables are said to be ‘bunched’ when two or more are contained within a single conduit, duct, ducting, or trunking, or, if not enclosed, are not separated from each other.

2.1.12 *Buried Direct* — A cable laid in the ground in intimate contact with the soil.

2.1.13 *Busbar Trunking System* — A type-tested assembly, in the form of an enclosed conductor system of

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comprising solid conductors separated by insulating materials. The assembly may consist of units such as:

a) Busbar trunking units, with or without tap-off facilities;

b) Tap-off units where applicable; and

c) Phase-transposition, expansion, building-movement, flexible, end-feeder and adaptor units.

2.1.14 *Bypass Equipotential Bonding Conductor* — Bonding conductor connected in parallel with the screens of cables.

2.1.15 *Cable* — A length of single-insulated conductor (solid or stranded), or two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

2.1.16 *Cable*, *Fire Survival* — A cable which continues to function and maintain the circuit integrity under circumstances of fire (against a specified temperature and period of the test) {*see* accepted standards [D-2(3)]}.

2.1.17 *Cable, Flame Retardant* (*FR*) — A cable which is flame retardant as per the accepted standard [D-2(4)].

2.1.18 *Cable*, *Flame Retardant Low Smoke and Halogen* (FR-LSH) — A cable which is flame retardant and emits low smoke and halogen as per the accepted standard [D-2(5)].

2.1.19 *Cable*, *Flexible* — A cable containing one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.

2.1.20 *Cable*, *Metal-Sheathed* — An insulated cable with a metal sheath.

2.1.21 *Cable*, *PVC Sheathed-Insulated* — A cable in which the insulation of the conductor is a polyvinylchloride (PVC) compound; with PVC sheath also providing mechanical protection to the conductor core or cores in the cable.

2.1.22 *Cable*, *Weatherproof* — A cable so constructed that when installed in uncovered locations, it will withstand all kinds of weather variations (*see* **2.1.195** for definition of weatherproof).

2.1.23 *Cable*, *XLPE* — A cable in which the insulation of the conductor is cross-linked polythene and the mechanical protection is provided for the core or cores by a sheath of a polyvinyl chloride compound.

2.1.24 *Cable Armoured* — A cable provided with a wrapping of metal (usually in the form of tape or wire) serving as a mechanical protection.

2.1.25 *Cable Bracket* — A cable support consisting of single devices fixed to elements of building or plant construction.

2.1.26 *Cable Channel* — An enclosure situated above or in the ground, open or ventilated or closed, and having dimensions which do not permit the access of persons but allow access to the conductor and/or cables throughout their length during and after installation.

NOTE — A cable channel may or may not form part of the building construction.

2.1.27 *Cable Cleat* — A component of a support system which consists of elements spread at intervals along the length of the cable or conduits and which mechanically retains the cable or conduit.

2.1.28 *Cable Coupler* — A means enabling the connection, at will, of two flexible cables. It consists of a connector and a plug.

2.1.29 *Cable Ducting* — A manufactured enclosure of metal or insulating material, other than conduit or cable trunking, intended for the protection of cables which are drawn-in after erection of the ducting, but which is not specifically intended to form part of a building structure.

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2.1.30 *Cable Ladder* — A cable support occupying less than 10 percent of the plan area and consisting of a series of supporting elements rigidly fixed to each other or to a main supporting member or members.

2.1.31 *Cable Raceways* — An enclosed channel of metal or non-metallic materials designed expressly for holding wires, cables or busbars, with openable/maintainable construction having provision of ventilation. These include electrical non-metallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways and wireways.

2.1.32 *Cable Support and Fixing Materials* (*Fire Survival*) — Supports and fixing materials for supporting fire survival cable (*see* **2.1.16**), which continues in service after exposure to fire for a specified duration.

2.1.33 *Cable Tray* — A cable support consisting of a continuous base with raised edges and no covering. The classification and perforation of cable tray shall be as per accepted standard [D-2(6)].

2.1.34 *Cable Trunking* — A factory made closed support and protection system into which conductors and/or cables are laid after removal of the cover.

2.1.35 *Cable Tunnel* — An enclosure (corridor) containing supporting structures for conductors and/or cables and joints and whose dimensions allow free access to persons throughout the entire length.

2.1.36 *Cartridge Fuse Link* — A device comprising a fuse element or several fuse elements connected in parallel enclosed in a cartridge usually filled with an arc-extinguishing medium and connected to terminations. The fuse link is the part of a fuse which requires replacing after the fuse has operated.

2.1.37 *Ceiling Rose* — A fitting (usually used to attach to the ceiling) designed for the connection between the electrical installation wiring and a flexible cord (which is in turn connected to a lamp holder).

2.1.38 *Circuit* — An assembly of electrical equipment supplied from the same origin and protected against overcurrent by the same protective device(s). Circuits are categorized as follows:

a) *Category* 1 *circuit* — A circuit (other than a fire alarm annunciation or emergency lighting circuit and other circuits required to work during fire in a building) operating at low voltage and supplied directly from a mains supply system;

b) *Category* 2 *circuit* — With the exception of Category 3 circuits, any circuit for extra low-voltage (ELV)/telecommunication [for example, radio, telephone, sound distribution, building management system (BMS), public address system (PAS), intruder alarm, bell and call and data transmission circuits] which is supplied from a safety source; and

c) *Category* 3 *circuit* — A fire alarm circuit or an emergency lighting circuit and other circuits required to work during fire in a building.

2.1.39 *Circuit Breaker* — A mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also of making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A circuit breaker is usually intended to operate infrequently, although some types are suitable for frequent operation.

2.1.39.1 *Miniature circuit breaker* (*MCB*) — A compact mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also making and carrying currents for specified times and automatically breaking currents under specified abnormal circuit conditions, such as those of overload and short circuits.

2.1.39.2 *Circuit breaker*, *linked* — A circuit breaker, the contacts of which are so arranged as to make or break all poles simultaneously or in a definite sequence.

2.1.39.3 *Moulded case circuit breaker* (*MCCB*) — A circuit breaker having a supporting housing of moulded insulating material forming an integral part of the circuit breaker.

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2.1.39.4 *Air circuit breaker* (*ACB*) — A circuit breaker in which the contacts open and close in air at atmospheric pressure.

2.1.40 *Circuit*, *Final Sub* — An outgoing circuit connected to one-way distribution board and intended to supply electrical energy at one or more points to current, using appliances without the intervention of a further distribution board other than a one-way board. It includes all branches and extensions derived from that particular way in the board.

2.1.41 *Compact Substation or Prefabricated Substation* — Prefabricated and type-tested assembly which can to be operated from inside (walk-in type) or outside (non-walk-in type) comprising components such as power transformer, high-voltage switchgear and controlgear, low-voltage switchgear and controlgear, corresponding interconnections (cable, busbar or other) and auxiliary equipment and circuits located next to each other, maintaining segregation and integrity of each compartment in which they are located along with external interconnecting cables, earthing, protections, etc. The components shall be enclosed by either a common enclosure or by an assembly of enclosures.

NOTE — *See* accepted standard [D-2(7)] for requirements of prefabricated substation.

2.1.42 *Conductor, Aerial* — Any conductor which is supported by insulators above the ground and is directly exposed to the weather.

NOTE — Following four classes of aerial conductors are recognized:

a) Bare aerial conductors;

b) Covered aerial conductors;

c) Insulated aerial conductors; and

d) Weatherproof neutral-screened cable.

2.1.43 *Conductor*, *Bare* — A conductor not covered with insulating material.

2.1.44 *Conductor, Earthed* — A conductor with no provision for its insulation from earth.

2.1.45 *Conductor*, *Insulated* — A conductor adequately covered with insulating material of such quality and thickness as to prevent danger.

2.1.46 *Conductor of a Cable or Core* — The conducting portion consisting of a single wire or group of wires, assembled together and in contact with each other or connected in parallel.

2.1.47 *Conduit* — A part of a closed wiring system, a circular or non-circular cross section for conductors and/or cables in electrical installations, allowing them to be drawn in and/or replaced. Conduits should be sufficiently closed-jointed so that the conductors can only be drawn in and not inserted laterally.

2.1.48 *Connector* — The part of a cable coupler or of an appliance coupler which is provided with female contact and is intended to be attached to the flexible cable connected to the supply.

2.1.49 *Connector Box or Joint Box* — A box forming a part of wiring installation, provided to contain joints in the conductors of cables of the installations.

2.1.50 *Connector for Portable Appliances* — A combination of a plug and socket arranged for attachment to a portable electrical appliance or to a flexible cord.

2.1.51 *Consumer's Terminals* — The ends of the electrical conductors situated upon any consumer's premises and belonging to him, at which the supply of energy is delivered from the service line.

2.1.52 *Continuous Operating Voltage* (U_c) — Maximum rms voltage which may be continuously applied to a surge protection device’s mode of protection. This is equal to rated voltage.

2.1.53 *Cord, Flexible* — A flexible cable having a large number of strands of conductors of small cross-sectional

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area. Two flexible cords twisted together are known as twin 'flexible cord'.

NOTE — Large number of fine strands of wires for each conductor makes the conductor capable of withstanding frequent bends thereby improving their flexibility.

2.1.54 *Core of a Cable* — A single conductor of a cable with its insulation but not including any mechanical protective covering.

2.1.55 *Current Carrying Capacity of a Conductor* — The maximum current which can be carried by a conductor under specified conditions without its steady state temperature exceeding a specified value.

2.1.56 *Current Using Equipment* — Equipment which converts electrical energy in to another form of energy, such as light, heat, or motive power.

2.1.57 *Cut-out* — Any appliance for automatically interrupting the transmission of energy through any conductor when the current rises above a pre-determined amount.

2.1.58 *Damp Situation* — A situation in which moisture is either permanently present or intermittently present to such an extent as likely to impair the effectiveness of an installation conforming to the requirements for ordinary situations.

2.1.59 *Danger* — Danger to health or danger to life or limb from shock, burn or injury from mechanical movement to persons (and livestock where present), or from fire attendant upon the use of electrical energy.

2.1.60 *Datacentre* — A structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage and processing with the necessary levels of resilience and security required to provide the desired service availability.

2.1.61 *Dead* — A portion of an electrical circuit (normally expected to carry a voltage) at or near earth potential or apparently disconnected from any live system. A circuit apparently disconnected from all sources is expected to be at earth potential; but capacitive storage of charge in cables, capacitors, etc, can keep the electric circuit at a significant voltage (and often dangerous voltages from aspects of shock). Such circuits with storage components will be dead only on connection to earth.

2.1.62 *Design Current* (*of a Circuit*) — The magnitude of the current intended to be carried by the circuit in normal service.

2.1.63 *Direct Contact* — Contact of persons or live stock with live parts which may result in electric shock.

2.1.64 *Discrimination* (*Selectivity-Over-Current Discrimination*) — Coordination of the operating characteristics of two or more over-current protective devices should be such that, on the incidence of over-currents within stated limits, the device intended to operate would be the device closest to the point of fault or abnormality, and if proper discrimination is achieved within these limits, only that device closest should operate, while the other circuit breakers upstream do not operate, thereby ensuring that there is minimum area of power supply which is interrupted.

NOTES

1 Protective devices should have discrimination so that only the affected part (minimum section) of the circuit is isolated, even though a number of protective devices may be in the path of the overcurrent.

2 The electrical network requires the discrimination for all the fault circuits, including overload, short-circuit, etc. The downstream device should take care of the fault up to the level of ultimate short-circuit breaking capacity (*I*cu) of the downstream breaker which should be equal to the bus which is connected.

3 Distinction is made between series discrimination involving different over-current protective devices passing substantially the same over-current and network discrimination involving identical protective devices passing different proportions of the over-current.

4 Different types of protective devices may have to be used to ensure effective discrimination in circuits where proper and effective discrimination is necessary. Apart from the built-in sensors and actuators in circuit breakers, external relays operating on different parameters, and comparison of parameters between two or more points will have to be used for complex installations.

5 *See also* relevant parts of the accepted standard [D-2(8)].

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2.1.65 *Disconnector* — A mechanical switching device which, in the open position, complies with the requirements specified for the isolation function.

NOTES

1 A disconnector is otherwise known as isolator.

2 A disconnector is capable of opening and closing a circuit when either a negligible current is broken or made, or when no significant change in the voltage across the terminals of each pole of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time, current under abnormal conditions, such as those of short-circuit.

2.1.66 *Distance Area or Resistance Area* (*for an Earth Electrode Only*) — The surface area of ground (around an earth electrode) on which a significant voltage gradient may exist.

2.1.67 *Diversity Factor* — A measure of the probability that a particular piece of equipment will turn on coincidentally to another piece of equipment. For aggregate systems it is defined as the ratio of the sum of the individual non-coincident maximum loads of various subdivisions of the system to the maximum demand of the complete system.

2.1.68 *Duct* — A closed passage way formed underground or in a structure and intended to receive one or more cables which may be drawn in.

2.1.69 *Ducting — See* **2.1.29**.

2.1.70 *Earth* — The conductive mass of the earth, whose electric potential at any point is conventionally taken as zero.

2.1.71 *Earth Continuity Conductor* — The conductor, including any clamp, connecting to the earthing lead or to each other, those parts of an installation which are required to be earthed. It may be in whole or in part, the metal conduit or the metal sheath or armour of the cables, or the special continuity conductor of a cable or flexible cord incorporating such a conductor.

2.1.72 *Earthed Concentric Wiring* — A wiring system in which one or more insulated conductors are completely surrounded throughout their length by a conductor, for example a sheath, which acts as a PEN conductor.

2.1.73 *Earth Electrode* — A conductor or group of conductors in intimate contact with the ground to provide a low resistance path for flow of current to earth.

2.1.74 *Earth Electrode Network* — Part of an earthing arrangement comprising of only the earth electrodes and their interconnections.

2.1.75 *Earth Electrode Resistance* — The resistance of an earth electrode to earth.

2.1.76 *Earth Fault* — An unintended and undesirable connection of phase/neutral conductor to earth. When the impedance is negligible, the connection is called a dead earth fault.

2.1.77 *Earth Fault Current* — A current resulting from a fault of negligible impedance between a line conductor and an exposed conductive part or a protective conductor.

2.1.78 *Earth Fault Loop Impedance* (Z_s) — The total impedance of the path that a fault current would take during an earth fault, starting at the point of the fault and returning to the supply's neutral point.

2.1.79 *Earthing* — Connection of the exposed conductive parts of an installation to the main earthing terminal of that installation.

2.1.80 *Earthing Conductor* — A protective conductor connecting the main earth terminal (or equipotential bonding conductor of an installation when there is no earth bus) to an earth electrode or to other means of earthing.

2.1.81 *Earthing Lead* — The final conductor by which the connection to the earth electrode is made.

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2.1.82 *Earth Leakage Current* — A current which flows to earth, or to extraneous conductive parts, in a circuit which is electrically sound.

NOTE — This current may have a capacitive component including that resulting from the deliberate use of capacitors.

2.1.83 *Earthing Resistance*, *Total* — The resistance between the main earthing terminal and the earth.

2.1.84 *Electrical Equipment* (*abb: Equipment*) — Any item for such purposes as generation, conversion, transmission, distribution or utilization of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, wiring materials, accessories, and appliances.

2.1.85 *Electrically Independent Earth Electrodes* — Earth electrodes located at such a distance from one another that the maximum current likely to flow through one of them does not significantly affect the potential of the other(s).

2.1.86 *Electrical Supply System for Life and Safety Services* — A supply system intended to maintain the operation of essential parts of an electrical installation and equipment:

a) for health and safety of persons and livestock; and

b) to avoid damage to the environment and to other equipment.

NOTES

1 The supply system includes the source and the circuit(s) up to the terminals of the electrical equipment.

2 *See also* Part F 'Fire and Life Safety' of this NBCS regarding emergency fire and life safety services.

2.1.87 *Electric Shock* — A dangerous patho-physiological effect resulting from the passing of an electric current through a human body or an animal.

2.1.88 *Electric Vehicle* (*EV*) — A vehicle that is propelled by one or more electric motors, using electrical energy stored in rechargeable batteries offering various benefits, including reduced emissions, lower running costs and potentially quieter operation compared to traditional gasoline-powered vehicles.

2.1.89 *EV Connector* — Different types of EV charging connectors, also called plugs, that works with different vehicles, charging speeds and locations.

2.1.90 *Electric Vehicle Supply Equipment* (*EVSE*) — Equipment or a combination of equipment, providing dedicated functions to supply electric energy from a fixed electrical installation or supply network to an EV for the purpose of charging.

2.1.91 *Emergency Switching* — Rapid cutting off of electrical energy to remove any hazard to persons, livestock, or property which may occur unexpectedly.

2.1.92 *Enclosure* — A part providing protection of equipment against certain external influences and, in any direction, protection against direct contact.

2.1.93 *Enclosed Distribution Board* — An enclosure containing busbars with one or more control and protected devices for the purpose of protecting, controlling or connecting more than one outgoing circuits fed from one or more incoming circuits.

2.1.94 *Equipotential Bonding* — Electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential.

NOTE — In a building installation equipotential bonding conductors shall interconnect the following conductive parts:

a) Protective conductor;

b) Earth continuity conductor; and

c) Risers of air conditioning system and heating systems (if any).

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2.1.95 *Exothermic Welding* — A welding process that uses a chemical reaction to generate intense heat, typically reaching temperatures of around 1 400 °C. This heat is used to melt metal and create a permanent, high-quality weld without the need for an external heat or power source. The process is particularly useful for joining conductors, such as in earthing and lightning protection systems, and can be used to weld dissimilar metals.

2.1.96 *Exposed Conductive Part* — A conductive part of electrical equipment, which can be touched and which is not normally live, but which may become live under fault conditions.

2.1.97 *Exposed Metal* — All metal parts of an installation which are easily accessible other than:

a) parts separated from live parts by double insulation;

b) metal name-plates, screw heads, covers, or plates, which are supported on, or attached, or connected to substantial non-conducting material only in such a manner that they do not become alive in the event of failure of insulation of live parts and whose means of fixing do not come in contact with any internal metal; and

c) parts which are separated from live parts by other metal parts which are themselves earthed or have double insulation.

2.1.98 *External Influence* — Any influence external to an electrical installation which affects the design and safe operation of that installation.

2.1.99 *Extraneous Conductive Part* — A conductive part not forming part of the electrical installation and liable to introduce a potential, generally the earth potential.

2.1.100 *Fault* — A circuit condition in which current flows through an abnormal or unintended path. This may result from an insulation failure or a bridging of insulation. Conventionally the impedance between live conductors or between live conductors and exposed or extraneous conductive parts at the fault position is considered negligible.

2.1.101 *Fault Current* — A current resulting from a fault.

2.1.102 *Fault Protection* — Protection against electric shock under single fault conditions.

NOTE — For low voltage installation, system's and equipment's fault protection generally corresponds to protection against indirect contact, mainly with regards to failure of basic insulation. Indirect contact is 'contact of persons or livestock with exposed-conductive parts which have become live under fault conditions'.

2.1.103 *Final Circuit* — A circuit connected directly to current using equipment, or to socket-outlets or other outlet points for the connection of such equipment.

2.1.104 *Fire Survival Distribution Board* — A distribution board which continues in service after exposure to fire to the required system rating.

2.1.105 *Fish Wire* — A draw wire to pull electrical wires or other cables through concealed spaces like conduits in ceilings/walls/floors.

2.1.106 *Fitting, Lighting* — A device for supporting or containing a lamp or lamps [for example, fluorescent or incandescent or halogen or compact fluorescent lamp (CFL) or light-emitting diode (LED)] together with any holder, shade, or reflector, for example, a bracket, a pendant with ceiling rose, an electrolier, or a portable unit.

2.1.107 *Fixed Equipment* — Equipment fastened to a support or otherwise secured.

2.1.108 *Flameproof Enclosure* — An enclosure which will withstand without injury any explosion of inflammable gas that may occur within it under practical conditions of operation within the rating of the apparatus (and recognized overloads, if any, associated therewith) and will prevent the transmission of flame which may ignite

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any inflammable gas that may be present in the surrounding atmosphere.

NOTES

1 Hazardous areas are classified into different zones, depending upon the extent to which an explosive atmosphere may exist at that place. In such areas, flame proof switchgear, fittings, accessories have to be used/installed in flameproof enclosure.

2 An electrical apparatus is not considered as flameproof unless it complies with the appropriate statutory regulations.

3 Other types of fittings are also in vogue in wiring installations, for example, 'increased safety'.

2.1.109 *Functional Earthing* — Connection to earth necessary for proper functioning of electrical equipment.

2.1.110 *Hand-Held Equipment* — Portable equipment intended to be held in the hand during normal use, in which the motor, if any, forms an integral part of the equipment.

NOTE — A hand held equipment is an item of equipment, the functioning of which requires constant manual support or guidance.

2.1.111 *Harmonics* (*Current and Voltage*) — All alternating current which is not absolutely sinusoidal is made up of a fundamental and a certain number of current and voltage harmonics [multiples of 50 Hz (basic frequency)] which are the cause of its deformation (distortion) when compared to the theoretical sine-wave.

2.1.112 *Hazardous Live-Part* — A live part which can give, under certain condition of external influence, an electric shock.

2.1.113 *Impulse Current* — A parameter used for the classification test for SPDs (*see* **2.1.177**); it is defined by three elements, a current peak value, a charge Q and a specific energy W/R.

2.1.114 *Impulse Withstand Voltage* — The highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified condition.

2.1.115 *Indirect Contact* — Contact of persons or livestock with exposed conductive parts made live by a fault and which may result in electric shock.

2.1.116 *Industrial Plugs and Sockets* — Plugs and socket-outlets, cable couplers and appliance couplers, primarily intended for industrial use, either indoors or outdoors.

NOTE — For the purpose of this NBCS, industrial plugs and sockets conforming to accepted standards [D-2(9)] shall be used for industrial purpose.

2.1.117 *Inflammable Material* — A material capable of being easily ignited.

2.1.118 *Installation* (*Electrical*) — An assembly of associated electrical equipment to fulfil a specific purpose or purposes and having coordinated characteristics.

2.1.119 *Insulated* — Insulated shall mean separated from adjacent conducting material or protected from personal contact by a non-conducting substance or an air space, in either case offering permanently sufficient resistance to the passage of current or to disruptive discharges through or over the surface of the substance or space, to obviate danger or shock or injurious leakage of current.

2.1.120 *Insulation* — Suitable non-conducting material, enclosing, surrounding or supporting a conductor.

2.1.120.1 *Insulation*, *basic* — Insulation applied to live parts to provide basic protection against electric shock and which does not necessarily include insulation used exclusively for functional purposes.

2.1.120.2 *Insulation*, *double* — Insulation comprising both basic and supplementary insulation.

NOTE — Double insulation for small hand held equipment allows them to be used without a safety earth connection, without shock risk of such hand held equipment.

2.1.120.3 *Insulation*, *reinforced* — Single insulation applied to live parts, which provides a degree of protection

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against electric shock equivalent to double insulation under the conditions specified in the relevant standard.

NOTE — The term 'single insulation' does not imply that the insulation is a homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

2.1.120.4 *Insulation*, *supplementary* — Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

2.1.121 *Inverter* — Electric energy converter that changes direct electric current to single-phase or polyphase alternating currents.

2.1.122 *Isolation* — Cutting off an electrical installation, a circuit, or an item of equipment from every source of electrical energy.

2.1.123 *Isolator* — A mechanical switching device which, in the open position, complies with the requirements specified for the isolating function. An isolator is otherwise known as a disconnector.

2.1.124 *Junction Box* — A box forming a part of wiring installation, intended to conceal electrical connections and joints of conductors/cables in order to protect the connection from external influences such as direct contact, dust, water, moisture, UV radiation, etc depending upon the protection requirement of the space or utility.

2.1.125 *Leakage Current* — Electric current in an unwanted conductive path under normal operating conditions.

2.1.126 *LEMP Protection Measures* (*SPM*) — Measures taken to protect internal systems against the effects of LEMP.

2.1.127 *Lightning Electromagnetic Impulse* (*LEMP*) — All electromagnetic effects of lightning current *via* resistive, inductive and capacitive coupling that create surges and radiated electromagnetic fields.

2.1.128 *Lightning Protection* — Complete system for protection of structures against lightning, including their internal systems and contents, as well as persons, in general consisting of an LPS and SPM.

2.1.129 *Lightning Protection Level* (*LPL*) — A number related to a set of lightning current parameters values relevant to the probability that the associated maximum and minimum design values will not be exceeded in naturally occurring lightning.

NOTE — Lightning protection level is used to design protection measures according to the relevant set of lightning current parameters.

2.1.130 *Lightning Protection System* (*LPS*) — Complete system used to reduce physical damage due to lightning flashes to a structure.

2.1.130.1 *Lightning protection system*, *External* — Part of the LPS consisting of an air-termination system, a down-conductor system and an earth-termination system.

2.1.130.2 *Lightning protection system, Internal* — Part of the LPS consisting of lightning equipotential bonding and/or electrical insulation of external LPS.

2.1.131 *Lightning Protection Zone* — Zone where the lightning electromagnetic environment is defined.

2.1.132 *Line Conductor* — A conductor of an a.c. system for the transmission of electrical energy other than a neutral conductor or a PEN conductor. This also means the equivalent conductor of a d.c. system unless otherwise specified in this NBCS.

2.1.133 *Live Part* — A conductor or conductive part intended to be energised in normal use including a neutral conductor but, by convention, not a PEN conductor.

2.1.134 *Live or Alive* — Electrically charged so as to have a potential different from that of earth.

2.1.135 *Locations*, *Industrial* — Locations where tools and machinery requiring electrical wiring are installed for manufacture or repair.

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2.1.136 *Locations*, *Non-Industrial* — Locations other than industrial locations, and shall include residences, offices, shops, showrooms, stores and similar premises requiring electrical wiring for lighting, or similar purposes.

2.1.137 *Low-Voltage Switchgear and Controlgear Assembly* — A combination of one or more low voltage switching devices together with associated control, measuring, signalling, protective, regulating equipment, etc, completely assembled under the responsibility of the manufacturer with all the internal electrical and mechanical interconnections and structural parts. The components of the assembly may be electromechanical or electronic.

2.1.138 *Luminaire* — Equipment which distributes, filters or transforms the light from one or more lamps and which includes any parts necessary for supporting, fixing and protecting the lamps, but not the lamps themselves, and, where necessary, circuit auxiliaries together with the means for connecting them to the supply.

NOTE — For the purposes of this NBCS a batten lamp holder, or a lamp holder suspended by flexible cord, is a luminaire.

2.1.139 *Main Earthing Terminal* — The terminal or bar which is the equipotential bonding conductor of protective conductors and conductors for functional earthing, if any, to the means of earthing.

2.1.140 *Meshed Bonding Network* (*MESH-BN*) — Bonding network in which all associated equipment frames, racks and cabinets and usually the d.c. power return conductor are bonded together as well as at multiple points to the CBN and may have the form of a mesh.

2.1.141 *Mobile Equipment* — Electrical equipment which is moved while in operation or which can be easily moved from one place to another while connected to the supply.

2.1.142 *Monitoring* — Observation of the operation of a system or part of a system to verify correct functioning or detect incorrect functioning by measuring system variables and comparing the measured value with the specified value.

2.1.143 *Multiple Earthed Neutral System* — A system of earthing in which the parts of an installation specified to be earthed are connected to the general mass of earth and, in addition, are connected within the installation to the neutral conductor of the supply system.

2.1.144 *Neutral Conductor* — Includes the conductor of a three-phase four-wire system; the conductor of a single-phase or d.c. installation, which is earthed by the supply undertaking (or otherwise at the source of the supply), and the middle wire or common return conductor of a three-wire d.c. or single-phase a.c. system.

2.1.145 *Origin of an Electrical Installation* — The point at which electrical energy is delivered to an installation.

NOTE — An electrical installation may have more than one origin.

2.1.146 *Overcurrent* — A current exceeding the rated value. For conductors the rated value is the current carrying capacity.

2.1.147 *Overload Current* (*of a Circuit*) — An overcurrent occurring in a circuit in the absence of an electrical fault.

2.1.148 *PEN Conductor* — A conductor combining the functions of both protective conductor and neutral conductor.

2.1.149 *Phase Conductor — See* **2.1.132**.

2.1.150 *Plug* — A device, provided with contact pins, which is intended to be attached to a flexible cable and which can be engaged with a socket-outlet or with a connector.

2.1.151 *Point* (*in Wiring*) — A termination of the fixed wiring intended for the connection of current using equipment.

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2.1.152 *Portable Equipment* — Equipment which is moved while in operation or which can easily be moved from one place to another while connected to the supply.

2.1.153 *Protection*, *Ingress* — The degree of protection against intrusions (body parts such as hands and fingers), dust, accidental contact and water.

NOTE — The classification of degrees of ingress protection provided by enclosures for electrical equipment shall be as per the accepted standard [D-2(10)].

2.1.154 *Protection*, *Mechanical Impact* — The degrees of protection provided by enclosures for electrical equipment against external mechanical impacts.

NOTE — The classification of degrees of protection against mechanical impact provided by enclosures for electrical equipment shall be as per accepted standard [D-2(10)]

2.1.155 *Prospective Fault Current* (I_{pf}) — The value of overcurrent at a given point in a circuit resulting from a fault of negligible impedance between live conductor having a difference of potential under normal operating conditions, or between a live conductor and an exposed-conductive part.

2.1.156 *Protective Conductor* — A conductor used for some measures of protection against electric shock and intended for connecting together any of the following parts:

a) Exposed conductive parts;

b) Extraneous conductive parts;

c) Main earthing terminal; and

d) Earthed point of the source, or an artificial neutral.

2.1.157 *Protective Conductor Current* — Electric current appearing in a protective conductor, such as leakage current or electric current resulting from an insulation fault.

2.1.158 *Protective Earthing* — Earthing of a point or points in a system or in equivalent, for the purpose of safety.

2.1.159 *Protective Separation* — Separation of one electric circuit from another by means of:

a) double insulation;

b) basic insulation and electrically protective screening (shielding); or

c) reinforced insulation.

2.1.160 *Rated Current* — Value of current used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system.

2.1.161 *Rated Impulse Withstand Voltage Level* (U_w) — The level of impulse withstand voltage assigned by the manufacturer to the equipment, or to part of it, characterizing the specified withstand capability of its insulation against overvoltage.

2.1.162 *Residual Current* — The algebraic sum of the instantaneous values of current flowing through all live conductors of a circuit at a point of the electrical installation.

2.1.163 *Residual Current Device* (*RCD*) — Mechanical switching device or association of devices designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions.

2.1.164 *Residual Current Operated Circuit Breaker with Integral Overcurrent Protection* (*RCBO*) — A residual current operated circuit breaker designed to perform the functions of protection against overload and/or short-circuit.

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2.1.165 *Residual Current Operated Circuit-Breaker without Integral Overcurrent Protection* (*RCCB*) — A residual current operated circuit breaker not designed to perform the functions of protection against overload and/or short-circuits.

2.1.166 *Residual Operating Current* — Residual current which causes the residual current device to operate under specified conditions.

2.1.167 *Service* — The conductors and equipment required for delivering energy from the electric supply system to the wiring system of the premises served.

2.1.168 *Shock Current* — A current passing through the body of a person or an animal and having characteristics likely to cause dangerous patho-physiological effects.

2.1.169 *Short-Circuit Current* — An overcurrent resulting from a fault of negligible impedance between live conductors having a difference in potential under normal operating conditions.

2.1.170 *Space Factor* — The ratio (expressed as a percentage) of the sum of the overall cross-sectional areas of cables (including insulation and sheath) to the internal cross-sectional area of the conduit or other cable enclosure in which they are installed. The effective overall cross-sectional area of a non-circular cable is taken as that of a circle of diameter equal to the major axis of the cable.

2.1.171 *Standby Supply System* — A system intended to maintain supply to the installation or part thereof, in case of interruption of the normal supply, for reasons other than safety of persons.

NOTE — Standby supplies are necessary, for example, to avoid interruption of continuous industrial processes or data processing.

2.1.172 *Stationary Equipment* — Either fixed equipment or equipment not provided with a carrying handle and having such a mass that it cannot easily be moved.

2.1.173 *Step Voltage* — The potential difference between two points on the earth's surface, separated by distance of one pace, that will be assumed to be one metre in the direction of maximum potential gradient.

2.1.174 *Socket-Outlet* — A device, provided with female contacts, which is intended to be installed with the fixed wiring and intended to receive a plug.

NOTE — A luminaire track system is not regarded as a socket-outlet system.

2.1.175 *Substation* — A facility containing power/distribution transformers interconnecting two or more networks of different voltages.

2.1.176 *Surge* — A transient created by LEMP (*see* **2.1.127**) that appears as an overvoltage and/or an overcurrent.

2.1.177 *Surge Protective Devices* (*SPD*) — A device intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component. Types of SPDs are as follows:

a) *Type* 1 *SPDs* (*Surge Arresters*) — For protection of high-energy surges, caused by direct lightning strikes or switching surges from utility grid, installed at the service entrance near the main distribution board;

b) *Type* 2 *SPDs* (*Transient Voltage Surge Suppressors or TVSS*) — For protection against secondary surges caused by utility grid switching or internal electrical faults. Installed in electrical distribution panel/sub-distribution board; and

c) *Type* 3 *SPDs* (*Plug-in Surge Protectors*) — For providing localized protection for sensitive electronic equipment like computers and TVs installed near the point of use.

2.1.178 *Sustainability* — Under electrical this refers to the generation of electricity using renewable sources such as solar, wind, hydro, geothermal and bioenergy that are naturally replenished and have minimal negative impact on the environment and to meet present energy needs without compromising the ability of future generations to meet their own, promoting long-term energy security and environmental protection.

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2.1.179 *Switch* — A mechanical switching device capable of making, carrying and breaking current under normal circuit conditions, which may include specified operating overload conditions; and also of carrying for a specified time currents under specified abnormal circuit conditions, such as those of short circuit.

NOTE — A switch may also be capable of making, but not breaking, short-circuit currents.

2.1.180 *Switchboard* — An assembly of switchgear with or without instruments, but the term does not apply to a group of local switches in a final circuit.

NOTE — The term 'switchboard' includes a distribution board.

2.1.181 *Switch Disconnector* — A switch which, in the open position, satisfies the isolating requirements specified for a disconnector.

NOTE — A switch disconnector is otherwise known as an isolating switch.

2.1.182 *Switch Disconnector Fuse* — A composite unit, comprising a switch with the fuse contained in or mounted on the moving member of the switch.

2.1.183 *Switch*, *Linked* — A switch, the contacts of which are so arranged as to make or break all poles simultaneously or in a definite sequence.

2.1.184 *Switchgear* — An assembly of main and auxiliary switching apparatus for operation, regulation, protection or other control of electrical installations.

2.1.185 *Systems*, *Earthing* — An electrical system consisting of a single source or multiple sources running in parallel of electrical energy and an installation. Types of system are identified as follows, depending upon the relationship of the source and of exposed-conductive parts of the installation, to earth:

a) *TN system* — A system having one or more points of the source of energy directly earthed, the exposed conductive-parts of the installation being connected to that point by protective conductors;

b) *TN-C system* — A system in which neutral and protective conductor functions are combined in a single conductor throughout the system;

c) *TN-S system* — A system having separate protective conductor throughout the system;

d) *TN-C-S system* — A system in which neutral and protective conductor functions are combined in a single conductor in part of the system;

e) *TT system* — A system having one point of the source of energy directly earthed, the exposed-conductive-parts of the installation being connected to the earth electrodes electrically independent of the earth electrodes of the source. This is also known as direct earthing system; and

f) *IT system* — A system in which all live parts are isolated from earth or one point connected to earth through an impedance. The exposed-conductive-parts of the electrical installation are earthed independently or collectively or to the earthing of the system.

NOTE — The types of systems depending upon the relationship to the source and of the exposed conductive parts of the insulations to earth are defined in good practice [D-2(11)].

2.1.186 *Thermal Runaway* — An unstable condition arising during constant voltage charging in which the rate of heat generation exceeds the heat dissipation capability, causing a continuous temperature increase and a further rise in charging current, which can lead to battery destruction.

2.1.187 *Touch Voltage* — The potential difference between the ground potential rise (GPR) of a grounded metallic structure and the surface potential at the point where a person could be standing while at the same time having a hand in contact with the grounded metallic structure. Touch voltage measurements can be 'open circuit' (without the equivalent body resistance included in the measurement circuit) or 'closed circuit' (with the equivalent body resistance included in the measurement circuit) voltage by which an installation or part of an installation is designated.

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2.1.188 *Usable Wall Space* — All portions of a wall, except that occupied by a door in its normal open position, or occupied by a fire place opening, but excluding wall spaces which are less than 1 m in extent measured along the wall at the floor line.

2.1.189 *Utility Building* — A standalone separate single or two storied service building structure outside the main building structure meant for only accommodating services' spaces, such as electric substation, diesel generator plant room, a.c. plant room, plumbing plant room, sewerage treatment plant, medical gases, electrical and mechanical maintenance rooms. Such buildings do not have any permanent occupancy other than by personnel on duty.

2.1.190 *Voltage Nominal* (*of an Installation*) — Voltage by which an installation or part of an installation is designated.

2.1.191 *Voltage*, *Extra Low* (*ELV*) — The voltage which does not normally exceed 50 V.

2.1.192 *Voltage*, *Low* (*LV*) — The voltage which normally exceeds 50 V but does not normally exceed 1 000 V in a.c. (alternating current) and 1 500 V in d.c. (direct current).

2.1.193 *Voltage*, *High* (*HV*) — The voltage which normally exceeds 1 000 V a.c. but less than or equal to 33 kV.

2.1.194 *Voltage*, *Extra High* (*EHV*) — The voltage, which normally exceeds 33 kV.

NOTE – The Central Electricity Authority and the Bureau of Indian Standards introduced norms for different voltages during 2017-2018, which have been adopted in good practice [D-2(1)]. These norms may differ from those adopted by various State Governments in India. In buildings across India over the past 75 years, 11 kV and 33 kV have been termed as high tension/high voltage. Electrical control switchgears available for 11 kV/33 kV are known as high voltage switchgears. Accordingly, the voltage norms specified in **2.1.191** to **2.1.194** are adopted for buildings in relation to this NBCS.

2.1.195 *Weatherproof* — Accessories, lighting fittings, current-using appliances and cables are said to be of the weatherproof type with ingress protection according to the application, if they are so constructed that when installed in open situation they will withstand the effects of rain, snow, dust and temperature variations.

2.2 Conventional Symbols

The architectural symbols that are to be used in all drawings, wiring plans, etc, for electrical installations in buildings shall be as given in Annex A.

For other graphical symbols used in electrotechnology, reference may be made to good practice [D-2(1)].

3 GENERAL REQUIREMENTS

3.1 Statutory Requirements

All electrical installations that are in use/being executed shall conform to *The Indian Electricity Act*, 2003 and *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 as amended up to date; and rules if any made there under. This NBCS covers brief information about the statutory requirements.

NOTE — After India's independence, India formulated *The IE Rules*, 1956 based on *The IE Act*, 1910. Thereafter in 2003, Government of India adopted *The Electricity Act*, 2003 and nominated CEA to adopt necessary regulations for electrical supply, safety, generation and distribution. Based on these directions, CEA issued *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations* in 2010 which is superseded with *CEA Regulations*, 2023. Consequent to this, *The IE Act*, 1910 and *IE Rules*, 1956 have been repealed. The norms for voltages under regulations were established by CEA during 2017-18 and based on the same good practice [D-2(12)] was issued in 2018 which has been adopted by good practice [D-2(1)]. Under this, good practice [D-2(1)] has categorized up to 33 kV as medium voltage. However, all State Electricity Boards have fixed voltage norms which are different from CEA/NEC norms. It has been the practice for over 75 years to refer to 11 kV and 33 kV as high tension or high voltage in buildings. Hence, it has been decided to give separate voltage norms for buildings in this NBCS.

3.1.1 *The Electricity Act*, 2003

Section 53 of *The Electricity Act*, 2003, states requirements relating to 'Provisions relating to safety and electrical supply'. Some of the important points included in this NBCS are protecting the public from the dangers arising out of electricity, reducing the risk of personal injury, and damage to property. In accordance, Central Electricity

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Authority under Section 70 of the Act, has been empowered to specify suitable measures. Such measures are updated and notified from time to time in the form of regulations. It may be noted that any failure to comply with any order, or any attempt or abetment that contravenes the rules and regulations framed under the act, may attract appropriate action as per the provisions therein.

NOTE — It may be noted that any failure to comply with any order, or any attempt or abetment that contravenes the rules and regulations framed under the Act, may attract appropriate action as per Section 146 of the Act. Section 149 decides responsibility and Section 150 stipulates that any act of abetment in relation to an offence may invite appropriate consequences. It means that the persons who is not directly involved in construction of electrical installation but indirectly relate to integrated part of electrical installation, such as architectural or civil construction, such as keeping provision of spaces, reserving routes, maintaining clearances, civil construction with required fire rating, etc come under the ambit of these sections. Accepted standard [D-2(13)] provides list of such stakeholders involved in electrical installation.

3.1.2 *Central Electricity Authority*

The Central Electricity Authority, formed under Section 70, is empowered to make regulations as directed under Section 53 and Section 177 of the *Indian Electricity Act*, 2003. In accordance, the following regulations have been notified and are in force. However, reference shall always be made to the latest versions/amendments.

3.1.2.1 *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023

These regulations state various requirements to be observed in the following activities:

a) Design;

b) Construction;

c) Verification and testing;

d) Maintenance;

e) Use;

f) Electric supply; and

g) Various activities integrated with the work of electrical installation.

NOTE — Regulation No. 14 (2) requires electrical installations to follow relevant standards, including this NBCS, the National Electrical Code of India, or the International Standards, where Indian Standards are unavailable. So, though the BIS Standards and Codes of practice are guidelines, their observance is no longer optional but mandatory when read with Section 146 of the Act.

3.1.2.2 *Central Electricity Authority* (*Technical Standards for the Construction of Electrical Plants and Electrical Lines*) *Regulations*, 2022

From the perspective of this NBCS, these regulations apply to transmission and distribution licensees. That is, whenever any electrical line, whether overhead or underground, passes through the plot area of the building/building-complex, observance of these provisions, which are in the scope of the respective owner of the line, may require verification.

NOTE — Important sections of the above regulations are given in Annex B.

3.2 Project Management of Electrical Works

3.2.1 From the perspective of project management, electrical work activities shall broadly be divided into the following stages:

a) Planning;

b) Designing;

c) Construction;

d) Verification and testing; and

e) Maintenance.

NOTE — For existing buildings, (a) to (c) may not apply unless there is a major change or complete renovation.

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3.2.2 *Coordination*

At all work stages and the activities within these stages, different persons/agencies concerning planning, civil construction and building services are involved. Mutual coordination between the stakeholders involved, directly or indirectly, is very important to avoid conflicts.

3.3 Stakeholders and their Responsibility

The role of stakeholders is very important in streamlining electrical work. Accepted standard [D-2(13)] identifies stakeholders as below:

a) Owner/developer;

b) Architect;

c) Civil contractor;

d) Other service providers;

e) Electrical consultant;

f) Electrical contractor;

g) Electrical inspector; and

h) Electricity supplier.

The standard states the responsibility of each stakeholder as per the related statutory compliances, quoting the clauses from related regulations, standards and codes. While assuming responsibility, each stakeholder shall have the required qualifications and experience in the respective field as set out in rules, regulations, bylaws, or any government notification. Where such eligibility criteria are not mandated, it will be the responsibility of the employer to appoint a person with qualifications and experience comparable to similar/correlating tasks. In addition, the provisions given in accepted standard [D-2(13)] may also be complied with.

NOTE — Most of the time, the electrical contractor who executes the work follows the design received from the consultant. But, for an electrical consultant who plays a key role of electrical design, there are no set rules or regulations to determine eligibility or accreditation procedures. Under the circumstances, until such rules come into force, reference to **3.5** from accepted standard [D-2(13)] may be taken, or the qualification and experience of such a person may be considered on par with the Chartered Electrical Safety Engineer as stated in regulation 6 of the *CEA* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 (*see* Annex B).

It should be noted that appointing technical experts like consultants/contractors from respective fields and assigning them responsibility are inherent parts of project management and need to be observed at the planning stage.

3.4 Appointment of Technical Professionals Concerning Electrical Installation

In addition to the requirements stated in accepted standard [D-2(13)], an electrical engineer shall be appointed on site as a registered building professional to streamline, monitor and certify, jointly with the consultant and the electrical contractor, all works relating to electrical services.

3.5 Roles and Responsibilities of the Persons Appointed for Electrical Work

There shall be a written agreement between the developer and the appointee deciding the scope of work and the responsibilities to be undertaken. Such an agreement shall include a declaration concerning the work the appointee will undertake (*see* Annex G).

3.5.1 *Electrical Engineer on Site*

To monitor the coordination of work between all stakeholders, from planning to completion, the electrical engineer on site has an important role. In the team of technical persons often referred to as ‘Registered building professional’ or ‘Licensed technical professional/person’, with different nomenclature in various building rules/regulations/byelaws, the inclusion of an electrical engineer shall be treated as an important requirement for

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controlling and monitoring electrical work activities. His duties and functions shall be:

a) observe all regulatory requirements;

b) maintain coordination between all stakeholders;

c) check electrical requirements from the perspective of location and spaces in the architectural plans;

d) check the electrical design prepared by the design consultant;

e) check specifications related to material and method of construction;

f) participate in preparing the activities chart, considering the smooth and coordinated work progress;

g) monitor and maintain surveillance from planning to completion and handing over, with special attention to the work that will be concealed;

h) check and jointly sign certificates/declarations and checklists as recommended in accepted standard [D-2(13)];

j) check required NOCs/Permissions from respective authorities; and

k) maintain a record of all documents.

3.5.2 *Electrical Consultant*

To perform the desired role as an electrical consultant, he shall have the necessary qualifications and experience. Reference may be taken from the note under **3.3**. Such a person shall have an updated knowledge of all regulatory requirements, standards and codes of practice related to the design, construction, verification, testing, and maintenance of electrical work. He shall be responsible for preparing designs with drawings and specifications that adhere to quality standards. He shall consult the architect regarding necessary points to consider at the planning and construction stage. Table 1 from accepted standard [D-2(13)] provides a list of activities and responsibilities. Some important points in this regard are given below:

a) Identify the existing overhead and underground electrical lines on the proposed development plot and the mandatory requirements, compliances, and NOCs related to clearances;

b) Spaces, locations and routes of the distribution network required for electrical installation;

c) Specific requirements related to RCC structure (static/dynamic load of electrical equipment, requirement of recess within RCC structure to avoid core cutting, required height between finished floor level and soffit of the beam);

d) Specific requirement related to wall thickness to accommodate concealed electric boxes, raised floor (false flooring) to accommodate cable work below;

e) Specific requirements where an aluminium formwork system is used to cast concrete for building elements like walls, floors, columns, beams and slabs. Similar provisions have to be used in case of prefabricated concrete works;

f) Specific requirements related to ventilation and avoiding the accumulation of heat;

g) Assessment of electrical load including future expansion (while assessing load, other service providers shall be consulted for their requirements);

h) Space requirement for the electrical sub-station as per the assessment of the required load. *See* Annex D for suggested space provision as per the substation's capacity;

j) Consult with the electric supply company for load sanction and requirements, if any, such as space/room (*see* Note), etc;

NOTE — The supply company may state the requirement for space within the consumer's premises for substation/equipment. There may also be a case where there is no spare capacity or possibility to augment the existing electrical distribution. The consultant shall be well aware of the conditions of the Supply Code approved by the respective State Electricity Regulatory Commission and, in accordance, give the architect the requirements related to space. All related correspondence shall be documented.

k) Prepare drawings showing the electrical equipment locations and the electric supply distribution network on site plans. Supplier and consumer distribution networks shall be segregated;

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m) Prepare drawings of electrical equipment rooms of substation, switch rooms and consult with the architect and civil engineer about the requirements related to technical specifications of civil construction like fire rating, ventilation facilities, doors/openings, ducts, floor level, clear ceiling height below beam soffit, access facility, dust-free areas, etc. Some of such requirements may be:

1) *Transformer sub-station* — Oil draining arrangement, oil soak pit, curb to prevent the spread of spillage/leaked/drained oil, the required clearances around apparatus considering the type of transformer dry/oil-cooled (O class)/liquid-cooled (K class), adjacent structure whether combustible/non-combustible, provision of baffle wall, etc;

2) *Standby power supply* — Genset, PUC norms, stack height and the building in the vicinity, safe location; and

3) *Standby power supply* — UPS system, location and specific requirements related to battery storage.

n) Drawings showing proposed internal routes and layouts of cables (mains, sub-mains, circuit mains, light, fan power outlet points, distribution boxes, boards with electrical accessories, outlet points and the required clearances between other services, accessibility, etc;

NOTE — Where aluminium formwork technology is used to cast concrete for building elements like walls, floors, columns, beams, and slabs, drawings showing precise locations of points and boxes are most important. Similar provisions have to be provided in case of prefabricated concrete works.

p) Design electrical installation with due consideration for general characteristics that adhere to protection for safety;

q) Consider the related requirements stated under the Energy Conservation Building Code to qualify buildings under a certain class;

r) Prepare specifications for the selection and erection of electrical equipment with due consideration to the factors of external influences;

s) State requirements relating to fire prevention, specific to electrical installation as given under CEA Regulations, for example, placement of extinguishers, PPE, automatic fire suppression system, etc;

t) State design requirements related EV charging stations and the clearances around;

u) State if there are any specific requirements relating to the access;

NOTE — In the event, the electric control panel room is being located in the basement there shall be at least two independent access to the ground floor to avoid any one access getting blocked leading to a serious situation in accessing, operating and controlling the electric supply of critical services in case of fire.

w) Provide technical support and guidance to site engineers/contractors during project execution to ensure material and installation quality, and assist in resolving issues arising during installation, verification, and commissioning;

y) State requirements related to verifying and testing of electrical installations; and

z) Maintain respective checklists updated as required under the accepted standard [D-2(13)].

3.5.3 *Electrical Contractor**

Electrical contractor shall have a licence issued by the appropriate government. It shall be valid at the time of agreement and renewed when necessary. He shall be aware of the obligations mandated as per the rules and regulations. The supervisor(s) appointed by him shall have competency and updated technical knowledge of all regulatory requirements and the codes of practice. The contractor shall be responsible for:

a) Resolving differences regarding the design, drawings, and specifications provided by the consultant, if any, and carrying out work as per the final design. In case of unresolved points, maintain the record;

*NOTE — Where the electrical contractor is also performing the job of electrical consultant, he shall also be responsible for observing requirements stated under **3.5.2**.

b) Before commencing work, get the drawing approvals from the respective authority, where applicable;

c) Employ electrical supervisor and the workmen having permits of the appropriate class or designated as per regulation 3 of the *CEA* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 to carry out work on/for the electrical installation (*see* Annex B);

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d) Weatherproof lockable storage space for materials at site to be arranged by the electrical contractor;

e) Observe workplace safety in respect of:

1) temporary electrical installation on site; and

2) provision of adequate tools and personal protective equipment (PPE) to workmen.

f) Check that requirements related to civil construction concerning electrical installation are satisfied;

g) Observe the activity chart based on a time schedule, which is mutually agreed upon between all concerned service providers and plan the work in coordination;

NOTE — Where an aluminium formwork is used to cast concrete for building elements like walls, floors, columns, beams and slabs, the coordination with civil work needs to be observed precisely. Similar provisions have to be ensured in case of prefabricated concrete works.

h) Carry out electrical installation according to the plans and finalised design by the consultant or, where applicable, the design approved by the authority (electrical inspector);

j) The execution shall be according to the approved methods of construction stated under the National or International codes of practice, where the NBCS has not set any parameters;

k) All work should be executed under the strict supervision of a competent person with the necessary permit issued by the government;

m) A record of hidden work shall be maintained with certificates of required compliance, which shall be jointly signed with the engineer on site before concealing;

n) Maintain electrical installation safety throughout the construction period and the defect liability period;

p) Get the installation verified and tested, preferably through a third party, at the following stages:

1) During construction; and

2) After completion, before certifying for its beneficial use.

q) Help the electrical engineer on site in maintaining updated checklists as required under the accepted standards [D-2(13)]; and

r) Prepare handing-over documents for the respective owner, stating details of the electrical installation as given the checklist.

3.6 Materials

All materials, fittings, appliances, etc used in electrical and allied installations, shall conform to Part B 'Building Materials' of this NBCS and other concerned Indian Standards.

3.7 Coordination with Local Supply Authority

a) In all cases, that is, whether the proposed electrical work is a new installation or extension of an existing one, or a modification involving major changes, the electricity supply undertaking shall be consulted about the feasibility, etc, at an early date. The wattage per square metre and permissible diversity consideration shall be defined as per the type of building (residential, commercial, mercantile, industrial, retail, convention, exhibition, hotel, hospital, institution, flatted factory, group housing, etc). The wattage per square metre (W/m^2) shall be defined considering probable loads as per city grading such that future loading into the development is accounted; and

b) *Addition to an installation* — An addition, temporary or permanent, shall not be made to the authorized load of an existing installation, until it has been definitely ascertained that the current carrying capacity and the condition of existing accessories, conductors, switches, etc, affected, including those of the supply authority are adequate for the increased load. The size of the cable/conductor shall be suitably selected on the basis of the ratings of the protective devices. Ratings of protective devices and their types shall be based on the installed load, switching characteristics and power factor.

Load assessment and application of suitable diversity factor to estimate the full load current shall be made as a first step. This should be done for every circuit, submain and feeder. Power factor, harmonics (*see* 5.3.6.6) and

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efficiency of loads shall also be considered. Diversity factor assumed shall be based on one's own experience or as per table under **4.2.2.2**. Allowance should be made for about 15 percent to 20 percent for extension in near future. The wiring system should be adopted taking into account the environmental requirements and hazards, if any in the building. The sizes of wiring cables are decided not merely to carry the load currents, but also to withstand thermal effects of likely overcurrents, short circuit and ensure acceptance level of voltage drop.

3.8 Power Factor Improvement in Consumers' Installation

3.8.1 Conditions of supply of electricity boards or licensees stipulate the lower-limit of power factor which is generally 0.95 lag or better.

3.8.2 Principal causes of low power factor are many. For guidance to the consumers of electric energy who take supply at low and medium voltages for improvement of power factor, reference shall be made to good practice [D-2(1)] and accepted standard [D-2(14)].

3.9 Execution of Work

Unless otherwise exempted under the appropriate regulation of the *CEA* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023 as amended from time to time, the work of electrical installations shall be carried out by a licensed electrical contractor and under the direct supervision of a person holding a certificate of competency and by persons holding a valid permit issued and recognized by the State government.

3.10 Safety procedures and practices shall be kept in view during execution of the work in accordance with accepted standard [D-2(15)].

3.11 Safety provisions given in Part F 'Fire and Life Safety' of this NBCS should be followed.

4 PLANNING OF ELECTRICAL INSTALLATIONS

4.1 General

The design and planning of an electrical wiring installation involve consideration of all prevailing conditions and is usually influenced by the type and requirements of the consumer. Various utility services including EV charging, ELV systems namely intercom, data cabling (*see* Part D 'Building Services, Section 6 Information and Communication Enabled Installations' of this NBCS), CCTV, fire detection, etc shall also be taken into account with anticipated future requirements. A competent electrical design engineer should be involved at the planning stage with a view to providing for an installation that will prove adequate for its intended purpose and ensure safety, reliability and energy efficiency in its use. The information/requirements given in **3** shall also be kept into consideration while designing and planning an electrical wiring installation. With the proliferation of the use of electrical and electronic devices in buildings as well as the increase in the generation/distribution capacities of power systems, the hazards of energy feed to a fault or defect in the electrical installation has increased. Reliability of power supply and continued supply even under abnormal conditions are becoming very important not only for the operation of services and activities in a building, but also for the life safety of occupants. . Electricity is linked to all services and addition of standby and emergency power supply systems adds to the complexity requiring proper coordinated design. Generally, it is not difficult to provide proper pathways and equipment installation spaces, if an integrated approach is taken from the beginning. The designs should also have to keep the availability of optimum access to installations to ensure proper maintenance. Considering various utility services and to avoid conflict amongst them, it is most important to estimate space requirement for electrical work including LV systems, at planning stage and allocate it in consultation with architect/civil engineer.

4.1.1 The design and planning of an electrical wiring installation shall take into consideration the following:

a) Type of supply, building utility, occupancy, envisaged load and the earthing arrangement available;

b) Provisioning and designing of circuits (circuit length, voltage drop and other aspects), cabling, equipment loads, selection of switchgears, protective devices, fittings and accessories, earthing system, electrical panel rooms, etc complete;

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c) Climatic condition, such as cooling air temperature, moisture or such other conditions which are likely to affect the installation adversely including provisioning of air conditioning systems for present and/or future expansion;

d) Provisions for lightning protection system (LPS) based on risk assessment including using building structure for the purpose;

e) Possible presence of inflammable or explosive dust, vapour or gas;

f) Degree of electrical and mechanical protection necessary;

g) Importance of continuity of service including the possible need for standby supply;

h) Probability of need for modification or future extension;

j) Probable operation and maintenance cost taking into account the electricity supply tariffs available;

k) Relative cost of various alternative methods;

m) Need for radio and telecommunication interference suppression;

n) Ease of maintenance;

p) Safety aspects;

q) Energy conservation;

r) Importance of proper discrimination between protective devices for continuity of supply and limited isolation of only the affected portion;

s) Reliability of power supply and redundancy (of sources and distribution paths) to cater to the needs for emergency power and standby power for continued operation of systems as well as integration of alternate sources of energy such as diesel generation, solar energy, wind power, etc; and

t) Integration of different types of energy sources such as (single or multi) grid power, DG set power backup, battery storage energy system, on grid solar PV power, on grid other renewable energy sources such as wind power, micro wind wheel, etc.

NOTE — The design and planning of electrical installations shall also comply with relevant provisions of good practice [D-2(1)].

4.1.2 All electrical apparatus shall be suitable for the services these are intended for and shall confirm to relevant Indian Standards.

4.1.3 *Coordination*

Proper coordination and collaboration among the architect, civil engineer, electrical engineer and mechanical engineer shall be ensured from the planning stage of the installation. The electrical engineer shall be conversant with the needs of the electrical supply provider for making electrical supply arrangement. Electrical supplier's installation, as per regulations, needs to be segregated from consumer's installation. Wherever required, prior approval of drawings shall be taken from concerned electrical supplier/electrical inspector. Further, depending on load and regulation provisions, consumer will need to submit to the electrical supplier the details regarding the accommodation of substation including transformers, switch-rooms, standby power, solar photovoltaic panels, lighting and ventilation scheme for the approval. Additional information sought by the Authority regarding details of electrical safety apparatus, fire safety apparatus, cable ducts, rising mains and distribution cables, sub-distribution boards, openings in floors and walls, etc for all electrical installations shall be provided. Provisions as-given in accepted standard [D-2(13)] shall also be complied.

4.1.4 While planning wiring and installation of fittings and accessories, information should be exchanged between the owner of the building/architect/consultant/electrical contractor and the local supply authority in respect of tariffs applicable, types of apparatus that may be connected under each tariff, requirement of space for installing meters, switches, etc, and for total load requirements of lights, fans and power. Consideration should also be taken for the anticipated increase in the use of electricity for lighting, general purpose socket-outlet, kitchen equipment, air conditioning, utility sockets, heating, etc.

4.1.5 It is essential that adequate provision should be made for all the services which may be required immediately and during the intended useful life of the building. If not provided, the user may be tempted to carry out extension

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of the installation himself or to rely upon use of multi-plug adaptors and long flexible cords, both of which are not recommended.

4.2 Substation and Switchrooms

4.2.1 *Location and Other Requirements*

The location and other requirements of a substation and switchrooms shall be as given below:

a) Availability of power lines nearby may be kept in view while deciding the location of the substation.

b) The substation should preferably be located near the load centre in a separate utility building adjacent to the generator room, if any. Location of substation in the basement should be avoided, as far as possible. If it is unavoidable, the floor level of substation shall be at least 0.6 m above the lowest point of the basement.

c) In case of more than 2 basements in a building/buildings, the substation/switchroom shall be provided in either first or second basement with floor of the substation not more than 10 m below the adjoining (site) ground level.

d) In places where flooding can occur and water level may go above 1 000 mm, the base substation may be located on one level above the ground level of a utility building or of main building. In such cases, only one feeder should feed ground level and levels below with automatic tripping of the feeder to avoid electrocution in case of live electricity coming in contact with water. Designers shall use their discretion in special cases depending on the degree of reliability, redundancy and the category of load and make suitable provisions.

NOTE — In cases, where the substation is located one level above ground level of utility building or main building, this should be after due evaluation of the other risks posed by such a location combined with the concurrence for such a decision from State Electricity Authority comprising the electrical inspectorate and the distribution licensee and the fire service. There should be direct access from outside the building for substation without entering building to substation.

e) Depending upon the topology of the area (in mountains/stepped terrain), location of substation and DG set should be such that flooding of the equipment area is avoided, with substation and DG set located at least 300 mm above maximum flood level with natural drainage of the substation/DG sets areas.

f) Ideal location for an electrical substation for a group of buildings will be at the electrical load centre. Generally, the load centre will be somewhere between the geometrical centre and the air conditioning plant room, as air conditioning plant room will normally be the largest load, if the building(s) are centrally air conditioned.

g) In order to prevent storm water entering the transformer and switch rooms, the floor level of the substation/switchroom shall be at least 300 mm above the highest flood water level that may be anticipated in the locality. Also, facility shall be provided for automatic removal of water.

h) Substation shall not be located immediately above or below plumbing water tanks or sewage treatment plant (STP) water tanks at the same location.

j) All door openings from substation, electrical rooms, etc, should open outwards. Vertical shutters (like fire rated rolling shutters) may also be acceptable provided they are combined with a single leaf door opening outwards for exit in case of emergency. For large substation room/electrical room having multiple equipment, two or more doors shall be provided which shall be remotely located from each other.

k) If substation is located at a height 1 000 m above MSL, then adequate derating of equipment shall be considered.

m) HV panel room and transformers should have direct access and located as near as possible. In case HV panel and transformers are located at different floors or at a distance of more than 20 m, HV isolator shall be provided nearer to the transformer.

n) In case transformer and main HV/LV panel room are located at different floors, the designer should also take care of the safety requirements caused by lack of direct visibility of the status of the controlling switch. To cater to the safety requirements under different conditions of operation as well as

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maintenance, it may be necessary to provide additional isolator or an emergency push button in the vicinity to trip the supply. Decision has to be taken based on the possible risks.

p) No services or ventilation shafts shall open into substation or switch room unless specific to substation or switch room.

q) *Oil-filled installation* — Substations with oil-filled equipment require great consideration for the fire detection, protection and suppression. Oil-filled transformers require a suitable soak pit with gravity flow to contain the oil in the event of the possibility of oil spillage from the transformer on its failure. Installation of oil-filled equipment shall meet the following requirements:

1) Substations with oil-filled equipment/apparatus (transformers and high voltage panels) shall be either located in open or in a utility building. They shall not be located in any floor other than the ground floor or the first basement of a utility building. They shall not be located below first basement slab of utility building. They shall have direct access from outside the building for operation and maintenance of the equipment.

2) Substations/utility buildings (where the substation or oil-filled transformer is located) shall be separated from the adjoining buildings including the main building by at least 6 m clear distance to allow passage of fire tender between the substation/utility building and adjoining building/main building.

3) There shall be no interconnecting basement with the main building underneath the oil-filled transformers.

4) Provisions for oil drainage to a tank (from which oil can be decanted and reused) at a lower level and separated by adequate fire barrier shall be provided. If there is a floor directly below the ground floor level or first basement where the oil-filled transformers and oil-filled circuit breakers are placed, then they should be separated by a fire barrier of appropriate fire rating as per Part F 'Fire and Life Safety' of this NBCS and proper oil drainage system shall be provided to avoid possible leakage of oil into the lower floor.

5) Substation equipment having more than 2 000 of oil whether located indoors in the utility building or outdoors shall have baffle walls of 4 h fire rating between apparatus (*see also* Part F 'Fire and Life Safety' of this NBCS for fire safety related requirements).

6) Provisions shall be made for suitable oil tank, and where use of more than 9 000 litre of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tank, receptacle or chamber containing the same. Special precautions shall be taken to prevent the spread of any fire resulting from the ignition of the oil from any cause and adequate provision shall be made for extinguishing any fire which may occur.

7) Oil filled transformers/stabilizers/auto transformers (with oil capacity more than 50 litre) or any equivalent electrical equipment shall not be used within the buildings other than utility buildings. Utility building should not be used for any other activity other than services. In case of less than 50 litre equipment placed in building, it should be kept in naturally ventilated areas and fire segregated from occupied areas and other areas prone to accidental fires.

8) Adequate fire barriers or deflectors shall be provided to avoid flames from the substation reaching or affecting the adjacent areas including upper floors (*see also* Part F 'Fire and Life Safety' of this NBCS).

9) Transformer, HV panel, LV isolator shall not be kept one above the other in a way that in case of oil leakage or fire in an equipment the other becomes unapproachable. Stacking of electrical equipment should not be done.

10) For transformers having large oil content (more than 2 000 litre), *Rule* 46(2) of the *Central Electricity Authority* (*MRSES*) *Regulations*, 2023 shall apply (*see* Annex B).

r) *Dry-type installation* — In case electric substation has to be located within the main multi-storeyed building itself for unavoidable reasons, it shall be a dry-type installation with very little combustible material, such as, a dry type transformer with vacuum breakers as HT switchgear and ACB or MCCB as low voltage (LV) switchgear. Such substations shall be located on the ground level or on first basement

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and shall have direct access from the outside of the building for operation and maintenance of the equipment.

Exceptionally, in case of functional buildings, such as air traffic control towers, high rise non – residential buildings, data centres and mixed use buildings of height more than 150 m having high electrical load requirement, dry-type installations/substations may also be provided at upper level without emergency backup systems requiring diesel or any inflammable material storage. This measure will decrease the current flow and short-circuit rating at various points, thereby reducing vulnerability to fire. In such cases, a base substation shall be located at ground floor/first basement to cater to the main HV/LV panel which feeds life and safety services loads as defined in **4.2.1**(h). The base substation shall be located in such a way to provide direct access to the firemen in case of any emergency. The power supply control to any substation or transformer located at upper floors shall be from the base substation so that in case of fire, the electrical supply can be easily disconnected to avoid additional losses.

s) The power supply HV cables voltage shall not be more than 36 kV and a separate dedicated and fire compartmented shaft should be provided for carrying such high voltage cables to upper floors in a building. These shall not be mixed with any other shaft and suitable fire detection and suppression measures shall be provided throughout the length of the cable on each floor.

t) The provision for installation and removal of substation equipment should be provided from inside or outside the building without disturbing the associate major equipment in the substation. In case of inside building path a designated elevator should be installed which is capable of handling weight and size of transformer parts being transported to designated floor for installation, maintenance and removal from the floor.

u) In case of compact substation {*see* accepted standard [D-2(7)]}, design and location of the substation shall ensure safety of the people around the compact substation installed along walkways, playgrounds, etc. Compact substation with incomer voltage of 12 kV or less, when located in open areas shall have fencing or barrier (of any metal based protection, such as wire mesh or chain link, which is duly earthed) against unauthorized contact possibility around it at a minimum distance of 750 mm around it with access for maintenance from all four sides. For incomer voltage more than 12 kV and less than 24 kV the fencing distance from substation may be 1 000 mm minimum. In case of more than 24 kV incomer, the distance may be further increased accordingly. The fencing design should take care of the servicing and maintenance requirements of the substation equipment.

w) In case of two transformers (dry type or transformers with cumulative oil quantity less than 2 000 litre) located next to each other without intermittent wall, the distance between the two shall be minimum 1 500 mm for 11 kV, minimum 2 000 mm for 22 kV and 33 kV. Beyond 33 kV, two transformers shall be separated by baffle wall of 4 h fire rating.

y) Horizontal routing of HT cable through functional/occupied areas should be avoided in view of safety.

z) If dry type transformer is used, it may be located adjacent to high voltage switchgear in the form of unit type substation. In such a case, no separate room or fire barrier for the transformer is required either between transformers or between transformer and the switchgear, thereby decreasing the room space requirement. however, minimum distances as specified in **4.2.1**(w) shall be maintained between the apparatus depending upon voltage ratings. Layout of equipment should take care of the need that any one piece of equipment or sub-assembly can be taken out of service and out of the installed location, while keeping the remaining system in service. Working space for access for maintenance of equipment, while keeping an adjoining section of the substation live to maintain power supply to essential loads, may require additional space between such sections of equipment.

aa) For acoustical enclosures/treatment, reference may be made to Part D 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of this NBCS and CPCB norms requirements.

bb) The minimum recommended spacing between the walls and the transformer periphery from the point of proper ventilation shall be in accordance with good practice [D-2(16)] (*see also* Fig. 1A). The actual spacing may be more than those given in the figure, depending on the circumstances, such as access to the accessories. Other requirements relating to installation of transformers shall also be in accordance with good practice [D-2(16)].

cc) *High voltage switch room/space* — The design should take care of HV equipment space and clearance required around for maintenance and personnel safety as given in **5.3.6.8**. This room may preferably

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have direct access from outside. In case of substation having one transformer and one source of supply, the owner shall provide one high voltage switch. In case of single point supply with two or more transformers, the number of switch required will be one for incoming supply and one for each transformer. Additional space may be provided keeping in mind future extension, if any. In case of dual supply, two switches shall be provided with mechanical/electrical inter locking arrangement. In case the number of incoming and outgoing switches exceed five, bus coupler of suitable capacity should invariably be provided.

dd) *Low voltage switch room/space* — The floor area required in respect of low voltage switchgear room may be determined keeping in view the number and type of incoming, outgoing, bus coupler switches including likely expansion in future, space requirement as given in **5.3.6.8**. The additional requirements of LV switchroom when located separate from the substation shall be as per **4.4**.

ee) Other requirements relating to installation of switchgears and controlgears as given in good practice [D-2(17)] shall also be complied with.

ff) The minimum height of substation room/HV switch room/LV switch room shall be arrived at considering 1 200 mm clearance requirement from top of the equipment to below the soffit of the beam (*see also* Annex C). In case cable entry/exit is from above the equipment (transformer, HV switchgear, LV switchgear), height of substation room/HV switch room/LV switch room shall also take into account requirement of space for turning radius of cable above the equipment height.

gg) All the rooms shall be provided with partitions up to the ceiling and shall have proper ventilation. Special care should be taken to dissipate transformer heat and where necessary fresh air louvers at lower level and exhaust fans at higher level shall be provided at suitable locations.

hh) In case of cable trench in substation/HV switch room/LV switch room, the same shall be adequately drained to ensure no water is stagnated at any time with live cables.

jj) *Power supply to emergency fire and life safety systems* — Emergency power supply of distribution system for critical requirement for functioning of fire and life safety system and equipment, shall be planned for efficient and reliable power and control supply to the following systems and equipment where provided:

1) Fire pumps;
2) Pressurization and smoke venting; including its ancillary systems such as dampers and actuators;
3) Fireman's lifts (including all lifts).
4) Exit signage lighting;
5) Emergency lighting;
6) Fire alarm system;
7) Public address (PA) system (relating to emergency voice evacuation and annunciation);
8) Magnetic door hold open devices; and
9) Lighting in fire command control and security room.

Power supply to these systems and equipment shall be from normal and emergency (standby generator) power sources with change over facility. It shall be ensured that in case the power supply is from HT source/HT generation, transformers should be planned in stand-by capacity to ensure continuity of power to such systems. Wherever transformers are installed at higher levels in buildings and backup DG sets are of higher voltage rating, then dual redundant cables shall be taken to all transformers. The generator shall be capable of taking starting current of all the fire and life safety systems and equipment as above. Where parallel HV/LV supply from a separate substation fed from different grid is provided with appropriate transformer for emergency, the provision of generator may be waived in consultation with the Authority.

NOTE — Standby generator shall not be kept at upper levels, *see* **4.3.1**.

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The power supply to the panel/distribution board of these fire and life safety systems shall be through fire proof enclosures or fire survival cables or through alternate route in the adjoining fire compartment to ensure that supply of power is reliable to these systems and equipment. It is to be ensured that the cabling from the adjoining fire compartment is to be protected within the compartment of vulnerability.

The location of the panel/distribution board feeding the fire and life safety system shall be in fire safe zone ensuring supply of power to these systems. The cable used shall as far as possible be fire survival cable as per the accepted standard [D-2(3)].

Cables for fire alarm and PA system shall be laid in metal conduits or armoured to provide physical segregation from the power cables.

NOTE — Fire control room to be located at or near the main entrance of the building which shall be treated as fire safe zone for all purposes.

kk) Other requirements as given in *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023 shall also be complied with. The fire safety requirements for substation and electrical rooms, including fire rating requirements of substations enclosure, that is, walls, floor, ceiling, openings, doors, etc, as given in Part F 'Fire and Life Safety' of this NBCS should also be complied with.

4.2.2 *Layout of Substation*

4.2.2.1 In allocating the area of substation, it is to be noted that the flow of electric power is from supply company's meter room to HV room, then to transformer and finally to the LV switchgear room. The layout of the room and trenches of required depth shall be in accordance with this flow, so as to optimize the cables, bus-trunking, etc. Visibility of equipment controlled from the operating point of the controlling switchgear is also a desirable feature, though it may not be achievable in case of large substations. Substations shall not be located at or across expansion joints. The rooms/spaces required in a substation shall be provided as below (*see also* Fig. 1):

a) *Supply company's meter room*, generally at the periphery of the premise with direct access from the road/outside;

b) *HV isolation room*, required in case the substation is away from the meter room and is planned adjacent to meter room for disconnecting supply in case of any repair required between meter room and substation;

c) *HV panel room/space*, located adjacent to transformer;

d) *Transformer room/space*, separate space in case of oil-filled transformer and combined space in case of dry type transformer;

e) *LV isolation room/space* required, in case LV panel is away from transformer or on a different level for isolating supply in case of any repair required between transformer and LV switchgear; and

f) *Main LV panel room/space*, required for distribution to different facility/utility in a building.

A typical layout of a substation is shown in Fig. 1B.

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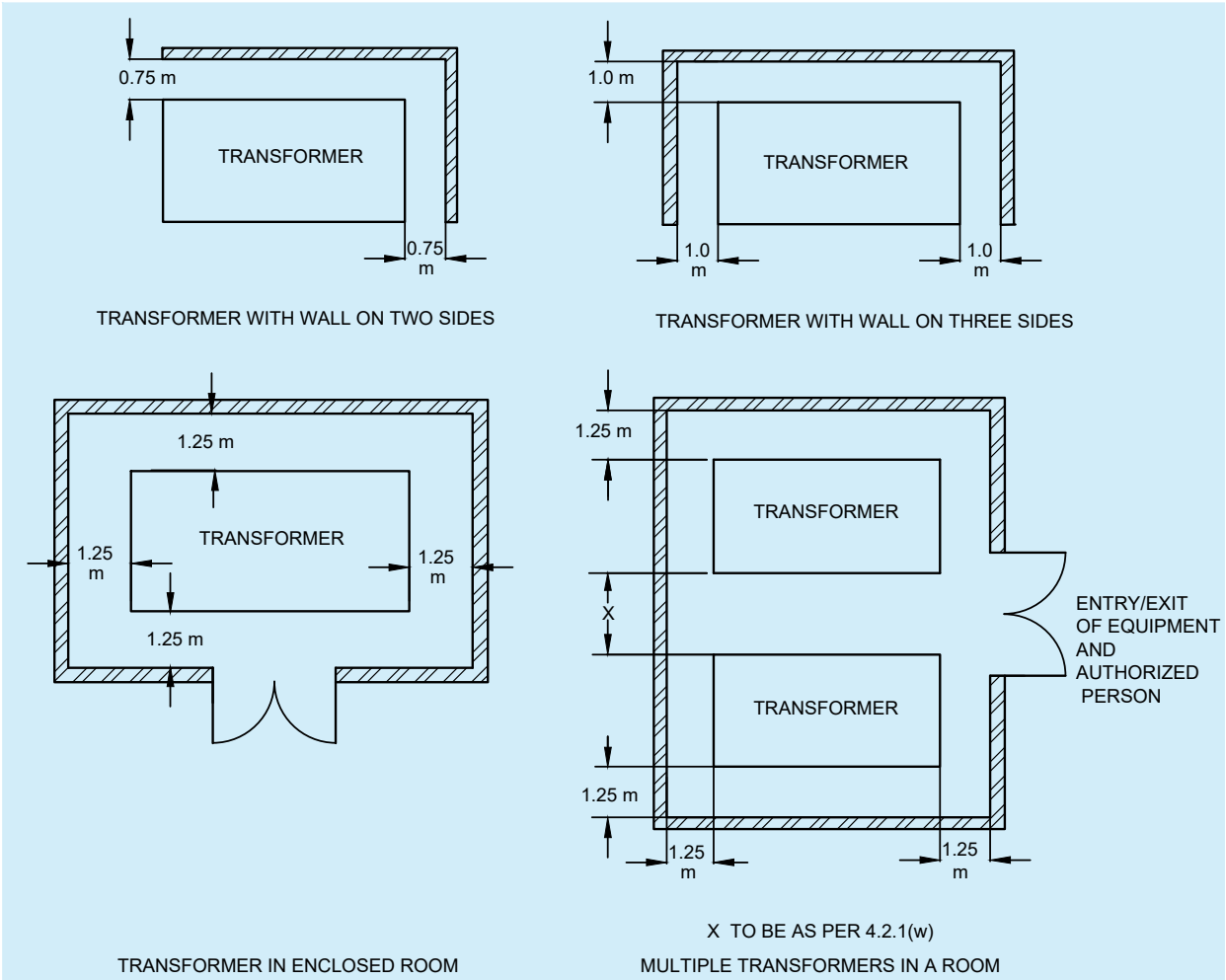

1A MINIMUM RECOMMENDED SPACING BETWEEN THE TRANSFORMER PERIPHERY AND WALLS

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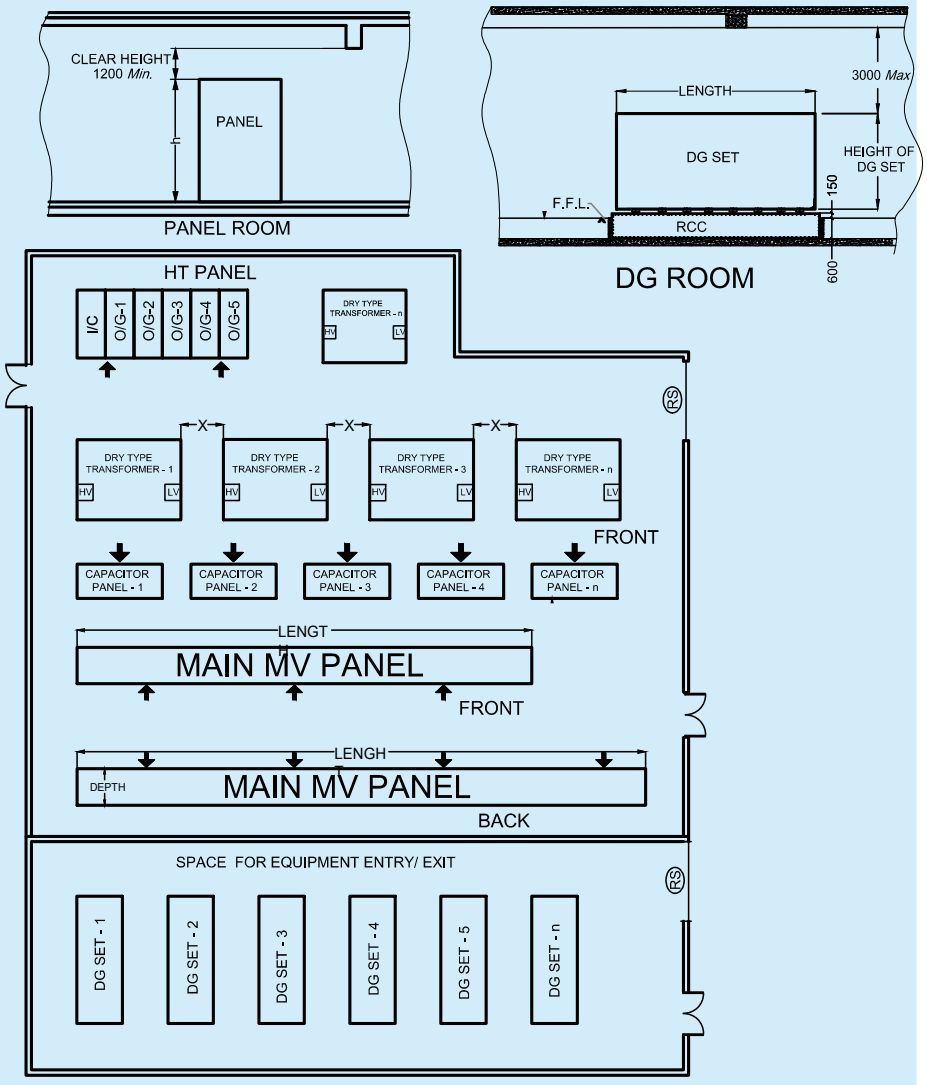

X TO BE AS PER 4.2.1(w)

ALL DIMENSIONS IN MILLIMETRES.

1B TYPICAL LAYOUT OF SUBSTATION WITH DRY TYPE EQUIPMENT IN A SINGLE ROOM

FIG. 1 TYPICAL LAYOUT OF SUBSTATION INCLUDING MINIMUM RECOMMENDED SPACING OF TRANSFORMER PERIPHERY FROM WALLS

4.2.2.2 *Capacity and size of substation*

The capacity of a substation depends upon the area of the building and its type. The capacity of substation may be determined based on the load requirements [*see also* 3.5.2 (g)]. The Annex F of **6.5.1** under Part 1 'General and Common Aspects, Section 9 Wiring Installations' of good practice [D-2(1)] gives broad values for different types of loads. Ratings of some electrical equipment are given in **6.1**. The Table given below

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provides broad values for different types of electrical loads. All these aspects shall be considered while calculating the load assessment for the building.

Sl No.	*Purpose of Final Circuit Fed from Conductors or Switchgear to which Diversity Applies*	*Typical Allowances for Diversity Based on*: *Type of Building*		
		Individual House-Hold Installations, Including Individual Dwelling of a Block	Small Shops, Stores, Offices and Business Premises	Small Hotels, Boarding Houses, etc
(1)	(2)	(3)	(4)	(5)
i)	Lighting and convenience power	66 percent of total current demand	90 percent of total current demand	75 percent of total current demand
ii)	Heating and power [*see also* Sl No. (iii) to (iv)]	100 percent of total current demand up to 10 A + 50 percent of any current demand in excess of 10 A	100 percent of full load of largest appliance + 75 percent of remaining appliances	100 percent of full load of largest appliance + 60 percent of second largest appliance + 40 percent of remaining appliances
iii)	Air-conditioning (non-centralized)	100 percent of connected AC load for spaces up to 100 m^2 and 60 percent to 75 percent of connected AC load beyond 100 m^2	100 percent of connected AC load for spaces up to 200 m^2 and 80 percent to 85 percent of connected AC load beyond 200 m^2	90 percent of full load for public spaces and FOTH/BOTH spaces + 60 percent – 75 percent of rooms
iv)	Air-conditioning (centralized)	70 percent of high side equipment and 80 percentage of low side equipment	80 percent of high side equipment and 90 percentage of low side equipment	80 percent of high side equipment and 90 percentage of low side equipment
v)	Cooking appliances	10 A + 30 percent full load of connected cooking appliances in excess of 10 A + 6 A if socket-outlet incorporated in the unit	100 percent of full load of largest appliance + 80 percent of full load of second largest appliance + 60 percent of full load of remaining appliances	70 percent to 60 percent of full load of kitchen equipment and its corresponding ventilation equipment
vi)	Laundry equipment's	100 percent of full load of largest motor + 50 percent of full load of remaining motors	100 percent of full load of largest motor + 50 percent of full load of remaining motors	100 percent of full load of largest motor + 50 percent of full load of remaining motors
vii)	Motors (other than lift, escalators and travellators motors which are subject to special consideration)	100 percent of full load of largest motor + 50 percent of full load of remaining motors	100 percent of full load of largest motor + 80 percent of full load of second largest motor + 60 percent of full load of remaining motors	100 percent of full load of largest motor + 50 percent of full load of remaining motors

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Table (*Concluded*)

Sl No.	*Purpose of Final Circuit Fed from Conductors or Switchgear to which Diversity Applies*	*Typical Allowances for Diversity Based on*: *Type of Building*		
		Individual House-Hold Installations, Including Individual Dwelling of a Block	Small Shops, Stores, Offices and Business Premises	Small Hotels, Boarding Houses, etc
(1)	(2)	(3)	(4)	(5)
viii)	Lift, escalators and travellators	100 percentage of cumulative loads	100 percentage of cumulative loads	100 percentage of cumulative loads
ix)	Water heater/heat pump (instantaneous type[1)])	100 percent of full load of largest appliance + 100 percent of full load of second largest appliance + 25 percent of full load of remaining appliances	100 percent of full load of largest appliance + 100 percent of full load of second largest appliance + 25 percent of full load of remaining appliances	100 percent of full load of largest appliance + 100 percent of full load of second largest appliance + 25 percent of full load of remaining appliances
x)	Water heater (thermostatically controlled)	No diversity allowable[2)]	–	–
xi)	Floor warming installations	No diversity allowable[2)]	–	–
xii)	Water heaters thermal storage space heating installations	No diversity allowable[2)]	–	–
xiii)	Standard arrangements of final circuits in accordance with good practice [D-2(18)]	100 percent of the current demand of the largest circuit + 40 percent of the current demand of every other circuit	100 percent of the current demand of the largest circuit + 50 percent of the current demand of every other circuit	100 percent of the current demand of the largest circuit + 40 percent of the current demand of every other circuit
xiv)	Socket-outlets other than those included in Sl No. (ix) and stationary equipment other than those listed above	100 percent of the current demand of the largest point + 40 percent of the current demand of every other point	100 percent of the current demand of the largest point + 75 percent of the current demand of every other point	100 percent of the current demand of the largest point + 75 percent of the current demand of every point in main rooms (dining rooms, etc) + 40 percent of the current demand of every other point

NOTE — Diversity may be considered if multiple units of water heater are there in an individual house-hold installation, including individual dwelling of a block.

[1)] For the purpose of the table, an instantaneous water heater is deemed to be a water heater of any loading which heats water only while the tap is turned on and therefore uses electricity intermittently.

[2)] It is important to ensure that the distribution boards are of sufficient rating to take the total load connected to them without the application of any diversity.

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After calculating the electrical load on the above basis, an overall load factor of 50 percent to 90 percent is to be applied to arrive at the minimum capacity of substation. A future load may also be considered for substation sizing [*see* **3.5.2** (g)]. The area required for substation and transformer room for different capacities is given in Annex C for general guidance. For reliability, it is recommended to split the load into more than one transformer and also provide for standby transformer as well as multiple sources, bus-section, etc.

4.3 Emergency Power Backup System (DG Sets/Gas Generators)

4.3.1 *Location*

The emergency power supply (such as generating sets) should not be allowed to be installed above ground floor or below the first basement level of the building in case of multiple basements. However, if necessary DG set can be installed in first floor with dedicated approach and in separate fire compartment. In case of DG set located in basement, facilities for forced ventilation shall be provided such that there is minimum derating of the equipment. The generating set should preferably be housed adjacent to LV switchgear in the substation building to enable transfer of electrical load efficiently and also to avoid transfer of vibration and noise to the main building.

4.3.2 *Room for Emergency Power Backup System*

The capacity of standby generating set shall be chosen on the basis of essential light load, essential air conditioning load, essential life and safety services load [*see* **4.2.1**(jj)], essential equipment load and essential services load, such as minimum one lift out of the bank of lifts and minimum one or all water pumps. In certain cases, more than one generating set is provided based on the type of essential and sensitive loads that are to be operational during power breakdowns. Hence depending on the change over time, the connected switchgears/automatic mains failure (AMF) panels are to be selected. Having chosen the capacity and number of generating sets, required space may be provided for their installation (*see* Annex D for general guidance). There shall be provision of separate direct escape and entry from outside so that in case of fire, electrical supplies can be disconnected to avoid additional losses which may be caused due to electrical supply, present at the time of fire. The height of diesel generating (DG) set rooms shall however be not more than 3 000 mm above the DG set height, unless required due to DG room ventilation requirements. Adequate space shall be provided for storing of fuel. Facilities including space at appropriate positions, relative to the location of the installed equipment has to be kept in the layout design for removal of equipment or sub-assemblies for repair or maintenance. When it is located at a place, other than the ground level with direct equipment access, a hatch or ramp shall be provided.

4.3.3 *Installation and Other Requirements*

Following installation and other requirements shall also be complied with:

a) Day-oil tanks for the DG sets shall be in compliance with *The Petroleum Act*, 1934. It is desirable to have day oil tanks of capacity less than 1 000 litre of diesel/high speed diesel (HSD) with the DG set and not exceeding 1 500 litre of HSD in separate rooms adjacent to DG sets/DG room. Additional quantities required should be kept in underground tanks as per provisions of *The Petroleum Act*, 1934 after taking necessary license;

b) The emergency installation shall comply with the norms laid down by the Central Pollution Control Board (CPCB) and shall also be in compliance with *The Petroleum Act*, 1934 and guidelines of Oil Industry Safety Directorate (OISD). Compartmentation for fire protection with detection and first-aid protection measures is essential;

NOTE — Different type of fire safety requirements exists for the DG set, for the oil storage area and for the switchgear (*see also* Part F 'Fire and Life Safety' of this NBCS).

c) Acoustic enclosure for DG sets/acoustic lining of the DG room and ventilation system for DG room shall be in line with the requirements of CPCB. If DG set is located outdoor, it shall be housed in acoustics enclosure as per the requirements of CPCB norms. For acoustical enclosures/treatment, reference shall also be made to Part D 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of this NBCS;

d) Vertical stacking of DG Sets should not be done to ensure at least one DG set is in operation when the other set is on fire or under maintenance. In case stacking of DG sets is unavoidable on ground, a proper fire barrier of 120 min fire rating between the two DG sets should be ensured. Both DG sets should be

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kept on free standing civil structure with independent access for each generating set and fire barriers in between, such that fire in one does not jump/drip to other. Also, both should be available independently for repair and maintenance. In case of horizontal stacking of DG sets not less than 1.2 m space between the DG sets shall be maintained. Proper ventilation arrangement within the space shall be provided where stacking of DG sets is done;

e) The DG set room should have proper ventilation for engine combustion requirements, heat produced by the body of DG set and the heat removal from radiator or cooling tower, etc to maintain ambient temperature inside the room. The other requirements given in Part F 'Fire and Life Safety' of this NBCS for room for emergency power backup system including DG set room should also be complied with;

f) Other environmental requirements under the provisions of *The Petroleum Act/Rules*, 2002 and norms laid down by CPCB, as amended from time to time, shall be taken into account particularly from the aspect of engine emissions including the height of exhaust pipe and permitted noise levels/controls; and

g) Provisions contained in the *CEA* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023, as amended up to date, good practice [D-2(1)] and relevant Indian Standards shall also be complied with.

4.4 Battery Storage Energy Power Backup System (Li-ion or Similar)

Bulk storage of batteries for power backup supply shall be allowed to be installed in rooms which are properly ventilated to avoid fire accidents (18 air changes per hour). The system shall comply with provisions under relevant IEC standards for storage batteries. There shall be proper space around the container having storage batteries. Necessary gas monitoring system with automatic ventilation arrangement shall be provided for the space. No other material shall be stored in the battery storage area. These batteries should be properly maintained and connected to avoid any sparking/flashing leading to fire. Protection measures shall be taken to avoid thermal runaway, short circuiting, overheating of connecting cables, etc. Container should be air-conditioned/air cooled/liquid cooled and kept as per OEM guidelines. All protection and safety measures as given in the relevant Indian Standards shall be complied. Only a.c. wiring should be taken out of the container for synchronizing with other emergency sources or feeding solar power to premise as individual supply.

4.5 Multiple Energy Sources

When multiple energy sources such as grid, DG set power backup with AMF panel, battery storage energy system, on grid solar PV power, on grid other renewable energy sources such as wind power, micro wind wheel, etc are to be used in the same project simultaneously, synchronization of voltage and frequency of each source is required for energies to be used optimally including setting priorities of source utilization. All protection and safety measures as given in the relevant Indian Standards for each of the energy sources shall also be complied with.

4.6 Location of LV Switch Room Other Than in Substation

In large installations other than where a substation is provided, a separate switch room shall be provided. This shall be located as close to the electrical load centre as possible, on the ground floor or on the first basement level of the building, preferably on the same floor as Transformers. In case LT panel and transformer and DG sets are on different floors then LT isolators shall be proposed adjacent to transformer and DG sets.

Suitable cable trays/busducts shall be laid with minimum number of bends from the points of entry of the main supply cable to the position of the main switchgear. The switch room shall also be placed in such a position that riser shafts may readily be provided therefrom to the upper floors of the building in one straight vertical run. In larger buildings, more than one riser shaft may be required and then horizontal cable trays/bus ducts may also be required for running cables from the switch room to the foot of each rising main. The support system shall be sufficient to take into account the load of the cables to be carried with seismic considerations.

Such cable trays shall either be reserved for specific voltage grades or provided with a means of segregation for low and extra low voltage installations, such as nurses call-bell systems in hospitals, intercom telephone installations, fire detection and alarm system, security systems, data cables and announcement or public address system. Cables/wires for emergency fire and life safety services and their routing should be in accordance with **4.2.1**(jj) and Part F 'Fire and Life Safety' of this NBCS so that these services are maintained even in the event of fire.

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Clear space around panels should be kept for access and maintenance depending on circuit breaker type as required. In case of ACB/MCCB front and back access should be planned with all sides movement clearance with 1 000 mm access on back and sides and 2 000 mm access in front of panel. However, space of less than or up to 200 mm is permitted on the back of the panel where there is no access or sufficient space.

4.7 Location and Requirements of Distribution Panels

All distribution panels including switchgears shall be installed in readily accessible position. The electrical controlgear distribution panels and other apparatus, which are required on each floor may conveniently be mounted adjacent to the rising mains, and adequate space considering clearances required as per **5.3.6.8** shall be provided at each floor for this purpose.

4.8 Substation Safety

The owner and the operator of any substation shall be collectively and severally be responsible for any lapse or neglect leading to an accident or an incidence of an avoidable abnormality and shall take care of the following safety requirements:

a) Enclose the substation or similar equipment where necessary to prevent, so far as is reasonably practicable, danger of electric shock or unauthorized access.

b) All equipment, entry and exit shall be always kept accessible.

c) Substation should be a separate fire compartment and its ventilation should be independent of any other fire compartment.

d) All substation rooms shall have two doors at opposite ends. Distance between all equipment such that exit/entry of equipment is feasible without removing of any equipment, light, cable or bus duct, etc.

e) Any part of the substation which is open to the air shall be enclosed, with a fence (earthed efficiently at both ends) or wall at least 600 mm above the height of tallest equipment; to prevent, so far as is reasonably practicable, danger of electric shock or unauthorized access.

f) Transformers (oil filled) when placed in open shall have fencing/wall at least 600 mm above the height of transformer. If trees are there around the substation, then a temporary cover should be provided to avoid leaves falling on the terminals of HT/LT terminations.

g) It shall be ensured that the following are displayed at all times in the substation:

   1) Sufficient safety signs of such size and placed in such positions as are necessary to give due warning of such danger as is reasonably foreseeable in the circumstances;

   2) A notice which is placed in a conspicuous position and which gives the location or identification of the substation, the name of each owner/operator who owns or operates the substation equipment making up the substation and the telephone number where a suitably qualified person appointed for this purpose by the owner/operator will be in constant attendance; and

   3) Such other signs, which are of such size and placed in such positions, as are necessary to give due warning of danger having regard to the siting of, the nature of, and the measures taken to ensure the physical security of, the substation equipment;

h) All reasonable precautions are taken to minimize the risk of fire associated with the equipment.

j) In addition to provisions mentioned in (c), name and emergency telephone number of the authorized personnel shall also be displayed at the substation and instructions covering schematic diagram; requirements of switchgear interlocking, if any; and permission requirements, if any, for load limitations on (incoming) feeders; be also prominently displayed.

4.9 Overhead Lines, Wires and Cables

All erections/alterations having relation to overhead lines, wires and cables shall comply with *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023 with special reference to regulation number 62 and 63 and the following points. However, in case of any conflict, the regulations shall prevail (*see* Annex B).

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4.9.1 *Height Requirement*

4.9.1.1 While overhead lines may not be relevant within buildings, regulations related to overhead lines are of concern from different angles as follows:

a) Overhead lines may be required in building complexes, though use of underground cables is the preferred alternative; and

b) Overhead lines may be passing through the site of a building. In such a case the safety aspects are important for the construction activity in the vicinity of the overhead line as well as portions of low height buildings that may have to be constructed below the overhead lines. Overhead lines running adjacent to buildings pose hazard from the aspect of certain maintenance activity (such as use of a ladder on external face of a building) causing temporary compromise of the minimum safety clearance.

4.9.1.2 If at any time subsequent to the erection of an overhead line, whether covered with insulating material or not, or underground cable, any person who proposes to erect a new building or structure or to raise any road level or to carry out any other type of work whether permanent or temporary or to make in or upon any building, or structure or road, any permanent or temporary addition or alteration, in proximity to an overhead line or underground cable, such person and the contractor whom he employs to carry out the erection, addition or alteration, shall give intimation in writing of his intention to do so to the supplier or owner and to the Electrical Inspector and shall furnish therewith a scale drawing showing the proposed building, structure, road or any addition or alteration and scaffolding thereof required during the construction. In this connection, Regulation 63 of *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023, shall also be complied with (*see* Annex B).

4.9.1.3 Any person responsible for erecting an overhead line will keep informed the authority(s) responsible for services in that area for telecommunication, gas distribution, water and sewage network; roads and so as to have proper coordination to ensure safety. He shall also publish the testing, energizing programme for the line in the interest of safety.

4.9.1.4 For minimum distance (vertical and horizontal) of electric lines/wires/cables from buildings, Regulations 60, 62, 63, and 67 of *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023, shall be complied with (*see* Annex B).

4.9.1.5 Regulation 66 of *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023, which govern conditions related to the storage of material including storage of construction material at a construction site, or other materials in a building in vicinity of overhead lines and underground cables, shall also be complied with (*see* Annex B).

4.9.2 *Position, Insulation and Protection of Overhead Lines*

4.9.2.1 Any part of an overhead line which is not connected with earth and which is not ordinarily accessible shall be supported on insulators or surrounded by insulation. Any part of an overhead line which is not connected with earth and which is ordinarily accessible shall be:

a) made dead; or

b) so insulated that it is protected, so far it is reasonably practicable, against mechanical damage or interference; or

c) adequately protected to prevent danger.

4.9.2.2 Any person responsible for erecting a building or structure which will cause any part of an overhead line which is not connected with earth to become ordinarily accessible shall give reasonable notice to the licensee or distributor who owns or operates the overhead line of his intention to erect that building or structure.

The expression ‘ordinarily accessible’ means the overhead line might be reachable by hand if any scaffolding, ladder or other construction was erected or placed on/in, against or near to a building or structure.

4.9.2.3 Any bare conductor not connected with earth, which is part of a low voltage overhead line, shall be situated throughout its length directly above a bare conductor which is connected with earth.

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4.9.3 *Precautions against Access and Warnings of Dangers*

4.9.3.1 Every support carrying a high voltage overhead line shall be fitted with anti-climbing devices to prevent any unauthorized person from reaching a position at which any such line will be a source of danger. In this connection, Regulation 76 of *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023, shall also be complied with (*see* Annex B).

4.9.3.2 Every support carrying a high voltage overhead line, and every support carrying a low voltage overhead line incorporating bare phase conductors, shall have attached to it sufficient safety signs and placed in such positions as are necessary to give due warning of such danger as is reasonably foreseeable in the circumstances.

4.9.3.3 Poles supporting overhead lines near the road junctions and turnings shall be protected by a masonry or earth fill structure or metal barricade, to prevent a vehicle from directly hitting the pole, so that the vehicle, if out of control, is restrained from causing total damage to the live conductor system and lead to a hazardous condition on the road or footpath or building.

4.9.4 *Fitting of Insulators to Stay Wires*

Every stay wire which forms part of, or is attached to, any support carrying an overhead line incorporating bare phase conductors (except where the support is a lattice steel structure or other structure entirely of metal and connected to earth) shall be fitted with an insulator, no part of which shall be less than 3 m above ground or above the normal height of any such line attached to that support.

4.10 Maps of Underground Networks

4.10.1 Any person or organization or authority laying cables shall contact the local authority in charge of that area and find out the layout of:

a) water distribution pipe lines in the area;

b) sewage distribution network;

c) telecommunication network;

d) gas pipeline network; and

e) existing power cable network;

and plan the cable network in such a manner that the system is compatible, safe and non-interfering either during its installation or during its operation and maintenance. Plan of the proposed cable installation shall be brought to the notice of the other authorities referred above.

4.10.2 Suitable cable markers and danger sign as will be appropriate for the safety of the workmen of any of the systems shall be installed along with the cable installation. Cable route markers shall be provided at every 20 m and also at turnings and/or crossings.

4.10.3 Notification of testing and energization of the system shall also be suitably publicized for ensuring safety.

4.10.4 Any person or organization or authority associated with the operation and maintenance of services in a complex is required to have a complete integrated diagram or drawings of all services with particular emphasis on the hidden pipes, cables, etc, duly kept up-to-date by frequent interaction with all agencies associated with the maintenance work.

Organization or agency responsible for laying cables shall have and, so far it is reasonably practicable, keep up-to-date, a map or series of maps indicating the position and depth below surface level of all networks or parts thereof which he owns or operates. Where adequate mapping has not been done and the excavation for cable laying reveals lines pertaining to any of the other services, three dimensional location should be marked and recorded. Even where mapping exists, it may be examined if the records have become obsolete due to change such as, in road level. Any map prepared or kept shall be available for inspection by any authority, such as

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municipality, water supply, sewage, service providers and general public, provided they have a reasonable cause for requiring reference to any part of the map.

4.10.5 Any agency working on any one or more service (occupying the underground space for service pipes, cables, etc) should keep the other agencies informed of the work so that an inadvertent action will not cause a disruption of service. Each agency should be responsible for keeping the latest information with the central authority of such records and should be responsible to ensure that the modifications, if any, are duly updated and notified among the other agencies.

5 DISTRIBUTION OF SUPPLY AND CABLING

5.1 General

5.1.1 In the planning and design of an electrical wiring installation, due consideration shall be made of all the prevailing conditions. It is recommended that advice of a competent electrical engineer be sought at the initial stage itself with a view to providing an installation that will prove adequate for its intended purpose, be reliable, safe and efficient.

While planning of routing of cables and bus trunking it shall be ensured to avoid passing of cables and bus trunking from lift lobbies, staircase lobbies and fire exits. Proper ventilations or air-changes shall be provided for heat rejected from bus trunking and cables.

5.1.2 A certain redundancy in the electrical system is necessary and has to be built in from the initial design stage itself. The extent of redundancy will depend on the type of load, its criticality, normal hours of use, quality of power supply in that area, coordination with the standby power supply, capacity to meet the starting current requirements of large motors, etc.

5.1.3 In modern building technology, following high demands are made of the power distribution system and its individual components:

a) long life and good service quality;

b) safe protection in the event of fire;

c) low fire load;

d) flexibility in load location and connection, but critical in design;

e) low space requirement; and

f) minimum effort involved in carrying out retrofits.

5.1.4 The high load density in modern large buildings and high-rise buildings demands compact and safe solution for the supply of power. The use of busbar trunking system is ideal for such applications. Busbar trunking can be installed in vertical riser's shafts or horizontally in passages for transmission and distribution of power. They allow electrical installations to be planned in a simple and neat manner. In the building complexes, additional safety demands with respect to fire barriers and fire load can also be met with the use of busbar trunking. Busbar trunking system also reduces the combustible material near the area with high energy in comparison with other distribution systems such as cables and makes the building safe from the aspect of vulnerability to fire of electrical origin. In addition, unlike cable systems the reliability of a busbar trunking system is very high. These systems also require very little periodic maintenance. Choice of busbar trunking for distribution in buildings can be made on the basis of:

a) reduced fire load (drastically reduced in comparison to the cable system);

NOTE — Insulation materials of cables are required to be fire resistant and an essential performance requirement is that the insulation material may burn or melt and flow when directly exposed to a temperature (or fire) higher than what it is class designated, but should not continue to burn after the flame or the source of heat or fire is extinguished. Even if the above fire resistant property is exhibited by the cable insulation, a large collection of cables will make the cable insulation fail to exhibit this retardant property. While specific guidelines for limiting number of cable and bunching is not available and in such cases the switch over to a busbar trunking system is the proper alternative.

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b) reduced maintenance over its entire lifetime;

c) longer service lifetime in comparison with a cable distribution; and

d) enhanced reliability due to rigid bolted joints and terminations and extremely low possibility of insulation failure.

NOTE — Provisions contained in electric supply and cabling shall also comply with the provisions relating to *the CEA* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023, good practice [D-2(1)] and relevant Indian Standards as amended up to date.

5.2 System of Supply

5.2.1 All electrical apparatus shall be suitable for the voltage and frequency of supply.

5.2.2 In case of connected load of 100 kVA and above, the relative advantage of high voltage three-phase supply may be considered. Though the use of high voltage supply entails the provisions of space and the capital cost of providing suitable transformer substation at the consumer's premises, the following advantages are gained:

a) advantage in tariff;

b) more effective earth fault protection for heavy current circuits;

c) elimination of interference with supplies to other consumers permitting the use of large size motors, welding plant, etc; and

d) better control of voltage regulation and more constant supply voltage.

NOTE — Additional safety precautions required to be observed in HV installations shall also be kept in view.

In many cases there may be no choice available to the consumer, as most of the licensees have formulated their policy of correlating the supply voltage with the connected load or the contract demand. Generally, the supply is at 240 V single phase up to 5 kVA, 415/240 V 3 phase from 5 kVA to 100 kVA, 11 kV (or 22 kV) for loads up to 5 MVA and 33 kV for consumers of connected load or contract demand more than 5 MVA.

In case of load exceeding 10 MVA at 33 kV for building complex, designer may explore option of having a combination of power transformers and distribution transformers to reduce the numbers and long lengths of power cables. 33 kV/11 kV power substation at site level/utility building for stepping down at 11 kV and then having 11 kV/415 Volt distribution substation at basement/ground/first floor/usage floors, near load centres to avoid long lengths of 415 volt cables.

5.2.3 In very large industrial buildings where heavy electric demands occur at scattered locations, the economics of electrical distribution at high voltage from the main substation to other subsidiary transformer substations or to certain items of plant, such as large motors and furnaces, should be considered. The relative economy attainable by use of high voltage distribution and high voltage equipment is a matter for expert judgment and individual assessment in the light of experience by a professionally qualified electrical engineer. *See also* good practice [D-2(1)] and accepted standard [D-2(19)].

5.2.4 In case of complex buildings/mixed use buildings where individual load of usage category (such as commercial, mercantile, residential, hotels, hospitals, storage, industry, etc has cumulative load of 1 000 kVA, then for EV charging requiring more than 100 kVA power should be proposed with independent distribution transformer(s) (200 kVA or more) with separate meter to avoid mixing of different type of loads, harmonics, etc.

5.2.5 As far as possible, EV charging arrangement shall be provided with independent transformer to ensure that harmonics created during EV charging do not interfere with power supply to other system. It shall be ensured that EV charging is not fed from diesel generator sets or gas generators or similar fuel based power generating systems (*see* **10.7** for more details).

5.3 Substation Equipment and Accessories

Substations require an approval from the Electrical Inspectorate. Such approval is mandatory before energizing the substation. Therefore, it is essential to get the approval for the general layout, schematic layout, protection plan, etc, before the start of the work from the Inspectorate. All substation equipment and accessories and

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materials, etc, shall conform to relevant Indian Standards, wherever they exist, otherwise the consumer (or his consultant) shall specify the standards to which the equipment to be supplied and that shall be approved by the authority. Manufacturers of equipment have to furnish certificate of conformity as well as type test certificates for record, in addition to specified test certificates for acceptance tests and installation related tests for earthing, earth continuity, load tests and tests for performance of protective gear. All works under this, shall comply with the requirements of relevant Indian Standards and provisions of **5.1** of Part 1 'General and Common Aspects, Section 9 Wiring Installations' of good practice [D-2(1)].

5.3.1 *Supply Company's High Voltage Meter Board*

In case of single point high voltage metering, energy meters shall be installed in building premise as per **4.2.2.1**, at such a place which is readily accessible/provides unobstructed access to the electric supply company. The supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device fixed in a conspicuous position at not more than 1.7 m above the ground so as to completely isolate the supply to the building in case of emergency.

In case of multipoint metering, main energy meter and reference meters shall be installed in building premises as per **4.2.2.1**, at a place which is readily accessible to the owner/operator of the building and the authority. These should be accompanied with smart metering system (with dual source pre-paid meters).

In this connection, the *Central Electricity Authority* (*Installation and Operation of Meters*) *Regulations*, 2006, as amended from time-to-time shall also be complied with.

5.3.2 *High Voltage Switchgear*

5.3.2.1 The selection of the type of high voltage switchgear for any installation inter alia depends upon the following:

a) voltage of the supply system;

b) prospective short-circuit current at the point of supply;

c) size and layout of electrical installation;

d) availability of space; and

e) nature of installation.

Making and breaking capacity of switchgear shall be commensurate with short-circuit potentialities of the supply system and the supply authority shall be consulted on this subject. The HV switchgear and controlgear shall conform to the relevant Indian Standards. For details see accepted standard [D-2(7)].

5.3.2.2 Guidelines on various types of switchgear equipment and their choice for a particular application shall be in accordance with good practice [D-2(20)].

5.3.2.3 In extensive installations of switchgear (having more than four incoming supply or having more than 12 circuit breakers), banks of switchgears shall be segregated from each other in order to prevent spreading of the risk of damage by fire or explosion arising from switch failure. Where a bus-bar section switch is installed, it shall also be segregated from adjoining banks in the same way {*see* good practice [D-2(21)]}.

5.3.2.4 It should be possible to isolate any section from the rest of the switchboards such that work might be undertaken on this section without the necessity of making the switchboard dead. Isolating switches used for the interconnection of sections or for the purpose of isolating circuit-breakers of other apparatus, shall also be segregated within its compartment so that no live part is accessible when work in a neighbouring section is in progress.

5.3.2.5 In the case of double or ring main supply, switchgears with interlocking arrangement shall be provided to prevent simultaneous switching of two different supply sources. Electrical and/or mechanical interlocks may preferably be provided.

5.3.2.6 The selection and erection shall also comply with the provisions of accepted standard [D-2(22)].

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5.3.3 *HV Cables*

5.3.3.1 The sizing of the cable shall depend upon the method of laying cable, current to be carried, permissible maximum temperature it shall withstand, voltage drop over the length of the cable, the prospective short-circuit current to which the cable may be subjected, the characteristics of the overload protection gear installed, load cycle, thermal resistivity of the soil and the operating voltage {*see also* good practice [D-2(23)]}.

5.3.3.2 All HV cables shall be installed in accordance with good practice [D-2(23)]. The HV cables shall either be laid on the cable rack/built-up concrete trenches/tunnel/basement or directly buried in the ground depending upon the specific requirement. When HV cable is hanging/running below the basement ceiling slab, the cable shall be laid in a fire rated enclosure/cable tray. The advice of the cable manufacturer with regard to installation, jointing and sealing should also be followed.

5.3.4 *High Voltage Busbar Trunking/Ducting*

HV busbar system is used for transporting power between HV generators, transformers and the infeed main switchgear of the main HV switchgear.

Generally, three types of bus ducts, namely non-segregated, segregated and isolated phase bus ducts are used. The non-segregated bus ducts consist of three phase busbars running in a common enclosure made of steel or aluminium. The enclosure shall provide safety for the operational personnel and shall reduce chances of faults. HV interconnecting busbar trunking for a.c. voltage above 1 kV up to and including 36 kV shall conform to accepted standard [D-2(24)]. The enclosures shall be effectively grounded.

Segregated phase bus ducts are similar to non-segregated phase duct except that metal or isolation barriers are provided between phase conductors to reduce chances of phase to phase faults. However, it is preferable to use metal barriers.

In the case of isolated bus ducts, each phase conductor shall be housed in a separate non-magnetic enclosure. The bus duct shall be made of sections which are assembled together at site to make complete assembly. The enclosure shall be of either round or square shape and welded construction. The enclosures of all phases in general should be supported on a common steel structure.

Seismic supports shall be provided for busbar trunking having continuous straight lengths of more than 24 m at a single stretch in horizontal formation and 12 m in vertical formation in accordance with relevant standards.

The bus duct system shall be coordinated with connecting switchgear so as to provide adequate protection.

When busbar trunking is crossing different fire compartments, they shall have fire barriers of same rating as that of the compartment (*see also* Part F ‘Fire and Life Safety’ of this NBCS).

5.3.5 *Transformers*

5.3.5.1 General design objective while selecting the transformer(s) for a substation should be to provide at least two or more transformers, so that a certain amount of redundancy is built in, even if a standby system is provided. With growing emphasis on energy conservation, the system design should be made for both extremes of loading. During the periods of lowest load in the system, it would be desirable to operate only one transformer and subsequently switching on the additional transformers as the load increases during the day. Total transformer capacity is generally selected on the basis of present load, possible future load, operation and maintenance cost and other system conditions. The selection of the maximum size (capacity) of the transformer is guided by the short-circuit making and breaking capacity of the switchgear used in the high voltage distribution system. Maximum size limitation is important from the aspect of feed to a downstream fault. The transformers shall conform to accepted standards [D-2(25)].

5.3.5.2 For reasons of reliability and redundancy it is normal practice to provide at least two transformers (especially where electrical load is beyond 1 500 kVA) for functional buildings, hospitals, hotels, institutes, etc. Providing distribution transformers beyond 1 600 kVA/2 000 kVA is not recommended. Interlinking by tie lines is an alternative to enhance reliability/redundancy in areas where there are a number of substations in close

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vicinity, such as a campus with three or four multi-storeyed blocks, each with a substation. Ring main type of distribution is preferred for complexes having a number of substations.

5.3.6 *Low Voltage Switchgear, Controlgear and their Assemblies*

5.3.6.1 The selection of the type of low voltage switchgear for any installation inter alia depends upon the following:

a) voltage of the distribution system;

b) prospective circuit current at the point at which the switchgear is proposed;

c) prospective short-circuit current at which the switchgear is proposed;

d) availability of space; and

e) nature of installation.

The switchgear, controlgear and their assemblies so selected, shall comply with the accepted standards [D-2(26)].

5.3.6.2 Switchgear (and its protective device) shall have breaking capacity not less than the anticipated fault level in the system at that point. System fault level at a point in distribution systems is predominantly dependent on the transformer size and its reactance. Parallel operation of transformers increases the fault level.

5.3.6.3 Where two or more transformers are to be installed in a substation to supply a low voltage distribution system, the distribution system shall be divided into separate sections each of which shall be normally fed from one transformer only unless the low voltage switchgear has the requisite short-circuit capacity. Provision may, however, be made to interconnect separate sections, through a bus coupler in the event of failure or disconnection of one transformer. *See* **4.2** for details of location and requirements of substation.

5.3.6.4 Isolation and controlling circuit breaker shall be interlocked so that the isolator cannot be operated unless the corresponding breaker is in open condition. The choice between alternative types of equipment may be influenced by the following considerations:

a) In certain installations supplied with electric power from remote transformer substations, it may be necessary to protect main circuits with circuit-breakers operated by earth fault, in order to ensure effective earth fault protection;

b) Where large electric motors, furnaces or other heavy electrical equipment is installed, the main circuits shall be protected from short-circuits by switch disconnector fuse or circuit breakers. For motor protection, the combination of contactor overload device and fuse or circuit breakers shall have total co-ordination at least for motor ratings up to 10 kW and for ratings above 10 kW, it shall be Type 2 co-ordination in accordance with relevant part of accepted standards [D-2(26)]. Wherever necessary, back up protection and earth fault protection shall be provided to the main circuit; and

c) Where means of isolating main circuits is separately required, switch disconnector fuse or switch disconnector may form part of main switchboards.

5.3.6.5 It shall be mandatory to provide power factor improvement at the substation bus with suitable capacity of inductor-capacitor combination and relative switchgear in consultation with the respective manufacturers depending upon the nature of electrical load anticipated on the system. Necessary switchgear/feeder circuit breaker shall be provided for controlling of inductor-capacitor bank.

Power factor of individual motor may be improved by connecting individual capacitor banks in parallel. For higher range of motors, which are running continuously without much variation in load, individual power factor correction at load end is advisable.

NOTE — Care should be taken in deciding the kVAr rating of the capacitor in relation to the magnetizing kVA of the motor. Over rating of the capacitor may cause injury to the motor and capacitor bank. The motor still rotating after disconnection from the supply, may act as generator by self-excitation and produce a voltage higher than supply voltage. If the motor is again switched on before the speed has fallen to about 80 percent of the normal running speed, the high voltage will be superimposed on the supply circuits and will damage both the motor and the capacitor.

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As a general rule, the kVAr rating of the capacitor should not exceed the no-load magnetizing kVA of the motor.

Generally, it will be necessary to provide an automatic control for switching on the capacitors matching the load power factor and the bus voltage. Such a scheme will be necessary as capacitors permanently switched in the circuit may cause overvoltage at times of light load. Capacitor panel shall be provided with adequate ventilation facility.

With the wide spread use of thyristor and rectifier based loads, there is a necessity of providing a full size neutral; but this requirement is generally limited to the 3-phase 4-wire distribution generally in the 415 V.

5.3.6.6 Harmonics on the supply systems are becoming a greater problem due to the increasing use of electronic equipment, computer, fluorescent lamps, LEDs and CFLs (both types have control/driver circuits operating in switch mode), mercury vapour and sodium vapour lighting, TV, microwave ovens, latest air conditioners, refrigerators, controlled rectifier and inverters for variable speed drives, power electronics and other non-linear loads. Harmonics may lead to almost as much current in the neutral as in the phases. This current is almost third, fifth, seventh and ninth harmonic. In such cases, phase rectification devices may be considered at the planning stage itself for the limits of harmonic voltage distortion. Use of active filters in combination/independent use with capacitor banks should be proposed with either 3-phase 3-wire or 3-phase 4 wire depending upon the equipment for which electricity is utilized. The active filters along with capacitor panel should be proposed to be located in controlled environment.

5.3.6.7 Sufficient clearances as below shall be provided for isolating the switchboard to allow access for servicing, testing and maintenance (*see* Fig. 2):

a) A clear space of not less than 1 m in width shall be provided in front of the switchboard;

NOTE — In case the board has a shutter in the front for aesthetic reasons, the opening of the shutter shall satisfy the requirement of working/safety space of 1 m in front of the switchgear.

b) If access behind the switchboard is provided then it shall be either less than 200 mm or more than 750 mm in width, measured from the farthest protruding part of any attachment or conductor;

c) If the space behind the switchboard exceeds 750 mm in width, there shall be a passageway from either end of the switchboard, clear to a height of 1.8 m; and

d) If two switchboards are facing each other, a minimum distance of 2.0 m shall be maintained between them.

The connections between the switchgear mounting and the outgoing cable up to the wall shall be enclosed in a protection pipe.

There shall be a clear distance of not less than 250 mm between the board and the insulation cover, the distance being increased for larger boards in order that on closing of the cover, the insulation of the cables is not subjected to damage and no excessive twisting or bending in any case. The cable alley in the metal board should enable within prescribed limit, twisting or bending of cable such that insulation of the cables is not subjected to damage.

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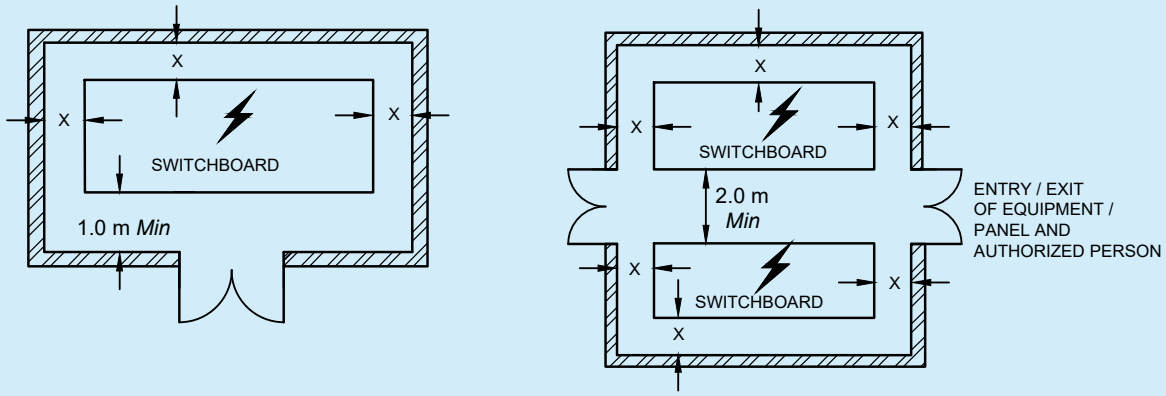

2A ONE SWITCHBOARD/PANEL

2B TWO SWITCHBOARDS/PANELS FACING EACH OTHER

X = LESS THAN 200 mm (IF SWITCHBOARD/PANEL IS NOT ACCESSIBLE FROM BEHIND)
= MORE THAN 750 mm (IF SWITCHBOARD/PANEL IS ACCESSIBLE FROM BEHIND)

NOTE — X TO BE MEASURED FROM THE FARTHEST PROTRUDING PART OF ANY ATTACHMENT OR CONDUCTOR.

FIG. 2 CLEARANCES AROUND SWITCHBOARD IN ENCLOSED ROOM

In this connection, for installation of voltages exceeding 250 V single phase, Regulation 37 of *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 shall also be complied with (*see* Annex B).

5.3.6.8 Sufficient additional space shall be allowed in substations and switch rooms to allow operation and maintenance. Sufficient additional space shall be allowed for temporary location and installation of standard servicing and testing equipment. Space should also be provided to allow for anticipated future extensions.

5.3.6.9 Panels in a room or cubicle, access to which is controlled by lock and key, shall be accessible to authorized persons only.

5.3.6.10 Except main LV panel, it will be preferable to locate the sub-panels/distribution boards/sub-meter boards near load centre. Further, it should be ensured that these panels are easily approachable. The panels should have clear access from common areas excluding staircase.

Where the switchboard is erected in a room of a building isolated from the source of supply or at a distance from it, adequate means of control and isolation shall be provided both near the boards and at the origin of supply. Sufficient clearances as per **5.3.6.8** shall be provided.

5.3.6.11 All switchboards shall be of metal clad totally enclosed type or any insulated enclosed pattern.

5.3.6.12 The selection and erection shall also comply with the provisions of accepted standard [D-2(22)].

5.3.7 *Medium/Low Voltage Cables*

5.3.7.1 The sizing of the cable shall depend upon the current to be carried, method of laying cable, permissible maximum temperature it shall withstand, voltage drop over the length of the cable, the prospective short-circuit current to which the cable may be subjected, the characteristics of the overload protection gear installed, load cycle, thermal resistivity of the soil and the operating voltage {*see also* good practice [D-2(18)]}.

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It is desirable to use flame retardant/flame retardant low smoke and halogen free cables and wires in electrical distribution systems.

It is recommended to use four core cable in place of three and half core in respect of sizes below 50 mm^2 to minimize heating of neutral core due to harmonic content in the supply system and to also avoid overload failures. As far as possible, balancing of single phase system shall be done to ensure minimum unbalanced current in neutral of three phase system. Only four core cables shall be used for internal electrical installation. Also, all cable sizes up to 25 mm^2 shall be of copper conductor to prevent overheating and fire incidence in internal electrical installations and capacity/size considerations. All cables shall be installed in accordance with good practice [D-2(18)]. The advice of the cable manufacturer with regard to installation, jointing and sealing should also be followed.

5.3.7.2 *Colour identification of cores of non-flexible cables* {*see also* accepted standard [D-2(27)]}

The colour of cores of non-flexible cables shall be in accordance with the following:

Sl No.	*Function*	*Colour Identification of Core of Rubber of PVC Insulated Non-flexible Cable, or of Sleeve or Disc to be Applied to Conductor or Cable Code*
(1)	(2)	(3)
i)	Protective or earthing	Green and yellow (*see* Note 1)
ii)	Phase of a.c. single-phase circuit	Red [or yellow or blue (*see* Note 2)]
iii)	Neutral of a.c. single or three-phase circuit	Black
iv)	Phase R of 3 phase a.c. circuit	Red
v)	Phase Y of 3 phase a.c. circuit	Yellow
vi)	Phase B of 3 phase a.c. circuit	Blue
vii)	Positive of d.c. 2 wire circuit	Red
viii)	Negative of d.c. 2 wire circuit	Black
ix)	Outer (positive or negative) of d.c. 2 wire circuit derived from 3 wire system	Red
x)	Positive of 3 wire system (positive of 3 wire d.c. circuit)	Red
xi)	Middle wire of 3 wire d.c. circuit	Black
xii)	Negative of 3 wire d.c. circuit	Blue
xiii)	Functional earth-telecommunication	Cream/grey

NOTES

1 Bare conductors are also used for earthing and earth continuity conductors. But it is preferable to use insulated conductors with green coloured insulation with yellow stripes.

2 As alternative to the use of red, if desired in large installations, up to the final distribution board.

3 For armoured PVC-insulated cables and paper-insulated cables, *see* relevant Indian Standard.

5.3.8 *LV Busbar Trunking/Rising Mains*

5.3.8.1 Where heavy loads and/or multiple distribution feeders are required to be supplied, busbar/rising main systems are preferred. The busbars are available for continuous run from point to point or with tap offs at standard intervals and have to be chosen as per specific requirement. Seismic supports shall be provided for busbar trunking having continuous straight lengths of more than 24 m at a single stretch in horizontal formation and 12 m in

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vertical formation in accordance with relevant standards. There are following two types of LV bus duct system for power distribution:

a) air insulated (conventional) type; and

b) compact and sandwich type.

5.3.8.1.1 *Air insulated* (*conventional*) *type bus duct*

These are used for large power handling between transformer and switchgear or between switchgear and large power loads such as compressor drive motor, etc. This type is generally used in plant rooms, riser shafts, substations, etc. These are generally air insulated with intermediate ceramic support insulators enclosed in a metallic enclosure, which should be earthed. They have the least amount of combustible material. However, when these are crossing different fire compartments, they shall have fire barriers of same rating as that of the compartment (*see also* Part F 'Fire and Life Safety' of this NBCS).

Air insulated (conventional) type bus ducts with non-metallic enclosures are also available. However, such bus ducts shall be used only if essential and with appropriate additional care.

5.3.8.1.2 *Compact and sandwich type bus duct*

Compact and sandwich type bus ducts are used within areas of the building which have space restrictions, functional reasons and for aesthetic considerations. The busbars shall be of copper considering the safety and longevity aspects. They may be used in false ceiling spaces or even in corridors and shafts for distribution without any false ceiling as they provide an aesthetically acceptable finish to merge with other building elements such as beams, ducts or pipes in functional buildings.

The insulation material in such ducts are generally glass fibre tape or epoxy encapsulation in combination with ceramic supports/spacers. These bus ducts should be duly enclosed by a metallic enclosure, which should be earthed.

5.3.8.1.3 The selection and erection shall also comply with the provisions of accepted standard [D-2(28)].

5.3.8.2 The bus duct system shall be coordinated with connecting switchgear so as to provide adequate protection.

5.3.8.3 When busbar trunking is crossing different fire compartments, they shall have fire barriers of same rating as that of the compartment (*see also* Part F 'Fire and Life Safety' of this NBCS).

5.3.8.4 The low voltage busbar trunking shall conform to accepted standard [D-2(28)].

5.4 Reception and Distribution of Main Supply (LV Connections)

5.4.1 *Control at Point of Commencement of Supply*

5.4.1.1 The supplier shall provide a suitable metering switchboard in which each meter units shall have its individual compartment housing meter, wiring, circuit breaker, etc within a consumer's premises, in an accessible position and such metering switchboard shall be contained within adequately enclosed fireproof receptacle. Where more than one consumer is supplied through a common service line, such consumer shall be provided with an independent metering unit in a switchboard housed in common area with an incoming breaker. Such meter switchboards should be housed in an enclosed and lockable space. Cables/wires from such switchboards connecting to individual consumers should terminate directly to consumer's distribution board without any interim termination or change of conductor. Such switchboards maybe located at ground floor or first basement, if building height is not exceeding 15 m. All metering panel/connection arrangements will have interconnection between circuit breakers, fuses, individual meters, etc should be using solid busbar instead of cables (where length of cables is less than 10 m).

However, for buildings above height of 15 m [Regulation 38 of the *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023] shall be having meters on individual floors. In case of

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commercial buildings/shopping malls/multi-use spaces where, combining of units maybe envisaged, meter switchboards should be placed on the floor where consumer unit is located (*see* Annex B).

In case of high rise buildings, the supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device with cut-out or breaker to operate on all phases except neutral in the 3 phase, 4 wire circuit and fixed in a conspicuous position at not more than 1.7 m above the ground so as to completely isolate the supply to the building in case of emergency. In this connection, Regulation 38 of *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023 shall also be complied with (*see* Annex B).

The supplier in accordance with Regulation 18 of *Central Electricity Authority* (*Measures relating to Safety and Electric Supply*) *Regulations*, 2023 shall provide and maintain on the consumer's premises for the consumer's use, a suitable earth terminal in an accessible position or near the point of commencement of supply as per relevant standards (*see* Annex B).

No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductor shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two wire-system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto. This requirement shall however not apply in case of:

a) a link for testing purposes; or

b) a switch for use in controlling a generator or transformer.

In this connection, Regulation 17 (ii) of *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 shall also be complied with (*see* Annex B).

The neutral shall also be distinctly marked.

5.4.1.2 The main switch shall be easily accessible and situated as near as practicable to the termination of service line.

5.4.1.3 Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, an indication of a permanent nature shall be provided for identification in accordance with Regulation 17 (i) of *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 (*see* Annex B).

5.4.1.4 *Energy meters*

5.4.1.4.1 Energy meters conforming to accepted standards [D-2(29)] shall be installed in all buildings at such a place which is readily accessible to the owner/operator/occupant of the building and the Authority. Meters should not be located at an elevated area or a depressed area that does not have access by means of a stairway of normal rise. The height of meter display shall be between 750 mm and 1 800 mm. In case the meter is provided with a secondary display unit, this requirement applies to the secondary display unit only. A minimum clearance of 50 mm should be maintained around the meter itself for better inspection. This includes the space between two meters, between meter and the mounting box and between two mounting boxes as the case may be. The energy meters should either be provided with a protecting covering, enclosing it completely except the glass window through which the readings are noted or should be mounted inside a completely enclosed panel provided with hinged arrangement for locking. Additionally, for outdoor installations, the meters and associated accessories shall be protected by appropriate enclosure of level of protection IP 55 and ensuring compliance with above conditions.

In large multi-storeyed buildings, installation of a large number of energy meters at the ground floor (or first basement) switch-room for the convenience of the meter-reader poses high fire hazard. More than 24 energy meters on one switchboard is undesirable. In such cases, where number of energy meters to be installed for feeding exceeds 24, energy meters shall be installed at each floor and therefore, the rising main (bus trunking) with tapping point at individual floor shall be provided for meters.

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The energy meters shall be protected by suitable circuit breaker. The provisions of **5.3.6.7** shall apply in case of energy meters installed in boards.

5.4.1.4.2 Main sources of energy, as given below shall be metered, as required at entry into the premises/ control panel:

a) utility grid points (high voltage/low voltage);

b) captive generator sets; and

c) on-site renewable energy system (if installed/operational) including net metering for grid connected system.

5.4.1.4.3 Testing, evaluation, installation and maintenance of energy meters shall be in accordance with the good practice [D-2(30)].

5.4.1.4.4 *Centralized metering system*

Smart metering and energy monitoring in a centralized metering system are used to monitor, measure and control the demand of electrical loads in a building. These systems are designed specifically for the control and monitoring of those facilities in a building which have significant electrical consumption, such as heating, ventilation, air conditioning, lifts, pumps and lighting installations at multiple locations in a campus. The scope may span from a single building to a group of buildings, such as residential apartments under common ownership, large multi-storeyed buildings, malls, university campuses, office buildings, retail store networks, factories, or any building with multi-tenanted occupancy. These systems provide metering, submetering and monitoring functions to allow facility and building managers to gather data and insight that allows them to make more informed decisions about demand management and demand control across their sites.

For such buildings with centralized metering, several main meters and sub-meters with following requirements should be provided:

a) Main meters should be digital energy meters with high accuracy, high sampling rates and power quality parameters, that is, harmonics, etc, for meters installed at incomer level;

b) Separate sub-meters should be provided for all energy end uses and functional areas that individually account for reasonable energy consumption in the building. These may include, but are not limited to, sub-meters for HVAC system; common area lighting, raw power, UPS, other common utility; lifts and escalators, pumps, external and internal lighting, individual units/flats/shops/offices; etc;

c) The sub-meters should be able to communicate data for monitoring. At a minimum, the sub-metering infrastructure should facilitate the aggregation of total energy use. For individual residential or commercial meters, if required it shall be controlled by the local electrical authority to take data for grid metering and later data be shared for emergency metering; and

d) Adequate smart metering and energy monitoring infrastructure should be installed in order to help monitor operational energy use and costs and to enable continuous energy performance improvement.

5.4.1.4.5 The *Central Electricity Authority* (*Installation and Operation of Meters*) *Regulations*, 2006, as amended from time-to-time shall also be complied with.

5.4.2 *Main Switches and Switchboard*

5.4.2.1 All main switches shall be either of metal-clad enclosed pattern or of any insulated enclosed pattern which shall be fixed at close proximity to the point of entry of supply. Every switch shall have suitable ingress protection level rating (IP), so that its operation is satisfactory and safe in the environment of the installation. All works under **5.4** shall comply with the provisions of relevant Indian Standards and good practice [D-2(1)].

NOTE — Woodwork shall not be used for the construction or mounting of switches and switch boards installed in a building.

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5.4.2.2 *Location*

The main switchboard shall comply with the following requirements relating to its location:

a) The location of the main board should be such that it is easily accessible to fireman and other personnel to quickly disconnect the supply in case of emergencies. If the room is locked for security reasons, means of emergency access, by schemes such as break glass cupboard, shall be incorporated;

b) Main switch board shall be installed in rooms or fire safe cupboards so as to safeguard against operation by unauthorized personnel. Otherwise, the main switch board shall have lock and key facility for small installations in residences or other occupancies having sanctioned loads less than 5 kW;

c) Switchboards shall be placed only in dry situations and in ventilated rooms and they shall not be placed in the vicinity of storage batteries or exposed to chemical fumes;

d) In damp situation or where inflammable or explosive dust, gas or vapour is likely to be present, the switchboard shall be totally enclosed and shall have adequate degree of ingress protection (IP). In some cases, flameproof enclosure may be necessitated by particular circumstances {*see* accepted standard [D-2(31)]};

e) Switchboards shall not be erected above gas stoves or sinks, or within 2.5 m of any washing unit in the washing rooms or laundries, or in bathrooms, lavatories or toilets, or kitchens;

f) In case of switchboards unavoidably fixed in places likely to be located outdoor, exposed to weather, drip, or to abnormal moist temperature, the outer casing shall be weatherproof and shall be provided with glands or bushings or adopted to receive screwed conduit, according to the manner in which the cables are run. The casing as well as cable entries shall have suitable IP ratings according to the installation;

g) Adequate illumination shall be provided for all working spaces around the switchboards; and

h) Easy access to the enclosure around switchgear is essential to enable easy and safe operation and maintenance. The provisions as given in **5.3.6.7** including requirements for sufficient clearances shall be complied with.

5.4.2.3 Metal-clad switchgear shall be mounted on any of the following types of boards:

a) *Fixed-type metal boards* — These shall consist of an angle or channel iron frame fixed on the wall or on floor and supported on the wall at the top, if necessary;

NOTE — Such type of boards is suitable for both small and large switchboards. They are particularly suitable for large switchboards for mounting number of switchgears or high capacity metal-clad switchgear or both in an arrangement which do not require rear access.

b) *Protected-type switchboards* — A protected switchboard is one where all of the switchgear and conductors are protected by metal or halogen free plastic enclosures. They may consist of a metal/plastic cubicle panel, or an iron frame upon which metal-clad switchgears are mounted. They usually consist of a main switch, busbars and circuit breakers or fuses controlling outgoing circuits; and

c) *Outdoor-type switchboards* — An outdoor-type switchboard is one which is totally enclosed and UV ray protected and having high ingress protection against dust and moisture and vermin-proof and high impact resistant (IP 55 or higher and IK 10). Such switchboards are of cubicle type and also provide high impact resistance. Cubicle type boards shall be with hinged doors interlocked with switch-operating mechanisms. The doors of these switchboards shall have facility to ensure that it is always in closed conditions. All such switches shall bear labels indicating their functions.

NOTE — Such switchboards shall be located away from areas likely to be crowded by the public.

Open type switchboards, wherever existing in old buildings, shall be phased out and replaced with protected-type switchboards with suitable circuit breakers. Switchboards should be composite including incoming and outgoing circuit breakers, meters, cable alleys, bus-bars, accessories, etc.

5.4.2.4 *Recessing of boards*

Where so specified, the switchboards shall be recessed in the wall. Ample room shall be provided at the back for connection and at the front between the switchgear mountings.

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5.4.2.5 *Marking of apparatus* {*see also* accepted standards [D-2(32)]}

Where a board is connected to voltage higher than 250 V, all the apparatus mounted on it shall be marked with the following colours to indicate the different poles or phases to which the apparatus or its different terminals may have been connected:

a) *Alternating current* (*three-phase*) *system*:

   Phase 1 – red, Phase 2 – yellow and Phase 3 – blue; and
   1 Neutral – black

b) *Direct current* (*three-wire system*):

   2 outer wire, Positive – red and Negative – blue; and
   1 Mid wire (Neutral) – black

Where four-wire three-phase wiring is done, the neutral shall be in one colour and the other three phase conductors in another colour (preferably red) or shall be suitably tagged or sleeved to ensure fool proof identification.

NOTE — Generally red colour identification is adopted for the phase conductors and black for neutral with additional tags or sleeves or coloured tapes at terminations.

Earth continuity conductor shall be marked with green colour or green with yellow line.

Where a board has more than one switchgear, each such switchgear shall be marked to indicate the section of the installation it controls. The main switchgear shall be marked as such. Where there is more than one main switchboard in the building, each such switchboard shall be marked to indicate the section of the installation and/or building it controls.

All markings shall be clear and permanent.

5.4.2.6 *Drawings*

Before proceeding with the actual construction, a proper drawing showing the detailed dimensions and design including the disposition of the mountings of the boards, which shall be symmetrically and neatly arranged for arriving at the overall dimensions, shall be prepared along the building drawing. Such drawings will show the mandatory clearance spaces if any, and clear height below the soffit of the beam required to satisfy regulations and safety considerations, so that other designers or installers do not get into such areas or spaces for their equipment.

5.4.3 *Distribution Boards*

A distribution board comprises of one or more protective devices against overcurrent and ensuring the distribution of electrical energy to the various circuits. Distribution board shall provide plenty of wiring space, to allow working as well as to allow keeping the extra length of connecting cables, likely to be required for maintenance.

5.4.3.1 Main distribution board shall be provided with a circuit breaker on each pole of each circuit, on the phase or live conductor and a link on the neutral or earthed conductor of each circuit. The switches shall always be linked.

All incomers should be provided with surge protection devices depending upon the current carrying capacity and fault level (*see* **11**). Surge protecting devices should be provided with backup circuit breaker/fuses, wherever required.

5.4.4 *Branch Distribution Boards*

5.4.4.1 Branch MCB distribution boards shall be provided, along with earth leakage protective device (RCCB/RCD) in the incoming, with a miniature circuit breaker of adequate rating/setting chosen on the live conductor of each sub-circuit and the neutral conductor shall be connected to a common link and be capable of being disconnected individually for testing purposes. At least one spare circuit of the same capacity shall be

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provided on each branch distribution board. Further, the individual branching circuits (outgoing) shall be protected against over-current with miniature circuit breaker of adequate rating. In residential/industrial lighting installations, the various circuits shall be separated and each circuit shall be individually protected so that in the event of fault, only the particular circuit gets disconnected. In order to provide protection against electric shock due to leakage current for human being, a 30 mA RCCB/RCD shall be installed at distribution board incomer of buildings, such as residential, schools and hospitals. For all other buildings, a 100 mA RCCB/RCD will suffice for protection against leakage current.

In case of phase segregated distribution boards, earth leakage protective device shall be provided in the sub-incomer to provide phase-wise earth fault protection. The provision of sub-incomer in distribution board shall be as per consumer requirement.

5.4.4.2 Common circuit shall be provided for installations at higher level (those in the ceiling and at higher levels, above 1 m, on the walls) and for installations at lower level but with separate switch control (sockets for portable or stationery plug in equipment). For devices consuming high power and which are to be supplied through supply cord and plug, separate wiring shall be done. For plug-in equipment provisions shall be made for providing RCCB/RCD protection in the distribution board. They shall be selected as per the type of load. The details of RCD classes are available in Part 1 'General and common aspects, Section 10 Protection for safety — Protection against electric shock' of good practice [D-2(1)].

5.4.4.3 It is preferable to have additional circuit for kitchen and bathrooms. Such sub-circuit shall not have more than a total of ten points of light, fans and 6 A socket-outlets. The load of such circuit shall be restricted to 800 W and the wiring with minimum 1.5 mm^2 copper conductor cable is recommended. If a dedicated circuit is planned for light fixtures, the load of such circuit shall be restricted to 800 W or 20 points whichever is less and the wiring with 1.5 mm^2 copper conductor cable is recommended. If a dedicated circuit is planned for 6 A sockets the load of such circuit shall be restricted to 800 W or a maximum of 8 numbers whichever is less, controlling MCB should be sized accordingly. The wiring shall be with 1.5 mm^2 copper conductor cable. If a separate fan circuit is provided, the number of fans in the circuit shall not exceed ten. Power sub-circuit shall be designed according to the load but in no case shall there be more than two 16A outlets on each sub-circuit which can be wired with 4 mm^2 copper conductor cable for miscellaneous socket loads and shall be with 4 mm^2 copper conductor cable for equipment consuming more than 1 kW. Power sockets complying with the accepted standards [D-2(33)] with current rated according to their starting load, wiring, MCB, etc, shall be designed for special equipment space heaters, air conditioners, heat pumps, VRF, etc.

For feeding final single phase domestic type of loads or general office loads it is advisable to introduce additional cables if required to allow lowering of short circuit rating of the switchgear required at user end so that use of hand held equipment, etc fed through flexible cords is safe.

5.4.4.4 The circuits for lighting of common area shall be separate. For large halls 3-wire control with individual control and master control installed near the entrance shall be provided for effective conservation of energy. Occupancy sensors, movement sensors, lux level sensors, etc, may also be considered as switching options for lights, fans, TV, etc, for different closed spaces [*see* also relevant guidelines/best practices (Handbook on 'Sustainability in Buildings')].

5.4.4.5 Where daylight is abundantly available, particularly in large halls, lighting in the area near the windows likely to receive daylight shall have separate controls for lights, so that they can be switched off/automatically reduce intensity selectively when daylight is adequate, while keeping the lights in the areas remote from the windows on [*see* also relevant guidelines/best practices (Handbook on 'Sustainability in Buildings')].

5.4.4.6 Circuits for socket-outlets may be kept separate from circuits feeding fans and lights. Normally, fans and lights may be wired on a common circuit. In large spaces, circuits for fans and lights may also be segregated. Lights may have group control in large halls and industrial areas. While providing group control, consideration may be given for the nature of use of the area lit by a group. Consideration has to be given for the daylight utilization, while grouping, so that a group feeding area near windows receiving daylight can be selectively switched off during daylight period.

5.4.4.7 The load on any low voltage sub-circuit shall not exceed 3 000 W. In case of a new installation, all circuits and sub-circuits shall be designed with an initial load of about 2 500 W, so as to allow a provision of 20 percent

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increase in load due to any future modification. Power sub-circuits shall be designed according to the load, where the circuit is meant for a specific equipment. Good practice is to limit a circuit to a maximum of three sockets, where it is expected that there will be diversity due to use of very few sockets in large spaces (example sockets for use of vacuum cleaner). General practice is to limit it to two sockets in a circuit, in both residential and non-residential buildings and to provide a single socket on a circuit for a known heavy load appliance such as air conditioner, cooking range, etc.

5.4.4.8 In wiring installations at special places like construction sites, stadia, shipyards, open yards in industrial plants, etc, where a large number of high wattage lamps may be required, there shall be no restriction of load on any circuit but conductors used in such circuits shall be of adequate size for the load and proper circuit protection shall be provided. The distribution boards (DBs) used in these areas shall be of UV resistant, double insulated type with IP 66 or higher degree of protection. Power tools and other temporary equipment connected to these DBs shall be sufficiently protected against electrical faults. Insulated IP 66 sockets complying with the accepted standards [D-2(28)] used in these DBs shall have interlocking facility in addition to protection to ensure safe plugging and unplugging of these equipment.

5.4.5 *Location of Distribution Boards*

a) The distribution boards shall be located as near as possible to the centre of the load they are intended to control;

b) These shall be fixed on suitable stanchion or wall and shall be accessible for replacement/reset of protective devices and shall not be more than 1.8 m from floor level;

c) These shall be of either metal-clad type, or polycarbonate enclosure of minimum IP 42. But, if exposed to weather or damp situations, these shall be of the weatherproof type conforming to IP 55 and, if installed where exposed to explosive dust, vapour or gas, these shall be of flameproof type in accordance with accepted standards [D-2(34)]. In corrosive atmospheres, these shall be treated with anti-corrosive preservative or covered with suitable plastic compound;

d) Where two and/or more distribution boards feeding low voltage circuits are fed from a supply of low voltage, the metal case shall be marked ‘Danger 415 Volts’ and identified with proper phase marking and danger marks;

e) Each shall be provided with a circuit list giving diagram of each circuit which it controls and the current rating of the circuit and capacity of MCB;

f) In wiring branch distribution board, total load of connecting devices shall be divided as far as possible evenly between the number of ways in the board leaving spare circuits for future extension;

g) Distribution board shall not be located at structural expansion joints of the building;

h) Distribution board/other electrical outlets shall have a minimum calculated separation distance from lightning protection down-conductors to avoid flash over in case of lightning; and

j) Walls with flushed distribution boards shall have adequate support behind and surrounding so that there is no physical weight of the distribution board on the civil structure around. Electrical switch sockets, etc shall also be avoided to be mounted behind the distribution board to avoid touching the board from behind.

5.4.6 *Protection of Circuits*

a) Appropriate protection shall be provided at switchboards, distribution boards and at all levels of panels for all circuits and sub-circuits against short circuit, over-current and other parameters as required. The protective device shall be capable of interrupting maximum short circuit current and the prospective earth fault current that may occur, without danger. The ratings and settings of the protective devices such as MCB shall be coordinated so as to afford selectivity in operation and in accordance with accepted standards [D-2(35)];

b) Where circuit-breakers are used for protection of a main circuit and of the sub-circuits derived therefrom, discrimination in operation may be achieved by adjusting the protective devices of the sub-main circuit-breakers to operate at lower current settings and shorter time-lag than the main circuit-breaker;

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c) Where HRC type fuses are used for back-up protection of circuit-breakers, or where HRC fuses are used for protection of main circuits and circuit-breakers for the protection of sub-circuits derived there from, in the event of short-circuits protection exceeding the capacity of the circuit-breakers, the HRC fuses shall operate earlier than the circuit-breakers; but for smaller overloads within the short-circuit capacity of the circuit-breakers, the circuit-breakers shall operate earlier than the HRC fuse blows;

d) The current rating of a circuit breaker shall not exceed the current rating of the smallest cable in the circuit protected by it; and

e) All distribution board or panel incomer may be protected by a surge protection device, if found necessary (*see* **11**). Separate CB with proper enclosure may be required in series with the surge protection device with main incomer. Back-up CB shall be of the capacity not lower than that recommended by the SPD manufacturer. Short circuit withstand capability of the SPDs should be coordinated with the CB and SPD should be selected to be matching the fault power expected/calculated at that point.

5.4.7 *Cascading*, *Discrimination and Limitation*

Cascading and discrimination in switchgear downstream and upstream shall be designed and maintained such that the continuity of power in case of any abnormal conditions such as overload, short circuit and earth faults, etc is maintained and only faulty circuit is isolated and power is made available to other loads.

Cascading technique allows the designer to select circuit breakers of lower breaking capacities. Utilizing the current limiting effect of the incoming breaker, outgoing breaker can sustain the higher faults than its capacity and even maintain the discrimination. The provisions of good practice [D-2(1)] and relevant Indian Standards shall be complied with while carrying out necessary works under **5.4**.

5.5 Protection Class of Equipment and Accessories

The class of ingress protection (IP) and protection against mechanical impact (IK) {*see also* accepted standard [D-2(36)]} shall be specific depending on the requirement at the place of installation.

5.6 Voltage and Frequency of Supply

It should be ensured that all equipment connected to the system including any appliances to be used on it are suitable for the voltage and frequency of supply of the system. The nominal values of low systems in India are 240 V single phase and 415 V a. c. three phase, respectively, and the frequency is 50 Hz.

NOTE — The design of the wiring system and the sizes of the cables should be decided taking into account following factors:

a) *Voltage drop* — This should be kept below 6 percent to ensure proper functioning of all electrical appliances and equipment including motors.

b) Thermal limit based current carrying capacity of the cable with appropriate derating factors applicable to the installation conditions.

c) Capacity to withstand the let through fault current based on the fault level and the controlling switchgear disconnection characteristics.

5.7 Rating of Cables and Equipment

The rating of the cables and the equipment shall be chosen based on the relevant Indian Standards, good practice [D-2(1)] and accepted standard [D-2(37)] read with availability of the material in the market.

5.8 Installation Circuits

5.8.1 The nominal cross-sectional area of copper phase conductors in a. c. circuits and of live conductors in d. c.

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circuits shall be not less than the values specified below:

Sl No.	*Type of Circuit*	*Minimum Copper Wire Size*	*Remarks*
(1)	(2)	(3)	(4)
i)	Lighting	1.5 mm^2	Per circuit for 2 or more circuits
ii)	Socket-outlets, 6 A	2.5 mm^2	Earthing of the 3rd pin shall be ensured
iii)	Socket-outlets, 16 A	2.5 mm^2	1
iv)	Water heater < 3 kW	2.5 mm^2	1
v)	Heaters or electric equipment more than or equal to 3 kW	4.0 mm^2	1
vi)	Free standing electric range Separate oven and/or cook top	4.0 mm^2	1
vii)	Air conditioner up to 2 T	4.0 mm^2	1
viii)	Permanently connected appliances including dishwashers, heaters, etc	2.5 mm^2	1 above 10 A. Up to 10 A can be wired as part of a socket-outlet circuit
ix)	Appliance rated > 3 kW < 6 kW	6.0 mm^2	–
x)	Submains to garage or out-building	2.5 mm^2	1 for each
xi)	Mains cable		It should be based on demand load/peaking loads and future loading

NOTE — The minimum conductor size in point wiring shall not be less than 1.5 mm^2 copper conductor cable for fixed (permanent) wiring insulations.

5.8.2 For conductor sizes less than or equal to 25 mm^2, only copper conductor cables shall be used since aluminium conductor cables in sizes less than 25 mm^2 may cause termination problems leading to heating at the terminals and enhance the possibility of a fire.

In case of very important public buildings and multi-storey buildings, for connections to meter board and connections from tap-off box to floor panel and beyond, use of copper conductor cable up to 50 mm^2 be considered to avoid frequent failure and fire accidents.

5.8.3 Switch or isolator controlling a water heater or geyser should not be located within 1 m from the location of a shower or bath tub, to avoid a person in wet condition reaching the switch or isolator. It is preferable to provide the control switch outside the bath room near the entrance and provide an indication at the water heater. A socket or a connector block with suitable protection against water spray should be provided to connect the water heater. The above considerations apply to switches for outdoor lights and other appliances, with the object of avoidance of operation of a switch when a person is wet.

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5.8.4 Sockets in kitchen, bathroom, toilet, garage, etc, should not be provided within a height of 1 m from the ground level. Similar care has to be taken for installations involving fountains, swimming pools, etc. Light fittings in such areas should be fed at low voltage, preferably through an isolating transformer with a proper earth leakage protection. Where possibility of a person in contact with a wet surface has to operate or touch an electrical switch or an appliance the circuit should be protected by a 30 mA RCCB/RCD, as applicable.

5.8.5 *Selecting and Installing Cables*

5.8.5.1 *Cable types*

For the purpose of this NBCS, cables above 1 mm^2 shall have stranded conductors. All cables when installed, shall be adequately protected against mechanical damage. This can be carried out by either having additional protection, such as being enclosed in PVC conduit or metal pipes, or placing the cables in a suitable location that requires no additional protection. The cables for wiring circuits in electrical installation shall have the appropriate wire size matching the requirement of the loads. The following table gives the recommendations for different types of loads:

For the mains cable	Cross-linked polyethylene (XLPE) cable
For internal wiring	Class II copper conductor flame retardant, low smoke halogen (FRLSH) cable
Fire alarm and other related services	Halogen free flame retardant (HFFR)/Fire survival copper conductor cable
For main earth or main equipotential wire	Poly vinyl chloride (PVC) insulated copper wire
Underground installation and installation in cable trench, feeders between buildings, etc	PVC insulated, PVC sheathed armoured cables or XLPE insulated, PVC sheathed cables armoured cables
Installation in plant rooms, switch rooms, etc, on cable tray or ladder or protected trench, where risk of mechanical damage to cable does not exist	PVC insulated, PVC sheathed or XLPE insulated, PVC sheathed unarmoured cables

5.8.5.2 *Circuit wire sizes*

Recommended minimum wire sizes for various circuits is given below:

Sl No.	*Circuits*	*Minimum Size of Copper Conductor Cable*	*Wire Colour*
(1)	(2)	(3)	(4)
i)	1-way lighting	2 + E cable of 1.5 mm^2	Red-black and green-yellow
ii)	2-way lighting control	3 wire cable of 1.5 mm^2	Red-white-blue
iii)	Storage water heaters up to 3 kW	2 + E cable of 2.5 mm^2 (stranded conductors)	Red-black and green-yellow
iv)	Storage water heaters between 3 kW and 6 kW	2 + E cable of 4 mm^2 (stranded conductors)	Red-black and green-yellow
v)	Socket-outlets and permanent connection units	2 + E cable of 2.5 mm^2 (stranded conductors)	Red-black and green-yellow

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Table (*Concluded*)

Sl No.	*Circuits*	*Minimum Size of Copper Conductor Cable*	*Wire Colour*
(1)	(2)	(3)	(4)
vi)	Submains to garages or out buildings	2 + E cable 2.5 mm^2 (stranded conductors)	Red-black and green-yellow
vii)	Cooking hobs	2 + E cable 1.5 mm^2	Red-black and green-yellow
viii)	Separate ovens	2 + E cable 4 mm^2 (stranded conductors)	Red-black and green-yellow
ix)	Electric range	2 + E cable 6 mm^2 (stranded conductors)	Red-black and green-yellow
x)	Mains	2 wire cable Upto 25 mm^2 (stranded conductors)	Red-black
xi)	Main equipotential bonding wire	4 mm^2 (stranded conductors)	Green-yellow
xii)	Main earth wire	6 mm^2 (stranded conductors)	Green-yellow

NOTES

1 2 + E cable is also known as twin and earth wire cable (two wires and earth).

2 Earth wire can be as per the following:

a) Green-Yellow throughout their length with, in addition, light blue markings at the terminations; or

b) Light blue throughout their length with, in addition, green/yellow markings at the terminations.

3 The above sizes are recommendatory and shall be modified as per voltage drop, starting current, distance from DB, etc.

5.8.6 *Requirements for Physical Protection of Underground Cables*

Sl No.	*Protective Element*	*Specifications*
(1)	(2)	(3)
i)	Bricks	a) 100 mm minimum width b) 25 mm thick c) sand cushioning 100 mm and sand cover 100 mm
ii)	Concrete slabs	At least 50 mm thick
iii)	Plastic slabs (polymeric cover strips) fibre reinforced plastic	At least 10 mm thick, depending on properties and has to be matched with the protective cushioning and cover
iv)	PVC conduit or PVC pipe or stoneware pipe or hume pipe	The pipe diameter should be such so that the cable is able to easily slip down the pipe
v)	Galvanized pipe	The pipe diameter should be such so that the cable is able to easily slip down the pipe

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The trench shall be backfilled to cover the cable initially by 200 mm of sand fill; and then a plastic marker strip shall be put over the full length of cable in the trench. The marker signs shall be provided where any cable enters or leaves a building. This will identify that there is a cable located underground near the building. The trench shall then be completely filled. If the cables rise above ground to enter a building or other structure, a mechanical protection such as a GI pipe or PVC pipe for the cable from the trench depth to a height of 2.0 m above ground shall be provided.

5.9 Lighting and Levels of Illumination

5.9.1 *General*

Lighting installation shall take into consideration the numerous factors on which the quality and quantity of artificial lighting depends. Recent practice in illumination is to provide the required illumination with a large number of light sources (not of higher illumination level) instead of fewer number of light sources of higher illumination level, to produce higher uniformity in illumination level.

With the increase in energy costs and awareness of the need to conserve energy for the protection of the environment, there has been a drastic change in the use of light sources during the last 10 years. Fluorescent lamps [tubular lamp (TL) and compact fluorescent lamp (CFL)] are no longer available in the market. Use of general lighting service (GLS) lamps, known as light bulbs, has almost become extinct. The space vacated by these light sources has been taken over by LED lamps in different configurations in the form of LED based bulbs, tube lights, ceiling flush light sources and floodlights with different wattages.

With this the lighting design has become more complex. With the developments in the types of light sources and their control systems now available, lighting design goes with the concept of better light with less energy and least impact on environment.

Automatic lighting control schemes may be considered to have efficient utilization of lights. Automatic controls can take care of the switching off when the space served has no activity or is illuminated by daylight.

While carrying out lighting design and layout reference shall also be made to good practice [D-2(38)].

5.9.2 *Electrical Installations for Lighting*

The concepts or needs of energy conservation today require more lights to be provided so that different sets of lights are used to light up the area of activity to the required higher level of lighting needed for the activity and provide a general minimum background level of lighting. Any space requires two or three different combination of lighting sets associated with the activity and this may require the wiring to be provided to accommodate the lighting groups in different circuits with group controls, automatic controls and remote controls.

Availability of LED lights with a wide range from 1 W to 100 W allows designers to provide spot task lighting of a high illumination level combined with a general space lighting of low illumination. As light follows the inverse square law, provision of the light source close to the task reduces the energy need.

Lighting demand for buildings should be considered as per type of building. Where nothing is specified, for lighting demand of any type of building a maximum of 13 W/m^2 of all built-up areas including balconies. Covered parking areas may be considered at 3.23 W/m^2 including balconies is to be considered. Service areas, corridors, etc, may be considered with very basic diversity of 80 percent to 100 percent. Power requirements shall be considered at least 55 W/m^2 with an overall diversity not exceeding 50 percent. These shall be excluding defined loads such as lifts, plumbing system, firefighting systems, ventilation requirement, etc.

Light emitting diode (LED) lamps have non-linear characteristics and require specifically made controlgear for each type of lamp for their proper operation. In some cases the controlgear is integral with the lamp, in some with light fitting and in some it is external. The electrical installation and wiring has to take this into account and provide appropriate space for such controlgear. There will be heat emission, introduction of harmonics, etc, and they also consume some energy. The electrical and lighting system design has to keep this aspect in the wiring design and installation.

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5.9.3 *Principles of Lighting*

When considering the function of artificial lighting, attention shall be given to the following principle characteristics before designing an installation:

a) Illumination and its uniformity.

b) Special distribution of light. This includes a reference to the composition of diffused and directional light, direction of incidence, the distribution of luminances and the degree of glare.

c) Colour of the light and colour rendition.

d) Natural light sources, if possible such as light tubes.

e) System wattage of the luminaire proposed.

5.9.4 The variety of purposes which have to be kept in mind while planning the lighting installation may be broadly grouped as:

a) industrial buildings and processes;

b) offices, schools and public buildings;

c) surgeries and hospitals; and

d) hostels, restaurants, shops and residential buildings.

5.9.4.1 It is important that appropriate levels of illumination for these and the types and positions of fittings determined to suit the task and the disposition of the working planes are ensured.

5.9.5 For detailed requirements for lighting and lighting design and installations, reference shall be made to the good practice [D-2(38)] and provisions in Part D 'Building Services, Section 1 Lighting and Natural Ventilation' of this NBCS.

5.10 In locations where the system voltage exceeds 415 V three phase, as in the case of industrial locations, for details of design and construction of wiring installation, reference may be made to good practice [D-2(18)].

5.11 Guideline for Electrical Layout in Residential Buildings

For guidelines for electrical installation in residential buildings, reference may be made to accepted standard [D-2(39)] and good practice [D-2(1)].

A typical distribution scheme in a residential building with separate circuits for lights and fans and for power appliances is given in Fig. 3.

5.12 For detailed information regarding the installation of different electrical equipment, reference may be made to good practice [D-2(40)].

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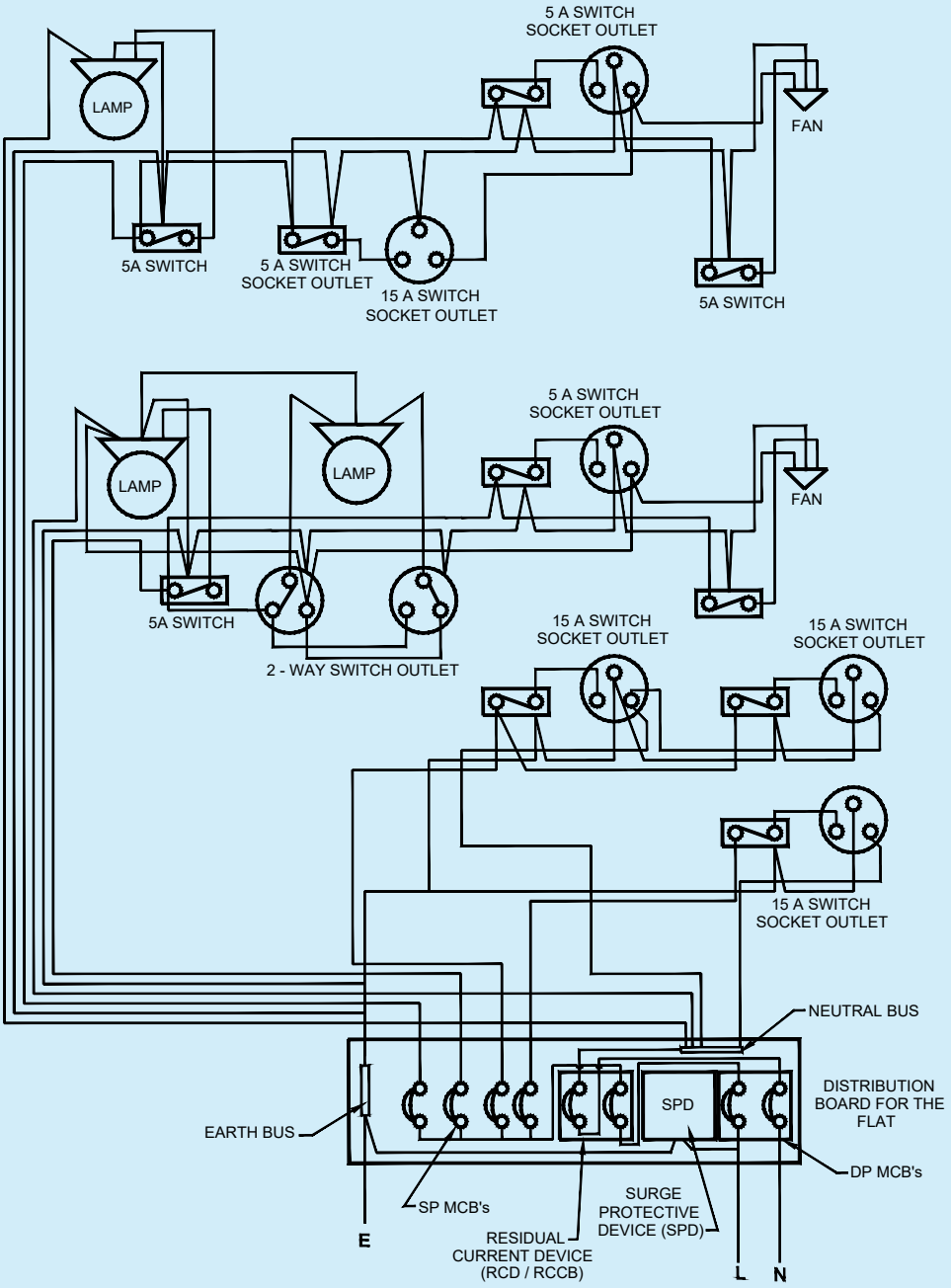

FIG. 3 WIRING DIAGRAM FOR A TYPICAL DISTRIBUTION SCHEME IN A RESIDENTIAL BUILDING FLAT

6 WIRING

6.1 General

The generic guidelines for wiring in buildings depending on the type of occupancy, local conditions, material selection and other relevant points are covered hereunder. Also, the construction requirements, safety aspects to be considered during construction and maintenance aspects which should be considered during construction are

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addressed. All works under this shall also comply with the relevant Indian Standards and provisions in good practice [D-2(1)].

6.1.1 *Estimation of Load Requirements*

All conductors, switches and accessories shall be of such size as to be capable of carrying, without their respective ratings being exceeded, the maximum current which will normally flow through them.

In estimating the current to be carried by any conductor the following ratings shall be taken, unless the actual values are known or specified for these elements:

Sl No.	*Element*	*Rating*, W
(1)	(2)	(3)
i)	Light point	60
ii)	Fan point	75
iii)	6 A 3/5 pins socket-outlet	100
iv)	16 A 3/6 pins socket-outlet	2 000
v)	High pressure mercury vapour (HPMV) lamps, high pressure sodium vapour (HPSV) lamps	According to their capacity, controlgear losses shall be also considered as applicable
vi)	Geyser (storage type)	2 000
vii)	Geyser (instant)	3 000
viii)	Computer point	150
ix)	Printer, laser	1 500
x)	Air conditioner:	
	a) Up to 1.5 TR	2 000
	b) 1.5 to 2 TR	3 000

6.1.2 *Commencement of Electrical Work*

Electrical installation in a new building shall normally begin with conduit laying at the commencement of preparations for first roof concreting work. The necessary conduits and ducts shall be positioned firmly by tying the conduit to the reinforcement before concreting in an RCC building. Location of fan points should be properly marked and fan clamp boxes should be provided along with conduit laying in roof. Care should be taken to avoid use of damaged conduit or ducts, the conduits ends shall be given suitable anti-corrosive treatment and holes blocked off by putties or caps to protect conduits from getting blocked. All conduit openings and junction box openings, etc shall be properly protected against entry of mortar, concrete, etc during construction. Laying of conduits in walls shall start with the taking up of wall construction work. In case of surface wiring, the work will start after completion of interior plaster including curing. The wiring, fixing of switch boxes and fixing of switches will start only after ensuring necessary weatherproof area with locking arrangement is available to take up electrical work.

6.2 Selection of Size of Conductors

The size of conductors for circuits shall be selected after fixing the location of main sub-station, main switchboard for the building, location of distribution board and the electrical points under the planning of electrical services. The overall voltage drop from the transformer end to consumer's final distribution board shall not exceed six percent. The voltage drop of six percent will be divided between different points indicated above in such a way that from the distribution board to the last point shall be three percent. From main board to distribution board, from distribution board to sub distribution board if any, circuit wiring from DB/SDB to switch board and from

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switch board to light/fan points/plug points shall be with Class II category copper conductors. The size of the conductor cable shall be decided based on the maximum load on each point. In main/submain/circuit/sub-circuit, the circuit-breaker shall be selected to match the current rating of the circuit to ensure the desired protection.

6.3 Branch Switches

Where the supply is derived from a three-wire or four-wire source, and distribution is done on the two-wire system, all branch switches shall be placed in the outer or live conductor of the circuit and no single phase switch or protective device shall be inserted in the middle wire, earth or earthed neutral conductor of the circuit. Single-pole switches (other than for multiple control) carrying not more than 16 A may be of flush/modular type. For controlling points for air conditioners and geysers, suitable MCB type switches shall be provided.

6.4 Layout and Installation Drawing

6.4.1 The electrical layout should be drawn indicating properly the locations of all outlets, such as lamps, fans, appliances (both fixed and movable), and motors and best route for wiring.

6.4.2 All runs of wiring and the exact positions of all points of switch-boxes and other outlets shall be first marked on the plans of the building and approved by the engineer-in-charge or the owner before actual commencement of the work.

6.4.3 Industrial layout drawings should indicate the relative civil and mechanical details.

6.4.4 *Layout of Wiring*

The layout of wiring should be designed keeping in view disposition of the lighting system to meet the illumination levels. All wirings shall be done on the distribution system with main and branch distribution boards at convenient physical and electrical load centres. All types of wiring, whether concealed or unconcealed, should be as near the ceiling as possible. In all types of wirings due consideration shall be given for neatness and good appearance.

6.4.5 Balancing of circuits in three-wire or poly-phase installation shall be arranged beforehand. Proper balancing can be done only under actual load conditions. Conductors shall be so enclosed in earthed metal or incombustible insulating material that it is not possible to have ready access to them. Means of access shall be marked to indicate the voltage present.

Where terminals or other fixed live parts between which a voltage exceeding 250 V exists are housed in separate enclosures or items of apparatus which, although separated are within reach of each other, a notice shall be placed in such a position that anyone gaining access to live parts is warned of the magnitude of the voltage that exists between them.

Where loads are single phase, balancing should be for the peak load condition based on equipment usage. Facility for change should be built into the distribution design.

NOTE — The above requirements apply equally to three-phase circuits in which the voltage between lines or to earth exceeds 250 V and to groups of two or more single-phase circuits, between which medium voltage may be present, derived therefrom. They apply also to 3 wire d.c. or 3 wire single-phase a.c. circuits in which the voltage between lines or to earth exceeds 250 V and to groups of 2 wire circuits, between which medium voltage may be present, derived there from.

6.4.6 Low voltage wiring and associated apparatus shall comply, in all respects, with the requirements of Regulation 35, 36, 37, 39, 40, 41 and 42 of *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023, as amended from time to time (*see* Annex B).

6.5 Conductors and Accessories

6.5.1 *Conductors*

Conductors for all the internal wiring shall be of copper. Conductors for power and lighting circuits shall be of adequate size to carry the designed circuit load without exceeding the permissible thermal limits for the insulation. For final selection of wiring to larger loads, the current carrying capacity will preside. The conductor size shall

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also be based on the voltage drop in the line so as to provide a terminal voltage not below the prescribed voltage requirement.

The conductor for final sub-circuit for fan and light wiring shall have a nominal cross-sectional area not less than 1.50 mm^2 copper. The cross-sectional area of conductor for power wiring shall be not less than 2.5 mm^2 copper. The minimum cross-sectional area of conductor of flexible cord shall be 1.50 mm^2 copper. All copper conductors used in wiring shall be of class II category for permanent wiring system.

In existing buildings where aluminum wiring has been used for internal electrification, changeover from aluminum conductor cables to copper conductor cables is recommended as it has been found that aluminum conductors pose a number of hazards.

NOTE — It is advisable to replace wiring which is more than 30 years old as the insulation also would have deteriorated, and will be in a state to cause failure on the slightest of mechanical or electrical disturbance.

6.5.2 *Flexible Cables and Flexible Cords*

Flexible cables and cords shall be of copper and stranded, and protected by flexible conduits or tough rubber or PVC sheath to prevent mechanical damage.

6.5.3 *Cable Ends*

When a stranded conductor having a nominal sectional area less than 6 mm^2 is not provided with cable sockets (thimbles/lugs) for end termination, all strands at the exposed ends of the cable shall be soldered together or crimped using suitable sleeve or ferrules.

6.5.4 *Special Risk*

Special forms of construction, such as flameproof enclosures, shall be adopted where there is risk of fire or explosion.

6.5.5 *Connection to Ancillary Buildings*

Unless otherwise specified, electric connections to ancillary buildings, such as out-houses, garages, etc adjacent to the main building and when no roadway intervenes shall be taken in an earthed GI pipe or heavy duty PVC or HDPE pipe of suitable size. This pipe can be taken either underground or over ground, however, in latter case, its height from the ground shall not be less than 5.8 m. This applies to both runs of mains or sub-mains or final sub-circuit wiring between the buildings.

6.5.6 *Expansion Joints*

Distribution boards shall be so located that the conduits shall not normally be required to cross expansion joints in a building. Where such crossing is found to be unavoidable, special care shall be taken to ensure that the conduit runs and wiring are not in any way put to strain or damaged due to expansion of building structure. Anyone of the standard methods of connection at a structural expansion joint shall be followed:

a) Flexible conduit shall be inserted at place of expansion joint;

b) Oversized conduit overlapping the conduit; and

c) Expansion box.

Supports and flexible joints shall be of same requirement as the rising main/bus duct in so far as resistance to seismic forces is concerned. This is further important when rising mains and bus-ducts cross expansion joints.

6.5.7 *Extra Low Voltage* (*Types of Wires/Cables*)

Extra low voltage services utilize various categories of cables/wires, such as fibre optic cable, co-axial cable, etc. These shall be laid at least at a distance of 300 mm from any power wire or cable. The distance may be reduced only by using completely closed earthed metal trunking with metal separations for various kind of cable. Special

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care shall be taken to ensure that the conduit runs and wiring are laid properly for low voltage signal to flow through it.

The power cable and the signal or data cable may run together under floor and near the equipment. However, separation may be required from the insulation aspect, if the signal cable is running close to a conductor carrying power at low voltage. All types of signal cables are required to have insulation level for withstanding 2 kV impulse voltage even if they are meant for service at low voltage.

6.6 Passing Through Walls, Floors and Expansion Joints

6.6.1 Where wires/cables are required to pass through walls, care shall be taken to see that wires/cables pass freely through protective pipe or box and that the wires pass through in a straight line without any twist or cross in wires. In case of wires crossing expansion joints in a recessed conduit system there shall be two loop wire boxes on two sides of the expansion joint which shall be connected with concentric pipes of different diameter in such a way that one box will hold the bigger diameter conduit while the other box will hold the smaller diameter conduit pipe. This way, the two sides can move freely as per structure without having any effect either on the structure or on the wiring system.

One of the following methods shall be employed for laying wires/cables:

a) *Conduit wiring system* (*see* **6.9**) — The conductor shall be drawn in either in a rigid steel conduit or a rigid non-metallic conduit conforming to relevant Indian Standards {*see* accepted standards [D-2(41)] and [D-2(42)]}. All conduits used for fire alarm and other fire related emergency relief services as well as security and UPS system shall only be of metallic conduit system.

The conduits shall be colour coded as per the purpose of wire carried in the same. The recommended colour coding may be in form of bands of colour (100 mm thick, with centre to centre distance of 300 mm) or coloured throughout. The colour scheme may be as follows:

Sl No.	*Conduit Type*	*Colour Scheme*
(1)	(2)	(3)
i)	Power conduit	Black
ii)	Security conduit	Blue
iii)	Fire alarm conduit	Red
iv)	Extra low voltage conduit	Brown
v)	UPS conduit	Green

Conduit wiring system shall comply with relevant Indian Standards. The number of insulated conductors that can be drawn into rigid conduit is given in Table 1 (*see* Table 1A for rigid steel conduits and Table 1B for rigid non-metallic conduits). As far as possible, cables of one circuit shall be housed in one conduit only.

b) *Cable trunking*/*cable ways*/*race ways* (*see* **6.10**) — Cable trunking/cable ways/race ways system should be used when number of wires/small cable sizes to be laid is more than the conduit capacity. Care should be taken to have space in the trunking system to minimize heating of wires and to provide identification of the different circuits. These can be laid in both floor and ceiling. Adequate junction boxes, access points shall be provided to pull in and out wire.

Cable trunking or ducting system shall comply with accepted standards [D-2(43)].

c) *Tray and ladder rack* — As tray provides continuous support, unless mounted on edge or in vertical runs (when adequate strapping or clipping is essential), the mechanical strength of supported cable is not as important as with ladder-racking or structural support methods. Consequently, tray is eminently suitable

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for the smaller unarmoured cabling while ladder racks call for armoured cables or larger unarmoured cables as they provide the necessary strength to avoid sagging between supports. Both tray and ladder racks are provided with accessories to facilitate changes of route, and they provide no difficulty in this respect on vertical runs.

Cable tray/ladder racks and support systems shall be installed in such a way that the deflection between the spans shall be less than 1 percent of the span.

Power cables running in cable ladders both horizontal and vertical shall be fixed with proper clamps which can withstand the mechanical force created on the cable in case of short circuit current. The complete installation consisting of cables, ladders, clamps, ladder supports and fixtures shall also withstand the mechanical force of short circuit current. Only one layer of power cable shall be laid in a ladder. The minimum space between two cables shall be equal to the diameter of the biggest cable.

Cable tray and ladder system shall comply with accepted standard [D-2(44)].

6.6.2 Insulated conductors while passing through floors shall be protected from mechanical injury by means of rigid steel/non-metal conduit or by mechanical protection up to a height not less than 1.5 m above the floor and flush with the ceiling below. These steel conduits shall be earthed and securely bushed.

Power outlets and wiring in the floor shall be generally avoided. If not avoidable, false floor trunking or metal floor trunking should be used. Power sockets of adequate IP/IK rating shall be used.

False floor shall be provided where density of equipment and interconnection between different pieces of equipment is high. Examples are, mainframe computer station, telecommunication switch rooms, etc. Floor trunking shall be used in large halls, convention centres, open plan offices, laboratory, etc.

In case of floor trunking, drain points/weep holes shall be provided within the trunking for installation for convention centres, exhibition areas or any other place where water may spill into the trunking, as there might be possibility of water seepage in the case of wiring passing through the floors. Proper care should be taken for providing suitable means of draining of water. Possibility of water entry exists from floor washing, condensation in some particular weather and indoor temperature conditions. At the design stage, these aspects shall be assessed and an appropriate means of avoiding or reducing ingress of water and draining method shall be built in. Floor trunking outlets shall be suitably IP rated for protection against dust and water. Floor trunking shall be of adequate IK rating. Floor or ceiling trunking shall have a maximum of 40 percent fill.

Floor outlet boxes are generally provided for the use of appliances, which require a signal or communication connection. The floor box and trunking system should cater to serve both power distribution and the signal distribution, with appropriate safety and non-interference.

6.6.3 Where a wall tube passes outside a building and be exposed to weather, the outer end shall be bell-mouthed and turned downwards and properly bushed at the open end.

6.7 Wiring of Distribution Boards

6.7.1 All connections between parts of apparatus or between apparatus and terminals on a board shall be neatly arranged in a definite sequence, following the arrangements of the apparatus mounted thereon, avoiding unnecessary crossings.

6.7.2 Cables shall be connected to a terminal only by soldered or welded or crimped lugs using suitable sleeve, lugs or ferrules unless the terminal is of such a form that it is possible to securely clamp them without the cutting away of cables strands. Cables in each circuit shall be bunched together.

6.7.3 All bare conductors shall be rigidly fixed in such a manner that a clearance of at least 25 mm is maintained between conductors or opposite polarity or phase and between the conductors and any material other than insulation material.

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6.7.4 If required, a pilot lamp shall be fixed and connected through an independent single pole switch and fuse to the busbars of the board. Leads connecting bus-bars to any instrument or indicating lamp or an outgoing connection switch or breaker face the same fault current that is applicable to the busbar and as such should be provided with a fuse capable of handling the prospective fault current.

6.7.5 In a hinged type board, the incoming and outgoing cables shall be fixed at one or more points according to the number of cables on the back of the board leaving suitable space in between cables and shall also, if possible, be fixed at the corresponding points on the switchboard panel. The cables between these points shall be of such length as to allow the switchboard panel to swing through an angle of not less than 90° and cables arranged and clamped in such a manner that the cables do not face bending, but only face a twist, when the hinged door is opened. The circuit breakers in such cases shall be accessible without opening the door of distribution board. Circuit breakers or any other equipment (having cable size more than 1.5 mm^2 multi-strand wire) shall also not be mounted on the door.

NOTE — Use of hinged type boards is discouraged, as these boards lead to deterioration of the cables in the hinged portion, leading to failures or even fire.

6.7.6 Wires terminating and originating from the protective devices shall be properly lugged and taped.

6.8 PVC-Sheathed Wiring System

6.8.1 *General*

Wiring with PVC-sheathed cables may be used for temporary installations for medium voltage installation and may be installed directly under exposed conditions of sun and rain or damp places.

6.8.2 *PVC Clamps/PVC Channel*

The clamps shall be used for temporary installations of 1 to 3 sheathed wires only. The clamps shall be fixed on wall at intervals of 100 mm in the case of horizontal runs and 150 mm in the case of vertical runs.

PVC channel shall be used for temporary installations in case of more than 3 wires or unsheathed wires. The channel shall be clamped on wall at intervals not exceeding 300 mm. PVC clamps/PVC channel shall conform to accepted standards.

6.8.3 *Protection of PVC-Sheathed Wiring from Mechanical Damage*

a) In cases where there are chances of any damage to the wirings, such wirings shall be covered with sheet metal protective covering, the base of which is made flush with the plaster or brickwork, as the case may be, or the wiring shall be drawn through a conduit complying with all requirements of conduit wiring system (*see* **6.9**); and

b) Such protective coverings shall in all cases be fitted on all down-drops within 1.5 m from the floor.

6.8.4 *Bends in Wiring*

The wiring shall not in any circumstances be bent so as to form a right angle but shall be rounded off at the corners to a radius not less than six times the overall diameter of the cable.

6.8.5 *Passing Through Floors*

All cables taken through floors shall be enclosed in an insulated heavy gauge steel conduit extending 1.5 m above the floor and flush with the ceiling below, or by means of any other approved type of metallic covering. The ends of all conduits or pipes shall be neatly bushed with porcelain, wood or other approved material.

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6.8.6 *Passing Through Walls*

The method to be adopted shall be according to good practice. There shall be one or more conduits of adequate size to carry the conductors [*see* **6.9.1**(a)]. The conduits shall be neatly arranged so that the cables enter them straight without bending.

6.8.7 *Stripping of Outer Covering*

While cutting and stripping of the outer covering of the cables, care shall be taken that the sharp edge of the cutting instrument does not touch the rubber or PVC-sheathed insulation of conductors. The protective outer covering of the cables shall be stripped off near connecting terminals, and this protective covering shall be maintained up to the close proximity of connecting terminals as far as practicable. Care shall be taken to avoid hammering on link clips with any metal instruments after the cables are laid. Where junction boxes are provided, they shall be made moisture-proof with an approved plastic compound.

6.8.8 *Painting*

If so required, the tough rubber-sheathed wiring shall, after erection, be painted with one coat of oil-less paint or distemper of suitable colour over a coat of oil-less primer, and the PVC-sheathed wiring shall be painted with a synthetic enamel paint of quick drying type.

6.9 Conduit Wiring System

Conduit wiring system shall comply with accepted standards [D-2(45)]. Requirements relating to conduit wiring system with rigid steel and non-metallic conduits shall be as per **6.9.1** to **6.9.3**.

6.9.1 *Surface Conduit Wiring System with Rigid Steel Conduits*

a) *Type and size of conduit* — All conduit pipes shall conform to accepted standards [D-2(46)], finished with galvanized or stove enamelled surface. All conduit accessories shall be of threaded type and under no circumstance pin grip type or clamp type accessories shall be used. No steel conduit less than 16 mm in diameter shall be used. The number of insulated conductors that can be drawn into rigid steel conduit is given in Table 1A.

b) *Bunching of cables* — Unless otherwise specified, insulated conductors of a.c. supply and d.c. supply shall be bunched in separate conduits. For lighting and small power outlet circuits phase segregation in separate conduits is recommended.

c) *Conduit joints* — Conduit pipes shall be joined by means of screwed couplers and screwed accessories only {*see* accepted standard [D-2(47)]}. In long distance straight runs of conduit, inspection type couplers at reasonable intervals shall be provided or running threads with couplers and jam-nuts (in the latter case the bare threaded portion shall be treated with anti-corrosive preservative) shall be provided. Threaded portion on conduit pipes in all cases shall be between 11 mm and 27 mm long sufficient to accommodate pipes to full threaded portion of couplers or accessories. Cut ends of conduit pipes shall have no sharp edges or any burrs left to avoid damage to the insulation of conductors while pulling them through such pipes.

d) *Protection against dampness* — In order to minimize condensation or sweating inside the tube, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects as far as possible.

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e) *Protection of conduit against rust* — The outer surface of the conduit pipes, including all bends, unions, tees in the conduit system shall be adequately protected against rust particularly when such system is exposed to weather. In all cases, no bare threaded portion of conduit pipe shall be allowed unless such bare threaded portion is treated with anti-corrosive preservative or covered with suitable plastic compound.

f) *Fixing of conduit* — Conduit pipes shall be fixed by heavy gauge saddles, secured to suitable wood plugs or other plugs with screws in an approved manner at an interval of not more than 1 m, but on either side of couplers or bends or similar fittings, saddles shall be fixed at a distance of 300 mm from the centre of such fittings. Conduit fittings shall be avoided as far as possible on conduit system exposed to weather; where necessary, solid type fittings shall be used.

g) *Bends in conduit* — All necessary bends in the system including diversion shall be done by bending pipes; or by inserting suitable solid or inspection type normal bends, elbows or similar fittings; or fixing cast iron, thermoplastic or thermosetting plastic material inspection boxes; whichever is more suitable. Radius of such bends in conduit pipes shall be not less than 75 mm. No length of conduit shall have more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

h) *Outlets* — All outlets for fittings, switches, etc, shall be boxes of suitable metal or any other approved outlet boxes for either surface mounting or flush mounting system.

j) *Conductors* — All conductors used in conduit wiring shall preferably be stranded. No single-core cable of nominal cross-sectional area greater than 130 mm^2 shall be enclosed along in a conduit and used for alternating current.

k) *Erection and earthing of conduit* — The conduit of each circuit or section shall be completed before conductors are drawn in. The entire system of conduit after erection shall be tested for continuity using a fish wire and permanently connected to earth conforming to the requirements. Gas or water pipes shall not be used as earth medium. If conduit pipes are liable to mechanical damage they shall be adequately protected.

m) Inspection type conduit fittings, such as inspection boxes, draw boxes, bends, elbows and tees shall be so installed that they can remain accessible for such purposes withdrawal of existing cables or of new cables.

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Table 1A Maximum Permissible Number of Single-Core Copper Cables up to and Including 1 100 V that can be Drawn into Rigid Steel Conduits

[*Clauses* 6.6.1(a) *and* 6.9.1(a)]

Sl No.	Size of Cable	Size of Conduit mm											
	Nominal Cross-Sectional Area	20		25		32		40		50		63	
		Number of Cables, *Max*											
	mm^2	S	B	S	B	S	B	S	B	S	B	S	B
(1)	(2)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
i)	1.5	7	5	12	10	20	14	–	–	–		–	–
ii)	2.5	6	5	10	8	18	12	–	–	–	–	–	–
iii)	4	4	3	7	5	12	10	–	–	–	–	–	–
iv)	6	3	2	6	5	10	8	–	–	–	–	–	–
v)	10	2	–	4	3	6	5	8	6	–	–	–	–
vi)	16	–	–	2	–	4	3	7	6	–	–	–	–
vii)	25	–	–	–	–	3	2	5	4	8	6	9	7
viii)	35	–	–	–	–	2	–	4	3	7	5	8	6

NOTES

1 The table shows the maximum capacity of conduits for the simultaneously drawing of cables. The columns headed S apply to runs of conduit which have distance not exceeding 4.25 m between draw-in boxes and which do not deflect from the straight by an angle of more than 15. The columns headed B apply to runs of conduit which deflect from the straight by an angle of more than 15.

2 In case an inspection type draw-in box has been provided and if the cable is first drawn through one straight conduit, then through the draw-in box and then through the second straight conduit, such systems may be considered as that of a straight conduit even if the conduit deflects through the straight by more than 15.

3 Conductor sizes for cables and wires above and including 2.5 mm^2 core size shall be multi-stranded.

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6.9.2 *Recessed Conduit Wiring System with Rigid Steel Conduit*

Recessed conduit wiring system shall be laid in concrete in the roof slab and in walls, and shall comply with all the requirements for surface conduit wiring system specified in **6.9.1(a)** to **6.9.1(k)** and also conform with the requirements specified under:

a) *Making of chase* — The chase in the wall shall be neatly made and be of ample dimensions to permit the conduit to be fixed in the manner desired. In the case of buildings under construction, chases shall be provided in the wall, ceiling, etc at the time of their construction and shall be filled up neatly after erection of conduit and brought to the original finish of the wall. In case of exposed brick/rubble masonry work, special care shall be taken to fix the conduit and accessories in position along with the building work.

b) *Fixing of conduit in chase* — The conduit pipe shall be fixed by means of staples or by means of saddles not more than 600 mm apart. Fixing of standard bends or elbows shall be avoided, as far as practicable and all curves maintained by bending the conduit pipe itself with a long radius which will permit easy drawing-in of conductors. All threaded joints of rigid steel conduit shall be treated with preservative compound to secure protection against rust.

c) *Inspection boxes* — Suitable inspection boxes shall be provided to permit periodical inspection and to facilitate removal of wires, if necessary. These shall be mounted flush with the wall. Suitable ventilating holes shall be provided in the inspection box covers. The minimum sizes of inspection boxes shall be 75 mm × 75 mm.

d) *Types of accessories to be used* — All outlet, such as switches and wall sockets, may be either of flush mounting type or of surface mounting type, as given below:

   1) *Flush mounting type* — All flush mounting outlets shall be of cast-iron or mild steel boxes with a cover of insulating material or shall be a box made of a suitable insulating material. The switches and other outlets shall be mounted on such boxes. The metal box shall be efficiently earthed with conduit by a suitable means of earth attachment.

   2) *Surface mounting type* — If surface mounting type outlet box is specified, it shall be of any suitable insulating material and outlets mounted in an approved manner.

The switches/socket-outlets shall have adequate IP rating for various utilizations.

6.9.3 *Conduit Wiring System with Rigid Non-Metallic Conduits*

Rigid non-metallic conduits are used for concealed conduit wiring. This type of wiring system is more preferred for coastal areas.

6.9.3.1 *Type and size*

All non-metallic conduits used shall conform to accepted standards [D-2(45)] and shall be used with the corresponding accessories {*see* accepted standards [D-2(48)]}. The conduits shall be circular or rectangular cross sections.

6.9.3.2 *Bunching of cables*

Conductors of a.c. supply and d.c. supply shall be bunched in separate conduits. For lighting and small power outlet circuits phase segregation in separate circuits is recommended. The number of insulated cables that may be drawn into the conduits are given in Table 1B. In Table 1B, the space factor does not exceed 40 percent of the available space.

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Table 1B Maximum Permissible Number of 250 V Grade Single-Core Copper Cables that may be Drawn into Rigid Non-Metallic Conduits

[*Clauses* 6.6.1(a) *and* 6.9.3.2]

Sl No.	Sizes of Cable	Size of Conduit, mm				
	Nominal Cross-Sectional Area mm^2	20	25	32	40	50
		Number of Cables, *Max*				
(1)	(2)	(5)	(6)	(7)	(8)	(9)
i)	1.5	6	10	14	–	–
ii)	2.5	5	10	14	–	–
iii)	4	3	6	10	14	–
iv)	6	2	5	9	11	–
v)	10	–	4	7	9	–
vi)	16	–	2	4	5	12
vii)	25	–	–	2	2	6
viii)	35	–	–	–	2	5

6.9.3.3 *Conduit joints*

Conduits shall be joined by means of couplers. Where there are long runs of straight conduit, inspection type couplers shall be provided at intervals. For conduit fittings and accessories reference may be made to the accepted standard [D-2(48)].

6.9.3.4 *Fixing of conduit in chase*

The conduit pipe shall be fixed by means of stapples or by means of non-metallic saddles placed at not more than 600 mm apart or by any other approved means of fixing. Fixing of standard bends or elbows shall be avoided, as far as practicable and all curves shall be maintained by bending the conduit pipe itself with a long radius which will permit easy drawing in of conductors. At either side of bends, saddles/stapples shall be fixed at a distance of 150 mm from the centre of bends.

6.9.3.5 *Inspection boxes*

Suitable inspection boxes to the nearest minimum requirements shall be provided to permit periodical inspection and to facilitate replacement of wires, if necessary. The inspection/junction boxes shall be mounted flush with the wall or ceiling concrete. Where necessary deeper boxes of suitable dimensions shall be used. Suitable ventilating holes shall be provided in the inspection box covers, where required.

6.9.3.6 The outlet boxes such as switch boxes, regulator boxes and their phenolic laminated sheet covers shall be as per requirements of **6.9.1**(h). They shall be mounted flush with the wall.

6.9.3.7 *Types of accessories to be used*

All accessories such as switches, wall sockets, etc, may be either flush mounting type or of surface mounting type.

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6.9.3.8 *Bends in conduits*

Wherever necessary, bends or diversions may be achieved by bending the conduits or by employing normal bends, inspection bends, inspection boxes, elbows or similar fittings. Heat may be used to soften the conduit for bending and forming joints in case of plain conduits.

6.9.3.9 *Outlets*

In order to minimize condensation or sweating inside the conduit, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects.

6.10 Cable Trunking/Cable Ways

Cable trunking and ducting system of insulating material are used for laying of cables and wire both in floor and ceiling. The maximum number of cables with sizes that can be drawn in a cable trunking or ducting shall be limited to a maximum of 40 percent of space available.

7 FITTINGS AND ACCESSORIES

7.1 General

This covers the requirements of fittings and accessories which are normally used in fixed wiring installations of buildings. This includes type of light fixtures which are typically selected based on the requirement of light at a particular location and fans based on the requirement of air movement for the purpose of comfort of occupants, especially during hot summer months, and also of exhaust fans to maintain the enclosed area with fresh outside air so that a hygienic and comfortable atmosphere is created inside the enclosed area. For buildings other than small dwellings the requirement of lighting is normally selected based on the illumination level for different areas and that of the fans based on the type of occupancy and different comfort levels. The fittings and accessories shall comply with relevant Indian Standards and ISI marked (where mandated).

7.2 Ceiling Roses and Similar Attachments

A ceiling rose or any other similar attachments shall only be used as a final terminating point in single phase and voltage not exceeding 250 V.

Normally, only one flexible cord shall be attached to a ceiling rose. Specially designed ceiling roses shall be used for multiple pendants.

A ceiling rose shall not embody fuse terminal as an integral part of it.

7.3 Socket-Outlets and Plugs

There are two types of socket-outlets, one for the use of light loads not exceeding 100 W which are designated as 6 A and is normally provided with 3 pin socket-outlets in which both 3 pin plug tops and 2 pin appliances like mobile chargers can be used. This type of socket-outlet shall normally be kept on the switch board as well as individually at convenient heights not exceeding 1.2 m from the floor level based on requirement.

The second type of socket-outlets is normally of 16 A capacity and are provided with 6 pin socket-outlets in which 3 pin plug tops of 16 A capacity as well as smaller type 3 pin plug tops of about 10 A capacity can be used. These types of socket-outlets are recommended for use in respect of domestic appliances not exceeding 2 kW. These are normally placed independently at suitable heights and also above kitchen slab at appropriate level based on the requirement (*see* Fig. 4).

Each socket-outlet shall be controlled by a switch which shall preferably be located immediately adjacent thereto or combined therewith. The switch controlling the socket-outlet shall be on the live side of the line.

In respect of individual air conditioners, it is recommended to use MCB controlled socket-outlet so that proper overload protection can be maintained based on the capacity of air conditioner used which may not exceed 3 TR.

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In case of public buildings, to facilitate operation of switches/socket-outlets by persons with disabilities and the elderly, these shall be installed at an accessible height for reaching and operating, between 800 mm and 1 100 mm above floor level and shall be located at a minimum of 600 mm with a preference of minimum 700 mm from any internal corner. They shall be so fixed so as to be away from danger of mechanical injury.

Suitable earth wire shall be drawn along with the power wiring for the respective socket-outlets so that the third pin is effectively earthed to ensure the equipment connected to the respective socket-outlet is properly earthed at the time of use.

NOTES

1 In situations where a socket-outlet is accessible to children, it is necessary to install an interlocked plug and socket or alternatively a socket-outlet which automatically gets screened by the withdrawal of plug. In industrial premises socket-outlet of rating 20 A and above shall preferably be provided with interlocked type switch.

2 As an exception, electrical wall socket-outlets, telephone points and TV sockets can be located at a minimum height of 400 mm above floor level.

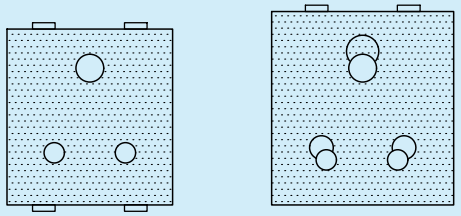

FIG. 4 6 A 3 PIN, 6/16 A COMBINED SOCKET-OUTLET

7.4 Light Fittings

7.4.1 *Lamp Holders*

There are different types of lamp holders namely pendant type, angle bracket type and batten mounted type lamp holders, each of which is further categorized as pin type and different sizes of screw type. These lamp holders are used in combination with different type of lamp shades to form ceiling suspended light fittings, wall mounted bracket type light fittings and chandelier type light fittings. These fittings can hold any of the GLS lamps of different wattage or CFL lamps and even the LED bulbs.

A switch shall be provided for control of every lighting fitting or a group of lighting fittings in the live wire. The neutral wire shall normally be looped in a light circuit. The earth wire of each point shall be used to earth the lamp holder or any such metallic point in the light fitting which does not carry electric current. Where control at more than one point is necessary, either two way or intermediate switches may be provided as required.

Shade made of flammable material shall not form a part of lighting fittings unless such shade is well protected against all risks of fire.

General and safety requirements for electrical lighting fittings shall be in accordance with provisions contained in good practice [D-2(1)] and relevant Indian Standards.

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7.4.2 *Lamps*

All bare lamps including light fittings unless otherwise required and suitably protected, shall be hung at a height of not less than 2.4 m above the finished floor level. All electric lamps and accessories shall conform to relevant Indian Standards.

7.4.3 *Outdoor Lighting*

External street light fittings, bollards light fittings, bulk-head fittings, etc shall be weatherproof to prevent the ingress of moisture and dust effectively.

7.5 Fans, Regulators and Clamps

7.5.1 *Ceiling Fans*

Ceiling fans, including their suspension, shall conform to the relevant Indian Standards and good practice [D-2(1)]. There are two main types of ceiling fans available, the conventional type regular a.c. fans and the brushless direct current (BLDC) type fans which consume less power but may be expensive. Selection of the fans shall be on the basis of following technical parameters:

a) fan sweep, in mm (900/1 050/1 200/1 400/1 500);

b) air delivery, in m^3/min;

c) maximum power input, in w; and

d) service value, in m^3/min/W.

The bottom most point of the ceiling fan shall not be less than 2 400 mm above the finished floor level {*see* good practice [D-2(1)]}.

All ceiling fans shall meet the following requirements:

a) Control of a ceiling fan shall be through its own regulator as well as a switch in series.

b) All ceiling fans shall be wired with normal wiring to ceiling roses or to special connector boxes to which fan rod wires shall be connected and suspended from hooks or shackles with insulators between hooks and suspension rods. There shall be no joint in the suspension rod. The suspension rod shall be of adequate strength to withstand the dead and impact forces imposed on it. Suspension rods should preferably be procured along with the fan.

c) Fan hooks (clamp) shall be of suitable design according to the nature of construction of ceiling on which these clamps are to be fitted. In all cases fan clamps shall be fabricated from new metal of suitable sizes and they shall be as close fitting as possible. Fan clamps for reinforced concrete roofs shall be buried with the casting of roof and care shall be taken to tie the fan clamp with the reinforcement of the roof slab. Fan clamps for wooden beams shall be of suitable flat iron fixed on two sides of the beam, and according to the size and section of the beam one or two mild steel bolts passing through the beam shall hold both flat irons together. Fan clamps for steel joist shall be fabricated from flat iron to fit rigidly to the bottom flange of the beam. *See also* good practice [D-2(1)]. Care shall be taken during fabrication that the metal does not crack while hammer to shape. Other fan clamps shall be made to suit the position, but in all cases, care shall be taken to see that they are rigid and safe.

d) Canopies on top and bottom of suspension rods shall effectively conceal suspensions and connections to fan motors, respectively.

e) The lead-in-wire shall be of nominal cross-sectional area, not less than 1.5 mm^2 copper and shall be protected from abrasion.

f) Unless otherwise specified, the clearance between the bottom most point of the ceiling fan and the floor shall be not less than 2.4 m. The minimum clearance between the ceiling and the plane of the blades shall be not less than 300 mm.

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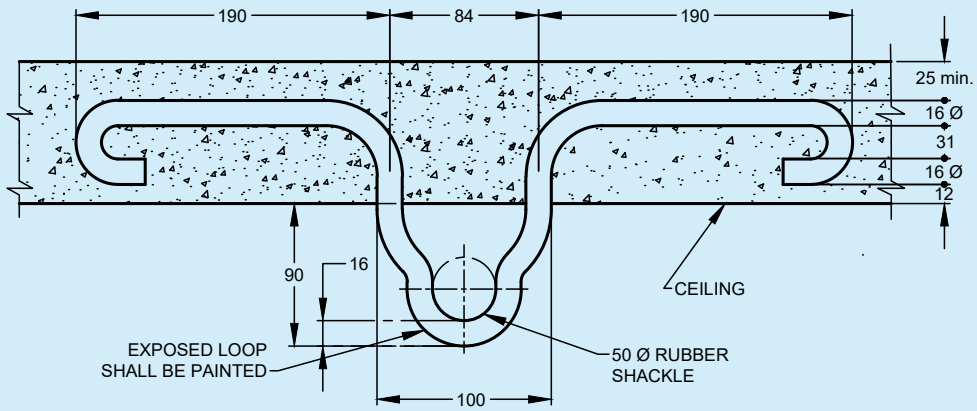
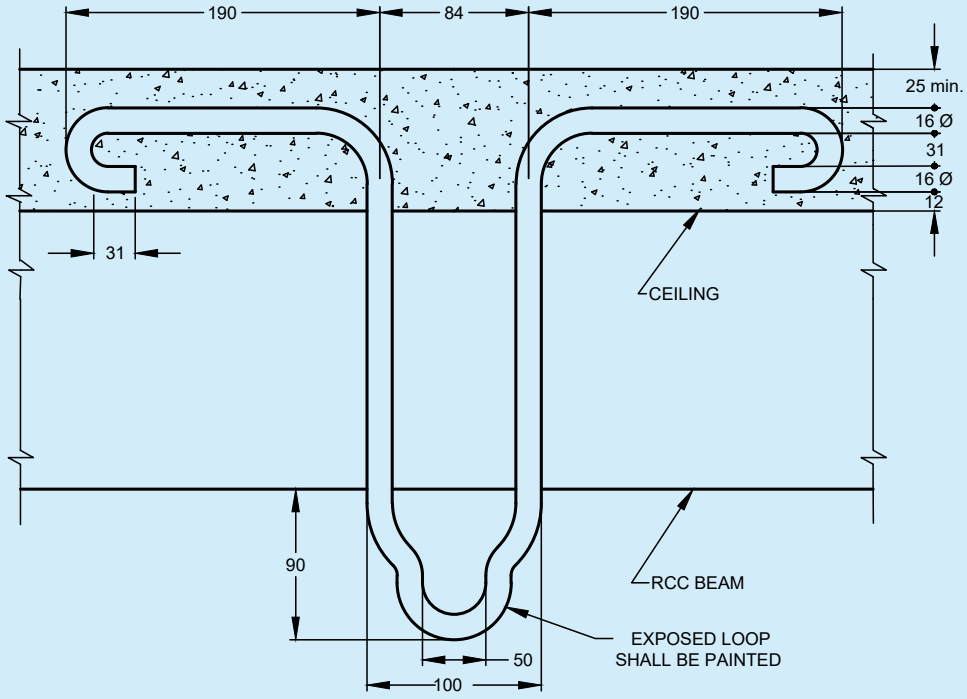
A typical arrangement of a fan clamp is given in Fig. 5.

NOTE — All fan clamps shall be so fabricated that fans revolve steadily.



5A SLAB



5B SLAB WITH BEAM

ALL DIMENSIONS IN MILLIMETRES.

NOTES
1 RCC SLAB STEEL REINFORCEMENT NOT SHOWN.
2 FAN CLAMP SHALL BE PLACED IN POSITION SUCH THAT ITS PROJECTING ARMS ARE IN THE LINE OF LENGTH OF BEAM.

FIG. 5 TYPICAL DESIGN OF FAN CLAMPS

7.5.2 *Exhaust Fans*

Exhaust fans are necessary for spaces, such as community toilets, kitchens and canteens and godowns to provide the required number of air changes (*see* Part D 'Building Services, Section 3 Air Conditioning, Heating and

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Mechanical Ventilation' of this NBCS). Since the exhaust fans are located generally on the outer walls of a room, appropriate openings in such walls shall be provided for, in the planning stage.

NOTE — Exhaust fan requirement is based on the recommended air changes (*see* Part D 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of this NBCS). Reference should also be made to Part F 'Fire and Life Safety' of this NBCS for exhaust fan requirements for smoke extraction.

Selection of exhaust fan can be made on the basis of:

a) blade sweep size in mm;

b) air changes in CFM or m^3/min; and

c) power input in W.

For fixing of an exhaust fan, a circular hole shall be provided in the wall to suit the size of the frame which shall be fixed by means of rag-bolts embedded in the wall. The hole shall be neatly plastered with cement and brought to the original finish of the wall. The exhaust fan shall be connected to exhaust fan point which shall be wired as near to the hole as possible by means of a flexible cord, care being taken that the blades rotate in the proper direction.

7.5.3 *Air Circulation* (*Ceiling Fans*)

7.5.3.1 Proper air circulation of rooms and halls of residential buildings/office can be achieved by suitable selection of ceiling fans based on their size and air displacement. In big halls, this can be done either by larger number of smaller fans or smaller number of larger fans. The economics of the system as a whole should be a guiding factor along with the bays of the building. For design guidelines in this regard, reference shall be made to Part D 'Building Services, Section 1 Lighting and Natural Ventilation' of this NBCS and good practice [D-2(1)].

7.5.3.2 Where ceiling fans are provided, the bay sizes of a building, which control fan point locations, play an important part. Fans of 1 200 mm/1 400 mm sweep normally cover an area of 9 m^2 to 10 m^2, for every part of a bay to be served by the ceiling fans, it is necessary that the bays shall be so designed that full number of fans can be suitably located for the bay, otherwise it will result in ill-ventilated pockets. In general, fans in long halls may be spaced at 3 m in both the directions. If building modules do not lend themselves for proper positioning of the required number of ceiling fans, other fans such as, air circulators or bracket fans will have to be employed for the areas uncovered by the ceiling fans. For this, suitable electrical outlets shall be provided although result may be disproportionate to cost on account of fans.

7.5.3.3 High volume low speed (HVLS) fans are generally ceiling fans having more number of blades which move slowly and distribute large amounts of air at low rotational speed. These are installed in very large areas like airports, hangers, warehouses and in commercial spaces like malls, etc, which have very big area with large movement of people. These are primarily recommended for bigger areas from the consideration of energy conservation.

7.5.3.4 Nowadays BLDC type fans having low wattage and higher air displacement are available with remote control operation. Choice of the same may be decided based on their operational efficiency in relation to cost.

7.6 Interchangeability

Similar parts of all switches, lamp holders, distribution fuse-boards, ceiling roses, brackets, pendants, fans and all other fittings shall be so chosen that they are of the same type and interchangeable in each installation.

7.7 Equipment

7.7.1 Electrical equipment which form integral part of wiring intended for switching or control or protection of wiring installations shall conform to the relevant Indian Standards, wherever they exist.

7.7.2 Positioning of fans and light fittings shall be chosen to make these effective without causing shadows and stroboscopic effect on the working planes.

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8 EARTHING

8.1 General

8.1.1 Earthing is an important part of any electrical installation. It is essential to provide safety of human beings from electrical shock. It is also necessary to prevent fire from electrical fault and to operate the protective devices to disconnect power during an electrical fault and to ensure safe operation of the equipment. Earthing is therefore meant to divert the fault current to the protective earth conductor without causing any major damage to the installations. Thus earthing/earth conductor (also known as a ground conductor or earthing conductor) is a safety feature in electrical systems which provides a low-impedance path to the earth and helps to prevent hazardous voltages from appearing on equipment ensuring that faults are cleared quickly. In principle, it acts as a safeguard, protecting both people and equipment from electrical hazards. With the proliferation in electrical/electronic gadgets and greater dependency on voice and data communication systems, proper and effective earthing or grounding is very important. Earthing is also necessary for safe dissipation of the effects of lightning strikes from the buildings and its contents, including from sensitive equipment. All works under earthing shall comply with the provisions of good practice [D-2(1)] and [D-2(11)] apart from other Indian Standards, where applicable.

8.1.2 Different types of earth electrodes and different types of earthing systems are available. For low voltage and high voltage systems which apply to almost all electrical systems of buildings, the common earthing system followed is with the neutral solidly earthed at the source. This system requires that there is always a protective earth continuity conductor running all through the system and all metal parts of electrical appliances connected to an electrical system are connected to the earth continuity conductor. The exception to this system is the double insulated appliances which are connected to the line and neutral and operate on low voltage (single phase) and are also of low power consumption. All appliances (other than double insulated devices) use the earthing through the earth continuity conductor. Single phase appliances use a 3 wire connection with line (live wire), neutral (return path wire) and the earth-wire. Three phase appliances use a connection with 4 wires for a load which does not require a neutral connection or use a 5 wire connection if the appliance requires a neutral connection. Care should be taken to ensure that the earthing system, the protective earth conductor and the earthing pin of the socket-outlets are not disconnected.

8.1.3 Different earthing systems have features which are suitable for different applications. Earthing system adopted should be so selected so as to match with the type of load, protection device, application, degree of reliability, etc. For classification of electrical systems based on the relationship of the source and of exposed-conductive parts of the installation, to earth, *see* **2.1.185**.

8.1.4 *System Earthing*

Earthing of system is designed primarily to preserve the security of the system by ensuring that the potential on each conductor is restricted to a value consistent with the level of applied insulation. It is equally important that earthing should ensure efficient and fast operation of protective gear in the case of earth faults.

a) *TN system* — A system having one or more points of the source of energy directly earthed, the exposed conductive-parts of the installation being connected to that point by protective conductors. This is divided into TN-C system, TN-S system and TN-C-S system which are described below:

   1) *TN-C system* — A system in which neutral and protective conductors are combined in a single conductor throughout the system. This is normally provided at their source by the electrical supply company in single phase two wire or three phase four wire system.

   2) *TN-S system* — A system having separate neutral and protective conductor throughout the system. This is provided by the consumer at the point of receipt of electric supply.

   3) *TN-C-S system* — A system in which neutral and protective conductors are combined in a single conductor in part of the system. It involves a shared neutral and earth conductor from the source up to the consumer's intake, where it is then separated into individual neutral (N) and protective earth (PE) conductors.

b) *TT system* — A system having one point of the source of energy directly earthed, the exposed-conductive-parts of the installation being connected to the earth electrodes electrically independent of the earth electrodes of the source.

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c) *IT system* — A system in which all live parts are isolated from earth or point connected to earth through high impedance. The exposed-conductive-parts of the electrical installation are earthed independently or collectively to the earthing of the system. This system is mostly used in hospitals, sensitive areas and places where stable power supply is essential for critical loads.

8.2 Selection and Design of Earthing System

8.2.1 Earthing shall generally be carried out in accordance with the requirements of Regulation 18, 43 and 50 of *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 (*see* Annex B), relevant Indian Standards and the relevant regulations of the Electricity Supply Authority concerned. All materials, fittings, etc used in earthing shall conform to relevant Indian Standard specification.

8.2.2 Conductors and earth electrodes in an earthing system shall be so designed and constructed that in normal use their performance is reliable and without danger to persons and surrounding equipment. Earthing system shall be designed so as to have touch potential, step potential and transfer potential within the specified limits as indicated in good practice [D-2(18)] and [D-2(11)] as amended up to date. The choice of a material depends on its ability to match the particular application requirement. The requirements for earthing arrangements are intended to provide a connection to earth which:

a) is reliable and suitable for the protective requirements of the installation;

b) can carry earth fault currents and protective conductor currents to earth without danger from thermal, thermo-mechanical and electromechanical stresses and from electric shock arising from these currents;

c) if relevant, is also suitable for functional requirements; and

d) is suitable for the foreseeable external influences as provided in good practices [D-2(1)], [D-2(18)], [D-2(11)] and IEC 60364-5-51 : 2005 'Electrical installations of buildings — Part 5-51: Selection and erection of electrical equipment — Common rules', for example, mechanical stresses and corrosion.

8.2.3 The main earthing system of an electrical installation shall consist of:

a) an earth electrode (electrode can be vertical rod/pipe/buried plate or an earth mat with several vertical installations or a ring earthing strip/conductor);

b) a main earthing wire;

c) main earthing terminal (MET), an earth bar (located on the main switchboard for small installation and installed in the wall/room in case of large industrial electronic installations) for the connection of the main earthing wire, protective earthing wires and/or bonding wires within the installation; and

d) a removable link, which effectively disconnects the neutral bar from the earth bar.

NOTE — The requirements of (c) and (d) above shall be carried out by a licensed electrician as part of the switchboard installation.

8.2.4 The main earthing wire connection shall:

a) be mechanically and electrically sound;

b) be protected against damage, corrosion, and vibration;

c) not place any strain on various parts of the connection;

d) not damage the wire or fittings; and

e) be secured at the earth electrode.

8.2.4.1 The main earthing wire termination shall be readily accessible at the earth electrode except for **8.2.22**. As far as possible, all earth connections, except exothermically welded, shall be visible for inspection.

8.2.5 Consideration shall be given to the earthing arrangements where currents with high frequencies are expected to flow {*see* good practice [D-2(18)] and IEC 60364-4-44 : 2007 'Low-voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances'}.

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8.2.6 Protection against electric shock {*see* good practice [D-2(18)] and IEC 60364-4-41: 2005 'Low-voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock'}, shall not be adversely affected by any foreseeable change of the earth electrode resistance (for example, due to corrosion, drying or freezing).

8.2.7 Where the supply to an installation is at high or extra high voltage, requirements concerning the earthing arrangements of the high or extra high voltage supply and of the low-voltage installation shall also comply with provisions of good practice [D-2(18)] and IEC 60364-4-44 : 2007 'Low-voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances'.

8.2.8 A permanent fitting (like a screwed-down label, or one that can be threaded onto the cable) shall be used at the connection point that is clearly marked with the words: 'EARTHING LEAD — DO NOT DISCONNECT' or 'EARTHING CONDUCTOR — DO NOT DISCONNECT'.

8.2.9 All low voltage, three phase equipment shall be earthed by two separate and distinct connections with earth. In case of single phase equipment, single distinct earth connection is sufficient. The contact area of earth conductor/plate shall be determined in accordance with good practice [D-2(11)].

8.2.9.1 The 415/240 V, 4 wire, 3 phase systems are normally operated with the neutral solidly earthed at source. At low voltage, the Central Electricity Authority regulations require that the neutral be earthed by two separate and distinct connections with earth. Neutral of transformers of 33 kV/415 V, 11 kV/415 V and neutral of low voltage DG sets and similar equipment shall be of the same size as the phase conductor or higher as per relevant Indian Standard.

NOTE — Neutral conductor of half the size of the phase conductor was permitted in earlier installations. But with the proliferation of equipment using non-linear devices and consequent increase in harmonics, the neutral will carry a current more than the notional out-of-balance current and therefore neutral conductor shall be of the same size as the phase conductor.

8.2.10 In the case of high and extra high voltages, the neutral points shall be earthed by not less than two separate and distinct connections to earth, each having its own electrode at the generating station or substation and may be earthed at any other point, provided no interference is caused by such earthing. The neutral may be earthed through suitable impedance. Neutral earthing conductor shall be sized as to have a current carrying capacity not less than the phase current.

8.2.11 For industrial/commercial installations having a transformer within the facility, soil resistivity of the place of installation shall be measured and recorded {*see* good practice [D-2(11)]}. For the adopted type of earth electrode configuration, earth fault impedance of the configuration shall be calculated and recorded {*see* good practice [D-2(11)]}.

8.2.12 It is recommended that a drawing showing the main earth connection and earth electrodes be prepared for each installation.

8.2.13 Earth system shall be so devised that the testing of individual earth electrode is possible. It is recommended that the value of any earth system resistance shall be such as to conform to the degree of shock protection desired. For measuring purposes, the joint shall be capable of being opened with the aid of a tool. In normal use it shall remain closed. Inclusion of online earth monitoring system with real time earthing grid resistance and integrity measurement at site level can be considered for buildings which house lot of sensitive systems and also number of electronic devices to ensure human safety and equipment protection.

8.2.14 Conductors, other than live conductors and any other parts intended to carry a fault current, shall be capable of carrying that current without attaining an excessive temperature.

8.2.15 No addition to the current carrying system, either temporary or permanent, shall be made which will increase the maximum earth fault current or its duration until it has been ascertained that the existing arrangement of earth electrodes, earth busbar, etc are capable of carrying the new value of earth fault current which may be obtained by this addition.

8.2.16 No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed conductor or earthed neutral conductor and the live conductors, shall be inserted on any supply system. This,

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however, does not include the case of a switch used in controlling a generator or a transformer or a link for test purposes.

8.2.17 The number of connections along the conductors shall be minimized to reduce potential failure points. The high energy lightning currents can induce significant thermal expansion, if bonding is inadequate and overlap is poor. Also, mechanical connections should be minimized. All conductors used in earthing and lightning protection system should be joined using methods that ensure long-term electrical, mechanical and environmental reliability. Critical connections, especially those below ground or exposed to moisture shall be made using exothermic welding which provides a permanent molecular bond with superior thermal and corrosion resistance. Exothermic welded joints shall conform to the relevant standards.

8.2.18 Earthing associated with current-carrying conductor is normally essential for the function of the system and is generally known as system earthing or functional earthing, while earthing of non-current carrying metal work and conductor is essential for the safety of human life, animals and of property and it is generally known as equipment earthing or equipotential bonding. The requirements for protective purposes shall always take precedence.

8.2.19 *Equipotential Bonding*

Equipotential bonding is through connecting exposed and extraneous conductive parts in a building to the main earthing terminal of the installation by protective bonding conductors. Where such conductive parts originate outside the building, they shall be bonded near their entry point within the building.

It shall be ensured that all exposed metal parts and extraneous conductive parts within a specific area or system are at the same potential. The same is achieved by creating a low resistance path between these conductive parts. Equipotential bonding allows fault currents to flow to earthed conductor without creating dangerous voltage difference that could harm individuals.

Equipotential bonding is used in various settings including buildings, industrial facilities, swimming pools and areas with lightning protection system. In the event of a fault equipotential bonding helps limit touch voltages and ensures that fault currents are safely directed to earth preventing electric shock (*see* Fig. 6).

8.2.20 All earthing systems in a building shall be interconnected at the earth level (ground).

8.2.21 For selection of electrodes for use in corrosive environments, reference shall be made to good practice [D-2(11)].

8.2.22 Test joints are not required in the case of natural down-conductors combined with foundation earth electrodes (*see* Fig. 7).

8.2.23 For computer and other sensitive electronic equipment system in industrial and commercial application, special bonding techniques with isolation transformer can be employed (*see* Fig. 8).

8.2.24 Isolated earthing is unsafe during a transient condition. In unavoidable conditions if isolated earthing is used to reduce potential difference between isolated earthing, earth couplers or isolating spark gaps shall be installed. This will reduce potential difference during a transient condition such as lightning.

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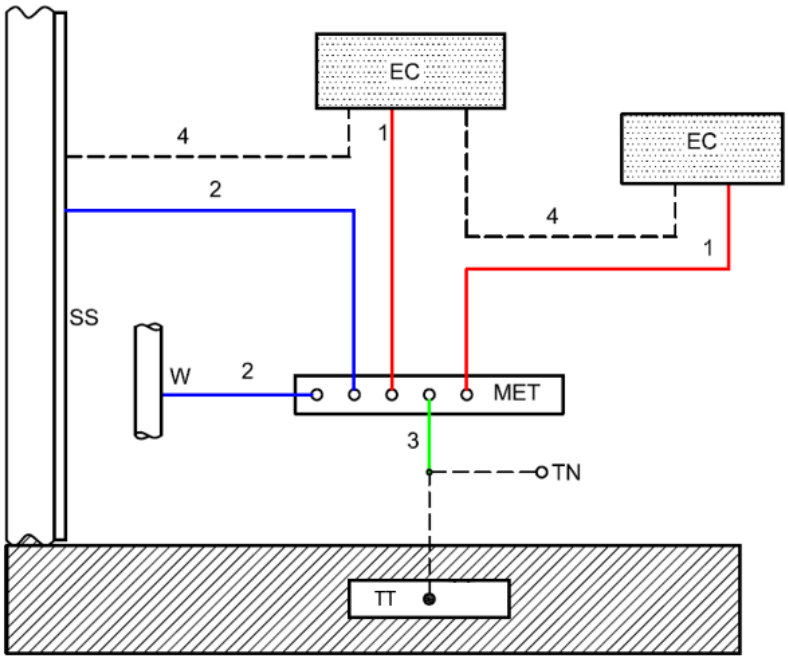

Key

EC	Exposed conductive part (panel board body)
MET	Main earthing terminal
SS	Structural steel (extraneous conductive part)
W	Metallic water pipe (extraneous conductive part)
TT	Earth electrode in a TT or IT system
TN	Other means of earthing in a TN system, for example, connection to earthed point of the power system
1	Circuit protective conductor
2	Main protective bonding conductor
3	Earthing conductor
4	Supplementary protective bonding conductors (additional bonding, if required)
1,2,3,4	Protective conductors

6A ILLUSTRATION OF EARTHING AND PROTECTIVE CONDUCTORS

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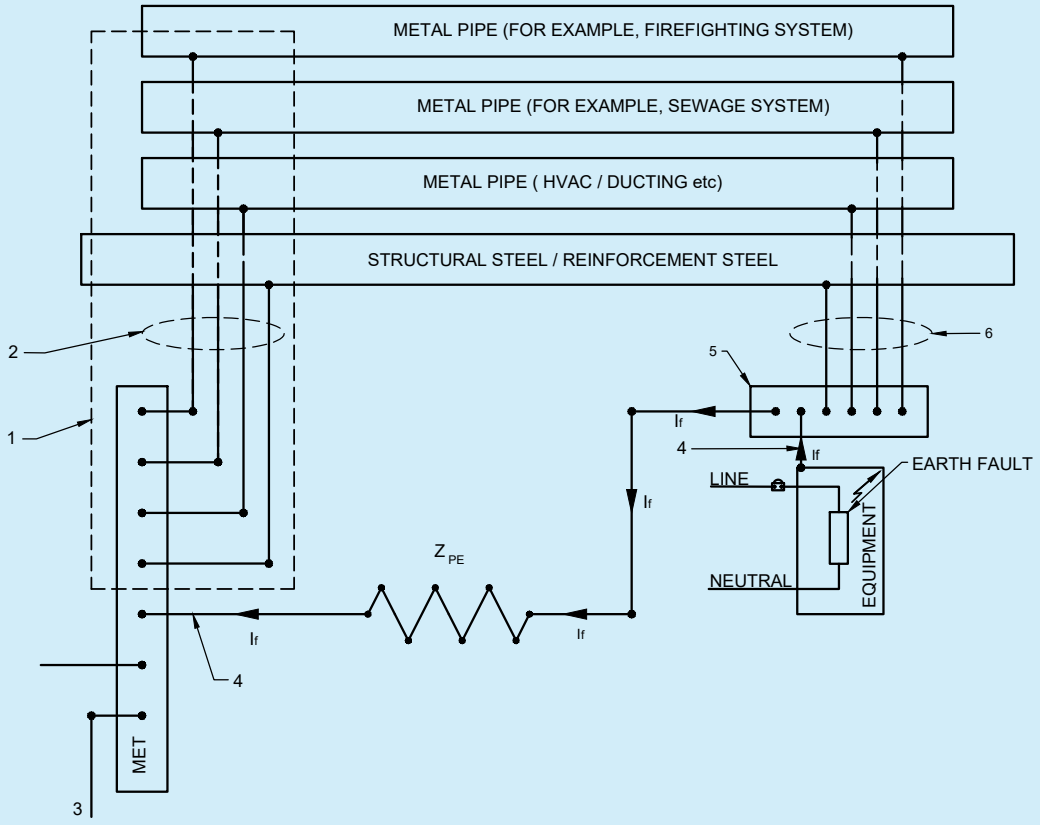

KEY

1 MAIN EQUIPOTENTIAL BONDING (CONNECTION BETWEEN MET AND EXTRANEOUS CONDUCTIVE PARTS).

2 MAIN EQUIPOTENTIAL BONDING CONDUCTOR (INDIVIDUAL CONNECTION, NO LOOPING). IN CASE OF LARGE NUMBER OF EXTRANEOUS CONDUCTIVE PARTS, AN EARTHING TERMINAL CAN BE LOCATED NEAR THE EXTRANEOUS CONDUCTIVE PARTS FOR INDIVIDUAL CONNECTION TO THESE PARTS AND A COMMON CONNECTION FROM THIS EARTHING TERMINAL TO MET. SUITABLE INDICATIONS SHALL BE MADE TO EVERY CONNECTION OF EQUIPOTENTIAL BONDING CONDUCTOR TO AVOID ACCIDENTAL DISCONNECTIONS.

3 EARTHING CONDUCTOR. (CONNECTS MET AND EARTHED POINT OF THE SOURCE IN TN SYSTEM OR MET AND EARTH ELECTRODE IN CASE OF TT/IT SYSTEM). ONE CONNECTION FROM MET IS ALSO NECESSARY TO LPS (IF INSTALLED).

4 PROTECTIVE EARTHING BY PROTECTIVE EARTHING CONDUCTOR (PE).

5 SUPPLEMENTARY EQUIPOTENTIAL BONDING TERMINAL (SEBT) (TO RE DUCE TOUCH VOLTAGE < 50 V).

6 SUPPLEMENTARY EQUIPOTENTIAL BONDING CONDUCTOR.

6B MAIN AND ADDITIONAL PROTECTIVE EQUIPOTENTIAL BONDING

FIG. 6 PROTECTIVE EQUIPOTENTIAL BONDING

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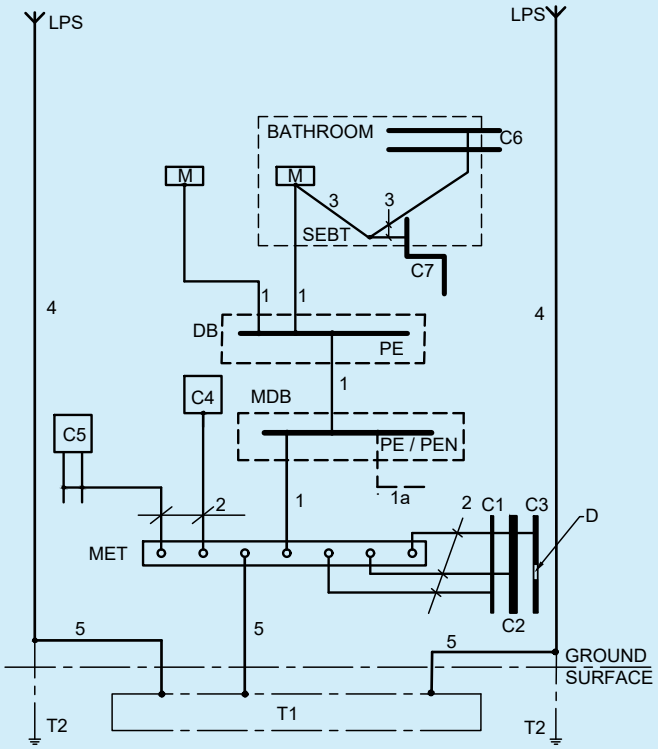

KEY	
C	Extraneous-conductive-part
C1	Water pipe, metal from outside
C2	Waste water pipe, metal from outside
C3	Gas pipe with insulating insert, metal from outside
C4	Air conditioning
C5	Heating system
C6	Water pipe, metal for example in a bathroom
C7	Waste water pipe, metal for example in a bathroom
D	Insulating insert
MDB	Main distribution board
DB	Distribution board
MET	Main earthing terminal
SEBT	Supplementary equipotential bonding terminal
T1	Concrete-embedded foundation earth electrode or soil-embedded foundation earth electrode
T2	Earth electrode for LPS, if necessary
LPS	Lightning protection system (if any)
PE	PE terminal(s) in the distribution board
PE/PEN	PE/PEN terminal(s) in the main distribution board
M	Exposed-conductive-part
1	Protective earthing conductor (PE)
1A	Protective conductor, or PEN conductor, if any, from supplying network
2	Protective bonding conductor for connection to the main earthing terminal
3	Protective bonding conductor for supplementary bonding
4	Down conductor of a lightning protection system (LPS), if any
5	Earthing conductor

NOTES

1 FUNCTIONAL EARTHING CONDUCTORS ARE NOT SHOWN IN FIGURE.
2 WHERE A LIGHTNING PROTECTION SYSTEM IS INSTALLED, THE ADDITIONAL REQUIREMENTS ARE GIVEN IN 11.

FIG. 7 EXAMPLE OF AN EARTHING ARRANGEMENT FOR FOUNDATION EARTH ELECTRODE, PROTECTIVE CONDUCTORS AND PROTECTIVE BONDING CONDUCTORS

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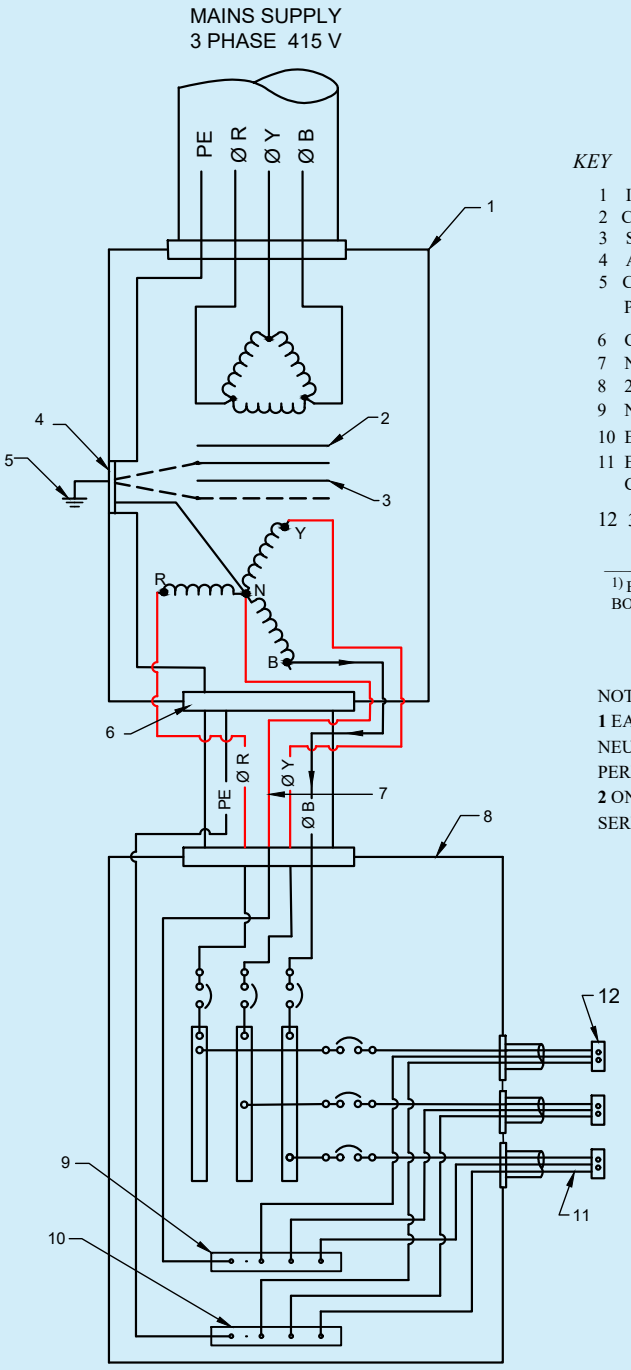

KEY

1 ISOLATION TRANSFORMER
2 CORE
3 SHIELD
4 ALL EARTHING CONNECTIONS MADE AT A POINT
5 CONNECTIONS TO BUILDING STEELS/EARTH PITS/RING EARTHING
6 CONDUIT EARTHING
7 NEUTRAL
8 240/415 VOLT POWER PANEL
9 NEUTRAL BUS[1)]
10 EARTH BUS [1)]
11 EARTH CONNECTION FOR SOCKET/WORK STATION/ COMPUTERS
12 3 PIN SOCKETS WITH ISOLATED EARTH PIN

[1)] BOTH BUSBARS ISOLATED FROM PANEL ENCLOSURE. NO BONDING CONNECTION BETWEEN NEUTRAL AND EARTH.

NOTES

1 EARTH BRANCH CIRCUIT SHALL HAVE A SEPARATE NEUTRAL AND EARTH WIRE. NO DAISY CHAINING PERMITTED.

2 ONLY COMPUTER OR CONTROL SYSTEM SHOULD BE SERVED FROM THIS PANEL.

FIG. 8 RECOMMENDED POWER DISTRIBUTION FOR A COMPUTER AND CONTROL SYSTEM WITH A DELTA/STAR ISOLATION TRANSFORMER

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8.3 Earth Electrodes

The efficacy of any earth electrode depends on its configuration and upon local soil conditions. Number of earth electrodes suitable for the soil conditions and the value of resistance to earth as well as earth fault impedance shall be considered. It is essential that earthing conductors of the earth system shall follow the provisions as per good practice [D-2(1)] read with good practice [D-2(11)] in view of provisions in CEA Regulation No. 43 (*see* Annex B) regarding earth fault loop impedance. Examples of earth electrodes which may be used are:

a) concrete-embedded foundation earth electrode;

b) soil-embedded foundation earth electrode;

c) metallic electrode embedded directly in soil vertically or horizontally (for example rods, wires, tapes, pipes or plates);

d) metal sheath and other metal coverings of cables according to local conditions or requirements;

e) other suitable underground metalwork (for example pipes) according to local conditions or requirements; and

f) welded metal reinforcement of concrete (except pre-stressed concrete) embedded in the earth.

The type, materials and dimensions of earth electrodes shall be selected to withstand corrosion and to have adequate mechanical strength for the intended lifetime. For materials commonly used for earth electrodes, the minimum sizes, from the point of view of corrosion and mechanical strength, when embedded in the soil or in concrete, shall be as specified in Table 2. In the case of lightning protection system, the provisions of **11.6.3** shall also be complied with.

NOTES

1 For corrosion, the parameters to be considered are: the soil *p*H at the site, soil resistivity, soil moisture, stray and leakage a.c. and d.c. current, chemical contamination, and proximity of dissimilar materials.

2 The minimum thickness of protective coating is greater for vertical earth electrodes than for horizontal earth electrodes because of their greater exposure to mechanical stresses while being embedded.

3 Interconnection of dissimilar metals should be avoided in earthing systems and earth conductors to prevent corrosion and loose connections.

Earth electrode either in the form of solid rod, pipe, plate or earth grid should be provided at all premises for providing an earth system. Details of typical pipe, rod and plate earth electrodes are given in Fig. 9 and Fig. 10. Other electrode configurations can be as in Fig. 11 {*see* good practice [D-2(11)]}.

Although electrode material does not affect initial earth resistance, care should be taken to select a material which is resistant to corrosion in the type of soil in which it is used. In case where soil condition leads to excessive corrosion of the electrode and the connections, it is recommended to use either copper/stainless steel or copper coated steel electrode and copper/stainless steel connections. Exothermic welding may also be adopted to have enhanced life and strength to the connection. It is recommended to use similar material for earth electrodes and earth conductors or otherwise precautions should be taken to avoid corrosion. As an alternate, 50 mm GI earth strip and 100 mm CI pipe can be provided as per good practice [D-2(11)].

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Table 2 Minimum Size of Commonly Used Earth Electrodes, Embedded in Soil or Concrete, Used to Prevent Corrosion and Provide Mechanical Strength[1)]

[*Clauses* 8.3, 9.2.2.1(s) *and Fig.* 9]

Sl No.	Material and Surface	Shape	Diameter mm	Cross-Sectional Area mm^2	Thickness mm	Weight of Coating g/m^2	Thickness of Coating/ Sheathing µm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Steel embedded in concrete (bare, hot galvanized or stainless)	Round wire	10	–	–	–	–
		Solid tape or strip	–	75	3	–	–
ii)	Steel hot-dip galvanized[2)]	Strip[3)] or shaped strip/plate – solid plate – lattice plate	–	90	3	500	63
		Round rod installed vertically	16	–	–	350	45
		Round wire installed horizontally	10	–	–	350	45
		Pipe	25	–	2	350	45
		Stranded (embedded in concrete)	–	70	–	–	–
		Cross profile installed vertically	–	(290)	3	–	–
iii)	Steel copper sheathed	Round rod installed vertically	(15)	–	–	–	2 000
iv)	Steel with electro-deposited copper coating	Round rod installed vertically	14	–	–	–	250[6)]
		Round wire installed horizontally	(8)	–	–	–	70
		Strip installed horizontally	–	90	3	–	70
v)	Stainless steel [4)]	Strip[3)] or shaped strip/plate	–	90	3	–	–
		Round rod installed vertically	16	–	–	–	–
		Round wire installed horizontally	10	–	–	–	–

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Table 2 (*Concluded*)

Table 2 Minimum Size of Commonly Used Earth Electrodes, Embedded in Soil or Concrete, Used to Prevent Corrosion and Provide Mechanical Strength[1)]

[*Clauses* 8.3, 9.2.2.1(s) *and Fig.* 9]

Sl No.	Material and Surface	Shape	Diameter mm	Cross-Sectional Area mm^2	Thickness mm	Weight of Coating g/m^2	Thickness of Coating/ Sheathing µm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Pipe	25	–	2	–	–
vi)	Copper	Strip		50	2	–	–
		Round wire installed horizontally	–	(25)[5)] 50	–	–	–
		Round rod installed vertically	(12) 15	–	–	–	–
		Stranded wire	1.7 for individual strands of wire	(25)[5)] 50	–	–	–
		Pipe[6)]	20	–	2	–	–
		Solid plate	–	–	(1.5) 2	–	–
		Lattice plate	–	–	2	–	–

[1)] As per Table B-1 under Part 1 'General and Common Aspects, Section 18: Earthing' of good practice [D-2(1)].

[2)] The coating shall be smooth, continuous and free from flux stains.

[3)] As rolled strip or slit strip with round edges.

[4)] Chromium ≥ 16 percent, nickel ≥ 5 percent, molybdenum ≥ 2 percent, carbon ≤ 0.08 percent.

[5)] Where experience shows that the risk of corrosion and mechanical damage is extremely low, 16 mm^2 can be used.

[6)] This thickness is provided to withstand mechanical damage of copper coating during the installation process. It may be reduced to not less than 100 µm where special precautions to avoid mechanical damage of copper during the installation process (for example, drilling holes or special protective tips) are taken according to the manufacturer's instruction.

NOTES

1 Values in bracket are applicable for protection against electric shock only, while values not in brackets are applicable for lightning protection and for protection against electric shock.

2 Metals inserted inside pipe will not influence in the final earth resistance value.

3 Unprotected ferrous materials are not recommended due to high corrosion (*see* IEC 60364-4-43 : 2008 'Low-voltage electrical installations — Part 4-43: Protection for safety — Protection against overcurrent').

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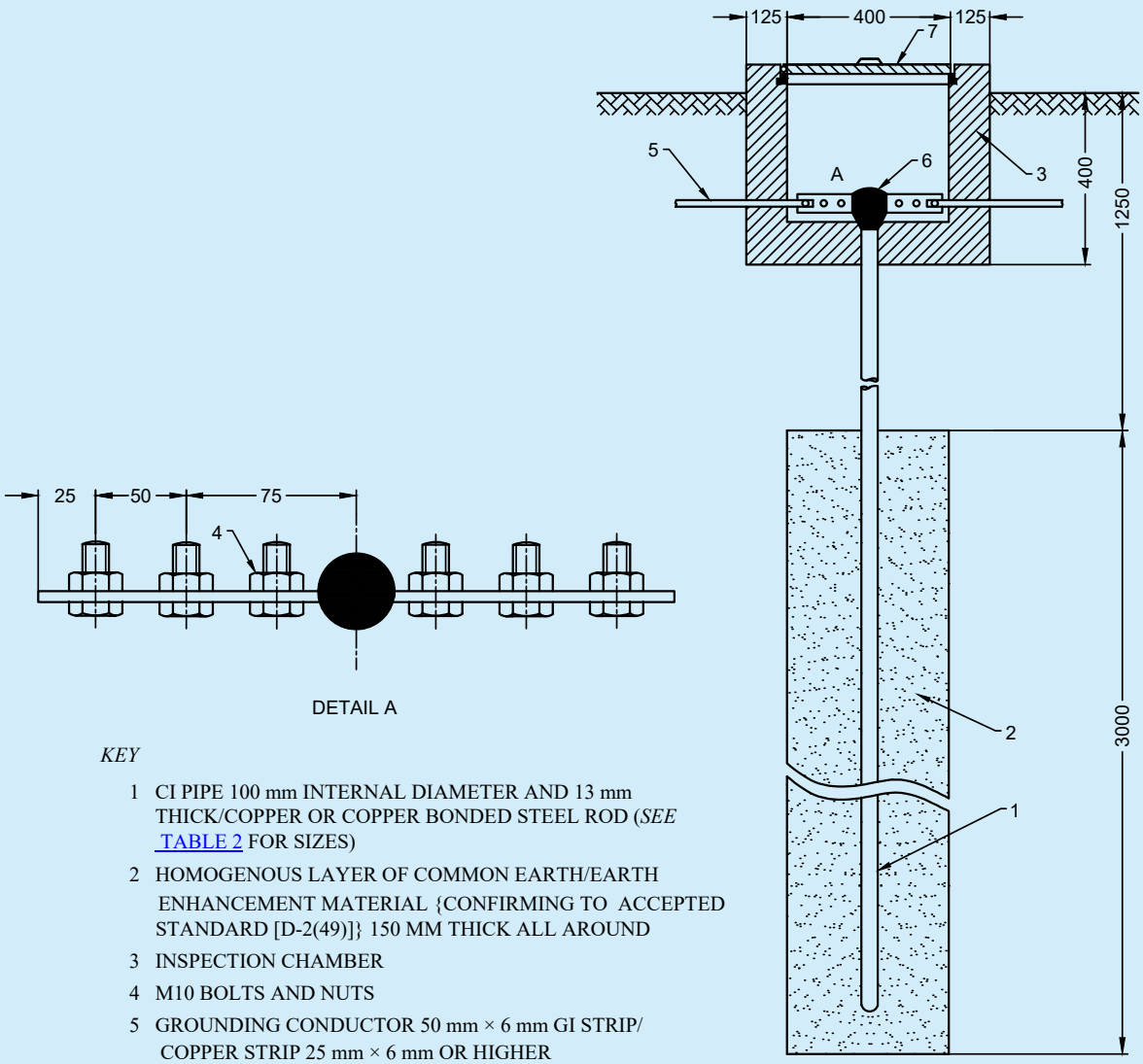

DETAIL A

KEY

1 CI PIPE 100 mm INTERNAL DIAMETER AND 13 mm THICK/COPPER OR COPPER BONDED STEEL ROD (*SEE* TABLE 2 FOR SIZES)
2 HOMOGENOUS LAYER OF COMMON EARTH/EARTH ENHANCEMENT MATERIAL {CONFIRMING TO ACCEPTED STANDARD [D-2(49)]} 150 MM THICK ALL AROUND
3 INSPECTION CHAMBER
4 M10 BOLTS AND NUTS
5 GROUNDING CONDUCTOR 50 mm × 6 mm GI STRIP/ COPPER STRIP 25 mm × 6 mm OR HIGHER
6 EXOTHERMIC WELDING
7 CI LID/COVER

ALL DIMENSIONS IN MILLIMETRES.

NOTE — INSPECTION HOUSING CAN ALSO BE OF FRP MATERIALS WITH CI COVER TESTED ACCORDING TO ACCEPTED STANDARD [D-2(50)].

FIG. 9 TYPICAL ARRANGEMENT OF EARTHING WITH COPPER/COPPER BONDED ELECTRODE WITH EXOTHERMIC WELDING (MAINTENANCE FREE ARRANGEMENT)

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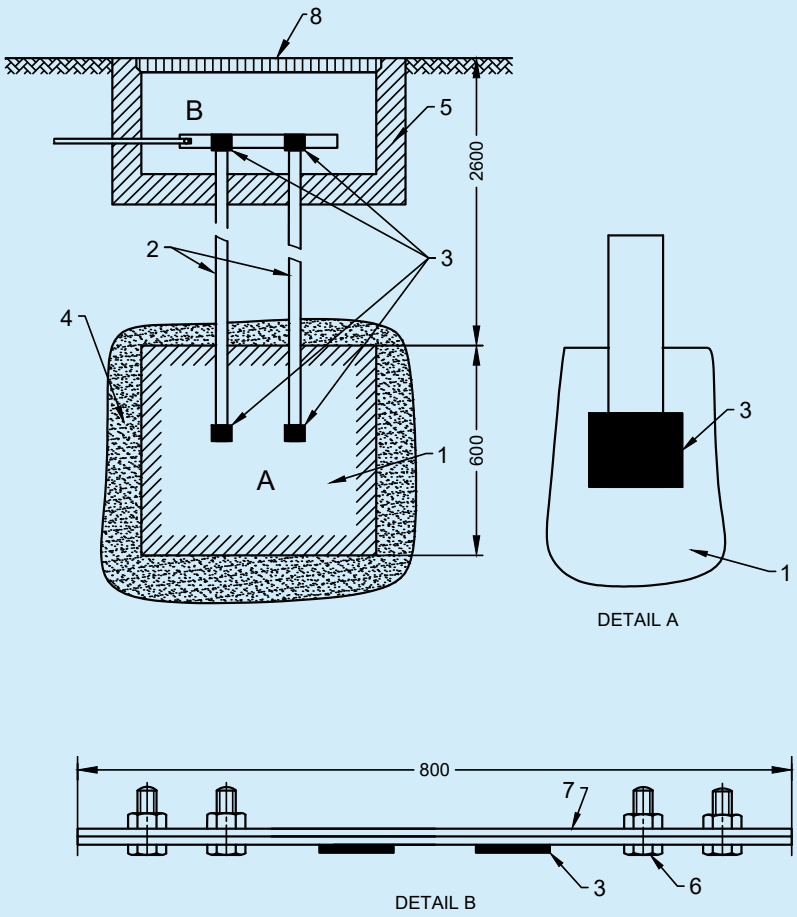

KEY

1 600 mm × 600 mm × 3 mm COPPER PLATE
2 30 mm × 6 mm COPPER STRIP
3 EXOTHERMIC WELDING
4 EARTH ENHANCEMENT MATERIAL {CONFORMING TO ACCEPTED STANDARD [D-2(49)]}
5 INSPECTION CHAMBER
6 M12 × 40 STAINLESS STEEL BOLTS AND NUTS
7 50 mm × 6 mm COPPER STRIP
8 CI LID/COVER

ALL DIMENSIONS IN MILLIMETRES.

NOTE — INSPECTION HOUSING CAN ALSO BE OF FRP MATERIALS WITH CI COVER TESTED ACCORDING TO ACCEPTED STANDARD [D-2(50)].

FIG. 10 TYPICAL ARRANGEMENT OF COPPER ELECTRODE PLATE EARTHING WITH EXOTHERMIC WELDING (MAINTENANCE FREE ARRANGEMENT)

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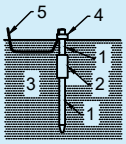
1		THREE RODS AT THE VERTICES OF AN EQUILATERAL TRIANGLE
2		TWO STRIPS SET AT RIGHT ANGLES TO EACH OTHER MEETING AT ONE CORNER
3		VERTICAL ELECTRODES INTERCONNECTED AS A SQUARE
4		THREE STRIPS SET AT 120°, MEETING AT THE STAR POINT ALL OF EQUAL LENGTH
5		FOUR STRIPS SET IN A CRUCIFORM
6		VERTICAL ROD 1 EXTENSIBLE EARTH ROD 2 ROD COUPLING 3 SOIL 4 CONDUCTOR TO ROD CLAMP 5 EARTHING CONDUCTOR

FIG. 11 MISCELLANEOUS ELECTRODE CONFIGURATIONS

8.4 Earth Enhancing Compound

Multiple rods, even in large numbers, may sometime fail to produce an adequately low resistance to earth. This condition arises in installations involving soils of high resistivity. The alternative is to reduce the resistivity of the soil immediately surrounding the earth electrode. To reduce the soil resistivity, artificial soil treatment shall be adopted.

8.4.1 Earthing enhancing compound is a conductive compound producing low resistance of an earth-termination system. These compounds used for artificial treatment of soil shall satisfy the requirements as per accepted standard [D-2(49)].

8.4.2 The material of the earthing enhancing compound shall be chemically inert to subsoil. It shall not pollute the environment. It shall provide a stable environment in terms of physical and chemical properties and exhibit low resistivity. The earthing enhancing compound shall not be corrosive to the earth electrodes being used. The usage of earth enhancing compound shall adhere to the conditions detailed in accepted standard [D-2(49)].

8.4.3 The materials used for artificial treatment should also fulfil toxicity characteristic leaching procedure (TCLP) requirements.

8.4.4 Use of salt [sodium chloride (NaCl)] for artificial treatment of soil should be avoided as it accelerates corrosion of ferrous materials.

8.4.5 The requirement and use of earth enhancing compound shall comply with the provisions as per accepted standard [D-2(49)].

8.5 Earth Electrode Inspection Housings and Earth Electrode Seals

8.5.1 *Earth Electrode Inspection Housing*

Earth electrode inspection housing is the metallic or non-metallic enclosure that houses the down-conductor/earth-termination connection for inspection and testing purposes and consists of a housing and a removable lid. The design of the earth electrode inspection housing shall be such that it carries out its function of enclosing the down-conductor/earth rod termination in an acceptable and safe manner, and has sufficient internal dimensions to permit

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the assembly/disassembly of the earth rod clamp. The material of the earth electrode inspection housing shall be compatible with its surrounding environment and shall comply with the tests given in accepted standard [D-2(50)]. The work shall also comply with the provisions of good practice [D-2(11)].

8.5.2 *Earth Electrode Seal*

Water pressure seal used in conjunction with an earth rod electrode shall be such that there will be no effect on the water proofing treatment for the foundation of the building. The design of the earth electrode seal shall be such that it carries out its function of preventing ground water bypassing the earth rod and entering the basement of a building, in an acceptable and safe manner and shall be compatible with its surrounding environment and comply with the tests given in accepted standard [D-2(50)].

8.6 Bonding and Inter Connection

All connections made in an earthing system above or below ground should meet electrical conductivity, corrosion resistance, current carrying capacity and mechanical strength of the conductor. These connections should be strong enough to maintain a temperature rise below that of the conductor and to withstand the effect of heating and the mechanical forces caused by fault currents. Consideration shall be given to electrolytic corrosion when using different materials in an earthing arrangement. The complete connections shall be able to resist corrosion for the intended life of the installation.

8.6.1 For external conductors (for example, earthing conductor) connected to a concrete-embedded foundation earth electrode, the connection made from hot-dip galvanized steel shall not be embedded in the soil.

8.6.2 Where an earth electrode consists of parts that should be connected together, the connection shall be by exothermic welding, pressure connectors, clamps or other suitable mechanical connectors.

8.6.3 All connection components shall meet the requirements according to accepted standard [D-2(51)] and also provisions of good practice [D-2(11)] and [D-2(1)] where applicable.

8.7 Equipment and Portions of Installations which shall be Earthed

8.7.1 *Equipment to be Earthed*

Except for equipment provided with double insulation, all the non-current carrying metal parts of electrical installations are to be earthed properly. All metal conduits, trunking, cable sheaths, switchgear, distribution fuse boards, lighting fittings and all other parts made of metal shall be bonded together and connected by means of two separate and distinct conductors to an efficient earth electrode.

8.7.2 *Structural Metal Work*

Earthing of metallic parts of the structure shall be done according to good practice [D-2(11)].

8.8 Neutral Earthing

To comply with relevant Central Electricity Authority regulations, no fuses or circuit breakers other than a linked circuit breaker shall be inserted in an earthed neutral conductor. A linked switch or linked circuit breaker shall be arranged to break the neutral either with or after breaking all the related phase conductors. This shall make (or close) the neutral before making (or closing) the phases.

If this neutral point of the supply system is connected permanently to earth, then the above rule applies throughout the installation including 2 wire final circuits. This means that no fuses may be inserted in the neutral or common return wire. And the neutral should consist of a bolted solid link or part of a linked switch, which completely disconnects the whole system from the supply. This linked switch shall be so arranged that the neutral makes before and break after the phases. For further details, reference should be made to good practice [D-2(11)].

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8.9 System of Earthing

Equipment and portions of installations shall be deemed to be earthed only if the earthing is done as per TN-S system with equipotential bonding as required. In all cases, the relevant provisions of the Central Electricity Authority regulations shall be complied along with provisions under good practice [D-2(11)].

8.10 The earthing of electrical installations for non-industrial and industrial buildings shall be done in accordance with good practice [D-2(11)] and good practice [D-2(1)].

9 INSPECTION, TESTING, VERIFICATION AND COMMISSIONING OF INSTALLATION

9.1 General Requirements

9.1.1 Before the completed installation, or an addition to the existing installation, is put into service, inspection and testing shall be carried out in accordance with the *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023, with special reference to Regulation numbers 5, 8, 14, 17, 18, 20, 21, 29 to 39, 42, 43, 46 to 48 and 50 (*see* Annex B), and also as per provisions in Part 1 'General and common aspects, Section 17 Erection and pre-commissioning — Testing of installations' of good practice [D-2(1)]. In the event of defects being found, these shall be rectified, as soon as practicable and the installation retested.

9.1.2 Initial and periodic inspection and testing shall be carried out in order to maintain the installation in a sound condition after putting into service. The periodicity shall be as per provisions in Annex E under Part 1 'General and common aspects, Section 17 Erection and pre-commissioning — Testing of installations' of good practice [D-2(1)].

9.1.3 Where an addition is to be made to the fixed wiring of an existing installation, the latter shall be examined for compliance with the recommendations of this NBCS.

9.1.4 The individual equipment and materials which form part of the installation shall generally conform to the relevant Indian Standard, wherever applicable. If there is no relevant Indian Standard for any item, these shall be approved by the appropriate authority.

9.1.5 *Completion Drawings*

On completion of the electric work, a wiring diagram shall be prepared and submitted to the Engineer-in-Charge or the owner. All wiring diagrams shall indicate clearly the main switch board, the runs of various mains and submains cables and the position of all points and their controls. All circuits shall be clearly indicated and numbered in the wiring diagram and all points shall be given the same number as the circuit in which they are electrically connected. Also the location and number of earth points and the run of each loads should be clearly shown in the completion drawings.

9.1.6 *Inspection and Testing*

The substations and other electrical installations shall be checked and tested as detailed in **4.2** and **4.3** under Part 1 'General and common aspects, Section 17 Erection and pre-commissioning — Testing of installations' of good practice [D-2(1)] and necessary test reports shall be prepared in the prescribed proforma therein. In addition, additional checks and tests as mentioned under the **9.2** and **9.3** shall also be carried out if not included in good practice [D-2(1)]. In case any defects are noticed, the same shall be rectified, retested and their test format shall be completed.

9.2 Inspection of the Installation

9.2.1 *General*

On completion of wiring a general inspection shall be carried out by competent personnel in order to verify that the provisions of this NBCS and that of *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 have been complied with. This, among other things, shall include checking whether all equipment, fittings, accessories, wires/cables used in the installation are of adequate rating and quality to meet

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the requirement of the load. General workmanship of the electrical wiring with regard to the layout and finish shall be examined for neatness that would facilitate easy identification of circuits of the system, adequacy of clearances, soundness, contact pressure and contact area. A complete check shall also be made of all the protective devices, with respect to their ratings, range of settings and co-ordination between the various protective devices. It is preferable to have a third party inspection to maintain quality assurance.

9.2.2 *Items to be Inspected*

All equipment in a substation including HV panel, transformer, LV panel, emergency DG sets, battery bank, cables, cable terminations, etc need inspection. Healthiness of the main distribution boards, metering panels, distribution cables, rising mains, bus ducts, etc need to be verified along with earthing system. In case of provisions of rooftop solar PV system and other services, the equipment connected therein shall also be included in the items to be inspected.

9.2.2.1 *Substation installations*

In substation installation, it shall be checked whether:

a) the installation has been carried out in accordance with the approved drawings;

b) phase to phase and phase to earth clearances are provided as required;

c) all equipment are efficiently earthed and properly connected to the required number of earth electrodes;

d) HV and LV switchgears are all vermin and damp-proof and all unused openings or holes are blocked properly;

e) the required ground clearance to live-terminals is provided;

f) suitable fencing is provided (with gate, lockable arrangements) and suitably earthed as required;

g) there is no vegetation in outdoor substation;

h) the required number of caution boards, firefighting equipment, operating rods, insulation mats of appropriate rating, etc, are kept in the substation;

j) in case of indoor substation sufficient ventilation and draining arrangements are made;

k) all cable trenches are provided with non-inflammable covers;

m) free accessibility is provided for all equipment for normal operation;

n) all name plates are fixed and the equipment are fully painted;

p) all construction materials and temporary connections are removed;

q) oil-level, busbar tightness, transformer tap position, etc are in order;

r) earth pipe troughs and cover slabs are provided for earth electrodes/earth pits and the neutral earth pits and earth pits of lightning protection system are marked for easy identification;

s) earth electrodes are of GI pipes or CI pipes or copper plates or Cu bonded rods as per Table 2 and, for earth connections, brass bolts and nuts with lead washers are provided in the pipes/plates;

t) earth pipe troughs and oil sumps/pits are free from rubbish and dirt and stone jelly, and the earth connections are visible and easily accessible;

u) earthing system designed are periodically checked for permissible limits of step and touch potential;

w) the earth busbars have tight connections and corrosion-free joint surfaces;

y) operating handle of protective device are provided at an accessible height from ground, that is, 300 mm to 1 800 mm;

z) adequate headroom is available in the transformer room for easy topping-up of oil, maintenance, etc;

aa) safety devices, horizontal and vertical barriers, busbar covers/shrouds, automatic safety shutters/doors interlock and handle interlock are safe and in reliable operation in all panels and cubicles;

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bb) clearances in the front, rear and sides of the main HV, LV and sub-switch boards are adequate;

cc) the switches operate freely, the 3 blades make contact at the same time, the arcing horns contact in advance, and the handles are provided with locking arrangements;

dd) insulators are free from cracks, and are clean;

ee) in oil cooled transformers, leakage of oil, if any should be checked;

ff) connections to bushing in transformers are tight and have good contact;

gg) bushings are free from cracks and are clean;

hh) accessories of transformers like breathers, vent pipe, buchholz relay, etc, are in order;

jj) connections to gas relay in transformers are in order;

kk) oil and winding temperature are set for specific requirements in transformers;

mm) in case of cable cellars, adequate arrangements made to pump out water that has entered due to seepage or other reasons;

nn) all incoming and outgoing circuits of HV and LV panels are clearly and indelibly labelled for identification;

pp) no cable is damaged;

qq) there is adequate clearance around the equipment installed; and

rr) cable terminations are proper.

9.2.2.2 *High/low voltage installation*

In high and low voltage installations, it shall be checked whether:

a) all blocking materials that are used for safe transportation in switchgears, contactors, relays, etc are removed;

b) all connections to the earthing system are feasible for periodical inspection;

c) sharp cable bends are avoided and cables are taken in a smooth manner in the trenches or alongside the walls and ceilings using suitable support clamps at regular intervals;

d) suitable circuit breaker or lockable push button is provided near the motors/apparatus for controlling supply to the motor/apparatus in an easily accessible location;

e) two separate and distinct earth connections are provided for the motor/apparatus;

f) control switch-fuse is provided at an accessible height from ground for controlling supply to overhead travelling crane, hoists, overhead busbar trunking;

g) the metal rails on which the crane travels are electrically continuous and earthed and bonding of rails and earthing at both ends are done;

h) four core cables are used for overhead travelling crane and portable equipment, the fourth core being used for earthing, and separate supply for lighting circuit is taken;

j) if flexible metallic hose is used for wiring to motors and other equipment, the wiring is enclosed to the full lengths, and the hose secured properly by approved means;

k) the cables are not taken through areas where they are likely to be damaged or chemically affected;

m) the screens and armours of the cables are earthed properly;

n) the belts of the belt driven equipment are properly guarded;

p) adequate precautions are taken to ensure that no live parts are so exposed as to cause danger;

q) ammeters and voltmeters are tested;

r) the relays are inspected visually by removing covers for deposits of dusts or other foreign matter;

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s) wherever bus ducts/rising mains/overhead bus trucking are used, special care being taken for earthing the system, and all tap off points are provided with adequately rated protective device like MCB, MCCB, fuses, RCCB/RCD, SPD (*see* **11**), etc;

t) all equipment are weather, dust and vermin proof; and

u) any and all equipment having air insulation as media maintain proper distances between phases, phase to neutral, phase to earth and earth to neutral.

9.2.2.3 *Overhead lines*

For overhead lines, it shall be checked whether:

a) all conductors and apparatus including live parts thereof are inaccessible;

b) the types and size of supports are suitable for the overhead lines/conductors used and are in accordance with approved drawing and standards;

c) clearances from ground level to the lowest conductor of overhead lines, sag conditions, etc, are in accordance with the relevant Indian Standards and the CEA Regulations;

d) where overhead lines cross the roads or cross each other or are in proximity with one another, suitable guarding is provided at road crossings and to also protect against possibility of the lines coming in contact with one another;

e) every guard wire is properly earthed;

f) the type, size and suitability of the guarding arrangement provided is adequate;

g) stays are provided suitably on the overhead lines, as required and are efficiently earthed or provided with suitable stay insulators of appropriate voltages;

h) anti-climbing devices and danger board/caution board notices are provided on all HV supports;

j) clearances along the route are checked and all obstructions, such as, trees/branches and shrubs are cleared on the route to the required distance on either side;

k) clearance between the live conductor and the earthed metal parts are adequate;

m) for the service connections tapped-off from the overhead lines, cut-outs of adequate capacity are provided;

n) all insulators are properly and securely mounted, also they are not damaged;

p) all poles are properly grouted/insulated so as to avoid bending of pole towards tension; and

q) steel poles, if used is properly earthed.

9.2.2.4 *Lighting and convenience power circuits*

For the lighting and convenience power circuits, it shall be checked whether:

a) wooden boxes are avoided;

b) panels are provided for mounting the lighting boards and switch controls, etc;

c) neutral links are provided in double pole switch-fuses which are used for lighting control and no protective device (such as MCB, MCCB, fuses, RCCB/RCD, etc) is provided in the neutral;

d) the plug points (6 A) in the lighting circuit are all of 3/5-pin type, the third pin being properly earthed;

e) the plug points (16 A) in the lighting circuit are all of 3/6-pin type, the third pin being properly earthed;

f) tamper-proof interlocked switch socket and plug are used for locations easily accessible;

g) wiring for lighting is taken in surface or recessed conduit and conduit properly earthed, or alternatively, armoured cable wiring is used in factories;

h) a separate earth wire is run in the lighting installation to provide earthing for plug points, fixtures and equipment;

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j) proper connectors and junction boxes are used wherever joints are to be made in conductors or cross-over of conductors takes place;

k) clear and permanent identification marks are painted in all distribution boards, switchboards, sub-main boards and switches as necessary;

m) the polarity has been checked and all protective devices (such as MCB, MCCB, fuses, RCCB/RCD, etc) and single pole switches are connected on the phase conductor only and wiring is correctly connected to socket-outlets;

n) spare knockouts are provided in distribution boards and switch fuses are blocked;

p) the ends of conduits enclosing the wiring leads are provided with ebonite or other suitable bushes;

q) the fittings and fixtures used for outdoor use are all of weather-proof construction and of suitable IP and IK rating and similarly, fixtures, fittings and switchgears used in the hazardous area, are of flame-proof application;

r) proper terminal connectors are used for termination of wires (conductors and earth leads) and all strands are inserted in the terminals;

s) flat ended screws are used for fixing conductor to the accessories;

t) as desirable, flat washers backed up by spring washers are used for making end connections; and

u) all metallic parts of installation, such as conduits, distribution boards, metal boxes, etc, have been properly earthed.

9.3 Testing of Installation

9.3.1 *General*

After inspection, the tests as indicated in **9.3.2** shall be carried out, before an installation or an addition to the existing installation is put into service. Any testing of the electrical installation in an already existing installation shall commence after obtaining permit to work from the Engineer-in-Charge and after ensuring the safety provisions.

Testing of the installations will cover the testing of equipment, connections, cables, switchgear, protective devices, circuit breakers and the associated relays, measuring instruments and earthing. Periodicity of testing should not exceed six months. More frequent testing may be prescribed for complex installations and installations feeding sensitive loads. Due date of next test cycle should be displayed on the equipment.

The tests as detailed in **4.3** under Part 1 'General and common aspects, Section 17 Erection and pre-commissioning — Testing of installations' of good practice [D-2(1)] shall be carried out before energizing the installation and shall be recorded in the proforma attached under Annex E.

9.3.2 *Testing*

9.3.2.1 *Switchboards*

HV and LV switchboards shall be tested in the manner indicated below:

a) All high voltage switchboards shall be tested for insulation (phase to phase, phase to earth and body to earth);

b) In case of oil type switchboards, dielectric strength of oil shall also be tested;

c) All earth connections shall be checked for continuity;

d) The operation of the protective devices shall be tested by means of secondary or primary injection tests;

e) The operation of the breakers shall be tested from all control stations;

f) Indication/signalling lamps shall be checked for proper working;

g) The operation of the breakers shall be tested for all interlocks;

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h) The closing and opening timings of the breakers shall be tested wherever required for auto-transfer schemes;

j) Contact resistance of main and isolator contacts shall be measured; and

k) The specific gravity and the voltage of the control battery shall be measured.

9.3.2.2 *Transformers*

Transformers shall be tested in the manner indicated below:

a) All commissioning tests shall be in accordance with good practice [D-2(16)]; and

b) Insulation resistance on HV and LV windings shall be measured at the end of 1 min, as also at the end of 10 min of measuring the polarization index. The absolute value of insulation resistance should not be the sole criterion for determining the state of dryness of the insulation. Polarization index values should form the basis for determining the state of dryness of insulation. For any class of insulation, the polarization index should be greater than 1.5. In case of oil type transformers, the dielectric strength shall be tested.

9.3.2.3 *Cables*

Cable installations shall be checked as given below:

a) It shall be ensured that the cables conform to the relevant Indian Standards. Tests shall also be done in accordance with good practice [D-2(23)]. The insulation resistance before and after the tests shall be checked;

b) The insulation resistance between each conductor and against earth shall be measured. The insulation resistance varies with the type of insulation used and with the length of cable;

c) Physical examination of cables shall be carried out;

d) Cable terminations shall be checked; and

e) Continuity test shall be performed before charging the cable with current.

9.3.2.4 *Motors and other equipment*

The following tests shall be made on motor and other equipment.

The insulation resistance of each phase winding against the frame and between the windings shall be measured. Megger of 500 V or 1 000 V rating shall be used. Star points should be disconnected. Minimum acceptable value of the insulation resistance varies with the rated power and the rated voltage of the motor.

The following relation may serve as a reasonable guide:

$$R_i = \frac{20 \times E_n}{1\,000 + 2P}$$

where

R_i = insulation resistance in MΩ at 25 °C;

E_n = rated phase to phase voltage; and

P = rated power, in kW.

If the resistance is measured at a temperature different from 25 °C, the value shall be corrected to 25 °C.

The insulation resistance as measured at ambient temperature does not always give a reliable value, since moisture may have been absorbed during shipment and storage. When the temperature of such a motor is raised, the insulation resistance will initially drop considerably, even below the acceptable minimum. If any suspicion exists on this score, motor winding shall be dried out.

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9.3.2.5 *Wiring installation*

The following tests shall be done:

a) The insulation resistance shall be measured by applying between earth and the whole system of conductor or any section thereof with all fuses in place and all switches closed, and except in earthed concentric wiring, all lamps in position or both poles of installation otherwise electrically connected together, a d.c. voltage of not less than twice the working voltage, provided that it does not exceed 500 V for low voltage circuits. Where the supply is derived from three-wire (a.c. or d.c.) or a poly-phase system, the neutral pole of which is connected to earth either direct or through added resistance, the working voltage shall be deemed to be that which is maintained between the outer or phase conductor and the neutral;

b) The insulation resistance in mega-ohm (MΩ) of an installation measured as in (a) shall be not less than 50 divided by the number of points on the circuit, provided that the whole installation need not be required to have an insulation resistance greater than 1 MΩ;

c) Control rheostats, heating and power appliances and electric signs, may, if desired, be disconnected from the circuit during the test, but in that event the insulation resistance between the case of framework, and all live parts of each rheostat, appliance and sign shall be not less than that specified in the relevant Indian Standard or where there is no such specification, shall be not less than 0.5 MΩ; and

d) The insulation resistance shall also be measured between all conductors connected to one pole or phase conductor of the supply and all the conductors connected to the middle wire or to the neutral on to the other pole of phase conductors of the supply. Such a test shall be made after removing all metallic connections between the two poles of the installation and in these circumstances the insulation resistance between conductors of the installation shall be not less than that specified in (b).

9.3.2.6 *Earthing*

The following tests shall be done for the earth electrodes (earthing):

a) The earth resistance of each electrode shall be measured;

b) Earth resistance of earthing grid shall be measured;

c) All electrodes shall be connected to the grid and the earth resistance of the entire earthing system shall be measured; and

d) After receipt of electrical supply, the fault loop impedance shall be measured to ensure that the value obtained is minimal and to comply with the provisions under the CEA Regulations No. 43 (*see* Annex B) and good practice [D-2(11)].

These tests shall preferably be done during the summer months.

9.3.2.7 *Lightning protection system* (*LPS*)

Lightning protection system (LPS) verification shall be done as per accepted standards [D-2(52)] including the details of calculation of risk assessment and the selection of lightning protection level. The objective of inspection of LPS shall include whether all components of LPS are in good condition and capable of performing their designed functions and there is no corrosion. Inspections shall include checking of embedded electrodes, earth resistance values for the earth termination system, conditions of connections, equipotential bonding and fixings. The complete LPS shall be tested by opening one of the test joints to ensure that the total LPS system does not have more than 10 Ω to the earth. In case, if the total resistance of LPS exceeds 10 Ω then additional down conductors should be planned from air terminations and mesh conductor system, based on rolling sphere/mesh/protection angle method, to the earth so that the overall resistance is brought down to below 10 Ω by uniformly placing the additional down conductors. The testing shall also comply with all provisions included in **4.4** of Part 1 'General and common aspects, Section 17 Erection and pre-commissioning — Testing of installations', of good practice [D-2(1)] and IEC 62305-3 : 2024 'Protection against lightning — Part 3: Physical damage to structures and life hazard'.

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9.4 Checklist for Installation

The testing and submission of reports of all electrical installations shall be done as detailed in the model form in Annex D of Part 1 'General and common aspects, Section 17 Erection and pre-commissioning — Testing of installations, of good practice [D-2(1)]. In addition, the checklist covering set of checks for installation, handing over and commissioning of typical equipment of a substation as given in Annex E is for general reference and use. For other allied installation, the proper checklist should be developed keeping in view the type of loads, quality of service, environmental conditions and operating requirements of redundancy and reliability.

9.5 Completion Certificate

On completion of an electrical installation (or an extension to an installation) a certificate shall be furnished by the contractor, counter-signed by the certified supervisor under whose direct supervision the installation was carried out. This certificate shall be in a prescribed form as required by the local electric supply authority. One such recommended form is given in Annex F. This is a general form giving the minimum basic requirements and the items in the form have to be augmented keeping in view the features of the particular equipment, system or installation and environmental conditions of its operation.

10 ALLIED/MISCELLANEOUS SERVICES

10.0 General

The allied and miscellaneous services covered under this are special type of services which may or may not be part of the main electrical installations of the building but are services which are used in the building and may sometimes use electrical supply to run the services. This also covers the photovoltaic and other rooftop generation system which will get integrated with the electrical supply system for the building. This clause also covers inverters, UPS and small portable generation system to meet certain emergency requirements. The chapter also covers broadly the provisions for EV charging, Data centres and multeystorey buildings beyond 24 storeys. This clause provides the requirements related to these services.

10.1 Telecommunication and Information and Communication Technology Services

10.1.1 *Telephone/Intercom Services*

10.1.1.1 House wiring of telephone subscribers in small buildings may be on the surface of walls or desirably, in a concealed manner through conduits. In large multi-storeyed buildings intended for commercial, business and office use as well as for residential purposes, wiring for telephone connections should be done in a concealed manner through conduits. The requirements of telecommunication facilities like telephone connections, private branch exchange and intercommunication facilities, should be planned well in advance so that suitable provisions are made in the building plan in such a way that the demand for telecommunication services in any part of the building at any floor are met at any time during the life of the building.

10.1.1.2 Layout arrangements, methods for internal block wiring and other requirements regarding provisions of space, etc may be decided depending on the number of phone outlets and other details in consultation with engineer/architect and user. *See also* Part D 'Building Services, Section 6 Information and Communication Enabled Installations' of this NBCS.

10.1.2 *Fibre to The Home* (*FTTH*) *Services*

Fibre to the home (FTTH) services provide high speed internet, television and phone directly to a home or business using fibre optic cables. These services provide significantly higher bandwidth, faster speeds and more reliable connections compared to traditional broadband with advanced features such as high-definition video streaming, online gaming, etc. Instead of copper wires, FTTH uses thin strands of glass or plastic fibre(s) which transmit data as light signals.

Installing FTTH network is straightforward fibre installation with some additional components like splitters, an optical network terminal (ONT) and associated hardware at the customer premises. For more details, reference

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may be made to Part D 'Building Services, Section 6 Information and Communication Enabled Installations' of this NBCS.

10.1.3 *Information and Communication Technology Services including Computer Networking*

See Part D 'Building Services, Section 6 Information and Communication Enabled Installations' of this NBCS.

10.2 Public Address System

See Part F 'Fire and Life Safety' of this NBCS.

10.3 Emergency and Standby Power Supply Systems

10.3.1 *General*

Use of electricity has grown tremendously and for various activities the dependency on electricity has increased to such an extent as to cause serious problems even with loss of electrical power for a very short time. As a result, a wide variety of alternate sources of electricity are being used in our built environment.

The different alternative sources of power are the uninterrupted power supply (UPS) system, inverter, diesel (CNG/LPG) generator sets, petrol/kerosene oil generator sets and bio-gas generator sets.

In addition to the above, there is a proliferation of power sources, such as solar photo-voltaic cells, wind generators, bio-mass and waste-based power plants, etc, primarily oriented towards reduction of the environmentally harmful CO_2 emissions.

These systems give electricity during the periods of the failure of the conventional grid based public energy system and keep our critical systems in continued operation. However, introduction of more than one source of electrical power results in safety related issues. For safety from electrical shock to human beings or livestock, the hazard is not just dependent on the main high-powered source such as the grid, but the hazard is the same from a low powered source also. Shock from a small 20 W inverter can be as dangerous as a shock from the grid with megawatts of power at the back. As such precautions from the angle of safety apply equally to all sources of power. Electric shock hazards are dependent on the system voltage and as such even a low capacity generator or an inverter (of capacity 100 VA) poses the same level of shock hazard as a multi-kilovolt ampere capacity generator and all protection provisions (such as earthing, earth leakage and overload breakers) shall be provided as done for a large capacity system.

Power devices contain fuel, batteries which are points of concentrated sources of energy constrained in a small place. Any unintended improper release of this bottled up energy can unleash devastating consequences, such as fire and as such care is required in location which houses any of these sources of electrical power and its associated components.

10.3.2 *Uninterrupted Power Supply* (*UPS*) *System*

UPS is an electrical device providing an interface between the mains power supply and sensitive loads (computer systems, instrumentation, etc). The UPS supplies sinusoidal a.c. power free of disturbances and within strict amplitude and frequency tolerances. It is generally made up of a rectifier/charger and an inverter together with a battery for backup power in the event of a mains failure with virtually no time lag.

In general UPS system shall be provided for sensitive electronic equipment like computers, printers, fire alarm panel, public address system equipment, access control panel, EPABX, etc, with the following provisions. In addition, provisions as given in good practice [D-2(1)] shall also be followed.

a) Isolation transformers may be provided for UPS systems to provide higher grade of power supply quality to the loads fed by the UPS.

b) UPS shall have dedicated neutral earth pits of IT system. This earth pit shall be interconnected with other earth pits below soil for equipotential bonding and comply with the provisions of good practice [D-2(11)].

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c) Adequate rating of protective devices such as MCB, MCCB, fuses, RCD, etc shall be provided at both incoming and outgoing sides.

d) UPS room shall be provided with adequate ventilation and/or air conditioning as per requirement, to avoid thermal runaway.

e) For all 3 phase UPS, 4 pole circuit breaker (CB) shall be used and for all 1 phase UPS, double pole CB shall be used.

f) The system shall confirm to set of accepted standards [D-2(53)].

10.3.3 *Inverter*

In general inverter system shall be provided for house lighting, shop lighting, etc.

NOTE — While a UPS system is provided to maintain power supply without any break even in the event of a failure of the incoming power supply, an inverter system is provided where a short break is acceptable.

Inverter systems also have a battery bank to supply power during the failure of the main power supply and the battery charged through a rectifier. The following provisions shall apply to inverter systems:

a) Adequate rating of protective devices such as MCB, MCCB, fuses, RCD, etc, shall be provided at both incoming and outgoing sides;

b) Earthing shall be done in accordance with good practice [D-2(11)];

c) Adequate ventilation space shall be provided around the battery section of the inverter; and

d) Care shall be taken in circuit design to keep the connected load in such a manner that the demand at the time of mains failure is within the capability of the inverter.

NOTE — If the inverter fails to take over the load at the time of the mains failure, the purpose of providing the inverter and battery backup is defeated.

10.3.4 The following provisions shall apply to both inverter and UPS systems:

a) Circuits which are fed by the UPS or inverter systems should have suitable marking to ensure that a worker does not assume that the power is off, once the mains have been switched off from the DB for maintenance;

b) Electric shock hazards are dependent on the system voltage and as such even a low capacity generator or an inverter (of capacity 100 VA) poses the same level of shock hazard as a multi-kilovolt ampere capacity generator and all protection provisions (such as safety earthing, earth leakage and overload breakers) shall therefore be provided as done in case of a large capacity system;

c) UPS and inverter systems should be provided with protection to shut the output during abnormal conditions, such as overload or short circuit. Such systems may also have the choice of auto-restoration after a preset time delay and an ultimate lock-out after a number of restoration attempts. Warning should be displayed wherever the possibility of automatic restoration is possible;

d) Batteries that go with UPS and inverter systems are required to be placed in well-ventilated spaces as oxygen and hydrogen gasses are produced in the batteries, which unless ventilated, can cause explosive conditions; and

e) The flooring for the battery room should be with acid (or alkali as the case may be) resistant tiles or coating.

10.4 Building Management System (BMS)

10.4.1 *General*

Building management system (BMS) is a computer-based system for monitoring and managing the building's mechanical, electrical and electro-mechanical systems including electrical substation equipment, HVAC, lighting, energy management, lifts, escalators, fire safety, security systems car parking management, etc. By its usage, building operations are optimized, energy efficiency is enhanced besides ensuring performance of all systems, safety and improving occupant's comfort.

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10.4.2 *Working*

BMS provides a central platform for effective monitoring and efficient management of various building services. It allows remote monitoring and control from a single desk/location.

Separate standalone monitoring and control system provided for each service like electrical sub-station equipment; solar power and renewable energy system; standby generation system; HVAC system for control of operation and monitoring of all equipment including comfort conditions like temperature, humidity and air quality; fire protection system combining fire detection and firefighting arrangements, public address system (evacuation system); security system consisting of access control, CCTV, security fencing, water management system; etc can all be further integrated with BMS for remote monitoring, control and management .

By using sensors, it collects data on various parameters of all systems including comfort conditions of individual rooms/areas such as temperature, humidity, air quality, energy consumption based on occupancy level and adjusts system settings automatically for optimization of performance and eliminating wastage of energy thereof. Additionally, it can also spot inconsistencies and can send alerts to maintenance engineers to address the problems promptly.

The software of BMS also includes various features of reporting and analytics for improving building performance and identification of improvement areas. By integrating it with other building systems a more comprehensive and efficient solution of building management can be attained.

10.4.3 *Compliance with Regulations and Standards*

Where mandated, the relevant energy efficiency and safety standards prescribed by the Bureau of Energy Efficiency (BEE), Part F 'Fire and Life Safety' of this NBCS and other relevant parts and sections of this NBCS should be complied with. It should also be capable of seamless integration and exchange of data with other systems and devices functioning within the building. Designed for optimal performance, this system should be protected against unauthorized access and cyber threats.

10.5 Security System

Security system may comprise an integrated closed circuit television system, access control system, perimeter protection systems, movement sensors, etc. These have a central control panel, which has a defined history storage capacity. This main control panel may be located where it can be manned suitably with provision for integration to the fire detection and alarm system when considered necessary.

These may be considered for high security areas or large crowded areas or complexes. High security areas may consider uncorded, high-resolution, black and white cameras in place of coloured cameras. These cameras may be accompanied or automatically controlled with movement sensors. Cameras may be linked to access controls so that proper recording of the movement at the points of access to high security areas is maintained.

Access control may be provided for entry to high security areas. The systems may have proximity card readers, magnetic readers, etc.

NOTE — *See* relevant guidelines/best practices (Handbook on 'Asset and Facility Management in Buildings') for provisions relating to security system.

10.6 Car Parking Area

10.6.1 *Car Parking Management System*

Wherever car park management system is provided in multi-level parking or other parking lots with features of boom barriers, pay and display machines (manned or unmanned type) and parking guidance system (for displaying number of car spaces vacant on various floors, direction of entry and exit, etc), the electrical provisions for the same shall be adequately backed with UPS for protection of vehicle and for efficient car parking management.

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10.6.2 *Emergency Lighting in Basement Car Parking*

Lighting at suitable points should be provided on the passageway of the cars so that the public in the area can safely move away from the passage in the event of power failure.

10.7 Electrical Vehicle Charging

10.7.1 *General*

Increased use of electric vehicles (EVs) here resulted in the need for providing adequate EV charging infra structure in the built environment. It is recommended to provide for EV charging infrastructure for 20 percent of the parking area of buildings. Provisions of charging infra structure should be adequately increased such that slow charging of vehicles in parked condition for long duration can be undertaken in parking area of residential, office, institutional and in about 40 percent of commercial parking areas. Further, considering the rising status of EV adoption, the initial proposal of 20 percent parking space allocation for EVs may be increased up to 30 percent, say by 2030.

10.7.2 *Charging Arrangement*

Standards for charging of electric vehicles presently restrict the charging arrangements to open area and upto first basement with provisions of necessary sprinkler arrangement for firefighting services and necessary water curtain/compartment for fire protection. The charging infrastructure in podium/above ground parking do not provide significant risk considering the availability of cross ventilation in most such parking arrangements. However, with increased demand for charging infrastructure, the use of other basement may have to be considered. The charging arrangement in parking should be segregated individually for two wheelers and for four wheelers.

Charging arrangement for cars (four wheelers), can be provided both in ground level and first basement having adequate ventilation. However, two wheelers need to be segregated from four wheelers in parking and charging arrangement; and should be restricted to only ground floor level with adequate ventilation and firefighting arrangement using water mist fire system. The use of water mist fire system having up to 85 percent reduced water required for fighting the fire makes it a better option for both cooling effect and controlling electric fire in electric vehicles. The parking facility for the two wheelers shall be so arranged that not more than two vehicles should be parked side by side for charging and a space of not less than 1 m should be kept between the vehicle groups. The charging infrastructure should be provided in groups of four outlet points with three pin socket-outlets of 10 A capacity with 30 mA RCD control for each socket-outlet with metering arrangement. The spacing of the charging outlet shall be at a distance of 4 m/5 m on the basis of the parking arrangement provided.

In residential complexes, charging of vehicles would be preferred while parked for the day. Accordingly, it will not be advisable to keep parking of electrical vehicles contiguous to/vicinity of the petrol/diesel/CNG gas based vehicles. Hence separate segregated parking lot is required to be created for EVs (four wheelers) preferably in ground level/first basement with compartmentalized and water sprinkler fire barrier arrangement (for the basement). Suitable fire alarm/fire detection and fire ventilation system shall also be provided. Building professionals can consider developing suitable independent tower arrangement (podium) for car parking of electrical vehicles among the residential/commercial tower blocks and the building plan approval authorities can consider for suitable exemptions from the permitted area for construction.

It is necessary to provide for at least 20 percent of the vehicles in a residential complex with electric charging using a slow charging arrangement, as per Government guidelines. Hence each charging point shall be provided with two numbers 15 kW single phase two wire and two numbers 15 kW three phase four wire outlets controlled by suitable MCCB and RCD of 30 mA capacity with suitable metering arrangement. Each outlet shall be controlled by appropriate RCD/RCBO with rated residual operating current not exceeding 30 mA and necessary metering arrangement. In case of covered parking (first basement/podium), each location shall be provided with two sets of charging points. Each charging point shall be provided with access to portable firefighting arrangement within 15 m. The charging arrangement will be initially permitted to first basement only with compartment/sprinkler based water curtain and normal ventilation requirement of 15 to 18 air changes per hour with gas monitoring system. No charging infrastructure or EV parking shall be provided in the last basement. EV charging is a critical application from the point of fire safety, it is essential that all cables used for feeding the

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EV charging stations of both two wheelers and four wheelers shall be of copper conductors for sizes upto 50 mm^2 4 core cables to prevent overheating with adequate earthing connections. All terminals shall be crimped to prevent loose connections.

It is also necessary to provide in the open area of the residential complex slow and fast charging points for 5 percent of the number of flats subject to minimum of two points with independent meter reading so that in case the number of electric vehicles increase in the complex, the users can take advantage of the fast charging arrangement. The arrangement shall be with two numbers 15 kW single phase two wire, 15 kW three phase four wire and 30 kW four wire outlets each controlled by MCCB of appropriate capacity, RCD of 30 mA capacity and metering arrangement.

10.7.3 As far as possible, EV charging arrangement shall be provided with independent transformer to ensure that harmonics created during EV charging do not interfere with power supply to other system and also to maintain other electrical parameters. A separate transformer is recommended for EV charging points where the total connected load exceeds 100 kW. It shall be ensured that EV charging is not fed from diesel generator sets or gas generators or similar fuel based power generating systems.

In case of hospitals, commercial complexes and big residential complexes, necessary public charging infrastructure shall be provided with 15 kW/30 kW/60 kW charging points duly controlled by appropriate capacity RCD/RCBO having rated residual current of 30 mA, necessary metering arrangement for each point with fast charger provisions. Spaces for EVs to be provided with charging facility for at least 20 percent of total vehicles. However, in the first basement, charging points shall be of capacity less 15 kW only.

All charging points, cabling, etc shall comply with accepted standards [D-2(54)] and good practice [D-2(1)] and the *CEA* (*Measures Relating to Electric Supply and Safety*) *Regulations*, 2023, with special reference to Regulation No. 123, 124, 125, 126, 127 and 128 (*see* Annex B).

10.7.4 *Battery Swapping System*

Battery swapping systems provide quick, safe and reliable swapping of the swappable battery system (SBS) of electric vehicles preferably two wheelers. The batteries will be loaded in a battery swap station (BSS). The SBS are stored in a battery rack in the BSS. The battery swapping is carried out by means of appropriate manipulators. EV battery swap system consists of:

a) battery swap station (BSS);

b) supporting systems;

c) swappable battery system (SBS); and

d) power supply system.

See accepted standard [D-2(55)].

Battery swap system shall be permitted only on ground floor (or on above ground floors) or outside the building line including battery storage zone and battery charging zone.

10.7.5 *Charging Infrastructure for Electric Buses*

Each electric bus depot shall be equipped with a minimum of two direct current (d.c.) fast chargers, each rated at not less than 240 kW, conforming to power level 3 or level 4. Chargers shall comply with the following Indian Standards:

a) d.c. charging protocol for heavy-duty vehicles — as per accepted standards [D-2(56)].

b) High-power d.c. charging systems — as per accepted standards [D-2(57)].

c) EV-EVSE communication protocol (power line communication) — as per accepted standards [D-2(58)].

d) Connector and plug interface for M3 category vehicles — as per accepted standards [D-2(59)].

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All installations shall conform to applicable safety norms as per the CEA Regulations and relevant Indian Standards.

10.7.6 *Safety Requirements for Residential Charging of Electric Vehicles*

10.7.6.1 *Scope*

This clause specifies safety requirements for the installation and use of electric vehicle (EV) charging systems in residential premises.

10.7.6.2 *General safety provisions*

a) Only devices listed by a qualified testing laboratory shall be used.

b) Manufacturer's instructions shall be read and complied with.

c) Chargers and cords shall be inspected for damage prior to use; damaged components shall not be used.

d) Use of extension cords with EV chargers shall not be permitted.

e) Charging equipment shall be installed in locations that are:

   1) away from high-traffic areas; and

   2) free from proximity to combustible materials.

f) Charging accessories shall be stored out of reach of children and animals when not in use.

g) Charging station outlets shall be covered to prevent ingress of water.

h) Prior to initiating home charging, a qualified electrician shall:

   1) assess the capacity of the existing electrical system; and

   2) install a dedicated circuit for the charging device.

10.7.6.3 *Precautionary measures*

Warning signs shall be prominently displayed to ensure the safety of maintenance personnel. The signage shall include the following statements:

a) The vehicle is equipped with high-voltage batteries;

b) Battery maintenance shall be undertaken only by the manufacturer or authorized personnel; and

c) Orange-coloured high-voltage cables shall not be touched.

10.8 Solar Photovoltaic Power Generating System in Buildings

10.8.1 *General*

Solar energy, which is available in two forms, heat and light, is a renewable and inexhaustible natural resource and can supplement/augment the depleting fossil fuel resources. Greenhouse gases and pollutant emissions which result from fossil fuel generation can also be offset by solar photovoltaic power generation. Most parts of the country receive good solar radiation of 4 kWh/m^2 to 7 kWh/m^2 per day and almost 300 sunny days in a year making solar PV system one of the most preferred renewable energy sources in the country.

10.8.2 Solar PV power generating system consists of components and subsystems that are used to convert incident solar radiation directly into electrical energy. The energy converter (namely, solar photovoltaic cells which convert solar energy directly into d.c. electric power) does not have moving parts and has a comparatively long lifetime. Also, it can be used in decentralized/distributed mode.

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10.8.3 *Rooftop Solar System*

The energy received from the sun is converted into electricity through photovoltaic cells and is called solar photovoltaic electricity. This is done by solar photo-voltaic system consisting of solar PV panels containing group of solar cells which generate d.c. power and using inverter and other equipment of appropriate capacity, the d.c. power is converted into a.c. power. The complete system comprising of inverter, cables both d.c. as well as a.c., protection system, interconnections, etc, which together is known as balance of system. Thus, solar PV system consists of solar PV panel and balance of system. The basic unit of solar panel, that is, solar cells are semiconductors made of silicon. The PV cells are made using different technologies namely monocrystalline silicon, polycrystalline silicon, thin film, etc. The choice among them is based on efficiency, cost and application among other factors. (*See* Fig. 12).

The installation of rooftop solar PV system shall be in accordance with the Regulation No. 119 and 121 of *Central Electricity Authority* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 (*see* Annex B).

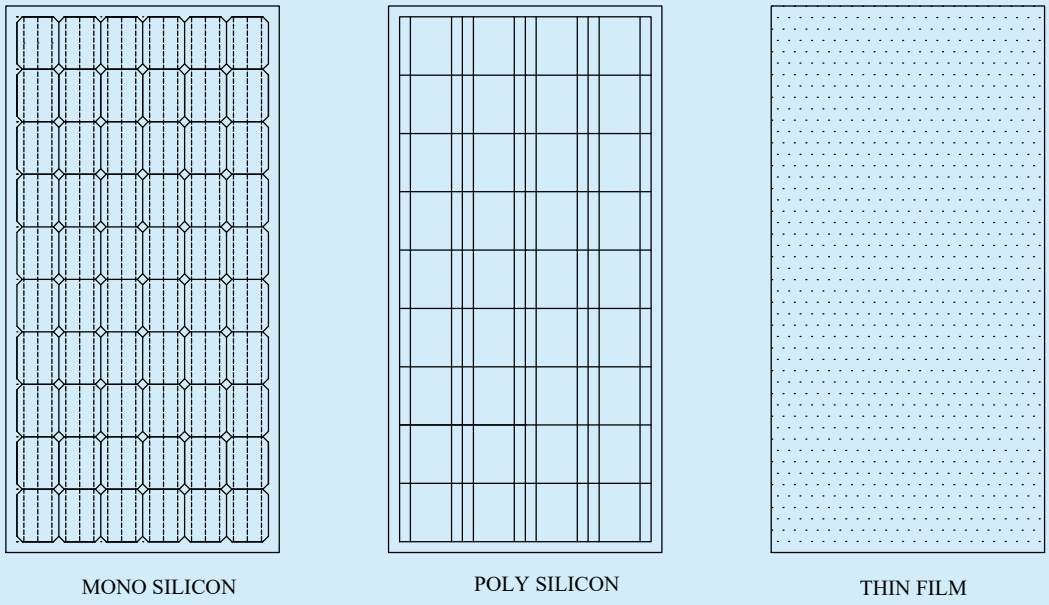

FIG. 12 MONO, POLY AND AMORPHOUS SILICON SOLAR CELL MODULE.

The solar PV systems used in buildings are of two types. Those installed on the rooftop are known as rooftop solar (RTS) system while solar PV system integrated with building facade is known as building integrated photovoltaic (BIPV) system.

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10.8.3.1 *Solar PV components*

A brief description of all the major components are listed below:

Sl No.	*Component*	*Purpose*	*Technical Requirements and Compliance Standard*
(1)	(2)	(3)	(4)
i)	PV modules	To generate electricity utilizing the sunlight	Higher efficiency and lower cost meeting performance and safety standard as per accepted standards [D-2(60)] Modules to be connected in series and parallel to meet the inverter input requirement *See* accepted standard [D-2(61)].
ii)	Module mounting structure	To provide stability and rigidity to modules, to orient them towards the south direction at the appropriate latitude angle	Made of galvanized iron {*see* accepted standard [D-2(62)]} It should be capable of withstanding highest wind speed {*see* accepted standard [D-2(63)]}; and should have more than 25 years life.
iii)	d.c. and a.c. distribution boxes	To combine PV strings, to protect interconnections from corrosion, to house protective devices-fuses, surge protection devices, earth termination, breakers and isolators	GRP/FRP/powder coated aluminum enclosure. Should be weather and vermin proof, having required number of string entries and one cable exit having the required power rating and protection (IP 65) and as per relevant Indian Standard and good practice [D-2(1)]
iv)	Inverter	To convert d.c. power to a.c.	The inverter shall comply with all requirements as mandated in relevant Indian Standards, good practice [D-2(1)] and should produce grid quality power and be able to synchronize with it and having all mandated protection features of IP 54; accepted standards [D-2(64)]; and **5** of [D-2(65)] Interconnection and power quality shall be as per CEA/state regulation
v)	Cables (d.c. and a.c.)	To connect solar panels to inverter and enable safe flow of current	Copper cables with the required voltage rating and current carrying capacity shall be used for interconnection. The voltage drop should not exceed 2 percent. All d.c. cables shall be solar d.c. cable as per accepted standard [D-2(66)] and a.c. cables as per accepted standard [D-2(4)] and shall be copper conductor cable for sizes upto 50 mm^2.

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Table (*Concluded*)

Sl No.	*Component*	*Purpose*	*Technical Requirements and Compliance Standard*
(1)	(2)	(3)	(4)
vi)	Earthing	To provide safe and alternate path for fault current and surge currents	Should be provided independently both on the d.c. and a.c. side of the circuit using copper/copper bonded steel down conductors {*see* good practice [D-2(11)]} and *CEA Safety Regulation*, 2023
vii)	Lightning protection system	To prevent damage caused by lightning surges	LPS should be provided as per accepted standard [D-2(52)]
viii)	Net meter	To measure net of energy exported to and imported from the grid	Installed by the DISCOM after calibration and sealing

10.8.3.2 *Solar PV systems classification*

There are mainly two types of PV systems namely grid tied system and the off-grid system.

In the grid tied system the building electrical loads are supported by both the solar power and the utility power. When solar power is insufficient to meet the load demand or is not available as during nights, power is drawn from the grid and when the generation is more, the excess is fed to the grid. A net meter is installed to measure the net of the energy drawn from and injected into the grid. The tariff for feeding excess power is typically fixed every year by the respective state regulatory commissions. A typical grid tie system is shown in Fig. 13.

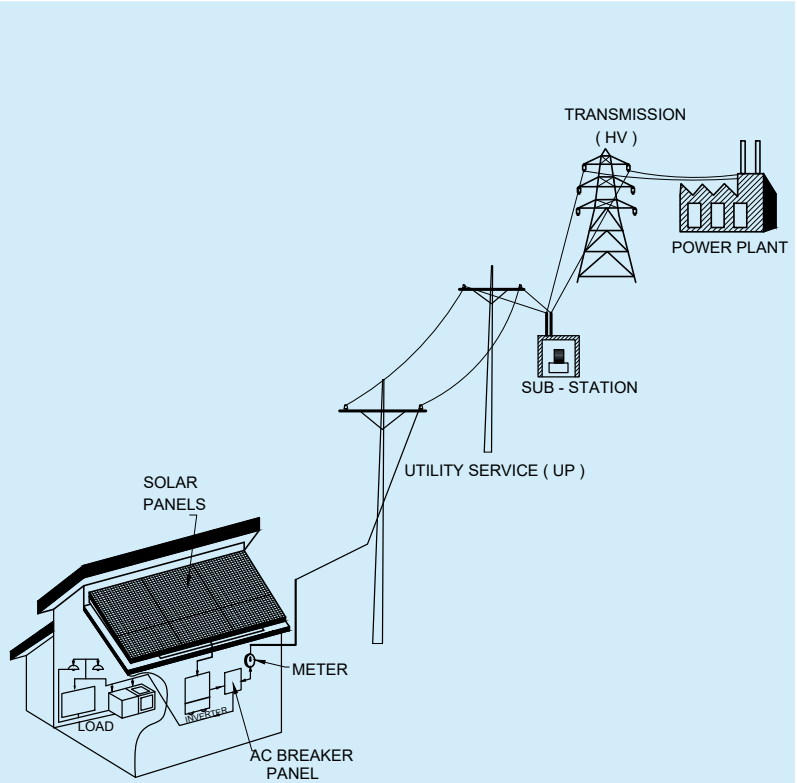

FIG. 13 GRID TIED SYSTEM

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Off grid system is not connected to the grid and the loads are fully powered by solar. Since sunlight varies depending on the time of the day and the cloud levels and also since it is not available in the night, batteries are an inherent part of an off-grid system. These systems are used in places without electrical grid or by building owners desirous of being independent of grid connection (*see* Fig. 14).

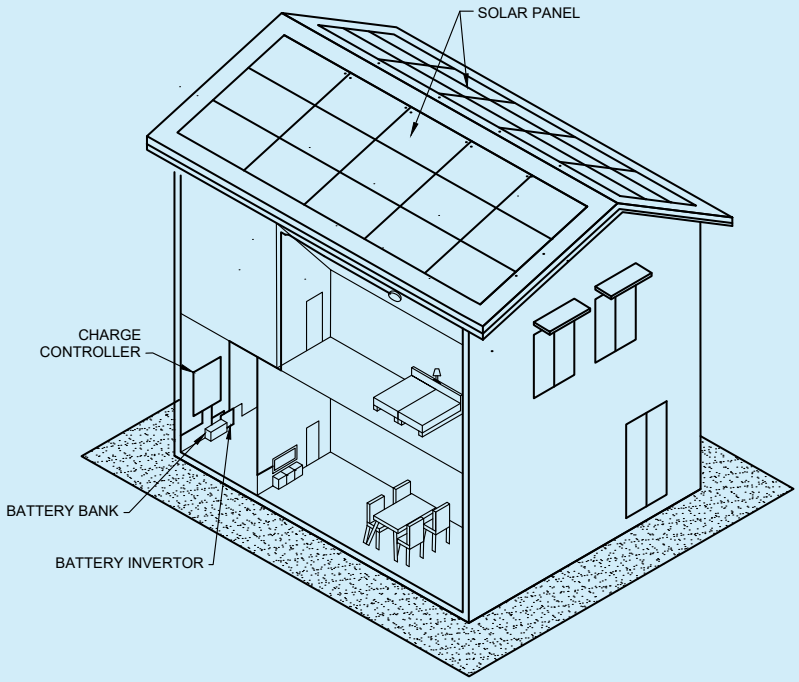

FIG. 14 AN OFF-GRID SYSTEM

10.8.3.3 *Protection system*

Since RTS is a power generating station on the topmost part of the building which is not in the view of occupants, it shall be protected against surge voltage, short circuit, lightning strike, earth fault, electrical fire, touch potential, shadow effect, etc by incorporating suitable protections into the system to avoid any mishap due to electrical fire. Special care should be taken to provide separate earth systems for d.c. power and a.c. power including interconnections and the earths will be interconnected at the earth level. The provisions for earthing and lightning protection shall be provided as per relevant Indian Standards and good practice [D-2(1)] including provision of necessary surge protection devices, where considered necessary.

10.8.3.4 *Solar PV system design*, *installation and maintenance*

Basic designing of the RTS depends upon the annual data relating to weather and solar insolation, shadow free area, generation potential, space required for other services, etc. For installation, all safety measures besides deployment of qualified personnel are required. Proper access to roof and distance between the row of solar panels is required for maintenance. System has to be maintained for guaranteed generation by regular cleaning of solar panels and inspection of the system for any abnormality from time to time.

10.8.3.5 *Regulations and standards relating to rooftop solar systems*

The system components shall comply with the relevant Indian Standards as amended up to date and work shall comply with the provisions of *Central Electricity Authority* (*Measures Related to Safety and Electric Supply*) *Regulations*, 2023 and good practice [D-2(1)]. Additionally, where mandated the use of solar d.c. cable as per accepted standard [D-2(67)] to prevent electrical fire on account of insulation failure due to exposure to UV radiations and weathering effect shall also be complied.

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10.8.4 *Building Integrated Photovoltaic System* (*BIPV*)

BIPV system is an approach where conventional building components such as roofs and facades are replaced with multi-functional parts of a building envelope that integrate PV to generate electricity while still fulfilling their structural role.

BIPV refers to solar electric (photovoltaic) components that are integrated into the building envelope replacing the conventional building materials. Instead of being added on like traditional solar panels, BIPV models are designed to be part of building structure such as roofs, facades or skylights. This integration allows BIPV to serve both as a power generator and building material improving aesthetics and reducing reliance on conventional energy. Thus, there shall be regular meeting and consultation among the architects, engineers and builders to ensure seamless integration of BIPV into building design.

Building-integrated photovoltaics (BIPV) is an innovative technology that integrates seamlessly into a building envelope such as roofs, facades, windows and skylights. BIPV materials function both as conventional building elements as well as electricity producers (*see* Fig. 15).

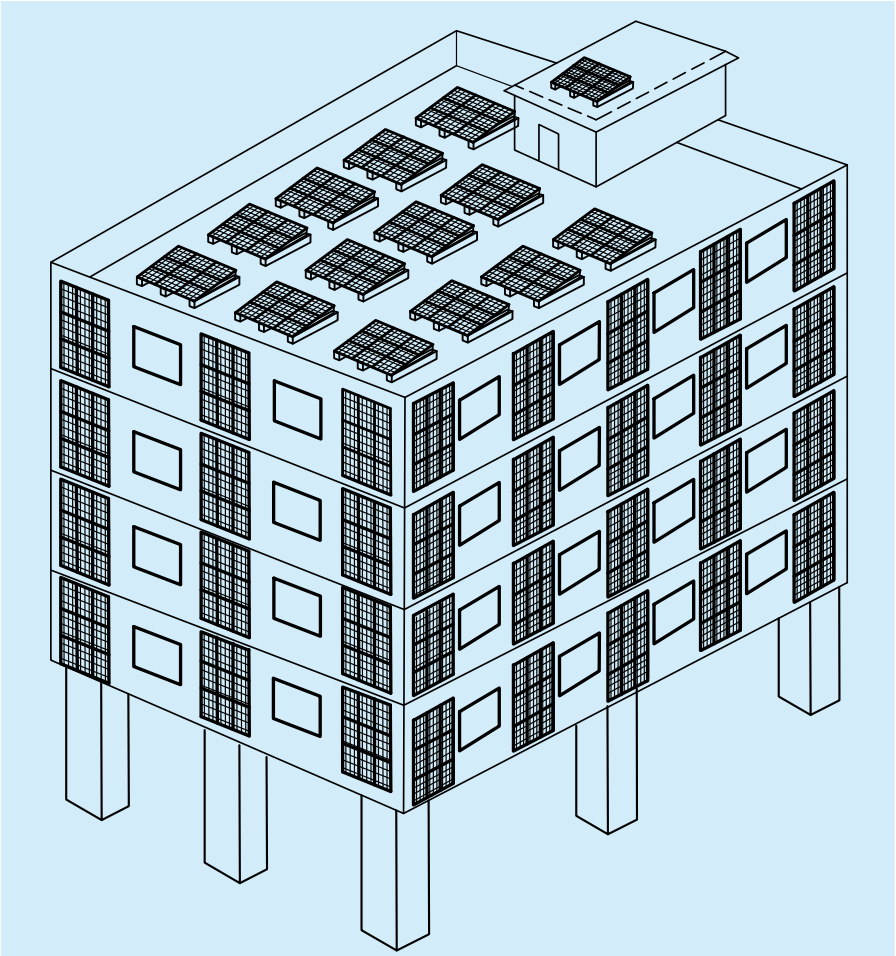

FIG. 15 BASIC STRUCTURE OF BIPV SYSTEM

10.8.4.1 *Design and planning of BIPV system*

a) *Building design integration* — Integration of BIPV technology into the building design is done, considering the factors like building orientation, shading, and structural integrity.

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b) *Solar panel selection* — Solar panels are so selected to enable them to meet the structural and civil engineering requirements and are suitable for BIPV applications such as for facades, roof tiles, balustrades, window glazing/ atrium skylights.

c) *Energy generation* — The potential for energy generation is worked out based on system design optimization to achieve the maximum energy output for the components used.

10.8.4.2 *Installation and testing*

10.8.4.2.1 *Installation*

The installation of BIPV systems shall follow the manufacturer guidelines of the respective components and shall also comply with the relevant provisions of the structural requirements to ensure proper connectivity among the components. BIPV system design and installation should be optimized through BIM.

10.8.4.2.2 *Testing*

See accepted standards [D-2(67)].

a) *Performance testing* — After installation, the BIPV system shall be checked to ensure that the system generates power as envisaged in the planning stage and the energy produced shall be monitored for assessing the overall energy output and efficiency. Suitable solar power meter with data logger and performance monitoring software shall be used to monitor the performance of the BIPV system installed.

b) *Safety inspection* — Necessary earth test measurements, insulation resistance test, continuity test, measurement of voltage and current shall be measured using appropriate earth tester, insulation resistance tester and multi-meter to confirm that all connections have been made correctly and the electrical components function as planned in the planning stage.

c) *Electrical testing* — Confirm that electrical components function correctly and safely by performing insulation resistance test and continuity test and by measuring voltage and current, using a multimeter, insulation resistance tester and earth tester.

d) *Structural testing* — Necessary structural testing shall be carried out to ensure the BIPV system can withstand environmental stresses that may occur during the lifetime of the building and also withstand necessary sun, rain, wind, etc.

e) *Integration testing* — All systems of the building so installed may be integrated using integration software load testers and communication testing tools so that the complete building acts as a single envelope.

f) *Weatherproofing and sealing* — Necessary leakage deduction and sealant inspection shall be carried out as per weather proofing guidelines so that BIPV system is weatherproof and does not cause any leakage or damage to the building or to the structure as a whole.

10.8.4.3 *Safety and maintenance*

a) *Electrical safety* — Electrical safety shall be ensured by following relevant good practices and accepted standards.

b) *Fire safety* — Fire safety shall be ensured by using fire-resistant materials and following the good practices.

c) *Maintenance* — The BIPV system shall be inspected at least once in a month to ensure optimal performance and timely maintenance including replacement of damaged components if any without any delay.

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10.9 Solar Water Heating System

10.9.1 *General*

This system is provided on the buildings to harness the energy of sun for heating water for kitchen and bathroom. Small systems from 100 litres to 300 litres are suitable for residential use while beyond this capacity are used for canteens, guest houses, hotels and hospitals. Located on top of building, the water is heated to 60 °C to 80 °C. However, in cloudy weather, back up electrical heater is sometimes required. Since it is provided on top of the building, it is necessary to provide equipotential bonding with the down conductor of LPS system as per relevant regulation and standards.

10.9.2 *Working*

When the sun's rays fall on the collector panel, which is a component of solar water heating system, a black absorbing surface (absorber) inside the collector absorbs solar radiation and transfers the heat energy to water flowing through it. Heated water is collected in a tank which is insulated to prevent heat loss. Circulation of water from the tank through the collectors and back to the tank continues automatically due to thermo-siphon system (*see* Fig. 16).

Solar water heating system are broadly categorized as active systems having pumps and controls, and passive systems relying on natural convection. Further, based on the collector system, solar water heaters can be of two types, namely flat plate collector type and evacuated tube collector type. In the first type, solar radiation is absorbed by flat plate collectors which consist of an insulated outer metallic box covered on the top with glass sheet. A black absorbing surface (absorber) inside the flat plate collectors absorbs solar radiation and transfers the energy to water flowing through it.

In the second type, the collector is made of double layer borosilicate glass tubes evacuated for providing insulation. The outer wall of the inner tube is coated with selective absorbing material. This helps absorption of solar radiation and transfers the heat to the water which flows through the inner tube.

10.9.3 *Compliance with Regulations and Standards*

As mandated by the government solar collectors shall adhere to the accepted standard [D-2(68)]. Further, municipal corporation/local bodies may require solar water heating systems to be installed in new buildings in their territories including in renovated buildings.

Accepted standard [D-2(69)] caters to the requirements and components of flat plate collector type solar water heating system while accepted standard [D-2(70)] caters to glass evacuated tubes solar water heating system. Accepted standard [D-2(71)] caters to storage water tank for all glass evacuated tubes solar water heating systems.

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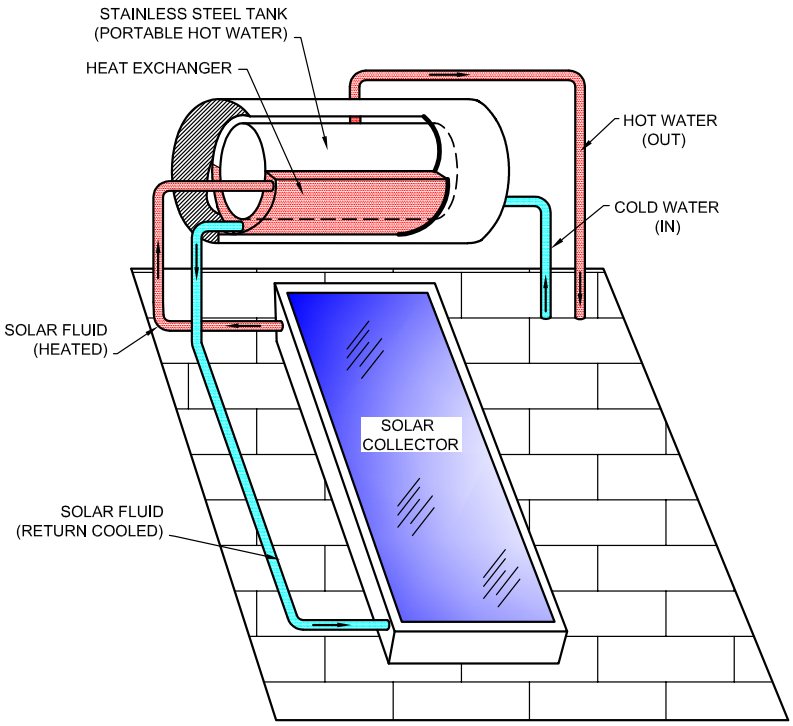
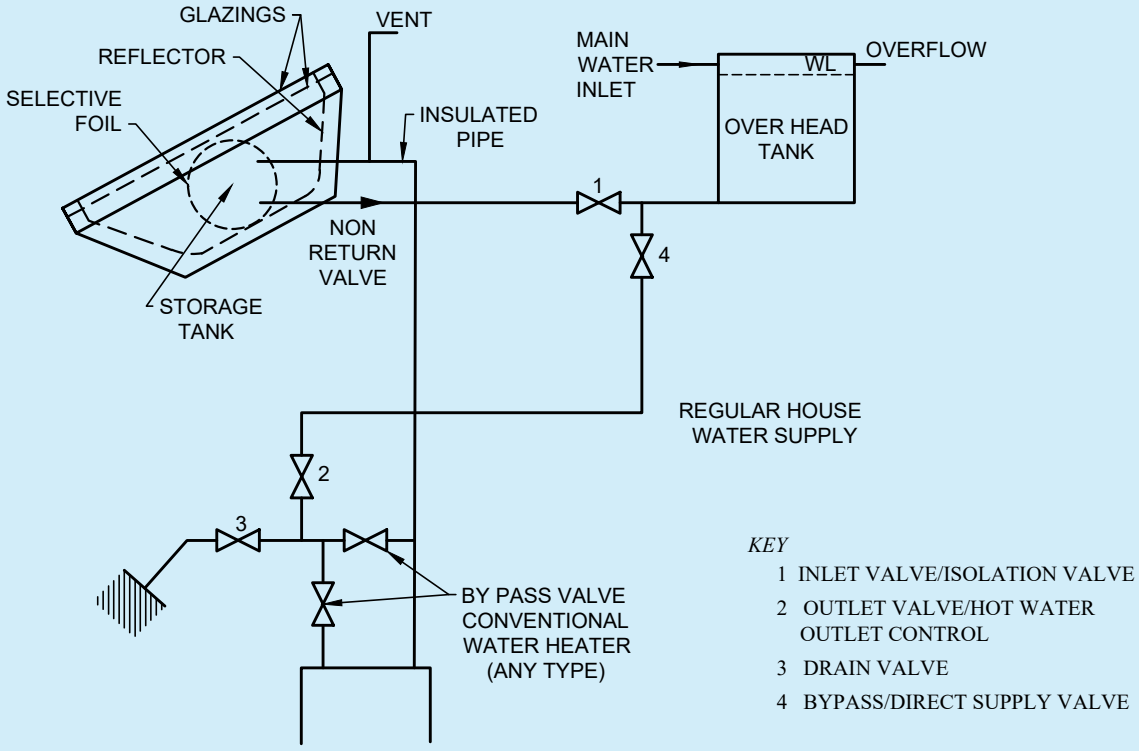


16A SOLAR COLLECTOR BASED WATER HEATER



16B SCHEMATIC OF CONNECTION BETWEEN SOLAR BASED WATER HEATER
OVERHEAD TANK BOTH CONNECTED TO THE CONVENTIONAL WATER HEATER

FIG. 16 WORKING OF SOLAR WATER HEATING SYSTEM

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10.10 Aviation Obstacle Lights

High-rise buildings and structures such as chimneys and towers are potential hazards to aircraft. The provision of aviation obstacle lights (AOL) on tall buildings/structures is intended to reduce hazards to aircraft by indicating their presence. AOLs, low, medium or high intensity obstacle lights, or a combination of such lights, shall be provided on buildings of different heights as per the requirements of Annex 14 to the 'Convention on International Civil Aviation, Volume I Aerodrome Design and Operations', International Civil Aviation Organization (ICAO). A general arrangement of AOLs in case of group of buildings is given in Fig. 17.

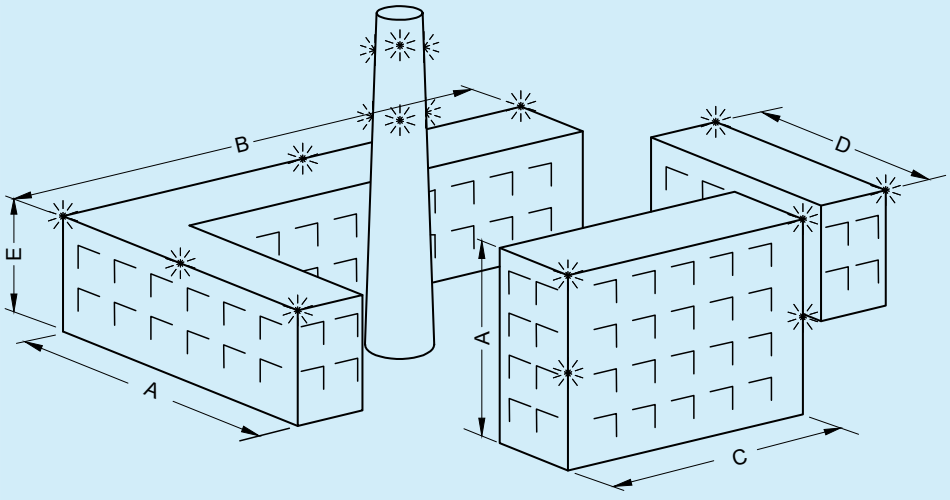

FIG. 17 TYPICAL ARRANGEMENT OF AVIATION OBSTACLE LIGHTS IN CASE OF GROUP OF BUILDINGS

10.11 Power/Electric Fence

10.11.1 *General*

Power/electric fence is provided in highly secured buildings to deter the intruders from climbing or sending a very low flying object, after proper risk assessment. It is provided on the boundary wall of the building and plays an important part in perimeter security by integrating with video surveillance software. This can also be used to protect the farms from the wild animals.

10.11.2 *Working*

This is a non-lethal fence consisting of wires carrying pulses of electric current and consists of an energizer producing regular current pulses. The supply lines conduct the pulses to the fence and takes back to the device from the earth stake. Wires should be good conductors and tied to the L-shaped posts securely over an insulator which separates the fence wire from the post and ensures that pulse current is not diverted to the ground. Height of the fence above the wall should be 1.5 m and spacing between wires shall be 100 mm. The distance between posts shall not be greater than 3 m and fence should be able to withstand the winds of 120 kmph when installed on boundary wall. A living object touching both wire and earth during pulse will get a shock and thus deter from entering the perimeter. The impact of shock depends upon the voltage, energy of the pulse, area of contact between the recipients, fence and ground, and the route of the current through the body. The intensity of shock can range from barely noticeable to uncomfortable or painful. It can also be solar powered. (*See* Fig. 18)

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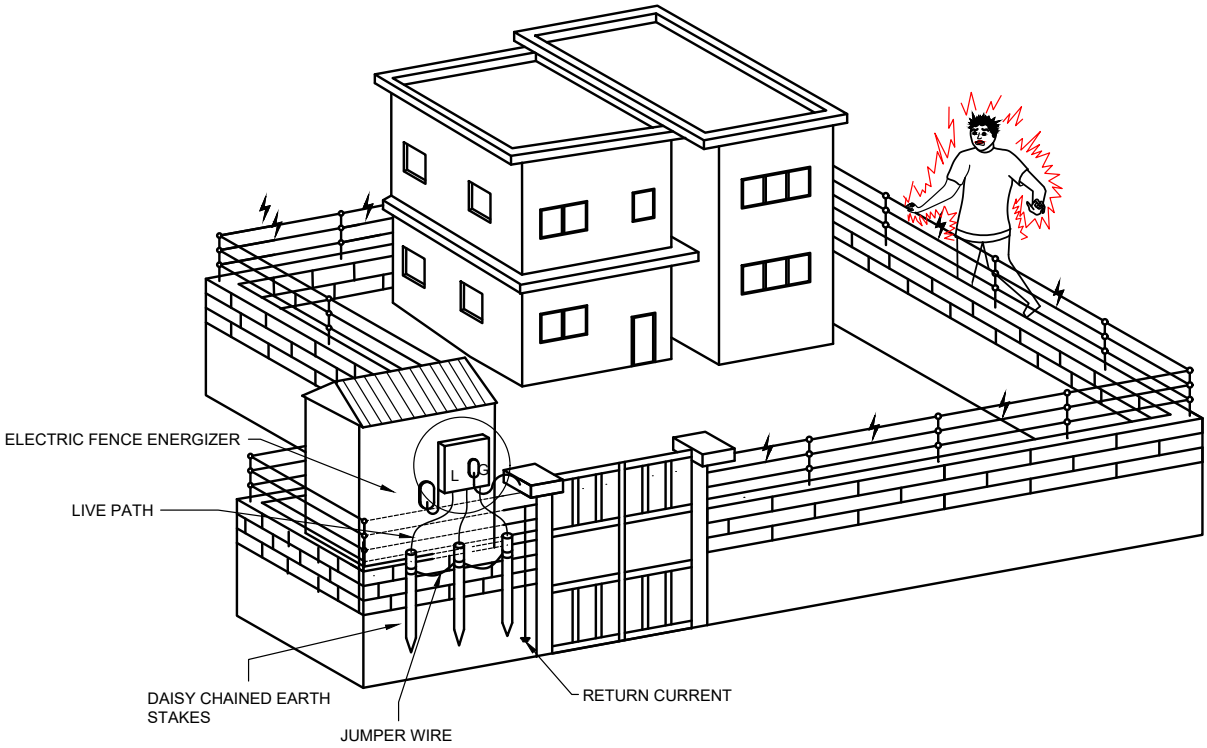

FIG. 18 POWER/ELECTRIC FENCE

10.11.3 *Compliance with Regulations and Standards*

It shall comply with specific safety and local regulatory standards. *See* accepted standard [D-2(72)] for safety and performance requirements. Prominent warning signs to alert people to the presence of the electric fence should also be displayed at regular intervals.

11 LIGHTNING PROTECTION OF BUILDINGS

11.1 General

Lightning flashes to, or nearby, structures (or lines connected to the structures) are hazardous to people, to the structures themselves, and to their contents and installations. Flashes of lightning discharges are of very high energy and can have devastating effects depending on the path of its discharge. Lightning strike is not predictable and is a random phenomenon both from the aspect of its occurrence and intensity or the energy discharge. There are no devices or methods capable of modifying the natural weather phenomena to the extent that they can prevent lightning discharges. Lightning protection measures therefore become essential. Lightning protection system (LPS) is the method of diversion of the lightning charges to the periphery of the building and to the ground so that the building, its occupants and sensitive equipment housed in the building, including connections from public systems to the building, are protected from the effects of lightning. The works carried out under this shall confirm to the relevant Indian Standards and the provisions of good practice [D-2(1)]. Brief details of the system are given hereunder.

NOTE — Reference is made to IEC 62305 (all parts) : 2024 instead of IS/IEC 62305 : 2010/11 since IEC 62305 : 2010/11 has been revised and is likely to be adopted by Bureau of Indian Standards shortly.

11.2 Steps for Deciding on Lightning Protection System

Lightning protection systems (LPS) are installed to avoid accidents, severe injuries and loss of life/deaths of humans and animals due to direct or indirect effects of lightning.

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The following steps are to be followed to ensure protection from lightning in a building:

a) In order to utilize the building components such as reinforced cement concrete (RCC) columns and RCC foundation for embedded down conductor and earth termination system, the lightning protection system shall be considered and designed before starting the construction of the building;

b) Assess the need and level for lightning protection system based on risk and frequency of damage assessment as per IEC 62305-2 : 2024 'Protection against lightning — Part 2: Risk management' and the level of protection shall be identified along with coordinated SPDs to be connected to the power system and the telecommunication system;

c) Decide on the type of external LPS including usage of building components, corrosion problems, sizing of conductors and routing of conductors;

d) Calculate the separation distances, if isolated or electrically insulated LPS is used and find out the possibility of maintaining separation distance. Note that for high rise buildings, maintaining separation distance may not be practically possible. In such cases, alternate methods recommended in IEC 62305-3 : 2024 'Protection against lightning — Part 3: Physical damage to structures and life hazard' should be used. Equipotential bonding with the attached LPS shall be done at multiple levels and for exposed and extraneous metallic parts of the building;

e) Down conductors shall be placed to surround the building structure as uniformly as possible. Down conductors shall be installed vertically to provide the shortest and most direct path to the earth, and bends and joints should be avoided;

f) Decide on the type of earth termination system and the provisions for equipotential bonding at ground level. Type A earth termination (vertical or horizontal earth electrodes) is not efficient for large buildings. Lightning protection system without equipotential bonding (at ground level) to electrical installation is a safety hazard and shall be avoided;

g) In buildings where sensitive and large electronic systems are present such as datacentres, hospitals, telecommunication centres, etc, appropriate shielding measures shall be provided to mitigate the effects of electromagnetic disturbances; and

h) Measures to reduce touch and step potential outside the building, shall be adopted to ensure safety of the people.

While designing and execution of LPS, the following points shall be observed and implemented to prevent any unforeseen accidents due to lightning:

a) Where architectural or structural constraints exist, multiple down conductors shall not be routed collectively through vertical shafts or internal facades. In all such cases, appropriate separation distance between the conductors, continuous metallic bonding with accessibility for inspection and testing when required shall be ensured.

b) Equipotential bonding with the MET of the electrical installation and termination of SPDs shall be done.

c) Routing down conductors near metal installations such as facades, pipes, etc, without equipotential bonding should not be done.

11.3 Classification of Lightning Protection System

Class of LPS denotes the classification of an LPS according to the lightning protection level for which it is designed. Four classes of LPS I, II, III and IV are defined, based on the corresponding LPL I, II, III and IV. Each class of LPS is characterized by the rolling sphere radius, mesh size, protection angle, typical distance between down conductors, separation distance against dangerous sparking and minimum length of earth electrodes (IEC 62305-3 : 2024 'Protection against lightning — Part 3: Physical damage to structures and life hazard'). Acceptable method to determine the position of air termination system includes the protection angle method, rolling sphere method and the mesh method. The rolling sphere method is suitable for all classes. The protection angle method is suitable for simple shaped buildings but is subject to limits indicated in Table 3. The mesh method is suitable for plane surface protection.

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11.4 Planning and Designing of Lightning Protection System

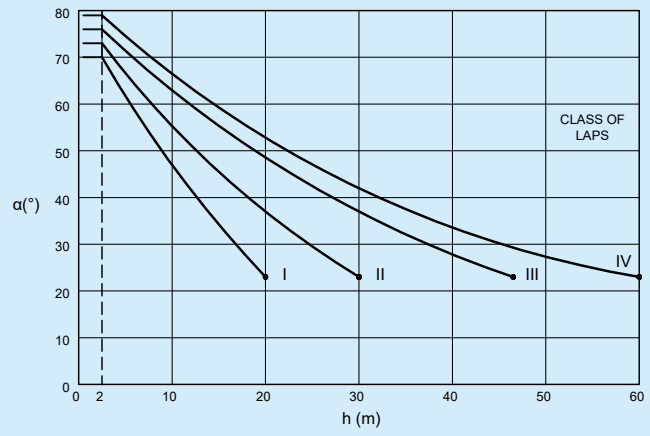
The lightning protection system (LPS) should be designed and installed by LPS designers or engineers experienced in LPS design. Planning, implementation and testing of an LPS encompasses a number of technical fields and demands for coordination by all parties involved with the construction and maintenance of the structure to ensure an efficient LPS.

It is essential to carry out the risk and frequency of damage assessment for a building based on IEC 62305-2 : 2024 'Protection against lightning — Part 2: Risk management' to decide the type of protection needed for lightning protection level and the level of coordinated SPDs required to be connected to the power line and telecommunication line. The lightning protection is divided into four levels (LPL I to IV) which helps in designing and implementing protection measures for an economical implementation. LPL I provides the maximum protection, whereas, LPL IV provides the least protection. Table 3 gives the values for different type of LPS.

Table 3 Maximum Values of Rolling Sphere Radius, Mesh Size and Protection Angle Corresponding to the Class of LPS

(*Clauses* 11.3, 11.4 *and* 11.6.1.7)

Sl No.	Class of LPS	Protection Method		
		Rolling Sphere Radius, r m	Mesh Size, W_m m	Protection Angle, α
(1)	(2)	(3)	(4)	(5)
i)	I	20	5 × 5	*See* Fig. 19 below
ii)	II	30	10 × 10	
iii)	III	45	15 × 15	
iv)	IV	60	20 × 20	



NOTES

1 NOT APPLICABLE BEYOND THE VALUES MARKED WITH • ONLY ROLLING SPHERE AND MESH METHODS APPLY IN THESE CASES.

2 h IS THE HEIGHT OF AIR-TERMINATION ABOVE THE REFERENCE PLANE OF THE AREA TO BE PROTECTED.

3 THE ANGLE WILL NOT CHANGE FOR VALUES OF h BELOW 2 m.

FIG. 19 PROTECTION ANGLE CORRESPONDING TO THE CLASS OF LPS

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Complete system for protection of structures against lightning, including their internal systems and contents, be installed to avoid damages to structures, accidents, severe injuries to humans due to direct or indirect lightning. Both protection measures should complement each other.

The management of the LPS should be efficient if the steps given in **11.2** are followed. Quality assurance measures are of great importance, in particular, for structures including extensive electrical and electronic installations. *See* accepted standards [D-2(73)] and [D-2(74)].

During the planning, various parties involved shall deliberate and agree on the following points which influence lightning protection system:

a) Decide whether or not the structure needs protection and if so, the special requirements have to be decided by making necessary calculations {*see* accepted standards [D-2(75)]};

b) Special attention shall be provided by architects and civil engineers on routing of down conductors, separation distance, usage of natural components and foundation earthing (*see also* Note);

c) Electrical separation and equipotential bonding shall be carefully analysed. Equipotential bonding of electrical services by SPD is also mandatory to complete lightning protection;

d) Ensure a close liaison between the architect/engineer, the builder, the lightning protection system engineer and the appropriate authorities throughout the design stages (*see* Note); and

e) Agree the procedures and define the period for testing and future maintenance {*see* accepted standard [D-2(76)]}.

NOTE — Modern buildings with electronic equipment need protection from radiated surges of lightning. To achieve this, structural steel of the building is also used as a part of lightning protection system {*see* accepted standard [D-2(73)]}. In such cases, lightning protection measures shall be included in the structural steel, particularly in column foundation.

11.5 Use of Building Components in Lightning Protection System

Conductive components installed not specifically for lightning protection system which can be used in addition to LPS or in some cases could provide the functions of one or more parts of LPS like natural air termination, natural down conductor, natural earth electrode are known as natural components of LPS {*see* accepted standard [D-2(76)]}.

Steel work within RCC structure is considered to be electrically continuous provided that major interconnections of vertical and horizontal bars are welded or otherwise securely connected. For new structures the connections between the RCC elements in the columns of the building shall be easily achieved by the designer in cooperation with the builder and the civil engineer by providing one additional smoothly finished copper/copper coated steel/stainless steel conductor/rod of diameter as indicated in Table 8. From foundation to the terrace continuously welded with suitable clamping/welding to all intervening horizontal bars (in case if single welded rod is not possible then necessary lapping between two rods shall be made as per IEC 62305-3 : 2024 ‘Protection against lightning — Part 3: Physical damage to structures and life hazard’). Thus, all external columns can act as down conductors for LPS and there will be no need for provision of separate external down conductors especially in architectural facia and glazed facia of the buildings. The overall electrical resistance of the reinforcement provided should not be greater than 0.2 Ω using test equipment suitable for this purpose. Suitable test joints shall be brought out from the structure at/near ground level for test purposes.

Interconnected reinforcement steel in concrete foundation buried directly in ground can be used as earth electrode. Special care shall be taken at the termination to prevent mechanical splitting of the concrete. Normally, a concrete raft foundation or pile foundation with pile caps of a building, provides reinforcement rods of not less than 25 mm having interconnected reinforcement steel duly clamped/welded, will provide a proper earth electrode and in closed loop formation. This will give a very good earth resistance for the down conductors and the overall value shall be measured to be less than earth resistance achieved normally.

The additional reinforcement provided for LPS shall be connected through welding to the foundation reinforcement and also with the roof conductors connecting the air termination through welding and suitably epoxy painted to prevent rusting. Thus, the LPS for the building shall become homogeneous after provision of air termination at the roof level based on rolling sphere/mesh system by interconnecting the top of the reinforcement from the columns with the terrace conductors (*see* Fig. 20).

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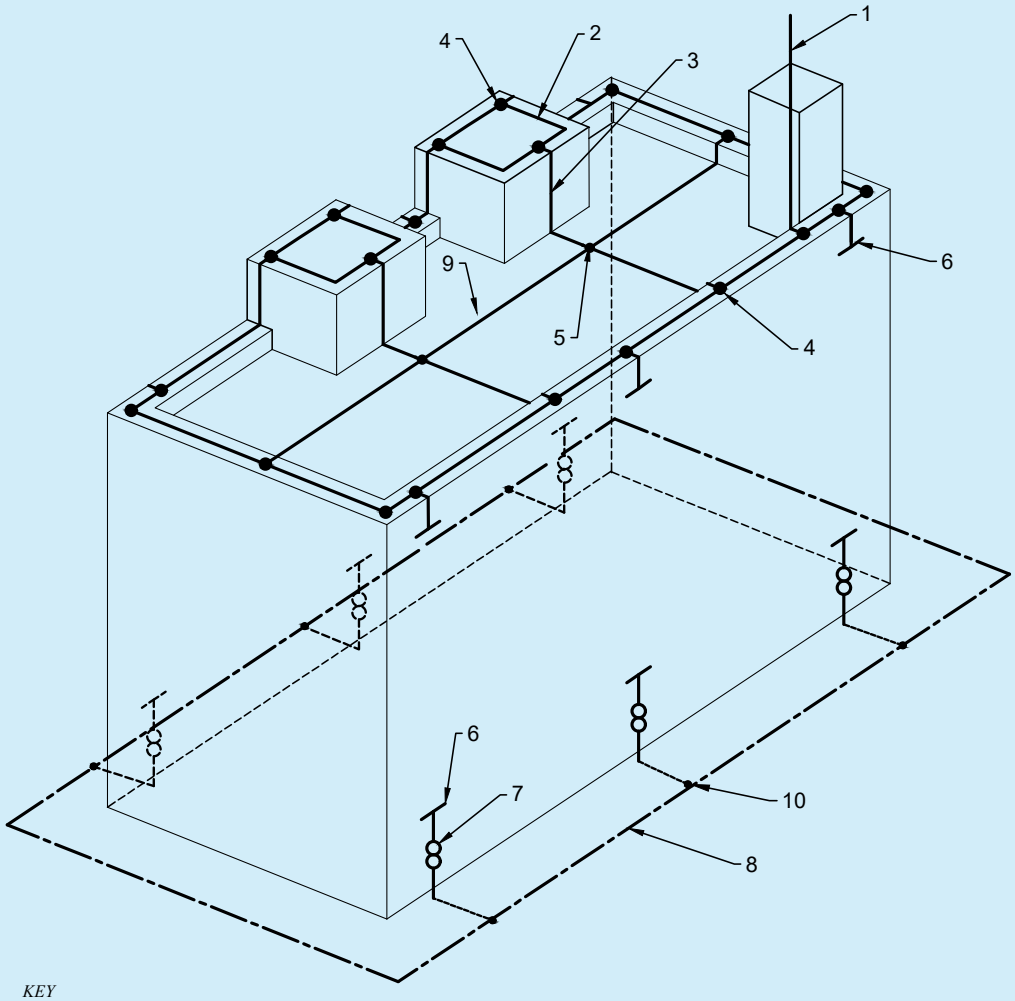
Use of building components namely the cement concrete foundation and the columns, reduces not only the work of providing down conductors and earthing sets for the LPS and the cost thereof but also saves the difficulties of placing down conductors of LPS in respect of architectural facia of modern buildings. Also, test joints are not required for these cases {*see* **5.3.6** of accepted standard [D-2(73)]}.

NOTE — When incorporating a structure's natural components, such as rebar within the concrete foundation, specialized mechanical couplers or clamps {*see* accepted standard [D-2(77)]} may be specified during design to create secure equipotential bonding as per IEC 62305-3 : 2024 'Protection against lightning — Part 3: Physical damage to structures and life hazard'.



KEY

1 AIR TERMINATION ROD
2 HORIZONTAL AIR TERMINATION CONDUCTOR
3 DOWN CONDUCTOR
4 T - TYPE JOINT
5 CROSS TYPE JOINT
6 CONNECTION TO STEEL REINFORCING RODS {*see* **E-4.3.3** AND **E-4.3.6** OF GOOD PRACTICE [D-2(73)]}
7 TEST JOINT
8 EARTH ELECTRODE TYPE B EARTHING ARRANGEMENT, RING EARTH ELECTRODE
9 FLAT ROOF WITH ROOF FIXTURES
10 T - TYPE JOINT - CORROSION RESISTANT

NOTE — THE STEEL REINFORCEMENT OF THE STRUCTURE SHOULD COMPLY WITH AVAILABLE INDIAN STANDARDS. ALL DIMENSIONS OF THE LPS SHOULD COMPLY WITH THE SELECTED PROTECTION LEVEL.

FIG. 20 CONSTRUCTION OF EXTERNAL LPS ON A STRUCTURE OF STEEL-REINFORCED CONCRETE USING THE REINFORCEMENT OF THE OUTER WALLS AS NATURAL COMPONENTS

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11.6 Components of Lightning Protection System (LPS)

The main and most effective measure for protection of structures against physical damage is considered to be the lightning protection system (LPS). It usually consists of both external and internal lightning protection systems.

An external LPS which consists of air-termination system, down-conductor system and earthing system {*see* accepted standard [D-2(73)]} is intended to:

a) intercept a lightning flash to the structure (with an air-termination system);

b) conduct the lightning current safely towards earth (using a down-conductor system); and

c) disperse the lightning current into the earth (using an earth-termination system).

An internal LPS comprises equipotential bonding or a separation distance (and hence electrical insulation) between the external LPS components and other electrically conducting elements internal to the structure.

Both external and internal protection systems should complement each other.

Access to the ground and the proper use of foundation steelwork for the purpose of forming an effective earth-termination may well be impossible once construction work on a site has commenced. Therefore, soil resistivity and the nature of the earth electrode should be considered at the earliest possible preferably during the design stage of a project. This information is fundamental to the design of an earth-termination system and may influence the foundation design work for the structure.

Regular consultation between LPS designers and installers, architects/civil engineer and builders is essential in order to achieve the best result at minimum cost. If lightning protection is to be added to an existing structure, every effort should be made to ensure that it conforms to the principles of this NBCS. The design of the type and location of an LPS should take into account the features of the existing structure.

11.6.1 *Air-Termination System*

Air-termination system is a part of an external LPS using metallic elements such as rods, mesh conductors or catenary wires intended to intercept lightning flashes. The probability of penetration by a lightning current on a structure is considerably decreased by the presence of a properly designed air-termination system. Air-termination systems can be composed of any combination of the following elements:

a) vertical rods (offers certain angle of protection);

b) catenary wires; and

c) meshed/grid conductors.

Franklin rod (conventional) type of air-termination system shall be positioned in accordance with **11.6.1.1**. The individual air-terminations rods should be connected together at roof level to ensure current division. Radioactive air-terminals shall not be allowed. Any other kind of air-terminal like dissipation system/ESE air-terminal/CSE air-terminal or any other air terminal not approved by IEC 62305-3 : 2024 ‘Protection against lightning — Part 3: Physical damage to structures and life hazard’ shall not be acceptable.

11.6.1.1 *Positioning*

Air-termination components installed on a structure shall be located at corners, exposed points and edges (especially on the upper level of any facades) in accordance with one or more of the following methods {*see also* Fig. 21 to Fig. 25 in conjunction with good practice [D-2(11)]}:

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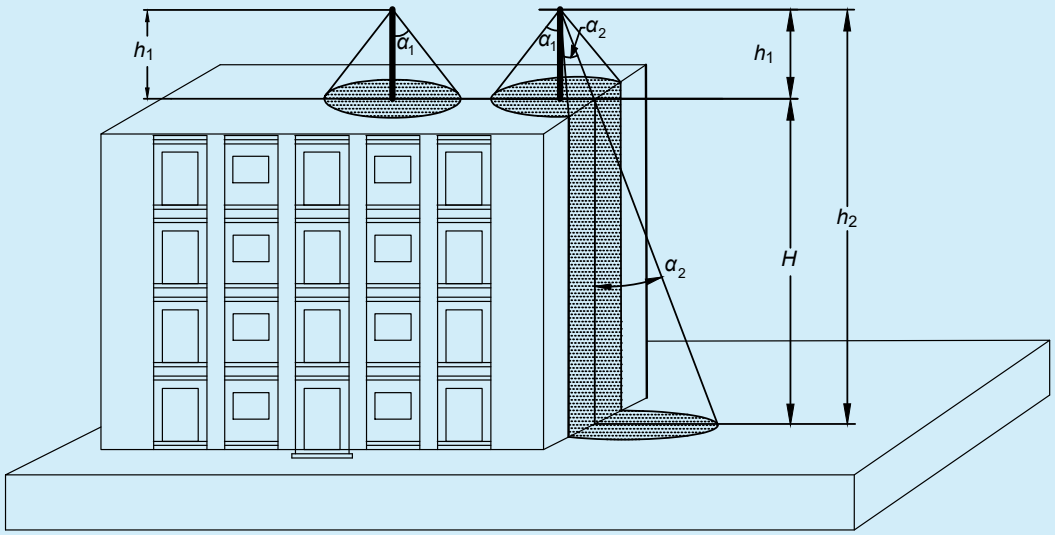


KEY

H HEIGHT OF BUILDING OVER THE GROUND REFERENCE PLANE

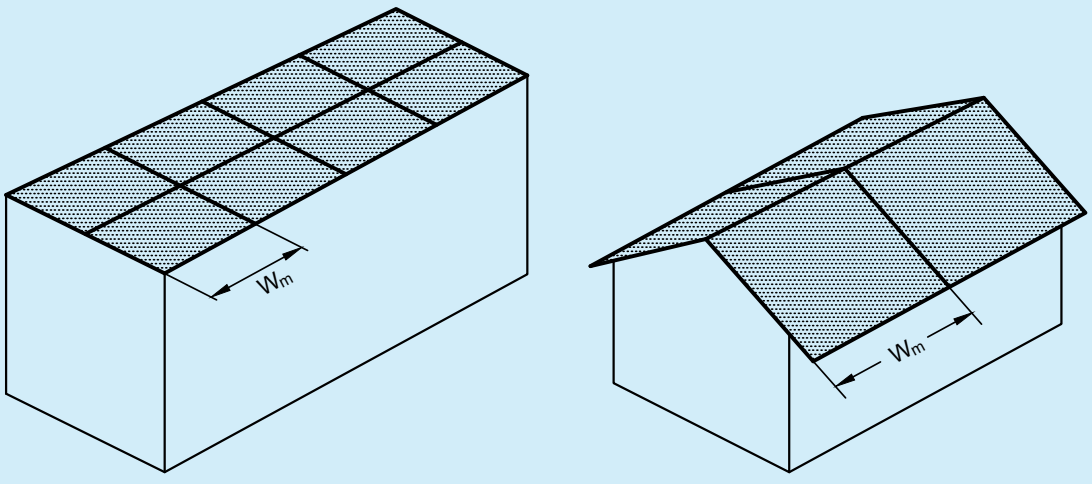
h_1 PHYSICAL HEIGHT OF AN AIR TERMINAL ROD

h_2 HEIGHT OF THE AIR TERMINATION ROD OVER THE GROUND = $h_1 + H$

α_1 THE PROTECTION ANGLE CORRESPONDING TO THE AIR TERMINATION HEIGHT, $h = h_1$, BEING THE HEIGHT ABOVE THE ROOF SURFACE TO BE MEASURED (REFERENCE PLANE)

α_2 THE PROTECTION ANGLE CORRESPONDING TO THE HEIGHT, $h_2 = H + h_1$

FIG. 21 PROTECTION ANGLE METHOD OF AIR TERMINATION DESIGN FOR DIFFERENT HEIGHTS



W_m – MESH SIZE

FIG. 22 DESIGN OF AIR-TERMINATION SYSTEM ACCORDING TO MESH METHOD

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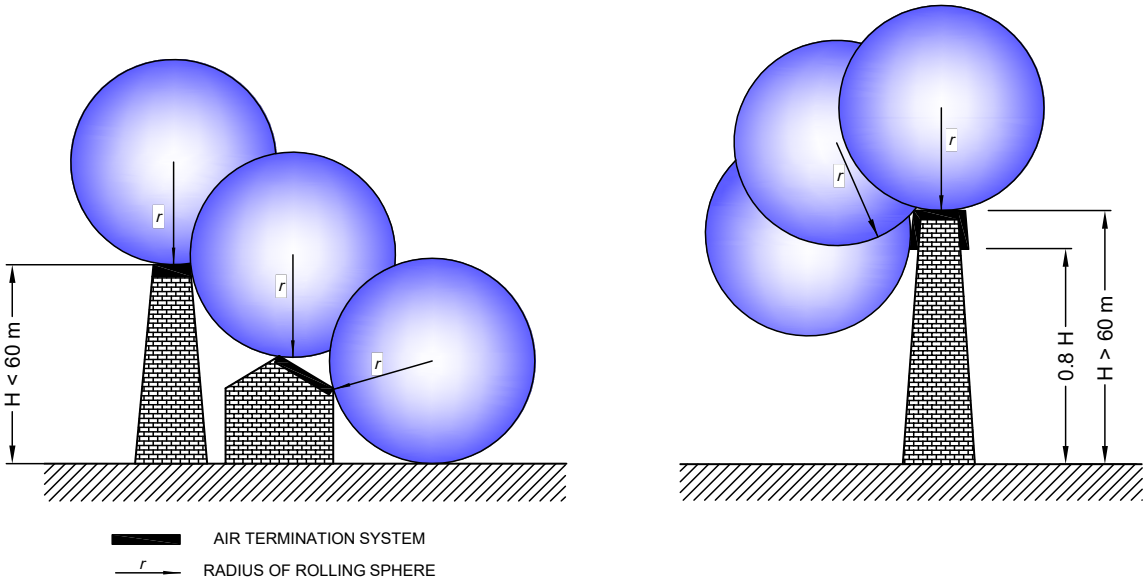
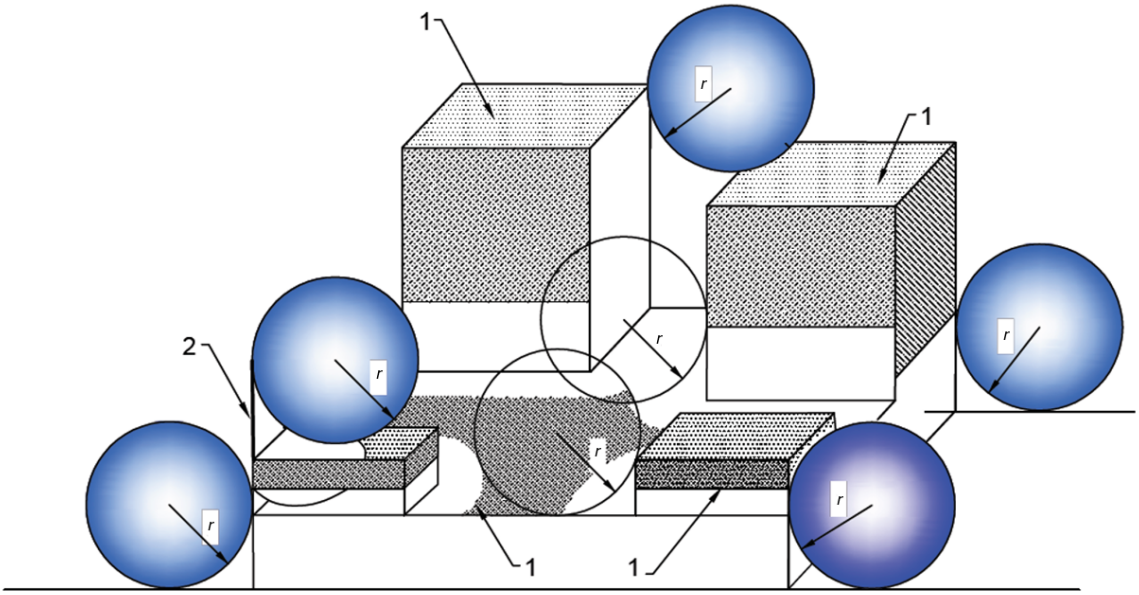


FIG. 23 DESIGN OF AIR-TERMINATION SYSTEM ACCORDING TO THE ROLLING SPHERE METHOD



Key

1 Shaded areas are exposed to lightning interception and need protection

2 Mast on the structure

r Radius of rolling sphere

FIG. 24 DESIGN OF AIR-TERMINATION CONDUCTOR NETWORK FOR A STRUCTURE WITH COMPLICATED SHAPE

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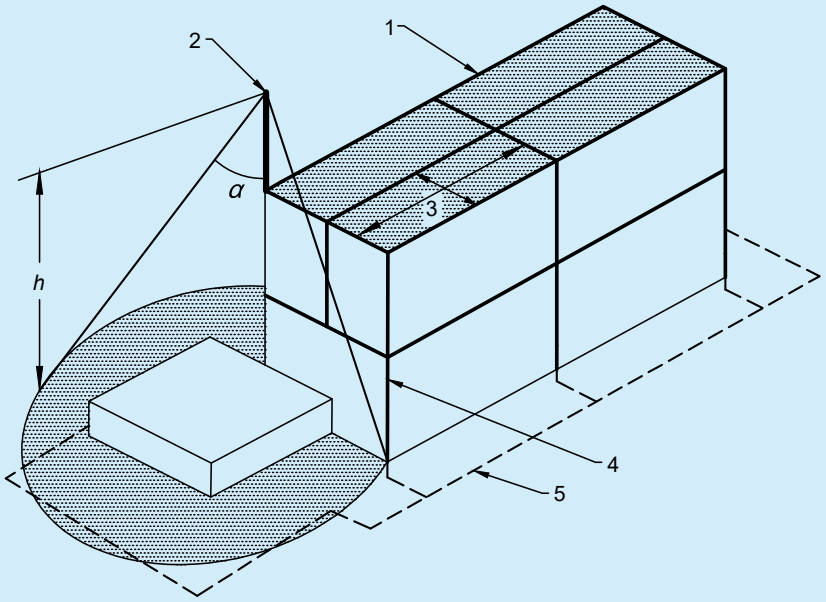

KEY

1 AIR - TERMINATION CONDUCTOR (ALSO CALLED AS MESH/FARADAY CAGE)
2 AIR - TERMINATION ROD
3 MESH SIZE
4 DOWN CONDUCTOR
5 EARTHING SYSTEM WITH RING CONDUCTOR
h HEIGHT OF THE AIR TERMINAL ABOVE GROUND LEVEL
α PROTECTION ANGLE

FIG. 25 DESIGN OF AN LPS AIR-TERMINATION ACCORDING TO THE PROTECTION ANGLE METHOD, MESH METHOD AND GENERAL ARRANGEMENT OF AIR-TERMINATION ELEMENTS

11.6.1.2 Roof mounted electrical/electronic equipment (for example, chillers, antennas, cameras and bill boards) need vertical air-termination to avoid direct strike. Power and data connection to these equipment should have proper SPDs (*see* **11.7.4**) to avoid failures. Overhead cables such as cable TV lines from one building to the other should be avoided.

11.6.1.3 Unearthed metallic roofs should be avoided. Metallic roofs shall be connected either to steel reinforcement or to other earthed steel parts of the building satisfying the requirements of number of down-conductors (*see* **11.6.2**).

11.6.1.4 *Structures of height less than* 60 m *and more than* 60 m

Lateral impacts of flashes to the side of tall structures are considered as negligible for structures up to 60 m in height measured from ground level. However, elements significantly protruding the facade can be endangered (for example, balconies, cameras, antennas).

On structures taller than 60 m, flashes to the side can occur, especially to protruding parts and to corners and edges of facades.

All external metal parts that have a conductive connection with internal metal parts separated by a distance $d > s$ from a down conductor (or air terminations) should not be connected to the down conductor so as to keep any unnecessary partial lightning currents out of the structure.

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If this is not possible, the metal part should be directly bonded to the LPS. The possibility of the occurrence of partial lightning current into the structure should be considered.

NOTE — In general, the risk due to these flashes is low because only a few per cent of all flashes to tall structures will be to the side and their parameters are significantly lower than those of flashes to the top of structures. However, electrical and electronic equipment on walls outside structures can be destroyed even by lightning flashes with low current peak values.

An air-termination system shall be installed to protect significant protrusions (such as balconies, viewing platforms) on vertical surfaces on the upper part of tall structures (that is, typically the topmost 20 percent of the height of the structure), as well as the equipment installed on them (*see* Annex D of IEC 62305-3 : 2024 'Protection against lightning — Part 3: Physical damage to structures and life hazard'). For parts of the upper 20 percent that do not exceed 60 m above ground level, protection of the vertical surface is optional.

NOTE — Elements protruding through the facade of structures up to 60 m in height are rarely endangered.

11.6.1.5 *Roof top solar PV and water heaters on Buildings*

Vertical air-terminals are required for protecting roof mounted installations such as solar PV, water heaters, chillers as well as water tanks. Vertical air-terminals need to be connected to the air-termination mesh/down-conductors. Metal support structure of these installations shall be bonded to the air-termination mesh/down-conductors. Class I/Class II surge protection devices (SPDs) (*see* **11.7.4**) should be installed in the electrical lines to protect the installations inside the building (typically d.c. SPD for solar PV output at inverter or junction box level and a.c. SPD for inverter output and mains input). The roof top PV system or 230 V a.c. water heaters or any other equipment should not pose any safety risk related to lightning protection and protection of overall building may be reviewed by the expert after installation of roof top PV system. Necessary measures may then be required to complete the lightning protection arrangement.

Vertical air-terminals for PV modules based on LPL III/IV connected directly to the frame shall protect against direct lightning impact in solar PV power plant. A design according to rolling sphere method should be done for zone of protection (for example, 1 m rod at 0.5 m height from panel at four corners provides protection to approximately 12 m × 9 m area). Maximum height of the air-termination rod above the panel should be calculated considering the falling of shadow or umbra region of shadow not falling on any PV module. To reduce step potential, structures should be interconnected with underground earth mats/isolating spark gaps, wherever necessary (*see* Fig. 26 and Fig. 27).

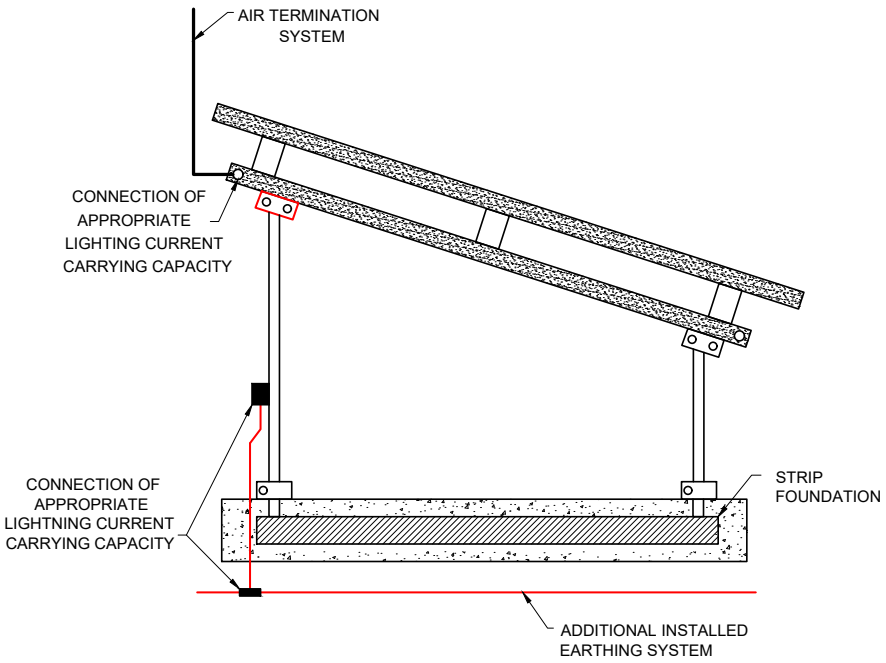

FIG. 26 TYPICAL INSTALLATION OF LIGHTNING PROTECTION SYSTEM IN SOLAR PV INSTALLATION

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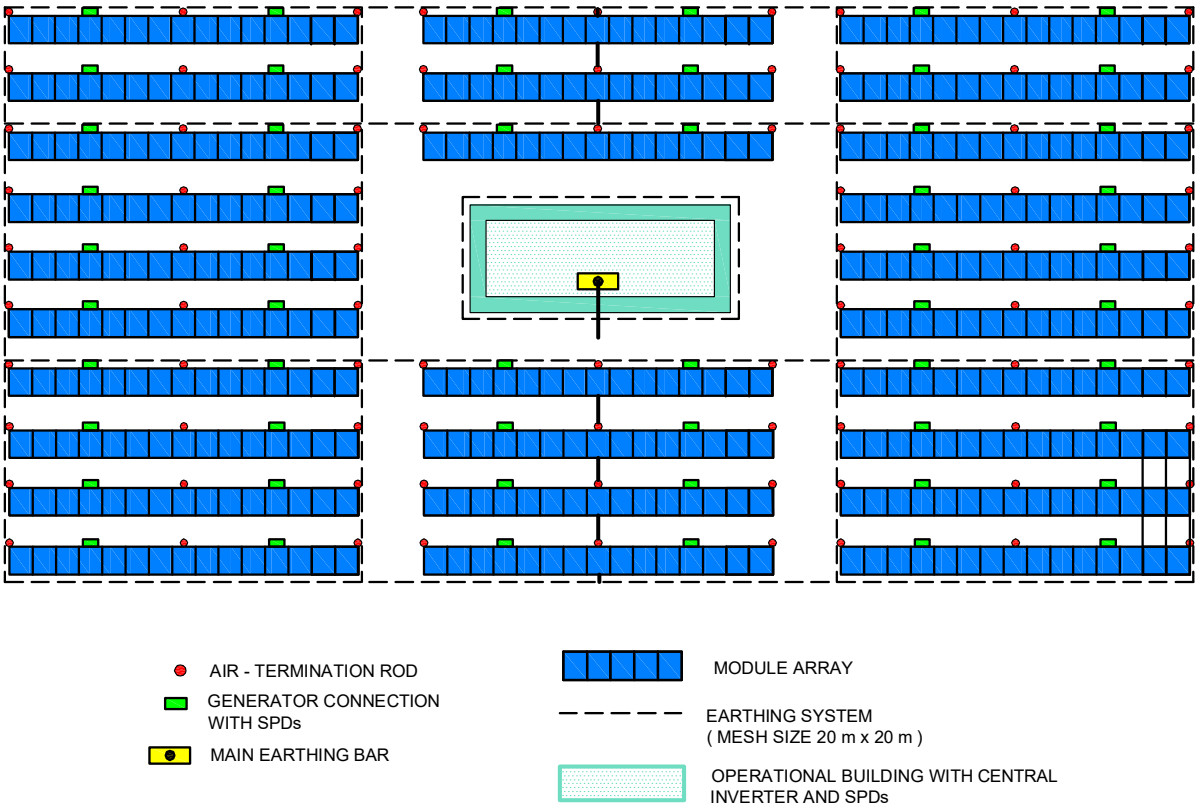

FIG. 27 TYPICAL ARRANGEMENT OF EARTHING AND SURGE PROTECTION DEVICES IN SOLAR PV INSTALLATION

11.6.1.6 *Buildings with roof top telecom towers*

The metallic tower itself will act as air-termination. Antennas mounted above these towers need air-terminals connected to the main structure. The main structure shall be connected to the air-termination conductors for the balance of the building, if available. Two separate down-conductors with a size of minimum 150 mm^2 should be used in addition to regular down-conductors to make the bonding between tower and ring earthing. In order to avoid uncontrolled flash overs and also to protect equipment, which may be mounted on the tower itself, special cable with increased dielectric strength as down-conductor should be used in order to avoid separation distance. The area of cross section will be significantly lower than 50 mm^2 but not less than 28 mm^2, which is sufficient enough to discharge the lightning current where mechanical strength is not an essential requirement.

Every power, coaxial, data and other metallic lines connected between the telecom installation and the other parts of the building shall be protected with suitable SPD. It should be ensured that SPDs during their operation do not impede fire safety.

11.6.1.7 *Lightning protection for multi-storeyed car park roofs/helipads*

Air-termination studs (*see* Fig. 28) may be used for lightning protection for multi-storeyed car park roofs/helipads. Air-termination studs used can be connected to the reinforcement steel of a concrete roof. In the case of roofs where a connection to the reinforcement cannot be made, the roof conductors can be laid in the seams of the carriageway slabs and air-termination studs can be located at the mesh joints. The mesh width shall not exceed the value corresponding to the protection class given in Table 3. The persons and vehicles on this parking area are not protected against direct lightning.

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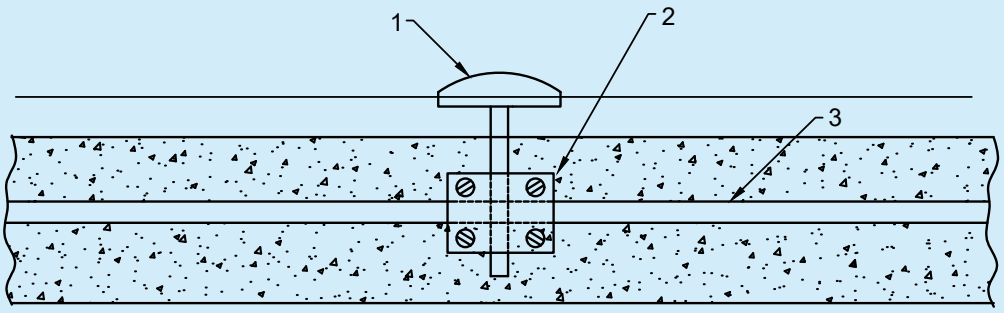

KEY

1 AIR - TERMINATION STUD
2 STEEL CONDUCTOR CONNECTING TO SEVERAL BARS OF THE REINFORCEMENT STEEL
3 STEEL REINFORCEMENT TO CONCRETE

FIG. 28 TYPICAL AIR-TERMINATION STUDS USED ON CAR PARK ROOFS

11.6.2 *Down-conductor System*

Down-conductor system is a part of an external LPS intended to conduct lightning current from the air-termination system to the earth-termination system. The down conductor system shall confirm to **5.3** of accepted standard [D-2(73)]. In order to reduce the probability of damage due to lightning current flowing in the air-termination system, the down-conductors shall be arranged in such a way that from the point of strike to earth:

a) several parallel current paths exist;

b) the length of the current paths is kept to a minimum; and

c) equipotential bonding to conducting parts of the structure is performed.

11.6.2.1 Typical values of the distance between down-conductors are given in Table 4. These values can be used for horizontal ring conductors installed for a tall building more than 60 m height. The minimum number of down-conductors shall be 2 (diagonally opposite to each other) for building with an area less than 100 m^2.

Table 4 Minimum Distance between Down-Conductors

(*Clause* 11.6.2.1)

Sl No.	Class of LPS	Distance m
(1)	(2)	(3)
i)	I	10
ii)	II	10
iii)	III	15
iv)	IV	20

11.6.2.2 Down-conductors shall be installed so that, as far as practicable, they form a direct continuation of the air-termination conductors. It shall be installed straight and vertical such that they provide the shortest and most direct path to earth. The formation of sharp bends and loops shall be avoided. Every down-conductor should be connected to a Type B ring/foundation earthing. Connection of down-conductor to a Type A earthing is allowed only in case of space constraints or existing buildings, where installation is difficult.

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11.6.2.3 While routing the down-conductors, separation distance need to be calculated based on accepted standard [D-2(73)] and maintained from live parts/services.

11.6.2.4 Lateral connection of down-conductors at ground level and every 10 m to 20 m of height as a ring conductor, as per below table, is considered to be good practice. The installation of as many down-conductors as possible, at equal spacing around the perimeter interconnected by ring conductors, reduces the probability of dangerous sparking and facilitates the protection of internal installations {*see* accepted standard [D-2(73)]}. This condition is fulfilled in metal framework structures and in reinforced concrete structures in which the interconnected steel is electrically continuous.

11.6.2.5 Routing of down-conductors (insulated or uninsulated) through shafts with electrical and electronic system is not allowed. But routing of down conductors can be done through other service shafts by maintaining separation distance or with equipotential bonding of extraneous metal components.

11.6.2.6 Separation distance is the distance required between air-terminals/lightning down-conductor and any conductive/metallic/electrical/electronic part of a building to avoid uncontrolled flashover.

11.6.2.6.1 While calculating the separation distance, the parameter l (length, in m along the air-terminal and the down-conductor from the point where the separation distance is to be considered, to the nearest equipotential bonding point or earth termination system is not bonded to equipotential bonding point or the earth termination) is a major influencing factor. If the down conductors or the earth terminal system is not bonded to equipotential bonding system of the electrical installation in the building, the lightning protection system will be ineffective.

Cable with increased dielectric strength and tested for lightning current discharge may be used to avoid specific separation distance to live parts of the building {*see* accepted standard [D-2(73)]}.

11.6.2.7 The down-conductor shall be supported using suitable clamps or connectors or exothermic welding. The clamps or connectors or exothermic welding shall be tested for the lightning current as per selected LPL. Reference may be made to table given below and accepted standard [D-2(73)] for supporting details:

Sl No.	*Arrangement*	*Fixing Centres for Tape, Stranded and Soft Drawn Round Conductors* mm	*Fixing Centres for Round Solid Conductors* mm
(1)	(2)	(3)	(4)
i)	Horizontal conductors on horizontal surfaces	1 000	1 000
ii)	Horizontal conductors on vertical surfaces	500	1 000
iii)	Vertical conductors from the ground to 20 m	1 000	1 000
iv)	Vertical conductors from 20 m and thereafter	500	1 000

NOTES

1 This table does not apply to built-in type fixings, which may require special considerations.

2 Assessment of environmental conditions (that is, expected wind load) should be undertaken and fixing centres different from those recommended may be found to be necessary.

11.6.2.8 The wind speed shall be taken into account while mounting the air-termination and down-conductor system {*see* accepted standard [D-2(73)]}.

11.6.3 *Earth-termination System*

Earth-termination system is a part of an external LPS which is intended to conduct and disperse lightning current into the earth. When dealing with the dispersion of the lightning current (high frequency behaviour) into the ground, whilst minimizing any potentially dangerous overvoltages, the shape and dimensions of the earth-

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termination system are the important criteria. In general, a low earthing resistance (if possible lower than 10 Ω when measured at low frequency) is recommended. From the viewpoint of lightning protection, a single integrated structure earth-termination system is preferable and is suitable for all purposes (that is, lightning protection, power systems and telecommunication systems).

Type A earth-termination comprising of vertical/horizontal conductor or Type B earth-termination comprising of ring earthing/foundation earthing shall be used satisfying the requirements of this NBCS as well as accepted standard [D-2(73)]. In structures where only electrical systems are provided, a Type A earthing arrangement may be used, but a Type B earthing arrangement is preferable. In structures with electronic systems, a Type B earthing arrangement is recommended.

11.6.3.1 *Type A earthing*

Length of the earth electrode depends on the soil resistivity and class of LPS {*see* good practice [D-2(11)] for details and Table 5 for vertical earth electrode}.

Table 5 Minimum Length of Vertical Earth Electrode

(*Clauses* 11.6.3.1 *and* 11.6.3.2)

Sl No.	Class of LPS	Typical Length of Each Vertical Earth Electrode Based on Soil Resistivity, m			
		Up to 500 Ω-m	1 000 Ω-m	2 000 Ω-m	3 000 Ω-m
(1)	(2)	(3)	(4)	(5)	(6)
i)	I	2.5	10	25	40
ii)	II	2.5	5	15	25
iii)	III	2.5	2.5	2.5	2.5
iv)	IV	2.5	2.5	2.5	2.5

11.6.3.2 *Type B earthing*

This type of arrangement comprises either a ring conductor external to the structure to be protected, in contact with the soil for at least 80 percent of its total length, or a foundation earth electrode. Such earth electrodes may also be meshed. For the ring earth electrode (or foundation earth electrode), the mean radius of the area enclosed by the ring earth electrode (or foundation earth electrode) shall be not less than the value of Type A earthing as given in Table 5 {*see* accepted standard [D-2(73)]}.

11.6.3.3 In industrial and commercial structures, the ring earth electrode around the structure or the ring earth electrode in the concrete at the perimeter of the foundation, should be integrated with a meshed network under and around the structure, having a mesh width of typically 5 m. This greatly improves the performance of the earth-termination system. If the basement's reinforced concrete floor forms a well-defined interconnected mesh and is connected to the earth-termination system, typically at every 5 m, the same will also be suitable {*see* accepted standard [D-2(73)]}.

11.6.3.4 Where large numbers of people frequently assemble in an area adjacent to the structure to be protected, further potential control for such areas should be provided. More ring earth electrodes should be installed at distances of approximately 3 m from the first and subsequent ring conductors. Ring electrodes further from the structure should be installed more deeply below the surface, that is, those at 4 m from the structure at a depth of 1 m, those at 7 m from the structure at a depth of 1.5 m and those at 10 m from the structure at a depth of 2 m. These ring earth electrodes should be connected to the first ring conductor by means of radial conductors.

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11.6.3.5 For large buildings integrating structural steel as down-conductor and earth-termination, earth resistivity measurements are not required. Proper drawings should be made based on the actual installation and submitted to authorities if necessary {*see also* accepted standard [D-2(73)]}. However, provisions shall be provided for continuity resistance measurement.

11.6.3.6 Touch and step voltage safety measures outside structure shall be installed and maintained as per accepted standard [D-2(73)].

11.6.4 *Use of Natural Components*

11.6.4.1 Natural components installed not specifically for lightning protection system can be used in addition to LPS or in some cases could provide the functions of one or more parts of LPS, like natural air termination, natural down conductor, natural earth electrode. The use of building components such as columns and foundation have been explained in **11.5** separately, in order to give special attention for use of such systems in modern buildings.

11.6.4.2 *Bonding network*

A low impedance bonding network is needed to avoid dangerous potential differences between all equipment inside the building. Moreover, such a bonding network also reduces the magnetic field, thereby reduces the radiated surges inside the building and provides more protection for electrical electronic equipment {*see* accepted standard [D-2(74)]}.

This can be realized by a meshed bonding network integrating conductive parts of the structure, or parts of the internal systems, and by bonding metal parts or conductive services at the boundary of each lightning protection zone (LPZ) directly or by using suitable SPDs.

The bonding network can be arranged as a three-dimensional meshed structure with a typical mesh width of 5 m (*see* Fig. 29 and Fig. 30). This requires multiple interconnections of metal components in and on the structure (such as concrete reinforcement, elevator rails, cranes, metal roofs, metal facades, metal frames of windows and doors, metal floor frames, service pipes and cable trays). Bonding bars (for example, ring bonding bars, several bonding bars at different levels of the structure) and magnetic shields of the LPZ shall be integrated in the same way.

Conductive parts (for example, cabinets, enclosures, racks) and the protective earth conductor (PE) of the internal systems shall be connected to the bonding network {*see* accepted standard [D-2(74)]}.

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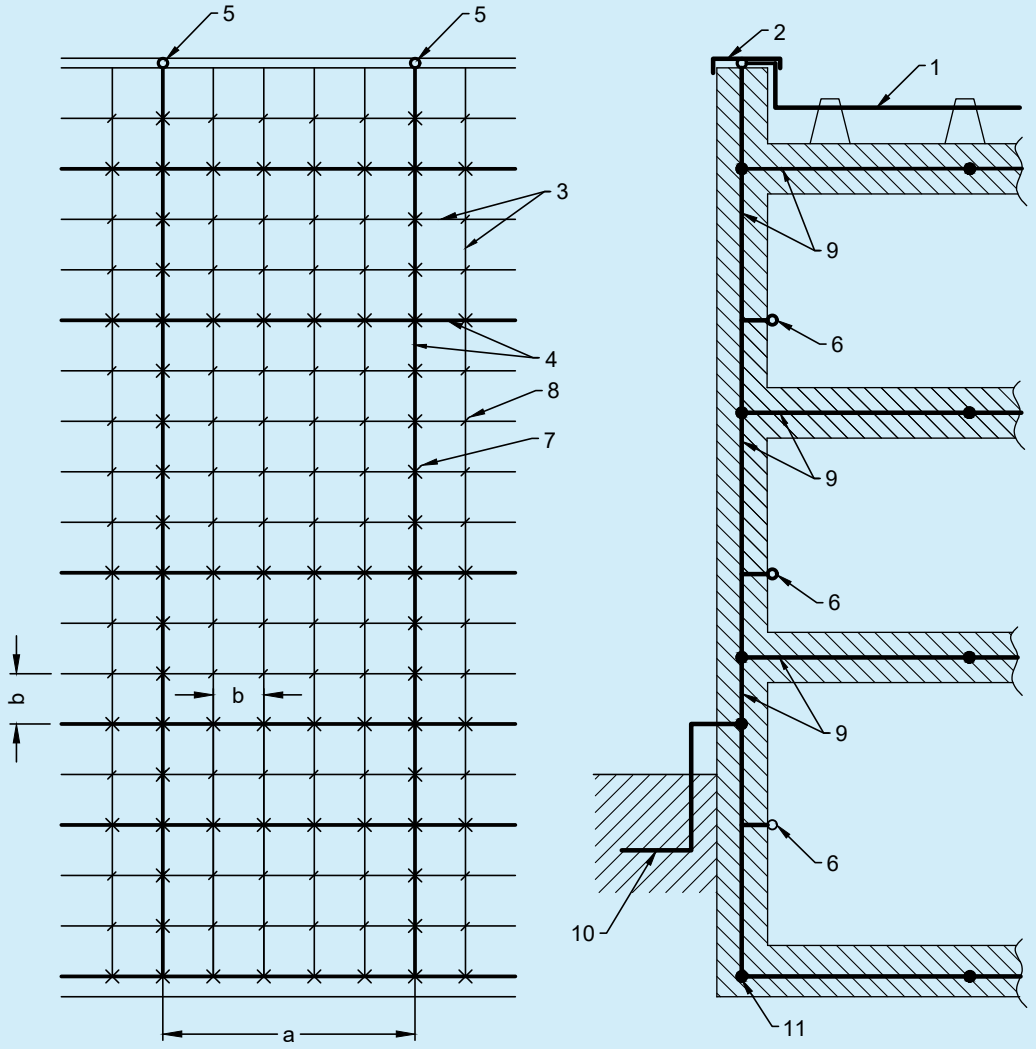

KEY

1 AIR-TERMINATION CONDUCTOR
2 METAL COVERING OF THE ROOF PARAPET
3 STEEL REINFORCING RODS
4 MESH CONDUCTORS SUPERIMPOSED ON THE REINFORCEMENT
5 JOINT OF THE MESH CONDUCTOR
6 JOINT OF THE INTERNAL BONDING BAR
7 CONNECTION MADE BY WELDING OR CLAMPING
8 ARBITARY CONNECTION
9 STEEL REINFORCEMENT IN CONCRETE (WITH SUPERIMPOSED MESH CONDUCTORS)
10 RING EARTHING ELECTRODE (IF ANY)
11 FOUNDATION EARTHING ELECTRODE

a TYPICAL DISTANCE OF 5 m FOR SUPERIMPOSED MESH CONDUCTOR
b TYPICAL DISTANCE OF 1 m FOR CONNECTING THIS MESH WITH THE REINFORCEMENT

FIG. 29 UTILIZATION OF REINFORCING RODS OF A STRUCTURE FOR EQUPOTENTIAL BONDING

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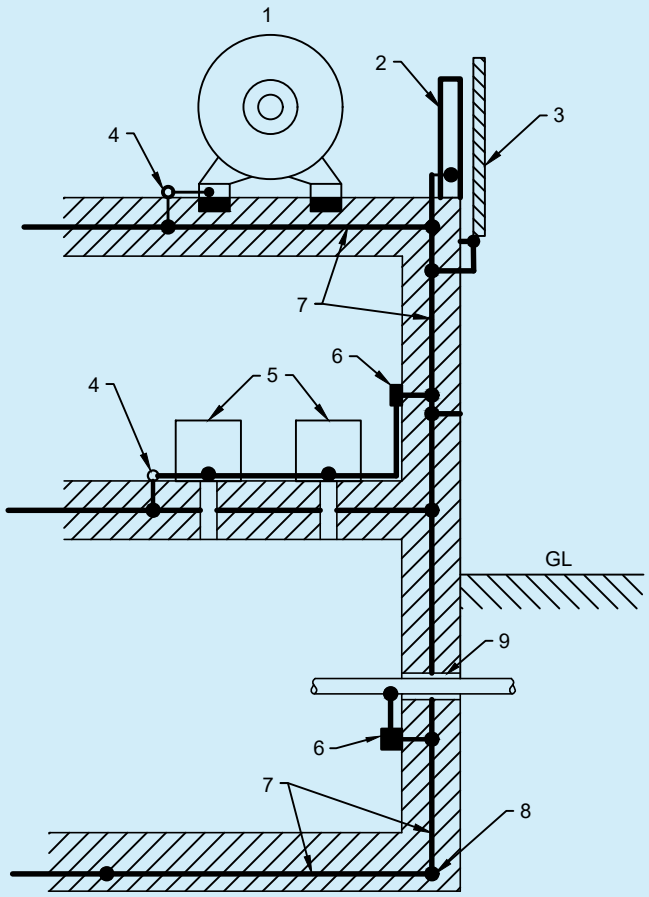

KEY

1 ELECTRIC POWER EQUIPMENT
2 STEEL GIRDER
3 METAL COVERING OF THE FACADE
4 BONDING JOINT
5 ELECTRICAL OR ELECTRONIC EQUIPMENT
6 BONDING BAR
7 STEEL REINFORCEMENT IN CONCRETE (WITH SUPERIMPOSED MESH CONDUCTORS)
8 FOUNDATION EARTHING ELECTRODE
9 COMMON INLET FOR DIFFERENT SERVICES

FIG. 30 EQUIPOTENTIAL BONDING IN A STRUCTURE WITH STEEL REINFORCEMENT

11.6.5 *Materials and Dimensions*

Copper and aluminium are recommended for exposed areas on installations required to have a long life. Galvanized steel may be preferred for temporary installations such as exhibition centres. Although it is a common practice to use material in the form of strip for horizontal air-terminations, down-conductors and bonds, it is more convenient to use round material, particularly as it facilitates the making of bends in any plane. *See* Table 6,

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Table 7 and Table 8 for details for different materials and conditions of use, refer accepted standard [D-2(74)] for minimum dimension of materials used in LPS.

Table 6 LPS Materials and Conditions of Use[1)]

(*Clause* 11.6.5)

Sl No.	Material	Use			Corrosion		
		In Open Air	In Earth	In Concrete	Resistance	Increased by	May be Destroyed by Galvanic Coupling with
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds Organic materials	–
		Stranded	Stranded	Stranded			
		–	As coating	As coating			
ii)	Hot galvanized steel[2), 3) and 4)]	Solid	Solid	Solid	Acceptable in air, in concrete and in benign soil	High chlorides content	Copper
		Stranded[5)]		Stranded[5)]			
iii)	Steel with electro deposited copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds	–
iv)	Stainless steel	Solid	Solid	Solid	Good in many environments	High chlorides content	–
		Stranded	Stranded	Stranded			
v)	Aluminium	Solid	Unsuitable	Unsuitable	Good in atmospheres containing low concentrations of sulphur and chloride	Alkaline solutions	Copper
		Stranded					

[1)] This table gives general guidance only. In special circumstances more careful corrosion immunity considerations are required.

[2)] Galvanized steel may be corroded in clay soil or moist soil.

[3)] Galvanized steel in concrete should not extend into the soil due to possible corrosion of the steel just outside the concrete.

[4)] Galvanized steel in contact with reinforcement steel in concrete may, under certain circumstances, cause damage to the concrete.

[5)] Stranded conductors are more vulnerable to corrosion than solid conductors. Stranded conductors are also vulnerable where they enter or exit earth/concrete positions. This is the reason why stranded galvanized steel is not recommended in earth.

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Table 7 Material, Configuration and Minimum Cross-Sectional Area of Air-Termination Conductors and Rods, Earth Lead-in Rods and Down-Conductors[1)]

(*Clause* 11.6.5)

Sl No.	Material	Configuration	Minimum Cross-Sectional Area mm^2
(1)	(2)	(3)	(4)
i)	Copper, tin plated copper	Solid tape	50
		Solid round[2)]	50
		Stranded[2)]	50
		Solid round[3)]	176
ii)	Aluminium	Solid tape	70
		Solid round	50
		Stranded	50
iii)	Aluminium alloy	Solid tape	50
		Solid round	50
		Stranded	50
		Solid round[3)]	176
iv)	Copper coated aluminium alloy	Solid round	50
v)	Hot dipped galvanized steel	Solid tape	50
		Solid round	50
		Stranded	50
		Solid round[3)]	176
vi)	Copper coated steel	Solid round	50
		Solid tape	50
vii)	Stainless steel	Solid tape[4)]	50
		Solid round[4)]	50
		Stranded	50
		Solid round[3)]	176

---

1) Mechanical and electrical characteristics as well as corrosion resistance properties shall meet the requirements as per accepted standard [D-2(78)].

2) 50 mm^2 (8 mm diameter) may be reduced to 25 mm^2 in certain application where mechanical strength is not an essential requirement. Consideration should in this case, be given to reducing the space between fasteners.

3) Applicable for air-termination rods and earth lead-in rods. For air-termination rods where mechanical stress such as wind loading is not critical, a 9.5 mm diameter, 1 m long rod may be used.

4) If the thermal and mechanical considerations are important, then these values should be increased to 75 mm^2.

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Table 8 Material Configuration and Minimum Dimensions of Earth Electrodes[1] and [2]

(*Clauses* 11.5 *and* 11.6.5)

Sl No.	Material	Configuration	Minimum Dimensions		
			Earth Rod Diameter mm	Earth Conductor mm^2	Earth Plate mm
(1)	(2)	(3)	(4)	(5)	(6)
i)	Copper, tin plated copper	Stranded	–	50	–
		Solid round	15	50	
		Solid tape	–	50	–
		Pipe	20	–	–
		Solid plate	–	–	500 × 500
		Lattice plate[3]	–	–	600 × 600
ii)	Hot dipped galvanized steel	Solid round	14	78	–
		Pipe	25	–	–
		Solid tape	–	90	–
		Solid plate	–	–	500 × 500
		Lattice plate	–	–	600 × 600
		Profile	[4]	–	–
iii)	Bare steel[5]	Stranded	–	70	–
		Sold round	–	78	–
		Solid tape	–	75	–
iv)	Copper coated steel	Solid round	14[6]	50	–
		Solid tape	–	90	–
v)	Stainless steel[7]	Solid round	15	78	–
		Solid tape	–	100	–

[1] Mechanical and electrical characteristics as well as corrosion resistance properties shall meet the requirements as per accepted standard [D-2(78)]

[2] In case of a Type B arrangement foundation earthing system, the earth electrode shall be correctly connected at least every 5 m with the reinforcement steel.

[3] Lattice plate constructed with a minimum total length of conductor of 4.8 m.

[4] Different profiles are permitted with a cross-section of 290 mm^2 and a minimum thickness of 3 mm, for example, cross profile.

[5] Shall be embedded in concrete for a minimum depth of 50 mm.

[6] 250 µm minimum radial copper coating, with 99.9 percent copper content.

[7] Chromium ≥ 16 percent, nickel ≥ 5 percent, molybdenum ≥ 2 percent, carbon ≤ 0.08 percent.

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11.6.6 Protection measures against injury to living beings due to touch voltage and step voltage shall be provided in accordance with accepted standard [D-2(74)].

11.6.7 Inspection of the LPS shall be done as per IEC 62305-3 : 2024 'Protection against lightning — Part 3: Physical damage to structures and life hazard'.

11.7 Protection of Electrical/Electronic Systems within Structures

11.7.1 The internal LPS shall avoid the occurrence of dangerous sparking within the structure to be protected due to lightning current flowing in the external LPS or in other conductive parts of the structure. Dangerous sparking between different parts can be avoided by means of equipotential bonding or electrical insulation between the parts.

Permanent failure of electrical and electronic systems can be caused by the lightning electromagnetic impulse (LEMP) *via*:

a) conducted and induced surges transmitted to equipment *via* connecting wiring; and

b) the effects of radiated electromagnetic fields directly into equipment itself.

11.7.2 *Equipment Protection Principles*

11.7.2.1 For protection against the effects of radiated electromagnetic fields impinging directly onto the equipment, SPM consisting of spatial shields and/or shielded lines, combined with shielded equipment enclosures should be used.

11.7.2.2 For protection against the effects of conducted and induced surges being transmitted to the equipment *via* connection wiring, SPM consisting of a coordinated SPD system should be used. SPD to be used according to their installation position are as follows:

a) At the line entrance into the structure (at the boundary of LPZ 1, for example at the main distribution panel):

   1) SPD tested with I_{imp} (typical waveform 10/350, for example, SPD tested according to class I); and

   2) SPD tested with I_n (typical waveform 8/20, for example, SPD tested according to class II).

b) Close to the apparatus to be protected (at the boundary of LPZ 2 and higher, for example, at secondary distribution board, or at a socket outlet):

   1) SPD tested with I_n (typical waveform 8/20 for example, SPD tested according to class II); and

   2) SPD tested with a combination wave (typical waveform 8/20 for example, SPD tested according to class II).

11.7.3 *Equipotentialization of Services to LPS*

Equipotentialization is achieved by interconnecting the LPS with structural metal parts, metal installations having no electrical power connection, internal systems, external conductive parts and lines connected to the structure. *See* Fig. 31.

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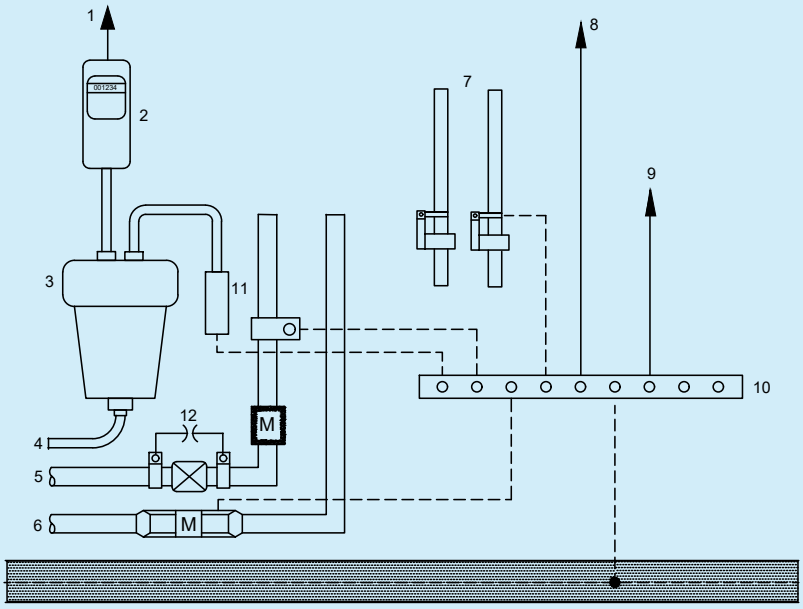

KEY

1 POWER TO USER
2 POWER METER
3 HOUSE CONNECTION BOX
4 POWER FROM UTILITY
5 GAS
6 WATER
7 CENTRAL HEATING/COOLING SYSTEM
8 ELECTRONIC APPLIANCES
9 SCREEN OF ANTENNA CABLE
10 EQUIPOTENTIAL BONDING BAR
M METER

FIG. 31 EXAMPLE OF AN EQUIPOTENTIAL BONDING ARRANGEMENT

Interconnection can be done with bonding conductors, where the electrical continuity is not provided by natural bonding or by using surge protective devices (SPDs), where direct connections with bonding conductors is not feasible (for example, installation of SPDs for power, data, telecom lines, etc). It contains at least one non-linear component to ensure perfect equipotential bonding. All SPDs at the service entrance to an installation should be able to divert 10/350 µS impulse current depending upon selected level of protection. A three phase four wire system should be designed for 50 percent of the I_{imp} of selected LPS and single phase two wire system should be designed for 25 percent of the I_{imp} of selected LPS. The lightning current distribution for three phase four wire system is given in Fig. 32 {*see also* accepted standard [D-2(75)]}.

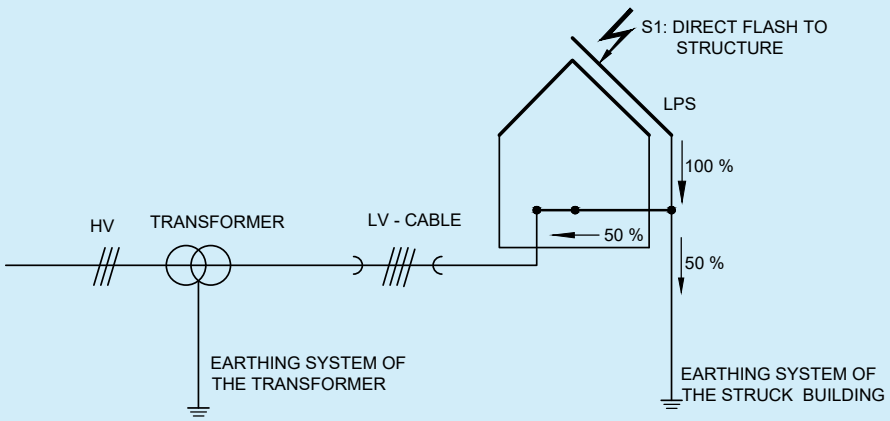

FIG. 32 BASIC EXAMPLE OF BALANCED CURRENT DISTRIBUTION

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11.7.4 *Protection Measures with Surge Protection Devices* (*SPDs*)

11.7.4.1 Lightning surges frequently cause failure of electrical and electronic systems due to insulation breakdown or when overvoltages exceed the equipment's common mode insulation level. Power line protection is fundamental, however equal importance should be given to data, communication and instrumentation lines of the equipment that need protection. Equipment is protected if its rated impulse withstand voltage U_W at its terminals is greater than the surge overvoltage between the live conductors and earth. If not, an SPD shall be installed.

Implementing coordinated SPDs will provide protection against radiated surges for equipment {*see* accepted standard [D-2(74)]}. Shielding and routing of power and data lines, bonding of services and various lightning protection zones (LPZ) {*see* accepted standard [D-2(74)]} and earthing also plays a major role in protecting electrical and electronic equipment.

The SPDs are used to protect under specified conditions, electrical systems and equipment against various overvoltages and impulse currents such as lightning and switching surges. SPD shall be selected according to their environmental conditions and the acceptable failure rates of the equipment and the SPDs.

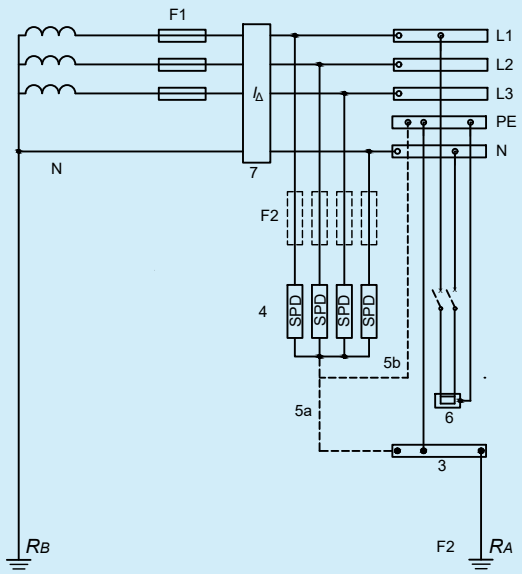
11.7.4.2 *Failure of SPDs*

Possibility of failure of any line to neutral or neutral to earth connected SPDs should not be ruled out, hence measures should be taken within the SPD for safe failure or withstand in worst conditions. SPD can fail in open or short modes. SPD should not create a fire hazard during failure. Safe failure mode is expected from the SPD.

11.7.4.3 *Status indicators*

Each SPD should have inbuilt health indicator so as to show if protection is available. SPD should be installed in a way that visual inspection is easily possible. Failed SPD shall be replaced.

11.7.4.4 SPDs for power line need to be installed according to the type of service such as TN, TT, IT, etc. In general, the SPDs connected as per connection diagram given in Fig. 33 (informative) is suitable for TT connections. Reference may be made to relevant Indian Standard for such installations.



33A SPDs ON THE LOAD SIDE OF RCD

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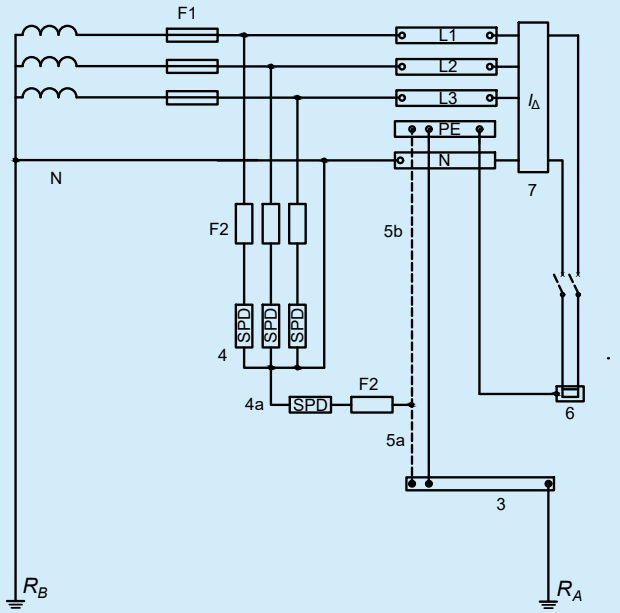

KEY

3 MAIN EARTHING TERMINAL OR BAR
4 SURGE PROTECTION DEVICES FOR SUB DB (CATEGORY II)
5 EARTHING CONNECTION OF SPDs
6 EQUIPMENT TO BE PROTECTED
7 RESIDUAL CURRENT PROTECTIVE DEVICE (RCD)
F1 PROTECTIVE DEVICE AT THE ORIGIN OF THE INSTALLATION
F2 PROTECTIVE DEVICE REQUIRED BY THE MANUFACTURER OF THE SPDs
R_A EARTHING ELECTRODE (EARTHING RESISTANCE) OF THE INSTALLATION
R_B EARTHING ELECTRODE (EARTHING RESISTANCE) OF THE SUPPLY SYSTEM
F2 IS REQUIRED IF F1 IS MORE THAN SPECIFIED VALUE OF BACK UP FUSE BY MANUFACTURER (OPTIONAL FOR N-PE CONNECTED SPD)

33B SPDs ON THE SUPPLY SIDE OF RCD

FIG. 33 TYPICAL INSTALLATION OF SPDs IN TT SYSTEM

11.7.4.5 *Selection of SPDs*

SPD(s) need to be selected based on the place of installation as well the impulse voltage withstanding capacity of the equipment. I_{imp} and I_n, are test parameters used to categorize Class I and Class II SPD(s). They are related to the maximum values of discharge currents, which are expected to occur at the LPL probability level at the location of installation (LPZ) of the SPD in the system. I_n is associated with Class II tests and I_{imp} is associated with Class I tests.

11.7.4.5.1 If no risk analysis according to accepted standard [D-2(76)] has been carried out or if the current value of SPD cannot be established, Class I SPDs should be installed with an I_{imp} not less than 12.5 kA (10/350µS) for connection according to Fig. 33A or between L to N or PE. For connection according to Fig. 33B, I_{imp} shall not be less than 50 kA (10/350µS) between N and PE for three-phase systems and 25 kA (10/350 µS) between N and PE for single-phase systems. Otherwise, the currents shall be considered as per level of protection.

11.7.4.5.2 *Follow current extinguishing capability of the SPD*

Follow current is the peak current (rms value) supplied by the electrical power system and flowing through the SPD after a discharge current impulse. Follow current extinguishing capability and short circuit withstand capacity of SPD shall be as per accepted standard [D-2(74)].

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11.7.4.5.3 Where Class II tested SPD {*see* accepted standard [D-2(76)]} are required at or near the origin of installation, the value of I_n shall be not less than 5 kA for connections according to Fig. 33A or between L to N or PE. For Class II tested SPDs connected between neutral and PE for connection in Fig. 33B, I_n shall not be less than 20 kA for three-phase systems and 10 kA for single-phase systems.

11.7.4.5.4 *Voltage protection level of SPD*

The voltage protection level of SPD is the maximum voltage to be expected at the SPD terminals due to an impulse stress with defined voltage steepness and an impulse stress with a discharge current with given amplitude and wave shape. The protection level of SPDs shall be selected in accordance with impulse withstand voltage category as per Table 9.

Table 9 Rated Impulse Voltage for the Equipment Energized Directly from the Low Voltages Mains

(*Clause* 11.7.4.5.4)

Sl No.	Nominal Voltage of the Supply System[1] Based on on Accepted Standard [D-2(79)][2]		Voltage Line to Neutral Derived from Nominal Voltages a.c. or d.c. up to and Including	Rated Impulse Voltage[3]			
	Three Phase	Single Phase		Overvoltage Category [4]			
				I	II	III	IV
	V	V	V	V	V	V	V
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)			50	330	500	800	1 500
ii)			100	500	800	1 500	2 500
iii)		120 to 240	150	800	1 500	2 500	4 000
iv)	230/400 277/480		300	1 500	2 500	4 000	6 000
v)	400/690		600	2 500	4 000	6 000	8 000
vi)	1 000		1 000	4 000	6 000	8 000	12 000

[1] *See* accepted standard [D-2(80)].

[2] The '/' mark indicates a four-wire three-phase distribution system. The lower value is the voltage line-to-neutral, while the higher value is the voltage line-to-line. Where only one value is indicated, it refers to three-wire, while the higher value is the voltage line-to-line. Where only one value is indicated, it refers to three-wire, three-phase systems and specifies the value line-to-line.

[3] Equipment with these rated impulse voltage can be used in installations in accordance with IEC 60364-4-44 'Low-voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances'.

[4] *See* **4.3.3.2.2** of accepted standard [D-2(80)].

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11.7.4.5.5 The preferred values of voltage protection level of SPDs, U_p is given below (*see* accepted standard [D-2(81)]):

0.08 kV, 0.09 kV, 0.10 kV, 0.12 kV, 0.15 kV, 0.22 kV, 0.33 kV, 0.4 kV, 0.5 kV, 0.6 kV, 0.7 kV, 0.8 kV, 0.9 kV, 1.0 kV, 1.2 kV, 1.5 kV, 1.8 kV, 2.0 kV, 2.5 kV, 3.0 kV, 4.0 kV, 5.0 kV, 6.0 kV, 8.0 kV and 10 kV

Hence, for protecting a 240 V/415 V connected equipment, selecting a $U_p \leq 1.5$ kV will be a safer choice. The U_p may be tested and certified by a third party as per the laid down test procedures. *See* Fig. 34 on connection diagram for SPD.

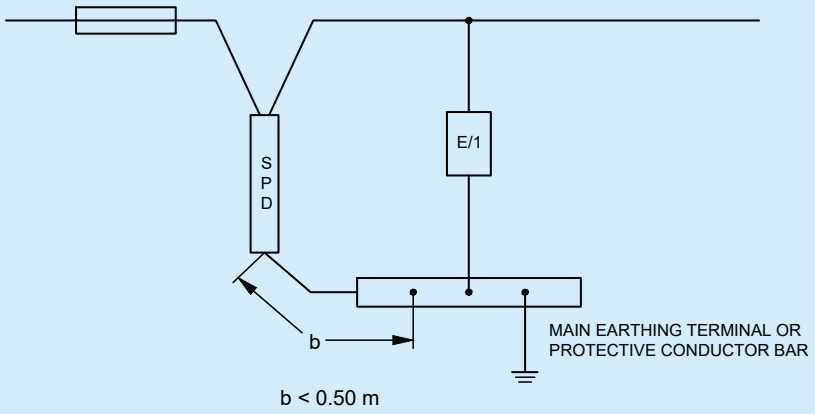

FIG. 34 EXAMPLE OF INSTALLATION OF SPDS AT OR NEAR ORIGIN OF INSTALLATION

11.7.4.6 For small residential buildings, power line SPD at the mains incoming panel will enhance the life of electronic equipment, such as TV, music system, refrigerators, LED lights, etc.

11.7.4.7 For large buildings, power line SPD is required at incoming panel as well as for sub distribution panels based on the LPZ principle {*see* accepted standard [D-2(74)]}.

11.7.4.8 For industrial and commercial buildings, critical and sensitive loads such as drives, PLC's, automation panels, etc, require protection with SPD in addition to SPD at incoming power panels and sub distribution boards. SPDs shall be selected to meet the requirements of relevant LPZs.

11.7.4.9 Lifts, escalators, moving walks and fire panels shall be protected with SPD in control panels. All electrical and control panels related to safety and security of building shall be protected with appropriate SPDs.

11.7.4.10 SPDs should be installed for outdoor equipment such as CCTV cameras, LED street lights, weighbridges, firefighting systems, roof top solar PV installations, etc. This will ensure availability of the vital services provided by these equipment as and when required.

11.7.4.11 Failure of equipment and chance of fire in electrical installations are more for buildings near tall structures (for example, telecom tower). These buildings should be protected with SPD at power incoming and ring earthing to avoid fire and equipment failure.

11.7.4.12 All SPDs should have status indication to show their healthy state for discharging the lightning current. The possibility of failure of L-N as well as N-PE connected SPD cannot be ignored.

11.7.4.13 The SPD shall be installed at the entrance to ensure perfect bonding to the ground at the time of lightning {*see* good practice [D-2(11)] and accepted standard [D-2(74)]}. The let through energy of the protection system shall be less than the energy that equipment can withstand. As per accepted standard [D-2(74)], the energy coordination method is the best method to ensure the protection of the equipment. The let through energy details of the SPD shall be provided by manufacturer.

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11.7.4.14 Maximum continuous operating voltage of the SPD (U_c) should not be less than 1.1 × $U_{nominal}$ = 1.1 × 230 = 253 V; temporary overvoltage (TOV) withstand values shall be as per accepted standard [D-2(81)].

11.7.4.15 Low-voltage SPDs for connection to low-voltage power systems shall be conforming to the accepted standard [D-2(81)].

11.8 Average Number of Thunderstorm Days

For the purpose of risk assessment, annual thunderstorm days in various places are provided in the table below read with Fig. 35.

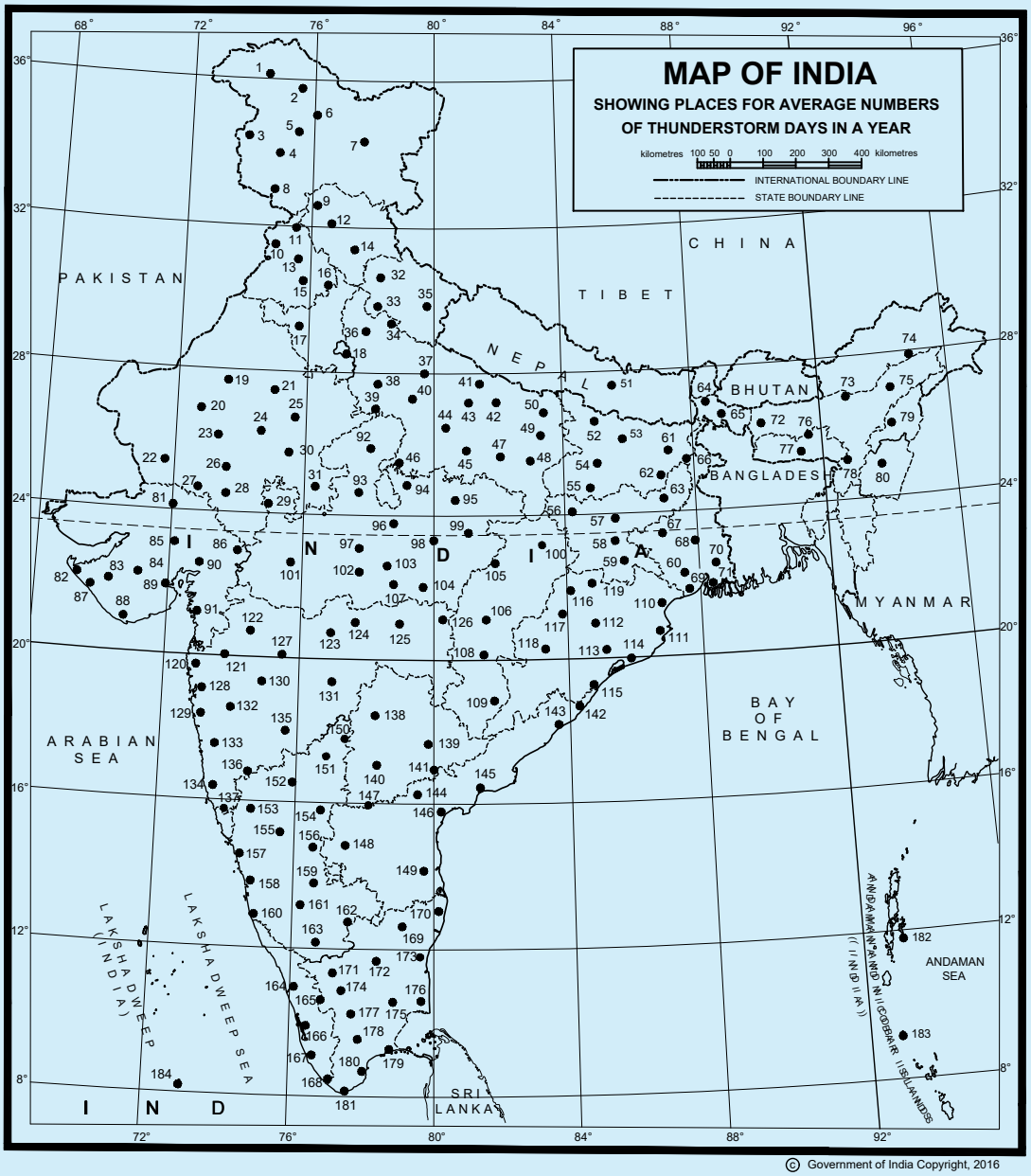

FIG. 35 MAP OF INDIA SHOWING PLACES FOR AVERAGE NUMBER OF THUNDERSTORM DAYS IN A YEAR

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Sl No.	Name of Place	Annual Thunder-storm Days
1	Gilgit	7
2	Skardu	5
3	Gulmarg	53
4	Srinagar	54
5	Dras	3
6	Kargil	2
7	Leh	3
8	Jammu	26
9	Dharmsala	13
10	Amritsar	49
11	Pathankot	4
12	Mandi	46
13	Ludhiana	12
14	Simla	40
15	Patiala	26
16	Ambala	9
17	Hissar	27
18	Delhi	30
19	Bikaner	10
20	Phalodi	14
21	Sikar	17
22	Barmer	12
23	Jodhpur	23
24	Ajmer	26
25	Jaipur	39
26	Kankroli	36
27	Mount Abu	5
28	Udaipur	38
29	Neemuch	28
30	Kota	27
31	Jhalawar	40
32	Mussorie	61
33	Roorkee	74
34	Najibabad	36
35	Mukteswar	53
36	Meerut	–
37	Bareilly	34
38	Aligarh	30
39	Agra	24
40	Mainpuri	23
41	Bahraich	31
42	Gonda	22
43	Lucknow	18
44	Kanpur	26
45	Fatehpur	24
46	Jhansi	20
47	Allahabad	51
48	Varanasi	51
49	Azamgarh	1
50	Gorakhpur	11
51	Katmandu	74
52	Motihari	38
53	Darbhanga	10
54	Patna	33
55	Gaya	38
56	Daltonganj	73
57	Hazaribagh	73
58	Ranchi	34
59	Chaibasa	70
60	Jamshedpur	66
61	Purnea	52
62	Sabour	76
63	Dumka	63
64	Darjeeling	28
65	Jalpaiguri	68
66	Malda	59
67	Asansol	71
68	Burdwan	39
69	Kharagpur	76
70	Kolkata	70
71	Sagar Island	41
72	Dhubri	8
73	Tezpur	27
74	Dibrugarh	98
75	Sibsagar	103
76	Shillong	75
77	Cherrapunji	49
78	Silchar	33
79	Kohima	34
80	Imphal	49
81	Deesa	7
82	Dwarka	5
83	Jamnagar	8
84	Rajkot	12
85	Ahmedabad	11
86	Dohad	17
87	Porbandar	3
88	Veraval	3
89	Bhavnagar	11
90	Vadodara	8
91	Surat	4
92	Gwalior	53
93	Guna	33
94	Nowgong	59
95	Satna	41
96	Sagar	36
97	Bhopal	44
98	Jabalpur	50
99	Umaria	37
100	Ambikapur	29
101	Indore	34
102	Hoshangabad	37
103	Panchmarhi	30
104	Seoni	51
105	Pendadah	56
106	Raipur	34
107	Chhindwara	27
108	Kanker	37
109	Jagdalpur	35
110	Balasore	81
111	Chandbali	75
112	Angul	81
113	Bhubaneswar	46
114	Puri	33
115	Gopalpur	34
116	Jharsuguda	85
117	Sambalpur	67
118	Titlagarh	24
119	Rajgangpur	1
120	Dahanu	1
121	Nasik	17
122	Malegaon	13
123	Akola	20
124	Amraoti	32
125	Nagpur	45
126	Gondia	10
127	Aurangabad	34
128	Mumbai	16
129	Alibag	12
130	Ahmadnagar	10
131	Parbhani	32
132	Pune	22
133	Mahabaleshwar	14
134	Ratnagiri	6
135	Sholapur	23
136	Miraj	25
137	Vengurla	39
138	Nizambad	36
139	Hnamkonda	43
140	Hyderabad	28
141	Khammam	26
142	Kalingapatam	20
143	Vishakapatnam	46
144	Rentichintala	42
145	Masulipatam	20
146	Ongole	25
147	Kurnool	29
148	Anantpur	22
149	Nellore	18
150	Bidar	15
151	Gulbarga	34
152	Bijapur	9
153	Belgaum	31
154	Raichur	17

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155	Gadag	21
156	Bellary	22
157	Karwar	27
158	Honavar	5
159	Chikalthana	24
160	Mangaluru	36
161	Hassan	26
162	Bengaluru	46
163	Mysuru	44
164	Kozhikode	39
165	Palghat	35

166	Kochi	69
167	Alleppey	51
168	Thiruvanantha-puram	68
169	Vellore	25
170	Chennai	47
171	Udhagamandalam	24
172	Salem	69
173	Cuddalore	37
175	Trichchirapalli	41

176	Nagappattinam	15
177	Kodaikanal	82
178	Madurai	39
179	Pamban	5
180	Tuticorin	14
181	Cape Comorin	68
182	Port Blair	62
183	Car Nicobar 1	18
184	Minicoy 1	20

12 ELECTRICAL INSTALLATIONS FOR CONSTRUCTION AND DEMOLITION SITES

12.1 General

12.1.1 Electrical hazards are a major cause of serious injury and even death in construction sites. Accidents also cause loss of productivity and destroy the morale of workers. The need to use electricity and electrical/electronic equipment has been constantly increasing. Without these gadgets productivity and quality of work will suffer. Therefore, the use of electricity and the use of gadgets has to increase. Such increase requires a proper electrical distribution system in the work site.

12.1.2 To ensure continuous supply of power during the construction activity and maintain productivity, site security, etc the city power supply may be required to be supplemented by on-site standby power generation. Some gadgets require continuity of power supply without interruption, thereby requiring UPS systems. In a typical large construction site there may be a large temporary distribution network combined with more than one source of electricity, which can make the system quite complex from the safety point of view.

12.1.3 Problem may also arise in case of lack of required training to workers in the safe use of the tools and equipment that they are required to handle in a system with multiple sources of power supply. In case of use of imported equipment which may be manufactured to their own standards, problems may arise, such as, during connection and inter-connection of equipment and tools and mismatch of plugs and sockets. Appropriate action is to be taken by employing qualified/experienced electrical engineer.

12.1.4 Practical guidance to employers, designers, manufacturers, importers, suppliers (including hirers), electrical contractors and electricians on eliminating or reducing the risk of electrocution and electric shock to any person is necessary.

12.1.5 Even though awareness exist about good practices, the same may be compromised at times in the name of speed or economy or due to ignorance and neglect. The materials, equipment, tools, cables, switchgear used in the temporary installation face far more severe environmental working conditions because of use of discarded switchgear, cables, etc at the construction sites which compounds the risk to workmen from shock and fire. Hence, the laid down Indian Standards for permanent installations, need to be followed during construction and demolition meticulously. The complete installation shall be duly earthed as per *Central Electricity Authority* (*Measures related to safety and Electric Supply*) *Regulations*, 2023, good practice [D-2(11)] and [D-2(1)].

12.2 Installation and Removal of Construction Wiring

All construction wiring work shall be installed by an appropriately registered electrical contractor and by electrical workmen holding license of the appropriate level of competency depending on the voltage, local generation, etc, as provided in *Central Electricity Authority* (*Measures Related to Safety and Electric Supply*) *Regulations*, 2023 and *the Indian Electricity Act*, 2003. The installation should be inspected prior to commissioning and at regular intervals by the Engineer-in-Charge (if one is qualified to inspect electrical installations) or by representative, who should be competent to inspect an installation.

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12.3 Provision of Indicating and Recording Instruments and Meters

Measurement is a prerequisite to analyse the performance. Construction site switchboards should have adequate instrumentation (such as, ammeters, PF meters, voltmeters, energy meters, etc) on different branches of the distribution system so that any abnormal condition or overload is noticed. Considering the nature of varying activity in a construction site, frequent visual, and instrument based inspections are necessary as well as keeping record of the same.

12.4 Residual-Current Circuit Breaker (RCCB)/Residual-Current Device (RCD)

The following shall be ensured in the construction and demolition sites:

a) Every electric supply to which electrical plant can be connected should incorporate an RCCB/RCD of appropriate capacity so as to protect persons who may come into contact with the electrical plant against electric shock;

b) The RCCB/RCD(s) should have a rated tripping current not exceeding 30 mA and should have the capacity to carry the load current required by the appliances permitted to be connected in that branch circuit or feeder;

c) Where construction work supply can only be obtained from a permanent wiring socket-outlet, RCCB/RCD should be connected at the socket-outlet;

d) Sub-mains supplying site sheds should incorporate an RCCB/RCD having a rated tripping current not exceeding 100 mA;

e) Every non-portable RCCB/RCD device on the worksite shall be trip tested by the built-in push button test every month, and performance tested for operation before being put into service and thereafter at least once every 12 months. It shall also be subjected to an imbalance of current not less than the rated residual current and shall trip in a time not exceeding 6 s;

f) Every portable RCCB/RCD device on the worksite shall be trip tested by the built-in push button test. The test shall be done prior to use and each day while in use; and it shall be performance tested for operation before being put into service and thereafter at least once every 3 months. It shall also be subjected to an imbalance of current not less than the rated residual current and shall trip in a time not exceeding 6 s;

g) Results of RCCB/RCD tests shall be recorded and kept on site or made available for audit and kept for a minimum period of 5 years or till the completion and handing over of the project, whichever is less [excluding the daily push button test for portable RCCB/RCD(s)];

h) Portable RCCB/RCD(s) when tested shall be fitted with a durable, non-reusable, non-metallic tag. The tag shall include the following information:

   1) The name of the person or company who performed the tests; and

   2) The test or retest date.

   The recommended colour coding for tags on tested RCCB/RCD, which is prescribed below should be indicated by its colour representing the period when the test was performed:

January to March	:	Red
April to June	:	Green
July to September	:	Blue
October to December	:	Yellow

j) Portable generators should be fitted with RCDs having a rated tripping current not exceeding 30 mA; and

k) Personal hoists used on construction sites shall be supplied from a separate final sub-circuit originating from the main switchboard; and be suitably identified by marking this supply on the RCD/MCB feeding it.

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12.5 Temporary Supply Switchboards

All temporary supply switchboards used on building, construction and demolition sites shall be of robust construction and either securely attached to a pole, post wall or other structure which may be of stable freestanding design and:

a) where installed in outdoor locations, should be constructed and maintained to IP23 (or higher) rating so that safe operation is not affected by the weather;

b) switchboards should incorporate the support and elevation of cables and flexible extension cords;

c) switchboard enclosures shall be provided with an insulated or covered tie-bar or similar arrangement for the anchorage of the cables or flexible cords in order to prevent strain and mechanical damage at the termination of the cables or cords;

d) switchboards should be provided with a door and locking facility. The doors should be designed and attached in a manner that will not damage any flexible cord connected to the board and should protect the switches from mechanical damage;

e) the door should be provided with signs (in English, Hindi and at least one local language) stating, 'KEEP CLOSED – LEADS THROUGH BOTTOM';

f) switchboards should have an insulated slot (with edges suitably shaped or covered with plastic or rubber trims to avoid damaging the cable insulation/sheath) at the bottom for the passage of leads;

g) switchboards should be attached to a permanent wall or suitable portable or temporary structure in an elevated position suitable for easy access and having least interference with the activity in the area;

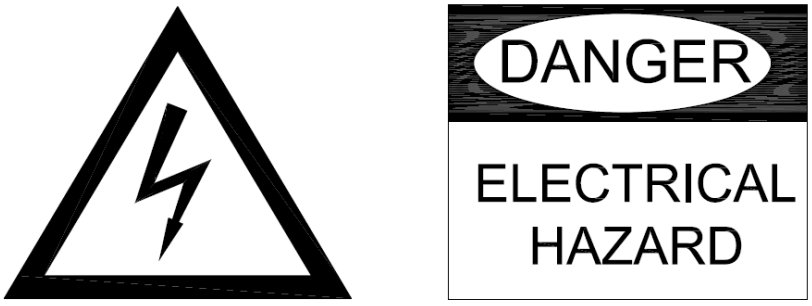
h) if the floor in that area is likely to be wet, additional precautions are necessary and an insulated platform should preferably be provided for access to operation of switches. Personal protective equipment such as helmet, electrician gloves, etc, should be available, placed near the switchboard, as an alternative;

j) a clearance of at least 1.2 m should be maintained in front of all switchboards;

k) the contractor or nominated persons should ensure that all power circuits are isolated or made inaccessible so as to eliminate the risk of fire, electric shock or other injury to persons after completion of the daily work;

m) switchboards shall be legibly and indelibly marked with a set of numbers or letters or both which uniquely identify the switchboard from others on a site;

switchboards shall be marked to indicate the presence of live parts in accordance with symbols such as the following drawing:



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p) chart indicating first aid measures for electric shock management should be placed near the switchboard;

q) 'Lock Out and Tag Out' procedures as adopted should be displayed;

r) the switchboard should be lighted properly to ensure its identification and safe working; and

s) all switchboards should have their identification names (or/and numbers) so that any communication/ instructions about them are unambiguous.

12.6 Cables Used in Worksite Installations

12.6.1 Worksite poses a number of hazards to the cables. The conditions are severe compared to those in permanent installations. Cables face dust, moisture, abrasives and even impact unlike those in permanent installations. Extra care should be taken to frequently inspect the cables and discard cables which show signs of damage as a damaged insulation combined with moisture can be dangerous.

12.6.2 Cables are likely to be run over by vehicles. Suitable protection is required by a steel pipe or hume pipe or steel plate, whichever is appropriate. Dragging of cables damages their sheath/insulation and may also cut a few strands of the conductor due to stretching, effectively reducing the current carrying capacity. Hence suitable care should be taken while laying the cables.

12.6.3 Overhead installation of cables is a common practice. Such installations should use a GI wire to carry the weight of the cable without causing the stretching of the cable. The carrier GI wire should be earthed. Unarmoured cables shall not be installed on metallic roofs or similar structures unless suitably protected against mechanical damage.

Overhead wiring should be positioned to avoid crossing roadways or accessways where cranes, high loads, or heavy machinery may travel. Where it is not possible to avoid accessways an effective means shall be provided to minimize the risk of the vehicular contact with the aerial wiring system. This condition may be satisfied by the placement of flagged catenary wires or cables of suitable material across the accessway, 6 m on either side of the overhead wiring and 0.6 m below the lowest point of the overhead electrical cables or lower.

All aerial conductors installed on construction and demolition sites shall be insulated. Cables supported by means of a catenary shall be stranded or shall be flexible cables affording double insulation or the equivalent of double insulation. Construction wiring (including switchboards) shall be visually inspected at intervals not exceeding 6 weeks.

12.7 Electrical Plant in Service Testing

Electrical plant shall be inspected and tested in accordance with the following:

a) Movable electrical plant that is hand held or portable during operation or moved between operations and is subject to damage or harsh environment shall be examined and tested every 3 months;

b) All other electrical plant used for construction purposes shall be inspected and tested at intervals not exceeding 6 months;

c) When any equipment inspected or tested in accordance with (a) and (b) is found to be unsatisfactory, it shall be withdrawn from service immediately and have a label attached to it, 'Warning against Further Use'. Electrical plant found to be unsatisfactory shall not be returned to service until it has been repaired and retested;

d) The inspection and testing specified should be carried out by an authorized/qualified person; and

e) The results of the inspection of electrical plant should be recorded and kept on site or made available for inspection by authorities. Information recorded shall include:

   1) the name of the person or company who performed the tests;

   2) the test or retest date; and

   3) identification of faulty equipment and action taken to repair or remove it from use.

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12.8 Lighting

Following in respect of lighting shall be ensured in construction and demolition sites:

a) *Access lighting* — Adequate artificial lighting should be installed to illuminate the work area if there is insufficient natural lighting. Lamps in luminaires shall be protected against mechanical damage. Luminaires installed as part of the permanent electrical installation in site accommodation, may not require further mechanical protection;

   Sufficient battery powered lighting shall be installed in stairways and passageways to allow safe access and exit from the area if there is insufficient natural lighting. If there is a loss of supply to the normal lighting in the area, it should be ensured that battery powered lighting has sufficient capacity to operate for one hour to allow persons to exit the building safely.

   Temporary wiring supplying lighting circuits should be connected to the designated lighting circuits of the switchboard.

b) *Task lighting* — Portable luminaires shall be provided with the appropriate ingress protection (IP) rating. Task lighting in many construction site may have to move continuously in steps as the work progresses. The lighting system should also be shifted in suitable steps instead of simply extending the cables without any consideration for safety. Hand held additional lights, if any, should be taken from a socket protected by a RCCB/RCD of 30 mA setting just like hand held tools;

c) *Lift and service shaft lighting* — Lift and service shaft lighting may have either construction wiring or permanent wiring. Fluorescent lighting should be used. The lights should be located on the floor above or below the work area. It shall be ensured that the emergency lighting has sufficient battery capacity to operate for a minimum of 1 h if there is a loss of supply to the normal lighting in the area;

d) *Lighting in means of egress* — Sufficient battery powered lighting shall be installed in stairways and passageways to allow safe access and exit from the area if there is insufficient natural lighting. If there is a loss of supply to the normal lighting in the area it shall be ensured that battery powered lighting has sufficient capacity to operate for 1 hr to allow persons to exit the building safely; and

e) *Illumination of signs and warning boards* — Sufficient lighting should be available to illuminate the sign boards and warning boards. These lights may also be a part of the lighting set for means of egress.

12.9 Transportable Construction Buildings (Site Sheds)

Electrical installations to transportable construction buildings shall comply with the following:

a) If supply is by means of a flexible cord, the same shall not be taken from one transportable building to another transportable building.

b) The flexible cord supplying a transportable building should not be more than 15 m in length.

c) Each amenity in the building shall be connected/supplied by a flexible cord to a final sub-circuit protected by an RCCB/RCD device with a rated tripping current not exceeding 30 mA; these flexible cords should be protected from mechanical damage and power outlets in site sheds should be used to supply power to the equipment and lighting within the shed only.

d) Socket-outlets installed on the outside of transportable building shall be used only to supply power to the following:

   1) Electrical equipment and lighting immediately adjacent to those transportable buildings.

   2) Other transportable buildings when the socket-outlet is part of an interconnecting system and the flexible cord supplying those transportable buildings has a maximum length of 15 m.

12.10 Lock-Out and Tag-Out Practices

Whenever an electrician is to work on a branch feeder from the switchboard it becomes necessary that the switch feeding the feeder on which work is done is to be switched-off and should be kept switched-off till the same

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electrician decides to switch on after completion of work either for testing or for putting the section back into service. To ensure that during the period an electrician is working on a feeder or the equipment it feeds, the practice is to put a 'tag' on the concerned switch. The tag will carry details about which authorized worker has put the tag and when and who is authorized to remove it. This is a very critical operating practice for maintenance of the electrical system and following it is of particular importance in the case of temporary installations, where such requirements arise more often than in permanent installations.

Lock-out procedure shall be similar to the above but the difference is that the relevant switch is kept locked in off position and the key is kept by the person or the team leader who will be working on the feeder. The system should also maintain a register where the activities of this nature and the details of action (repair, transfer of the end equipment to a new location, addition of a new appliance on the feeder, etc) are recorded.

12.11 Standard Operating and Maintenance Practices in Sites with More Than One Source of Electricity

12.11.1 In medium and large construction sites it is common to use local generation of electricity by a diesel generating set. The reasons may be lack of dependable local/city distribution system for continuous power supply, high cost of temporary connection charges, restrictions on use of certain equipment like welding transformers on temporary connection, etc. Apart from DG sets for power requirement of site construction equipment, there may be office equipment with computers and site laboratory equipment which require un-interruptible power supply. Shock hazards depend on the voltage of the system and the consequent current flow through the body. As such shock risk associated with all these sources is the same.

12.11.2 Wherever an alternative power supply is provided, proper protocols shall be adopted for the supply from different systems and the associated change-over switch or contactors. Risk increases due to existence of more than one source of power supply. System schematics, operating practice and essential interlock between the different sources of power should be displayed and followed systematically. Earthing for each system should be provided. Changeover switches should be of 4 pole in order to ensure that earth leakage protections operate properly with each one of the power sources. The system should also maintain a register where the activities related to each source of power is recorded and the actions to be taken are provided.

12.12 Earthing or Grounding

12.12.1 Earthing or grounding is an essential pre-requisite for any electrical system from the aspect of safety of personnel, equipment, appliances and for avoidance of fire due to short-circuit or of feeding energy to a short circuit originating from any other cause consequent to damage to insulation by the fire.

12.12.2 The standard earthing practice is applicable to temporary installations also. The earth sets installed at the initial development of the site can be planned to be retained as earthing sets for use even after the completion of the building for the permanent installation.

12.12.3 The minimum requirement of earthing for any temporary electrical installation is given hereunder for easy adherence to the basic minimum. It is recommended to follow the earthing requirements given in **8** and accepted standard [D-2(11)].

12.12.3.1 The neutral of the system of each source or generator shall be having two distinct connection to two distinct earthing sets. All metal parts associated with electrical equipment are required to be connected to earth. The minimum requirement is the provision of two pipe earthing sets each with a pipe of 4.2 m length and separated by at least 2.5 m between them in accordance with good practice [D-2(11)] and connected to the source neutral by a conductor of cross-section more than half the size used for the phase conductor.

12.12.3.2 Earth continuity shall be maintained all over the site wherever electricity is made available and the earth continuity conductor shall have a cross-section at least more than that used for the phase conductor.

12.12.3.3 Wherever the requirements of earthing and use of RCD or RCCB cannot be satisfactorily met with at any site and electrical hand tools are required to be used, low voltage (< 50 V) appliances or self-contained battery operated tools shall be used as a safe alternative. This applies to work under damp or water logged areas also.

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13 PROTECTION OF HUMAN BEINGS FROM ELECTRICAL HAZARDS

13.1 General

Danger to persons due to contact with live parts is caused by the flow of the current through the human body. The effects on the human body are dependent on the amount of the current flow and the duration of the flow. The current flow through the human body depends on the voltage and the resistance in the path. The contact resistance forms an important or significant contributor to the total resistance for the current flow. The contact resistance reduces by a factor of 100 to 1 000 due to the body part being wet and also the touch pressure at the point of contact. The works under this clause shall cover the relevant Indian Standards and good practice [D-2(1)].

13.1.1 *Physiological Effects of Electric Shock*

The following are the physiological effects of electric shock:

a) *Tetanization* — The muscles affected by the current flow involuntarily contract and letting go of gripped conductive parts is difficult;

NOTE — Very high currents do not usually induce muscular tetanization because, when the body touches such currents, the muscular contraction is so sustained that the involuntary muscle movements generally throw the subject away from the conductive part.

b) *Breathing arrest* — If the current flows through the muscles controlling the lungs, the involuntary contraction of these muscles alters the normal respiratory process and the subject may die due to suffocation or suffer the consequences of traumas caused by asphyxia;

c) *Ventricular fibrillation* — The most dangerous effect is due to the superposition of the external currents with the physiological ones, which, by generating uncontrolled contractions, induce alterations of the cardiac cycle. This anomaly may become an irreversible phenomenon since it persists even when the stimulus has ceased; and

d) *Burns* — They are due to the heating deriving, by Joule effect, from the current passing through the human body.

13.1.2 On a time-current diagram (*see* Fig. 36), four zones to which the physiological effects of alternating current (15 Hz to 100 Hz) passing through the human body have been related as given below:

13.1.3 In general, 'special locations' involve one or more of the following environmental conditions or different risks, which in the absence of special arrangements, will give rise to an increased risk of electric shock:

a) wetness or condensation, that is, reduced skin resistance;

b) absence of clothing, that is, greater opportunity to make direct or indirect contact through increased area of bare skin and bare feet;

c) proximity of earthed metalwork, that is, increased risk of indirect contact; and

d) arduous or onerous site conditions, that is, conditions of use that may impair the effectiveness of the protective measures.

13.1.3.1 The additional requirements for these 'special locations' have been devised by assessing the relevant risks under each of the above categories and making adjustments to the protective measures accordingly. The intention is to remove or minimize the additional risks to users presented by the electrical installations within these 'special locations'. Designers, installers and operators of such installations should consider the particular requirements of the installation and design and install or operate the installation to reduce or protect against risks from these requirements. It should be however recognized, that all installations require adequate regular periodic inspection and testing, and any necessary maintenance or repair works be properly carried out.

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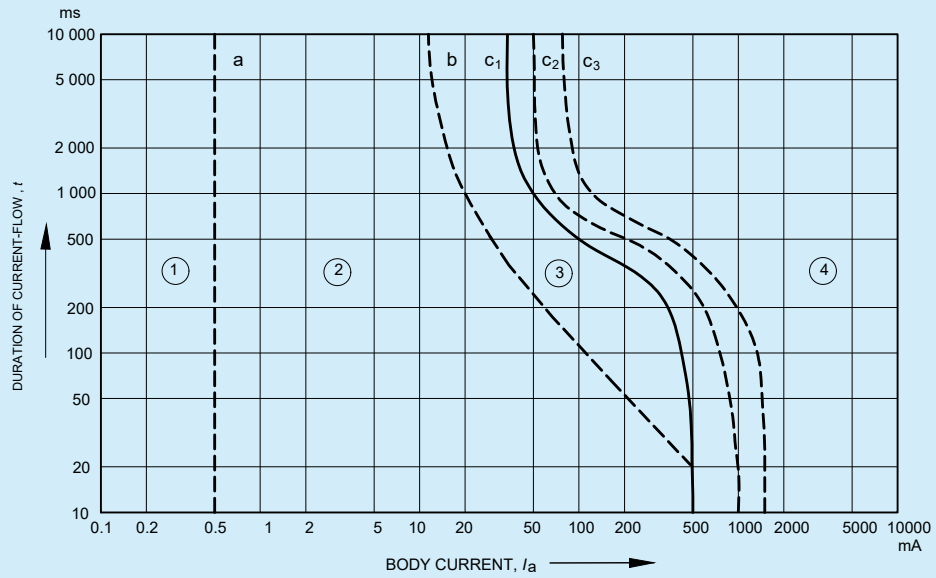

NOTES

1 AS REGARDS VENTRICULAR FIBRILLATION, THIS FIGURE RELATES TO THE EFFECTS OF CURRENT WHICH FLOWS IN THE PATH 'LEFT HAND TO FEET'. FOR OTHER CURRENT PATHS, SEE 5 AND TABLE III OF ACCEPTED STANDARD [D-2(82)].

2 THE POINT 500 MA/100 MS CORRESPONDS TO FIBRILLATION PROBABILITY IN THE ORDER OF 0.14 PERCENT.

Zones	Physiological effects
Zone 1	Usually no reaction effects.
Zone 2	Usually no harmful physiological effects.
Zone 3	Usually no organic damage to be expected. Likelihood of muscular contractions and difficulty in breathing, reversible disturbances of formation and conduction of impulses in the heart, including atrial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with current magnitude and time.
Zone 4	In addition to the effects of Zone 3, probability of ventricular fibrillation increasing up to about 5 percent (curve c_2), up to about 50 percent (curve c_3) and above 50 percent beyond curve c_3. Increasing with magnitude and time, pathophysiological effects such as cardiac arrest, breathing arrest and heavy burns may occur.

FIG. 36 TIME/CURRENT ZONES OF THE EFFECTS OF a.c. CURRENTS (15 Hz TO 100 Hz)

13.2 Protection Against Electric Shocks

13.2.1 Protective measures against electric shock are based on following two common dangers:

a) Contact with an active conductor, which is live with respect to earth in normal circumstances; and is referred to as a 'direct contact' hazard;

b) Contact with a conductive part of an apparatus which is normally dead, but which has become live due to insulation failure in the apparatus; and is referred to as an 'indirect contact' hazard; and

The third type of shock hazard exists in the proximity of HV or LV (or mixed) earth electrodes which are passing earth-fault currents.

c) This hazard is due to potential gradients on the surface of the ground and is referred to as a 'step-voltage' hazard; shock current enters one foot and leaves by the other foot, and is particularly dangerous for four-legged animals. A variation of this danger, known as a 'touch voltage' hazard can occur, for instance, when an earthed metallic part is situated in an area in which potential gradients exist. Touching the part

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would cause current to pass through the hand and both feet. Animals with a relatively long front-to-hind legs span are particularly sensitive to step-voltage hazards.

NOTE — Cattle have been killed by the potential gradients caused by a low voltage (240/415 V) neutral earth electrode of insufficiently low resistance.

13.2.2 Potential-gradient problems as mentioned in **13.2.1** are not normally encountered in electrical installations of buildings, provided that equipotential conductors properly bond all exposed metal parts of equipment and all extraneous metal (that is, those which are not part of an electrical apparatus or the installation, for example structural steelwork, etc) to the protective-earthing conductor.

Potential-gradient problems do exist at the switchboards of electrical installations. Even where components, such as the metallic cubicle and operating handle are earthed, there is a possibility that for very short duration when a fault current is flowing through the metal part, the potential of the earthed metal part may be increased due to the current flow. The practice of using an insulating mat at places where the switches are to be operated, is for protection against such transient over-voltages in earthed metal parts (if the metal part is not earthed the transient overvoltage will be beyond safe limits).

With the increased use of pumped water in bathrooms for spa-baths, power showers, etc, there is a need, on occasions, to provide for motive power within the area of the bath. In order to protect against direct and indirect contact, supplies for such equipment shall be by extra-low-voltage-system with the nominal voltage not exceeding 12 V r.m.s.

It is a requirement to provide supplementary equipotential bonding by bonding all simultaneously accessible exposed and extraneous conductive parts. This should include all in-coming metallic services (including metal wastes) and any structural metalwork, including a metallic floor grid, if provided.

Protection measures as given in **13.2.3** to **13.2.5** shall also be provided for protection against electric shock.

13.2.3 *Direct-Contact Protection or Basic Protection*

The main form of protection against direct contact hazards is to contain all live parts in housings of insulating material or in metallic earthed housings, by placing out of reach (behind insulated barriers or at the top of poles) or by means of obstacles. Where insulated live parts are housed in a metal envelope, for example, transformers, electric motors and many domestic appliances, the metal envelope is connected to the installation protective earthing system. Protection classification and the details of the different levels of protection are designated by IP XX and IK X {*see* accepted standard [D-2(36)] and [D-2(10)]. The metallic enclosure has to demonstrate an electrical continuity, then establishing a good segregation between inside and outside of the enclosure. Proper grounding of the enclosure further participates the electrical protection of the operators under normal operating conditions. For LV appliances this is achieved through the third pin of a 3 pin plug and socket. Total or even partial failure of insulation to the metal, can raise the voltage of the envelope to a dangerous level (depending on the ratio of the resistance of the leakage path through the insulation, to the resistance from the metal envelope to earth). The minimum standard for any equipment has to be IP2X to limit the possibility of a finger touching a live part of an electrical system.

13.2.4 *Indirect-Contact Protection or Fault Protection*

A person touching the metal envelope of an apparatus with a faulty insulation is said to be making an indirect contact. An indirect contact is characterized by the fact that a current path to earth exists (through the protective earthing (PE) conductor) in parallel with the shock current through the person concerned. The hazard in such cases is dependent on the earth resistance and the resistance of the earth continuity conductor, which would effectively be in parallel to the path of flow of current through the human body.

Extensive tests have shown that, providing the potential of the metal envelope not greater than 50 V with respect to earth, or to any conductive material within reaching distance, no danger exists.

If the insulation failure in an apparatus is between a HV/LV conductor and the metal envelope, it is not generally possible to limit the rise of voltage of the envelope to 50 V or less, simply by reducing the earthing resistance to a low value. The solution in this case is to create an equipotential ‘earthing systems’. Insulation faults affecting

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the LV substation's equipment (internal) or resulting from atmospheric overvoltages (external) may generate earth currents capable of causing physical injury or damage to equipment.

a) Preventive measures essentially consist of all substation frames and connecting them to the earth bar;

b) Minimizing earth resistance; and

c) Fast tripping and isolation of the fault by the operation of the fuse or circuit breaker.

13.2.5 In order to provide protection against electric shock due to leakage current for human being, a 30 mA RCCB/RCD shall be installed at distribution board incomer of buildings, such as residential, schools and hospitals. For all other buildings, a 100 mA RCCB will suffice for protection against leakage current.

13.2.6 *Additional Protection Against Electric Shocks*

In a.c. systems, additional protection by means of a residual current protective device (RCD) with sensitivity not exceeding 30 mA shall be provided for:

a) socket-outlets with a rated current not exceeding 20 A that are for use by ordinary person and are intended for general use; and

b) mobile equipment with a current rating not exceeding 32 A for use outdoors.

The residual current devices shall be independent of the line voltage, except for installation operated, tested and inspected by skilled persons.

13.3 Hazards Due to Multiple Electrical Sources

The need for reliability of power supply and continued supply for different equipment leads to provision of redundant equipment chains as well as the provision of more than one source of power.

For critical installations it is normal to have more than one service connection, preferably from two different paths, so that at least one of the paths is in service at any time.

At the next level, to cover the failure of the area distribution network, local standby generating systems such as diesel generating sets are provided. For extremely critical loads which cannot tolerate even short break in service UPS systems which store energy in a battery bank and release it during the power failure become necessary.

As such, multiple sources have become a necessary common feature in most large buildings. Even in small buildings activities depending on computers, etc leads us to provide a standby system with an UPS or an inverter.

Where there is more than one source the shock hazards increase due to various reasons and a proper drill and display of instructions becomes necessary so that the users and in particular the operating and maintenance personnel are warned of the different sources and the associated protocol.

13.4 Care and Design of Electrical Installations for Human Safety

Location of switches and location of electrical equipment has to be done with a view to avoid electrical hazards to the users from the angle of human safety.

Most common hazard is of direct contact and that too when associated with wet surfaces. Wet surface reduces the contact resistance and thereby increases the current flow.

The second most common hazard comes up from old or/and damaged or under-sized flexible cords used for connection of portable equipment or devices.

The recommendations for typical areas requiring special attention are given in **13.4.1** to **13.4.5**.

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13.4.1 *Bath Room Installations*

13.4.1.1 *Geyser*

The geyser or a storage water heater in not a portable device as it requires connection to the electricity line as well as to the water supply lines. The electrical connection will be from a 16 A socket-outlet located at least 500 mm away from the plumbing connections. The switch for the geyser should not be accessible from the bath area or the shower area, to avoid a person standing on the wet surface touching the switch. The switch should be located away from the wet floor area of a bath room and preferably outside near the entrance to the bath room. This switch should have a built in indicator to display the status.

13.4.1.2 *Shaver socket*

Shaver sockets are located near the mirror. The socket will be fed from an isolating transformer (which in addition to providing electrical isolation between the output to the shaver and the building electrical system, may also give a voltage choice selection) to avoid shock hazard.

Shaver sockets which do not have a built in isolating transformer should be protected at the back by a RCCB/RCD of 30 mA sensitivity.

13.4.1.3 *Protection against electric shocks in bathrooms*

All circuits in bathrooms shall be protected by a RCCB/RCD with a sensitivity of 30 mA. The RCCB/RCD shall be in compliance with its relevant Indian Standards.

13.4.1.4 *Protection against electric shocks in sauna heater*

All circuits in sauna shall be protected by a RCCB/RCD with a sensitivity of 30 mA. The RCCB/RCD shall be in compliance with the relevant Indian Standards.

13.4.2 *Bed Room Installations*

For the convenience of operating the lights, fan, nurses call bell system, etc from the bed, it is quite a common practice to provide a pendent switch wired with a flexible cord. The flexible cord used should be with an outer sheath and the sheath should be securely clamped at the pendent switch. Use of twisted flexible cables without double insulation is hazardous and should be avoided.

A bed-head control set for all outlets to be controlled, mounted either on the wall accessible from the bed or mounted on the head board of the bed would be a preferable and safer alternative. This alternative requires the termination of the permanently installed wiring at a box near the bed and a flexible multicore sheathed cable for connection from the wall termination box to the control switch set mounted on the bed-head.

13.4.3 *Kitchen Installations*

Today a large number of gadgets are in use in the kitchen and it would be desirable to provide a large number of combinations of 6 A/16 A sockets. As a general guideline any part of the kitchen counter should be within 1 m from a socket-outlet as most kitchen appliances come with a 1.5 m or 2 m flexible cord.

The sockets should be located on the basis of the equipment layout and the general-purpose outlets would be placed at 150 mm above the kitchen counter level.

For safety, all the socket-outlets should be from circuits with a RCCB/RCD protection of sensitivity 30 mA. If an instant geyser is provided the same has to be wired from circuit with a 100 mA RCCB/RCD as 30 mA may cause nuisance tripping for a geyser.

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13.4.4 *Protection Against Electric Shocks in Swimming Pools and the Other Basins*

For swimming pools and other basins such as basins of swimming pools, paddling pools and their surrounding zones; areas in natural waters such as lakes in gravel pits, coastal and similar areas, specially intended to be occupied by persons for swimming, paddling and similar purposes and their surrounding zones, basins of fountains and their surrounding zones; all electrical systems provided shall be protected by residual current devices with a sensitivity not exceeding 30 mA. The RCD shall be in compliance with its product standard and the relevant Indian Standard. All circuits for lighting, etc in contact with water shall be at 24 V or less.

13.4.5 For protection against electric shock including those pertaining to medical and all other applications not mentioned above, reference shall be made to good practice [D-2(1)].

13.5 Earthing Requirements

Earthing is an essential need for protection against shock. Almost all devices require a proper earth connection through the earthing pin (and socket) and in turn through the protective earth conductor and shall comply with the requirements as per good practices [D-2(1)] and [D-2(11)].

13.6 Heating Appliances and Hot Appliances

Electrical appliance incorporating a heating element pose additional hazards from the possibility of overheating and inadvertent ignition of combustible material in the vicinity. While the installation by itself cannot be made failsafe, it is necessary to provide conspicuous indicators with the switches for the sockets used for such appliances, so that visible indication warns the user that the appliance is ON (many appliances which have their own built-in indication, may be in OFF position in their standby mode or in the cut-off mode. Under such conditions the indication associated with the switch would be a gentle reminder).

Almost all electrical appliances produce heat and require ventilation. The surface of the equipment is likely to be hot. Wherever the surface temperature is likely to be more than 45 °C, there should be a protection against the possibility of touching the surface and getting scalded or burnt.

13.7 Switches Getting Supply from Multiple Sources

Use of critical electrical equipment requiring continued power supply even in the absence of the commercial supply are on the increase both at home and in any general office, apart from special functional buildings where multiple or redundant sources is a necessity. Use of UPS systems has become common.

Where there are such points or switches fed from multiple sources, it is desirable to mark these switches or adopt a colour code so that they are identified readily.

Many UPS and inverters have the feature of tripping on overload followed by automatic restoration after a brief time delay. Such characteristics should be made known to the users, so that accidents do not happen by the uninformed user taking some action assuming that the power supply is not there. Shock hazards are dependent on the system voltage and the hazard level is the same whether it is from the power system or from a mini UPS of a few watts.

13.8 Protection Against Environmental Over-Voltages

Any building today has a number of metallic connections coming into the building or installed over (or near) the building such as lines for electricity, telephone, dish antenna, radio antenna, pipe lines for water supply, sewage, cable of cable TV, solar hot water system, solar photovoltaic array, cell phone tower, wind generator, etc. External disturbances such as lightning, faults in external systems, etc, can induce over-voltage in the installations within the building.

Buildings are to be provided protection from lightning strikes by a system of ‘Faraday cage’ on the basis of hazard assessment. But at the same time use of dish antenna for TV, cable TV (the cable for which is run from building to building on the top, apparently forming a line to catch a lightning stroke) are on the rise and are without any regulation. These installations pose hazards to the installations inside the building. Care should be taken while

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allowing such installations in buildings. In case the occupant is not in a position to avoid such incidence, suitable SPD should be provided in the circuit. Good practice [D-2(1)] may also be referred in this regard.

For sensitive and critical equipment, it is necessary to make a separate detailed study and build in appropriate protective device such as shield, suppressor or diverter, as may be appropriate for the equipment as well as the type of hazard assessed.

13.9 Flammable Atmosphere and Risk of Ignition by Electricity Leading to Fire or Explosion

13.9.1 Flammable atmospheres may result in electrical fire and explosion hazards. They are dealt with separately because of the complexities and problems peculiar to the subject. They occur when flammable gas, vapour, mist, aerosol or dust is present in a concentration in air between the upper (UEL) and lower (LEL) explosive limits. Such mixtures ignite if there is a source of ignition is present, such as incentive arcs or sparks from electrical equipment. The risk areas are divided into following zones for flammable gases/vapours:

a) *Zone* 0 Where the flammable atmosphere is always present;

b) *Zone* 1 Where the flammable material is present during normal operations and a flammable atmosphere is likely to occur; and

c) *Zone* 2 Where the flammable atmosphere is unlikely during normal operation and if it occurs, it will exist only for a short time.

13.9.2 A spark such as from a switch in an explosive atmosphere can trigger a fire or an explosion. In such areas special 'flame-proof' category switches, light fittings, cables, etc will have to be used. The installation practices are also precise. Zonal boundaries have to be determined by the occupier's specialist staff and marked on the site drawing in plan and elevation. It is a difficult task and requires a knowledge of the characteristics of the material and how it disperses from the source of emission.

To illustrate by an example, if LPG leaks from a domestic gas cylinder it creates a hazardous situation. LPG is heavier than air and will settle down at the bottom on the floor with gradually changing ratio of air/LPG mixture as you go up above the floor level and it would be an explosive mixture at a height of a few centimetres above the floor level, which can easily be ignited by a spark or a flame. LPG stored in a basement (particularly if it is without exhaust picked up from floor level) can be serious situation.

Armed with the zonal boundary plans, the next step is to determine the position of the electrical equipment. Wherever possible, the risk should be avoided or minimized by locating the electrical equipment outside the risk areas or in Zone 2 areas rather than in Zones 0 and 1.

Zone 0 is usually inside reaction vessels or storage tanks. There is not much electrical equipment available for use in Zone 0 and as the risk is high it should be avoided by locating the equipment outside, example, a container can have glazed port-holes so that the interior can be viewed through one and lit from a luminaire shining through another. Zone 1 areas often occur only in the immediate vicinity of where the flammable material is processed. They are invariably surrounded by Zone 2 areas where the electrical apparatus should preferably be situated. It is sometimes possible to light outside site zones by luminaires located at high level in safe areas above the vertical zone boundaries. For flammable interiors, lighting can often be provided by positioning the luminaires outside in a safe location and shining the light through glazed panels in the roof or walls. Again, motors can be outside and drive an internal machine through a long shaft extension passing through a gas-tight seal in the wall. In some plants, it is convenient to locate the motor starters together on a starter panel in a motor control room. This room may either be in a safe area or if within the flammable zone, fed with clean air, from outside the zone, maintained at a positive pressure to ensure that gas cannot enter. Conduits for wiring should be solid drawn or seam welded with screwed joints. Where flammable gases have to be excluded from equipment, barrier seals may be necessary. Flexible metallic conduit should be lined to prevent abrasion of the cable insulation. Aluminium and aluminium alloy conduits and accessories should not be used where frictional contact with oxygen-rich items such as rusty steel might occur and cause sparking.

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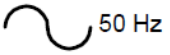
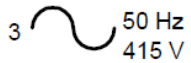
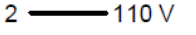
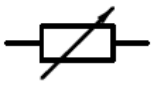
13.10 Protection against Fire Due to Leakage Current in the Building

Large number of fires in the building occur due to faulty electrical installation. Mostly, the cause is assigned to over load or short-circuit fault. But there can be one more reason for causing the fire in the building. As the quality of insulation of the cables deteriorate due to ageing over a period of time, certain amount of leakage current flows in the system. This leakage current or tracking is difficult to detect and if it is allowed for a long period of time, say months or years, sparks occur which on a favourable condition, may lead to devastating fire in the building. Ignition of fire due to leakage current or tracking may be prevented by providing residual current devices of 300 mA as part of the main distribution board.

ANNEX A

(*Clause* 2.2)

DRAWING SYMBOLS FOR ELECTRICAL INSTALLATIONS IN BUILDINGS

Sl No.	*Details*	*Symbol*
1.	Direct current	
2.	Alternating current, general symbol	
3.	Alternating current, single-phase, 50Hz	
4.	Alternating current, three phase, 415 V	
5.	Alternating current, three phase with neutral, 50 Hz	
6.	Neutral	
7.	Positive polarity	
8.	Negative polarity	
9.	Direct current, 2 conductors 110 V	
10.	Direct current 3 conductors including neutral 220 V	
11.	Underground cable	
12.	Overhead Line	
13.	Winding, delta	
14.	Winding, star	
15.	Terminals	
16.	Resistance/Resistor	
17.	Variable resistor	

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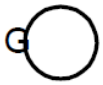
18.	Impedance	
19.	Inductance/Inductor	
20.	Winding	
21.	Capacitance, Capacitor	
22.	Earth	
23.	Fault	
24.	Flexible conductor	
25.	Generator	
26.	a.c. generator	
27.	d.c. generator	
28.	Motor	
29.	Synchronous motor	

30.	Mechanically coupled Machines	
31.	Induction motor, Three-phase, squirrel cage	
32.	Induction motor with Wound rotor	
33.	Transformers with two separate windings	
34.	Auto-transformer	
35.	3-Phase transformer with three separate windings-star-star-delta	
36.	Starter	
37.	Direct-on-line-starter for reversing motor	
38.	Star-delta starter	
39.	Auto-transformer starter	
40.	Rheostatic starter	
41.	Switch	

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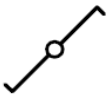
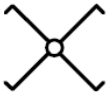
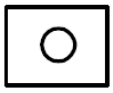
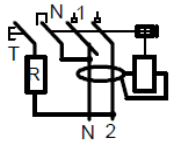
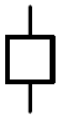
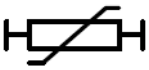
42.	Contactor	
43.	One - way switch, single pole	
44.	One - way switch, two pole	
45.	One - way switch, three pole	
46.	Single pole pull switch	
47.	Multiposition switch for different degrees of lighting	
48.	Two-way switch	
49.	Intermediate switch	
50.	Period limiting switch	
51.	Time switch	
52.	Pendant switch	

53.	Push button	
54.	Luminous push button	
55.	Restricted access push button	
56.	Relay	
57.	Circuit-Breaker	
58.	Isolator	
59.	Residual current circuit breaker	
60.	Surge protective device	
61.	Fuse	
62.	Signal lamp	
63.	Link	

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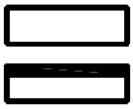
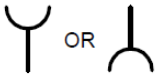
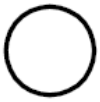
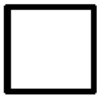
64.	Distribution boards, cubicle box, main fuse board with switches	
65.	Socket outlet, 6A	
66.	Socket outlet, 16 A	
67.	Combined Switch and Socket Outlet, 6A	
68.	Combined switch and socket outlet, 16 A	
69.	Interlocking switch and socket outlet, 6A	
70.	Interlocking switch and socket outlet, 16A	
71.	Plug	
72.	Voltmeter	
73.	Ammeter	
74.	Wattmeter	

75.	Varmeter	
76.	Power factor meter	
77.	Ohmmeter	
78.	Indicating instrument (General symbol)	
79.	Recording instrument (General symbol)	
80.	Integrating meter	
81.	Watthour meter	
82.	Clock	
83.	Master clock	
84.	Current transformer	
85.	Voltage transformer	

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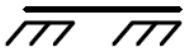
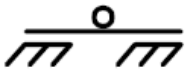
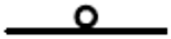
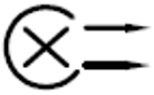
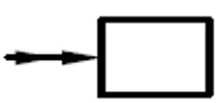
86.	Wiring on the surface	
87.	Wiring under the surface	
88.	Conduit on surface	
89.	Concealed conduit	
90.	Wiring in conduit	
91.	Lamp	
92.	Lamp mounted on a ceiling	
93.	Lamp, mounted on a wall	
94.	Emergency lamp	
95.	Panic lamp	
96.	Water—tight lighting fitting	
97.	Batten lamp holder	

98.	Spot light	
99.	Flood light	
100.	Heater	
101.	Storage type water heater	
102.	Bell	
103.	Buzzer	
104.	Siren	
105.	Ceiling fan	
106.	Exhaust fan	
107.	Fan regulator	
108.	Aerial	
109.	Radio receiving set	

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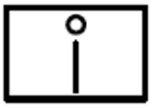
110.	Television receiving set	
111.	Manually operated fire alarm	

112.	Automatic fire detector switch	

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ANNEX B

[*Clauses* 3.1.2.2 (Note) 3.3 (Note), 3.5.3(c), 4.2.1(q)(10), 4.9, 4.9.1.2, 4.9.1.4, 4.9.1.5, 4.9.3.1, 5.3.6.7, 5.4.1.1, 5.4.1.3, 6.4.6, 8.2.1, 8.3, 9.1.1, 9.3.2.6(d), 10.7.3 *and* 10.8.3]

EXTRACTS FROM *CENTRAL ELECTRICITY AUTHORITY (MEASURES RELATING TO SAFETY AND ELECTRIC SUPPLY) REGULATIONS*, 2023

B-1 The following are the extracts of some of the rules:

Regulation 3, Designated person to operate and carry out the work on electrical lines and apparatus

(1) The supplier or consumer, or owner of electrical installation, owner or agent or manager of a mine, or agent of any company operating in an oil-field or owner of a drilled well in an oil-field or a contractor who has entered into a contract with a supplier or a consumer, or owner of electrical installation, owner or agent or manager of a mine, or agent of any company operating in an oil-field or owner of a drilled well in an oil-field to carry out duties incidental to the generation, transformation, transmission, conversion, distribution or use of electricity shall designate person for the purpose to operate and carry out the work on electrical lines and apparatus.

(2) The supplier or consumer, or owner or agent or manager of a mine, or agent of any company operating in an oil-field or the owner of a drilled well in an oil-field or a contractor referred to in sub-regulation (1) shall maintain a record, in paper or electronic form, wherein the names of the designated person and the purpose for which they are designated, shall be entered.

(3) No person shall be designated under sub-regulation (1) unless-

(i) he possesses a certificate of competency or electrical work permit, issued by the Appropriate Government; and

(ii) his name is entered in the register referred to in sub-regulation (2).

Regulation 5, Electrical Safety Officer

(1) All suppliers of electricity including generating companies, transmission companies and distribution companies shall designate an Electrical Safety Officer for ensuring observance of safety measures specified under these regulations in their organisation for construction, operation and maintenance of electrical system of all generating stations, transmission lines, substations, distribution systems and supply lines.

(2) The Electrical Safety Officer shall possess a degree in Electrical Engineering with at least five years experience in operation and maintenance of electrical installations or a Diploma in Electrical Engineering with at least ten years experience in operation and maintenance of electrical installations:

Provided that the Electrical Safety Officer designated for mines shall possess educational qualification as mentioned in sub-regulation (2) with at least five years of experience in operation and maintenance of electrical installations relevant to mines.

(3) For every electrical installation including factory registered under the *Factories Act*, 1948 (63 of 1952) with more than 250 kW connected load and mines and oil-field as defined in the *Mines Act*, 1952 (35 of 1952), with more than 2 000 kW connected load, the owner of the installation or the management of the factory or mines, as the case may be, shall designate Electrical Safety Officer under sub-regulation (1) and having qualification and experience specified in sub-regulation (2), for ensuring the compliance of the safety provisions laid under the Act and the regulations made thereunder:

Provided that the Electrical Safety Officer shall carryout recommended periodic tests as per the relevant standards, and inspect such installations at intervals not exceeding one year, and keep a record thereof in Form I or Form II or Form III or Form IV, as the case may be, of Schedule II of these regulations; test reports and a register of recommendations in regard with safety duly acknowledged by owner; compliances made thereafter; and such records shall be made available to the Electrical Inspector, as and when required.

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Regulation 6, Chartered Electrical Safety Engineer

(1) The Appropriate Government shall authorise Chartered Electrical Safety Engineer from amongst persons having the qualification and experience as per the guidelines issued by the Authority to assist the owner or supplier or consumer of electrical installations for the purpose of selfcertification under Regulation 32 and Regulation 45 of these regulations.

(2) The Appropriate Government shall upload the name of the Chartered Electrical Safety Engineer, as soon as any person is authorised as Chartered Electrical Safety Engineer, on the web portal of the Government or the Department dealing with matters of inspection of electrical installations for the information of the owner or supplier or consumer.

Regulation 8, Safety measures for operation and maintenance of transmission and distribution systems

(1) The Engineers or Supervisors engaged or appointed to operate or undertake maintenance of transmission and distribution systems shall hold degree or diploma in appropriate trade of Engineering from a recognised institute or university.

(2) The Engineers and Supervisors engaged or appointed to operate or undertake maintenance of transmission and distribution systems shall have successfully undergone the type of training specified in guidelines as per sub- regulation (4), within two years from the date of engagement or appointment.

(3) The Technicians to assist Engineers or Supervisors shall possess a certificate in appropriate trade, preferably with a two years course from an Industrial Training Institute recognised by the Central Government or State Government and should have successfully undergone the type of training as specified in guidelines as per sub- regulation (4), within two years from the date of engagement or appointment:

Provided that the existing employees, as on the date of notification of these regulations, who are extending technical assistance to Engineers or Supervisors and do not have requisite qualification as mentioned in this regulation, shall have to undergo the training either from Power Sector Skill Council or from training institute recognised by the Authority for carrying out trade specific course as per the guidelines issued by the Authority and get certificate as mentioned above within two years from the date of notification of these regulations.

(4) The Authority shall issue guidelines for the training for operation and maintenance of transmission, distribution systems within six months of the notification of these regulations:

Provided that the duration and content of the training course shall be as specified in the guidelines.

(5) Owner of every transmission or distribution system shall arrange for training of their personnel engaged or appointed to operate and undertake maintenance of transmission and distribution system, in his own institute or any other institute recognised by the Authority or State Government as per the guidelines and shall maintain records of the assessment of these personnel issued by the training institute in the format prescribed in guidelines and such records shall be made available to the Electrical Inspector, as and when required.

Regulation 14, General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric supply lines and apparatus

(1) All electric supply lines and apparatus shall be of sufficient rating for power, insulation and estimated fault current and of sufficient mechanical strength, for the duty cycle which they may be required to perform under the environmental conditions of installation, and shall be constructed, installed, protected, worked and maintained in such a manner as to ensure safety of human beings, animals and property.

(2) Save as otherwise provided in these regulations, the relevant standards including National Electrical Code and National Building Code shall be followed to carry out the purpose of these regulations and where relevant Indian Standards are not available, International standards shall be followed and in the event of any inconsistency, the provisions of these regulations shall prevail.

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(3) The material and apparatus used shall conform to the relevant standards.

(4) All electrical equipment shall be installed above the Highest Flood Level and where such equipment is not possible to be installed above Highest Flood Level, it shall be ensured that there is no seepage or leakage or logging of water.

Regulation 17, Identification of earthed and earthed neutral conductors and position of switches and switchgear therein

Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be complied with-

(i) an indication of a permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such conductor to be distinguished from any live conductor and such indication shall be provided as per relevant standards, namely: –

(a) where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply;

(b) where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor, at the point where such connection is to be made; and

(c) in all other cases, at a point corresponding to the point of commencement of supply.

(ii) no cut-out, link, switch or circuit breaker other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two wire-system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto:

Provided that the above requirement shall not apply in case of a link for testing purposes, or a switch for controlling a generator or transformer.

Regulation 18, Earthed terminal on consumer's premises

(1) The supplier shall provide and maintain on the consumer's premises for the consumer's use, a suitable earthed terminal in an accessible position at or near the point of commencement of supply as per relevant standards:

Provided that in the case of installation of voltage exceeding 250 V the consumer shall, in addition to the aforementioned earthing arrangement, provide his own earthing system with an independent electrode and the same shall be interlinked with the earthed terminal mentioned in sub-regulation (1) through a suitable link.

(2) The consumer shall take all reasonable precautions to prevent mechanical damage to the earthed terminal and its lead belonging to the supplier.

Regulation 20, Danger notices

The owner of every installation of voltage exceeding 250 V shall affix permanently in a conspicuous position a danger notice in Hindi or English and the local language of the district, with a sign of skull and bones of a design as per relevant standards on:

(a) every motor, generator, transformer and other electrical plant and equipment together with apparatus used for controlling or regulating the same;

(b) all supports of overhead lines of voltage exceeding 650 V which can be easily climbed upon without the aid of ladder or special appliances; and

(c) luminous tube sign requiring supply, X-ray and similar high frequency installations of voltage exceeding 650 V but not exceeding 33 kV:

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Provided that where it is not possible to affix such notices on any generator, motor, transformer or other apparatus, they shall be affixed as near as possible thereto, or the word 'danger' and the voltage of the apparatus concerned shall be permanently painted on it:
Provided further that where the generator, motor, transformer or other apparatus is within an enclosure one notice affixed to the said enclosure shall be sufficient for the purposes of this regulation.

Explanation — For the purposes of clause (b) rails, tubular poles, wooden supports, reinforced cement concrete poles and pre stressed cement concrete poles without steps, I-sections and channels, shall be deemed as supports which cannot be easily climbed upon.

Regulation 21, Handling of electric supply lines and apparatus

(1) Before any conductor or apparatus is handled, adequate precautions shall be taken, by earthing or other suitable means, to discharge electrically such conductor or apparatus, and any adjacent conductor or apparatus if there is danger therefrom, and to prevent any conductor or apparatus from being accidentally or inadvertently electrically charged when persons are working thereon shall be followed as per the relevant standards.

(2) Every person who is working on an electric supply line or apparatus or both shall be provided with, –

(a) personal protective equipment, tools and devices such as rubber gloves and safety footwear suitable for working voltage, safety belts for working at height, nonconductive ladder, earthing devices of appropriate class, helmet, line tester, hand lines, voltage detector and hand tools as per the relevant standards; and

(b) any other device for protecting him from mechanical and electrical injury due to arc flash and such personal protective equipment, tools and devices shall conform to the relevant standards and shall always be maintained in sound working condition.

(3) No person shall operate and undertake maintenance work on any part or whole of an electrical plant or electric supply line or apparatus and no person shall assist such person on such work, unless he is designated in that behalf and observes the safety precautions given in Part-I, Part-II, Part-III and Part-IV, as the case may be, of Schedule I.

(4) Every telecommunication line on supports carrying an overhead line of voltage exceeding 650 V but not exceeding 33 kV shall, for the purpose of working thereon, be deemed to be a line of voltage exceeding 650 V:

Provided that prior permission shall be taken from the concerned licensee before laying telecommunication lines on electric supports.

(5) For the safety of operating personnel, all non-current carrying metal parts of switchgear and control panels shall be properly earthed and insulating floors or mat conforming to the relevant standards, of appropriate voltage level shall be provided in front and rear of the panels where such personnel are required to carry out operation, maintenance or testing work.

(6) All panels shall be painted with the description of its identification at front and at the rear.

Regulation 29, Provisions applicable to protective equipment

(1) Fire buckets filled with clean dry sand and ready for immediate use for extinguishing fires, in addition to fire extinguishers suitable for dealing with fires, shall be conspicuously marked and kept in all generating stations, enclosed substations and enclosed switching-stations in convenient location.

(2) Appropriate type of fire extinguisher conforming to the relevant standards, shall be installed, maintained, periodically inspected and tested as per the relevant standards for extinguishing and controlling fire and record of such tests shall be maintained.

(3) Sufficient number of first-aid boxes or cupboards conspicuously marked and equipped with such contents as the State Government may specify or as per the relevant standards, shall be provided and maintained at appropriate locations in every generating station, enclosed substation, enclosed switching

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station and in vehicles used for maintenance of lines so as to be readily available and accessible at all the times and all such boxes and cupboards shall, except in the case of unattended substations and switching stations, be kept under the charge of responsible persons who are trained in first-aid treatment and one of such persons shall be available during working hours.

(4) Two or more gas masks shall be provided conspicuously and installed and maintained at accessible places in every generating station with capacity of five megawatt and above and enclosed substation with transformation capacity of five megavolt-ampere and above for use in the event of fire or smoke:

Provided that where more than one generator with capacity of five megawatt and above is installed in a power station, each generator shall be provided with at least two separate gas masks in an accessible and conspicuous place.

(5) In every generating station, substation or switching station, an artificial respirator, fire extinguishers, first-aid boxes and gas masks shall be provided and kept in good working condition and locations of the same shall be displayed in the control room and operator cabin.

(6) Address and contact number of the nearest Doctor, Hospital with a facility for first-aid treatment for electric shock and burns, ambulance service and fire service shall be prominently displayed near the electric shock treatment chart in control room and operator cabin.

Regulation 30, Display of instructions for resuscitation of persons suffering from electric shock

(1) Instructions, in English or Hindi and the local language of the District and where Hindi is the local language, in English and Hindi for the resuscitation of persons suffering from electric shock, shall be affixed by the owner in a conspicuous place in every generating station, enclosed substation, enclosed switching station, mines and in every factory as defined in the Factory Act, 1948 (63 of 1952) in which electricity is used and in such other premises where electricity is used as the Electrical Inspector may, by notice in writing served on the owner, direct.

(2) The owner of every generating station, enclosed substation, enclosed switching station and every factory or other premises to which these regulations apply, shall ensure that all designated persons or persons engaged or appointed to operate and maintain electrical plants or transmission or distribution systems are acquainted with and are competent to apply the instructions referred to in sub-regulation (1).

Regulation 31, Precautions to be adopted by consumers, owners, occupiers, electrical contractors, electrical workmen and suppliers

(1) No electrical installation work, including additions, alterations, repairs and adjustments to existing installations, except such replacement of lamps, fans, fuses, switches, domestic appliances of voltage not exceeding 250 V and fittings as in no way alters its capacity or character, shall be carried out upon the premises of or on behalf of any consumer, supplier, owner or occupier for the purpose of supply to such consumer, supplier, owner or occupier except by an electrical contractor licenced in this behalf by the State Government and on its behalf under the direct supervision of a person holding a certificate of competency and by a person holding a permit issued or recognised by the State Government:

Provided that in the case of works executed for or on behalf of the Central Government and in the case of installations in mines, oil-fields and railways, the Central Government and in other cases the State Government, may, by notification in the Official Gazette, exempt on such conditions as it may impose, any such work described therein either generally or in the case of any specified class of consumers, suppliers, owners or occupiers.

Provided further that in the case of works executed for or on behalf of the Central Government and in the case of installations in mines, oil-fields and railways, an electrical contractor having licence issued by any State Government or Union Territory administration shall not require licence from other State Government in which the works are to be executed.

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(2) No electrical installation work which has been carried out in contravention of sub-regulation (1) shall either be energised or connected to the works of any supplier.

Regulation 32, Periodical inspection and testing of installations

(1) The periodic inspection and testing of installation of voltage above the notified voltage belonging to the owner or supplier or consumer, as the case may be, shall be carried out by the Electrical Inspector:

Provided that the electrical installation below or equal to the notified voltage shall be self-certified by the owner or supplier or consumer, as the case may be.

(2) The periodicity of electrical inspection by the Electrical Inspector or the self-certification by the supplier, owner or consumer shall be as directed by the Appropriate Government.

Provided that the periodicity of electrical inspection and self-certification shall not exceed five years.

Provided further that in respect of the electrical installation belonging to mines, oil-fields and railways, such direction shall be issued by the Central Government.

(3) The periodic inspection and testing of installation of voltage equal to or below the notified voltage belonging to the owner or supplier or consumer, as the case may be, shall be carried out by the owner or supplier or consumer and shall be self-certified for ensuring observance of safety measures specified under these regulations and the owner or supplier or consumer, as the case may be, shall submit the report of self-certification to the Electrical Inspector in the Form I or Form II or Form III or Form IV, as the case may be, of Schedule II:

Provided that the electrical installation so self-certified shall be considered as duly inspected and tested only after the report of self-certification is duly received by the office of Electrical Inspector and if not acknowledged by the Electrical Inspector within three working days, it shall be deemed to be received:

Provided further that the owner or supplier or consumer has the option to get his installation inspected and tested by the Electrical Inspector of the Appropriate Government.

(4) Notwithstanding anything contained in sub-regulation (3), every electrical installation covered under section 54 of the Act including every electrical installation of mines, oil-fields and railways shall be periodically inspected and tested by the Electrical Inspector of the Appropriate Government.

(5) Where the supplier is directed by the Central Government or the State Government, as the case may be, to inspect and test the installation, such supplier shall report on the condition of the installation to the consumer concerned in the Form I, Form II, Form III and Form IV as provided in Schedule II and shall submit a copy of such report to the Electrical Inspector.

(6) The Electrical Inspector may, on receipt of such report, accept the report submitted by the supplier or record variations as the circumstances of each case may require and may recommend that the defects may be rectified as per report.

(7) In the event of the failure of the owner of any installation to rectify the defects in his installation pointed out by the Electrical Inspector in his report and within the time indicated therein, such installation shall be liable to be disconnected under the directions of the Electrical Inspector after serving the owner of such installation with a notice for a period not less than forty eight hours:

Provided that the installation shall not be disconnected in case an appeal is made under sub section (2) of section 162 of the Act and appellate authority has stayed the orders of disconnection.

(8) It shall be the responsibility of the owner of all installations to maintain and operate the installations in a condition free from danger and as recommended by the manufacturer or by the relevant standards.

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Regulation 33, Testing of consumer's installation

(1) Upon receipt of an application for a new or additional supply of electricity and before commencement of supply or recommencement of supply after the supply has been disconnected for a period of six months, the supplier shall either test the installation himself or accept the test results submitted by the consumer when same has been duly signed by the licenced electrical contractor:

Provided that in case of voltage level equal to or below the notified voltage, Chartered Electrical Safety Engineer can also test the installation on request of owner.

(2) The testing and verifications shall be carried out as per relevant standards.

(3) The testing equipment shall be calibrated by a Government authorised or National Accreditation Board for Testing and Calibration Laboratories accredited laboratory at periodical interval as per the periodicity specified by them.

(4) The supplier shall maintain a record of test results obtained at each supply point to a consumer, as per the forms provided in Schedule III.

(5) If as a result of such inspection and test, the supplier is satisfied that the installation is likely to be dangerous, he shall serve on the applicant a notice in writing requiring him to make such modifications as are necessary to render the installation safe and may refuse to connect or reconnect the supply until the required modifications have been completed.

Regulation 34, Generating units required to be inspected by electrical inspector

The capacity above which generating units including generating units producing electricity from renewable sources of energy shall be required to be inspected by the Electrical Inspector before commissioning, shall be as per the notification issued by the Appropriate Government in this regard.

Regulation 35, Precautions against leakage before connection

(1) The supplier shall not connect its works with the apparatus in the premises of any applicant seeking supply unless the supplier is satisfied that at the time of making the connection cause a leakage from that installation or apparatus of a magnitude detrimental to safety which shall be checked by measuring the installation or apparatus insulation resistance as stipulated in the relevant standards.

(2) If the supplier declines to make a connection under the provisions of sub-regulation (1) the supplier shall convey to the applicant the reasons thereof, in writing for so declining.

Regulation 36, Leakage on consumer's premises

(1) If the Electrical Inspector or the supplier has reasons to believe that there is leakage in the system of a consumer which is likely to affect injuriously the use of electricity by the consumer or by other persons, or which is likely to cause danger, he may give notice to the consumer in writing to inspect and test the consumer's installation.

(2) If after such notice, the consumer fails to provide access to its installation for inspection and testing, or an insulation resistance of the consumer's installation is so low as to prevent safe use of electricity, the supplier may, and if directed so by the Electrical Inspector shall discontinue the supply of electricity to the installation but only after giving to the consumer forty eight hours notice in writing for disconnection of supply and shall not recommence the supply until he or the Electrical Inspector is satisfied that the cause of the leakage has been removed.

Regulation 37, Supply and use of electricity

(1) The electricity shall not be supplied, transformed, converted, inverted or used or continued to be supplied, transformed, converted, inverted or used unless the conditions provided in sub- regulations (2) to (8) are complied with.

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(2) The following controls of requisite capacity to carry and break the current shall be installed as near as possible after the point of commencement of supply so as to be readily accessible and capable of completely isolating the supply to the installation, such equipment being in addition to any control switch installed for controlling individual circuits or apparatus, namely:

Supplied at voltage	*Control*
Below 11 kV.	Switch fuse unit or a circuit breaker by consumers.
11 kV and above.	A circuit breaker by consumers.

(i) In case of every transformer the following shall be provided, namely: –on primary side of transformer, a linked switch with fuse or gang operated air break switch with fuse or circuit breaker of adequate capacity:

Provided that the linked switch with fuse on the primary side of the transformer may be of such capacity as to carry the full load current and to break only the magnetising current of the transformer:

Provided further that for transformer having capacity of 1 000 kVA and above, a circuit breaker shall be provided:

Provided also that the linked switch with fuse or gang operated air break switch with fuse or circuit breaker on the primary side of the transformer shall not be required for the unit auxiliary transformer and generator transformer;

(ii) on the secondary side of all transformers a circuit breaker of adequate rating shall be installed:

Provided that for supplier's transformers of capacity below 1 000 kVA, a linked switch with fuse or circuit breaker of adequate rating shall be installed on secondary side.

(4) Except in the case of composite controlgear designed as a unit each distinct circuit is to be protected against excess energy by means of a suitable fuse link or a circuit breaker of adequate breaking capacity, suitably located and so constructed as to prevent danger from overheating, arcing or scattering of hot metal when it comes into operation and to permit for ready renewal of the fuse link without danger.

(5) The supply of electricity to each motor or a group of motors or other apparatus meant for operating one particular machine shall be controlled by a suitable linked switch or a circuit breaker or an emergency tripping device with manual reset of requisite capacity placed in such a position as to be adjacent to the motor or a group of motors or other apparatus readily accessible to and easily operated by the person incharge and so connected in the circuit that by its means all supply of electricity can be cut off from the motor or group of motors or apparatus from any regulating switch, resistance of other device associated therewith.

(6) All insulating materials shall be as per their application and their mechanical strength shall be sufficient for the purpose so as to maintain adequately their insulating property under all working conditions in respect of temperature, moisture, salinity and pollution.

(7) Adequate precautions shall be taken to ensure that no live parts are exposed as to cause danger.

(8) Every consumer shall use all reasonable means to ensure that where electricity is supplied by the supplier, no person other than the supplier shall interfere with service lines and apparatus placed by the supplier on the premises of the consumer.

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Regulation 38, Provisions for supply and use of electricity in multi-storeyed building more than 15 metres in height

(1) The connected load and voltage of supply above which inspection is to be carried out by an Electrical Inspector for a multi-storeyed building of more than fifteen metre height shall be notified by the Appropriate Government.

(2) Before making an application for commencement of supply or recommencement of supply after an installation has been disconnected for a period of six months or more, the owner or occupier of a multi-storeyed building shall give not less than thirty days notice in writing to the Electrical Inspector specifying therein the particulars of installation and the supply of electricity shall not be commenced or recommenced within this period, without the approval in writing of the Electrical Inspector.

(3) The following safety measures shall be provided in the multi-storeyed buildings of more than fifteen metre height and other premises such as airports, hospitals, hotels, places of entertainment, places of worship, cultural centres, stadium, academic buildings, test labs, industrial installations, installation with explosive or flammable material, railway or metro stations and other public buildings, namely:

(i) the supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device with cut-out or breaker to operate on all phases except neutral in the three-phase, four-wire circuit and fixed in a conspicuous position at not more than 1.70 metre above the ground so as to completely isolate the supply to the building in case of emergency;

(ii) the owner or occupier of a multi-storeyed building shall ensure that electrical installations and works inside the building are carried out and maintained in such a manner as to prevent danger due to shock and fire hazards, and the installation is carried out as per the relevant standards;

(iii) no other service pipes and cables shall be taken through the ducts provided for laying of power cables and all ducts provided for power cables and other services shall be provided with fire barrier at each floor crossing;

(iv) the Fire Retardant Low Smoke and Low Halogen power cables shall be used in building of more than fifteen metre height as per relevant standards;

(v) Provided that Halogen Free Flame Retardant power cables as per the relevant standards shall be used in airports, hospitals and hotels irrespective of height;

(vi) distribution of electricity to the floors shall be done using busbar trunking system;

(vii) lightning protection of the building shall be as per the relevant standards;

(viii) verification of electrical wiring of the building shall be carried out as per the relevant standards; and

(ix) electricity meter shall not be installed in the passage of staircase.

Regulation 39, Conditions applicable to installations of voltage exceeding 250 Volts

The following conditions shall be compiled with where electricity of voltage above 250 V is supplied, converted, transformed or used, namely:

(i) all conductors, other than those of overhead lines, shall be completely enclosed in mechanically strong metal casing or metallic covering which is electrically and mechanically continuous and adequately protected against mechanical damage unless the said conductors are accessible only to a designated person or are installed and protected so as to prevent danger:

Provided that non-metallic conduits conforming to the relevant standards may be used for installations of voltage not exceeding 650 V;

(ii) all metal works, enclosing, supporting or associated with the installation, other than that designed to serve as a conductor shall be connected with an earthing system as per relevant standards and the provisions of regulation 43;

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(iii) every switch board shall comply with the following, namely:

(a) a clear space of not less than one metre in width shall be provided in front of the switchboard;

(b) if there are any attachments or bare connections at the back of the switchboard, the space, if any, behind the switchboard shall be either less than twenty centimetre or more than seventy five centimetre in width, measured from the farthest protruding part of any attachment or conductor; and

(c) if the space behind the switchboard exceeds seventy five centimetre in width, there shall be a passage way from either end of the switchboard, clear to a height of 1.8 metre;

(iv) in case of installations provided in premises where inflammable materials including gases and chemicals are produced, handled or stored, the electrical installations, equipment and apparatus shall comply with the requirements of flame proof, dust tight, totally enclosed or any other suitable type of electrical fittings depending upon the hazardous zones as per the relevant standards;

(v) where an application has been made to a supplier for supply of electricity to any installation, the supplier shall not commence the supply or where the supply has been discontinued for a period of six months or more, recommence the supply unless the consumer has complied with the relevant provisions in these regulations;

(vi) where a supplier proposes to supply or use electricity at or to recommence supply of voltage exceeding 250 V but not exceeding 650 V after it has been discontinued for a period of six months, he shall, before connecting or reconnecting the supply, give notice in writing of such intention to the Electrical Inspector; and

(vii) if at any time after connecting the supply, the supplier is satisfied that any provision of these regulations have not been complied with, the supplier shall give notice of the same in writing to the consumer and the Electrical Inspector, specifying the defects and to rectify such defects in a reasonable time:

Provided that if the consumer fails to rectify such defects the supplier may discontinue the supply after giving the consumer a reasonable opportunity of being heard and recording reasons in writing and the supply shall be discontinued only on written orders of an officer duly notified by the supplier in this behalf and shall be restored with all possible speed after such defects are rectified by the consumer to the satisfaction of the supplier.

Regulation 40, Appeal to electrical inspector in regard to defects

(1) If any applicant for a supply or a consumer is aggrieved by the action of the supplier in declining to commence, to continue or to recommence the supply of electricity to his premises on the grounds that the installation is defective or is likely to be dangerous, he may appeal to the Electrical Inspector to test the installation and the supplier shall not, if the Electrical Inspector intimates that the installation is free from the defect or danger complained of, refuse supply to the consumer on the grounds aforesaid, and shall, within twenty four hours after the receipt of such intimation from the Electrical Inspector, commence, continue or recommence the supply of electricity.

(2) Any test for which application has been made under sub-regulation (1), shall be carried out within seven days after the receipt of such application.

Regulation 41, Precautions against failure of supply and notice of failures

(1) The layout of the electric supply lines of the supplier for the supply of electricity throughout his area of supply shall under normal working conditions be sectionalised and so arranged, and provided with switchgear or circuit-breakers, so located, as to restrict within reasonable limits the extent of the portion of the system affected by any failure of supply.

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(2) The supplier shall take all reasonable precautions to avoid any accidental interruptions of supply, and also to avoid danger to the public or to any employee or designated person when engaged on any operation during and in connection with the installation, extension, replacement, repair and maintenance of any works.

(3) The supplier shall send to the Electrical Inspector a notice of failure of supply of such kind as the Electrical Inspector may from time to time require to be notified to him, and such notice shall be sent by the earliest mode of communication after the failure occurs or after the failure becomes known to the supplier and shall be in the Form given in Schedule IV.

(4) For the purpose of testing or for any other purpose connected with the efficient working of the supplier's installations, the supply of electricity may be discontinued by the supplier for such period as may be necessary, subject to not less than twenty four hours notice being given by the supplier to all consumers likely to be affected by such discontinuance:

Provided that no such notice shall be given in cases of emergency.

Regulation 42, Test of insulation resistance

Where any electric supply line for use at voltages not exceeding 650 V has been disconnected from a system for the purpose of addition, alteration or repair, such electric supply line shall not be reconnected to the system until the supplier or the owner has carried out the test.

Regulation 43, Connection with earth

The following conditions shall apply to the connection with earth of systems at voltage exceeding 50 V but not exceeding 650 V, namely:

(i) neutral conductor of a three phase, four-wire system and the middle conductor of a two-phase, three-wire system shall be earthed as per the relevant standards;

(ii) neutral conductor shall also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which shall be at the consumer's premises;

(iii) in the case of a system comprising electric supply lines having concentric cables, the external conductor or armour of such cables shall be earthed by two separate and distinct connections with earthing system;

(iv) in a direct current system, earthing and safety measures shall be as per the relevant standards;

(v) every building shall have protective equipotential bonding by interconnecting the exposed and extraneous conductive parts as per the relevant standards;

(vi) the alternating current systems which are connected with the earth as provided in this regulation shall be electrically interconnected:

Provided that each connection with the earth is bonded to the metal sheathing and metallic armouring, if any, of the electric supply lines;

(vii) the frame of every generator, stationary motor, portable motor, and the metallic parts, not intended as conductors, all transformers and any other apparatus used for regulating or controlling electricity, and all electricity consuming apparatus, of voltage exceeding 250 V but not exceeding 650 V shall be earthed by two separate and distinct connections with earth by the owner as specified in the relevant standards;

(viii) all metal casing or metallic coverings containing or protecting any electric supply line or apparatus shall be connected with the earth and shall be so joined and connected across all junction boxes and other openings as to provide good mechanical and electrical connection throughout the length:

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Provided that the conditions mentioned in this regulation shall not apply, where the supply voltage does not exceed 250 V and the apparatus consists of wall tubes or brackets, electroliers, switches, ceiling fans or other fittings, other than portable hand lamps and portable and transportable apparatus, unless provided with the earth terminal and to class-II apparatus and appliances of the relevant standards:

Provided further that where the supply voltage is not exceeding 250 V and where the installations are either new or renovated, all plug sockets shall be of the three pin type, and the third pin shall be permanently and effectively earthed;

(ix) All earthing systems shall:

(a) consist of equipotential bonding conductors capable of carrying the prospective earth fault current without exceeding the allowable temperature limits as per relevant standards in order to maintain all non- current carrying metal works reasonably at earth potential and to avoid dangerous contact potentials being developed on such metal works;

(b) have earth fault loop impedance sufficiently low to permit adequate fault current for the operation of protective device within the time stipulated in the relevant standards; and

(c) be mechanically strong, withstand corrosion and retain electrical continuity during the life of the installation and all earthing systems shall be tested to ensure effective earth bonding as per the relevant standards, before the electric supply lines or apparatus are energised.

(x) all earthing systems belonging to the supplier shall in addition, be tested for resistance on dry day during the dry season at least once in a year;

(xi) earth fault loop impedance shall be tested to ensure the automatic operation of the protective device and a record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Electrical Inspector when required;

(xii) earth fault loop impedance of each circuit shall be limited to a value determined by the type and current rating of the protective device used such that, on the occurrence of an earth fault, disconnection of the supply shall occur before the prospective touch voltage reaches a harmful value; and

(xiii) the neutral point of every generator and transformer shall be earthed by connecting it to the earthing system not by less than two separate and distinct connections.

Regulation 46, Use of electricity at voltage exceeding 650 V.

(1) The Electrical Inspector where the supply voltage exceeds the notified voltage shall not authorise the supplier to commence supply or recommence the supply, where the supply has been discontinued for a period of six months or more, or the supplier, where the supply voltage is equal to or below the notified voltage but exceeds 650 V, shall not commence supply or recommence the supply where supply has been discontinued for a period of six months or more, to any consumer unless:

(a) all conductors and apparatus situated on the premises of the consumer are so placed as to be inaccessible except to the designated person;

(b) the consumer has provided and agreed to maintain a separate building or a locked weather proof and fire proof enclosure of agreed design and location, to which the supplier at all times shall have access for the purpose of housing his apparatus and metering equipment, or where the provision for a separate building or enclosure is impracticable, the consumer has segregated the aforesaid apparatus of the supplier from any other part of his own apparatus:

Provided that the segregation shall be made by the fire walls, if the Electrical Inspector considers it to be necessary:

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Provided further that in the case of an outdoor installation the consumer shall suitably segregate the aforesaid apparatus belonging to the supplier from his own;

(c) all pole type substations are constructed and maintained in accordance with regulation 52.

(2) Where electricity at voltage exceeding 650 V is supplied, converted, transformed or used, the owner shall:

(i) maintain safety clearances for electrical apparatus as per relevant standards specification so that sufficient space is available for easy operation and maintenance without any hazard to the operating and maintenance personnel working near the equipment and for ensuring adequate ventilation:

Provided that in case of mines, the safety clearances for electrical apparatus to be as per relevant mining regulations;

(ii) not allow any encroachment below such installation:

Provided that where the Electrical Inspector comes across any such encroachment, he shall direct the owner to remove such encroachments;

(iii) maintain minimum safety working clearances specified in Schedule V for the bare conductors or live parts of any apparatus in outdoor substations excluding overhead lines of installations of voltage exceeding 650 V;

(iv) ensure that the live parts of all apparatus within the reach from any position in which a person may require to be, are suitably protected to prevent danger;

(v) ensure that where the transformer is used, suitable provision shall be made, either by connecting with earth, a point of the circuit at the lower voltage or otherwise, to guard against danger by reason of the said circuit becoming accidentally charged above its normal voltage by leakage from or contact with the circuit at the higher voltage;

(vi) not install a substation or a switching station with apparatus having more than 2 000 litres of oil in the basement where proper oil draining arrangement cannot be provided;

(vii) undertake the following measures, where a substation or a switching station with oil-filled apparatus, such as transformer, static condenser, switchgear or oil circuit breaker having more than 2 000 litres of oil is installed, whether indoor or outdoors:

(a) the separation wall or fire barrier walls of thickness and dimensions as specified in the relevant standards shall be provided between the apparatuses and between the apparatus and adjacent building if building wall adjacent to the apparatuses is not rated for four hours fire withstand rating;

(b) provisions shall be made for suitable oil soakpit and where use of more than 9000 litre of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tank, receptacle or chamber containing the same, and special precautions shall be taken to prevent the spread of any fire resulting from the ignition of the oil from any cause and adequate provision shall be made for extinguishing any fire which may occur;

(c) spare oil shall not be stored in the vicinity of any oil filled equipment in any such substation or switching station; and

(d) all the transformers and switchgears shall be maintained in accordance with the maintenance schedules prepared in accordance with the relevant standards;

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(viii) without prejudice to the above measures, undertake adequate fire detection and protection arrangement for quenching the fire of the apparatus;

(ix) ensure that every transformer of 10 MVA or reactor of 10 MVAR and above rating shall be provided with automatic firefighting system as per relevant standards;

(x) undertake the following measures, where it is necessary to locate the substation, or switching station in the basement, namely:

(a) the transformer room be in the first basement at the periphery;

(b) the direct access to the transformer room be provided from outside and the surrounding walls of four hours fire withstand rating be provided as per relevant standards;

(c) the entrances to the transformer room be provided with fire resistant doors of two hour fire rating and the door shall always be kept closed and a notice of this effect be affixed on outer side of the door;

(d) a curb of a suitable height be provided at the entrance in order to prevent the flow of oil from a ruptured transformer into other parts of the basement;

(e) the cables to primary side and secondary side have sealing at all floors and wall opening of atleast two hours fire withstand rating; and

(f) Fire Retardant Low Smoke Low Halogen cable as per relevant standards be used;

(xi) ensure that oil filled transformers installed indoors in other than residential or commercial buildings are placed on the ground floor or not below the first basement;

(xii) ensure that only dry type transformer shall be used inside the residential and commercial buildings;

(xiii) ensure that cable trenches inside the substations and switching stations containing cables are filled with sand, pebbles or similar non-inflammable materials or completely covered with non-inflammable slabs; and

(xiv) ensure that unless the conditions are such that all the conductors and apparatus may be made dead at the same time for the purpose of cleaning or for other work, the said conductors and apparatus shall be so arranged that these may be made dead in sections, and that work on any such section may be carried on by the person designated or appointed or engaged or permitted under these regulations without danger.

(3) The minimum clearances specified in Schedule VI shall be maintained for bare conductors or live parts of any high voltage direct current apparatus in outdoor substations, excluding high voltage direct current overhead lines.

(4) There shall not be tapping of another transmission line from the main line for 66 kV and above class of lines:

Provided that during natural calamities, tapping may be allowed to ensure emergency power supply to affected areas till normalcy is restored.

Regulation 47, Inter-locks and protection for use of electricity at voltage exceeding 650 volts

(1) The owner shall ensure the following, namely-

(i) isolators and the controlling circuit breakers shall be inter-locked so that the isolators cannot be operated unless the corresponding breaker is in open position;

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(ii) isolators and the corresponding earthing switches shall be inter-locked so that no earthing switch can be closed unless and until the corresponding isolator is in open position;

(iii) where two or more supplies are not intended to be operated in parallel, the respective circuit breakers or linked switches controlling the supplies shall be inter-locked to prevent possibility of any inadvertent paralleling or backfeed;

(iv) when two or more transformers are operated in parallel, the system shall be so arranged as to trip the secondary breaker of the transformer in case the primary breaker of that transformer trips;

(v) all gates or doors which provide access to live parts of an installation shall be inter-locked in such a way that these cannot be opened unless the live parts are made dead and proper discharging and earthing of these parts shall be ensured before any person comes in close proximity of such parts; and

(vi) where two or more generators operate in parallel and neutral switching is adopted, inter-lock shall be provided to ensure that the generator breaker cannot be closed unless one of the neutrals is connected to the earthing system.

(2) The following protection shall be provided in all systems and circuits to automatically disconnect the supply under abnormal conditions, namely:

(i) overcurrent protection to disconnect the supply automatically if the rated current of the equipment, cable or supply line is exceeded for a time which the equipment, cable or supply line is not designed to withstand;

(ii) earth fault or earth leakage protection to disconnect the supply automatically, if the earth fault current exceeds the limit of current for keeping the contact potential within the reasonable values;

(iii) buchholz relay, pressure relief device and winding and oil temperature protection with alarm and trip contacts shall be provided on all transformers of ratings 1 000 kVA and above;

(iv) transformers of capacity 10 MVA and above shall be protected against incipient faults by differential protection;

(v) all generators with rating of 100 kVA and above shall be protected against earth fault or leakage;

(vi) all generators of rating 1 000 kVA and above shall be protected against faults within the generator winding using restricted earth fault protection or differential protection or by both;

(vii) high speed busbar differential protection along with local breaker back up protection shall be commissioned and shall always be available at all 132 kV and above voltage substations and switching stations and generating stations connected with the grid:

Provided that in respect of existing 132 kV substations and switching stations having more than one incoming feeders, the high speed busbar differential protection along with local breaker back up protection, shall be commissioned and shall always be available; and

(viii) in addition to above, all electrical protection system for generating stations, substations and transmission lines shall be as per the regulations notified by the Authority under clause (e) of sub-section (2) of section 177 of the Act.

Regulation 48, Testing, operation and maintenance

(1) Before the approval is accorded by the Electrical Inspector under regulation 45, the manufacturer's test certificates shall, if required, be produced for all the type, acceptance and routine tests as required under the relevant standards.

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(2) No new apparatus, cable or supply line of voltage exceeding 650 V shall be commissioned unless such apparatus, cable or supply line are subjected to site tests as per relevant standards.

(3) No apparatus, cable or supply line of voltage exceeding 650 V which has been kept disconnected for a period of six months or more from the system for alterations or repair, shall be connected to the system until such apparatus, cable or supply line are subjected to the site tests as per relevant standards.

(4) Notwithstanding the provisions of this regulation, the Electrical Inspector may require certain tests to be carried out before or after charging the installations.

(5) All apparatus, cables and supply lines shall be maintained in healthy conditions and tests shall be carried out periodically as per the relevant standards.

(6) Records of all tests, trippings, maintenance works and repairs of all apparatus, cables and supply lines shall be duly kept in such a way that these records can be compared with the past records.

(7) It shall be the responsibility of the owner of all installations of voltage exceeding 650 V to maintain and operate the installations in a condition free from danger and as recommended by the manufacturer or by the relevant standards.

(8) Failures of any 220 kV and above voltage level transformer, reactor and transmission line towers shall be reported by the owner of electrical installation, within forty eight hours of the occurrence of the failure, to the Authority and the reasons for failure and measures to be taken to avoid recurrence of failure shall be sent to the Authority within one month of the occurrence in the forms provided in Schedule VII:

Provided that in case of mines and oil-fields, the failure of 10 MVA or above transformers shall be reported to Electrical Inspector of mines.

Regulation 50, Connection with earth for apparatus exceeding 650 volts

(1) The entire switchyard or substation equipment and buildings including all non-current carrying metal parts associated with an installation shall be effectively earthed to an earthing system or mat which shall –

(i) limit the touch and step potential to tolerable values as per relevant standards;

(ii) limit the earth potential rise to tolerable values as per relevant standards, so as to prevent danger due to transfer of potential through ground, earth wires, cable sheath, fences, pipe lines or other such equipment; and

(iii) maintain the resistance of the earth connection to such a value as to make operation of the protective device effective.

(2) In the case of star connected system with earthed neutrals or delta connected system with earthed artificial neutral point:

(i) the neutral point of every generator and transformer shall be earthed by connecting it to the earthing system not by less than two separate and distinct connections:

Provided that the neutral point of a generator may be connected to the earthing system through an impedance to limit the fault current:

Provided further that in the case of multi-machine systems, neutral switching may be resorted to, for limiting the injurious effect of harmonic current circulation in the system;

(ii) the generator or transformer neutral shall be earthed through a suitable impedance where an appreciable harmonic current flowing in the neutral connection causes interference with the communication circuits; and

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(iii) in case of the delta connected system, the neutral point shall be obtained by the insertion of a earthing transformer and current limiting resistance or impedance wherever considered necessary at the commencement of such a system.

(3) In case of generating stations, substations and other installations of voltage exceeding 33 kV, the system neutral earthing and protective frame earthing may be, if system design so warrants, integrated into common earthing grid provided the resistance to earth of combined mat does not cause the step and touch potential to exceed the values as per relevant standards.

(4) Single phase systems of voltage exceeding 650 V shall be effectively earthed.

(5) In the case of a system comprising electric supply lines having concentric cables, the external conductor shall be connected with the earth.

(6) Where a supplier proposes to connect with earth an existing system for use at voltage exceeding 650 V which has not hitherto been so connected with earth, he shall give not less than fourteen days notice in writing together with particulars of the proposed connection with earth to the telegraph authority established under the *Indian Telegraph Act*, 1885 (13 of 1885).

(7) Where the earthing lead and earth connection are used only in connection with earthing guards laid under overhead lines of voltage exceeding 650 V but not exceeding 33 kV where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage protective device, the earth resistance shall not exceed 25 Ω and the project authorities shall obtain no objection certificate from Railway Authorities and Power and Telecommunication Coordination Committee before energisation of the facilities.

Every earthing system belonging to either the supplier or the consumer shall be tested for its resistance to earth on a dry day during dry season not less than once in a year and records of such tests shall be maintained and produced, if so required, before the Electrical Inspector.

Regulation 60, Clearance in air of the lowest conductor of overhead lines

(1) The minimum clearance above ground and across road surface of National Highway or Expressway or State Highway or other road or highest traction conductor of railway corridor or navigational or non-navigational river of the lowest conductor of an alternating current overhead line, including service lines, of nominal voltage shall have the values specified in Schedule VIII A.

(2) The minimum clearances regarding high voltage direct current line shall be as per Schedule VIII B.

(3) In case of Electric lines of 33 kV and below passing through the protected areas (National Parks, Wildlife Sanctuaries, Conservation Reserves, Community Reserves), Eco-sensitive zones around the protected areas and Wildlife Corridors, only underground cable shall be used.

(4) No tower footing or structure of an overhead line of voltage 33 kV or above or high voltage direct current, shall be closer than twenty five metre from the edge of the right of way of a Petroleum or Natural Gas pipeline.

(5) Wherever overhead line of voltage 33 kV or above or high voltage direct current intending to cross the right of way of a Petroleum or Natural Gas pipeline, the angle of crossing of the overhead line with respect to the pipelines shall preferably be at right angles and, in any case, the crossing angle shall not be less than seventy five degrees.

Regulation 62, Clearance from buildings of lines of voltage and service lines not exceeding 650 Volts

(1) An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

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(2) Where an overhead line of voltage not exceeding 650 V passes above or adjacent to or terminates on any building, the following minimum clearances from any accessible point, on the basis of maximum sag, shall be observed, namely–

(i) for any flat roof, open balcony, *verandah* roof and lean-to-roof:

(a) when the line passes above the building, a vertical clearance of 2.5 metre from the highest point; and

(b) when the line passes adjacent to the building, a horizontal clearance of 1.2 metre from the nearest point;

(ii) for pitched roof:

(a) when the line passes above the building, a vertical clearance of 2.5 metre immediately under the line; and

(b) when the line passes adjacent to the building, a horizontal clearance of 1.2 metre.

(3) Any conductor so situated as to have a clearance less than that specified in sub-regulation (2) shall be replaced with Aerial Bunched Cable and to be attached at suitable intervals to a bare earthed bearer wire having a breaking strength of not less than 350 kgf.

(4) The horizontal clearance shall be measured when the line is at a maximum deflection from the vertical due to wind pressure.

(5) The vertical and horizontal clearances shall be measured as per illustration provided in Schedule VIII C.

Explanation — For the purposes of this regulation, the expression 'building' shall be deemed to include any structure, whether permanent or temporary.

Regulation 63, Clearance from buildings of lines of voltage exceeding 650 V

(1) An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

(2) Where an overhead line of voltage exceeding 650 V passes above or adjacent to any building or part of a building it shall have on the basis of maximum sag a vertical clearance above the highest part of the building immediately under such line, of not less than:

(i)	for lines of voltage exceeding 650 Volts up to and including 33kV	-	3.7 m
(ii)	for lines of voltage exceeding 33 kV	-	3.7 m plus 0.30 m for every additional 33 kV or part thereof.

(3) The horizontal clearance between the nearest conductor and any part of such building shall, on the basis of maximum deflection due to wind pressure, be not less than:

(i)	for lines of voltage exceeding 650 V up to and including 11 kV	-	1.2 m
(ii)	for lines of voltage exceeding 11 kV and up to and including 33 kV	-	2.0 m
(iii)	for lines of voltage exceeding 33 kV	-	2.0 m plus 0.3 m for every additional 33 kV or part thereof.

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(4) For high voltage direct current systems, the vertical and horizontal clearances, on the basis of maximum deflection due to wind pressure, from buildings shall be maintained as below:

Sl No.	*High Voltage Direct Current*	*Vertical Clearance* m	*Horizontal Clearance* m
1.	100 kV	4.6	2.9
2.	200 kV	5.8	4.1
3.	300 kV	7.0	5.3
4.	400 kV	7.9	6.2
5.	500 kV	9.1	7.4
6.	600 kV	10.3	8.6
7.	800 kV	12.4	10.7

(5) The vertical and horizontal clearances shall be as measured as illustrated in Schedule VIII C.

Regulation 66, Transporting and storing of material near electric lines

(1) No rods, pipes or similar materials shall be taken below, or in the vicinity of any bare overhead conductors or lines:

Provided that if these materials contravene the Regulations 62 and 63, such materials shall be transported under the direct supervision of a person designated or appointed or engaged or permitted under these regulations.

(2) No rods, pipes or other similar materials shall be brought within the flash over distance of bare live conductors or overhead lines.

(3) No material or earth work or agricultural produce shall be dumped or stored, no trees grown below or in the vicinity of bare overhead conductors or lines in contravention to the Regulations 62 and 63.

(4) No flammable material shall be stored under the electric line.

(5) No fire shall be allowed below overhead lines and above the demarcated underground cables.

Regulation 67, General clearances

(1) For the purpose of computing the vertical clearance of an overhead line, the maximum sag of any conductor shall be calculated on the basis of the maximum sag in still air and the maximum temperature as specified under Regulation 59 and computing any horizontal clearance of an overhead line the maximum deflection of any conductor shall be calculated on the basis of the wind pressure specified under Regulation 59.

(2) No blasting for any purpose shall be done within three hundred metre from the boundary of a substation or from the electric supply lines of voltage exceeding 650 V or tower structure thereof without the written permission of the owner of such substation or electric supply lines or tower structures; and in case of mining lease hold area, without the written permission of the Electrical Inspector of mines.

(3) No cutting of soil within ten metre from the tower structure of 110 kV and above voltage level shall be permitted without the written permission of the owner of tower structure.

(4) No person shall construct brick kiln or other polluting units near the installations or transmission lines of 220 kV and above within a distance of 500 metre.

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Regulation 76, Safety and Protective Devices

(1) Every overhead line which is not being suspended from a dead bearer wire, not being covered with insulating material and not being a trolley-wire, is laid over any part of a street or other public place or in any factory or mine or on any consumer's premises shall be protected with earth guarding for rendering the line electrically harmless in case its conductor breaks.

(2) An Electrical Inspector may, by notice in writing, require the owner of any such overhead line, wherever it may be laid, to protect it in the manner specified in sub-regulation (1) of this regulation.

(3) To prevent bird dropping on the suspension insulator strings, suitable bird guards as per relevant standards, shall be provided on cross arms of suspension tower or suspension pole structures, over the suspension insulator strings.

Regulation 119, Additional safety requirements for renewable generating stations

The regulations under this chapter shall be applicable to renewable generating stations which shall be in addition to the regulations provided from chapter I to VII.

Regulation 121, Safety Requirements for Solar Installations

(1) The following general safety requirement for solar installations shall be ensured, namely –

(i) clear pathways of minimum seventy five centimetre in width with hand rails for roof access and emergency exit shall be provided for roof top system;

(ii) there shall be clear pathways, walkways between the rows or columns of solar panels which is necessary for cleaning and maintenance;

(iii) cables shall be laid in trenches for ground based photovoltaic installation;

(iv) ground mounted solar installations shall be protected by fencing or other means not less than 1.8 metre in height so as to prevent unauthorised entry;

(v) disconnection switches or circuit breakers provided in combiner boxes to disconnect the photovoltaic system from all other conductors of the system shall be located at a readily accessible location;

(vi) three phases on the alternating current side, and positive and negative conductor on the direct current side shall be marked and identified with different colours;

(vii) inverter unit for solar photovoltaics shall be installed in the periphery of the building and as near as the solar panel:

Provided that the direct current cable shall be ultraviolet protected or routed through ultraviolet protected pipe;

(viii) there shall be a manual disconnection switch to isolate the system from grid and shall be situated outside the alternating current combiner box; and

(ix) protection shall be deployed (for both input and output) on site for overload, surge current, surge voltage, short circuit, high temperature, over voltage, under voltage and over frequency, under frequency, reverse polarity and lightning.

(2) The following earthing requirements for solar installations shall be ensured, namely –

(i) solar earthing shall be as per the relevant standard;

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(ii) the frame of inverter cabinet shall be connected with the earthing bus bar through the earthing terminals using flexible braided copper wire;

(iii) all metal casing and shielding of the plant, each array structure of the photovoltaic yard, equipment, inverters and control systems shall be earthed through proper earthing;

(iv) earthing system shall connect all non-current carrying metal receptacles, electrical boxes, appliance frames, chasis and photovoltaic module mounting structures in one long run and the earth strips shall be interconnected by proper welding and shall not be bolted;

(v) there shall be adequate number of interconnected earth pits provided in each location and minimum required gap shall be provided in between earth pits as per relevant standard.

(3) The following protection, testing and interlocking requirement for solar installations shall be ensured; namely:

(i) the solar photovoltaic power plant shall be provided with lightning and over voltage protection by deploying required number of lightning arresters as per the relevant standards;

(ii) every combiner box shall be provided with suitable surge protective device with arc extinguishing capability as per the relevant standards to avoid any risk of fire;

(iii) the input circuits of combiner box shall be provided with over current protection as per the relevant standards;

(iv) the output circuits of combiner box shall be provided with isolation protection;

(v) earth fault protection and insulation monitoring for photovoltaic arrays and inverters shall be provided;

(vi) all photovoltaic modules safety qualification shall comply with relevant standards.

(4) *Requirement to prevent fire for solar installations* — A fire detection system and automatic fire suppression system shall comply with the relevant standards.

(5) *Additional safety requirements for floating solar photovoltaic energy installations* — Photovoltaic modules and associated structure of floating solar power plant shall comply with the relevant standards for tests such as salt mist, ammonia corrosion, environmental stress cracking of High Density Poly Ethylene, stress cracking resistance of High Density Poly Ethylene and standard test method for tensile properties of plastics.

Regulation 123, Additional safety requirements for electric vehicle charging station

The regulations under this chapter shall be applicable to electric vehicle charging stations which shall be in addition to the regulations provided from chapter I to VII.

Regulation 124, General safety requirements for electric vehicle charging station

(1) Electric vehicle charging stations shall be provided with separate protection against the overload of input supply and output supply as per relevant standards.

(2) Socket-outlet of supply of electric vehicle charging points shall be installed at least 800 millimetre above the finished ground level.

(3) A cord extension set or second supply lead shall not be used in addition to the supply lead for the connection of the electric vehicle to the charging point and shall not be used as a cord extension set.

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(4) No adaptor shall be used to connect a vehicle connector to a vehicle inlet.

(5) The distance between the charging point and the connection on the electric vehicle shall not be more than five metre during charging.

(6) The portable socket outlets shall not be permitted for electric vehicle charging.

(7) The lightning protection system shall be provided for the electric vehicle charging stations as per relevant standards.

(8) The electric vehicle charging station shall be equipped with a protective device against the uncontrolled reverse power flow from electric vehicle to the charging point.

(9) One second after disconnecting the electric vehicle from the supply mains, the voltage between accessible conductive parts or any accessible conductive part and earth shall be less than or equal to 42.4 Vpeak (30 Vrms), or 60 V DC, and the stored energy available shall be less than 20 J:

(10) Provided that, if the voltage is greater than 42.4 Vpeak (30 Vrms) or 60 V DC, or the energy is 20 J or more, a warning label shall be attached in a conspicuous position on the charging stations.

(11) A vehicle connector used for direct current charging shall be locked on the vehicle inlet if the voltage is higher than 60 V DC and in case of charging system malfunction, a means for safe disconnection shall be provided.

(12) The electric vehicle charging point shall disconnect supply of electricity to prevent overvoltage at the battery, if the output voltage exceeds maximum voltage limit permissible for the vehicle.

(13) The electric vehicle charging points shall not energise the charging cable when the vehicle connector is in unlock position.

(14) The electric vehicle connector shall not unlock if the voltage between the vehicle connector and the earth is more than 60 V.

(15) Safety clearance between the oil or gas dispenser and electric vehicle charging point shall be as per the order issued by the Authority.

(16) Only four core cable shall be used for charging points which require three phase power supply.

(17) Underground cables shall not cross the underground oil tank or oil pipeline.

(18) Underground cables through the charging area or vehicles passage shall be avoided and if provided shall be at a minimum depth of one metre from the finished ground surface.

Regulation 125, Earth Protection System for the Charging Station

(1) Each electric vehicle charging points shall be supplied individually by a dedicated sub-circuit protected by an overcurrent protective device complying with the relevant standards and the overcurrent protective device shall be part of a switchboard.

(2) Co-ordination of all protective devices in the charging stations shall be ensured.

(3) All electric vehicle charging stations shall be provided with an earth continuity monitoring system that disconnects the supply in the event of the earthing connection to the vehicle becomes ineffective.

(4) The charging lead shall be fitted with an earth-connected metal shielding and the cable insulation shall be wear resistant and maintain flexibility over the operating temperature range.

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(5) A protective earth conductor shall be provided to establish an equipotential connection between the earth terminal of the supply and the conductive parts of the vehicle which shall be as per the relevant standards.

Regulation 126, Requirement to Prevent Fire for Electric Vehicle Charging Station

(1) The enclosure of electric vehicle supply equipment shall be made of fire retardant material with self-extinguishing property and free from halogen.

(2) The fire detection, alarm and control system shall be provided as per relevant standards.

Regulation 127, Testing of Charging Station

The owner of the charging station shall ensure that the tests as specified in the manufacturer's instructions for the residual current devices and the charging station have been carried out.

Regulation 128, Maintenance of records

(1) The owner of the charging station shall keep records of design, construction and labelling to be compatible with a supply of standard voltage at a nominal frequency of 50 Hz of the charging station.

(2) The owner of the charging station shall keep records of the relevant test certificates as indicated in these regulations and as per the relevant standards.

(3) The owner of the charging station shall keep records of the results of every inspection, testing and periodic assessment and details of any issues observed during the assessment and any actions required to be taken in relation to those issues.

(4) The owner of the charging station shall retain a copy of all records, as specified in sub-regulation (1), (2) and (3) of above, either in hard form or in electronic form, for at least seven years and shall provide a copy of the records to the officials during the inspection.

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ANNEX C

[*Clauses* 4.2.1(ff), 4.2.2.2 *and* D-1 (Note)]

AREA REQUIRED FOR TRANSFORMER ROOM AND SUBSTATION FOR DIFFERENT CAPACITIES

C-1 The requirement for area for transformer room and substation for different capacities of transformers is given below for guidance:

Sl No.	*Capacity of Transformer*(*s*)	*Total Transformer Room Area*, *Min*	*Total Substation Area* (*Incoming*, *HV Panels*, *MV Panels*, *Transformer Roof but Without Generators*), *Min*	*Suggested Minimum Face Width*
	kVA	m^2	m^2	m
(1)	(2)	(3)	(4)	(5)
i)	1 × 160	14.0	90	9.0
ii)	2 × 160	28.0	118	13.5
iii)	1 × 250	15.0	91	9.0
iv)	2 × 250	30.0	121	13.5
v)	1 × 400	16.5	93	9.0
vi)	2 × 400	33.0	125	13.5
vii)	3 × 400	49.5	167	18.0
viii)	2 × 500	36.0	130	14.5
ix)	3 × 500	54.0	172	19.0
x)	2 × 630	36.0	132	14.5
xi)	3 × 630	54.0	176	19.0
xii)	2 × 800	39.0	135	14.5
xiii)	3 × 800	58.0	181	14.0
xiv)	2 × 1 000	39.0	149	14.5
xv)	3 × 1 000	58.0	197	19.0

NOTES

1 The areas given in respect of the different categories of rooms hold good, if they are provided with independent access doors in accordance with local regulations.

2 The minimum height of substation room/HV switch room/MV switch room shall be arrived at considering 1200 mm clearance requirement from top of the equipment to the below of the soffit of the beam. In case cable entry/exit is from above the equipment (transformer, HV switchgear, MV switchgear), height of substation room/HV switch room/MV switch room shall also take into account requirement of space for turning radius of cable above the equipment height

3 Additional space will be required in cases where the load requirement calls for redundancy for enhanced reliability through addition of switchgear, such as, bus couplers, etc.

4 For transformers of other capacity, it may lead to some minor changes in dimensioning.

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ANNEX D

(*Clauses* 3.5.2(h) *and* 4.3.2)

ADDITIONAL AREA REQUIRED FOR GENERATOR IN ELECTRIC SUBSTATION

D-1 The requirement of additional area for generator in electric substation for different capacities of generators is given in the table below for guidance.

NOTES

1 The space requirements vary for specific installations due to factors such as derating due to site conditions (temperature, altitude, etc); type of cooling (radiator, heat exchanger, cooling tower, etc); type of ventilation; noise suppression system and special characteristics of loads, if any.

2 If the generator is located away from the substation, then additional switchgear will be required, area requirement for which can be estimated from the norms given in Annex C.

3 The area requirement suggested below covers the space requirement for day-tank and not the space for the bulk fuel storage.

Sl No.	*Capacity*	*Area*	*Clear Height below the Soffit of the Beam*
	kVA	m^2	m
(1)	(2)	(3)	(4)
i)	25	56	3.6
ii)	48	56	3.6
iii)	100	65	3.6
iv)	150	72	3.6
v)	248	100	4.2
vi)	350	100	4.2
vii)	480	100	4.2
viii)	600	110	4.6
ix)	800	120	4.6
x)	1 010	120	6.5
xi)	1 250	120	6.5
xii)	1 600	150	6.5
xiii)	2 000	150	6.5

NOTE — The area and height required for generating set room given in the above table are for general guidance only and may be finally fixed according to actual requirements.

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ANNEX E

(*Clauses* 9.3.1 *and* 9.4)

CHECKLIST FOR INSPECTION, HANDING OVER AND COMMISSIONING OF VARIOUS EQUIPMENT OF SUBSTATION

E-1 Typical format for checklist for inspection, handing over and commissioning of HV cables is given below:

NOTE — Format given below covers a basic minimum check list; it should be augmented for specific and special cases. The checklist has to be repeated for each HV cable.

HV CABLE INSPECTION, HANDING OVER AND COMMISSIONING DETAILS

A. DETAILS OF WORK

1) Scope of works :
2) Handed over by :
3) Taken over by :
4) Date of commissioning :
5) Date of handing over :
6) Details of enclosures :

Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
i)	Quality check list		
ii)	Site test report		
iii)	As built GA drawing/layout		
iv)	Manufacturer's test certificates		
v)	Operation and maintenance manual		

Handed Over By

Authorized Signatory

Taken Over By

Authorized Signatory

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B. QUALITY CHECK LIST

Item: Installation of HV Cables				
Make:				
Sl No.	*Tests Parameters*	*Bench Mark*	*Actual Observations*	*Remark*
(1)	(2)	(3)	(4)	(5)
i)	Cable size			
ii)	Voltage grade			
iii)	Type of material			
iv)	Check for routing			
v)	Meggering using 2.5 kV insulation tester			
	R-Y			
	Y-B			
	B-R			
	R-E			
	Y-E			
	B-E			
vi)	Minimum width of trench			
vii)	Minimum depth of trench			
viii)	Hume pipes used			
ix)	Hume joints with collar properly aligned and packed with 75 mm of cement concrete			
x)	Cable laying with suitable rollers			
xi)	Bending radius			
xii)	Cable tagging			
xiii)	Hi-Pot test (18 kV)			
xiv)	Sealing of cable ends, if not being terminated immediately			
xv)	Trench closing			

C. HI-POT TEST REPORT

1) Date of testing:

2) Equipment details:

Cable details

Location :
Panel No. :
Size :

3) Insulation Resistance Test (Value in MΩ, using 5 kV Megger):

Reference	*Measured Values* MΩ	
	Before	After
R-E		
Y-E		
B-E		
R-Y		

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Y-B		
B-R		

4) Winding Resistance Test:

Applied Voltage kV	*Measured Current* mA
R = Y + B + E	
Y = B + R + E	
B = R + Y + E	

5) Remarks

E-2 Typical format for checklist for handing over and commissioning of HV panels is given below:

NOTE — Format given below covers a basic minimum check list; it should be augmented for specific and special cases. The checklist has to be repeated for each HV panel.

HV PANEL INSPECTION, HANDING OVER AND COMMISSIONING DETAILS

Project:

Owner:

Package:

Contractor:

A. HANDING OVER DETAILS

1) Scope of works :
2) Panel name and number :
3) Location :
4) Handed over by :
5) Taken over by :
6) Date of commissioning :
7) Date of handing over :
8) Details of enclosures :

Sl No.	Description	Applicable	Not Applicable
(1)	(2)	(3)	(4)
i)	Quality check list		
ii)	Site test report		
iii)	As built GA drawing/layout		
iv)	Manufacturer's test certificates		
v)	Operation and maintenance manual		

Handed Over By Taken Over By

Authorized Signatory Authorized Signatory

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B. QUALITY CHECK LIST

Item: HV panel
Make:
Relevant Indian Standard:
As-built Drawing No:

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observations*
(1)	(2)	(3)	(4)
	Physical Checks for:		
	Circuit Breaker		
i)	Dimension enclosure		
ii)	Gauge		
iii)	Paint		
iv)	Degree of protection		
v)	Front doors		
vi)	Back cover		
vii)	Extension type enclosure		
viii)	Type of circuit breaker		
ix)	Number of circuit breakers		
x)	Type of surge arresting device included in the circuit breakers		
xi)	Earthing terminal		
xii)	Front plate with view glass		
xiii)	Space for mounting of current transformers		
xiv)	Space for mounting of potential transformers		
xv)	Cable entry		
xvi)	Interlocking with isolator		
xvii)	Earthing switch for cable in cable chamber		
xviii)	Earthing switch interlock with circuit breaker only it can be operated in ‘OFF’ condition		
xv)	Low voltage plug and socket		
xvi)	Vents for breaker/busbar/cable chambers		
xvii)	Insulation level		
xviii)	Toggle switch		
xix)	Ammeter selector switch		
xx)	Voltmeter selector switch		
xxi)	Trip/Neutral/Close		
xxii)	Local/remote selector switch		
xxiii)	LED lamps		
xxiv)	Mechanical operation		
xxv)	Remote operation		
xxvi)	Local operation		
xxvii)	Interlocking with isolator		
	Meters		
xxviii)	Voltmeter		

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Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observations*
(1)	(2)	(3)	(4)
xxix)	Ammeter		
xxx)	Tri vector meter		
xxxi)	Power factor meter		
xxxii)	Frequency meter		
	Specification Checks for		
xxxiii)	Rated current		
xxxiv)	Rated voltage		
xxxv)	Rated short circuit breaking capacity		
xxxvi)	Contact resistance		
xxxvii)	Control wiring		
xxxviii)	All control circuits Alarm and trip for OTI/WTI/Buchholz/ PRV		
xxxix)	SF6 pressure alarm and trip operation test		

C. COMMISSIONING REPORT

Customer:	
Project:	
Contractor:	
Panel Name:	
Location:	
Breaker Details:	

INSULATION TEST (MΩ)

R-Y	Y-B	B-R	R-E	Y-E	B-E	R-N	Y-N	B-N

RELAY SETTINGS

Overcurrent, Earth Fault and Undervoltage Relay	
CT ratio: Earth fault >Settings: I_o> Settings: Under voltage relay:	

GENERAL CHECKS

Breaker ‘ON’/‘OFF’	
Meters reading	
Indicating lamps	
Control supply	

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E-3 Typical format for checklist for handing over and commissioning of transformers is given below:

NOTE — Format given below covers a basic minimum check list; it should be augmented for specific and special cases. The checklist has to be repeated for each transformer.

TRANSFORMER INSPECTION, HANDING OVER AND COMMISIONING DETAILS

Project:

Owner:

Package:

Contractor:

A. HANDING OVER DETAILS

1) Scope of works :
2) Transformer No. :
3) Location :
4) Handed over by :
5) Taken over by :
6) Date of commissioning :
7) Date of handing over :
8) Details of enclosures :

Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
i)	Quality check list		
ii)	Site test report		
iii)	As built GA drawing/layout		
iv)	Manufacturer's test certificates		
v)	Operation and maintenance manual		

Handed Over By

Authorized Signatory

Taken Over By

Authorized Signatory

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B. QUALITY CHECK LIST

Item: Transformer
Make:
Relevant Indian Standard:
As-built Drawing No:

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
a)	*Physical Checks for:*		
	i) Transformer Sl No.		
	ii) Dimension of enclosure		
	iii) Enclosure – Degree of protection		
	iv) Gauge		
	v) Paint		
	vi) Provision for lifts and jacking		
	vii) Wheels		
	viii) Locking facility for wheel		
	ix) Enclosure door (if applicable)		
	x) Enclosure door interlock wiring		
	xi) Removable case for access of taps		
	xii) Earthing terminal		
	xiii) Disconnecting type chamber for cable termination		
	xiv) LT side flanges (Bus ducts/Cables/ Overhead)		
	xv) Oil temperature indicator (relay unit)		
	xvi) Winding temperature indicator (relay unit)		
	xvii) Marshalling box winding and door switch		
	xviii) Thermistors for alarm and trip		
	xix) Separate neutral earthing chamber		
	xx) Rating and diagram plate		
	xxi) Tap changing options name plate		
	xxii) Oil level in conservator tank		
	xxiii) Oil level in breather cup		
	xxiv) Operation of PRV		
	xxv) Oil leakage (if applicable)		
	xxvi) Clearances around transformer		
	xxvii) Body earthing resistance		
	xxviii) Neutral earthing resistance		
b)	*Specification checks for*:		
	i) Rating of transformer		
	ii) Type		
	iii) Winding conductor		
	iv) Primary voltage		
	v) HV winding connections		

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Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
	vi) Secondary voltage		
	vii) LV side connections		
	viii) Vector symbol		
	ix) System of supply		
	x) Impedance percentage		
	xi) Oil temperature rise		
	xii) Winding temperature rise		
	xiii) Tap changing		
	xiv) Tapping range		
	xv) Insulation type		
	xvi) Type of cooling		
	xvii) Vector group test		
	xviii) Polarity test		
	xix) Magnetizing test		
	xx) Tan delta test (as per capacity)		
	xxi) Breakdown voltage test: *Oil sample – I* (*Top*) *Oil sample – II* (*Bottom*)		

C. COMMISSIONING REPORT

Customer:	
Project:	
Contractor:	
Transformer Number:	
Location:	
Rating:	

INSULATION TEST (MΩ)

R-Y	Y-B	B-R	R-E	Y-E	B-E	R-N	Y-N	B-N

RELAY SETTINGS

Transformer Protection Relay (*WTI Scanner*): Winding temperature alarm set Winding temperature trip set (*OTI Scanner*): Oil temperature alarm set Oil temperature trip set	
Buchholz Relay	

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GENERAL CHECKS

Breaker 'ON'/'OFF'	
Meters reading	
Indicating lamps	
Control supply	

E-4 Typical format for checklist for handing over and commissioning of MV/LV panel is given below:

NOTE — Format given below covers a basic minimum check list; it should be augmented for specific and special cases. The checklist has to be repeated for each MV/LV panel.

MV/LV PANEL INSPECTION, HANDING OVER AND COMMISIONING DETAILS

Project:
Owner:
Package:
Contractor:

A. HANDING OVER DETAILS

1) Scope of works :
2) Panel name :
3) Location :
4) Handed over by :
5) Taken over by :
6) Date of commissioning :
7) Date of handing over :
8) Details of enclosures :

Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
i)	Quality check list		
ii)	Site test report		
iii)	As built GA drawing		
iv)	Manufacturer's test certificates		
v)	Operation and maintenance manual		

Handed Over By

Authorized Signatory

Taken Over By

Authorized Signatory

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B. QUALITY CHECK LIST

Item: MV/LV Panel
Make:
Relevant Indian Standard:
As-built Drawing No:

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
a)	*Physical Checks for:*		
	i) Dimension enclosure		
	ii) Paint		
	iii) Degree of protection		
	iv) Front doors		
	v) Back cover		
	vi) Earthing terminal		
	vii) Front plate with view glass		
	viii) Cable entry		
	ix) Indication lamps		
	x) Check for any damages		
	xi) Check for rubber beading for the panel sections		
	xii) Coupling of panel		
	xiii) Coupling of busbars		
	xiv) Coupling of earth bus		
	xv) Number of shipping sections		
	xvi) Fish plate tightening		
	xvii) Any damages in busbar supports		
	xviii) Make of MCCB		
b)	*Specification Checks for:*		
	i) Rated current		
	ii) Rated voltage		
	iii) Rated short circuit capacity		
c)	*Circuit Breaker*:		
	i) Current rating		
	ii) Interlocks with other CB/relay		
	iii) Compartment		
	iv) End terminals segregation		
d)	*Busbar*:		
	i) Earth busbar		
	ii) Main busbar		
	iii) Link busbar		
	iv) Busbar sleeve		
e)	3 *Phase – Potential transformer*:		
	i) Make		
	ii) Ratio		

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Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
	iii) Class		
	iv) Serial Nos.		
f)	*Current transformer*:		
	i) Make		
	ii) Ratio		
	iii) Class		
	iv) Serial No's		
g)	*Multi digital meter*:		
	i) Make		
	ii) Input voltage		
	iii) Input current		
	iv) Wiring		
	v) For potential transformer		
	vi) For current transformer		
	vii) Incomer		
	viii) Outgoing		

C. COMMISSIONING REPORT

Customer:	
Project:	
Contractor:	
Panel Name:	
Location:	
Breaker Details:	

INSULATION TEST (MΩ)

R-Y	Y-B	B-R	R-E	Y-E	B-E	R-N	Y-N	B-N

RELAY SETTINGS

GENERAL CHECKS

Breaker 'ON'/'OFF'	
Meters reading	
Indicating lamps	
Control supply	

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ANNEX F

(*Clause* 9.5)

FORM OF COMPLETION CERTIFICATE

I/ We certify that the installation detailed below has been installed by me/us and tested and that to the best of my/our knowledge and belief, it complies with *Central Electricity Authority* (*Measures Relating to Safety and Electricity Supply*) *Regulations*, 2023 as amended up-to-date and also the relevant provisions of Indian Standards and National Electrical Code of India, 20xx.

Electrical Installation at _____

A. INSTALLATION DATA

Voltage and system of supply _____

a) *Particulars of Works*:

1) Internal electrical installation:

Sl No.	*Description*	*No.*	*Total Load*	*Type of System of Wiring*
i)	Light point			
ii)	Fan point			
iii)	Plug point			
	3-pin 6 A			
	3-pin 16 A			
	5-pin 6 A			
	6-pin 16 A			

2) Others:

Sl No.	*Description*	*HP/kW*	*Type of Starting*
i)	Motors		
	1)		
	2)		
	3)		
ii)	Other plants		
	1)		
	2)		
	3)		

3) If the work involves installations of overhead line and/or underground cable:

i)	1) Type and description of over headline	
	2) Total length and No. of spans	
	3) No. of street lights and its description	
ii)	1) Total length of underground cable and its size	
	2) No. of joints:	
	End joint:	
	Tee joint:	
	Straight through joint:	

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b) *Earthing*:

i)	Description of earthing electrode	
ii)	No. of earth electrodes	
iii)	Size of main earth lead	
iv)	Earth electrode resistance	

The date on which the measurements for item (iv) was taken has to be recorded.

NOTE — The above data should be supported by an appropriate drawing and tables indicating the reference points at which the measurements were taken at the construction/installation stage.

B. PRE-COMMISSIONING TEST DATA

a) *Test Results*:

1) Appropriate drawings showing the points at which the measurements were taken should accompany this report.

2) Environmental notes pertaining to the day on which the tests are conducted:

i) Temperature:

ii) Date and time:

iii) Previous day/days history from the aspect of rain (in as much as it would affect the test results):

3) List of test instruments used:
(Please record the calibration certificate date, calibration authority and the validity date of each instrument listed.)

i) ----------

ii) ----------

4) Results:

i) Insulation resistance

a)	Insulation resistance of the whole system of conductors to earth	…… Megaohms
b)	Insulation resistance between the phase conductor and neutral:	
	Between phase R and neutral	…… Megaohms
	Between phase Y and neutral	…… Megaohms
	Between phase B and neutral	…… Megaohms
c)	Insulation resistance between the phase conductors in case of polyphase supply	
	Between phase R and phase Y	…… Megaohms
	Between phase Y and phase B	…… Megaohms
	Between phase B and phase R	…… Megaohms
d)	Insulation resistance between neutral conductor and earth in case of systems with neutral solidly earthed at the source	…… Megaohms

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ii) Polarity test:

Polarity of non-linked single pole branch switches:

iii) Earth continuity test:

Maximum resistance between any point in the earth continuity conductor including metal conduits and main earthing lead ……Ohms.

iv) Earth electrode resistance:

a) Resistance of each earth electrode:

1) …….. Ohms
2) …….. Ohms
3) …….. Ohms
4) …….. Ohms

b) Resistance of each earth grid:

1) …….. Ohms
2) …….. Ohms
3) …….. Ohms
4) …….. Ohms

v) Lightning protective system:

a)	Designed lightning protection level (LPL)	…..
b)	Total roof area (L X W)	….. m^2
c)	Air-termination mesh size (L X W)	….. m x m
d)	Number of vertical rods/terminal (Down-conductors)	…..
e)	Distance between down-conductors	….. m
f)	Impulse current rating of SPD, if any	…… kA
g)	Voltage protection level of incoming SPD	…….kV
h)	Resistance of down-conductor for reinforced concrete structure/PEB structures, if natural components are used as per NBCS (Part D/ Section 2) 'Building Services, Electrical and Allied Installations'	……. ohms
j)	Resistance of the whole of lightning protective system to earth before any bonding is effected with earth electrode and metal in/on the structure	……. ohms

Signature of Supervisor

Name and Address

Signature of Contractor

Name and Address

Persons witnessing the test:

Name	Designation/Address	Signature	Remarks
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ANNEX G

(*Clause* 3.5)

DECLARATIONS

G-1 DECLARATION FOR DESIGN

I/We being the person(s) responsible for the design of the electrical installation (as indicated by my/our signatures below), particulars of which are described below, having exercised reasonable skill and care when carrying out the design, hereby DECLARE that the design work for which I/we have been responsible is to the best of my/our knowledge and belief conform to the *CEA* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 and in accordance with the National Electrical Code of India, 20xx, National Building Construction Standards, 2026 and relevant standards of the products used and except for the departures, if any, detailed as follows:

Departures

Project/Site details

(Sign)
Electrical Consultant
Name and Address

(Sign)
Electrical Engineer on site

G-2 DECLARATION FOR CONSTRUCTION

I/We being the person(s) responsible for the construction of the electrical installation (as indicated by my/our signatures below), particulars of which are described below, having exercised reasonable skill and care when carrying out the construction, hereby DECLARE that the construction work for which I/we have been responsible is to the best of my/our knowledge and belief conform to the *CEA* (*Measures relating to Safety and Electric Supply*) *Regulations,* 2023 and in accordance with the relevant Indian Standards, National Electrical Code of India, 20xx, and National Building Construction Standards, 2026 and except for the departures, if any, detailed as follows:

Departures

Project/Site details

(Sign)
Electrical Contractor
Name and Address

(Sign)
Electrical Engineer on site

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G-3 DECLARATION FOR INSPECTION AND TESTING

I/We being the person(s) responsible for the inspection and testing of the electrical installation (as indicated by my/our signatures below), particulars of which are described below, having exercised reasonable skill and care when carrying out the inspection and testing, hereby DECLARE that the construction work for which I/we have been responsible is to the best of my/our knowledge and belief conform to the *CEA* (*Measures Relating to Safety and Electric Supply*) *Regulations*, 2023 and in accordance with the relevant Indian Standards, National Electrical Code of India, 20xx and National Building Construction Standards, 2026 and except for the departures, if any, detailed as follows:

Departures

Project/Site details

(Sign)
Electrical Safety Verifier
L. No./Registration No.
Name and Address

(Sign)
Electrical Engineer on site

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used for conformance with the requirements of the referred clauses in the NBCS.

In the following list, the number appearing in the first column within parenthesis indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	SP 30 : 2023	National Electrical Code of India, 2023 (*second revision*)
(2)	IS 8270 (Part 1) : 2023/ IEC 61082-1 : 2014	Preparation of documents used in electrotechnology: Part 1 Rules (*first revision*)
	IS 1885 (Part 16) : 2023/ IEC 60050-845 : 2020	Electrotechnical — Vocabulary: Part 16 Lighting
	IS 1885	Electrotechnical vocabulary:
	(Part 17) : 2024/ IEC 60050-441 : 1984	Switchgear and control gear (*second revision*)
	(Part 32) : 2019/ IEC 60050-461 : 2008	Electrical cables (*second revision*)
	(Part 78) : 1993/ IEC Pub 50 (601) : 1985	Generation, transmission and distribution of electricity — General
	IS 19127 : 2025/ IEC 60617 : 2024	Graphical symbols for diagrams in the field of electrotechnology
(3)	IS 17505 (Part 1) : 2021	Specification for thermosetting insulated fire survival cables for fixed installation having low emission of smoke and corrosive gases when affected by fire for working voltages upto and including 1 100 V a.c. and 1500 V d.c.: Part 1 Requirements for armoured cables
(4)	IS 694 : 2010	Polyvinyl chloride insulated unsheathed and sheathed cables/cords with rigid and flexible conductor for rated voltages up to and including 1 100 V (*fourth revision*)
(5)	IS 17048 : 2018	Halogen free flame retardant (HFFR) cables for working voltages up to and including 1 100 volts — Specification
(6)	IS/IEC 61537 : 2006	Cable management — Cable tray systems and cable ladder systems
(7)	IS/IEC 62271-202 : 2022	High-voltage switchgear and controlgear: Part 202 a.c. prefabricated substations for rated voltages above 1 kV and up to and including 52 kV (*first revision*)
(8)	IS/IEC 60947-1 : 2020	Low-voltage switchgear and controlgear: Part 1 General rules (*second revision*)
	IS/IEC 60947-2 : 20xx	Low-voltage switchgear and controlgear: Part 2 Circuit-breakers (*under publication*)

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	IS/IEC 60947-3 : 2020	Low-voltage switchgear and controlgear: Part 3 Switches, disconnectors, switch-disconnectors and fuse-combination units (*second revision*)
	IS/IEC 60947-4-1 : 2023	Low-voltage switchgear and controlgear: Part 4 Contractors and motor-starters, Section 1 Electromechanical contactors and motors-starters (*third revision*)
	IS/IEC 60947-4-2 : 2020	Low-voltage switchgear and controlgear: Part 4 Contractors and motor-starters, Section 2 Semiconductor motor controllers, starters and soft-starters (*second revision*)
	IS/IEC 60947-4-3 : 2020	Low-voltage switchgear and controlgear: Part 4 Contactors and motor-starters, Section 3 Semiconductor controllers and semiconductor contactors for non-motor loads (*third revision*)
	IS/IEC 60947-5-1 : 2016	Low-voltage switchgear and controlgear: Part 5 Control circuit devices and switching elements, Section 1 Electromechanical control circuit devices (*second revision*)
	IS/IEC 60947-5-2 : 2019	Low-voltage switchgear and control gear: Part 5 Control circuit devices and switching elements, Section 2 Proximity switches (*first revision*)
(9)	IS/IEC 60309-1 : 2021	Plugs, fixed or portable socket-outlet and appliance inlets for industrial purposes: Part 1 General requirements (*second revision*)
	IS/IEC 60309-2 : 2021	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes: Part 2 Dimensional compatibility requirements for pin and contact-tube accessories (*second revision*)
(10)	IS 17050 : 2023/ IEC 62262 : 2021 +AMD1 2021	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code) (*first revision*)
(11)	IS 3043 : 2018	Code of practice for earthing (*second revision*)
(12)	IS 17036 : 2018	Distribution system supply voltage quality
(13)	IS 18732 : 2023	Guide for implementation of electrical installation standards in building
(14)	IS 7752 (Part 1) : 1975	Guide for improvement of power factor in consumers' installation: Part 1 Low and medium supply voltages
(15)	IS 5216	Recommendations on safety procedures and practices in electrical work:
	(Part 1) : 1982	General (*first revision*)
	(Part 2) : 1982	Life saving techniques (*first revision*)
(16)	IS 10028 (Part 2) : 1981	Code of practice for selection, installation and maintenance of transformers: Part 2 Installation

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(17)	IS 10118 (Part 3) : 1982	Code of practice for selection, installation and maintenance of switchgear and controlgear: Part 3 Installation
(18)	IS 732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
(19)	IS 16996 : 2018/ IEC 60364-8-1 : 2014	Low-voltage electrical installations — Energy efficiency
(20)	IS 10118 (Part 2) : 1982	Code of practice for the selection, installation and maintenance of switchgear and controlgear: Part 2 Selection
(21)	IS 1646 : 2015	Fire safety of buildings (general): Electrical installations — Code of practice (*third revision*)
(22)	IS/IEC 61439 – All parts/ Sections	Low-voltage switchgear and controlgear assemblies — All parts/Sections
(23)	IS 1255 : 1983	Code of practice for installation and maintenance of power cables (up to and including 33 kV rating) (*second revision*)
(24)	IS 8084 : 2025	Interconnecting bus-bars for a.c. voltage above 1 kV up to and including 36 kV — Specification (*first revision*)
(25)	IS 1180 (Part 1) : 2014	Outdoor type oil immersed distribution transformers upto and including 2 500 kVA, 33kV — Specification: Part 1 Mineral oil immersed (*fourth revision*)
	IS 2026	Power transformers:
	(Part 1) : 2011	General (*second revision*)
	(Part 2) : 2010	Temperature-rise (*first revision*)
	(Part 3) : 2018/ IEC 60076-3 : 2000	Insulation levels, dielectric tests and external clearances in air (*fourth revision*)
	IS 2026 (Part 4) : 1977	Specification for power transformers: Part 4 Terminal marking, tappings and connections (*first revision*)
	IS 2026	Power transformers:
	(Part 5) : 2011	Ability to withstand short circuit (*first revision*)
	(Part 7) : 2009/ IEC 60076-7 : 2005	Loading guide for oil-immersed power transformers
	(Part 8) : 2009/ IEC 60076-8 : 1997	Applications guide
	(Part 10) : 2025/ IEC 60076-10 : 2016	Determination of sound levels (*first revision*)
	(Part 11) : 2021 IEC 60076-11 : 2018	Dry-type transformers
(26)	IS/IEC 61439-2 : 2020	Low-voltage switchgear and controlgear assemblies: Part 2 Power switchgear and controlgear assemblies (*first revision*)

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	IS/IEC 60947-1 : 2020	Low-voltage switchgear and controlgear: Part 1 General rules (*second revision*)
	IS/IEC 60947-2 : 20xx	Low-voltage switchgear and controlgear: Part 2 Circuit-breakers (*under publication*)
	IS/IEC 60947-3 : 2020	Low-voltage switchgear and controlgear: Part 3 Switches, disconnectors, switch-disconnectors and fuse combination units (*second revision*)
	IS/IEC 60947-4-1 : 2018	Low-voltage switchgear and controlgear: Part 4 Contractors and motor-starters, Section 1 Electromechanical contactors and motors-starters (*second revision*)
	IS/IEC 60947-4-2 : 2020	Low-voltage switchgear and controlgear: Part 4 Contractors and motor-starters, Section 2 Semiconductor motor controllers starters and soft-starters (*second revision*)
	IS/IEC 60947-4-3 : 2020	Low-voltage switchgear and controlgear: Part 4 Contractors and motor-starters, Section 3 Semiconductor controllers and Semiconductor contactors for non-motor loads (*third revision*)
	IS/IEC 60947-5-1 : 2024	Low-voltage switchgear and controlgear: Part 5 Control circuit devices and switching elements, Section 1 Electromechanical control circuit devices (*third revision*)
	IS/IEC 60947-5-2 : 2019	Low-voltage switchgear and control gear: Part 5 Control circuit devices and switching elements, Section 2 Proximity switches (*first revision*)
	IS/IEC 61439 (Part 0) : 2014	Low-voltage switchgear and controlgear assemblies: Part 0 Guidance to specifying assemblies
	IS/IEC 61439-1 : 2020	Low-voltage switchgear and controlgear assemblies: Part 1 General rules (*first revision*)
(27)	IS 11353 : 2023/ IEC 60445 : 2021	Basic and safety principles for man-machine interface, marking and identification — Identification of equipment terminals, conductor terminations and conductors (*first revision*)
(28)	IS/IEC 61439-6 : 2012	Low-Voltage switchgear and controlgear assemblies Part 6 Busbar trunking systems (Busways)
(29)	IS 13010 : 2002	ac watthour meters, class 0.5, 1 and 2 — Specification (*first revision*)
	IS 13779 : 2020	a.c. static watthour meters, class 1 and 2 — Specification (*second revision*)
	IS 14697 : 2021	a.c. static transformer operated watthour meters (class 0.2 s and 0.5 s) and var-hour meters (class 0.2 s, 0.5 s and 1 s) — Specification (*first revision*)
	IS 15884 : 2024	Alternating current direct connected static prepayment meters for active energy (class 1 and class 2) — Specification (*first revision*)
	IS 16444 : 2015	a.c. static direct connected watthour smart meter class 1 and 2 — Specification

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(30)	IS 15707 : 2006	Testing, evaluation, installation and maintenance of ac electricity meters — Code of practice
(31)	IS/IEC 60079-1 : 2014	Explosive atmospheres: Part 1 Equipment protection by flameproof enclosures “d” (*first revision*)
(32)	IS 5578 : 1984	Guide for marking of insulated conductors (*first revision*)
	IS 11353 : 2023/ IEC 60445 : 2021	Basic and safety principles for man-machine interface, marking and identification — Identification of equipment terminals, conductor terminations and conductors (*first revision*)
(33)	IS/IEC 60309-1 : 2021	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes: Part 1 General requirements (*second revision*)
	IS/IEC 60309-2 : 2021	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes: Part 2 Dimensional compatibility requirements for pin and contact-tube accessories (*second revision*)
(34)	IS/IEC 60079 (Part 1) : 2014	Explosive Atmospheres: Part 1 Equipment Protection by Flameproof Enclosures "d"
	IS 10322 (Part 5/Sec 5) : 2026/IEC 60598-2-5 : 2015	Luminaires: Part 5 Particular requirements, Section 5 Flood lights (*second revision*)
(35)	IS 12640 (Part 1) : 2024/ IEC 61008-1 : 2013	Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs): Part 1 General rules (*third revision*)
	IS 12640 (Part 2) : 2016/ IEC 61009-1 : 2012	Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs): Part 2 General rules (*second revision*)
	IS 14614 : 2023/ IEC 61543 : 2022	Residual current-operated protective devices (RCDs) for household and similar use — Electromagnetic compatibility (*first revision*)
	IS/IEC 60898-1 : 2015	Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations: Part 1 Circuit-breakers for a.c. operation (*first revision*)
	IS/IEC 60947-1 : 2020	Low-voltage switchgear and controlgear: Part 1 General rules (*second revision*)
	IS/IEC 60947-2 : 20xx	Low-voltage switchgear and controlgear: Part 2 Circuit-breakers (*under publication*)
	IS/IEC 60947-3 : 2020	Low-voltage switchgear and controlgear: Part 3 Switches, disconnectors, switch-disconnectors and fuse combination units (*second revision*)
	IS/IEC 60947-4-1 : 2023	Low-voltage switchgear and controlgear: Part 4 Contractors and motor-starters, Section 1 Electromechanical contactors and motors-starters (*third revision*)
	IS/IEC 60947-4-2 : 2020	Low-voltage switchgear and controlgear: Part 4 Contractors and motor-starters, Section 2 Semiconductor motor controllers starters and soft starters (*second revision*)

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	IS/IEC 60947-4-3 : 2020	Low-voltage switchgear and controlgear: Part 4 Contractors and motor-starters, Section 3 Semiconductor controllers and semiconductor contactors for non-motor loads (*third revision*)
	IS/IEC 60947-5-1 : 2024	Low-voltage switchgear and controlgear: Part 5 Control circuit devices and switching elements, Section 1 Electromechanical control circuit devices (*third revision*)
	IS/IEC 60947-5-2 : 2019	Low-voltage switchgear and control gear: Part 5 Control circuit devices and switching elements, Section 2 Proximity switches (*first revision*)
(36)	IS/lEC 60529 : 2001	Degrees of protection provided by enclosures (IP code)
	IS 17050 : 2023 IEC 62262 : 2021 +AMD1 2021	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK Code) (*first revision*)
(37)	IS 3961	Recommended current ratings for cables:
	(Part 2) : 2017	PVC insulated and PVC sheathed heavy duty cables (*first revision*)
	(Part 3) : 1968	Rubber insulated cables
	(Part 5) : 1968	PVC insulated light duty cables
	(Part 6) : 2016	Crosslinked polyethylene insulated PVC sheathed cables
(38)	SP 72 : 2025	National Lighting Code of India 2025 (*first revision*)
(39)	IS 4648 : 1968	Guide for electrical layout in residential buildings
(40)	IS 900 : 2019	Code of practice for storage, installation and maintenance of induction motors (*third revision*)
(41)	IS 9537	Specification for conduits for electrical installations:
	(Part 1) : 1980	General requirements
	(Part 2) : 1981	Rigid steel conduits
	(Part 3) : 1983	Rigid plain conduits of insulating materials
(42)	IS 16205	Conduit systems for cable management:
	(Part 1) : 2017	General requirements
	(Part 24) : 2017	Particular requirements — conduit systems buried underground
(43)	IS 14297 : 2024/ ISO 9226 : 2012	Corrosion of metals and alloys — Corrosivity of atmospheres — Determination of corrosion rate of standard specimens for the evaluation of corrosivity (*first revision*)
(44)	IS/IEC 61537 : 2006	Cable management — Cable tray systems and cable ladder systems
(45)	IS 9537	Specification for conduits for electrical installations:

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	(Part 1) : 1980	General requirements
	(Part 3) : 1983	Rigid plain conduits of insulating materials
(46)	IS 9537	Specification for conduits for electrical installations:
	(Part 1) : 1980	General requirements
	(Part 2) : 1981	Rigid steel conduits
(47)	IS 3837 : 1976	Specification for accessories for rigid steel conduits for electrical wiring (*first revision*)
	IS 14768	Conduit fittings for electrical installations — Specification:
	(Part 1) : 2000	General requirements
	(Part 2) : 2003	Metal conduit fittings
	IS 14772 : 2020	Boxes and enclosures for electrical accessories for household and similar fixed electrical installations — General requirements (*first revision*)
(48)	IS 3419 : 1988	Specification for fittings for rigid non-metallic conduits (*second revision*)
	IS 14772 : 2020	Boxes and enclosures for electrical accessories for household and similar fixed electrical installations — General requirements (*first revision*)
(49)	IS 18925 (Part 7) : 2025/ IEC 62561-7 : 2024	Lightning protection system components (LPSC): Part 7 Requirements for earthing enhancing compounds
(50)	IS 18925 (Part 5) : 2025/ IEC 62561-5 : 2023	Lightning protection system components (LPSC): Part 5 Requirements for earth electrode inspection housings and earth electrode seals
(51)	IS 18925 (Part 1) : 2025/ IEC 62561-1 : 2023	Lightning protection system components (LPSC): Part 1 Requirements for connection components
(52)	IS/IEC 62305-1 : 2010	Protection against lightning: Part 1 General principles
	IS/IEC 62305-2 : 2010	Protection against lightning: Part 2 Risk management
	IS/IEC 62305-3 : 2010	Protection against lightning: Part 3 Physical damage to structures and life hazard
	IS/IEC 62305-4 : 2010	Protection against lightning: Part 4 Electrical and electronic systems within structures
(53)	IS 16242	Uninterruptible power systems (UPS):
	(Part 1) : 2025/ IEC 62040-1 : 2017 + AMD1 : 2021 + AMD2 : 2022 CSV	Safety requirements (*first revision*)

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	(Part 2) : 2020/ IEC 62040-2 : 2016	Electromagnetic compatibility EMC requirements (*first revision*)
	(Part 3) : 2025/ IEC 62040-3 : 2021	Method of specifying the performance and test requirements *(first revision*)
	(Part 5/Sec 3) : 2025/ IEC 62040-5-3 : 2016	d.c. output UPS, Section 3 Performance and test requirements
(54)	IS 17017 — All parts/sections	Specification for electric vehicle conductive charging system — All parts/sections
(55)	IS 17896 (Part 1) : 2022/ IEC TS 62840-1 : 2016	Electric vehicle battery swap system: Part 1 General and guidance
	IS 17896 (Part 2) : 2022/ IEC 62840-2 : 2016	Electric vehicle battery swap system: Part 2 Safety requirements
(56)	IS 17017 (Part 23) : 2021	Electric vehicle conductive charging systems: Part 23 d.c. electric vehicle supply equipment
(57)	IS 17017 (Part 24) : 2021	Electric vehicle conductive charging system: Part 24 Digital communication between a DC electric vehicle supply equipment and an electric vehicle for control of DC charging
(58)	IS/ISO 15118 — All parts/sections	Road vehicles — Vehicle to grid communication interface — All parts/sections
(59)	IS 17017 (Part 2/Sec 3) : 2020	Electric vehicle conductive charging system: Part 2 Plugs, socket — outlets, vehicle connectors and vehicle inlets, Section 3 Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers
(60)	IS 14286 : 2023 IEC 61215 : 2021 — All parts/sections	Terrestrial photovoltaic (PV) modules — Design qualification and type approval — All parts/sections
	IS 16228 : 2024/ IEC 62108 : 2022	Concentrator photovoltaic (CPV) modules and assemblies — Design qualification and type approval (*second revision*)
	IS 17210 (Part 1) : 2019/ IEC TS 62804-1 : 2015	Photovoltaic (PV) modules — Test methods for the detection of potential-induced degradation: Part 1 Crystalline silicon
	IS 16664 : 2018/ IEC 62716 : 2013	Photovoltaic (PV) modules — Ammonia corrosion testing
	IS/IEC 61730 — All parts	Photovoltaic (PV) module safety qualification — All parts
	IS/IEC 61701 : 2011	Salt mist corrosion testing of photovoltaic (PV) modules
(61)	IS 14286 : 2023 IEC 61215 : 2021 — All parts/sections	Terrestrial photovoltaic PV modules design qualification and type approval — All parts/sections
	IS 16170 (Part 1) : 2014/ IEC 61853-1 : 2011	Photovoltaic (PV) module performance testing and energy rating: Part 1 Irradiance and temperature performance measurements and power rating

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	IS/IEC 61730 — All parts/sections	Photovoltaic (PV) module safety qualification — All parts/sections
	IS 17210 (Part 1) : 2019/ IEC TS 62804-1 : 2015	Photovoltaic (PV) modules — Test methods for the detection of potential-induced degradation: Part 1 Crystalline silicon
(62)	IS 2062 : 2011	Hot rolled medium and high tensile structural steel — Specification (*seventh revision*)
	IS 4759 : 1996	Hot-dip zinc coatings on structural steel and other allied products — Specification (*third revision*)
(63)	IS 2062 : 2011	Hot rolled medium and high tensile structural steel — Specification (*seventh revision*)
	IS 1079 : 2017	Hot rolled carbon steel sheet, plate and strip — Specification (*seventh revision*)
	IS 1161 : 2014	Steel tubes for structural purposes — Specification (*fifth revision*)
	IS 1239 (Part 1) : 2004	Steel tubes, tubulars and other wrought steel fittings — Specification: Part 1 Steel tubes (*sixth revision*)
(64)	IS/IEC 61683 : 1999	Photovoltaic systems — Power conditioners — Procedure for measuring efficiency
	IS/IEC 60068-2-1 : 2007	Environmental testing: Part 2 Tests, Section 1 Test A: Cold
	IS 16169 : 2019/ IEC 62116 : 2014	Utility-interconnected photovoltaic inverters — Test procedure of islanding prevention measures (*first revision*)
	IS/IEC 60068-2-2 : 2007	Environmental testing: Part 2 Tests, Section 2 Test B dry heat
	IS/IEC 60068-2-14 : 2023	Environmental testing: Part 2 Tests, Section 14 Test N: Change of temperature (*first revision*)
	IS/IEC 60068-2-30 : 2005	Environmental testing: Part 2 Tests, Section 30 Test Db: Damp heat cyclic (12 h + 12 h cycle)
	IS 14700 — All parts	Electromagnetic compatibility (EMC) — All parts
	IS 16221 (Part 2) : 2015/ IEC 62109-2 : 2011	Safety of power converters for use in photovoltaic power systems: Part 2 Particular requirements for inverters
(65)	IS 16221 (Part 2) : 2015/ IEC 62109-2 : 2011	Safety of power converters for use in photovoltaic power systems: Part 2 particular requirements for inverters
(66)	IS 17293 : 2020	Electric cables for photovoltaic systems for rated voltage 1 500 V d.c.
(67)	IS 14286 (Part 1/Sec 1) : 2023/ IEC 61215-1-1 : 2021	Terrestrial photovoltaic (PV) modules — Design qualification and type approval: Part 1-1 Special requirements for testing of crystalline silicon photovoltaic (PV) modules *(third revision*)

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	IS/IEC 61730-1 : 2023	Photovoltaic (PV) module — Safety qualification: Part 1 Requirements for construction (*second revision*)
(68)	IS 12933	Solar flat plate collector — Specification:
	(Part 1) : 2025	Requirements (*third revision*)
	(Part 2) : 2025	Components (*third revision*)
	IS 16544 : 2016	All glass evacuated tubes solar water heating system
	IS 16542 : 2016	Direct insertion type storage water tank for all glass evacuated tubes solar collector — Specification
(69)	IS 12933	Solar flat plate collector — Specification:
	(Part 1) : 2025	Requirements (*third revision*)
	(Part 2) : 2025	Components (*third revision*)
(70)	IS 16544 : 2016	All glass evacuated tubes solar water heating system
(71)	IS 16542 : 2016	Direct insertion type storage water tank for all glass evacuated tubes solar collector — Specification
(72)	IS 302 (Part 2/Sec 76) : 1999	Safety of household and similar electrical appliances: Part 2 Particular requirements, Section 76 Electric fence energizers
(73)	IS/IEC 62305-3 : 2010	Protection against lightning: Part 3 Physical damage to structures and life hazard
(74)	IS/IEC 62305-4 : 2010	Protection against lightning: Part 4 Electrical and electronic systems within structures
(75)	IS/IEC 62305-1 : 2010	Protection against lightning: Part 1 General principles
(76)	IS/IEC 62305-2 : 2010	Protection against lightning: Part 2 Risk management
(77)	IS 16172 : 2023	Reinforcement couplers for mechanical splices of steel bars in concrete — Specification (*first revision*)
(78)	IS 18925 — All parts/sections	Lightning protection system components (LPSC) — All parts/sections
(79)	IS 12360 : 2026	Voltage bands for electrical installations including preferred voltage and frequency (*first revision*)
(80)	IS 15382 (Part 1) : 2022/ IEC 60664-1 : 2020	Insulation coordination for equipment within low-voltage systems: Part 1 Principles, requirements and tests (*second revision*)
(81)	IS 16463 (Part 11) : 2016/ IEC 61643-11 : 2011	Low-voltage surge protective devices: Part 11 Surge protective devices connected to low-voltage power systems — Requirements and test methods
(82)	IS/IEC 60479-1 : 2018	Effects of current on human beings and livestock: Part 1 General aspects

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 3 AIR CONDITIONING, HEATING AND MECHANICAL VENTILATION

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part D/Section 3) deals with the planning, selection, design considerations, and installation of air conditioning, heating and mechanical ventilation system for different types of building application and in towns and cities under all the climatic zones of India. It covers all aspects including the goals and objectives, basis of design, input parameters for design, guidelines for design of system, performance parameters, available system options, pre-planning considerations, range of equipment and system components, building management system, installation of the system, testing, commissioning and handing over and also operation and maintenance of the air conditioning, heating and mechanical ventilation system.

Indian construction industry is poised to add an-order-of-magnitude built foot-print in the coming years. With the advent of information technology and computers becoming part of our life-style, the requirement of air conditioning of built environment is being increasingly felt and met with. The challenge faced for this unprecedented development is the lack of material resources and natural resources like energy, water and clean air. Therefore, the selection of air conditioning and mechanical ventilation system, optimally suited for the specific type of building application and its climatic zone, becomes critical. It is necessary for the owner, designer, builder and developer to understand the provisions of this Section, and consult an air conditioning engineer at the planning stage.

Sustainable buildings movement in the country has gained tremendous momentum. The relevant 'Handbook on Sustainability in Buildings', deals with all aspects of sustainable buildings, from selection of site, building design, energy and water efficient systems, use of recycled material resources, construction, third party commissioning, operation and maintenance of sustainable buildings. By following the provisions of this Section in conjunction with those given in relevant 'Handbook on Sustainability in Buildings', India can successfully adopt sustainable buildings as the way of life, as has been the practice for centuries, prior to the onslaught of industrial revolution in India.

Computerized weather data is now available and has been included for around 145 locations across the country, covering all the five climatic zones. This data is based on the latest values obtained from India Metrological Department, Government of India.

This Section was first formulated in 1970 and was subsequently revised in 1983, 2005 and 2016 as a part of National Building Code of India. The major modifications made in 2005 version of this code included addition of several new terms and their definitions; incorporation of a new clause on design criteria; inclusion of 'indoor air quality' as one of the factors that needed to be controlled in the conditioned space; incorporation of recommendation for independent air handling unit rooms for each floor of large and multi storeyed buildings; inclusion of inside design conditions for various applications replacing earlier Table 2 and Table 3; revision of provisions on minimum outside fresh air in the light of the then accepted international norms thus covering a wider variety and a larger number of applications; addition of new details on temperature, humidity, vibration and noise; updation of provisions on application considerations, covering a wide variety of commercial applications, such as, offices, hotels, restaurants and computer rooms; inclusion of a new clause on statutory regulation/safety considerations; description of various system options available, under the clause on design considerations; updation of provisions on the characteristics and application of options available in piping, water distribution systems and piping layout; revision of provisions on air filters; revision of the clause on energy conservation and energy management to include concepts like energy targets, demand targets and consumption targets, the factors to be considered in system design that influence energy aspects, the need for analysis of operation of systems during various seasons of the year, and the need to incorporate energy recovery strategies. Apart from above, 'Automatic Controls' included in the 1983 version was replaced by building management system, which addressed not only the control function, but also had a telling impact on operation and maintenance as well, most importantly on the opportunities afforded to implement various energy conservation strategies; provisions on packaged air conditioners and room air conditioners were elaborated; provisions on heating were revised; provisions on symbols, units, colour code and identification of services, pipe work services, duct work services, valve labels and charts, and also on inspection, commissioning and testing were updated; and list of various parameters to be checked for performance of air handling unit, hydronic system balancing, and finally, the hand-over procedure were included.

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The 2016 revision of this part introduced several important updates to align HVAC systems with modern needs and sustainable practices. It added new definitions to reflect emerging concepts and technologies and updated refrigerant guidelines to include eco-friendly options like zero-ozone-depleting and low-global-warming-potential refrigerants. Planning considerations were expanded to incorporate advanced systems such as VRF, district cooling, and hybrid central plants, supported by tools like energy modelling and solar shade analysis to optimize energy efficiency. The outdoor and indoor design conditions were updated using adaptive comfort standards and comprehensive weather data from across India. Key advancements in HVAC equipment included provisions for chilled beams, radiant floors, and geothermal systems were made. Specialized applications were addressed in greater detail, covering data centers, metro stations, and cold storage facilities critical for food security. Ventilation received a significant focus, emphasizing sustainability, demand control, and advanced fan designs. Installation practices were refined for ease of maintenance and better integration with building automation systems. The revision also standardized symbols and colour coding, introduced web-based monitoring for building management systems, and enhanced testing and commissioning protocols to ensure state-of-the-art performance.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

This revision of this Part D/ Section 3 of this NBCS focuses on improving air conditioning, heating, and ventilation systems for better efficiency and sustainability. New features include advanced refrigerants, geothermal systems, and tools for energy-saving designs. It also addresses specialized needs like data centres and metro stations. These changes help ensure better performance, lower energy use, and reduced environmental impact.

The significant changes incorporated in this revision include the following:

a) Additional details on systems like variable refrigerant flow (VRF) and inverter-based cooling for better efficiency, in **4.1.4**.

b) Added new eco-friendly refrigerants with no harm to the ozone layer and very low impact on global warming, in **5.3**.

c) Addition of modern low-energy heating and cooling solutions, including evaporative cooling, radiant cooling, and solar-assisted systems. Additionally, it provides improved guidelines for system selection, installation, and applications across residential, commercial, and industrial sectors, in **6**.

d) Inclusion of new methods for cooling and heating using the earth's natural temperature are included, in **6.4**.

e) Addition of efficient heating solutions like solar-powered systems and ground heat pumps for cold regions, in **6.5**.

f) Addition of guidelines for selecting air-conditioning and ventilation systems across various building typologies, including residential, commercial, and transport hubs, in **12**.

g) New guidelines for cold storage facilities to improve food preservation and reduce waste, in **13.2**.

h) Inclusion of enhanced guidelines for using automation systems to monitor and control building performance, in **15.2**.

j) Introduction of uniform standards for hydronic and refrigerant piping in HVAC systems to enhance performance covering material selection, sizing, installation, testing, and maintenance for efficient fluid transport, in **16**.

k) Inclusion of new procedures for testing and setting up HVAC systems to ensure they work efficiently, in **17**.

m) Introduction of comprehensive smoke mitigation guidelines for substructures, superstructures, and exit pathways, in **19.**

n) Terminology clause has been updated with new terms and definitions.

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The information contained in this section is based largely on the following Indian Standards:

IS 1391	Room air conditioners specification
(Part 1) : 2023	Unitary air conditioners (*fourth revision*)
(Part 2) : 2023	Split air conditioners (*fourth revision*)
IS 2379 : 2024	Colour code for pipeline identification — Code of practice (*second revision*)
IS 3315 : 2024	Direct evaporative air cooler — Specification (*fourth revision*)
IS 8148 : 2018	Ducted and package air-conditioners – Specification (*second revision*)
IS 7896 : 2023	Air conditioning outdoor design conditions data for Indian cities (*second revision*)

Assistance has also been derived from the following publications in the preparation of this Section:

Handbooks of Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE)

India Model for Adaptive Comfort, CEPT University, Ahmedabad

ISO 16484-1: 2024 Building automation and control systems (BACS) — Part 1: Project specification and implementation

The provisions on natural ventilation are given in Part D 'Building Services, Section 1 Lighting and Ventilation' of this NBCS.

The provisions of this Section are without prejudice to the various Acts, Rules and Regulations including *The Factories Act*, 1948 and the rules and regulations framed thereunder.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties using this Section are encouraged to investigate the possibility of applying the most recent edition of the standards.

As the regulation of land development and buildings is a state subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **"accepted standard"** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [D-3(1)] refers to the Indian Standard given at serial number (1) of the list of standards given at the end of this Section, that is, IS 3615 : 2020 'Glossary of terms used in refrigeration and air conditioning (*second revision*)'.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 3 AIR CONDITIONING, HEATING AND MECHANICAL VENTILATION

1 SCOPE

This NBCS (Part D/Section 3) covers the planning, design considerations, installation, testing, commissioning and handing over also operation and maintenance of air conditioning, heating and mechanical ventilation systems for buildings. It also covers refrigeration for cold storages.

The provisions of this Section aim to ensure an air conditioning, heating and mechanical ventilation system which shall provide comfort by managing air temperature, humidity, indoor air quality and distribution of conditioned air for the specific use and occupancy of built space while giving due consideration to minimizing energy consumption and other resources.

The provisions on natural ventilation are covered in Part D 'Building Services, Section 1 Lighting and Ventilation' of this NBCS.

The provisions in respect of air conditioning, heating and mechanical ventilation system in sustainable buildings are covered in relevant ‘Handbook on Sustainability in Buildings'.

2 TERMINOLOGY

For the purpose of this Section the following definitions shall apply in addition to those given in the accepted standard [D-3(1)] and the following shall apply.

2.1 Air Conditioning — The process of treating air so as to control simultaneously its temperature, humidity, purity, distribution and movement and pressure to meet the requirements of the conditioned space.

2.2 Air System Balancing — Adjusting air flow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitter vanes, extractors, etc, or by using automatic control devices, such as constant-air-volume or variable-air-volume (VAV) boxes.

NOTE — Air system should be balanced in order to minimize throttling losses. For fans, its speed should be adjusted to meet design flow conditions. By creating correct air flow at fans and outlet, system performance shall be increased.

2.3 Atmospheric Pressure — The force per unit area exerted against a surface by the weight of the air above that surface. It is the pressure indicated by a barometer. Standard atmospheric pressure or standard atmosphere or barometric pressure is the pressure of 760 mm of mercury column having a density of 13 600 kg/m^3 under standard gravity of 9.8 m/sec^2 (10.332 mm of water column/101.325 kPa).

NOTE — Generally atmospheric pressure is used as a datum for indicating the system pressures in air conditioning and accordingly, pressures are mentioned above the atmospheric pressure or below the atmospheric pressure considering the atmospheric pressure to be zero. A ‘U’ tube manometer will indicate zero pressure when pressure measured is equal to atmospheric pressure.

2.4 Building Management System (BMS) — An energy management system relating to the overall operation of the building in which it is installed. It often has additional capabilities, such as equipment monitoring, protection of equipment against power failure, and building security. It may also be a direct digital control (DDC) system where the mode of control uses digital outputs to control processes or elements directly.

NOTE — Mechanical and electrical equipment installed in the building, such as, air conditioning, ventilation, lighting, lifts, power, pumping stations, firefighting systems, security systems are controlled and managed through BMS.

2.5 Building Energy Simulation — Use of computer models for design and optimization of building's energy performance, to compare the cost-effectiveness of energy conservation measures in the design stage as well as assessing various performance optimization measures during the operational stage.

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2.6 Building Integrated Renewable Energy — Integration of renewable energy application in parts of the building envelope such as the roof, skylights, or facades.

2.7 Buildings Related Illnesses (BRI) — The diagnosable illness attributed directly to the specific air-borne building contaminants, like legionnaire's disease, occupational asthma, etc.

NOTE — Indicators of BRI include complaints of cough, chest tightness, chills, fever and muscle aches. Occupants may need prolonged recovery times after leaving the building.

2.8 Coefficient of Performance, Compressor, Heat Pump — Ratio of the compressor heating effect (heat pump) to the rate of energy input to the shaft of the compressor, in consistent units, in a complete heat pump, under designated operating conditions.

2.9 Coefficient of Performance, Compressor, Refrigerating — Ratio of the compressor refrigerating effect to the rate of energy input to the shaft of the compressor, in consistent units, in a complete refrigerating plant, under designated operating conditions.

2.10 Coefficient of Performance (Heat Pump) — Ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete operating heat pump plant or some specific portion of that plant, under designated operating conditions.

2.11 Coefficient of Performance (Refrigerating) — Ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating plant or some specific portion of that plant, under designated operating conditions.

2.12 Cooling Load — Amount of cooling per unit time required by the conditioned space or product; or heat that a cooling system shall remove from a controlled system over time.

2.13 Cooling Tower — An enclosed device, often tower like, for evaporatively cooling water by contact with air.

2.14 Dedicated Outdoor Air System (DOAS) — A unit that is used to separately condition outdoor air brought into the building for ventilation or to replace air that is being exhausted.

2.15 Demand Based Ventilation — Intelligent airflow management that adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create.

2.16 Design Pressure Difference — The desired pressure difference between a given space and an adjacent space measured at the boundary of the given space under a specified set of conditions, such as, that required in various spaces of hospital, clean rooms, protected space in case of smoke control operation, etc.

2.17 Dew Point Temperature — The temperature at which condensation of moisture begins when the air is cooled at same pressure.

2.18 Dry-Bulb Temperature — The temperature of the air, read on a thermometer, taken in such a way as to avoid errors due to radiation.

2.19 Duct System — A continuous passageway for the transmission of air which, in addition to the ducts, may include duct fittings, dampers, plenums, grilles and diffusers.

2.20 Economizer, Air — It consist of duct, damper and control system that allow outside air to cool the building when outside air is cooler than inside.

2.21 Economizer, Water — In this system the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat transfer or mass transfer to the environment without the use of mechanical cooling.

2.22 Effective Temperature — Combined effects of air temperature, humidity, air movement, mean radiant temperature, clothing and activity on the sensation of warmth or cold felt by the human body. Numerically equivalent to the temperature of still air producing similar thermal sensation as produced by combination of above six parameters of thermal comfort.

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2.23 Energy Efficiency Ratio (EER) — Ratio of net cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions.

2.24 Energy Recovery Unit — A heat exchanger assembly for transferring energy between two isolated fluid sources. The recovery system may be of air-to-air design or a closed loop hydronic system design. The system will include all necessary equipment such as fans and pumps, associated ducts or piping and all controls (operating and safety), and other custom-designed features

2.25 Evaporative Cooling — The process of evaporating part of a liquid by supplying the necessary latent heat from the sensible heat of the main bulk of the liquid which is thus cooled.

2.26 Fire Damper — The damper, normally held open, installed in an air distribution system or in a wall or floor assembly and designed to close automatically in the event of a fire and maintain fire compartmentation.

2.27 Geothermal Heat Pump — A heating and/or cooling system utilizes the earth's crust, as heat source (in the winter) or a heat sink (in the summer) by using fluid to be pumped into the earth and circulated in order to exchange heat for the purpose of heating or cooling applications

2.28 Global Warming Potential (GWP) — The relative measure of how much a given mass of a refrigerant contributes to global warming over a given time period compared to the same mass of carbon dioxide over the same period.

NOTE — The GWP value of carbon dioxide is taken to be 1.0. The GWP value of a refrigerant is calculated over a time horizon. The time horizon shall greatly affect the numerical value of GWP. Usually the GWP values are reported over a 100 years' time horizon.

2.29 Heating Load — Heating rate required to replace heat loss from the space being controlled.

2.30 Heat Pump — A thermodynamic heating/refrigerating system to transfer heat. The condenser and evaporator may change roles to transfer heat in either direction. By receiving the flow of air or other fluid, a heat pump is used to cool or heat. Heat pumps may be the air source with heat transfer between the indoor air stream to outdoor air or water source with heat transfer between the indoor air stream and a hydronic source (ground loop, evaporative cooler, cooling tower, or domestic water).

2.31 Heat Recovery — Use of heat that would otherwise be wasted from a system or process, for example, heat-recovery chiller which uses hot waste gases as a heat source.

2.32 Hybrid Building — A building which contains both active and passive systems of heating or cooling. It requires small amount of non-renewable energy to maintain required amount of coefficient of performance (COP).

2.33 Hydronic Systems — The water systems that transfer heat to or from a conditioned space or process with hot or chilled water. The water flows through piping that connects a chiller or the water heater to suitable terminal heat transfer units located at the space or process.

2.34 Hydronic System Balancing — Adjusting water flow rates through hydronic distribution system devices, such as pumps and coils, by manually adjusting the position valves or by using automatic control devices, such as automatic flow control valves.

2.35 Indirect-Direct Cooling — The cooling which involves two stages:

a) The first stage, in which the air is made to pass through heat exchanger for sensible cooling (no direct contact of air and water), whereby the leaving air dry-bulb temperature (DBT) as well as the wet-bulb temperature (WBT) are reduced; and

b) The second stage, in which the air after the first stage is made to pass through the evaporative air-cooling (adiabatic cooling) application where water and air are in direct contact and there is simultaneous removal of sensible heat and the addition of moisture to the air giving lower DBT.

The resultant of this two-stage cooling is that the leaving air DBT is lower than ambient WBT.

NOTE — The first stage cooling is through indirect cooling. In this method, air-dry bulb and wet-bulb temperature are reduced without direct contact of air with water and through heat exchange only.

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2.36 Indoor Air Quality (IAQ) — Air quality that refers to the nature of unconditioned or conditioned air that circulates throughout the space/area where one works or lives, that is, the air one breathes when indoors.

2.37 Infiltration/Exfiltration — The phenomenon of air leaking into (infiltration) or leaking out (exfiltration) out of an air-conditioned space.

2.38 Latent Heat — Change of enthalpy during a change of state, usually expressed, in kcal/kg. With pure substances, latent heat is absorbed or rejected at constant temperature at any pressure.

2.39 Latent Heat Load — Cooling load required to remove latent heat.

2.40 Mean Radiant Temperature — The uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure.

2.41 Mixed Mode Building — A hybrid approach to space conditioning that uses a combination of natural ventilation and mechanical systems. These buildings utilize mechanical cooling only when and where it is necessary to supplement the natural ventilation.

2.42 Naturally Conditioned Building — A building in which the ventilation system rely on opening and closing of window of the space to maintain the thermal comfort of the space rather than mechanical systems.

2.43 Operative Temperature — A uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. It is the combined effects of the mean radiant temperature and air temperature calculated as average of the two. It is also known as dry resultant temperature or resultant temperature.

2.44 Ozone Depletion Potential (ODP)—A relative capability of a refrigerant or a gas to degrade ozone in the atmosphere as compared to trichlorofluoromethane [R-11 or Clorofluorocarbon-11(CFC-11)]. The ODP of CFC-11 is taken to be 1.0.

2.45 Passive Cooling — A building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or zero energy consumption by using natural ventilation, air cooling and shades.

2.46 Passive Heating — Passive heating uses the energy of natural source such as the sun, to keep the occupants of the building comfortable by design approach of building without the use of mechanical or electrical heating systems.

2.47 Plenum — An air compartment connected to one or more distributing ducts.

2.48 Positive Ventilation — The supply of outside air by means of a mechanical device, such as a fan.

2.49 Psychrometric Chart — A chart graphically representing the thermodynamic properties of moist air.

2.50 Recirculated Air — The return air that has been passed through the conditioning apparatus before being re-supplied to the space.

2.51 Refrigerant — The fluid used for heat transfer in a refrigerating system, which absorbs heat at a low temperature and a low pressure of the fluid and rejects heat at a higher temperature and a higher pressure of the fluid, usually involving changes of state of the fluid.

2.52 Relative Humidity — Ratio of the partial pressure of actual water vapour in the air as compared to the partial pressure of maximum amount of water that may be contained at its dry-bulb temperature.

NOTE — When the air is saturated, dry-bulb, wet-bulb and dew point temperatures are all equal, and the relative humidity is 100 percent.

2.53 Return Air — Air returned from conditioned or refrigerated space.

2.54 Sensible Heat — Heat which is associated with a change in temperature; in contrast to a heat interchange in which a change of state (latent heat) occurs.

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2.55 Sensible Cooling — The process of removing sensible heat (lowering the dry-bulb temperature) from the air passing through it under specified conditions of operation.

2.56 Shade Factor — The ratio of instantaneous heat gain through the fenestration with shading device to that through the fenestration.

2.57 Sick Building Syndrome (SBS) — A term used to describe the presence of acute non-specific symptoms in the majority of people, caused by working in buildings with an adverse indoor environment.

NOTE — SBS could be a cluster of complex irritative symptoms like irritation of the eyes, blocked nose and throat, headaches, dizziness, lethargy, fatigue irritation, wheezing, sinusitis, congestion, skin rash, sensory discomfort from odours, nausea, etc. These symptoms are usually short-lived and experienced immediately after exposure; and may disappear when one leaves the building.

2.58 Smoke Barrier — A continuous membrane, either vertical or horizontal, such as a wall, floor, or ceiling assembly, that is designed and constructed to restrict the movement of smoke in conjunction with a smoke control system.

2.59 Smoke Damper — A damper similar to fire damper, however, having provision to close automatically on sensing presence of smoke in air distribution system or in conditioned space.

2.60 Smoke Management — A smoke control method that utilizes natural or mechanical systems to maintain a tenable environment for the means of egress from a large-volume space or to control and reduce the migration of smoke between the area on fire and communicating spaces.

2.61 Stack Effect — The vertical airflow within buildings driven by air buoyancy due to temperature-induced density differences between the building interior and exterior or between two interior spaces.

2.62 Static Pressure — The normal force per unit area that would be exerted by a moving fluid on a small body immersed in it if the body were carried along with the fluid. Practically, it is the normal force per unit area at a small hole in a wall of the duct through which the fluid flows (piezometer) or on the surface of a stationary tube at a point where the disturbances, created by inserting the tube. It is supposed that the thermodynamic properties of a moving fluid depend on static pressure in exactly the same manner as those of the same fluid at test depend upon its uniform hydrostatic pressure.

2.63 Supply Air — The air that has been passed through the conditioning apparatus and taken through the duct system and distributed in the conditioned space.

2.64 Terminal Devices — Devices fixed in the air-conditioned space for distribution of conditioned supply air and return of air such as, supply and return air grilles and diffusers.

2.65 Thermal Adaptation — The gradual diminution of the people's response to repeated environmental stimulation and subsumes all processes which building occupants undergo in order to improve the fit of the indoor climate.

2.66 Thermal Comfort – That condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

2.67 Thermal Insulation Material — A material used over the conducting material to retard the flow of heat energy in the form of heat loss or gain to facilitate the temperature control as the process and prevent permeability of moist vapour and reduces condensation on cold surfaces.

2.68 Thermal Energy Storage — Storage of thermal energy, sensible, latent or combination thereof for use in central system for air conditioning or refrigeration. It uses a primary source of refrigeration for cooling and stored thermal energy for reuse at peak demand or for backup as planned.

2.69 Velocity Pressure — The pressure exerted by movement of air which makes the air to travel to longer distance in ducts. This pressure is always in the direction of flow.

2.70 Variable Refrigerant Flow (VRF) System — A heating and/or cooling system in which the flow of the refrigerant shall be varied according to the load.

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2.71 Water Hardness — The hardness in water represented by the sum of calcium and magnesium salts in water, which may also include aluminium, iron, manganese, zinc, etc.

2.72 Water Treatment — The treatment of water circulating in a hydronic system, so that it shall be used without creating undue corrosion or scaling to the piping systems and other deleterious effects.

2.73 Wet-Bulb Temperature — The temperature at which liquid or solid water, by evaporating into air, shall bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature is the temperature indicated by a wet-bulb thermometer constructed and used according to specifications.

2.74 Definitions/Terminology Reference to Refrigerants — Refer to the accepted standard [D-3(2)] for all the definitions. In addition, below are some definitions.

2.74.1 *Glide* — The difference in the dew and bubble point of a zeotropic refrigerant at constant pressure.

2.74.2 *Occupational Exposure Limit* (*OEL*) — The threshold amount of time-weighted average (TWA) concentration a normal 8 hour shift and a 40 hour work week to which nearly all workers shall be repeatedly exposed without any adverse effects.

3 BASIS OF DESIGN

3.1 Planning and Design Considerations

In any building, clear definition of design considerations holds the key for a good HVAC system. This includes, appropriate system selection, system sizing, layout and location planning, planning for operation, maintenance and controls as explained in following pages.

3.2 Fundamental Planning Requirements

The objective of installing air conditioning, heating and mechanical ventilation in buildings shall be to provide comfortable conditions without compromising on health and safety of occupants. Air conditioning, heating and mechanical ventilation installation shall aim at controlling the following factors in the building:

a) thermal comfort;

b) air quality, air quantity and air movement;

c) sound and vibration;

d) through meeting the minimum energy efficiency levels;

e) ensuring electrical; and

f) fire safety requirements.

3.2.1 All plans, design, drawings, specifications and data for air conditioning, heating and mechanical ventilation systems of all buildings and serving all occupancies within the scope of this NBCS, shall be supplied to the Authority, where called for.

3.2.2 The plans, design and drawings for air conditioning, heating and mechanical ventilation (HVAC) systems shall include all details and data necessary for detailed load calculation through computer simulation such as:

a) building name, type and location, address;

b) owners' name;

c) HVAC designers' name;

d) use of building;

e) building orientation: north direction on plans and design drawings;

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f) general plans, dimensions and height of all rooms in SI unit;

g) intended use of internal spaces;

h) detail or description of wall construction, including insulation and finish;

j) detail or description of roof, ceiling and floor construction, including insulation and finish;

k) detail or description of windows and outside doors, including sizes, thermal properties, weather stripping, chajjas or projections;

m) internal load, such as people, equipment, computer/server load and lighting load;

n) layout showing the location, size and components of the HVAC equipment being installed;

p) information regarding air distribution system;

q) information on air and water systems and their flow rates and pressure drops;

r) information regarding location, size and accessibility of shafts;

s) information regarding type and location of dampers (both volume control and fire/smoke dampers) used in air conditioning system, such as, whether motorized or manually operated and rating;

t) location and grade of the required fire separations;

u) water treatment and softening arrangement;

v) information on presence of any chemical fumes or gases; and

w) HVAC automation design, description and piping and instrumentation (generally referred to as P&I drawing) drawing.

3.3 Fundamental Design Requirements

The following guidelines address critical factors such as load calculations, system adjustments for off-peak hours, and specialized needs for various applications, ensuring optimal performance and energy conservation across diverse scenarios.

3.3.1 Heat load calculation shall take into account the following factors:

a) recommended indoor temperature, relative humidity, air velocity, mean radiant temperature, clothing, activity and IAQ parameters;

b) outside and indoor design conditions as specified;

c) details of building construction and orientation of exposures of building components;

d) fenestration area, thermal properties and shading factors;

e) occupancy: number of people and their schedule of activities;

f) ventilation: requirement for fresh air;

g) infiltration, air leakage;

h) internal load: Equipment, computer/server and lighting;

j) effective volume; and

k) occupancy, lighting and equipment schedule.

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3.3.2 The design of air conditioning, heating and mechanical ventilation system and its associated controls shall also consider the following:

a) application;

b) permissible control limits;

c) fire safety;

d) opportunities for heat recovery, condensate drain recovery;

e) energy efficiency;

f) filtration standard;

g) hours of use;

h) suitable diversity factor based on usage; and

j) outdoor and indoor air quality.

3.3.3 Due consideration shall be given to air conditioning load encountered during off-peak hours including night, weekend, holidays. The system shall be designed for the maximum operational efficiency to achieve lowest annual energy consumption. Consideration shall be given to the anticipated future changes (permanent or temporary) in building load. The system shall be designed for maximum operational efficiency is achieved throughout.

3.3.4 The air conditioning system for special applications like hospitals, operating theatres, computer rooms, data centres and telecommunication rooms, clean rooms, laboratories, libraries, museums, art galleries, sound recording studios, etc shall be designed as per specific requirement.

3.3.5 Computer based hourly load calculation and energy simulation tools should be used for HVAC equipment sizing and to identify effect of various energy conservation measures on energy consumption.

3.3.6 An uncertainty analysis should be carried out based on the input parameter accuracy level. The system design should be determined by the uncertainty analysis considering the parameters like variation in climatic conditions, material properties, usage pattern, internal loads over design or under design of the should be avoided.

3.3.7 The system sizing shall be based upon outdoor and indoor design conditions, considering a safety factor, together with capacity deration due to local conditions as well as aging of equipment. Performance maps of major equipment at different climatic conditions and loads should be considered for accessing their suitability, sufficiency and energy efficiency.

3.4 System Layout and Space Planning

Each type of HVAC system has peculiar space and layout requirement. Major requirements for planning an efficient and serviceable layout are explained below.

3.4.1 *Equipment Room for Central Air Conditioning Plant*

These guidelines address the provisions of equipment room for central air conditioning plant.

3.4.1.1 This room shall be located preferably within the building being air conditioned and closer to external wall for facilitating ventilation and equipment movement. The equipment may also be installed in a separate service block which should also be located as close as possible to the load/building being conditioned. The clear headroom below soffit of beam should be minimum 4.5 m for larger capacity chillers (500 TR and above) and minimum 3.6 m for smaller plants.

3.4.1.2 The floors of the equipment rooms should be compacted and finished. For floor loading, the air conditioning engineer should be consulted (*see* Part C 'Structural Design, Section 1 Loads and Load Effects' of this NBCS).

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3.4.1.3 Supporting of pipe within plant room spaces should be normally from the floor. However, outside plant room areas, structural provisions shall be made for supporting the water pipes from the floor/ceiling slabs. All floor and ceiling supports shall be isolated from the structure to prevent vibration transmission.

3.4.1.4 Equipment rooms, wherever necessary, shall have provision for mechanical ventilation. In hot and dry climate, evaporative air cooling shall be considered to maintain plant room temperature.

3.4.1.5 Plant machinery in the plant room shall be placed on levelled plain/reinforced cement concrete foundation block and provided with anti-vibratory supports or alternatively on inertia bases. Supports for appliances shall be designed and constructed to sustain vertical and horizontal loads within the stress limitations specified in the Part C 'Structural Design' of this NBCS. All foundations should be protected from damage by providing epoxy coated angle nosing. Seismic restraints requirement should also be considered (*see* **17.4.3**).

3.4.1.6 Appropriate sound insulation and noise control measures shall be taken in plant room space as per Part D 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of this NBCS. Acoustic treatment as may be required shall be provided in plant room space to prevent noise transmission to adjacent occupied areas.

3.4.1.7 In case air conditioning plant room is located in basement, equipment movement route shall be planned to facilitate future replacement and maintenance. Service ramps or hatch in ground floor slab should be provided in such cases. Fire egress and emergency battery backup lighting shall be provided for the plant room operator.

3.4.1.8 Floor drain channels or dedicated drain pipes in slope shall be provided within plant room space for effective disposal of waste water, if necessary, by automatic level-controlled sump pumps. Fresh water connection may also be provided in the air conditioning plant room.

3.4.1.9 Thermal Energy Storage should be used for limiting maximum demand, by controlling peak electricity load through reduction of chiller capacity, and by taking advantage of high system efficiency during low ambient conditions. Thermal storage will also help in reducing operating cost by using differential time-of-the day power tariff, where applicable. In case of central plant designed with thermal energy storage, its location shall be decided in consultation with the air conditioning engineer. For roof top installations, structural provision shall take into account load coming on the building/structure due to the same. For open area surface installation, horizontal or vertical system options shall be considered and approach ladders for manholes provided. Buried installation shall take into account loads due to movement of vehicles above the area. Provision for adequate expansion tank and its connection to thermal storage tanks shall be made.

3.4.2 *Equipment Room for Air Handling Units and Package Units*

These guidelines ensure optimal placement, safety, and functionality of equipment rooms for air handling and package units within the building's HVAC system**.**

3.4.2.1 This shall be located as centrally as possible to the conditioned area and contiguous to the corridors or other service areas for carrying air ducts in ceiling spaces.

3.4.2.2 In case of special and high-rise buildings, air handling units shall be provided in accordance with fire and life safety considerations, given in Part F 'Fire and Life Safety' of this NBCS. Air handling unit rooms should preferably be located vertically one above the other.

3.4.2.3 Provision shall be made for the entry of outdoor ventilation air into air handling unit room. For energy conservation, it is desirable to install mechanism for modulating the outdoor air quantity based on demand.

3.4.2.4 Exterior openings for outdoor air intake and also exhaust outlets shall have louvers with rain protection profile, volume control damper, pre-filter and bird screen.

3.4.2.5 In all cases, outdoor air intakes shall be located to avoid contamination from exhaust outlets and pollution sources in concentration higher than normal in the building locality. The separation distance between fresh air intake and any exhaust outlets shall be 8 m preferably.

3.4.2.6 Exhaust air from any dwelling unit shall not be circulated/ingress directly or indirectly to any other dwelling unit, to public corridor or into public stairway.

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3.4.2.7 All air handling rooms should have floor drains. The trap in floor drain shall provide a water seal between the air-conditioned space and the drain line.

3.4.2.8 Supply/return air duct serving other areas shall not be taken through fire exits.

3.4.2.9 Waterproofing of air handling unit rooms shall be carried out to prevent damage to floor below.

3.4.2.10 The floors should be finished smooth. For floor loading, the air conditioning engineer should be consulted (*see* Part C 'Structural Design, Section 1 Loads and Load Effects' of this NBCS).

3.4.2.11 Structural design should avoid beam obstruction to the passage of supply and return air ducts. Adequate ceiling space should be made available outside the air handling unit room to permit installation of supply and return air ducts and fire/smoke dampers at compartment wall crossings.

3.4.2.12 Appropriate sound insulation and noise control measures shall be taken in air handling unit rooms, if located in close proximity to occupied areas, as per Part D 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of this NBCS. The air handling unit rooms shall be acoustically treated in accordance with the noise control requirements if located in close proximity to occupied areas.

3.4.2.13 Access door to air handling unit room shall be single/double leaf type, air tight, opening outwards and should have a sill to prevent flooding of adjacent occupied areas. It is desired that access panels in air-conditioned spaces should be provided with tight sealing, gaskets and self-closing devices for air conditioning to be effective.

3.4.2.14 It should be possible to isolate the air handling unit room in case of fire. The door should be fire resistant (*see* Part F 'Fire and Life Safety' of this NBCS) and fire/smoke dampers shall be provided in supply/return air duct at air handling unit room wall crossings. Annular space between the duct and the wall should be fire sealed using appropriate fire resistance rated material.

3.4.2.15 Fire isolation shall be provided for vertical fresh air duct, connecting several floors.

3.4.2.16 It is desirable that individual air handling unit should be installed for each fire compartment, alternately, fire barrier should be provided at each fire separation for air handling units serving more than one compartment.

3.4.3 *Pipe Shafts*

These guidelines address the placement, safety, and accessibility requirements for pipe shafts to ensure effective distribution and maintenance of building services.

3.4.3.1 The shafts carrying chilled water pipes should be located adjacent to air handling unit room or within the room.

3.4.3.2 Shaft carrying condensing water pipes to cooling towers located on terrace should be vertically aligned.

3.4.3.3 All shafts shall be provided with fire barrier at floor crossings following the fire safety requirements.

3.4.3.4 Access to shaft shall be provided at every level, if there is any serviceable component in the shaft. In case of tall buildings, care shall be taken for expansion/contraction of pipes while planning the supports.

3.4.4 *Supply Air Ducts and Return Air Ducts*

These guidelines ensure efficient and safe design of supply and return air ducts, focusing on airflow distribution, energy conservation, and compliance with safety standards.

3.4.4.1 The duct supports shall be designed to handle the load and also to take into account seismic considerations. The support material should be galvanized/coated steel or aluminium and facilitate ease of installation at site using alternatives such as fully threaded rod/angle, chromium plated steel threaded rods or channel section/wire support systems using stud anchors provided in the ceiling slab from drilled holes or anchors suitable for threaded rods, wires without damaging the slab or structural member. Wire Rope when used shall be rated to take seismic loads. Steel sections shall be analysed for both tensile and compressive loads for strength and serviceability for the maximum length of element being used for bracing and other supports. Appropriate loads

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and its combinations, as per relevant clauses in Indian standards should be considered in design. Each straight run of the service shall be braced with a minimum of one transverse braces and one longitudinal-transverse brace with distance not greater than 12 m between them.

3.4.4.2 If false ceiling is provided, the supports for the duct and the false ceiling, shall be independent. Collars for grilles and diffusers shall be taken out only after false ceiling/boxing framework is done and frames for fixing grilles and diffusers have been installed. Flexible ducts may be used for making the final connections.

3.4.4.3 Where a duct penetrates the masonry wall, it shall either be suitably covered on the outside to isolate it from masonry, or an air gap shall be left around it to prevent vibration transmission. Further, where a duct passes through a fire resisting compartment/barrier, the annular space shall be sealed with fire sealant to prevent smoke and fire transmission as per relevant clauses of this NBCS.

3.4.5 *Cooling Tower*

These guidelines focus on the efficient design, placement, and maintenance of cooling towers to optimize cooling performance, minimize energy use, and ensure safe operation.

3.4.5.1 Cooling towers are used to dissipate heat from water cooled refrigeration, air conditioning and industrial process systems to the atmosphere. Cooling is achieved by evaporating a small proportion of recirculating water into outdoor air stream. Cooling towers shall be installed at a place where free flow of ambient air is available.

3.4.5.2 Range of a cooling tower is defined as temperature difference between the entering and leaving water. Approach of the cooling tower is the difference between leaving water temperature and the ambient air wet-bulb temperature.

3.4.5.3 *Selection of cooling tower*:

Following factors shall be considered for selection of cooling tower:

a) design wet-bulb temperature and approach of cooling tower. The designer shall endeavour for reducing the approach for maximizing the energy conservation potential;

b) height limitation and aesthetic requirement;

c) location of cooling tower considering possibility of easy drain back from the system;

d) placement with regard to adjacent walls, windows and other buildings, and effects on these from any water carried over by the air stream;

e) vibration and noise levels, particularly during silent hours;

f) material of construction for the tower;

g) direction and flow of prevailing wind;

h) quality of water used for make-up;

j) maintenance and service space availability; and

k) ambient air quality.

3.4.5.4 The recommended floor area requirement for various types of cooling tower is as given below:

a) Natural draft: 0.15 to 0.20 m^2/3.516 kW cooling tower; and

b) Mechanical draft: 0.07 to 0.10 m^2/3.516 kW cooling tower.

3.4.5.5 Structural provision for the cooling tower shall be taken into account while designing the building. Vibration isolation shall be an important consideration in structural design.

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3.4.5.6 Special care should be taken in design where noise transmitted to the adjoining building shall be of serious concern. Special vibration control and sound attenuation devices may be required in that case. Appropriate sound insulation and noise control measures shall be taken in such cases in accordance with relevant requirements of this NBCS. System may be designed to have sound absorption ≥ 0.8 and sound insulation of ≥ 50 dB.

3.4.5.7 Certain amount of water is lost from circulating water in the cooling tower, as given below:

a) *Evaporation loss* — It is usually about 1 percent of the rate of water circulation.

b) *Drift loss* — The drift loss shall be below 0.1 percent of rate of water circulation.

c) *Blow-down/bleed-off* — The amount of blowdown shall be below 0.8 percent of the total water circulation. If simple blow-down is inadequate to control scale formation, chemicals may be added to inhibit corrosion and limit microbiological growth. Provision shall be made to make-up for the loss of circulating water.

3.4.5.8 Provision for make-up water tank to the cooling tower shall be made. Make-up water tank to the cooling tower shall be separate from the tank serving drinking water. Makeup water should be sourced from treated water from sewage treatment, waste water treatment plant, or from rain water harvesting. Make-up water having contaminants or hardness, which shall adversely affect the refrigeration plant life, shall be treated. Treated water where hardness as ppm of $CaCO_3$ is reduced to 50 ppm or below is recommended for air conditioning applications. Water with *p*H value less than 5 shall also need to be treated.

3.4.5.9 Cooling tower should be so located as to eliminate nuisance from drift to adjoining structures.

3.4.6 *Building Envelope*

The envelope of the building including wall, roof and fenestration may be planned as per relevant guidelines/best practices (‘Handbook on Sustainability in Buildings’).

3.4.7 *Fire Safety*

For fire safety in case of special and high-rise buildings, provisions of Part F ‘Fire and Life Safety’ of this NBCS should be applicable.

3.4.8 *Sound Insulation and Noise Control*

Sound insulation and noise control measures for HVAC system shall be in accordance with Part D ‘Building Services, Section 4 Acoustics, Sound Insulation and Noise Control’ of this NBCS.

3.4.8.1 *Designing for background noise control and vibration*

The background noise and vibration created by air distribution through the HVAC system, combined with noise from equipment and outdoor sources of noise and vibration may causes significant disturbance to building users. Adoption of measures for adhering to indoor noise limits and vibration control should be ensured in the design of equipment, their foundation, supports and air distribution system. Threshold values for indoor sound levels, are given in Table 1 and Table 2 below. The buildings/indoor spaces will be classified as Class A, B and C where Class A refers to aspirational, Class B refers to acceptable and Class C refers to minimum acceptable.

3.4.9 *Energy Conservation*

Designers shall aim for energy efficiency in buildings with the right blend of passive and active design strategies in accordance with relevant guidelines/best practices (‘Handbook on Sustainability in Buildings’), so as to minimise the energy use while ensuring comfort.

3.5 Outside design conditions

The outdoor design conditions shall be considered in accordance with accepted standard [D-3(3)]. Table 3 presents design conditions taken from this standard as ready reference. For cities not included in this table, it is recommended that extrapolation may be done, from the data of the nearby listed city, but keeping into consideration the specific topographical and climatic conditions of the concerned location. Values of ambient

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dry-bulb temperatures and wet-bulb temperatures, against the various annual percentiles, represent the value that is exceeded on average by the indicated percentage of the total number of hours. The 0.4 percent, 1.0 percent, 2.0 percent values are exceeded on average 35 h, 88 h and 175 h respectively in a year. The 99.0 percent and 99.6 percent values are defined in the same way but are usually reckoned as the values for which the corresponding weather elements are less than the design conditions of 88 h and 35 h respectively.

Mean coincidental values are the average of the indicated weather element occurring concurrently with the corresponding design value. After the calculation of design dry-bulb temperatures, the program locates the values of corresponding wet-bulb temperatures from the database for that particular station, the average of these values is computed, which are then called mean of coincidental wet-bulb temperature. In the same way, design wet-bulb temperatures and coincidental dry-bulb temperatures are evaluated.

The design values of 0.4 percent, 1.0 percent and 2.0 percent annual cumulative frequency of occurrence may be selected depending upon application of air conditioning system. For normal comfort conditions, values under 1.0 percent column should be used for cooling loads and 99 percent column for heating loads. For critical applications, values under 0.4 percent column should be used for cooling loads and 99.6 percent column for heating loads.

Table 1 Requirements of Acoustic Comfort

(*Clause* 3.4.8.1)

SI No.	Types of Buildings	Noise Criterion			Reverberation Time			Speech Transmission Index		
		A	B	C	A	B	C	A	B	C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	**Residences, apartments, condominiums**	30	35	40	< 0.8 s	NA	NA	*0.6	*0.5	*NA
								Applicable for atriums and corridors		
ii)	**Hospitality**									
a)	Individual rooms or suites	30	35	40	< 0.8 s	< 0.6 s	< 1.0	0.6	0.5	NA
b)	Meeting/banquet rooms	30	35	40	< 0.5 s			0.7	0.6	0.5
c)	Corridors, lobbies	40	45	45	NA			NA	NA	NA
d)	Service/Support areas	40	45	50	NA			0.5	NA	NA
e)	All day dining and restaurants	45	50	50	<1.2s	<1.5s	<1.75s	0.6	0.5	NA
iii)	**Office buildings**									
a)	Executive and private offices	30	35	40	< 0.6 s	< 0.7 s	< 0.8 s	0.6	0.5	NA
b)	Conference rooms	30	35	35	< 0.6 s			0.7	0.6	0.5
c)	Teleconference rooms	25 (max)			< 0.6 s			0.7	0.6	0.5
d)	Open – plan offices	35	40	40	< 0.8 s			0.6	0.5	NA

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Table 1 (*Concluded*)

SI No.	Types of Buildings	Noise Criterion			Reverberation Time			Speech Transmission Index		
		A	B	C	A	B	C	A	B	C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
e)	Corridors and lobbies	40	45	45	NA			NA	NA	NA
f)	Collaborative space				< 0.8 s			0.5	NA	NA
g)	Cafeteria/Town hall	40	45	45	< 1.0 s	< 1.2 s	< 1.2 s	0.6	0.5	NA
iv)	**Education**									
a)	Class rooms up to 70 m^2	40 (*Max*)			< 0.6 s	< 0.8 s	< 1.0 s	0.6	0.5	NA
b)	Class rooms over 70 m^2	35 (*Max*)						0.6	0.5	NA
c)	Large lecture rooms, without speech amplification	35 (*Max*)						0.6	0.55	0.5
v)	**Libraries**	35	40	40	< 1.0 s	< 1.2 s	< 1.2 s	0.6	0.5	NA
vi)	**Health care***									
a)	Open Ward	35	35	45	< 1.0s	< 0.8 s	< 1.0 s	0.7	0.6	0.5
b)	Individual rooms or suites	30	35	40	< 0.8s			0.7	0.6	0.5
c)	Meeting rooms /Conference room	25	30	35	< 0.6s			0.5	NA	NA
d)	Teleconferencing rooms	25	NA	NA	< 0.6s			0.7	0.6	0.5
e)	Operating rooms	35	40	45	< 0.8s			0.6	0.5	NA
f)	Corridors, lobbies	35	45	45	< 1.0s			NA	NA	NA
g)	Testing/research lab, minimal speech	45	50	55	< 0.8s			0.5	NA	NA
h)	Research lab, extensive speech	40	45	50	< 0.8s			0.7	0.6	0.5
j)	Auditoria, large lecture rooms	25	30	NA	< 0.8s			0.6	0.5	NA

NOTES

1 In this table are given the performance requirements in terms of recommended dBA noise level (ideal), the not to exceed noise level (max), and the maximum acceptable reverberation time (T60) for many spaces including offices.

2 For the Class A and Class B, a building should score 90 percent and 80 percent respectively on the occupant satisfaction survey. There is no such requirement to achieve Class C.

3 Any other type of space not mentioned in the Table above shall meet requirements of the nearest representative category of that space.

4 For more details on Reverberation Time, refer graph with respect to volume and application in annexure.

5 * values measured in unoccupied condition.

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Table 2 Threshold Noise Isolation Criteria Level Depending Upon Type of Space

(*Clause* 3.4.8.1)

SI No.	Building	Type of space	D_w/NIC		
			Class A	Class B	Class C
(1)	(2)	(3)	(4)	(5)	(6)
i)	Office	Between two offices	45	40	40
		Where privacy is important			
		Cellular offices			
		Between enclosed office and circulation area	40	35	30
		Between two meeting or conference rooms	50	45	45
		Between meeting or conference room and circulation area	40	35	30
		Between two training rooms	50	45	45
		Between training room and circulation area	40	35	30
ii)	Residential	Partitions separating a water closet (WC) from a noise sensitive room	45	40	35
iii)	Hospitality	Partitions and floors between rooms and corridors			
		Walls and floor between two guestrooms/suites	55	50	45
		Between guestrooms/suites and circulation area	40	40	40
		Walls and floor between banquet halls and guestrooms/suites	55	50	50
		Between banquet hall and circulation area or pre functions	45	40	40
iv)	Entertainment	Walls of cinemas, auditoriums, studios, pubs	60	55	50
v)	Education	Between classrooms, labs, lecture halls	50	50	45
vi)	Hospital or Health care*	Between two patient rooms and circulation area	40	40	35
		Between patient room and circulation area (with entrance)	35	30	25
		Between Patient Room and Service Area	50	45	45
		Between Consultation Room and Public Space/Patient Rooms	40	40	40
		Between Consultation Room and Circulation Area (with entrance)	35	30	25

NOTE — Weighted level difference (D_w) a single integer number found by comparing the measured spectrum with the 'standard' curves for airborne and impact insulation. The D_w value is where the curve meets the 500 Hz curve and the unfavourable deviation is 32 dB. D_w will be identical to $D_{Nt,w}$ when T = 0.5 seconds. Noise Isolation Class NIC a single number rating of the degree of speech privacy achieved through the use of an acoustical ceiling and sound absorbing screens in an open office..

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Table 3 Summary for Outdoor Design Conditions

(*Clause* 3.5)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
1)	Agartala	10.8	11.6	35.2	25	34.5	25	33.8	27	28.5	33	28.1	32	27.8	32
2)	Agra	4.6	6.1	42.1	21	40.8	22	39.8	22	28.7	31	28.3	30	28	31
3)	Ahmedabad	12.3	13.2	42.7	25	41.7	22	41	22	30.2	35	29.3	34	28.4	33
4)	Aizawl	10.5	11.3	30.5	20	29.5	21	28.9	21	24.8	27	24.5	26	24.1	27
5)	Ajmer	4.8	5.6	41.5	22	40.7	21	39.4	21	25.2	34	24.9	34	24.7	33
6)	Akola	12.4	13.9	43.1	23	42.2	21	41.4	22	26.9	33	26.5	32	26.2	31
7)	Aligarh	3.9	5.3	42.9	23	41.8	23	40.4	24	28.3	33	27.9	34	27.6	33
8)	Allahabad	9.8	10.6	43.1	23	41.7	23	40.3	23	28.7	32	28.3	33	28	32
9)	Amaravati	19.2	19.8	42	27	39.7	27	38.1	26	28.4	33	28.2	32	27.8	33
10)	Amritsar	3	4.5	42	23	41	23	39	23	29.2	32	28.6	32	28.2	31
11)	Anantapur	16.9	18.1	40	24	39.5	24	38.7	23	26.3	35	25.8	33	25.5	34
12)	Aurangabad	11.8	12.9	40.1	23	39.3	22	38.3	22	26.8	34	26	32	25.5	31
13)	Balasore	12.9	13.9	36.8	26	35.5	26	34.6	27	28.8	33	28.4	33	28.1	33
14)	Bareilly	6.4	7.2	39.6	23	38.7	26	37.7	25	29.2	34	28.8	33	28.4	33
15)	Barmer	10.6	11.5	43.2	23	42	22	40.4	24	28.3	36	27.9	35	27.5	34

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Table 3 (*Continued*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
16)	Belgaum	13.5	14.6	36.7	19	35.5	18	34.2	19	24.1	29	23.7	29	23.4	28
17)	Bengaluru	15.6	16.2	34.1	21	33.4	20	32.7	19	23.5	29	23.1	29	22.8	28
18)	Bhagalpur	13.1	13.8	38.3	22	36.8	25	35	27	29.3	34	28.9	33	28.7	32
19)	Bhavnagar	12	12.8	42.4	25	41.3	27	39.8	25	28.4	30	28.1	32	27.8	32
20)	Bhilai	12.7	14	42.6	23	41.7	24	40.4	23	26.8	31	26.5	32	26.2	31
21)	Bhopal	9	10.2	42	21	40.7	25	39.5	21	26	30	25.7	30	25.3	29
22)	Bhubaneswar	14.1	15.1	38.9	27	37.8	27	36.7	26	30.1	35	29.5	33	29.1	33
23)	Bhuj	12.4	13.3	40.5	23	39.5	24	38.3	23	28.1	36	27.6	33	27.3	33
24)	Biharsharif	7.8	8.7	40.1	24	38.7	24	37.6	24	28.4	31	28	32	27.7	31
25)	Bikaner	7.6	9.1	44.8	22	43.3	23	41.9	23	27.6	34	27.2	32	26.8	33
26)	Bilaspur	11.8	13	43.2	22	42.3	23	41.3	23	26.9	31	26.6	31	26.4	31
27)	Chandigarh	2.8	4	43	22	40.8	20	39.2	18	27.2	33	26.8	32	26.5	32
28)	Chennai	20.5	21	39	26	38	26	37	26	28.5	34	28.1	34	27.8	35
29)	Chitradurga	16.2	16.9	37.4	21	36.5	21	35.6	20	23.8	27	23.5	26	23.2	26
30)	Coimbatore	18.6	19.5	36.5	23	35.8	24	34.9	24	25.4	33	25.1	31	24.9	29

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Table 3 (*Continued*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
31)	Cuddalore	20.1	20.8	37.9	26	37.1	26	36.1	27	29	33	28.7	33	28.3	34
32)	Dahod	8.6	9.8	41.1	20	40.4	23	39.3	21	27	30	26.5	32	25.7	33
33)	Daltonganj	8.8	9.9	43.3	24	42	25	41	24	28.1	32	27.7	31	27.5	32
34)	Davanagere	16.9	17.7	37.4	21	36.5	21	35.7	21	24.2	29	23.8	29	23.5	29
35)	Dehradun	5.8	6.6	37.7	22	36.2	23	34.5	22	27	30	26.5	30	26.2	30
36)	Dhanbad	8	9.3	41.5	23	40.5	22	39.7	22	27.4	32	27	32	26.7	31
37)	Dharmsala	3.7	4.7	32.1	20	31.1	21	30.2	18	23.7	28	23.4	26	22.9	25
38)	Dibrugarh	10.2	11	35	28	34	27	33.2	27	29.2	34	28.6	33	28.1	32
39)	Diu	10.5	11.4	35.9	24	34.6	23	33.6	22	25.1	30	24.8	29	24.6	29
40)	Erode	18.3	18.9	40.3	23	39.3	23	38.3	24	26.5	31	25.8	30	25.4	31
41)	Etawah	3.8	5.3	44.2	24	43.1	25	42	25	28.9	36	28.2	37	27.6	34
42)	Ganganagar	4.6	6.1	44.2	22	42.7	26	40.8	25	29.1	35	28.7	34	28.4	35
43)	Gangtok	1.4	2.3	23.1	19	22.7	18	22.3	19	19.8	22	19.6	22	19.4	22
44)	Gaya	7	9	43.3	20	41.8	23	40.2	21	28.5	33	28	33	27.7	32
45)	Gorakhpur	8.5	9.6	40.7	23	38.9	23	37.7	22	28.1	32	27.8	33	27.5	33

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Table 3 (*Continued*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
46)	Gulbarga	19.4	20.4	41.5	24	40.6	25	39.8	25	27.4	36	27	34	26.6	35
47)	Guna	8.5	10	42.8	22	41.9	22	40.9	22	27	33	26.7	31	26.4	32
48)	Guntur	16.6	17.7	41.1	25	39.6	25	38.5	25	28.6	31	28.3	31	28.1	31
49)	Guwahati	11.2	12.1	35.4	27	34.5	29	33.9	27	29.2	34	28.9	33	28.6	33
50)	Gwalior	4.9	5.7	43.2	24	42.2	24	40.9	23	28.5	34	28.2	35	27.8	33
51)	Hissar	4.1	5.1	43.8	25	42.6	24	41.2	23	29	37	28.7	34	28.3	33
52)	Honavar	18.8	19.8	34.3	24	33.6	24	33.1	25	27.8	32	27.4	32	27.2	31
53)	Hubballi	12.5	13.2	41.8	24	40.7	23	39.4	24	26	26	25.5	29	25.2	30
54)	Hyderabad	15.3	16.3	41	22	39.6	22	38.4	24	25.4	34	25	31	24.7	31
55)	Imphal	4.9	5.9	32	21	31.3	23	30.7	23	25.7	31	25.2	30	24.8	29
56)	Indore	10.4	11.3	39.9	19	38.9	21	37.9	21	25.6	31	25.1	29	24.8	29
57)	Itanagar	8.8	9.7	35.2	29	34.3	29	33.4	29	29.8	34	29.5	34	29.1	32
58)	Jabalpur	8.4	9.8	41.6	20	40.7	20	39.5	20	26.3	30	25.9	31	25.6	30
59)	Jagdalpur	9.6	11.1	39.2	20	38.1	23	37	23	26.6	36	25.9	32	25.5	31
60)	Jaipur	8.4	9.3	42.4	20	41	21	40	21	27.6	33	27.2	31	26.9	32

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Table 3 (*Continued*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
61)	Jaisalmer	8.3	9.3	44.3	24	42.8	23	41.7	25	28.1	38	27.6	34	27.2	36
62)	Jalandhar	4.3	5.5	43.7	21	42.4	21	40.7	21	25.6	33	25	36	24.6	33
63)	Jammu	4.8	5.8	41.9	21	40.1	20	38.9	21	28.6	32	27.9	30	27.4	32
64)	Jamnagar	7.9	8.9	38.7	24	37.5	23	36.5	24	27.7	30	27.5	31	27.3	32
65)	Jamshedpur	9.8	10.7	41.4	23	39.8	23	38.2	24	27.6	33	27.3	33	27	32
66)	Jhansi	6.1	7	44.9	24	43.7	22	42.8	22	27.6	34	27.1	31	26.9	33
67)	Jharsuguda	11	12	42	24	40.8	24	39.5	23	27.8	31	27.4	32	27.1	31
68)	Jodhpur	9	10.4	42.1	22	40.7	23	39.8	23	27.9	33	27.4	34	27	32
69)	Jorhat	8.5	9.2	33.1	27	32.6	26	31.6	27	27.7	31	27.5	30	27.2	30
70)	Kakinada	18.1	19.4	42.2	26	39.4	25	37.3	28	29.2	35	28.8	33	28.4	34
71)	Kalingapatam	15.8	17.6	35.3	29	34.6	29	34	28	29.7	34	29.5	33	29.1	33
72)	Kannur	20.6	21.2	36.4	24	35.6	24	34.9	24	26.8	30	26.5	31	26.3	30
73)	Kanpur	6.4	7.2	43.4	23	42	23	40.9	23	28.5	34	28.2	34	28	33
74)	Karaikal	21.8	22.7	37	26	36.2	26	35.3	26	29.1	34	28.9	34	28.4	32
75)	Karimnagar	13.4	14.7	42.7	24	41.9	26	40.7	25	28.2	37	27.6	34	27.2	35

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Table 3 (*Continued*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
76)	Karnal	4.7	5.6	40.8	22	39.7	24	38.4	22	27.8	33	27.3	31	26.9	32
77)	Karwar	20.6	21.6	35.9	27	35.4	26	34.9	26	29.6	34	29.2	34	28.8	33
78)	Kavaratti	23.3	24	33.8	28	33.4	27	32.9	27	28.6	33	28.2	33	27.9	32
79)	Kochi	22.8	23.2	32.9	26	32.6	26	32.3	26	27.6	32	27.3	31	27.1	31
80)	Kodaikanal	7	7.7	24.4	15	23.4	14	22.6	14	15.8	22	15.4	22	15.1	21
81)	Kohima	5.9	6.8	27.1	20	26.3	21	25.6	20	21.6	23	21.3	24	21.1	24
82)	Kolhapur	19.4	20.3	35.6	20	35.1	20	34.5	20	27.4	28	26.6	27	25.5	29
83)	Kolkata	12	13	37	28	36.3	28	35.7	28	29.6	33	29.2	34	28.8	34
84)	Kollam	21.8	22.3	34.2	25	33	23	32.4	23	26.8	30	26.6	30	26.4	29
85)	Kota	10	11.2	43.5	21	42.3	21	41	22	27.1	32	26.8	31	26.5	31
86)	Kozhikode	22.6	23.1	34.8	29	34.3	28	33.9	27	29.2	34	28.9	33	28.6	33
87)	Kurnool	17.1	18	41.1	22	40.1	24	39.2	24	26.1	32	25.8	34	25.5	33
88)	Leh	-20.7	-19	26.6	10	25.8	11	24.8	11	14	23	13.5	21	12.9	20
89)	Lucknow	6.7	8	42	23	41	23	40	24	29.4	34	29	36	28.6	34
90)	Ludhiana	2.6	3.6	40.7	22	39.3	24	38.1	22	28.1	30	27.6	32	27.2	32

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Table 3 (*Continued*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
91)	Machilipatnam	20.4	20.9	40.3	28	38.7	27	37.1	27	29.7	36	29.3	36	28.8	34
92)	Madurai	18.1	18.8	40.9	24	39.6	25	38.8	25	28.1	32	27.4	32	27	32
93)	Mangaluru	21.3	22	34.2	24	33.7	25	33.3	25	27	33	26.7	31	26.5	30
94)	Minicoy	23.9	24.4	33.3	28	32.9	28	32.5	28	28.7	32	28.3	32	28.1	32
95)	Moradabad	5.2	6.6	42.1	23	40.7	24	39.4	25	28.8	35	28.3	33	27.8	33
96)	Mumbai	19	20.2	35	23	34.7	24	33.9	23	27.9	31	27.7	31	27.3	31
97)	Muzaffarpur	8.5	9.3	38.9	25	37.9	26	36.8	27	29.5	35	29.2	34	28.9	32
98)	Mysuru	14.6	15.1	36.7	21	35.5	22	34.4	22	24	25	23.6	29	23.2	27
99)	Nagappattinam	22.7	23.2	36.9	26	36.2	26	35.4	27	29.1	32	28.9	32	28.6	32
100)	Nagpur	12	13	44	22	43	22	42	22	27.5	31	27.1	29	26.7	31
101)	Nashik	9.5	10.1	37.3	19	36.5	20	35.6	19	26.3	28	25	27	24.3	27
102)	Nellore	21	21.6	41	28	39.6	27	38.4	28	28.8	36	28.5	38	28.2	35
103)	New-Delhi	5	6.5	43.6	21	42.6	22	41	23	28.2	36	27.8	35	27.5	30
104)	Nizamabad	15.4	16.6	43.3	24	41.9	24	40.3	23	26.2	30	25.9	30	25.6	31
105)	Ongole	21.5	21.8	41.9	27	39.2	26	37.7	27	28.7	36	28.3	36	27.8	34

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Table 3 (*Continued*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
106)	Panaji	19.8	20.5	34.1	26	33.8	27	33.3	26	28.2	33	27.9	32	27.6	32
107)	Pasighat	11	11.9	34.1	26	33.3	27	32.4	26	27.7	32	27.3	31	27	31
108)	Patiala	6.2	7	42.2	26	40.4	24	38.8	25	29.4	34	29	34	28.6	33
109)	Patna	7	8.2	41	24	39.6	26	37.7	23	28.6	33	28.3	33	28	32
110)	Pendra-road	9	10.2	39.7	21	38.7	21	37.6	23	26.2	31	25.7	30	25.3	29
111)	Port-Blair	22.1	22.9	33.1	27	32	27	31.3	26	27.5	32	27.2	31	26.9	30
112)	Pune	10.2	11.2	38.7	19	37.5	20	36.3	19	24.6	30	24	30	23.8	29
113)	Raipur	13.1	14.2	42.1	24	41.1	23	40	24	27.1	31	26.8	32	26.5	31
114)	Rajkot	12	13	41.3	21	39.9	23	38.9	24	27.4	29	27	30	26.7	31
115)	Ranchi	8.9	10	38.9	20	37.7	20	36.3	20	25.9	30	25.4	29	25.2	29
116)	Ratnagiri	17.9	18.6	34.1	22	33.7	24	33.1	23	27.1	31	26.9	30	26.7	30
117)	Raxaul	8.3	9.3	38.6	25	36.3	26	34.8	25	29	32	28.6	32	28.3	32
118)	Roorkee	4.4	5.3	40.4	24	39.1	23	37.9	23	27.9	32	27.4	31	27.2	32
119)	Sagar	8.1	9.5	41.9	24	41.1	23	40	21	26.5	37	25.9	33	25.5	30
120)	Saharanpur	4.2	4.9	43.2	22	42	23	40.7	24	28.5	33	28.2	33	27.9	34

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Table 3 (*Continued*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
121)	Salem	17.5	18.2	39.9	24	39.1	22	38.1	23	25.6	30	25.2	31	25	30
122)	Sangli	7.8	8.5	40.1	20	38.9	19	37.8	18	24.5	27	24.2	27	23.9	28
123)	Satna	7.6	8.6	43.4	23	42.2	22	40.5	23	27.5	33	27	31	26.7	30
124)	Shillong	3.3	4.3	26.1	21	25.5	21	24.9	20	21.5	24	21.1	24	20.9	24
125)	Shivamogga	13.7	14.7	39	21	38	20	36.9	20	24	29	23.8	29	23.6	28
126)	Siliguri	8.6	9.6	36.3	30	35	28	33.9	28	30.8	32	30	31	29.1	32
127)	Silvassa	9	10.6	36.8	22	35.4	18	34.6	20	25.7	29	25.4	29	25	28
128)	Solapur	15.2	16.4	40.7	21	39.9	22	39.1	21	26.1	34	25.5	34	25.1	34
129)	Srinagar	-3.7	-2.4	31	20	29.9	20	28.9	20	22.4	30	21.9	28	21.3	26
130)	Surat	13.3	14.7	37.5	22	36.1	23	35.1	24	28.4	31	28.1	31	27.8	30
131)	Tezpur	11.2	12.1	34.5	29	33.8	26	33.1	27	29	32	28.6	32	28.2	32
132)	Thanjavur	18.8	19.8	41.5	26	40.5	25	39.3	25	27.4	35	27.1	32	26.9	31
133)	Thiruvananthapuram	22.5	23	34.3	26	33.6	25	33.1	26	27.8	32	27.4	31	27.2	32
134)	Thoothukudi	20.2	21	39.2	25	38.4	25	37.6	26	27.8	32	27.5	31	27.2	31

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Table 3 (*Concluded*)

Sl No.	City	Heating DB		Cooling DB/MCWB						Evaporation WB/MCDB					
		99.6 percent	99 percent	0.40 percent		1 percent		2 percent		0.40 percent		1 percent		2 percent	
(1)	(2)	(3)	(4)	(5)		(6)		(7)		(8)		(9)		(10)	
135)	Thrissur	19.3	20.3	37.8	26	36.1	27	34.8	25	28.8	31	28.6	32	28.2	31
136)	Tiruchrapalli	20	20.7	39	26	38.4	26	37.8	26	27.1	35	26.8	34	26.5	34
137)	Tirunelveli	20.3	21	41.8	24	40.3	25	39.1	24	26.5	30	26.2	30	26	31
138)	Tiruppur	16.4	17	31.9	20	30.8	20	29.9	18	21.9	25	21.6	24	21.4	24
139)	Tumakuru	14.7	15.5	37.8	19	36.4	20	35.2	18	22.3	30	21.9	30	21.5	28
140)	Udaipur	6.5	8.4	40.7	22	39.9	20	38.6	21	26.2	31	25.9	30	25.6	31
141)	Varanasi	8	9.9	43	24	42	24	41	24	28.7	35	28.4	33	27.9	33
142)	Vellore	15.9	16.7	42.1	23	40.3	23	38.8	22	25.6	29	25.3	31	25.1	30
143)	Veraval	15.5	16.5	35.2	22	34	26	33.2	28	28.8	33	28.5	32	28.3	32
144)	Vishakhapatnam	20	21.2	34	27	33.4	27	33	28	29.3	32	28.8	32	28.4	32
145)	Warangai	13.8	14.6	43.9	23	42.9	23	41.6	23	27.5	32	27.2	32	26.9	31

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3.6 Inside Design and Operating Conditions

One of the primary objectives of designing indoor environment is to ensure thermal comfort and indoor air quality of all occupants. Air conditioning, heating and mechanical ventilation (HVAC) system is employed to achieve thermal comfort inside building, when means to achieve the same only through building design is limited.

According to the internationally accepted definition, thermal comfort is that state of mind which expresses satisfaction with the indoor environment. The above definition clearly highlights the importance of both the psychological (mental) and physiological (physical) factors in determining acceptable thermal comfort conditions. The following five environmental parameters are important for thermal comfort and indoor air quality while designing the HVAC system because these are directly controllable by an HVAC system**:**

a) air temperature (ºC);

b) radiant temperature (ºC);

c) air speed (m/s);

d) relative humidity (percent); and

e) indoor air quality.

In addition to the above five environmental parameters, there are two personal or behavioural parameters that also affect thermal comfort but are not controllable by the HVAC system and they are:

1) activity rate (W/m^2); and

2) clothing insulation ($m^2.K/W$).

There are number of secondary parameters also which are important to define thermal comfort conditions such as, radiative temperature asymmetry, temperature gradient, and draught rate.

Air conditioning systems for interior spaces intended for human occupancy shall be sized for not more than 26 °C for cooling and for not less than 18 °C for heating at occupied level.

HVAC systems should also be designed to control the humidity. Relative humidity in occupied spaces should not fall below 30 percent and should not exceed 70 percent. Adequate measures should be provided in system design itself for keeping it in the prescribed range including humidification and dehumidification as needed.

Air velocity control should be used to facilitate thermal adaptation as well as to save energy as described in **3.6.1**. However, air velocity should not exceed 1.5 m/s at the work plane to avoid discomfort due to draft and fluttering of papers etc.

While the system sizing needs to be done for design conditions mentioned above, the systems should be provided with features that facilitate thermal adaptation to be practiced by occupants. Buildings should provide users and facility managers to control air velocity in spaces and around individuals so that higher temperature set point shall be kept for saving energy. Buildings should provide spaces to control the set point individually as the temperature at which set point is to be kept varies as per the change in outdoor conditions over the time.

In conditioned buildings, the values for quality of thermal environment parameters for representative occupant of a space shall be as specified in Table 4 below.

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Table 4 Conditions for Thermal Comfort

(*Clause* 3.6)

Sl No.	Air Velocity	Weather Condition	Level of Activity	Reference Table or Threshold Values
(1)	(2)	(3)	(4)	(5)
i)	Up to 0.2 m/s	Summer/winter	Met value ≤ 1.2	Table 5
ii)	Above 0.2 m/s	Summer/winter	Met value ≤ 1.2	Table 5 + Fig. 1 or Table 6
iii)	-	Summer	-	Relative humidity: 30 to 70 percent

Table 5 Acceptable Range of Operative Temperature with Air Velocity up to 0.2 m/s

(*Table 4*)

Sl No.	Level of Activity	Operative Temperature (°C)	
		Summer (Cooling Season) ~ 0.5 clo	Winter (Heating Season) ~ 1.0 clo
(1)	(2)	(3)	(4)
i)	Met > 1 and up to 1.2	23.0 ± 3.0	19.0 ± 4.0
ii)	Met ≤ 1.0	24.5 ± 2.5	22.0 ± 3.0

NOTE — At still air condition, operative temperature is the average of air temperature and mean radiant temperature. For details ISHRAE IEQ Standard 10001 can be referred.

High air velocity shall give opportunity of keeping higher air temperature without compromising thermal comfort. However, it is also suggested to keep under consideration noise and other effect of high indoor air velocity.

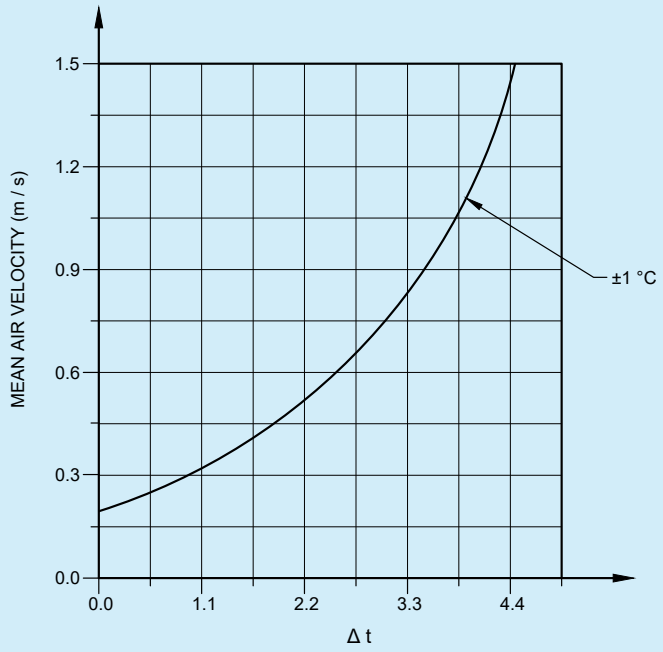

FIG. 1 REQUIRED AIR SPEED TO OFFSET INCREASED OPERATIVE TEMPERATURE (IN CELSIUS)

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3.6.1 *Designing for Using Adaptive Thermal Comfort in Operation*

Design based on use of an adaptive thermal comfort model during operation of building plays a major role in reducing energy use whilst maintaining the comfort, productivity and well-being of occupants. This approach recognizes that people's thermal comfort needs depend on their past and present context and that these needs vary with the outdoor environmental conditions of their location. For more details, refer Part D 'Building Services, Section 1 Lighting and Natural Ventilation' of this NBCS.

3.6.1.1 *Path A*

The general requirements concerning predominantly dry bulb temperature (DBT) and mean radiant temperature (MRT) based adaptive thermal comfort model which differentiates the thermal response of occupants in air conditioned and mixed-mode buildings. For more details, refer Part D 'Building Services, Section 1 Lighting and Natural Ventilation' of this NBCS.

3.6.1.2 *Path B*

Since in many buildings, especially where microclimatic interventions or where occupants from wide range of ambient/indoor conditions (outside of the period of occupancy in the building in consideration) are likely to be present, it may be difficult to determine their running mean monthly outdoor temperature and they are likely to display different order of thermal adaptation. This alternate path for estimation of thermal comfort is through calculation of standard effective temperature (SET) using the look up Table 6 and Table 7, given below provided option for determining set of indoor conditions that are likely to provide thermal comfort.

The recommended range of SET for Indian conditions over all types of buildings is 23.5 ºC to 25.5 ºC, with 80 percent acceptability. The term SET includes combined effect of all five parameters that govern thermal comfort, including various adaptive actions such as air velocity, adjusting clothing, adjusting temperature set point, adjusting activity level, and humidity. Same method shall be used in unconditioned buildings as well for assessment of thermal comfort.

The desired value of SET shall be achieved at different values of air temperatures depending upon the values of other parameters. This Table 6 and Table 7 shall also be used in designing radiant cooling systems, personalised air conditioning system etc.

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Table 6 Calculated Standard Effective Temperature for Adaptive Thermal Comfort

(*Clause* 3.6.1.2 *and Table* 4)

Standard Effective Temperature for Activity Level 1 Met (Office Work Type Activity) and Clothing 1.0 Clo (Winter Clothing)																																					
AT (°C) ↓	MRT (°C) →	14				16				18				20				22				24				26				28				30				32			
	AV (m/s) → RH (percent) ↓	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4
14	20	16.1	13.9	12.8	12.1	17	14.6	13.5	12.7	18	15.4	14.1	13.4	19	16.2	14.8	14	19.9	16.9	15.5	14.6	20.9	17.7	16.2	15.3	21.9	18.5	16.9	15.9	23	19.3	17.7	16.6	24	20.2	18.4	17.3	24.9	21	19.1	17.9
	40	16.2	14	13	12.3	17.2	14.8	13.6	12.9	18.1	15.5	14.3	13.5	19.1	16.3	15	14.2	20.1	17.1	15.7	14.8	21.1	17.9	16.4	15.4	22.1	18.7	17.1	16.1	23.1	19.5	17.8	16.7	24.1	20.3	18.5	17.4	25	21.1	19.3	18.1
	60	16.4	14.2	13.1	12.4	17.3	14.9	13.8	13.1	18.3	15.7	14.5	13.7	19.2	16.5	15.2	14.3	20.2	17.2	15.8	15	21.2	18	16.5	15.6	22.2	18.8	17.3	16.2	23.2	19.6	18	16.9	24.3	20.5	18.7	17.6	25.2	21.3	19.4	18.2
	80	16.5	14.3	13.3	12.6	17.4	15.1	13.9	13.2	18.4	15.8	14.6	13.9	19.4	16.6	15.3	14.5	20.3	17.4	16	15.1	21.3	18.2	16.7	15.8	22.3	19	17.4	16.4	23.4	19.8	18.1	17.1	24.4	20.6	18.9	17.7	25.4	21.4	19.6	18.4
16	20	17	15.1	14.2	13.7	17.9	15.9	14.9	14.3	18.9	16.6	15.6	14.9	19.8	17.4	16.2	15.5	20.8	18.2	16.9	16.1	21.8	18.9	17.6	16.8	22.8	19.7	18.3	17.4	23.8	20.5	19	18.1	24.7	21.4	19.8	18.7	25.6	22.2	20.5	19.4
	40	17.2	15.3	14.4	13.9	18.1	16	15.1	14.5	19	16.8	15.7	15.1	20	17.6	16.4	15.7	21	18.3	17.1	16.3	22	19.1	17.8	17	23	19.9	18.5	17.6	24	20.7	19.2	18.3	24.9	21.5	19.9	18.9	25.8	22.4	20.7	19.6
	60	17.3	15.5	14.6	14	18.2	16.2	15.3	14.7	19.2	17	15.9	15.3	20.1	17.7	16.6	15.9	21.1	18.5	17.3	16.5	22.1	19.3	18	17.2	23.1	20.1	18.7	17.8	24.1	20.9	19.4	18.4	25.1	21.7	20.1	19.1	26.1	22.5	20.8	19.8
	80	17.5	15.6	14.8	14.2	18.4	16.4	15.4	14.8	19.3	17.1	16.1	15.5	20.3	17.9	16.8	16.1	21.3	18.7	17.5	16.7	22.3	19.5	18.2	17.3	23.3	20.3	18.9	18	24.3	21.1	19.6	18.6	25.4	21.9	20.3	19.3	26.4	22.7	21	19.9
18	20	17.9	16.4	15.7	15.2	18.8	17.1	16.3	15.8	19.8	17.8	17	16.4	20.7	18.6	17.6	17	21.7	19.4	18.3	17.7	22.7	20.2	19	18.3	23.7	20.9	19.7	18.9	24.6	21.8	20.4	19.6	25.4	22.6	21.1	20.2	26.3	23.4	21.8	20.9
	40	18.1	16.5	15.9	15.4	19	17.3	16.5	16	19.9	18	17.2	16.6	20.9	18.8	17.8	17.2	21.9	19.6	18.5	17.9	22.9	20.4	19.2	18.5	23.9	21.1	19.9	19.1	24.8	21.9	20.6	19.8	25.7	22.8	21.3	20.4	26.6	23.6	22	21.1
	60	18.2	16.7	16.1	15.6	19.2	17.5	16.7	16.2	20.1	18.2	17.4	16.8	21.1	19	18.1	17.4	22	19.8	18.7	18.1	23	20.5	19.4	18.7	24.1	21.3	20.1	19.3	25	22.1	20.8	20	26	23	21.5	20.6	26.9	23.8	22.2	21.3
	80	18.4	16.9	16.3	15.8	19.3	17.7	16.9	16.4	20.3	18.4	17.6	17	21.2	19.2	18.3	17.7	22.2	20	18.9	18.3	23.2	20.7	19.6	18.9	24.3	21.5	20.3	19.5	25.4	22.3	21	20.2	26.4	23.1	21.7	20.8	27.4	24	22.4	21.5
20	20	18.8	17.6	17.1	16.7	19.7	18.3	17.7	17.3	20.6	19.1	18.4	17.9	21.6	19.8	19	18.5	22.6	20.6	19.7	19.1	23.6	21.4	20.4	19.8	24.5	22.2	21.1	20.4	25.3	23	21.8	21	26.1	23.8	22.5	21.7	27	24.4	23.2	22.3
	40	19	17.8	17.3	17	19.9	18.6	17.9	17.6	20.8	19.3	18.6	18.2	21.8	20.1	19.3	18.8	22.8	20.8	19.9	19.4	23.8	21.6	20.6	20	24.7	22.4	21.3	20.6	25.6	23.2	22	21.3	26.5	23.9	22.7	21.9	27.3	24.6	23.4	22.5
	60	19.2	18	17.5	17.2	20.1	18.8	18.2	17.8	21	19.5	18.8	18.4	22	20.3	19.5	19	23	21	20.2	19.6	24	21.8	20.8	20.2	25	22.6	21.5	20.9	26	23.4	22.2	21.5	26.9	24.1	22.9	22.1	27.8	24.9	23.6	22.8
	80	19.4	18.3	17.8	17.5	20.3	19	18.4	18	21.2	19.7	19.1	18.6	22.2	20.5	19.7	19.2	23.2	21.3	20.4	19.8	24.3	22	21.1	20.5	25.4	22.8	21.8	21.1	26.4	23.6	22.4	21.7	27.4	24.4	23.1	22.3	28.4	25.2	23.8	23
22	20	19.7	18.8	18.5	18.3	20.6	19.6	19.1	18.8	21.5	20.3	19.8	19.4	22.5	21	20.4	20	23.5	21.8	21.1	20.6	24.3	22.6	21.8	21.2	25.2	23.4	22.4	21.9	26	24	23.1	22.5	26.8	24.7	23.8	23.1	27.6	25.3	24.3	23.7
	40	19.9	19.1	18.7	18.5	20.8	19.8	19.4	19.1	21.8	20.5	20	19.7	22.7	21.3	20.7	20.3	23.7	22.1	21.3	20.9	24.6	22.8	22	21.5	25.5	23.6	22.7	22.1	26.4	24.3	23.4	22.7	27.3	24.9	24	23.4	28.1	25.6	24.6	23.9
	60	20.1	19.3	19	18.8	21	20.1	19.6	19.4	22	20.8	20.3	20	22.9	21.5	20.9	20.5	24	22.3	21.6	21.1	25	23.1	22.3	21.8	26	23.8	22.9	22.4	26.9	24.6	23.6	23	27.9	25.3	24.3	23.6	28.8	26	24.9	24.2
	80	20.3	19.6	19.3	19.1	21.3	20.3	19.9	19.6	22.2	21	20.5	20.2	23.2	21.8	21.2	20.8	24.4	22.6	21.8	21.4	25.5	23.3	22.5	22	26.6	24.2	23.2	22.6	27.6	25	23.9	23.2	28.6	25.8	24.6	23.9	29.6	26.6	25.3	24.5
24	20	20.6	20.1	19.9	19.8	21.5	20.8	20.5	20.3	22.4	21.5	21.1	20.9	23.4	22.3	21.8	21.5	24.3	23	22.4	22.1	25.1	23.7	23.1	22.7	25.9	24.4	23.8	23.3	26.7	25	24.3	23.9	27.5	25.6	24.8	24.3	28.3	26.2	25.3	24.8

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Table 6 (*Continued*)

Standard Effective Temperature for Activity Level 1 Met (Office Work Type Activity) and Clothing 1.0 Clo (Winter Clothing)																																							
AT (°C) ↓	MRT (°C) →	14				16				18				20				22				24				26				28				30				32			
	AV (m/s) → RH (percent) ↓	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4
	40	20.8	20.3	20.2	20.1	21.7	21.1	20.8	20.6	22.7	21.8	21.4	21.2	23.6	22.5	22.1	21.8	24.6	23.3	22.7	22.4	25.5	24	23.4	23	26.4	24.7	24	23.6	27.3	25.3	24.6	24.1	28.1	26	25.1	24.6	28.9	26.6	25.7	25.1
	60	21.1	20.6	20.5	20.4	22	21.4	21.1	20.9	22.9	22.1	21.7	21.5	24	22.8	22.4	22.1	25	23.6	23	22.7	26	24.3	23.7	23.3	27	25.1	24.3	23.8	28	25.8	24.9	24.4	28.9	26.5	25.6	25	29.8	27.2	26.2	25.6
	80	21.3	20.9	20.7	20.6	22.3	21.6	21.4	21.2	23.3	22.4	22	21.8	24.5	23.1	22.7	22.4	25.7	24	23.3	23	26.8	24.9	24.1	23.6	27.9	25.7	24.8	24.3	28.9	26.5	25.5	24.9	29.9	27.3	26.2	25.6	30.8	28.1	26.9	26.2
26	20	21.5	21.3	21.3	21.3	22.4	22	21.9	21.8	23.3	22.7	22.5	22.4	24.2	23.5	23.2	23	25	24.1	23.7	23.5	25.8	24.7	24.2	24	26.6	25.3	24.8	24.5	27.4	25.9	25.3	24.9	28.2	26.5	25.8	25.4	29	27.1	26.3	25.9
	40	21.7	21.6	21.6	21.6	22.7	22.3	22.2	22.1	23.6	23.1	22.8	22.7	24.6	23.7	23.5	23.3	25.5	24.4	24	23.8	26.4	25.1	24.6	24.3	27.3	25.7	25.2	24.8	28.1	26.4	25.7	25.3	29	27	26.3	25.8	29.8	27.7	26.8	26.3
	60	22	21.9	21.9	21.9	23	22.6	22.5	22.5	24.1	23.4	23.2	23	25.1	24.2	23.8	23.6	26.2	24.9	24.5	24.2	27.2	25.7	25.1	24.8	28.1	26.4	25.7	25.3	29.1	27.1	26.4	25.9	29.9	27.8	27	26.5	30.8	28.5	27.6	27
	80	22.3	22.2	22.2	22.2	23.5	23	22.9	22.8	24.8	23.9	23.6	23.5	26	24.8	24.4	24.1	27.2	25.7	25.1	24.8	28.3	26.5	25.9	25.5	29.3	27.4	26.6	26.1	30.3	28.2	27.3	26.8	31.3	28.9	28	27.4	32.2	29.7	28.7	28
28	20	22.4	22.5	22.6	22.7	23.3	23.2	23.3	23.3	24.1	23.8	23.8	23.7	25	24.4	24.3	24.2	25.8	25	24.8	24.6	26.6	25.6	25.3	25.1	27.4	26.2	25.8	25.5	28.1	26.8	26.3	26	28.9	27.3	26.8	26.4	29.7	27.9	27.3	26.9
	40	22.7	22.9	23	23.1	23.7	23.6	23.6	23.6	24.6	24.2	24.1	24.1	25.5	24.9	24.7	24.6	26.4	25.6	25.3	25.1	27.3	26.2	25.8	25.6	28.2	26.8	26.4	26.1	29	27.5	26.9	26.6	29.8	28.1	27.5	27.1	30.6	28.7	28	27.6
	60	23.1	23.3	23.4	23.5	24.2	24.1	24.1	24.1	25.3	24.8	24.7	24.7	26.4	25.6	25.4	25.2	27.4	26.4	26	25.8	28.4	27.1	26.6	26.4	29.3	27.8	27.2	26.9	30.2	28.5	27.9	27.5	31.1	29.2	28.5	28	31.9	29.9	29.1	28.6
	80	23.8	24	24.1	24.2	25.2	25	24.9	24.9	26.5	25.9	25.7	25.6	27.8	26.8	26.5	26.3	28.9	27.6	27.2	27	30	28.5	27.9	27.6	31	29.3	28.6	28.2	32	30	29.3	28.9	32.9	30.8	30	29.5	33.7	31.5	30.6	30.1
30	20	23.3	23.6	23.8	24	24.1	24.2	24.3	24.4	24.9	24.8	24.8	24.8	25.8	25.4	25.3	25.3	26.6	26	25.8	25.7	27.3	26.5	26.3	26.2	28.1	27.1	26.8	26.6	28.9	27.7	27.3	27	29.6	28.2	27.7	27.5	30.3	28.8	28.2	27.9
	40	23.7	24.1	24.3	24.5	24.7	24.8	24.9	25	25.6	25.4	25.4	25.4	26.5	26.1	26	25.9	27.4	26.7	26.5	26.4	28.3	27.4	27.1	26.9	29.2	28	27.6	27.4	30	28.6	28.1	27.9	30.8	29.2	28.7	28.4	31.5	29.8	29.2	28.8
	60	24.5	24.9	25.1	25.3	25.6	25.7	25.8	25.9	26.7	26.4	26.4	26.4	27.8	27.2	27	27	28.8	27.9	27.7	27.5	29.8	28.6	28.3	28.1	30.7	29.3	28.9	28.6	31.5	30	29.5	29.2	32.4	30.7	30	29.7	33.2	31.3	30.6	30.2
	80	25.9	26.4	26.6	26.8	27.3	27.3	27.4	27.5	28.7	28.2	28.2	28.1	29.9	29.1	28.9	28.8	31	29.9	29.6	29.4	32	30.7	30.3	30	33	31.5	30.9	30.6	33.9	32.2	31.6	31.2	34.7	32.9	32.2	31.8	35.5	33.5	32.8	32.3
32	20	24.1	24.6	24.9	25.1	24.9	25.2	25.4	25.5	25.7	25.8	25.9	25.9	26.5	26.3	26.3	26.4	27.3	26.9	26.8	26.8	28.1	27.5	27.3	27.2	28.8	28	27.8	27.6	29.6	28.6	28.2	28.1	30.3	29.1	28.7	28.5	31	29.6	29.2	28.9
	40	24.8	25.4	25.7	25.9	25.8	26	26.2	26.4	26.7	26.7	26.8	26.9	27.6	27.3	27.3	27.3	28.5	28	27.8	27.8	29.3	28.6	28.4	28.3	30.2	29.2	28.9	28.7	31	29.8	29.4	29.2	31.7	30.4	29.9	29.7	32.5	30.9	30.4	30.1
	60	26.1	26.7	27	27.3	27.2	27.5	27.7	27.8	28.3	28.2	28.3	28.4	29.4	28.9	28.9	28.9	30.3	29.7	29.5	29.4	31.3	30.3	30.1	30	32.2	31	30.7	30.5	33	31.6	31.2	31	33.8	32.3	31.8	31.5	34.5	32.9	32.3	32
	80	28.7	29.3	29.7	29.9	30.1	30.2	30.4	30.5	31.4	31.1	31.1	31.2	32.5	31.9	31.8	31.8	33.5	32.6	32.4	32.3	34.5	33.4	33	32.9	35.3	34	33.6	33.4	35.6	34.7	34.2	33.9	36.1	35.3	34.7	34.4	36.7	35.3	34.7	34.9

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Table 6 (*Continued*)

Standard Effective Temperature for Activity Level 1 Met (Office Work Type Activity) and Clothing 0.5 Clo (Summer Clothing)

AT (°C) ↓	MRT (°C) →	14				16				18				20				22				24				26				28				30				32			
	AV (m/s) → RH (percent) ↓	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4
14	20	11	7.2	5.3	4	12.1	8.2	6.2	4.9	13.3	9.1	7.1	5.7	14.4	10.1	8	6.5	15.6	11.1	8.9	7.4	16.8	12.2	9.8	8.3	18	13.2	10.7	9.1	19.2	14.2	11.7	10	20.4	15.2	12.6	10.9	21.6	16.3	13.6	11.8
	40	11.1	7.4	5.5	4.3	12.3	8.4	6.4	5.1	13.4	9.4	7.3	5.9	14.6	10.3	8.2	6.8	15.8	11.3	9.1	7.6	17	12.4	10	8.5	18.1	13.4	11	9.4	19.3	14.4	11.9	10.2	20.5	15.4	12.8	11.1	21.7	16.5	13.8	12
	60	11.3	7.6	5.8	4.5	12.4	8.6	6.6	5.4	13.6	9.6	7.5	6.2	14.8	10.6	8.4	7	15.9	11.6	9.3	7.9	17.1	12.6	10.3	8.7	18.3	13.6	11.2	9.6	19.5	14.6	12.1	10.5	20.7	15.6	13.1	11.3	21.9	16.7	14	12.2
	80	11.5	7.8	6	4.8	12.6	8.8	6.9	5.6	13.8	9.8	7.8	6.4	14.9	10.8	8.7	7.3	16.1	11.8	9.6	8.1	17.3	12.8	10.5	9	18.4	13.8	11.4	9.8	19.6	14.8	12.3	10.7	20.8	15.8	13.3	11.6	22	16.9	14.2	12.5
16	20	12.1	8.8	7.2	6.1	13.2	9.8	8.1	6.9	14.3	10.7	8.9	7.8	15.5	11.7	9.8	8.6	16.7	12.7	10.7	9.4	17.8	13.7	11.6	10.3	19	14.7	12.6	11.1	20.2	15.7	13.5	12	21.4	16.7	14.4	12.9	22.6	17.7	15.3	13.7
	40	12.2	9	7.5	6.4	13.4	10	8.3	7.2	14.5	11	9.2	8	15.7	11.9	10.1	8.9	16.8	12.9	11	9.7	18	13.9	11.9	10.5	19.2	14.9	12.8	11.4	20.4	15.9	13.7	12.2	21.5	17	14.7	13.1	22.7	18	15.6	14
	60	12.4	9.3	7.7	6.7	13.6	10.2	8.6	7.5	14.7	11.2	9.5	8.3	15.9	12.2	10.3	9.1	17	13.2	11.2	10	18.2	14.2	12.1	10.8	19.3	15.2	13.1	11.7	20.5	16.2	14	12.5	21.7	17.2	14.9	13.4	22.9	18.2	15.8	14.2
	80	12.6	9.5	8	7	13.7	10.5	8.8	7.8	14.9	11.4	9.7	8.6	16	12.4	10.6	9.4	17.2	13.4	11.5	10.2	18.3	14.4	12.4	11.1	19.5	15.4	13.3	11.9	20.7	16.4	14.2	12.8	21.9	17.4	15.1	13.6	23	18.4	16.1	14.5
18	20	13.1	10.4	9.1	8.2	14.3	11.3	9.9	9	15.4	12.3	10.8	9.8	16.5	13.3	11.7	10.6	17.7	14.3	12.6	11.4	18.8	15.2	13.4	12.3	20	16.2	14.3	13.1	21.2	17.2	15.2	13.9	22.3	18.2	16.2	14.8	23.5	19.2	17.1	15.6
	40	13.3	10.7	9.4	8.5	14.5	11.6	10.2	9.3	15.6	12.6	11.1	10.1	16.7	13.5	12	10.9	17.9	14.5	12.8	11.7	19	15.5	13.7	12.6	20.2	16.5	14.6	13.4	21.4	17.5	15.5	14.2	22.5	18.4	16.4	15.1	23.7	19.4	17.3	15.9
	60	13.6	10.9	9.7	8.8	14.7	11.9	10.5	9.6	15.8	12.8	11.4	10.4	16.9	13.8	12.2	11.2	18.1	14.8	13.1	12	19.2	15.7	14	12.9	20.4	16.7	14.9	13.7	21.6	17.7	15.8	14.5	22.7	18.7	16.7	15.4	23.9	19.7	17.6	16.2
	80	13.8	11.2	9.9	9.1	14.9	12.2	10.8	9.9	16	13.1	11.7	10.7	17.1	14.1	12.5	11.5	18.3	15	13.4	12.3	19.4	16	14.3	13.2	20.6	17	15.2	14	21.7	17.9	16.1	14.8	22.9	18.9	17	15.6	24	19.9	17.8	16.5
20	20	14.2	12	10.9	10.2	15.3	12.9	11.8	11	16.4	13.9	12.6	11.8	17.6	14.8	13.5	12.6	18.7	15.8	14.3	13.4	19.9	16.7	15.2	14.2	21	17.7	16.1	15	22.2	18.7	17	15.9	23.3	19.6	17.9	16.7	24.3	20.6	18.7	17.5
	40	14.4	12.3	11.3	10.6	15.6	13.2	12.1	11.4	16.7	14.2	12.9	12.2	17.8	15.1	13.8	12.9	18.9	16.1	14.7	13.7	20.1	17	15.5	14.6	21.2	18	16.4	15.4	22.4	18.9	17.3	16.2	23.5	19.9	18.1	17	24.5	20.8	19	17.8
	60	14.7	12.6	11.6	10.9	15.8	13.5	12.4	11.7	16.9	14.5	13.3	12.5	18	15.4	14.1	13.3	19.2	16.3	15	14.1	20.3	17.3	15.8	14.9	21.4	18.2	16.7	15.7	22.6	19.2	17.6	16.5	23.7	20.1	18.4	17.3	24.8	21.1	19.3	18.1
	80	14.9	12.9	11.9	11.3	16	13.8	12.7	12	17.1	14.8	13.6	12.8	18.3	15.7	14.4	13.6	19.4	16.6	15.3	14.4	20.5	17.6	16.1	15.2	21.6	18.5	17	16	22.8	19.5	17.9	16.8	23.9	20.4	18.7	17.6	25.1	21.3	19.6	18.4
22	20	15.3	13.6	12.8	12.3	16.4	14.5	13.6	13	17.5	15.4	14.4	13.8	18.6	16.3	15.3	14.6	19.7	17.3	16.1	15.4	20.9	18.2	17	16.1	22	19.2	17.8	16.9	23.1	20.1	18.7	17.7	24.2	21	19.5	18.5	25.1	22	20.3	19.3
	40	15.5	13.9	13.1	12.6	16.6	14.8	14	13.4	17.7	15.7	14.8	14.2	18.9	16.7	15.6	14.9	20	17.6	16.5	15.7	21.1	18.5	17.3	16.5	22.2	19.5	18.1	17.3	23.4	20.4	19	18.1	24.4	21.3	19.8	18.8	25.3	22.2	20.6	19.6
	60	15.8	14.2	13.5	13	16.9	15.1	14.3	13.8	18	16.1	15.1	14.5	19.1	17	16	15.3	20.2	17.9	16.8	16.1	21.3	18.8	17.6	16.9	22.5	19.7	18.5	17.6	23.6	20.7	19.3	18.4	24.7	21.6	20.1	19.2	25.7	22.5	20.9	19.9
	80	16.1	14.6	13.9	13.4	17.2	15.5	14.7	14.2	18.3	16.4	15.5	14.9	19.4	17.3	16.3	15.7	20.5	18.2	17.1	16.4	21.6	19.1	18	17.2	22.7	20	18.8	18	23.9	20.9	19.6	18.7	25	21.9	20.4	19.5	26.2	22.8	21.2	20.2
24	20	16.3	15.1	14.6	14.2	17.4	16	15.4	15	18.5	16.9	16.2	15.7	19.6	17.8	17	16.5	20.7	18.7	17.8	17.2	21.9	19.7	18.6	18	23	20.6	19.5	18.8	24	21.5	20.3	19.5	24.9	22.4	21.1	20.3	25.8	23.3	21.9	21

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Table 6 (*Continued*)

Standard Effective Temperature for Activity Level 1 Met (Office Work Type Activity) and Clothing 0.5 Clo (Summer Clothing)

AT (°C) ↓	MRT (°C) →	14				16				18				20				22				24				26				28				30				32			
	AV (m/s) → RH (percent) ↓	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4	0.2	0.6	1	1.4
	40	16.6	15.5	15	14.7	17.7	16.4	15.8	15.4	18.8	17.3	16.6	16.1	19.9	18.2	17.4	16.9	21	19.1	18.2	17.6	22.1	20	19	18.4	23.2	20.9	19.8	19.1	24.2	21.8	20.6	19.9	25.2	22.7	21.4	20.6	26.2	23.6	22.2	21.3
	60	16.9	15.9	15.4	15.1	18	16.7	16.2	15.8	19.1	17.6	17	16.5	20.2	18.5	17.8	17.3	21.3	19.4	18.6	18	22.4	20.3	19.4	18.7	23.5	21.2	20.2	19.5	24.6	22.1	20.9	20.2	25.7	23	21.7	20.9	26.7	23.8	22.5	21.7
	80	17.2	16.2	15.8	15.5	18.3	17.1	16.6	16.2	19.4	18	17.3	16.9	20.5	18.9	18.1	17.7	21.6	19.7	18.9	18.4	22.7	20.6	19.7	19.1	23.8	21.5	20.5	19.8	25.1	22.4	21.3	20.6	26.3	23.3	22	21.3	27.4	24.1	22.8	22
26	20	17.4	16.6	16.4	16.2	18.5	17.5	17.1	16.9	19.6	18.4	17.9	17.6	20.6	19.3	18.7	18.3	21.7	20.2	19.5	19.1	22.8	21.1	20.3	19.8	23.9	21.9	21	20.5	24.8	22.8	21.8	21.2	25.6	23.7	22.6	21.9	26.5	24.3	23.4	22.6
	40	17.7	17.1	16.8	16.6	18.8	17.9	17.6	17.3	19.9	18.8	18.3	18	21	19.7	19.1	18.8	22	20.5	19.9	19.5	23.1	21.4	20.6	20.2	24.2	22.3	21.4	20.9	25.1	23.1	22.2	21.6	26.1	23.9	22.9	22.3	27.1	24.6	23.7	23
	60	18	17.4	17.2	17.1	19.1	18.3	18	17.8	20.2	19.2	18.7	18.5	21.3	20	19.5	19.2	22.3	20.9	20.3	19.9	23.4	21.8	21	20.6	24.6	22.6	21.8	21.3	25.7	23.4	22.5	21.9	26.7	24.2	23.3	22.6	27.8	25	23.9	23.3
	80	18.4	17.8	17.6	17.5	19.4	18.7	18.4	18.2	20.5	19.5	19.1	18.9	21.6	20.4	19.9	19.6	22.6	21.2	20.6	20.2	23.9	22.1	21.4	20.9	25.2	22.9	22.1	21.6	26.5	23.8	22.9	22.3	27.7	24.8	23.6	23	28.8	25.7	24.4	23.6
28	20	18.4	18.1	18.1	18	19.5	19	18.8	18.7	20.6	19.8	19.6	19.4	21.7	20.7	20.3	20.1	22.7	21.6	21.1	20.8	23.8	22.4	21.8	21.5	24.6	23.2	22.6	22.1	25.5	24	23.3	22.8	26.4	24.6	23.9	23.5	27.2	25.2	24.5	24
	40	18.8	18.6	18.5	18.5	19.9	19.4	19.3	19.2	20.9	20.3	20	19.9	22	21.1	20.7	20.5	23.1	21.9	21.5	21.2	24.1	22.8	22.2	21.9	25.1	23.6	22.9	22.5	26.1	24.3	23.6	23.2	27	25	24.2	23.8	27.9	25.7	24.8	24.3
	60	19.2	19	19	19	20.2	19.8	19.7	19.6	21.3	20.7	20.4	20.3	22.3	21.5	21.2	21	23.4	22.3	21.9	21.6	24.6	23.1	22.6	22.3	25.8	24	23.3	22.9	26.9	24.8	24	23.5	27.9	25.6	24.7	24.1	28.9	26.4	25.4	24.8
	80	19.5	19.4	19.4	19.4	20.6	20.2	20.1	20.1	21.6	21.1	20.8	20.7	22.7	21.9	21.6	21.4	24.1	22.7	22.3	22	25.5	23.6	23	22.6	26.8	24.6	23.8	23.3	28.1	25.6	24.6	24.1	29.3	26.5	25.4	24.8	30.4	27.4	26.2	25.5
30	20	19.5	19.6	19.7	19.8	20.5	20.4	20.4	20.5	21.6	21.3	21.2	21.1	22.6	22.1	21.9	21.8	23.7	22.9	22.6	22.4	24.5	23.6	23.3	23.1	25.4	24.3	23.9	23.6	26.3	24.9	24.4	24.1	27.1	25.5	24.9	24.6	28	26.1	25.5	25.1
	40	19.9	20.1	20.2	20.3	20.9	20.9	20.9	21	22	21.7	21.6	21.6	23	22.5	22.3	22.2	24	23.3	23	22.8	25.1	24	23.6	23.4	26.1	24.7	24.2	24	27	25.4	24.8	24.5	28	26.1	25.4	25	28.9	26.8	26	25.6
	60	20.3	20.5	20.7	20.8	21.3	21.3	21.4	21.4	22.3	22.1	22.1	22	23.5	22.9	22.7	22.6	24.7	23.7	23.4	23.2	25.9	24.6	24.1	23.9	27.1	25.4	24.8	24.5	28.2	26.2	25.5	25.1	29.2	27	26.2	25.8	30.2	27.8	26.9	26.4
	80	20.7	21	21.1	21.2	21.7	21.8	21.8	21.9	22.7	22.5	22.5	22.5	24.4	23.6	23.3	23.1	26	24.7	24.2	24	27.4	25.7	25.1	24.8	28.8	26.7	26	25.5	30	27.7	26.8	26.3	31.2	28.6	27.6	27	32.3	29.4	28.4	27.7
32	20	20.5	21	21.3	21.5	21.5	21.8	22	22.1	22.6	22.6	22.7	22.7	23.6	23.4	23.3	23.3	24.5	24	23.8	23.8	25.3	24.6	24.4	24.2	26.2	25.2	24.9	24.7	27.1	25.8	25.4	25.2	27.9	26.4	25.9	25.6	28.7	27	26.4	26.1
	40	21	21.5	21.8	22	22	22.3	22.5	22.6	23	23.1	23.1	23.2	24.1	23.8	23.7	23.7	25.1	24.5	24.3	24.2	26.1	25.2	24.9	24.8	27.1	25.9	25.5	25.3	28	26.6	26.1	25.8	29	27.3	26.7	26.3	29.9	27.9	27.3	26.9
	60	21.4	22	22.3	22.5	22.4	22.7	22.9	23.1	23.6	23.6	23.7	23.7	25	24.5	24.4	24.4	26.2	25.4	25.1	25	27.4	26.2	25.9	25.7	28.6	27	26.5	26.3	29.6	27.8	27.2	26.9	30.7	28.6	27.9	27.5	31.6	29.4	28.6	28.1
	80	21.8	22.4	22.9	23.3	23.1	23.7	24	24.2	25.1	25	25	25.1	26.9	26.2	26	25.9	28.5	27.3	26.9	26.7	29.9	28.3	27.8	27.5	31.2	29.3	28.6	28.2	32.4	30.2	29.4	29	33.5	31.1	30.2	29.7	34.5	31.9	30.9	30.3

NOTE — AT: Dry bulb temperature of indoor air, AV: Air velocity around occupant, MET: Metabolic rate, Clo: Thermal resistance due to clothing, MRT: Mean radiant temperature

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Table 7 Minimum Ventilation Rates in Breathing Zone (*See* Notes 1 to 5)

(*Clause* 3.6.1.2)

(This table is not valid in isolation; it shall be used in conjunction with the accompanying notes)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air[1)] Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s.person	l/s.m^2		Persons per 100 m^2	l/s.person	
(1)	(2)	(4)	(6)	(7)	(8)	(10)	(11)
i)	Correctional facilities:						
	a) Cell	2.5	0.6	–	25	4.9	2
	b) Dayroom	2.5	0.3	–	30	3.5	1
	c) Guard Stations	2.5	0.3	–	15	4.5	1
	d) Booking/waiting	3.8	0.3	–	50	4.4	2
ii)	Educational facilities:						
	a) Daycare (through age 4)	5	0.9	–	25	8.6	2
	b) Daycare sickroom	5	0.9	–	25	8.6	3
	c) Classrooms (ages 5-8)	5	0.6	–	25	7.4	1
	d) Classrooms (age 9 plus)	5	0.6	–	35	6.7	1
	e) Lecture classroom	3.8	0.3	–	65	4.3	1
	f) Lecture hall (fixed seats)	3.8	0.3	–	150	4.0	1
	g) Art classroom	5	0.9	–	20	9.5	2
	h) Science laboratories	5	0.9	–	25	8.6	2
	j) University/college laboratories	5	0.9	–	25	8.6	2

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Table 7 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air[1)] Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s.person	l/s.m^2		Persons per 100 m^2	l/s.person	
(1)	(2)	(4)	(6)	(7)	(8)	(10)	(11)
	k) Wood/metal shop	5	0.9	–	20	9.5	2
	m) Computer lab	5	0.6	–	25	7.4	1
	n) Media centre	5	0.6	*See* Note 6	25	7.4	1
	p) Music/theatre/dance	5	0.3	–	35	5.9	1
	q) Multi-use assembly	3.8	0.3	–	100	4.1	1
iii)	Food and beverage service:						
	a) Restaurant dining rooms	3.8	0.9	–	70	5.1	2
	b) Cafeteria/fast-food dining	3.8	0.9	–	100	4.7	2
	c) Bars, cocktail lounges	3.8	0.9	–	100	4.7	2
iv)	General:						
	a) Break rooms	2.5	0.3	–	25	5.1	1
	b) Coffee stations	2.5	0.3	–	20	5.5	1
	c) Conference/meeting	2.5	0.3	–	50	3.1	1
	d) Corridors	-	0.3	–	-	-	1
	e) Storage rooms	-	0.6	*See* Note 7	-	-	1

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Table 7 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air[1)] Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s.person	l/s.m^2		Persons per 100 m^2	l/s.person	
(1)	(2)	(4)	(6)	(7)	(8)	(10)	(11)
v)	Hotels, motels, resorts, dormitories:						
	a) Bedroom/living room	2.5	0.3	–	10	5.5	1
	b) Barracks sleeping areas	2.5	0.3	–	20	4.0	1
	c) Laundry rooms, central	2.5	0.6	–	10	8.5	2
	d) Laundry rooms within dwelling units	2.5	0.6	–	10	8.5	1
	e) Lobbies/pre-function	3.8	0.3	–	30	4.8	1
	f) Multipurpose assembly	2.5	0.3	–	120	2.8	1
vi)	Office buildings:						
	a) Office space	2.5	0.3	–	5	8.5	1
	b) Reception Areas	2.5	0.3	–	30	3.5	1
	c) Telephone/data entry	2.5	0.3	–	60	3.0	1
	d) Main entry lobbies	2.5	0.3	–	10	5.5	1
vii)	Miscellaneous spaces:						
	a) Bank vaults/safe deposit	2.5	0.3	–	5	8.5	2
	b) Computer (not printing)	2.5	0.3	–	4	10.0	1

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Table 7 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air[1)] Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s.person	l/s.m^2		Persons per 100 m^2	l/s.person	
(1)	(2)	(4)	(6)	(7)	(8)	(10)	(11)
	c) Electrical equipment rooms	–	0.3	*See* Note 7	–	–	1
	d) Elevator machine rooms	–	0.6	*See* Note 7	–	–	1
	e) Pharmacy (preparation area)	2.5	0.9	–	10	11.5	2
	f) Photo studios	2.5	0.6	–	10	8.5	1
	g) Shipping/receiving	–	0.6	*See* Note 7	–	–	1
	h) Telephone closets	–	0.0	–	–	–	1
	j) Transportation waiting	3.8	0.3	–	100	4.1	1
	k) Warehouses	–	0.3	*See* Note 7	–	–	2
viii)	Public assembly spaces:						
	a) Auditorium seating area	2.5	0.3	–	150	2.7	1
	b) Places of religious worship	2.5	0.3	–	120	2.8	1
	c) Courtrooms	2.5	0.3	–	70	2.9	1
	d) Legislative chambers	2.5	0.3	–	50	3.1	1
	e) Libraries	2.5	0.6	–	10	8.5	1

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Table 7 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air[1)] Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s.person	l/s.m^2		Persons per 100 m^2	l/s.person	
(1)	(2)	(4)	(6)	(7)	(8)	(10)	(11)
	f) Lobbies	2.5	0.3	–	150	2.7	1
	g) Museums (children's)	3.8	0.6	–	40	5.3	1
	h) Museums/galleries	3.8	0.3	–	40	4.6	1
ix)	Residential:						
	a) Dwelling unit	2.5	0.3	*See* Notes 8 and 9	*See* Note 8	–	1
	b) Common corridors	–	0.3	–	–	–	1
x)	Retail:						
	a) Sales (except as below)	3.8	0.6	–	15	7.8	2
	b) Mall common areas	3.8	0.3	–	40	4.6	1
	c) Barbershop	3.8	0.3	–	25	5.0	2
	d) Beauty and nail salons	10	0.6	–	25	12.4	2
	e) Pet shops (animal areas)	3.8	0.9	–	10	12.8	2
	f) Supermarket	3.8	0.3	–	8	7.6	1
	g) Coin-operated laundries	3.8	0.3	–	20	5.3	2
xi)	Sports and entertainment:						
	a) Sports arena (play area)	–	1.5	*See* Note 10	–	–	1

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Table 7 (*Continued*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air[1)] Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s.person	l/s.m^2		Persons per 100 m^2	l/s.person	
(1)	(2)	(4)	(6)	(7)	(8)	(10)	(11)
	b) Gym, stadium (play area)	–	1.5	–	30	–	2
	c) Spectator areas	3.8	0.3	–	150	4.0	1
	d) Swimming (pool and deck)	–	2.4	*See* Note 11	–	–	2
	e) Disco/dance floors	10	0.3	–	100	10.3	1
	f) Health club/aerobics room	10	0.3	–	40	10.8	2
	g) Health club/weight rooms	10	0.3	–	10	13.0	2
	h) Bowling alley (seating)	5	0.6	–	40	6.5	1
	j) Gambling casinos	3.8	0.9	–	120	4.6	1
	k) Game arcades	3.8	0.9	–	20	8.3	1
	m) Stages, studios	5	0.3	*See* Note 12	70	5.4	1

[1)] Air Class Characteristic

1 Air with low contaminant concentration, low sensory-irritation intensity, and inoffensive odour.

2 Air with moderate contaminant concentration, mild sensory-irritation intensity, or mildly offensive odours. Class 2 air also includes air that is not necessarily harmful or objectionable but that is inappropriate for transfer or recirculation to spaces used for different purposes.

3 Air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odour.

4 Air with highly objectionable fumes or gases or with potentially dangerous particles, bio aerosols, or gases, at concentrations high enough to be considered harmful.

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Table 7 (*Concluded*)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p	Area Outdoor Air Rate, R_a	Notes	Default Values		Air[1)] Class
					Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)	
		l/s.person	l/s.m^2		Persons per 100 m^2	l/s.person	
(1)	(2)	(4)	(6)	(7)	(8)	(10)	(11)

NOTES

1 The rates in this table are based on all other applicable requirements being met.

2 This table applies to no-smoking areas only. Rates for smoking-permitted spaces shall be determined using other methods.

3 Volumetric airflow rates are based on an air density of 1.2 kg of dry air/m^3, which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 21°C. Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.

4 Actual occupant density should be considered, the default occupant density shall be used only when actual occupant density is not known. Default combined outdoor air (per person) rate is based on the default occupant density.

5 If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.

6 For high school and college libraries, use values shown for public assembly spaces- libraries.

7 The prescribed value may not be sufficient when stored materials include those having potentially harmful emissions.

8 Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.

9 Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

10 When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.

11 The prescribed value does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.

12 The prescribed value does not include special exhaust for stage effects, for example, dry ice vapours, smoke.

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3.6.2 *Designing for Air Quality*

The HVAC system shall be designed with adequate filtration for achieving following levels of indoor pollutants:

The threshold values for IAQ pollutants will be as mentioned in as per the Table 8 provided below. The buildings/indoor spaces will be classified as Class A, B and C where Class A refers to aspirational, Class B refers to acceptable and Class C refers to minimum acceptable.

Table 8 Threshold Values for IAQ Pollutants

(*Clause* 3.6.2)

Sl No.	Pollutants	Units	Classification		
			A	B	C
(1)	(2)	(3)	(4)	(5)	(6)
i)	CO_2	ppm	ambient + 350	ambient + 500	ambient + 700
ii)	$PM_{2.5}$	ug/m^3	< 15	< 25	< 25
iii)	PM_{10}	ug/m^3	< 50	< 100	< 100
iv)	O_3	ug/m^3	< 50	< 100	-
v)	TVOC (equivalent to isobutylene)	ug/m^3	< 200	< 400	< 500
vi)	CH_2O	ug/m^3	< 30	< 100	-
vii)	SO_2	ug/m^3	< 40	< 80	-
viii)	NO_2	ug/m^3	< 40	< 80	-
ix)	CO	ppm	< 2	< 9	< 9

NOTE — PM1.0 (sub-micron particles less than 1.0 µm in size) poses various health risks. PM1 particles may penetrate deep into the lungs and bloodstream, and prolonged exposure is associated with serious illnesses. Many bacteria and viruses are also within the PM1 size range, facilitating their spread indoors. The designers may consider filtration and air purification strategies that are effective in removing PM1 particles, thereby improving occupant well-being, productivity, and overall indoor air quality.

3.6.3 *Designing for Background Noise Control and Vibration*

The background noise and vibration created by air distribution through the HVAC system, combined with noise from equipment and outdoor sources of noise and vibration may causes significant disturbance to building users. Adoption of measures for adhering to indoor noise limits and vibration control should be ensured in the design of equipment, their foundation, supports and air distribution system.

4 HVAC SYSTEM TYPES

HVAC system requirements for the design, construction, installation, operation, replacement, repair, alteration, maintenance and end of life of mechanical cooling systems. It encourages the adoption of products designed with recyclability, reusability, and remanufacturing in mind, aiming to minimize waste, reduce environmental impacts, and promote resource efficiency throughout the entire lifecycle of the systems.

Following points to be considered for selection of cooling systems:

a) safeguard people from illness, injury or loss (including loss of amenity) due to the failure of air-conditioning installation;

b) it may be ensured that air-conditioning installation is suitable to meet the sizing requirement as per 3;

c) conserve water and energy;

d) safeguard the environment;

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e) safeguard public and private infrastructure; and

f) ensure that air-conditioning installation is designed and is capable of being maintained so that throughout its serviceable life it will continue to satisfy objectives (a) to (e).

Mechanical services, plant and equipment that are used for cooling, heating and/or ventilation of a building shall be adequate for the purpose meeting the basis of design. A building's HVAC system installation and maintenance shall support energy efficient outcomes and minimise any adverse impact on building occupants or occupants of adjoining places, the network utility operator's infrastructure, property and the environment.

Compliance with the requirement shall be verified either:

1) by satisfying the required criteria when tested in accordance with a specified test method endorsed by a recognised certification body; or

2) by calculation and certification by persons or organisations with recognised credentials in the testing of ventilation and air conditioning systems.

4.1 General

Systems for air conditioning may be broadly grouped as air-to-air, air-to-water, and liquid-to-liquid type. Suitability of system type shall not be generalized; hence it shall need to be building specific decision, considering initial cost, efficiency, maintenance, effect on building aesthetics, sound level, service life and other factors. Lower operating cost, central maintenance and control shall be of primary considerations.

It may be noted that central systems often require a higher initial cost than distributed systems but often result in annual energy savings. They also have a potential of reducing the total installed capacity by using load diversity. Over the life cycle, the centralized cooling systems usually prove to be more cost-effective when the total building load exceeds 350 kW (approximately 100 TR), depending on climate and patterns of occupancy use.

When low initial cost and simplicity are primary concerns, designers may select zone-by-zone distributed systems, incorporating either cooling or both heating and cooling facility. This approach shall normally be used for smaller buildings, however, larger buildings with multiple tenancy may also consider this as an option.

NOTES

1 Distributed systems, also known as unitary systems, individually consists of fan, cooling coil, compressor and outdoor condenser. Examples of distributed systems include unitary air conditioners, packaged rooftop air conditioners, variable refrigerant flows (VRFs), heat pumps, as well as refrigerant-based split-system fan-coil units (single or multi-unit).

2 Water-source heat pumps (WSHPs) are also considered as distributed systems in which the compressor is located close to the occupied space, but they are collectively served by a centralized water system with auxiliary heat rejection devices.

Comparative advantages, disadvantages and constraints of each option should be carefully evaluated before zeroing down to final HVAC system selection. Table 9 lists out various system characteristics of different HVAC systems; it may be used as a guiding tool for system selection.

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Table 9 HVAC System Analysis and Selection Matrix

(*Clause* 4.1)

Sl No.	System Characteristics	Fixed Speed Unitary Systems (Window ACs/Split ACs/ Package ACs)	Variable Speed/Flow/ Frequency/capacity Unitary Systems (Split ACs/ Package ACs)	Variable Speed Multi or Modular Systems (VRF)	Central Systems
(1)	(2)	(3)	(4)	(5)	(6)
i)	Temperature	No uniform and effective control	Minimal uniform and effective control possible	Reasonably uniform and effective control possible	Uniform and effective control possible
ii)	Humidity	Effective control not possible	Effective control not possible	Effective control not possible	Effective control possible
iii)	Space pressure	Effective control not possible	Effective control not possible	Effective control not possible	Effective control possible
iv)	Capacity requirements	Capacity to suit zone peak, No diversity	Capacity to suit zone peak, No diversity	Capacity to suit zone peak, Limited diversity shall be considered	Allows the design engineer to consider HVAC diversity factors that reduce installed equipment capacity
v)	Redundancy	Does not have the benefit of back-up or standby equipment	Does not have the benefit of back-up or standby equipment	It has the benefit of partial back-up or standby equipment	Back-up or standby equipment shall easily be accommodated
vi)	Facility management	Allows minimal provision to maximize performance using good facility management techniques in operation	Allows minimal provision to maximize performance using good facility management techniques in operation	Limited possibilities to maximize performance using good facility management techniques in operation	Allows maximize performance using good facility management techniques in operation

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Table 9 (*Continued*)

Sl No.	System Characteristics	Fixed Speed Unitary Systems (Window ACs/Split ACs/ Package ACs)	Variable Speed/Flow/ Frequency/capacity Unitary Systems (Split ACs/ Package ACs)	Variable Speed Multi or Modular Systems (VRF)	Central Systems
(1)	(2)	(3)	(4)	(5)	(6)
vii)	Spatial requirements	No plant/ equipment room required. Compromises building elevation	No plant/ equipment room required. Compromises building elevation	No plant/equipment room required. Outside units shall be located on roof or on adjacent ground. Very small depth but larger linear length (based on number of modular outdoor units) for shaft is required for refrigerant piping.	Equipment rooms/ spaces and accessible shaft required for chilled water piping
viii)	Electric supply	Distributed electric supply required	Distributed electric supply required	Zone wise distributed electric supply required	Minimal distribution cost by centralised supply near the substation
ix)	First cost	Minimum first cost	First cost marginally higher than fixed speed system	Moderate first cost but marginally higher than variable speed unitary product	Even with HVAC diversity, a central system may be of a bit higher or similar cost as a decentralized HVAC system
x)	Operating cost	Higher operating cost Strategic scheduling of multiple pieces of equipment shall save marginal operating cost. But equipment less efficient	Strategic scheduling of multiple pieces of equipment shall save reasonable operating cost. Higher peak energy requirement	Strategic scheduling of equipment shall save operating cost better than unitary product. Higher peak energy requirement	More energy-efficient primary equipment and multiple pieces of HVAC equipment allow staging of operation to match building loads while maximizing operational efficiency
xi)	Maintenance cost	Comparatively less maintenance cost	Maintenance cost marginally higher than fixed speed	Maintenance cost higher than both fixed and variable speed unitary system but less than central system	Comparatively higher since centralised equipment room requires operator with no access to occupant workspace, but with

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Table 9 (*Concluded*)

Sl No.	System Characteristics	Fixed Speed Unitary Systems (Window ACs/Split ACs/ Package ACs)	Variable Speed/Flow/ Frequency/capacity Unitary Systems (Split ACs/ Package ACs)	Variable Speed Multi or Modular Systems (VRF)	Central Systems
(1)	(2)	(3)	(4)	(5)	(6)
					fewer pieces of HVAC equipment to service
xii)	Reliability	Reliable equipment but low service life	Reliable equipment but low service life	Reliable equipment but moderate service life	Reliable equipment with much longer service life
xiii)	Flexibility	Has to be placed at fixed locations	Has to be placed at fixed locations	Can be placed at distributed locations	Flexibility available in terms of alternative locations
xiv)	Level of control	Limited control level available	Limited control level available	Moderate control level available	Close control level available
xv)	Noise and vibration	Noise and vibration within/adjacent to occupied spaces for unitary window type air conditioners which is substantially reduced in case of split system	It is generally available in split system only for which noise and vibration is substantially reduced in occupied and adjacent spaces as compared to a window type air conditioner	Noise and vibration on roof terrace or ground away from occupied spaces, however the same shall be reduced with good installation practices	Noise and vibration away from occupied spaces
xvi)	Constructability	Multiple and similar-in-size equipment makes standardization a construction feature	Multiple and similar-in-size equipment makes standardization a construction feature	Multiple and similar equipment makes standardization a construction feature	Require more coordinated installation with added benefit of consolidated primary equipment in a central location.

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4.1.1 *Window Air Conditioners*

Window Air Conditioners, as the name itself suggests, are usually fitted in a window or a recess created in a wall of a building. These are unitary direct expansion (DX) systems, having all the components packaged in a single box. The front side is designed to deliver the conditioned air to the connected space, and rear side shall be exposed to ambient for easy discharge of heat without any direct adverse effect on anyone else.

4.1.1.1 *Suitability*

Window air conditioners are suitable for residences, office cabin, general office area, and similar applications, where rigid comfort conditions are not required to be maintained.

4.1.1.2 *Limitations*

a) *Sound level* — Noise level of window air conditioner inside the conditioned room presents a serious problem due to close proximity of compressor to the occupied space;

   The noise level of window air conditioner shall be in accordance with the levels specified in Table 5 of accepted standard [D-3(4)];

b) *Fresh air for ventilation* — Most window air conditioners have a very small opening for entry of outdoor air for ventilation. As a result, the conditioned space, especially if occupied by more than 2-3 persons, may have higher levels of CO_2, as compared to centralised system; and

c) *Location* — Window air conditioner shall be mounted preferably at the window sill level on an external wall, where hot air from air-cooled condenser shall be discharged to the outdoor space without causing inconvenience to others. There should not be any obstruction for the inlet air to, nor for discharge air from, the condenser.

While deciding location of the window air conditioner, care shall be taken to ensure that the condensate drain water is piped to the ground level and does not drip in open space, causing nuisance.

Window air conditioner shall not be used for special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired, nor in applications where high amount of fresh air is desired for ventilation. It shall also not be used for areas that require close control of both the indoor temperature and relative humidity.

For detailed information regarding constructional and performance requirements and methods for establishing ratings of unitary (window) air conditioners, reference shall be made to the accepted standard [D-3(4)] and [D-3(5)].

4.1.1.3 For detailed information regarding constructional and performance requirements and methods for establishing rating of window type room air conditioners, reference shall be made to the accepted Indian standards.

4.1.2 *Split Air Conditioner*

Split air conditioners comprise of an indoor unit and an outdoor unit. Depending on its type, the Indoor unit may be mounted on either on floor, on wall, or at the roof. The outdoor unit consisting of compressor, heat exchanger, fan and motor; is installed in a separate independent cabinet. The indoor unit is an air handling system, designed primarily to provide conditioned air to an enclosed space, room or zone (conditioned space). It includes a prime source of refrigeration for cooling and dehumidification/heating and means for the circulation and filtering of air.

Various types of split air conditioners may be categorized based on type of compressor for outdoor unit and air-distribution for indoor unit, as below:

a) *Outdoor unit with variable speed compressor* — Also called an inverter AC or variable speed AC, works on part load depending on the demand for the conditioned space. This often uses a variable-frequency drive to control the frequency and thereby the speed of the compressor motor.

b) Outdoor unit with fixed speed compressor.

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c) *Free-blow indoor unit* — It could be high wall mounted, ceiling suspended cassette (exposed type), or floor-mounted.

d) *Indoor unit* (*ceiling suspended*) — It is mounted in the ceiling void and provided with a duct collar and grille. This is commonly used in the vestibule of a hotel room.

e) *Ducted indoor unit* — It is generally mounted in ceiling void and requires duct work for air distribution.

4.1.2.1 *Suitability*

Split air conditioners are suitable for wide range of applications including residence, small office, club, restaurant, showroom, departmental store and others except for locations having high occupancy and requirement of high ventilation rates.

4.1.2.2 *Operating parameters*

In general, nominal capacity of the split air conditioner is rated as per accepted standard [D-3(6)] for an ambient temperature of 35 °C. Split ACs gets de-rated at higher ambient temperature (above 35 °C) in summer months, in most Indian cities, and locations where for significant duration ambient temperature is likely to be above 35 °C, information related to capacity deration and reduction in energy efficiency shall be the basis of system sizing.

At locations having high voltage fluctuation and inferior power quality, a voltage stabilizer shall be required to get stabilized rated voltage as per specifications defined by manufacturer. For 3 phase unit, it is recommended to use phase reversal protection device in power supply to the outdoor unit.

4.1.2.3 *Location*

Split air conditioner indoor units are to be mounted within the air-conditioned space or above the false ceiling from where the air distribution ducts are to be taken to the conditioned space for distribution of the conditioned supply air. When the indoor unit is mounted in the false ceiling, inspection panel shall be kept in the false ceiling to attend to the indoor unit, and periodic cleaning requirement of air filter. Outdoor unit shall be mounted at the nearest open area where unobstructed flow of outside air is available for the air-cooled condenser.

4.1.2.4 *Installation*

Wall mounted unit and similar exposed indoor unit are to be provided with installation plate for ease in installation. Care shall be taken to ensure clearance space as specified by the manufacturer is provided. The intake of return air shall not have any restrictions.

Ceiling suspended indoor unit shall be provided with vibration absorbers and isolators to minimize vibration transmission to the ceiling.

Outdoor unit shall be mounted on metal frame with anticorrosive coating or made of corrosion resistant material in an open area so that the condenser outlet air is thrown out with no obstruction and possible return of the air to condenser inlet side. Precaution shall also be taken that hot air from any one outdoor unit does not mix with the outdoor air intake of any other air-cooled condenser. This is generally referred as short cycling of the air and shall be avoided. The spacing around the condenser unit shall be ensured as per the manufacturer's installation guideline and recommendation. In case of multiple outdoor units in the same premise, the installations of all the condensing units shall be such that the outlet air from condensers shall not mix with the air inlet of any of the condensing units.

Service valves shall be provided on the outdoor unit for pressure testing of the system for leakages, for evacuation of moisture and air from the system, and to carry out predetermined gas quantity charge into the system. In case of maintenance of any part, it shall be provided with service valves to isolate and store the entire refrigerant charge within the outdoor unit by pumping down, thus saving the entire charge of refrigerant.

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4.1.2.5 *Limitations*

Split air conditioners are not recommended for:

a) where distance between indoor and outdoor – Horizontal, vertical and total exceeds the limits as specified by manufacturers. Generally, the maximum of 30 m or higher as per recommendation of manufacturer from the outdoor unit for units up to 10 500 W (3 TR approximately), the horizontal distance between the indoor unit and outdoor unit should not exceed 10 m;

b) area requiring close and higher accuracy control of both the indoor temperature and relative humidity which is also referred as precision air conditioning;

c) special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired; and

d) spaces with large occupancy or high fresh air requirements.

4.1.2.6 For detailed information regarding constructional and performance requirements and methods for establishing rating of split type room air conditioners, reference shall be made to the accepted Indian standards.

4.1.3 *Ducted Split Air Conditioner*

Ducted split air conditioner (packages DX) units are ducted and packaged systems including rooftop and indoor packaged units in commercial air conditioning segment. Also known as unitary and light commercial systems, these typically should be used for small-to-medium commercial buildings to avoid the complexities associated with chilled water air conditioning systems. Packaged air conditioner shall be a self-contained unit suitable for floor mounting, or ceiling suspended ducted indoor units, designed to provide conditioned air through ducting in to the moderate sized conditioned spaces. It shall include a prime source of refrigeration for cooling and dehumidification, distinct facility for drawing of fresh air and mixing with return air, means for cleaning of mixed return and fresh air, and provision for external ducting for uniform air distribution in the conditioned spaces. If required, it shall also include winter heating and humidification package for winter operation. The machine shall be equipped with compressor, evaporator, expansion device and remote air-cooled condenser or water-cooled condenser with interconnected copper refrigerant piping.

Water cooled condenser packaged unit gives higher cooling capacity with lower power consumption as compared to an air-cooled condenser packaged unit which gets considerably de-rated in capacity for high (beyond 35 °C) ambient temperature in summer months for most of the cities in India. Air cooled package unit consequently also consumes more power in peak summer months. On the other hand, water-cooled condenser unit requires cooling tower with necessary piping and pump sets for circulating condenser-cooling water but is far more energy efficient at locations where ambient wet bulb temperatures are low in dry-summer months.

Water cooled systems shall be used where water for cooling is available. Treated wastewater, with proper TDS control shall be used in water cooled systems where available.

Packaged units with vertical air discharge should be used; however, if horizontal air discharge unit is procured then heat island effect would have to be avoided by providing clear unblocked space ahead of the condenser discharge.

4.1.3.1 *Suitability*

Packaged units are suitable for wide range of applications including office, club, restaurant, showroom, departmental store, banquet halls and others.

4.1.3.2 *Location*

Ducted split unit shall be mounted within the air-conditioned space with discharge air plenum or in a separate room from where the air distribution duct is taken to the conditioned space. While deciding location for the packaged unit, provision shall be kept for ease of servicing of the unit.

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4.1.3.3 *Installation*

Ducted split unit shall be normally mounted on resilient pads which prevent vibration of the unit from being transmitted to the floor.

4.1.3.4 *Limitations*

Packaged air conditioners are not recommended for:

a) large multi-storey buildings, where multiplicity of compressors may entail subsequent maintenance problems;

b) where the length of air distribution ducting may exceed 30 m. However, duct length limitation depends upon permissible external static pressure specified by the manufacturer;

c) where the vertical distance of air-cooled condenser from the packaged unit exceeds about 20 m. The sum of horizontal and vertical distance should generally be kept within 25 m;

d) special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired. For these applications, special packaged units are available with high micron efficiency filters; and

e) operation theatres, where 100 percent fresh air is needed and fire hazard exists depending on the type of anaesthesia being used.

4.1.4 *Variable Refrigerant Flow System*

Variable refrigerant flow (VRF) systems are direct expansion (DX) multi-split system with compressors having ability to vary the refrigerant mass flow rate and, capable of delivering capacity according to variable load requirement. By delivering the variable refrigerant flow, VRF unit delivers required cooling/heating capacity allowing for substantial energy savings at partial-load conditions. VRF system has an outdoor unit connected with multiple number of indoor units via refrigerant piping, an attribute that distinguishes VRF system from other DX system. Other advantages of VRF system are its scalability, variable capacity, distributed temperature control, and the simultaneous cooling/heating mode application in different connected zones.

VRF system achieves temperature control on a zone-by-zone basis primarily by using refrigerant side control. As compared to the basic DX system, VRF Indoor unit has an additional electronic expansion device to control refrigerant flow passing through evaporator coil, to control indoor temperature, precisely based on the instantaneous load requirement. Similar to other air-cooled systems, air cooled VRF systems get derated at temperatures higher than rating temperature 35 °C. Therefore, sizing calculation shall be carried out based upon the information provided by the manufacturer about cooling/heating and energy performance at elevated temperatures.

VRF system is available with a dedicated air handling unit for supply of treated fresh air (TFA). In order to cater to fresh air needs, VRF system outdoor unit should be connected with TFA-AHU. A control box equipped with electronic expansion device and communication PCB is needed for TFA-AHU so that it shall communicate seamlessly with the VRF system outdoor unit.

VRF technology comes in two pipe or three pipe system. In a 2-pipe heat pump system, all of the zones shall either be in cooling mode or in heating mode. Application requiring simultaneous heating and cooling should have 3 pipe systems for enabling heat recovery.

4.1.4.1 *Configuration*

VRF system is available with air cooled or water-cooled condenser. Outdoor unit in VRF system could have multiple compressors, with one or more compressor provided with variable speed control. Generally, for air cooled VRF system, outdoor unit is available both with top discharge and with side discharge.

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4.1.4.2 *Suitability*

VRF systems are suitable for a wide range of applications including residence, apartment, villa, small and big office, club, restaurant, showroom, departmental store, healthcare facility, hospitality, cultural facility, educational facility and industrial facility.

In VRF system, depending on application, same or different type of indoor units shall be connected to a single outdoor unit or to multiple outdoor units. VRF Indoor units and air handling units for fresh air or for special treatment of re-circulated air, shall be connected to the same refrigerant line, to facilitate more flexible system design, in mid and large size applications. However, usage of bigger AHU in VRF systems may have evident effect on the part load energy efficiency advantage of the system.

4.1.4.3 *Controls*

VRF systems shall have factory-packaged integral controls in each component; these communicate through their system specific protocol, to ensure that all system components operate collectively. VRF indoor and outdoor units include refrigerant and air side sensing and control devices which allow the system to optimize its output (compressor speed, discharge temperature, fan speed) based on inputs from controllers. Depending on the application and design, a VRF systems shall able to operate with at least one of the three different levels of controls: individual/group controller, centralized controller with remote monitoring and interface with building management system (BMS).

a) *Individual/group controller*

   VRF indoor units shall be controlled individually with wired or wireless individual remote controller. Control options include ON/OFF temperature change, mode change, fan speed change and integration with the BMS system of the building. Applications such as a large common area in which multiple indoor units are running simultaneously, at the same condition, shall be controlled by a single remote controller by combining these indoor units as a group. All setting conditions remain same for all indoor units connected in the group. Each of the grouped indoor unit may operate according to the sensed return air temperature.

b) *Centralized controller with remote monitoring and control*

   Centralized controller allows user to operate and monitor multiple indoor units centrally. Besides having all functions of individual remote controller, centralized controller has the additional facility of scheduling energy saving by operation restrictions, and web monitoring. In some applications, single outdoor unit is used by different tenants connected to different indoor units. In such cases, centralized controller offers facility of tenant billing through software application, depending on individual usage through proportional power distribution.

c) *Interface with building management system*

   VRF system shall be integrated with building management system if available, with the use of different interface gateways that communicate with different protocols. With this interfacing, it is easy to operate and monitor air conditioning with user's building management system.

4.1.5 *Liquid Chilling System*

Liquid chilling system may be based on chilled water, brine, or other secondary coolant for air conditioning or refrigeration. The most frequent application of water chilling is for air conditioning. However, brine cooling systems for low temperature refrigeration requirement and chilling fluids for thermal storage processes, are also common.

The basic components of a vapour-compression, liquid-chilling system shall include a compressor, liquid cooler (evaporator), condenser – which could be air cooled or water cooled), compressor drive, liquid-refrigerant expansion or flow control device and control centre; it also normally includes a receiver, economizer, expansion turbine and/or sub cooler. In addition, auxiliary components may be used, such as a lubricant cooler, lubricant separator, lubricant-return device, purge unit, lubricant pump, refrigerant transfer unit, refrigerant vents, and/or

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additional control valves. Liquid chilling units are available with air cooled or water-cooled condensers. Wherever water is available for cooling, water cooled chillers shall be opted for.

4.1.5.1 *Vapour compression water chiller*

The unit shall be installed on to a solid foundation on appropriately designed resilient mountings as per the manufacturer recommendation. Pipe connections shall have flexible couplings; these should be considered in conjunction with the design of the pump mountings and the pipe supports.

Capacity control is required in all the chillers that shall be capable to maintain an approximately constant temperature of the chilled water leaving the evaporator. This may be adequate for one or two chiller packages, but a more elaborate central control and plant optimization system is desirable for a large number of chillers. The design of the refrigeration control system should be integrated, or be compatible, with the control system for the heat transfer medium circulated within the cooler.

Multiple chiller configuration, same or different size and types shall be used to achieve the highest energy efficiency and adequate system capacity availability at all conditions. System COP shall be the basis for design and selection of equipment.

Power consumption during operation should be reduced by taking advantage of a fall in the ambient dry bulb and wet bulb temperatures, which permit a corresponding increase in chilled water temperature and decrease in the condenser water temperature, and consequent considerable reduction in the compressor power consumption. It is important to optimize operating cost by optimum equipment selection and careful design of the automatic control system.

The water chilling packages are classified based on the type of compressor, as given below:

a) *Centrifugal compressor* — These compressors use impellers to impart pressure energy to the refrigerant. These may be modulated down to approximately 40 percent of full load capacity, with careful control of the condensing pressure. Part load operation of centrifugal compressor should be restricted to 40 percent or above in order to avoid surging of compressor that may damage it if continues to occur.

   In order to save energy, centrifugal compressors with variable speed drives (VFD's) should be preferred over fixed speed chillers. VFD's are used on chillers not only to enhance the part load performance but also to act as an alternate to auto-tap change starter for minimizing the starting current for the compressor.

   Modern variable-speed oil-free centrifugal chillers have the shaft with impeller levitated during rotation, using digitally controlled magnetic bearings. This unique feature reduces the friction and heat caused by conventional bearings, adding to the overall high efficiency. It also eliminates the need for lubricating oil and the ancillary components required to support the lubricating oil system, which further improves efficiency.

b) *Screw compressor* — Screw compressors are available in open and semi-hermetic form and are generally coupled directly to two-pole motors. The capacity of the compressor may be modulated down to about 20 percent of full load capacity.

   Similar to centrifugal compressors, screw compressors with VFD's may be used as an effective way to enhance the part load performance and also minimize the starting current for the compressor.

   These are generally specified and used for capacities up to 1 400 kW (approximately 400 TR).

   In systems using a direct expansion evaporator (DX chiller), oil is trapped in the evaporator and an oil recovery system is necessary. With some systems, oil cooler is required in the oil circulation system, to remove the heat gathered by oil during compression cycle.

c) *Scroll Compressor* — Scroll compressors are generally used in residential and small/light commercial air-conditioning. Scroll chillers may be used in smaller sizes up to 425 kW. They offer relatively higher efficiency over other types of compressors, however, scroll compressors are not suitable for higher capacity range.

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d) *Reciprocating compressor* — Due to their relatively lower efficiency, reciprocating compressors are nearly phased out from the comfort air-conditioning application. However, for cold storage and other special purpose applications, these still have importance due to their capacity to offer high pressure ratio.

4.2 Vapour Absorption/Adsorption System

The absorption cycle uses a solution which, typically has two working fluids: an absorber and an absorbent. These fluids typically in liquid state, have significant change in solubility of the absorbent at different temperatures. Function of a vapor compressor is replaced by a liquid pump. The absorbent/refrigerant mixture is pumped to a higher pressure as a solution, where the refrigerant is boiled off by the application of heat and is subsequently condensed in the condenser.

Absorption machines are extensively used in liquid-chilling applications. These are most suitable for applications where waste heat is readily available. Solar energy assisted air-conditioning/cooling systems also use absorption system.

4.2.1 *Indirect Firing*

The lithium bromide/water absorption system shall be powered by medium or high temperature hot water and low or medium pressure steam. Water is the refrigerant and lithium bromide the absorbent. The four compartments enclosing the heat exchanger tube bundles for the condenser, evaporator, generator and absorber shall be in a single or multiple pressure vessel arrangement. The whole assembly has to be maintained under a high vacuum for the correct functioning of the unit. Water and absorbent solutions are circulated within the unit by electrically driven pumps.

Capacity control down to 10 percent of full load capacity is achieved by modulating the flow of the heating medium in relation to the cooling demand. There is some loss in performance at part load, which shall be compensated by refinements in the system design and control.

4.2.2 *Direct Firing*

Direct fired lithium bromide/water absorption systems have become common, by incorporating precise control of generator temperature necessary to avoid crystallization.

Ammonia/water systems are generally direct fired, but are rarely used for water chilling duties, except for small sized units, which are installed outside the building.

There are two reasons for this; firstly, capital costs are higher and secondly the danger to personnel in the event of leakage of the refrigerant.

Direct firing has the advantage that the losses in an indirect heating system are avoided, but in an air conditioning installation where a boiler system is installed to provide heating, the advantage is not of much concern.

Adsorption machines differ from absorption machines in the manner the two working media interact. Adsorption is a surface phenomenon, unlike absorption. More details about such systems are provided under 6.

5 REFRIGERANTS

The refrigerant is a working fluid used in the refrigeration cycle of a refrigeration and air conditioning system. Due to its deteriorating impacts on climate (especially ozone depletion and global warming) overview of the requirements for the safe use of refrigerants, except for ammonia, in mechanical or vapor-compression refrigeration and air conditioning systems that are partly or completely installed inside buildings shall be provided. It is intended for the guidance of the engineers, contractors, installers, and service technicians on the safe use of these systems and summarizes the guidelines applicable for the safe design, construction, installation, and operation of systems thereby providing insight of environmental impact of refrigerant emission and its management to minimize the emission of environmentally damaging refrigerants.

The refrigerant is a working fluid that is used in the refrigerating cycle of a refrigeration and air conditioning system {*see* accepted standards [D-3(2)], [D-3(5)], [D-3(7)], [D-3(8)], [D-3(9)], [D-3(10)] and [D-3(11)]}. Refrigerant molecules shall be broadly classified into three categories: halocarbons, organic compounds, and

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inorganic compounds. The halocarbons shall be further subdivided into chlorofluorocarbon (CFC), hydrochlorofluorocarbon (HCFC), hydrofluorocarbon (HFC), hydrofluoroolefin (HFO) and hydrochlorofluoroolefin (HCFO). The organic compounds consist mostly of hydrocarbons (HC). Inorganic compounds include carbon dioxide and ammonia. Both zeotropic and azeotropic mixtures of two or more pure refrigerants are also used as refrigerants.

5.1 Numbering of Refrigerants

Refrigerants are numbered with an R-, followed by the identification number. The identifying numbers for hydrocarbons (for example, assigned identification of propane is R-290) and halocarbons (for example, assigned identification of difluoromethane is R-32) are explicitly related to their chemical formula. Isomers are identified by appending lowercase letters at the end of the identifying number (for example 1,1,2,2-Tetrafluoroethane and 1,1,1,2-Tetrafluoroethane are isomers, which have assigned identification of R-134 and R-134a, respectively). Alkenes are identified by adding "1" at the beginning of the number determined by the above method. The structural isomers are identified by appending lower case letters at the end. The suffixes "(Z)" and "(E)" are used to differentiate cis- and trans- isomers. For example, R-1234yf, R1234ze(E) and R1234ze(Z) are all isomers of tetrafluoropropene. An inorganic compound is identified by the digit 7 at the hundreds place of the identifying number followed by its molecular weight (for example, assigned identification of Ammonia is R-717). Refrigerant blends having the same pure components are assigned the same number, but different compositions are identified with an uppercase letter after the number. Series 400 (for example, R-410A is a blend of 50 percent by weight of R-32 and 50 percent by weight of R-125) and 500 refrigerant (for example, R-507A is a blend of 50 percent by weight of R-143a and 50 percent by weight of R-125) blends are zeotropic and azeotropic, respectively.

5.2 Safety Group Classification

The Table 10 provides the toxicity and flammability-based classifications for refrigerant safety.

Table 10 Refrigerant Classification Based on Toxicity and Flammability

(*Clause* 5.2)

Sl No.	Flammability	Lower Toxicity Safety Group	Higher Toxicity Safety Group
(1)	(2)	(3)	(4)
i)	Higher Flammability	A3	B3
ii)	Flammable	A2L	B2L
iii)	Lower Flammability	A2L	B2L
iv)	No Flame Propagation	A1	B1

The accepted standard [D-3(2)] has also established the maximum refrigerant concentration limit (RCL) in the air to avoid escape-impairing effects such as asphyxiation, acute toxicity, and flammability in normally occupied enclosed spaces. The RCL is established based on the most conservative limit between asphyxiation, acute toxicity, and flammability. This safety group classification is referred to in the installation and maintenance standards for HVAC equipment {*see* accepted standard [D-3(8)], [D-3(9)], [D-3(10)] and [D-3(11)]}.

Product safety standards for AC equipment, such as accepted standard [D-3(5)] and [D-3(7)] specify safety requirements for electrically operated refrigeration and air conditioning appliances that have an incorporated compressor. Accepted standard [D-3(5)] deals with the safety of electrical heat pumps, air-conditioners, and dehumidifiers, while accepted standard [D-3(7)] deals with the safety of commercial refrigerating appliances.

Refrigerants should preferably be non-flammable or have lower flammability. The flammable refrigerant system shall be built with necessary protection system. Similarly, refrigerants with lower toxicity are preferable. Suitable risk mitigation processes and instruments should be implemented to mitigate risk to the occupants and the property per the accepted standards. Accepted standards [D-3(8)], [D-3(9)], [D-3(10)] and [D-3(11)], set forth requirements for safeguarding people and property where refrigeration facilities are located and prescribes safety requirements.

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5.3 Environmental Impact of Refrigerants

Refrigerants shall be released from the system during installation, minimizing refrigerant leaks, proper refrigerant recovery, and recycling during installation, operation, and disposal. Commercially used refrigerants shall be either ozone-depleting substances or greenhouse gases or shall be both. Releasing such refrigerants into the atmosphere shall be damaging to the environment. CFCs and HCFCs are ozone-depleting substances.

NOTE — India ratified the Montreal Protocol Agreement on Substances that Deplete the Ozone Layer in 1992 and CFCs in RAC units manufactured beyond 1 January 2003 have been phased out. The HCFCs are being phased out under the HCFC Phase-Out Management Plan (HPMP), and their use in RAC units manufactured beyond 1 January 2025 will be prohibited. The Kigali Amendment to the Montreal Protocol calls for the phase-down of HFCs due to their high GWP. India will complete its phase-down of HFCs in 4 steps from 2032 onwards with a cumulative reduction of 85 percent in 2047. The HFC phase-down schedule for India is scheduled to begin in 2032 and it will be completed in 2047. The baseline will be the average production and consumption of HFCs for the years 2024, 2025 and 2026. The quota will be frozen at the baseline level in 2028. The phase down will be achieved in four steps, with the cumulative reductions of production and consumption by 10 percent in 2032, 20 percent in 2037, 30 percent in 2042 and 85 percent reduction in 2047.

5.4 Classification of Commonly Used Refrigerants

The refrigerants shall be classified in accordance with accepted standard [D-3(2)] as listed in Table 11. This list is not exhaustive. The users must refer to tables from accepted standard [D-3(2)] for a complete list of refrigerants and accepted standards [D-3(8)], [D-3(9)], [D-3(10)] and [D-3(11)] for RCL values.

Table 11 Classification of Commonly Used Refrigerants

(*Clause* 5.4)

Sl No.	Refrigerant	Type	Refrigerant Safety Group Classification	Amount of Refrigerant in Occupied Space	
				RCL (g/m^3)	LFL (g/m^3)
(1)	(2)	(3)	(4)	(5)	(6)
i)	R11	CFC	A1	6.1	–
ii)	R12	CFC	A1	90	–
iii)	R22	HCFC	A1	210	–
iv)	R32	HFC	A2L	77	306
v)	R123	HCFC	B1	57	–
vi)	R134a	HFC	A1	210	–
vii)	R290	HC	A3	9.5	38
viii)	R404A	HFC	A1	500	–
ix)	R407C	HFC	A1	290	–
x)	R410A	HFC	A1	420	–
xi)	R448A	HFO	A1	390	–
xii)	R449A	HFO	A1	370	–
xiii)	R454A	HFO	A2L	52	293.9
xiv)	R454B	HFO	A2L	49	352.6
xv)	R454C	HFO	A2L	71	289.5
xvi)	R455A	HFO	A2L	79	432.1
xvii)	R513A	HFO	A1	320	–
xviii)	R514A	HFO	B1	14	–
xix)	R600a	HC	A3	9.5	38

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Table 11 (*Continued*)

Sl No.	Refrigerant	Type	Refrigerant Safety Group Classification	Amount of Refrigerant in Occupied Space	
				RCL (g/m^3)	LFL (g/m^3)
(1)	(2)	(3)	(4)	(5)	(6)
xx)	R744	CO_2	A1	72	–
xxi)	R1234yf	HFO	A2L	75	289
xxii)	R1234ze(E)	HFO	A2L	76	303
xxiii)	R1233zd(E)	HFO	A1	85	–
xxiv)	R1336mzz(Z)	HFO	A1	84	–

NOTE — The RCL/LFL data is taken from accepted standard [D-3(8)], [D-3(9)], [D-3(10)] and [D-3(11)].

5.5 Occupancy Based Classification

Refrigerating systems shall have different locations based on how the space connected to them is occupied, which shall depend on how people in that space react to possible refrigerant exposure.

5.5.1 *Institutional Occupancy*

Portion of a building which occupants shall not readily leave without assistance. For example, prisons, hospitals etc.

5.5.2 *Public Places/Public Assembly Occupancy*

Where large number of people gather, and the occupants shall not quickly leave the space due to large gathering. For example, restaurants, movie theatres, auditoriums etc.

5.5.3 *Residential Occupancy*

Where people/occupants live either permanently or temporarily. For example, home/apartment/hotel/hostel etc.

5.5.4 *Commercial Occupancy*

Where people/occupants gather to do commercial transactions like small shops/offices etc.

5.5.5 *Large Mercantile Occupancy*

Where occupants/people gather in large quantities like 70+ people gather to a big grocery store like Big Bazaar.

5.5.6 *Industrial Occupancy*

Occupancy where general public is not allowed. Only controlled people are allowed which shall be used for manufacturing or as a warehouse

5.6 Classification as per Leakage Probability

These guidelines classify systems based on their likelihood of leakage, ensuring appropriate safety measures and maintenance practices are in place for each classification.

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5.6.1 *Low Probability Systems* (*Indirect Systems*)

Any system where the design or placement of parts makes it unlikely that refrigerant will leak from a broken connection, seal, or component into the occupied space. Examples of low-probability systems include water-cooled chillers in machinery rooms.

5.6.2 *High Probability Systems* (*Direct Systems*)

Those systems where the components are designed or located in a way that makes it likely for refrigerant to leak into an occupied space from a broken connection, seal, or component. Examples of high-probability systems include direct expansion (DX) split systems, packaged DX rooftop units, and variable refrigerant flow (VRF) systems.

5.7 Classification as per System Locations

These guidelines categorize mechanical equipment by location to ensure safety and accessibility, from units within occupied spaces to those in dedicated machinery rooms or ventilated enclosures.

5.7.1 *Class* I – *Mechanical Equipment Located within the Occupied Space*

If the refrigerating system or any of its refrigerant-containing parts is located indoors in occupied space or non-occupied space that is not sealed from the occupied space or shall leak into the occupied space, then the system is considered to be of Class I unless the system complies with the requirements for other classes. Integral display units are typical examples of this category.

5.7.2 *Class* II – *Compressors and Pressure Vessels Outside the Occupied Space*

If all compressors and pressure vessels are outside the occupied space and refrigerant leaks from compressors or pressure vessels shall not flow into the occupied space then the requirements for a class II location shall apply to any refrigerant containing part located in the occupied space or that shall leak into the occupied space. Coil-type heat exchangers and pipework, including valves, may be located in an occupied space.

Refrigerant shall leak into the occupied space through heat transfer fluid if, for example:

a) the heat transfer fluid is ventilation air;

b) the heat transfer fluid is an open spray system;

c) leakage of the refrigerant into the occupied space is caused by leakage of the refrigerant into the heat transfer fluid; or

d) there is a heat transfer fluid relief valve or an automatic purge point vents into the space.

5.7.3 *Class* III – *Machinery Room or Open Air*

The requirements for a Class III location shall apply to any refrigerant containing part located in the open air or in a machinery room that is as per the requirements of accepted standard [D-3(10)]. Water or air-cooled chillers are typical examples of this type.

5.7.4 *Class* IV – *Ventilated Enclosures*

If, with the intent of preventing migration of leaked refrigerant to the surrounding area, refrigerant-containing parts are located in a ventilated enclosure that is as per the requirements of accepted standard **5.2.17** of [D-3(9)] and **4.6** of [D-3(10)] then the requirements for a Class IV location shall apply.

Heat pumps within a ventilated enclosure are typical examples.

5.8 Classification as per Access to Occupied Spaces, Machinery Rooms and Open Air

Access classification shall be determined according to Table 12.

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The access category is defined according to Table 12 by consideration of the group of occupants who are least familiar with the safety precautions. For example, in a supermarket, department store or transport terminus an unregulated number of customers who are not familiar with the location or its safety precautions shall gather. In a general office the number of people in the building is more easily regulated and occasional visitors will be accompanied by a regular occupant who shall advise on the safety precautions in the event of an emergency. In a manufacturing facility all of the occupants will be familiar with the safety requirements and access to the workplace will be restricted.

A complex building shall contain several access categories, for example the public areas and the plant rooms in a hospital shall be classified as access Category A and access Category C respectively.

Table 12 Categories of Access

(*Clause* 5.8)

Sl No.	Categories	General Characteristics	Examples
(1)	(2)	(3)	(4)
i)	A	General access (least restrictive access to the space) Parts of buildings where a) Sleeping facilities are provided, b) People are restricted in their movement, c) An uncontrolled number of people are present, or d) To which any person has access without being personally acquainted with the necessary safety precautions.	Hospitals, courts or prisons, theatres, supermarkets, schools, lecture halls, public transport termini, hotels, dwellings, restaurants, car parks, footpaths, gardens
ii)	B	Supervised access Parts of buildings where only a limited number of people shall be assembled, some being necessarily acquainted with the general safety precautions of the establishment.	Business or professional offices, laboratories, places for general manufacturing, where people work, delivery zones and some non-public areas in supermarkets
iii)	C	Authorized access (most restrictive access to the space) Parts of buildings where only authorized persons have access, who are acquainted with general and special safety precautions of the establishment and where manufacturing, processing, or storage of material or products take place.	Manufacturing facilities, for example, for chemicals, food, cold stores, some non-public areas in supermarkets, fenced outdoor compounds or roofs with restricted access

Open air locations including roofs, car parks and outdoor equipment compounds are considered to be parts of the building. Machinery rooms shall not be considered as occupied space except as defined in **5.1** of accepted standard [D-3(10)].

Refrigerant quantity limits shall be as per accepted standard [D-3(8)] expect for:

a) *Institutional Occupancy* — Consider a safety factor of 0.5 (limiting the charge to 50 percent of the calculated charge) while calculating the charge limits;

b) *Residential Occupancy* — Listed self-contained systems limited to 3 kg charge limit;

c) *Commercial Occupancy* — Listed self-contained systems limited to 10 kg charge limit; and

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d) Industrial occupancy and large mercantile occupancy spaces to follow requirements of charge limits in accepted standards [D-3(8)], [D-3(9)], [D-3(10)] and [D-3(11)].

5.9 Mixing of Refrigerants

Refrigerants with different refrigerant designations as per accepted standard [D-3(2)] shall not be mixed.

5.10 Purity

Refrigerants used in refrigeration systems shall be new, recovered or reclaimed refrigerants as per below.

5.10.1 *New Refrigerants*

Refrigerants shall be of purity level specified by the equipment or appliance manufacturer as per accepted standard [D-3(12)].

5.10.2 *Recovered Refrigerants*

Shall not be used in the refrigeration system as it may not meet the quality requirements of a system.

5.10.3 *Recycled Refrigerants*

Refrigerants that are recovered from refrigeration and air-conditioning systems shall not be used in other than the system from which they were recovered and in other systems of the same owner.

5.10.4 *Reclaimed Refrigerants*

Used refrigerants shall not be reused in a different owner's equipment or appliances unless tested and found to meet the purity requirements. Contaminated refrigerants shall not be reused unless reclaimed and found to meet the purity requirements. For additional information on purity requirements of refrigerants refer to accepted standard [D-3(12)].

5.10.5 High probability direct systems for human comfort applications shall only use A1 and A2L refrigerants. If the equipment is listed, it shall follow the requirements of accepted standard [D-3(5)] and [D-3(7)]. If the system is designed and installed at site, the requirements of accepted standards [D-3(8)], [D-3(9)], [D-3(10)] and [D-3(11)] will follow.

5.11 Machinery room/plant room systems shall follow accepted standards [D-3(8)], [D-3(9)], [D-3(10)] and [D-3(11)] requirements.

5.12 Lifecycle Management of Refrigerants

Lifecycle management of refrigerants shall encompass all phases from design, manufacturing, installation, operation, servicing, to decommissioning and end-of-life. In the design stage, appropriate selection of corrosion-resistant materials, robust packaging for transport and handling, protective coatings on brazed joints, and dimensioning of interconnecting tubes to prevent fractures shall be ensured. Manufacturing processes such as brazing shall be carried out under controlled conditions to minimize leakage risks. During installation and commissioning, only trained and certified technicians shall be permitted, using calibrated tools (for example, torque wrenches) and considering environmental conditions at site. In line with the *Kigali Amendment*, the phasedown of HCFCs and high-GWP HFCs shall be undertaken in accordance with national schedules, with preference given to adoption of lower-GWP alternatives such as olefins (HFOs).

At the operational and end-of-life stages, systems shall incorporate leak detection, regular monitoring, and timely repair. Recovery, recycling, reclamation, or safe destruction of refrigerants shall be carried out in accordance with the *E-Waste* (*Management*) *Rules*, the *Hazardous Waste Management Rules*, and relevant CPCB guidelines. Venting of refrigerants during maintenance, servicing, or decommissioning shall be strictly prohibited. All systems using flammable refrigerants shall be evacuated with vacuum pumps and purged with nitrogen as per manufacturer's specifications. Producers and manufacturers shall bear extended producer responsibility (EPR) for the collection and environmentally sound management of appliances containing refrigerants at end-of-life. Certified recovery and destruction facilities shall be used, with proper record-keeping and reporting to CPCB/state

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pollution control boards. Awareness among consumers, technicians, and service providers shall be promoted to ensure safe handling and environmentally responsible lifecycle management of refrigerants.

5.12.1 *Refrigerant Recovery*

When decommissioning an appliance that contains refrigerant, it should be properly recovered using certified equipment before servicing or disposing of the appliance.

5.12.2 *Certified Technicians*

Only individuals who are certified under Ozone Cell Regulations are allowed to handle and remove refrigerant from appliances.

5.12.3 *Responsible Disposal*

The final person or entity responsible for the disposal of the appliance (for example, scrap metal recyclers, landfills) should ensure that the refrigerant has been recovered beforehand.

5.12.4 *Documentation*

If the final disposer accepts an appliance that has had its refrigerant charge removed, they should maintain a signed statement from the person who removed the refrigerant. This statement should include details like the name and address of the person who performed the recovery and the date of recovery.

5.12.5 *Recovered Refrigerant Usage*

Recovered refrigerants should generally be reused only in the system from which they were recovered or in other systems owned by the same entity in line with **5.10.2** and **5.10.3**.

5.12.6 *Reclaiming Contaminated Refrigerant*

Contaminated refrigerants cannot be reused unless they are reclaimed to meet the purity requirements as per the accepted standard [D-3(12)] and in line with **5.10.4**.

5.12.7 *Filtering and Drying*

Recovered refrigerants should be filtered and dried before reuse.

Venting of refrigerants to the atmosphere should be avoided. During commissioning, any purging, if necessary, should be done outside or in a well-ventilated area to avoid formation of flammable or toxic atmosphere.

5.13 Total Equivalent Warming Impact (TEWI)/Life Cycle Climate Performance (LCCP)

There are 2 metrics used to calculate the greenhouse impact of a product/equipment over its lifetime. This is given in terms of its equivalent CO_2 emissions; in kg or Tonnes depending upon its absolute value.

The second metrics an extension of the first one in that it includes even the warming impact due to the manufacturing of the product as well as the indirect emission due to the atmospheric decomposition of the refrigerant including the energy consumed during the manufacture of the raw materials. For example, consider a Window unit. The coils are made of copper tubes and aluminium fins. Thus, if the copper tube manufacturing process and/or aluminium fin stock manufacturing process is highly energy inefficient then it will reflect badly in the LCCP of the Window unit. LCCP is more comprehensive as it has a “cradle to grave” approach and it has its merit in evaluating the overall impact.

The following equation gives the expression for calculating TEWI for a particular product (it shall not be generalized; it is application/product specific):

$$TEWI = GWP \times L \times n + GWP \times m \times (1-\alpha) + n \times E \times \beta$$

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where

GWP	=	Refrigerant global warming potential (kg of CO_2/kg of refrigerant);
L	=	Annual leakage rate (kg/year);
n	=	System operating life time (years);
m	=	Refrigerant charge (kg);
α	=	Recycling factor (percent);
E	=	Annual energy consumption (kWh/year); and
β	=	CO_2 emissions on energy generation [kg CO_2/kWh].

The above equation is considering both the direct (due to refrigerant leakage/non recycling) and the indirect effect (due to energy consumption). TEWI is completely product/system/location dependent and shall not be generalized. However, it does give an idea as to how the indirect impact is much more than the direct impact. With the new low-GWP refrigerants being introduced, the value(s) of TEWI would be different than what they were with the old high-GWP refrigerants. Also, an important parameter is the β factor. This is based on the location/country where the system is operating. It is directly dependent on the fuel source/type of power generation plants being used to supply the electrical power. Naturally if the major source of power generation is fossil fuel. Coal-based thermal power generation then this factor will be high, and which turn will result in higher TEWI.

The following equation gives the expression for calculating LCCP for a particular product:

$$LCCP = Direct\ Emissions + Indirect\ Emissions$$

$$Direct\ Emissions = C \times (L \times ALR + EOL) \times (GWP + Adp.GWP)$$

$$Indirect\ Emissions = L \times AEC \times EM + \sum(M \times mm) + \sum(mr \times RM) \times + C(1 + L \times ALR) \times RFM + C \times (1 - EOL) \times RFD$$

where

C	=	Refrigerant charge (kg);
L	=	Average lifetime of equipment (year);
ALR	=	Annual leakage rate (percent of refrigerant charge);
EOL	=	End of life refrigerant leakage (percent of refrigerant charge);
GWP	=	Global warming potential (kg CO_{2e}/kg);
Adp. GWP	=	GWP of atmospheric degradation product of the refrigerant (kg CO_{2e}/kg);
AEC	=	Annual energy consumption (kWh);
EM	=	CO_2 Produced /kWh (kg CO_{2e}/kg);
M	=	Mass of unit (kg);
MM	=	CO_2 Produced/material (kg CO_{2e}/kg)
mr	=	Mass of recycled material (kg);
RM	=	CO_{2e} Produced/recycled material (kg CO_{2e}/kg);
RFM	=	Refrigerant manufacturing emissions (kg CO_{2e}/kg); and
RFD	=	Refrigerant disposal emissions (kg CO_{2e}/kg).

The above equation is as per the Guideline for LCCP recommended by International Institute for Refrigeration.

When it comes to selecting refrigerants and equipment, both choices are crucial due to their direct impact on a user's scope 1 and scope 2 emissions. Scope 1 emissions encompass direct greenhouse gas (GHG) emissions, which, in the case of refrigerants, primarily result from gas leakage at the premises. To mitigate these emissions, it is vital to adopt low global warming potential (GWP) refrigerants that minimize the environmental impact.

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However, as we push for the rapid adoption of these low-GWP refrigerants, it is equally important to ensure that the efficiency and capacity of the equipment are not compromised. This balance is required because any reduction in equipment performance shall increase scope 2 emissions, which are indirect GHG emissions from the energy consumed by the equipment.

Leveraging digitally enabled and AI-driven solutions shall significantly enhance our approach to managing refrigerants. These advanced technologies provide predictive insights that help prevent gas leakages, reducing the need for technician visits and minimizing downtime for repairs. By integrating generative AI, we shall proactively address potential issues, further reducing scope 1 emissions by preventing leaks before they occur. Moreover, reducing technician visits not only lessens service providers' tailpipe emissions lowering the end user's scope 3 emissions, which are indirect emissions from third-party activities.

When selecting equipment and refrigerants, it's crucial to consider the Total Equivalent Warming Impact (TEWI), which factors in both scope 1 and scope 2 emissions. This comprehensive approach ensures that the chosen solutions are sustainable over their entire lifecycle. Additionally, implementing digitization, advanced leak detection systems, and remote monitoring of refrigerants shall effectively map and manage the operational emissions associated with the equipment's deployment at a user's premise. These technologies ensure that emissions are minimized, aligning with broader sustainability goals and regulatory requirements.

In summary, achieving a balanced and strategic selection of refrigerants and equipment, underpinned by AI and digital solutions, for reducing scope 1, scope 2, and scope 3 emissions. This integrated approach supports the fast-tracking of low-GWP refrigerants while maintaining operational efficiency and capacity, ultimately contributing to a more sustainable and compliant future in building operations.

6 LOW ENERGY COOLING

In addition to the popular air-conditioning options and traditional passive cooling options, various types of modern low energy heating/cooling solutions have also emerged which may be used to provide thermal comfort to occupants using alternative strategies. These include direct, indirect and hybrid evaporative cooling, radiant cooling/heating, structural cooling, solar assisted cooling/heating, and few others.

6.1 Evaporative Air Coolers

Evaporative coolers use the process of evaporation of water to lower air temperature. This method of comfort cooling not only conserves energy but also offers numerous benefits for environment. The principle for evaporative air cooling is straightforward: when water evaporates, it absorbs latent heat of evaporation from the surrounding air, thereby cooling the air. This is also termed as adiabatic cooling. This process is most effective in arid and semi-arid climates where the humidity is low, making evaporation more efficient.

An evaporative cooler typically consists of a fan, absorbent pads, a water reservoir and some kind of water distribution system including pump to distribute water on the pads, and often some set of louvers/deflectors to guide air to desired direction.

The process is:

a) the fan draws warm, dry air from the outside into the cooler;

b) the air passes through the water-saturated pads, where the water evaporates, and thereby absorbing heat from the air; and

c) the cooler but more humid air is then blown into the living space, lowering the temperature.

6.1.1 *Advantages of Evaporative Cooling*

These points highlight the key benefits and positive aspects of the specified system or approach, emphasizing efficiency, performance, and practicality.

a) *Energy efficiency* — Evaporative coolers consume significantly less energy compared to conventional air conditioners. They use only the power needed to run the fan and water pump, resulting in lower electricity bills and reduced carbon footprint;

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b) *Environmental benefits* — Traditional air conditioners use refrigerants like CFCs and HFCs, which are harmful to the environment. Evaporative coolers, on the other hand, do not use these chemicals, making them an eco-friendly alternative;

c) *Cost-effective* — The initial purchase cost and maintenance expenses of evaporative coolers are significantly lower than those of air conditioning systems for a given cooling area. Evaporative air coolers have fewer mechanical parts, which means there are fewer components that shall break down;

d) *Improved air quality* — Evaporative coolers add moisture to the air, which shall be beneficial in dry climates where low humidity shall cause respiratory problems and dry skin. They also filter out dust and pollen as the air passes through the pads, improving indoor air quality;

   At times, several processes need humidity (for example, paper mill, garment industry, etc) and hence evaporative air cooling serves dual purpose of cooling and providing humidity; and

e) *Easy installation and maintenance* — These coolers are relatively simple to install, requiring only a water source and an electrical outlet. Maintenance is straightforward, typically involving the periodic cleaning or replacement of pads and ensuring the water reservoir is filled.

6.1.2 *Applications of Evaporative Cooling*

These points describe the various uses and suitable scenarios for implementing evaporative cooling, focusing on its effectiveness in specific environments and conditions. Following are some of different uses:

a) *Residential use* — They are ideal for cooling homes in dry climates. Portable models shall be moved from room to room, providing flexible cooling solutions. Even table top models are available for personal cooling purposes. Window or wall mounted units are available too;

b) *Commercial and industrial use* — Large evaporative coolers shall be used in showrooms, restaurants, institutes, warehouses, factories, and workshops where traditional air conditioning may be impractical or too expensive especially in semi-open spaces;

c) *Outdoor cooling* — Evaporative coolers are popular for outdoor events, patios, and agricultural applications. They shall create comfortable environments in open spaces where conventional cooling systems are ineffective; and

d) *Greenhouses* — These coolers are beneficial in horticulture for maintaining optimal temperature and humidity levels, promoting healthy plant growth. Other related uses are poultry farms, pig farms, etc.

6.1.3 *Sizing of Evaporative Cooling*

Air coolers are used either for spot cooling or space cooling:

a) *For spot cooling* — An important parameter to consider is the air throw the distance to which the air cooler will throw air with adequate velocity and air quantity;

b) *For space cooling* — Important parameter is air changeover. Generally, 20 to 40 air changeovers per hour (ACH) are required depending upon application and heat load; and

c) *The residential air coolers* — It shall be as per accepted standard [D-3(13)]. The large commercial air evaporative air-cooling system shall be as per the special publication.

NOTES

1 Further, ISHRAE simulation tool called EvapCal shall be used for sizing guidelines based upon city, heat load, required thermal comfort to correctly size the system.

2 Special publication may be ISHRAE Standard 2005 : 2024.

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6.1.4 *Limitations of Evaporative Cooling*

These points outline the challenges and constraints associated with evaporative cooling, highlighting factors that may affect its efficiency and suitability in certain conditions.

a) *Climate dependence* — The efficiency of evaporative coolers decreases significantly in humid climates. When the air is already saturated with moisture, it shall not absorb much more, making evaporation less effective and reducing the cooling capacity of the device;

b) *Limited to cooling only* — Evaporative coolers are designed to only cool the space and shall not condition it like air conditioner. Hence shall not be used for heating or dehumidification;

c) *Increased humidity* — While added humidity shall be beneficial in dry climates, it shall be problematic in areas that are already humid. High humidity levels shall create a sticky, uncomfortable indoor environment and potentially promote mould growth if not designed properly; and

d) *Water usage* — Evaporative coolers require a continuous supply of potable quality of water to operate, which shall be a concern in regions facing water scarcity or unavailability. However, their overall water consumption is relatively low compared to other water-intensive appliances.

6.1.5 *New Trends/Technologies in Evaporative Cooling*

Smart Controls, efficient cooling media and two stage, multi stage hybrid evaporative cooling system enhances the efficiency and comfort level. These technologies should be considered based on the climate conditions and application. Two stage are:

a) *Evaporative cooling systems* — Advanced version of direct evaporative cooling system, many times referred as dual stage evaporative cooling combines use of direct and indirect evaporative cooling system to provide supply air temperature which are much lower than wet bulb temperature and with lower specific humidity making the space temperature very comfortable in dry conditions; and

b) *Hybrid systems* — Some systems combine single or multiple stage evaporative cooling with traditional air conditioning, optimizing cooling performance while minimizing energy use. These hybrid systems switch between modes based on ambient conditions, providing efficient cooling in various climates. Indirect (air cooling by passing over a cool coil or heat exchanger) cooling is also often combined with a direct evaporative cooling process such devices are often termed as indirect direct evaporative coolers (IDEC). Cool coil may in turn use chilled water, evaporatively cooled water, pre-cooled air, or any such other cooling media.

6.2 Radiant Cooling and Heating

Radiant cooling system is a temperature-controlled system in which the temperature of the building surface facing indoor (ceiling, floor, wall etc) is reduced by the means of cool/chilled water which flows through a network of pipes embedded in the surfaces.

Any system shall only be called a radiant system if more than 50 percent of heat transfer takes place by radiative heat exchange by the temperature-controlled surface. Reduced surface temperature causes radiative heat exchange between human body and cold/hot surfaces and provide sensible cooling/heating inside the building. A separate air system shall be used for the ventilation requirements and handling the latent load.

The radiant cooling system design and installation shall ensure no condensation in the conditioned space.

6.2.1 *Advantages of Radiant Cooling System*

These points highlight the key benefits of radiant cooling, focusing on energy efficiency, comfort, and improved indoor air quality:

a) *Energy efficiency* — In radiant cooling system, cooling is provided through water which has a higher heat capacity than air which loses more energy in transportation. In radiant cooling system less fan

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energy is required than conventional all-air system due to very significant reduction in amount of air handled;

b) *Indoor air quality* — As a radiant cooling system is a hybrid system that also includes a separate air system to provide 100 percent outdoor air, the indoor air quality is enhanced;

c) *Thermal comfort* — Uniform temperature shall be maintained with radiant cooling system ensuring better thermal comfort;

d) *Integration with low grade energy/passive cooling sources* — In radiant cooling system a higher temperature 15 ºC to 20 ºC water temperature shall be used. The low-grade energy sources like cooling tower, geo-thermal and others shall be used; and

e) *Noise and reduced duct work* — This cooling system reduces noise, as they do not rely on fan and compressor for cooling, and this system use water pipes instead of the ducts, thereby having reduced duct work.

6.2.2 *Limitations of Radiant Cooling*

Radiant cooling is useful in the building where sensible load is higher and have humidity control. There are several areas like restaurant, lobby, and kitchen, etc where humidity control is very difficult, at such places, its application shall attract a problem of condensation. Similarly, if the latent load in a zone is significant then the use of radiant cooling system is limited. The radiant cooling system also has a limitation of cooling capacity in order to counter the condensation problem. Hence, the surfaces have to be maintained at a higher temperature as compared to the dew point temperature of indoor air.

6.2.3 *Types of Radiant Cooling Systems*

Following three types of Radiant systems are used:

a) *Radiant cooling panels system* (*RCP*) — The most extensively used system of radiant systems is the PANEL Systems. The insulation over the aluminium panel plays an important role in avoiding the heat transfer to the building structure. Poor connection shall lead to less heat transfer resulting in an inefficient system;

b) *Thermally activated building system* (*TABS*) — In thermally active building system (TABS) the conditioning plant operation is varied based on thermal loads. TABS has a high thermal inertia, which enables it to hold a large amount of heat within it during the day time and release this heat during night time to the hydronic system; and

c) *Embedded surface cooling systems* (ESC) — In embedded surface cooling system, an insulation cover on the pipes mounted on the side adjacent to the building structure minimizing thermal energy exchange of heat carrier with the building structure. Some floor systems are made by extruded plastic plates which forms capillary channels. In this case the heat exchange surfaces is very wide and at the same time the thickness of the system is very less which allows very low temperature differences.

6.2.4 *Requirement of Fresh Air Delivery*

Radiant cooling systems require a dedicated an outdoor air system responsible for supply of fresh/ventilation air into the radiant cooled space operating in parallel to the radiant cooling.

In case of high latent load and in case of oversized DOAS, energy savings from a radiant cooling system is reduced.

6.2.5 *Control Requirements*

Following controls are required to efficiently operate a radiant cooling system:

a) radiant surface temperature minimum two degree centigrade higher than indoor dew point temperature to avoid condensation on radiant surfaces. In case of occurrence;

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b) water supply temperature or flow rate or both need to be controlled; and

c) modulate ventilation air supply as per the CO_2 monitoring.

6.3 Structural Cooling

Due to the high solar insolation during the daytime on built structures, heat gets embedded in the structure or the thermal mass of the buildings and is transmitted indoors. This heat raises the temperature of the indoor surfaces resulting in higher mean radiant temperatures experienced by occupants making them uncomfortable.

This heat has to be flushed out before it shall enter the living space.

This approach significantly reduces the cooling loads on the air conditioning system, in case the indoors are air conditioned.

Structural cooling generally employs the use of cooled water between 15 °C to nearly 30 °C, which is circulated in embedded piping network laid within the structure.

For air-conditioned areas, the minimum water temperature is 15 °C. Depending on the requirements this water temperature shall be higher up to 24 °C. This generally requires mechanical refrigeration similar to the chilled water supply in radiant cooling system.

Water between 20 °C and 30 °C can be generated employing natural cooling processes, which make use of the ambient conditions of air.

Naturally cooled water in ponds, rivers, or from geothermal sources should be considered. Properly designed and selected cooling towers make use of the lower wet bulb temperatures to achieve this cooling of water to slightly above prevailing wet bulb temperatures.

NOTES

1 In a conducive weather condition, cooled water shall be obtained by utilising the night sky cooling and storing the cooled water in an insulated and properly sized tank during the night. The same water shall be used to cool the structure during the harsh times of the day.

2 The water is circulated by employing a small pump, in the closed loop system. Principally, these systems are quite similar to thermally activated buildings covered under radiant cooling section.

6.3.1 *Advantages of Structural Cooling*

Structural cooling impedes solar heat from roof and floors by absorbing it before it causes thermal discomfort to occupants. Following are the advantages of structural cooling:

a) floor temperatures are maintained below body skin temperature, allowing the body to radiate the heat to the cooler surfaces;

b) reduces the cooling load on the building and lower size of ancillary cooling systems are required, leading to smaller pipes and ducting;

c) because of the large thermal mass of the structure, it shall act as a storage of cooling effect; and

d) as the Structure is cooled, it is maintained in a small band of temperature variations, thus eliminating the heat stress on the structure. The thermal expansion and contraction of the structure are very low, as compared to a building which is not structurally cooled.

6.3.2 *Applications*

Structural cooling is very versatile and shall be used to cool places like public utility areas, malls, hospitals, residential areas, office buildings, commercial spaces, educational institutes and many more applications to reduce air conditioner loads and provide comfort.

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6.4 Geothermal for Heating and Cooling

Geothermal heating and cooling systems, also known as ground source heat pumps (GSHPs), uses the stable temperatures of the earth's subsurface to provide efficient climate control for buildings. By using the ground as a heat source in the winter and a heat sink in the summer, these systems shall achieve high efficiencies compared to conventional HVAC systems and needs to balance the earth as source.

NOTE — Geothermal systems shall be used in residential, commercial, and industrial buildings. They are particularly beneficial for new constructions but shall also be retrofitted into existing structures. Large-scale applications include district heating systems where multiple buildings are connected to a central geothermal system.

6.4.1 *Advantage of GSHP Systems*

GSHP systems offer significant energy efficiency, environmental benefits, and long-lasting performance. Following are the advantages of GSHP systems:

a) *Energy efficiency* — GSHPs achieves high efficiencies on the coldest winter nights, meaning they produce 3 units to 6 units of heat for every unit of electricity consumed;

b) *Cost savings* — GSHP systems provide substantial cost savings by delivering multiple units of heat for each unit of electricity, reducing energy bills over time;

c) *Environmental impact* — Reduce greenhouse gas emissions and reliance on fossil fuels; and

d) *Longevity* — Ground loops life of 50 years and above, and indoor components life of 20 years and above.

6.4.2 *Challenges with GSHP*

GSHP systems face certain challenges related to installation, maintenance, and initial investment:

a) *High initial cost* — Installation are expensive due to drilling and trenching requirements depending on terrain;

b) *Site-specific design* — Soil conditions, land availability, and local climate affect feasibility and design; and

c) *Maintenance* — While minimal, the system requires periodic maintenance, especially the indoor components. Geothermal heating and cooling systems represent a sustainable and efficient technology for managing building climate control. Despite the high initial investment, their long-term benefits in terms of energy savings, environmental impact, and system longevity make them an attractive option for a wide range of applications. As technology advances and installation costs decrease, geothermal systems are likely to become an increasingly common choice for sustainable building design.

6.5 Solar Cooling

There are different ways to utilise solar energy for producing cooling effect:

a) Solar thermal cooling systems

b) Solar photovoltaic cooling systems

Solar photovoltaic cooling systems is a vapour compression-based systems powered by electricity generated by solar photo voltaic system. Solar thermal based cooling systems use heat-based cooling systems that do not need electricity driven mechanical compressor.

6.5.1 *Solar Thermal Cooling Systems*

There are two different types of solar thermal cooling systems absorption type and desiccant type. All of these are driven by the heat from solar energy as explained below.

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6.5.1.1 *Absorption cooling*

Vapour absorption machines (VAMs) are used for cooling using waste steam or hot water as a byproduct of process in various industries. VAMs use a salt-based solution (typically lithium bromide solution) to alternative evaporate water out and then condense it back into the solution. Types of VAMs depending on the temperature of the heat source:

a) *Single effect* — Uses hot water source between 80 °C to 90 °C to drive the cooling cycle.

b) *Double effect* — Uses 120 °C to 140 °C steam to drive the cooling cycle.

c) *Triple effect* — Uses 180 °C to 210 °C steam to drive the cooling cycle.

For most buildings, single effect VAM and double using solar hot water is the viable configuration. Double effect VAMs offer higher COP of 1.2 to 1.4, it is recommended to use single effect VAMs it is recommended to design the VAM around this temperature even though the COP of such system is only 0.7 to 0.8. Higher operating hours in a year make such a system more viable at lower COP.

Double and triple effect VAMs shall be used in buildings where waste heat or low-cost heat >120 °C is available in immediate vicinity. This would typically be in industrial settings.

6.5.1.2 *Adsorption cooling*

Adsorption cooling systems use solid desiccant material like silica gel to enable a heat driven cooling cycle. Water is used as a refrigerant in such systems. The cycle works by alternating ‘adsorption’ and ‘desorption’ of water from a solid desiccant. Heat between 60 °C to 80 °C is required for ‘desorption’ and heat from solar collectors shall be used.

The COP of adsorption chiller is between 0.35 to 0.55 depending on the chilled water temperature required, hot water source temperature and condenser water temperature. While lower COP increases the solar field size, adsorption chiller’s ability to operate even at 60 °C source temperature allows.

6.5.1.3 *Desiccant cooling*

This typically refers to liquid desiccant cooling where solar heat is used to regenerate the desiccant. Typical regeneration temperature is 60 °C that be consistently achieved using solar collectors.

6.5.2 *Advantages of Solar Thermal Cooling Systems*

Solar thermal cooling systems offer sustainable and energy-efficient solutions by harnessing solar energy for cooling purposes, reducing reliance on conventional energy sources. Following are the advantages of solar thermal cooling systems:

a) *Energy efficiency* — Overall cooling system electricity consumption shall be 0.4 kW/Ton to 0.6 kW/Ton compared to 1 kW/Ton to 1.4 kW/Ton for conventional air conditioning systems; and

b) *Lower carbon footprint* — Lower electricity consumption leads to lower carbon footprint of the system. This shall be useful for achieving decarbonization goals of the building or organization.

6.6 Personal Environmental Control Systems

Personal environmental control systems (PECS) includes low-energy, low-powered personalised HVAC systems as well as controls and sensors. The PECS largely shall be categorised into the following five categories and further detailed in Table 13:

a) Heating only PECS;

b) Cooling only PECS;

c) Ventilation only PECS;

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d) Heating and ventilation PECS;

e) Cooling and ventilation PECS; and

f) Heating, cooling and ventilation PECS.

NOTE — Heating PECS and cooling PECS rely only on conduction and radiative heat transfer without convection (air movement). While all PECS with ventilation, rely on air as a heat transfer medium, hence air movement in ventilation PECS is inherent.

Table 13 Personal Environmental Control Systems

(*Clause* 6.6)

a) Heating only PECS Devices

Warmed Seat	**Device Description**	**Warmed Seat Heated Using Electrical Elements or Embedded Water Tubes**	The warmed seat is recommended to be used in combination with a foot heater.
	T_{room}	> 5 °C	
	$T_{PECS-surface}$	< 44 °C	
	V_{PECS}	N/A	
	Target body parts	Back, buttocks, thighs	
	PECS position	As the occupant's seat	
	Restriction of movement	Occupant shall remain in contact with the seat fabric	
	Manual control	Temperature	
	Background ventilation	Required	
Radiant Foot Heater		**Radiant Foot Heater heated using electrical elements**	The radiant foot heater should be operated in the range of T_{room}+10 °C to T_{room}+20 °C for optimum comfort.
	T_{room}	> 10 °C	
	$T_{PECS-surface}$	< 30 °C	
	V_{PECS}	N/A	
	Target body parts	Feet	
	PECS position	~20 cm from the feet	
	Restriction of movement	Feet shall remain adjacent to the heated surface	
	Manual control	Temperature	
	Background ventilation	Required	
Radiant Heating Panel		**Radiant Heating Panels placed as desktop partitions heated using electrical elements or embedded water tubes**	The exposed surface area of the radiant heating panel to the occupant should be optimized by placing more panels to the left and right sides of the occupant.
	T_{room}	> 19 °C	
	$T_{PECS-surface}$	< 23 °C	
	V_{PECS}	N/A	
	Target body parts	Face, chest, arms, legs	
	PECS position	~50 cm from the occupant, as the desk partition	

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Table 13 (*Continued*)

	Restriction of movement	Occupant should remain in the field of view of the Radiant Panel	
	Manual control	Temperature	
	Background ventilation	Required	
Palm Warmer		**Desktop-based Palm Warmers heated using electrical elements**	The device shall be placed such that it acts as a resting spot for the hands while typing.
	T_{room}	> 18 °C	
	$T_{PECS-surface}$	< 35 °C	
	V_{PECS}	N/A	
	Target body parts	Palms	
	PECS position	On the desktop, between the computer keyboard and the occupant.	
	Restriction of movement	Palms shall be in direct contact with the device surface	
	Manual control	None	
	Background ventilation	Required	
b) Cooling only PECS Devices			
Cooled Seat	**Device Description**	**Seat cooling using embedded water pipes cooled using compressive cooling**	It is recommended to use a movable desktop fan in combination with the cooled seat.
	T_{room}	< 45 °C	
	$T_{PECS-air}$	> 18 °C	
	V_{PECS}	N/A	
	Target body parts	Back, buttocks, thighs	
	PECS position	As the occupant's seat	
	Restriction of movement	Occupant shall remain in contact with the seat fabric	
	Manual control	Temperature	
	Background ventilation	Required	
Cooled Garment		**Jacket-like garment using phase change materials or compressive cool air supply**	Typical cooled garments are battery-operated, with an average charge lasting for ~ 6 hours; they weigh around 3 kg to 5 kg; cooled garments with phase change materials typically perform better than those with embedded fans.
	T_{room}	< 34 °C	
	$T_{PECS-air}$	> 21 °C	
	V_{PECS}	N/A	
	Target body parts	Chest, back, shoulders	
	PECS position	As the occupant's vest	
	Restriction of movement	None	
	Manual control	Temperature	
	Background ventilation	Required	

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Table 13 (*Continued*)

Radiant Cooling Panel		**Radiant Cooling Panels placed as desktop partitions cooled using embedded water pipes using compressive cooling**	The exposed surface area of the radiant cooling panel to the occupant should be optimized by placing more panels to the left and right sides of the occupant.
	T_{room}	< 32 °C	
	$T_{PECS-air}$	> 17 °C	
	V_{PECS}	N/A	
	Target body parts	Face, chest, arms, legs	
	PECS position	~ 50 cm from the occupant, as the desk partition	
	Restriction of movement	Occupant should remain in the field of view of the radiant panel	
	Manual control	Temperature	
	Background ventilation	Required	
c) Ventilation only PECS Devices			
Desktop-based Devices	**Device Description**	**Desk-mounted air-terminal device supplying (fresh or recirculated) air at room temperature**	The airflow shall not strike the desktop and the airflow pattern should preferably be kept as close to the natural wind pattern in terms of its turbulence and frequency of variability.
	T_{room}	< 30 °C	
	$T_{PECS-air}$	Same as T_{room}	
	V_{PECS}	< 1.5 m/s	
	Target body parts	Face, neck, chest, arms	
	PECS position	~50 cm from the occupant, on the desktop	
	Restriction of movement	Occupant shall move while manually changing the airflow direction of the fan/device	
	Manual control	Air velocity, direction	
	Background ventilation	Optional	
Movable Panel		**Desktop based movable air-terminal device supplying (fresh or recirculated) air at room temperature**	The air stream should enter the occupant's breathing zone parallel to the cheek, avoiding direct contact with the eyes.
	T_{room}	< 28 °C	
	$T_{PECS-air}$	Same as T_{room}	
	V_{PECS}	< 0.7 m/s	
	Target body parts	Face, neck, chest, arms	
	PECS position	~50 cm from the occupant, on the desktop	
	Restriction of movement	Occupant is free to move within the flow region while adjusting the direction of the panel	
	Manual control	Air velocity, direction	
	Background ventilation	Optional	
Headrest-embedded Device		**Seat headrest-based air-terminal device supplying recirculated air at room temperature**	Air terminal devices with a large opening area require low air

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Table 13 (*Continued*)			
	T_{room}	< 26 °C	velocity and vice versa.
	$T_{PECS-air}$	Same as T_{room}	
	V_{PECS}	< 0.6 m/s	
	Target body parts	Face	
	PECS position	As the seat headrest, next to the cheeks	
	Restriction of movement	Occupant shall keep the head on the headrest.	
	Manual control	Air velocity	
	Background ventilation	Required	
Pedestal Fan		**Pedestal fan supplying recirculated air at room temperature**	The fan direction should be kept such that it does not cause discomfort by displacement of light-weight objects on the desktop.
	T_{room}	< 30 °C	
	$T_{PECS-air}$	Same as T_{room}	
	V_{PECS}	< 2.5 m/s	
	Target body parts	Whole body	
	PECS position	~ 1.5 m from the occupant	
	Restriction of movement	Occupant is free to move within the flow region while adjusting the direction of the fan	
	Manual control	Air velocity, direction	
	Background ventilation	Optional	
Ceiling Fan		**Ceiling-mounted fan supplying recirculated air at room temperature**	To optimize the effect of the fan, it should be placed on the ceiling right above the desktop, with the rotating blades at an angle of 30° to 45° from the ceiling.
	T_{room}	< 30 °C	
	$T_{PECS-air}$	Same as T_{room}	
	V_{PECS}	< 1 m/s	
	Target body parts	Head, shoulders	
	PECS position	~ 1.5 m above the occupant, on the ceiling	
	Restriction of movement	Occupant shall remain in the flow direction	
	Manual control	Air velocity	
	Background ventilation	Optional	
Ventilated Seat		**Ventilated seat embedded with fans supplying recirculated air at room temperature**	The occupant's body should not block the complete airflow and it should reach the breathing zone.
	T_{room}	< 32 °C	
	$T_{PECS-air}$	Same as T_{room}	
	V_{PECS}	< 2 m/s	
	Target body parts	Buttocks, back, thighs	
	PECS position	As the occupant's seat	
	Restriction of movement	Occupant shall remain in contact with the seat fabric	
	Manual control	Air velocity	

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Table 13 (*Continued*)

	Background ventilation	Required	
Ventilated Garment		**Jacket-like garment embedded with low-wattage fans supplying recirculated air at room temperature**	A typical battery-operated ventilated garment operates up to 7 hours on 60 percent output power.
	T_{room}	< 34 °C	
	$T_{PECS-air}$	Same as T_{room}	
	V_{PECS}	Equivalent to a flow rate of < 22 L/s	
	Target body parts	Chest, Back	
	PECS position	As the occupant's vest	
	Restriction of movement	No restriction in movement	
	Manual control	Air velocity	
	Background ventilation	Required	
d) Heating and Ventilation PECS Devices			
Desk-mounted Device	**Desk-mounted air-terminal device supplying air warmed through compressive heating**		The device should be used in combination with a Foot-heating Panel; the airflow should not directly strike the eyes of the occupant as it might lead to dry-eye discomfort.
	T_{room}	> 19 °C	
	$T_{PECS-air}$	< 25 °C	
	V_{PECS}	< 1 m/s	
	Target body parts	Face, arms, chest, front thighs	
	PECS position	~ 50 cm from the occupant, on the desktop	
	Restriction of movement	Occupant shall remain in the flow direction	
	Manual control	Temperature, air velocity, direction	
	Background ventilation	Optional	
Ventilated and Warmed Seat	**Warmed seat with embedded fans – the seat is warmed using electrical elements or embedded water pipes**		The device should be used in combination with a foot-heating panel
	T_{room}	> 20 °C	
	$T_{PECS-air}$	< 45 °C	
	V_{PECS}	< 0.7 m/s	
	Target body parts	Neck, back, buttocks, back thighs	
	PECS position	As the occupant's seat	
	Restriction of movement	Occupant shall remain in contact with the seat	
	Manual control	Temperature, air velocity	
	Background ventilation	Required	
Nozzle	**Nozzle-based air terminal device supplying air warmed through compressive heating**		The air stream should enter the occupant's breathing zone parallel to the cheek, avoiding direct contact with the eyes.
	T_{room}	> 19 °C	
	$T_{PECS-air}$	< 50 °C	
	V_{PECS}	< 1 m/s	

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Table 13 (*Continued*)

	Target body parts	Head, neck	
	PECS position	~ 1 m from the occupant, directed towards the head	
	Restriction of movement	Occupant shall remain in the flow direction	
	Manual control	Temperature, air velocity	
	Background ventilation	Optional	
Movable Panel	**Desk-mounted movable air terminal device supplying air warmed through compressive heating**		The air stream should enter the occupant's breathing zone parallel to the cheek, avoiding direct contact with the eyes.
	T_{room}	> 20 °C	
	$T_{PECS-air}$	< 26 °C	
	V_{PECS}	< 1 m/s	
	Target body parts	Head, neck, chest, arms	
	PECS position	~ 50 cm from the occupant, directed towards the head	
	Restriction of movement	Occupant is free to move within the flow region while adjusting the direction of the panel	
	Manual control	Temperature, air velocity, direction	
	Background ventilation	Optional	
e) Cooling and Ventilation PECS Devices			
Desk-mounted Device	**Desk-mounted air-terminal device supplying air cooled through compressive cooling**		The air stream should enter the occupant's breathing zone parallel to the cheek, avoiding direct contact with the eyes.
	T_{room}	< 30 °C	
	$T_{PECS-air}$	> 15 °C	
	V_{PECS}	< 1.5 m/s	
	Target body parts	Face, neck, chest	
	PECS position	~50 cm from the occupant, on the desktop	
	Restriction of movement	Occupant shall remain in the flow direction	
	Manual control	Temperature, air velocity	
	Background ventilation	Optional	
Desk-edge based Device	**Desk-edge mounted horizontal air terminal slits supplying air cooled through compressive cooling**		The device should preferably provide a vertical airflow directly under the occupant's chin and should have adjustable vanes for manual adjustment of airflow direction.
	T_{room}	< 26 °C	
	$T_{PECS-air}$	> 20 °C	
	V_{PECS}	< 1 m/s	
	Target body parts	Face, neck	
	PECS position	~ 10 cm from the occupant, on the desk edge	

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Table 13 (*Continued*)			
	Restriction of movement	Occupant shall remain directly above the device outlet	
	Manual control	Temperature, air velocity, direction	
	Background ventilation	Optional	
Movable Panel	**Desk-mounted movable air terminal device supplying air cooled through compressive cooling**		The air stream should enter the occupant's breathing zone parallel to the cheek, avoiding direct contact with the eyes.
	T_{room}	< 30 °C	
	$T_{PECS-air}$	> 20 °C	
	V_{PECS}	< 1 m/s	
	Target body parts	Face, neck, chest, shoulders, arms	
	PECS position	~50 cm from the occupant, on the desktop	
	Restriction of movement	Occupant is free to move within the flow region while adjusting the direction of the panel	
	Manual control	Temperature, air velocity, direction	
	Background ventilation	Optional	
Armrest-embedded Device	**Seat armrest-mounted air terminal device supplying air cooled through compressive cooling**		The airflow should strike the occupant at a 45° angle from below.
	T_{room}	< 25 °C	
	$T_{PECS-air}$	> 20 °C	
	V_{PECS}	< 0.7 m/s	
	Target body parts	Face, neck, chest, arms	
	PECS position	As the armrest of the occupant's seat	
	Restriction of movement	Occupant shall remain seated and the armrests shall not be blocked	
	Manual control	Temperature, Air Velocity	
	Background ventilation	Required	
Floor-mounted Device	**Floor-mounted air terminal device supplying air cooled through compressive cooling, also known as underfloor air distribution**		The device should be used in combination with a desk-mounted or movable panel device for better control
	T_{room}	< 27 °C	
	$T_{PECS-air}$	> 16 °C	
	V_{PECS}	< 1 m/s	
	Target body parts	Feet, legs, thighs, buttocks	
	PECS position	~50 cm from the occupant's seat, on the floor	
	Restriction of movement	Occupant shall move radially around the device	
	Manual control	Temperature, air velocity	
	Background ventilation	Optional	
	Ceiling-mounted air terminal device supplying air cooled through compressive cooling		The airflow should have a low turbulence

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Table 13 (*Concluded*)			
Ceiling-mounted Device	T_{room}	< 29 °C	intensity and long range.
	$T_{PECS-air}$	> 21 °C	
	V_{PECS}	< 0.8 m/s	
	Target body parts	Head, neck, shoulders	
	PECS position	~1.5 m above the occupant's head, on the ceiling	
	Restriction of movement	Occupant shall move around the vertical flow	
	Manual control	Temperature, air velocity	
	Background ventilation	Optional	
Radiant Cooling Panel with Fan	**Radiant panels placed as desktop partitions with embedded water pipes cooled using compressive cooling - used in combination with low-power desktop fans**		The exposed surface area of the radiant panel to the occupant should be maximized; the airflow from the fan should not strike the desktop.
	T_{room}	< 28 °C	
	$T_{PECS-air}$	> 17 °C	
	V_{PECS}	< 1.5 m/s	
	Target body parts	Face, neck, chest, arms	
	PECS position	Radiant panels as the desk partition ~ 50 cm from the occupant; Fan on the desktop, ~ 40 cm from the occupant	
	Restriction of movement	Occupant shall remain exposed to the radiant surface and shall move fan as per comfort	
	Manual control	Temperature, air velocity, direction	
	Background ventilation	Optional	

7 DISTRICT COOLING SYSTEMS

District cooling systems (DCS) provides and distributes cooling energy from a central plant to a surrounding cluster of residences, commercial spaces, industries, or institutions occupied by tenants or clients.

In a district cooling system, a large central plant produces chilled water for supply to multiple buildings through an insulated closed-loop underground piping network. Traditional AC systems consume a majority of a building's peak electricity demand, usually at peak cost. With district cooling, peak demand on the grid, as well as operating energy consumption, decreases. It avoids the capital costs of installing multiple HVAC systems that is chillers and cooling towers and associated mechanical and electrical equipment at each building to a central location, freeing up valuable rooftop and building space. By aggregating the cooling needs of multiple buildings, district cooling generates economies of scale. Further, DCS also contributes to sustainability by ensuring reuse of STP water and reducing refrigerant requirement and leakages.

In India, DCS is ideal for mixed-use developments, large infrastructure projects such as aero cities, industrial clusters, residential clusters, educational campuses, IT parks, smart city infrastructure or retrofit of a DCS system for an existing cluster of individually cooled buildings or a redevelopment of existing buildings.

DCS provide several economic benefits to end-users, including reduced capital and operating costs, less frequent maintenance, space savings, and lower electricity usage than in more traditional AC systems (*see* Table 14).

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Table 14 Benefits of DCS Systems

(*Clause* 7)

Environmental	Societal	Economic
(1)	(2)	(3)
		For DCS Service Providers/Investors:
a) Energy saving b) Peak energy demand reduction c) Carbon and GHG emission saving d) Enabling transition to low or zero GWP refrigerants e) Water conservation f) Improved micro-climatic conditions by reduced urban Heat Island Effect g) Improved air quality	a) Enhanced aesthetics b) Local business development c) Skill development and improved employability d) Security of supply for cooling e) Access to affordable cooling for achieving thermal comfort f) Improved quality of life g) Reduced noise from cooling equipment	a) New business venture with competitive advantage b) Long-term stable and profitable revenues c) Employment generation Avoided investments in summer electricity peak production, transmission, and distribution Higher energy and resource utilization **For end-users of DCS:** a) Avoided capital expenditure (CAPEX) and space requirement for cooling equipment like chillers and cooling towers and related costs b) Reduced O&M cost

7.1 Key Components of District Cooling System

District cooling systems (DCS) shall utilize recycled treated water from sewage effluent as cooling tower makeup water. Municipalities should provide this recycled water for in-house treatment, addressing water shortages and promoting water circularity initiatives in cities. Following are the requirements of DCS:

a) DCS benefit from technologies like thermal energy storage (TES) and free cooling. TES reduces peak electricity costs by shifting cooling production to off-peak hours, while free cooling leverages ambient conditions to lower overall electricity demand.

b) In some cases, district cooling systems may directly use seawater or fresh surface water for heat rejection, subject to local laws.

c) Large central plants should use waste heat or geothermal energy for absorption refrigeration in district cooling systems. This approach is more feasible at the district scale than for individual buildings.

7.1.1 *District Cooling Plant*

The district cooling plant (DCP) generates chilled water for cooling services. It includes chillers, cooling towers, pumps, and auxiliary systems. Thermal energy storage (TES) shall enhance chiller capacity. DCPs play a crucial role in efficient and sustainable cooling solutions for urban areas. All new plants with capacity equal to or greater than 10 000 TR shall include a TES system. All new plants with capacity equal to or greater than 10 000 TR shall carry out due feasibility analysis to include a TES system. Further, for all cluster development of multiple buildings with cumulative cooling demands above 5 000 TR, setting up of District Cooling System, if feasible, should be considered.

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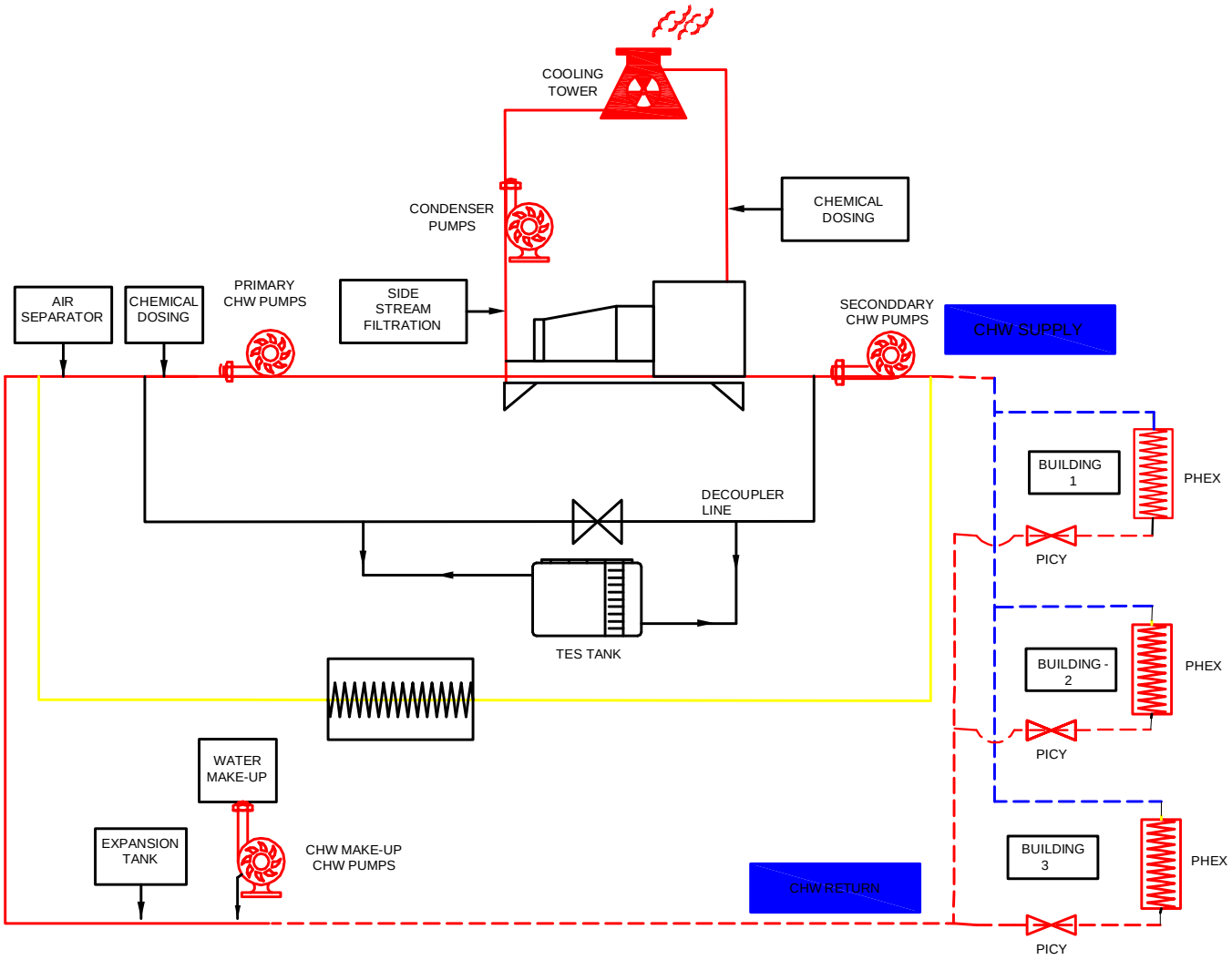

FIG. 2 LAYOUT OF A DISTRICT COOLING SYSTEM

7.1.2 *Distribution Network*

Based upon ease of operation, geographical constraints, safety, and applications, there are two kinds of distribution networks underground pre-insulated and above-ground site insulated chilled water distribution systems. Carbon steel or mild steel pipes should be used for chilled water and condenser water distribution piping, with proper protective coating wrap for preventing thermal losses. In the Indian context, an indicative DC system design (including the distribution system) is presented in Fig. 2. However, the actual design specifications may vary depending on a multitude of factors. Distribution pipelines should be designed with a life expectancy of minimum 40 years. Following shall be the default design conditions for the distribution network, unless specified by the designer/user:

a) Ambient temperature (for design): based on where the DC system is located;

b) Chilled water supply temperature at DCP: 5 ºC ± 1 ºC;

c) Temperature rise in the chilled water supply distribution network: 0.5 ºC to1 ºC per unit length (0.5 ºC up to 5 000 m);

d) Approach across Energy Transfer Station: </= 1.1 ºC;

e) Chilled water supply temperature at consumer end: 6 ºC ± 1 ºC;

f) Chilled water return temperature at consumer end: 15 ºC ± 1 ºC;

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g) Temperature drop in the chilled water return distribution network: 0.5 ºC to 1 ºC;

h) Chilled water return temperature at DCP: 14 ºC ± 1 ºC; and

j) Design pressure of the chilled water distribution network: 5 bar to 15 bar (g) (depends on the overall DCS design and building elevation).

7.1.3 *Energy Transfer Station*

An energy transfer station (ETS) serves as a bridge between a district cooling (DC) service and consumers' air conditioning systems. Energy transfer shall be direct or indirect transfer. In district cooling plants where there is uniform time of operation of all spaces and the cooling service provider and end user have no need for decoupling then direct transfer that is supply of chilled water to all air handling units shall be applied. In all other cases indirect heat transfer via an ETS shall be applied.

The ETS transfers thermal energy generated at the central plant to buildings. Within the ETS, heat exchangers allow buildings to utilize this energy for space conditioning. Key components include pumps, isolation valves, and control elements. Proper sizing ensures meeting cooling demand without redundancy. Consideration for equipment access, maintenance, and transport pathways shall be done. Controls, such as pressure independent control valves, help in maintaining efficiency.

7.1.4 *Instrumentation, Monitoring and Control System* (*SCADA*)

A DC instrumentation and control system shall be designed, installed, and commissioned to monitor and control various system components for enhancing operational efficiency of the DC system. The main components of an instrumentation and control system are a programme logic controller (PLC), human machine interface (HMI), and distribution control system. The control system shall be designed to maintain the entire DC plant operations and functionality, and integration with ETSs to maintain transparency in operations. The control system shall monitor comprehensive chiller plant parameters, cooling tower parameters, TES parameters, chemical treatment equipment parameters, building management system (BMS) of the DC plant building, firefighting status of the plant building, etc and may be integrated on SCADA.

7.1.5 *Measurement and Billing System*

The measurement and monitoring system shall facilitate real time monitoring of kW/TR of the plant. Infrastructure for continuous measurement and logging of cooling production and consumption (TR-h) and complete breakdown of all associated power demand (kW, voltage, ampere, power factor), and energy consumption (kWh) is crucial for district cooling (DC) systems. Separate BTU meters for each cooling consumer, installed at the Energy Transfer Station (ETS), generate monthly cooling bills. Individualizing BTU metering by consumer or apartment enhances responsibility for thermal energy consumption. Properly sized BTU meters accurately measure the entire cooling load range. All BTU meters shall be calibrated annually.

7.2 Design Approach for DCS

7.2.1 *Site Selection Criteria*

Site selection involves careful evaluation of various aspects with different degrees of importance. A methodology should be prepared to ensure that the critical aspects are not overlooked. The aim is to define a set of criteria that helps in shortlisting the most optimum site, which has the following characteristics:

a) resource-efficient;

b) minimum environmental impact;

c) cost-effective;

d) adequate in terms of logistics;

e) ensures maximum efficiency;

f) offers possibility of easy future expansion;

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g) proximity to utilities (power and STP infrastructure) and drainage; and

h) proximity to load centre of large multi tower developments.

The first stage of site selection is determining the study area and indicators. The second stage involves the diagnosis process, wherein indicators are ranked and weighted according to benchmarks, guidelines, and preferences. Furthermore, this stage involves analysis of data collected for various indicators. The last stage is decision making, where potential sites are ranked, followed by the development of a feasibility plan. The process shall take place via the traditional method of site suitability analysis or using computer-based applications and the major factors influencing DCS implementation are given in Table 15.

7.2.2 *Sizing Philosophy for DCS*

The sizing of both mechanical and electrical systems shall ensure optimal performance, energy efficiency, and reliability of the district cooling system.

7.2.2.1 *Mechanical system sizing* (*chiller sizing, network and delta T*)

In sizing a chiller for a district cooling system, following critical factors shall be considered.

a) First, the required cooling capacity based on the peak cooling load and combined load diversity. This load shall vary significantly depending on the specific application (for example, residential, commercial, or industrial) and local climate conditions.

b) The desired temperature difference between the inlet and outlet water is to be decided. This difference affects the chiller's efficiency and overall performance.

c) The ambient conditions, such as the local climate and ambient temperature. Hotter climates may necessitate larger chillers to handle higher cooling demands effectively.

d) Assess installation constraints, such as available space, and any limitations related to the chiller's physical placement within the district cooling network proper chiller sizing is crucial for achieving efficient and reliable district cooling operations.

The successful implementation of district cooling systems depends greatly on the ability of the system to obtain high-temperature differentials that is delta temperatures (T) between the supply and return water. It is crucial to ensure that the district cooling system shall operate with reasonable size distribution piping and pumps to minimize the pumping energy requirements.

The pipe sizing is governed by four key factors:

1) the system's delta T;

2) maximum allowable flow velocity;

3) distribution network pressure at the design load conditions; and

4) minimum differential pressure requirements to service the most remote customers.

NOTES

1 Generally, it is most cost-effective to design for a high delta T in the district cooling system because this allows for smaller pipe sizes in the distribution system. The system operating efficiency also increases with an increased delta T due to the reduced pumping requirements caused by the reduced flow rates and the reduced heat gains/losses in the distribution system. The system's delta T is typically limited to 8 ºC to 11 ºC.

2 The maximum allowable flow velocities are governed by pressure drop constraints and critical system disturbances caused by transient phenomena (that is water hammer effects). Generally, velocities higher than 2.5 m/s to 3.0 m/s should be avoided unless the system is specifically designed and protected to allow for higher flow velocities.

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Table 15 Major Factors Influencing DC System Implementation

(*Clause* 7.2.1)

Building Design and Use	Building Energy Demand	Local Context	Resource Requirement	Policy and Governance
(1)	(2)	(3)	(4)	(5)
a) Availability of space for distribution centre or possibility of extension b) Floor Area Ratio or Floor Space Index c) Carpet area d) Total floor area e) Diverse use of buildings f) Ownership g) Availability of water and power to meet current and future demand h) Electricity and water cost	a) Peak demand b) Demand density c) Delivery density d) Time distribution of energy demand over days, weeks, months and years. e) Potential future cooling demand	a) Topography b) Slope and contours c) Existing and proposed utility lines d) Water e) Drainage f) Telecom, PNG line, electricity line, etc. g) Access to natural cold-water body h) Access to renewable energy and/or waste energy source j) Road network	a) Financial assistance b) Capital Investment c) Rate of return d) Payback period e) Labour and other resources f) Availability of skilled labourers g) Availability of machinery h) Time j) Project timeline	a) Existing policies, programmes, and missions b) Proactiveness of local government c) Administrative capacity d) Ease of getting permissions and clearances

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7.2.2.2 *Electrical system sizing (transformers, diesel generators and substation)*

For efficient and safe functioning of DCS, the electrical supply system plays a critical role. The sizing of electrical supply system components such as transformers, diesel generator and substation shall be designed considering the parameters listed below:

a) *Transformers* — Transformers play a critical role in stepping up or down voltage levels within the distribution network. Sizing shall be done considering:

   1) system voltage level requirements;

   2) capacity for transformer selection;

   3) diversity considerations;

   4) efficiency/losses; and

   5) redundancy/outage considerations.

b) *Diesel generators* — DG is a power backup during emergency when main power supply not available. Sizing shall be done considering:

   1) backup voltage level requirements;

   2) quantum of backup power required when the main power is not available;

   3) allowable loading during continuous operation;

   4) redundancy/outage considerations; and

   5) allowable noise considerations as per CPCB guidelines.

c) *Substation design* — Substation design involves planning, engineering, and constructing electrical substations for efficient power transmission and distribution. It needs to be done based on district cooling plant (DCP) capacity requirement. Accurate sizing ensures efficient and reliable electrical operations in district energy systems. Here are some key points about substation design:

   1) voltage and power capacity requirements;

   2) component selection;

   3) CapEx and OpEx; and

   4) footprint requirements.

7.3 General Requirements

These requirements ensure that DCS installations meet operational efficiency, safety, and performance standards.

7.3.1 *Specific Power Consumption for DCS*

The specific power consumption shall be measure as ratio of kW electric power to kW thermal output the system efficiency of a DC chiller plant shall not be less than 0.85 input kilowatts per TR (ikW/TR). However, depending on system size and detailed economic analysis, there are opportunities to improve the efficiency levels of DCS.

7.3.2 *Testing and Commissioning Procedures for Hydrotesting and Pipe Conditioning*

Necessary hydro testing shall be carried out for the distribution network. The distribution pipes should be subjected to pressure testing as per the design specifications and guidelines approved by the owner and their design consultant representatives. Where required for certain equipment like chillers, factory testing will be required to ensure design conditions are being complied with. Once the individual equipment is all put together as a system, proper testing of the complete system should be carried out.

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The procedures for hydrotesting and flushing of pipes during the testing and commissioning phase for district cooling systems:

7.3.2.1 *Hydrostatic testing*

The strength and integrity of piping system shall be tested by hydrostatic testing at water pressure equivalent to 1.5 times the design operating pressure for stipulated time.

a) *Hydrostatic pressure testing procedure* – The hydrostatic pressure test shall be conducted as mentioned below:

   1) *Step* 1 – Filling the System

      i) Fill the entire piping network with water.

      ii) Ensure that all air pockets are removed.

   2) *Step* 2 – Pressurization

      i) Gradually increase the water pressure to at least 1.5 times the design pressure.

      ii) Maintain this pressure for a specified duration (usually a few hours).

   3) *Step* 3 – Inspection

      i) Inspect the entire system for leaks.

      ii) Pay attention to joints, welds, and connections.

   4) *Step* 4 – Record Keeping

      i) Document the test results, including pressure readings and any observed leaks.

   5) *Step* 5 – Depressurization

      i) Gradually reduce the pressure and drain the system.

b) *Safety considerations*

   1) Ensure safety protocols are followed during pressurization and depressurization.

   2) Personnel should be aware of potential hazards.

c) *Pipe conditioning*

   Pipe conditioning removes debris, dirt, and contaminants from the pipes and to form a protective anti corrosive layer on the inner surface of the pipes. The procedure for pipe conditioning is as follows:

   1) *Step* 1 – Preparation

      i) Ensure the system is clean and free from construction debris.

   2) *Step* 2 – Flushing Process

      i) Flush the pipes with water to remove loose particles.

      ii) Use stipulated high-velocity flow to dislodge any remaining debris.

      iii) Passing criteria to next step is to get clean water after flushing.

   3) *Step* 3 – Chemical cleaning

      i) Flush the pipes with water mixed with cleaning chemicals.

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ii) Use stipulated high-velocity flow to dislodge any remaining debris.

iii) Passing criteria to next step is to get clean water and to meet certain water parameters at the end of chemical cleaning.

4) *Step* 4 – Passivation

i) Circulate the water mixed with passivation chemicals for stipulated period

ii) Passing criteria is to get clean water and to meet certain water parameters at the end of passivation

iii) Minimum quantity of passivation chemicals shall be ensured at the end of passivation and throughout the operation period.

5) *Step* 5 – Verification

i) Verify that the system is clean and ready for operation.

6) *Step* 6 – Record Keeping

i) Document the pipe conditioning process.

7.3.2.2 *Performance testing of DCS*

Performance tests fall under two categories, operational performance and availability performance. Operational performance is to ensure that during operation plant is meeting the designed electrical and water performance. Availability test is to ensure that availability of the plant equipment is meeting the availability and reliability conditions set forth over a stipulated time without any downtime.

Following indices shall be used to establish performance of a DCS:

Overall plant efficiency	kWh/TR-h
Water consumption	litre/h
Cooling tower water discharge	litre/h

Table 16 shall be used for benchmarking of performance of DCS.

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Table 16 Recommended Performance of DCS

(*Clause* 7.3.2.2)

Sl No.	DCS Plant Type	TES	Condenser Cooling	Water Source	Max kW/ TR-h
(1)	(2)	(3)	(4)	(5)	(6)
	Energy Consumption				
i)	New	Chilled Water	Cooling Tower	Recycled/City supplied	0.87
ii)	New	None	Cooling Tower	Recycled/City supplied	0.91
iii)	New	Ice	Cooling Tower	Recycled/City supplied	1.17
iv)	New	None	Cooling Tower	Sea Water	0.96
v)	Existing	Chilled Water	Cooling Tower	Recycled/City supplied	1.00
	Condenser Water Consumption				litres/TR-h
i)	New/Existing	Ch Water/None	Cooling Tower	City Supply	8.00
ii)	New/Existing	Ch Water/None	Cooling Tower	Recycled	11.00
	Cooling Tower Water Discharge				
i)	New/Existing	Ch Water/None	Cooling Tower	City Supply	1.5 to 2.0
ii)	New/Existing	Ch Water/None	Cooling Tower	Recycled	4.5 to 5.0

7.4 Operation and Maintenance of DCS – Best O&M Practises

Practices as given below shall be followed for operating and maintaining a district cooling system:

a) Regular inspections and maintenance:

   1) Conduct routine inspections of equipment, pipelines, and components;

   2) Address minor issues promptly to prevent major failures; and

   3) Implement PPM strategies

b) Water treatment and quality:

   1) Maintain water quality in chilled water and hot water systems:

      i) Regularly clean and treat cooling towers to prevent scaling, corrosion, and biological growth.

c) Energy efficiency measures:

   1) Optimize the operations of chillers, pumps, cooling towers etc;

   2) Monitoring and control strategies; and

   3) Implement variable flow systems and energy-efficient equipment.

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d) Leak detection and repair:

1) Monitor for leaks in distribution networks and fix them promptly; and

2) Leaks waste energy and reduce system efficiency.

e) Thermal storage optimization:

1) Use thermal energy storage (TES) effectively to balance supply and demand; and

2) Charge TES during off-peak hours and discharge during peak demand.

f) Metering and billing accuracy:

1) Ensure accurate metering for billing purposes; and

2) Individualize metering for end-users where possible.

7.5 Economics of DCS [Business Model for DCS – CaaS (Cooling as a Service)]

Cooling as a service (CaaS) is an innovative business model where end-users subscribe to cooling services without owning the infrastructure. The district cooling provider finance, build and maintains the cooling plant, promoting energy efficiency and sustainability. Users benefit from reduced upfront costs and simplified operations, while the provider ensures reliable service delivery. CaaS shifts the focus from ownership to access, fostering efficient and sustainable cooling solutions

7.5.1 *Tariff Structure - Fixed and Variable Charges + Connection Charges*

The tariff structure for district cooling systems is monthly and typically includes the following components. The recovery mechanism shall be tailored based on the various models in the real estate market say lease, sale, hybrid model etc and hence various contract strictures shall be tailored between real estate developer, DCS developer and end users:

a) *Connection charge* — It's a one-time fee paid by users when connecting to the district cooling system.

b) *Contract capacity charges* — These charges are effectively availability fees, covering capital expenditures (CapEx) and fixed operation and maintenance (O&M) costs. They ensure that the district cooling provider maintains the capacity to deliver cooling services.

c) *Consumption charge* — The consumption charge covers variable O&M costs, including chemicals, electricity, and water (potable or treated sewage effluent) consumed by the end users.

7.5.2 *Service Level Agreement* (*SLA*) *and Key Performance Indicators* (*KPI*)

These ensure clear expectations and measurable standards for the performance and maintenance of district cooling systems:

a) *Service level agreement* (*SLA*) — A Service level agreement (SLA) outlines the expected level of service between a service provider (district cooling plant) and its customers. Key components of an SLA for a district cooling plant might include:

1) cooling capacity commitment;

2) reliability and availability; and

3) penalty terms basis performance matrix.

b) Key Performance Indicators (KPIs):

1) Coefficient of performance (COP);

2) Chilled water supply and return temperature (CHWST/CHWRT);

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3) Chilled water return temperature (CHWRT); and

4) Water usage efficiency (Litre/TRh).

8 SUPPLY AIR DUCTS AND RETURN AIR DUCTS

Following provisions to be considered for supply air ducts and return air ducts construction:

a) duct Systems are a continuous passageway for the transportation of air which, in addition to the ducts, may include duct fittings, dampers, plenums, grilles and diffusers and such other accessories as may be required. Leak tightness, adequate supporting and proper installation are important requirements;

b) due to aerodynamic considerations, it is recommended that the aspect ratio of rectangular ducts (height to width ratio) be kept within 1 : 4;

c) designer shall specify the material of ducts, appropriate standard to be followed, maximum permitted velocity of air in the duct and the required pressure class as indicated in Table 17 and Table 18;

d) the duct supports shall be designed to handle the load and also to take into account seismic considerations;

e) if false ceiling is provided, the supports for the duct and the false ceiling, shall be independent. Collars for grilles and diffusers shall be taken out only after false ceiling/boxing framework is done and frames for fixing grilles and diffusers have been installed; and

f) where a duct penetrates the masonry wall, it should either be suitably covered on the outside to isolate it from masonry, to prevent vibration transmission. Refer Part F 'Fire and Life Safety' of this NBCS for safety requirements.

For more details on duct construction and installation, refer to the latest edition of accepted standard [D-3(14)].

Table 17 Classification by Internal Pressure and Pressure Range

(*Clause* 8)

Sl No.	Classification by Pressure	Normal Service Pressure Pa		Pressure Limits Pa	
		Positive Pressure	Negative Pressure		
(1)	(2)	(3)	(4)	(5)	(6)
i)	Low Pressure Duct	$P \leq + 500$	$- 500 \leq P$	+ 1 000	– 750
ii)	Medium Pressure Duct	$+ 500 < P \leq + 1\,000$	$- 500 > P \geq - 1\,000$	+ 1 500	– 1 500
iii)	High Pressure Duct	$+ 1\,000 < P \leq + 2\,500$	$- 1\,000 > P \geq - 2\,000$	+ 3 000	– 2 500

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Table 18 Recommended *Max* Duct Velocities

(*Clause* 8)

Sl No.	Application	Controlling Factor Noise Generation Main Ducts	Controlling Factor - Duct Friction			
			Main Ducts		Branch Ducts	
			Supply	Return	Supply	Return
		m/s	m/s	m/s	m/s	m/s
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Residences	3	5	4	3	3
ii)	Apartments	5	8	7	6	5
iii)	Hotel Rooms	5	8	7	6	5
iv)	Hospital Rooms	5	8	7	6	5
v)	Private Offices	6	10	8	8	6
vi)	Directors Rooms	6	10	8	8	6
vii)	Libraries	6	10	8	8	6
viii)	Theatres	4	7	6	5	4
ix)	Auditoriums	4	7	6	5	4
x)	General Offices	8	10	8	8	6
xi)	Restaurants	8	10	8	8	6
xii)	Stores	8	10	8	8	6
xiii)	Banks	8	10	8	8	6
xiv)	Cafeterias	9	10	8	8	6
xv)	Industrial **	13	15	9	11	8

NOTE — ** For specific industrial applications, refer to customer specific needs and choose a velocity to optimize energy consumption requirements.

8.1 Space Air Distribution

Space air distribution shall be classified by:

a) their primary objective; and

b) the methods by which the objectives are attempted to be accomplished.

The objectives of space air distribution shall be classified as one of the following:

1) providing occupant thermal comfort;

2) to support processes within the space; or

3) a combination of (i) and (ii).

The occupied zone is a space in any location where occupants normally reside and may differ from project to project. It may be application-specific and should be carefully defined by the designer. The occupied zone is generally considered to be the room volume between the floor level and 1.8 m above the floor level. For additional information special publication may be referred.

NOTE — Special publication maybe ANSI/ASHRAE Standard 55 and Standard 62.1 for further information.

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Space Air Distribution methods shall be classified as one of the following:

i) fully mixed systems (for example, overhead air distribution) which have zero or very little thermal stratification of air in the occupied zone or process space.

ii) fully stratified systems (for example, thermal displacement ventilation) have practically no air mixing in the occupied zone or Process Space.

iii) partially mixed systems (for example, most underfloor air distribution designs) provide limited air mixing in the occupied zone or process space.

iv) unidirectional air flow system (for example a laminar flow system) is designed to ensure no mixing and maintain a consistent air flow pattern, ensuring that air always moves from a clean to less clean areas.

v) personalized system (for example task/ambient air distribution systems) is an air distribution strategy that combines two different air supply methods to optimize IAQ, thermal comfort and energy efficiency.

8.1.1 *Fully Mixed Systems*

In mixed air systems, comfort is maintained by mixing of high velocity supply air with the room air. The air mixing, heat transfer and velocity reduction should occur outside the occupied zone. The three fundamental characteristics of the system are:

a) the supply air outlets are located far away from the occupied zone;

b) the supply air temperature is considerably lower than the room temperature (the normal ΔT between supply air and room air would be of the order of 11 °C to 12 °C). When supplying heated air from overhead outlets, ensure that the ΔT between supply air temperature and room air temperature is not more than 8 °C to 9 °C to avoid stratification; and

c) the supply air (SA) outlet velocity should be much higher than the desired occupied zone air velocity. The supply air outlet velocity should be of the order of 3.5 m/s to 5.0 m/s. The resultant occupied zone velocity should be between 0.2 m/s to 0.25 m/s for cooling, and not more than 0.15 m/s for heating. When SA outlets are used at the perimeter with vertical projections for heating and/or cooling, they should be located near the perimeter surface. Outlet selection shall be done on the basis of the isothermal terminal velocity of 0.75 m/s extends at least half way down the surface or 1.5 m above the floor (whichever is lower) thus ensuring that the warm air mixes with the cool downdraft on the perimeter surface, to reduce draft in the occupied zone.

8.1.2 *Fully Stratified Systems*

Systems that discharge cool air at low sidewall or floor locations with very little entrainment of room air into the primary air stream create vertical thermal stratification throughout the space. The three fundamental characteristics of the system are:

a) the supply air outlets are located directly in the occupied zone;

b) the supply air temperature is much closer to the room temperature (the normal ΔT between supply air and room air would be of the order of 3 °C to 6 °C); and

c) the supply air (SA) outlet velocity should be of the order of 0.25 m/s to 0.35 m/s.

In spaces where the internal heat gain density exceeds 120 W/m^2, care should be taken to ensure comfort by providing supplementary localized cooling terminals to address the higher heat gain densities. Care should be taken to limit downward drafts driven by cold walls or windows. The vertically stratified temperature field needs to be stable for proper functioning.

Ensure that the design provides for appropriate measures for maintaining the RH within the specified levels.

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Stationary occupants should not be subjected to discharge velocities exceeding about 0.2 m/s. SA outlets shall not be located closer than 1 m from any occupant. SA outlets should not be located behind furniture and other obstructions that impede airflow.

Stratified systems shall not be used in conjunction with mixed air systems because mixing destroys natural stratification that drives displacement ventilation.

8.1.3 *Partially Mixed Systems*

Supply air (SA) (usually from the floor) is discharged vertically at relatively high velocities and entrains room air akin to SA outlets in fully mixed systems. Underfloor air distribution systems (UFAD) shall be classified as partially mixed systems. The cavity below the access floor tiles is generally pressurized and used as SA Plenum.

As with fully stratified systems, the partially stratified systems in humid climates should ensure that the design provides for appropriate measures for maintaining the RH within the specified levels.

SA outlets should be of the swirl type with a high-induction core which promotes quick reduction in velocities and temperature gradients.

SA outlets should be located far enough from stationary occupants to ensure that they are not exposed to drafts and noise causing discomfort.

SA temperature in the access floor cavity should be kept at or above 16 °C to minimize the risk of condensation and consequent fungal growth.

Access floor plenums should be well sealed to prevent air leakages. Exterior walls should be well insulated and have proper vapour retarders. Night/holiday temperature set-backs should be avoided (or at least reduced) to minimize plenum condensation and thermal mass effect problems.

Return static pressure drop should be relatively equal throughout the space being served by the plenum. This reduces the chances of unequal pressurization within the Plenum.

Partially stratified systems shall not be used in conjunction with mixed air systems because mixing destroys natural stratification that drives displacement ventilation.

8.1.4 *Unidirectional Air Flow Systems*

A unidirectional air flow system is a type of ventilation system that provides a controlled, one-way flow of air through a facility or room. This system is designed to minimize contamination, reduce air turbulence, and improve indoor air quality.

Key features of this system are:

a) air flows in a single direction, from the cleanest area to the most contaminated area;

b) air flows in a smooth, parallel stream, reducing turbulence and mixing (laminar flow);

c) air is filtered to remove particles and contaminants before entering the space;

d) the space is maintained at a positive pressure to prevent outside air from entering; and

e) contaminated air is exhausted directly outside, without recirculation.

The key benefits of the unidirectional air flow system is improved air quality, reduced risk of cross-contamination, enhanced particle count control thus leading to easier regulatory compliance in required applications like cleanrooms, laboratories, healthcare facilities (operating room, isolation rooms), food processing facilities and the like.

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8.1.5 *Personalized Systems*

Task/Ambient air distribution systems is an air distribution strategy that combines two different air supply methods to optimize IAQ, thermal comfort and energy efficiency.

Following are the two methods:

a) *Task air* — Supplies conditioned air directly to the breathing zone (directly via special outlets inbuilt in the seating systems/workstations). The SA is very precisely tempered to the correct temperature and humidity; and

b) *Ambient air* — Supplies to the overall space above and out of the breathing zone so as to maintain a comfortable thermal environment and air quality.

Such personalized systems, by separating the air components into task and ambient, offer several benefits including improved air quality, enhanced thermal comfort and increased energy efficiency.

8.1.6 *Supply Air Outlet* (*Airflow Mixing*) *Types and Ventilation Effectiveness*

The Table 19 and Table 20 below provides an understanding of the various types of systems, their ventilation efficiencies.

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Table 19 Various Types of Systems and Their Ventilation Efficiencies

(*Clause* 8.1.6)

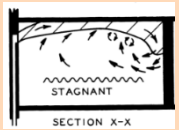
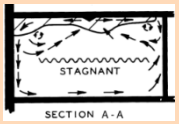
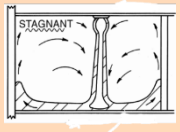
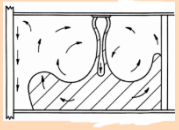
Sl No.	Methods	Suitable Air Outlet	Zone Air Distribution/Change Effectiveness (E_z)		
			Cooling	Heating	Features
(1)	(2)	(3)	(4)	(5)	(6)
i)	Fully Mixed System, Entrainment from Sidewall	High Sidewall Grilles, Sidewall Diffuser, Nozzle and similar outlet providing ceiling attached flow	E_z=1 (Ideal)	 E_z =0.8 (Ideal)	Suitable for summer cooling and minor winter heating (temperature difference +10K warm air). Velocity in the occupied zone should be less than 0.35 m/s
ii)	Fully Mixed System, Horizontal Discharge from Ceiling	Ceiling Diffuser, Linear Ceiling Diffuser or similar outlets with Horizontal diffusion pattern	E_z =1 (Ideal)	 E_z =0.8 (Ideal)	Suitable for summer cooling and minor winter heating (temperature difference +10K warm air). Velocity in the occupied zone should be less than 0.35 m/s
iii)	Fully Mixed System, Vertical Downward Air Projection from Ceiling	Adjustable Grille, Jet Nozzle, Ceiling Spot Diffuser, Linear Ceiling Diffuser or similar outlets with vertical downward air projection	 E_z =1 (Ideal)	 E_z =1 (Ideal)	Suitable for either cooling or heating with increased terminal velocity in order to project warm air up-to the occupied zone.
iv)	Partially Mixed System, Non Spreading Vertical Jet in or near floor	Floor Diffuser, Sidewall Grilles, Sidewall Diffuser or similar outlets with fixed vertical spread pattern.			Suitable for cooling and heating both at terminal velocity ~ 0.75 m/s (ideal). Outlet shall be placed at 150 mm distance from wall.

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Table 19 (*Concluded*)

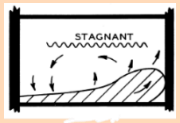
Sl No.	Methods	Suitable Air Outlet	Zone Air Distribution/Change Effectiveness (E_z)		
			Cooling	Heating	Features
(1)	(2)	(3)	(4)	(5)	(6)
			E_z =1 (Ideal)	E_z =1 (Ideal)	
v)	Partially Mixed System, Spreading Vertical Jet in or near floor	Floor Diffuser, Sidewall Grilles, Sidewall Diffuser with adjustable spread pattern or similar outlets			Suitable for severe heating and minor cooling requirements (temperature difference -8K cool air). Velocity at 1.4m above floor i.e. occupied region should be less than 0.25 m/s
			E_z =1 (Ideal)	E_z =1 (Ideal)	
vi)	Fully Stratified System, Low Horizontal Discharge near floor	Baseboard or Low sidewall Grille, Displacement Diffuser or similar outlets			These outlets direct high velocity total air directly into the occupied zone and therefore not recommended for particularly summer cooling. Terminal Velocity <1.5 m/s and mostly suitable for process installations where controlled air velocities are desired.
			E_z =1.2 (Ideal)	E_z =1 (Ideal)	
vii)	Unidirectional Airflow System, Plug type from ceiling exhausted through wall	Laminar Flow Diffuser with perforated/helical face plate			Generally, a preferred choice for use in a cleanroom for manufacturing, healthcare and research. Other performance parameters such as colony forming unit and room class affects its choice and selection

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Table 20 Recommended Supply Air Outlet Selection

(*Clause* 8.1.6)

Outlet Types	Fully Mixed			Fully Stratified		Partially Mixed		
	Outlet Location							
	Ceiling	Wall	Floor	Wall	Floor	Ceiling	Wall	Floor
Grilles								
Adjustable Blade	☑	☑	NR	NR	NR	NR	NR	NR
Fixed Blade	NR	☑	NR	☑	NR	NR	NR	NR
Linear Bar Grille	NR	☑	☑	☑	☑	NR	NR	☑
Jet Nozzle	NR	☑	NR	NR	NR	NR	NR	NR
Diffusers								
Round	☑	NR	NR	NR	NR	NR	NR	NR
Square	☑	NR	NR	NR	NR	NR	NR	NR
Perforated Face	☑	NR	NR	NR	NR	NR	NR	NR
Louvered Face	☑	NR	NR	NR	NR	NR	NR	NR
Plaque Face	☑	NR	NR	NR	NR	NR	NR	NR
Laminar Flow	☑	NR	NR	NR	NR	NR	NR	NR
Slot Diffuser	☑	☑	NR	NR	NR	NR	NR	NR
Swirl Diffuser	☑	NR	NR	NR	☑	NR	☑	☑
Displacement	NR	NR	NR	☑	☑	NR	NR	NR

NOTES

1 Obstructions, vane adjustments, and other ceiling elements influencing airflow patterns shall affect comfort and efficiency.

2 Personalised system will increase E_z when used in combination with the above listed methods up to 1.5

3 During partial load, VAV systems shall affect E_z by reducing the air velocity at the outlet. Minimum airflow should be considered so that velocity in the occupied region does not go below 0.1 m/s while designing such systems and other performance criteria such as outdoor air intake and critical space CO_2 concentration should be monitored and controlled (demand control ventilation). Additionally, a dual duct system, fan powered and reheat terminal may be used in combination with VAV systems where precise and wide climate control range is required without affecting the E_z.

8.1.7 *Return Air Inlets*

Return air intake affects room air motion only immediately around the inlet. the selection of return air inlets should be based on performance data and not merely based on aesthetic and architectural considerations. The Table 21 below provides the recommended face velocities across Inlets based on their location.

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Table 21 Recommended Face Velocities Across Inlets Based on their Location

(*Clause* 8.1.7)

Sl No.	Inlet Location	Velocity Across Inlet m/s
(1)	(2)	(3)
i)	Above occupied zone	> 4
ii)	In occupied zone (not near seats)	3 to 4
iii)	In occupied zone (near seats)	2 to 3
iv)	Door/wall louvers	1 to 1.5
v)	Through door under-cuts	2 to 1.5

8.2 Airflow Measurements in Space Air Distribution Systems

Air flow measurement requirements and methods of air distribution systems aim to ensure adequate indoor air quality, energy efficiency, and occupant comfort in the occupied space. These requirements vary depending on the specific standard in use, but there are common elements that are often addressed. Understanding and adhering to these requirements and methods ensures that air distribution systems in buildings provide adequate ventilation, maintain indoor air quality, and operate efficiently. It is recommended that the airflow measurement should be conducted to meet the following requirements.

8.2.1 *System Balancing*

Air distribution systems shall be balanced to ensure each space receives the designed air flow. This typically involves testing, adjusting, and balancing (TAB) procedures to verify system performance. Airflow measurements using one of the following methods should be conducted in each space to achieve the designed values within a band of ± 5 percent. Proper documentation of all measurements, adjustments and maintenance activities shall be maintained. The following describes various airflow measurement methods to comply with the above requirements of system balancing:

a) *Anemometers* — Anemometers are used to measure the velocity of air flowing through ducts or at registers/diffusers.

b) *Barometers/flow hoods* — Barometers or Flow hoods are used to measure the airflow directly at the supply air outlets.

c) *Duct traverse method* — Duct traverse method involves measuring air velocity at multiple points across the duct cross-section using a pitot tube or hot-wire anemometer and calculating the average velocity to determine airflow rate.

d) *Pressure measurement* — Differential pressure measurements across known resistances (for example, orifice plates, flow hoods) shall be used to determine airflow rates.

e) *Tracer gas method* — Trace gas method introduces a tracer gas into the airflow and measures its concentration downstream to determine the airflow rate based on dilution principles.

For airflow measurements within ducts, it is recommended to use an air flow measuring station. Such air flow measuring station should ideally be located with a clear straight duct length of at least 4 times the equivalent duct diameter (of the duct in which they are installed), at the inlet of the air flow measuring station.

8.3 Flow Control – Volume Control Dampers

A damper is a valve or plate that stops or regulates the flow of air inside a duct, and other air-handling equipment.

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Manual dampers are operated by a handle on the outside of a duct. Automatic dampers are used to regulate airflow constantly and are operated by electric or pneumatic motors, in turn controlled by a thermostat or the building automation system.

Dampers are customized in terms of size to suit the openings, where they are to be installed. A right choice of volume control dampers/s shall result in energy conservation.

8.4 Variable Air Volume (VAV)

Variable air volume terminal units are devices that regulate the amount of air supplied to a specific zone or space in a building. They are an important component of fully mixed systems, which help to optimize energy efficiency and indoor air quality.

By optimizing air flow and conditioning, VAV terminal units play a crucial role in creating a comfortable, efficient, and sustainable indoor environment. When using VAV terminal units, observe the following guidelines to ensure safe and efficient operation:

a) Wherever possible, a straight duct inlet connection with a minimum length of three duct diameters and the same internal diameter as the inlet should be provided.

b) Never insert a duct inside the Inlet or control calibration will be adversely affected.

c) Ensure accurate sensor calibration to maintain precise control and avoid oscillations.

d) Balance airflow to prevent uneven distribution, reduced efficiency, and increased energy consumption.

e) Inlet air velocity should not exceed 12 m/s at max flow and should not be below 2 m/s. Ensure unit sizing is adequate to meet flow range and also meets noise criterion for the space.

f) When using terminals equipped with re-heat elements, to avoid compromising zone ventilation effectiveness, the discharge temperature should not be more than 8 °C warmer than the zone it serves. If electrical re-heat is being used, ensure all safety controls (like air stats/flow switch and other safety cut outs) as required by local codes are provided.

g) Ensure proper access is provided for the unit (like adequately sized access doors).

8.5 Thermal Beams

Chilled beams are a type of convection HVAC system used to heat or cool rooms they are air distribution devices with integral coils designed to heat or cool large buildings. Chilled beams shall be classified into two main categories, passive and active.

Passive chilled beams work using the phenomenon of natural convection, and they do not require any primary air supply.

Active chilled beams consist of a primary air supply connection that provides conditioned/dehumidified air and enhances air induction through the coil.

8.5.1 *Application Considerations*

Chilled beams are intended to operate without condensation. Consequently, active chilled beam supply water temperatures should be maintained at or above the room dew point temperature to prevent condensation on the coil. Passive chilled beam should be kept slightly above the room dew point temperature. In both cases, the chilled water piping shall be adequately insulated to prevent condensation on the pipe itself. Where adequate control of space humidity levels shall not be ensured, higher supply water temperatures and/or suitable condensation control should be considered.

Heating with passive beams is not effective. For heating, the hot water temperature serving the beam's coil shall be selected to limit the discharge air temperature to less than 8 °C above the room design set point.

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8.6 Air Curtains

An air curtain unit acts as a controlled barrier for environmental and thermal separation and wind resistance when a building's doors or windows are opened. Air curtains create an invisible barrier at openings and doors which separates different temperature zones without limiting access for people and vehicles. Air curtains are used where it is not feasible to have an engineered air lock.

8.6.1 *Application Considerations*

Air curtain unit selection depends on the opening's width and height. To maximize effectiveness, the air curtain unit shall at least cover or slightly overlap the entire opening and have a minimum velocity projection of 2 m/s at the target surface. The air curtain unit discharge shall have a free and clear path to the entire opening for optimum performance.

9 AIR FILTRATION AND ALTERNATE AIR CLEANING METHODS

With people spending a significant portion of their time indoors, ensuring good indoor air quality (IAQ) is paramount for occupant health, productivity, and overall well-being. The provisions related to indoor spaces that are regularly occupied and are either naturally or mechanically ventilated are covered. Following are the aspects to be considered for air filtration and alternate air cleaning methods.

9.1 Threshold Levels for Pollutants

Threshold values are made available for different pollutants depending on the severity of the health hazard that a pollutant shall create for the occupants. For details of threshold values for the different pollutants encountered in indoor air refer to **3.6.2**.

9.2 IAQ Monitoring

IAQ is a critical component in ensuring the health, comfort and productivity of occupants in commercial buildings. Monitoring IAQ involves the assessment of various air quality parameters. Some critical pollutants and air quality parameters are monitored continuously, while some are monitored/tested periodically. Continuous monitoring and periodic testing data are required for interpreting the indoor environment and initiating necessary mitigation measures.

9.2.1 *Continuous Real Time Monitoring*

Pollutants for continuous monitoring include CO_2, TVOC, PM2.5, and ozone. These pollutants should be monitored continuously in all regularly occupiable areas of the building. Regularly occupiable areas may be defined as spaces intended for human occupancy within commercial buildings, excluding areas like the pantry, toilets and store rooms. When determining compliance, missing measurements and data loss will be interpreted as a threshold/range exceedance for that period.

9.2.1.1 *Sampling frequency*

For continuous monitoring of temperature, relative humidity, CO_2, TVOC, PM2.5 and O3, the sampling frequency should be at least once every 5 minutes. Monitoring of these parameters should be done on a 24 h basis to establish a trend. This provides insights into indoor air quality, leading to possible actions for improvement. PM1.0 (particulate matter ≤ 1.0 µm) is increasingly recognized for its potential health impacts and may also be considered for monitoring as an emerging best practice.

9.2.1.2 *Deployment of sensors/monitoring devices*

Deployment refers to the position and the number of sensors/monitoring devices installed in the indoor space. Ideally, the sensors/monitoring devices should be installed in the breathing zone. The breathing zone is defined as that region of the indoor space between the horizontal planes at 1.1 m and 1.7 m height above the finished floor level. Sensors/monitoring devices may be installed under the ceiling if the ceiling height is restricted to 2.13 m. In such cases, it is necessary to ensure that the air distribution in the room is uniform so that the air parameters at the ceiling will be similar to those in the breathing zone. Sensors/monitoring devices should be installed at least 0.9 m from exits, window openings and air conditioning vents. Every enclosed place, such as cabins or meeting

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rooms occupied for an average of 50 percent of the daily working hours, shall have dedicated monitoring devices. General office and common areas shall have at least one device for every 450 m^2 floor area.

9.2.1.3 *Calibration of sensors*

All sensors and pumps used in the monitoring devices shall be calibrated to ensure that the accuracy levels are maintained as specified by the manufacturer and to identify any measurement errors. Calibration should cover the parametric range the sensors are expected to experience in real service. Sensors measuring PM2.5 and TVOC values should be recalibrated or replaced annually. CO_2 sensors utilising the automatic baseline correction method shall be recalibrated or replaced once every three years. Sensors measuring thermal comfort parameters shall be recalibrated or replaced once every three years. Field calibrations using a reference sensor are acceptable, provided the master sensor is similar in range, accuracy, least count and resolution to the sensor being calibrated. Moreover, the calibration procedure should be such that the master sensor will perform within the manufacturer's specified range and accuracy. The master sensor should have been calibrated at a laboratory. The calibration process shall capture a sufficient range and contaminant concentration using known span gases or exposure to ambient pollution to perform adjustments accurately. The calibration activity should be properly documented, and traceability certificates shall be provided wherever applicable. Appropriate calibrations of PM1.0 sensors may be done if provided.

9.2.1.4 *Display of IAQ data*

All IAQ parameters, under the purview of continuous monitoring, should be prominently displayed in a format that provides easy viewing and understanding to all occupants of the building. Having at least one common electronic data display on each floor/section showing the real-time snapshot of all the devices on that particular floor/section is recommended. Alternatively, there could be one common display at the main entrance that provides a real-time representation of the IAQ data for the entire building.

9.2.1.5 *Recommended sensor specifications for continuous monitoring*

The selection of the sensors is a crucial requirement for obtaining reliable and accurate measurements. Improper sensor selection will lead to erroneous data on IAQ. The Table 22 provides details about the type of sensor to be used and their recommended range, accuracy, and resolution to capture meaningful IAQ data.

Table 22 Required Range and Accuracy of Sensors Used for Continuous Monitoring

(*Clause* 9.2.1.5)

Sl No.	Parameters	Unit	Range	Accuracy	Resolution
(1)	(2)	(3)	(4)	(5)	(6)
i)	PM10	µg/m³	0 µg/m³ to 1 000 µg/m³	± 10 percent of reading	1 µg/m³
ii)	PM2.5	µg/m³	0 µg/m³ to 1 000 µg/m³	± 10 percent of reading	1 µg/m³
iii)	CO_2	ppm	400 ppm to 5 000 ppm	± 50 ppm or ± 5 percent of reading (whichever is greater)	1 ppm
iv)	TVOCs	ppb	0 ppm to 5 000 ppb	± 20 ppb or ± 15 percent of reading (whichever is greater)	1 ppb
v)	Temperature	°C	0 °C to 100 °C	± 1 °C	0.1 °C
vi)	Relative humidity	percent	5 percent to 95 percent	± 5 percent of reading	1 percent
vii)	Ozone	ppb	20 ppb to 500 ppb	± 10 ppb at 0-100 ppb	5 ppb

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9.2.2 *Periodic Monitoring/Testing*

Periodic monitoring refers to measuring pollutants at a reasonably low frequency, typically several months apart. Pollutants for periodic monitoring include CO, SOx, NOx and HCHO. Sampling locations for periodic monitoring shall be representative of occupied spaces and should be located in the breathing zone as defined in **9.2.1.2**. Testing should be carried out under regular building conditions. Any test conducted without occupants or when the occupancy is considerably lower than on regular days shall be avoided.

9.2.2.1 *Sampling Frequency during periodic monitoring/testing*

Based on the pollutant's characteristics, the constraints in their monitoring technology, and their occurrence indoors, some pollutants are assessed periodically. The periodicity of such tests may be defined as "at least once every six months" (may be considered by NABL Labs). Building operators may resort to a more frequent periodicity if the test results warrant the same.

9.2.2.2 *Procedure for periodic monitoring/testing*

a) HCHO — The test shall be in accordance with best practices[1)]. The sampling duration should be a minimum of one continuous hour or the equivalent duration of the sampling procedure special publication[2)] may be referred.

b) CO — The sampling shall be carried out for at least one continuous hour (10 minutes of acclimation followed by 50 minutes of measurement time), with measurements recorded at least once every minute. Recommended procedures are the special publications[3)] may be referred. (CO by gas bag sampling).

c) NOx — NOx is measured gravimetrically using the modified Jacob and Hochheiser method and the chemiluminescence test. The monitoring of NOx shall be carried out in accordance with best practices[4)].

d) SOx — SOx shall be monitored gravimetrically using the improved West and Gaeke method and Ultraviolet Fluorescence in accordance with best practices[5)].

[1)] best practices maybe ISO 16000-3 for HCHO.

[2)] Special publication maybe ISO16000-3 for sampling procedure in case of HCHO.

[3)]Special publication for recommended procedures for CO maybe NIOSH Manual of Analytical Methods (NMAM), Fifth Edition,1997, OSHA Methods ID 209: 1993 (CO by direct-reading monitor) and OSHA Methods ID 210: 1991.

[4)] best practices maybe ISO 16000-15 for NOx.

[5)] best practices maybe ISO 16000-1 for SOx.

9.2.2.3 *Recommended sensor specifications for periodic monitoring/testing*

During periodic monitoring/testing, appropriate measuring instrument shall be used to obtain reliable and accurate measurements. The following Table 23 provides details about the type of instrument to be used and their recommended range, accuracy, and resolution to obtain factual test results.

Table 23 Sensor Specifications for Periodic Monitoring/Testing

(*Clause* 9.2.2.3)

Sl No.	Parameters	Unit	Range	Accuracy	Resolution
(1)	(2)	(3)	(4)	(5)	(6)
i)	CO	ppm	0.1 to 25	± 3 percent or ± 1 ppm (whichever is greater)	0.1 ppm
ii)	NOx	ppb	0 to 500	± 20 ppb or ± 15 percent of reading (whichever is greater)	1 ppb

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Table 23 (*Concluded*)

Sl No.	Parameters	Unit	Range	Accuracy	Resolution
(1)	(2)	(3)	(4)	(5)	(6)
iii)	SOx	ppb	0 to 500	± 5 percent of reading	1 ppb
iv)	Formaldehyde	ppb	20 to 1 000	± 20 ppb	1 ppb

9.3 Air Filters for Removing Pollutants in Indoor Spaces

Air filters shall be used in HVAC systems to remove airborne pollutants from indoor air and prevent outdoor pollutants from entering the building through outdoor air intakes.

The filters shall be as per accepted standards [D-3(15)], [D-3(16)], [D-3(17)] and [D-3(18)] for classification and performance requirements may be referred.

9.3.1 *Classification of Air Filters*

Air filters are classified mainly based on their ability to filter out pollutants. Due to the differences in the methods for determining this ability, air filters shall be classified in multiple ways. Air filters are classified based on their gravimetric efficiency, particulate matter efficiency or fractional particle size efficiency.

9.3.1.1 *Classification of air filters*

The accepted standard [D-3(15)] shall be adopted to classify air filters based on particulate matter efficiency. This method of specifying the performance of air filters applies to fine filters. It is a preferred method of classification while specifying air filters for general human health and wellness applications (comfort applications), as particulate matter concentrations inside buildings directly correlate with the adverse health effects on the occupants. The test method mentioned in the standard determines the initial efficiency of the air filter in both the "as-manufactured" condition and the discharged condition to calculate the minimum and average particulate matter efficiency. The filter class is reported as ISO ePMx (y percent), where x is the particle size referred to (1 µm, 2.5 µm or 10 µm) and y is the particulate matter efficiency. Classification of air filters based on particulate matter efficiency as per accepted standard [D-3(15)] is given Table 24.

NOTE — The symbol ePMx describes the efficiency of an air cleaning device to particles with an optical diameter between 0.3 µm and x µm.

Table 24 Classification of Air Filters based on Particulate Matter Efficiency

(*Clause* 9.3.1.1)

Sl No.	Group Designation	Requirement $ePM_{1,\ min}$	Requirement $ePM_{2.5,\ min}$	Requirement $ePM_{10,\ min}$	Class Reporting Value
(1)	(2)	(3)	(4)	(5)	(6)
i)	ISO Coarse	NA	NA	< 50 percent	Initial gravimetric arrestance
ii)	ISO *e*PM10	NA	NA	≥ 50 percent	ePM_{10}
iii)	ISO *e*PM2.5	NA	≥ 50 percent	NA	$ePM_{2.5}$
iv)	ISO *e*PM1	≥ 50 percent	NA	NA	ePM_{1}

9.3.2 *Resistance to Airflow in Air Filters*

The resistance to airflow is measured as the differential pressure across the air filter in a test setup. The resistance vs airflow rate characteristics are established at 25 percent, 50 percent, 75 percent, 100 percent and 125 percent of the rated flow of the air filter. Procedures mentioned in accepted standard [D-3(17)] shall be followed to

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determine the same. The resistance as a function of airflow rate provides useful information on the selection and performance of an air filter.

9.3.3 *Air Filters Using Electrostatically Charged Fibrous Media*

Some air filters use fibrous media that carries an electrostatic charge. The charge helps in improving the filtration efficiency of smaller particles. This will help achieve higher filtering capabilities at a lower initial resistance for a given airflow rate, thereby reducing operating costs. However, should the charge be compromised for any reason, the filtering capability of these air filters will be drastically reduced. Hence, when electrostatically charged fibrous media air filters are used, it is recommended that suitable monitoring systems be used for measuring the indoor particle concentrations so that any reduction in the filtering capability of the air filter shall be noticed and suitable actions shall be taken.

9.3.4 *High-Efficiency Filters*

High-efficiency filters shall be used in critical industrial, scientific and research applications that demand stringent control of airborne solid and liquid phase pollutants. They are classified based on their filtration efficiency at most penetrating particle size (MPPS). The MPPS is defined as the particle size of the challenge aerosol that will offer the lowest efficiency when challenged onto an air filter. The accepted standard [D-3(19)] shall be used to classify high-efficiency filters. This standard classifies high-efficiency filters based on their overall efficiency and local efficiency (leak scan test). (*see* Table 25)

Table 25 Classification of High-Efficiency Air Filters

(*Clause* 9.3.4)

Sl No.	Filter class	Overall Efficiency at MPPS	Local Efficiency at MPPS
		percent	percent
(1)	(2)	(3)	(4)
i)	ISO 15 E	≥ 95	NA
ii)	ISO 20 E	≥ 99	NA
iii)	ISO 25 E	≥ 99.5	NA
iv)	ISO 30 E	≥ 99.90	NA
v)	ISO 35 H	≥ 99.95	≥ 99.75
vi)	ISO 40 H	≥ 99.99	≥ 99.95
vii)	ISO 45 H	≥ 99.995	≥ 99.975
viii)	ISO 50 U	≥ 99.999	≥ 99.995
ix)	ISO 55 U	≥ 99.999 5	≥ 99.997 5
x)	ISO 60 U	≥ 99.999 9	≥ 99.999 5
xi)	ISO 65 U	≥ 99.999 95	≥ 99.999 75
xii)	ISO 70 U	≥ 99.999 99	≥ 99.999 9
xiii)	ISO 75 U	≥ 99.999 995	≥ 99.999 9

9.3.5 *Air Filters for Removing Airborne Molecular Contamination*

A gaseous state pollutant in the air is called an airborne molecular contamination. Many gas phase pollutants are detected in the indoor air of buildings, and they shall be broadly classified as acid gases, base gases, aldehydes, oxidising gases, VOCs and other miscellaneous gases. Adsorption and chemisorption filters are used in HVAC systems and outdoor air intakes to remove these pollutants (for example H_2S, NH_3, HCHO, O_3, VOCs, NOx, SOx, Cl_2, CO etc.) from indoor air. These filters use adsorbents, known as molecular sieves, to remove the pollutants from the air stream through physical adsorption. Activated carbon, activated alumina and zeolites are the commonly used adsorbents. Additionally, the adsorbents are impregnated with suitable chemicals that react with

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the adsorbed pollutant to prevent their desorption. This process is called chemisorption. Molecular sieves are available as granules, pellets, and powders coated on fibrous media; hence, they shall be constructed as packed bed filters and extended surface pleated filters. For additional information special publications may be referred to assess the performance of these air filters.

NOTE — Special publications maybe ISO 10121-2 : 2013 and ISO 10121-3 : 2022.

The fundamental criteria for air filter selection is based on its:

a) filtration efficiency at the particle size range of interest;

b) gravimetric, particulate matter, or fractional particle size efficiencies;

c) resistance the air filter offers at its rated airflow; and

d) test dust capacity.

9.3.6 *Installation of Air Filters in HVAC Systems*

Most air filter installations in HVAC systems comprise of multiple air filters in a single system. The installation of air filters is vital since improper installation could lead to filter bypass, compromising the overall filtration system's efficiency even though the individual air filters may be good. Proper mounting arrangements and usage of gaskets to avoid filter bypass for ensuring the proper installation of an air filter.

9.3.7 *Field Testing of Air Filters*

Since the test results from standard laboratory tests shall vary from performance results in real service, conducting a filtration performance test in situ under real service conditions will help understand the actual performance. For *in-situ* testing purpose special publications may be referred, which provides the method for *in-situ* field testing of air filters and systems, shall be adopted.

NOTE — Special publication maybe ISO 29462 : 2022.

9.4 Alternate Air Cleaning Technologies

To ensure the indoor concentration of these pollutants within the safe levels as mentioned in **3.6.2**. The following text provides functional principle and instructions for use of various types of air cleaning technologies.

9.4.1 *Electrostatic Precipitators*

Electrostatic precipitators (ESP) use the principle of electrostatic attraction to trap particles. They are commonly used in industrial applications with high particle concentrations where mechanical (fibrous media extended surface) air filters may not be practical. ESPs have been used in comfort HVAC/AHU applications to reduce indoor PM2.5 concentration. ESPs also efficiently remove oil mist, such as in kitchen smoke and certain other industrial applications.

Ionization of the air stream may lead to ozone generation. When using ESPs, it shall be ensured that the ozone concentration in occupied spaces does not exceed the values mentioned in **3.6.3**. To ensure this, it is recommended to use suitable "ozone removal/reduction" technologies as a part of the system. ESPs shall be designed with safety interlocks to avoid electrical shocks and to stop the power module in case of less airflow.

The pressure loss of the electrostatic precipitator is very low and stays nearly constant. However, the filtration efficiency decreases as the collection plates accumulate with particles. Hence, the ionization and collection sections need to be cleaned regularly. ESPs are preferably located upstream of AHU cooling coils.

9.4.2 *Ultraviolet Germicidal Irradiation*

Ultraviolet germicidal irradiation (UVGI) systems in buildings shall be installed inside air handling units (AHUs) or air ducts. Additionally, they shall be installed as upper-zone UVGI systems (UZ-UVGI). The upper zone units have uniquely designed baffles that irradiate the upper zone of the room towards the ceiling. A gentle air movement in the room makes the upper zone unit more effective. For UZ-UVGI systems, the UV equipment/lamp

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shall be out of the line of sight for the occupants from all parts of the room. To meet the safe exposure limit of 60 J/m^2 for an 8-hour exposure period, the UV radiation intensity at the occupied zone shall be less than 0.002 W/m^2.

The use of UVGI for the heat transfer coils of air conditioning equipment is found to be very effective in eliminating biofilm build-up on coils and condensate drain pans, thereby improving heat transfer efficiency and hygiene inside air conditioning equipment.

Direct and visual contact of humans with UVGI systems shall be avoided. Service personnel shall wear the required safety goggles and aprons while attending to any service issue in AHU fitted with UVGI systems. The HVAC equipment fitted with UVGI shall have visible stickers on the equipment mentioning 'UVGI installed inside'.

NOTE — The degradation of materials used in HVAC equipment like AHUs due to UV exposure is another important aspect to consider when installing UVGI systems. Material compatibility with UVGI shall be assessed during design or subsequent retrofits.

9.4.3 *Photocatalytic Oxidation*

Photocatalytic oxidation (PCO) is a light-mediated redox (oxidation and reduction) reaction of gases and biological matter. This is achieved by impinging ultraviolet rays on a catalyst material and giving out hydroxyl radicals and super oxides, commonly referred to as reactive oxidative species (ROS).

9.4.4 *Photo-Hydro Ionization*

Photo-hydro ionization (PHI) is a light-mediated active air cleaning method similar to PCO. Removes bioaerosols (bacteria, viruses, fungi, etc), VOCs, formaldehyde and certain odour-causing chemicals from the air.

9.4.5 *Air Ionizers*

The use of air ionizers helps easier removal of particles by agglomeration.

9.4.6 *Plasma Air Ionization*

Ions are formed as air passes over the ionization tubes. Pollutants, including bioaerosols coming in contact with the ions, are oxidized and destroyed. Additionally, the generated ions encourage the agglomeration of particles, allowing them to be more easily removed through gravitational settlement and by the air filtration systems.

10 OTHER COMPONENTS OF CENTRAL HVAC SYSTEM

These components are required for the efficient functioning and regulation of heating, ventilation, and air conditioning in a centralized system.

10.1 Cooling Tower

Cooling towers are used to dissipate heat from water cooled refrigeration, air conditioning and industrial process systems to the atmosphere. Cooling is achieved by evaporating a small proportion of the recirculating water to the atmosphere. Cooling towers shall be installed at a place where free flow of atmospheric air is available.

Range of a cooling tower is defined as temperature difference between the entering and leaving water. Approach of the cooling tower is the difference between leaving water temperature and the ambient air wet-bulb temperature.

10.1.1 *Selection of Cooling Tower*

Following factors shall be considered for selection of cooling tower:

a) recirculating water flow rate;

b) design wet-bulb temperature;

c) approach, the designer shall endeavour for reducing the approach for maximizing energy conservation in the chiller;

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d) range;

e) water quality and;

f) outside air quality for cooling tower;

g) height limitation and aesthetic requirement;

h) location of cooling tower considering possibility of easy drain back from the system;

j) placement with regard to adjacent walls, windows and other buildings, and effects on these from any water carried over by the air stream, also known as drift;

k) sound levels, particularly during silent hours;

m) material of construction of the tower; particularly considering the nature/quality of ambient air and recirculating water;

n) direction and flow of prevailing wind; to minimise recirculation and interference; and

p) quality of water used for make-up; maintenance and service space availability.

10.1.2 *Selection Criteria*

These factors ensure the optimal performance, efficiency, and suitability of cooling towers for specific HVAC system requirements.

10.1.2.1 *Location of the cooling tower*

Location of cooling tower shall be determined by one or more of the following:

a) architectural compatibility;

b) rigging limitations;

c) structural support requirements;

d) cost of bringing auxiliary services to the cooling tower; and

e) noise transmission, plume, and drift considerations.

These are best handled by proper site selection during the planning stage. Cooling tower shall be installed raised above the mounting surface by 0.45 m to 1.25 m to permit installation of pot strainer in condenser water line from cooling tower sump; also, to provide easy drainage and maintenance of mounting surface as follows:

1) Cooling tower accessories shall be project-specific and shall include such items as walking platform; stairs and ladder safety cage; bird screen; tower loading and supporting structure; and variable speed drive fan motor. However, variable speed drives should be used only in very specific instances as allowing the cooling tower fan to run at full speed during periods of low load is generally more beneficial due to the lower water temperature achieved by the cooling tower that results in higher condenser efficiency and, hence, lower power consumption in the air-conditioning plant.

2) Cooling tower installation shall include installation of conductivity controller, flow meter on the makeup water line, overflow alarm and low-level alarm.

3) The recommended floor area requirement for various types of cooling tower is as given below:

Mechanical draft cooling tower : 0.014 to 0.28 m^2/kW (0.05 to 0.10 m^2/TR)

NOTE — The recommended floor area above does not include the area required around the tower for unobstructed air flow.

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4) Structural provision for the cooling tower shall be taken into account while designing the building. Vibration isolation shall be an important consideration in structural design.

5) Special care should be taken in design where noise transmitted to the adjoining building shall be of serious concern. Special vibration control and sound attenuation devices may be required in that case. Appropriate sound insulation and noise control measures shall be taken in such cases in accordance with Part D 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of this NBCS.

10.1.2.2 *Water quality*

Water is commonly used as a heat transfer medium to remove heat from the refrigerant vapour in the condenser. A cooling tower is used to dissipate the heat from the air-conditioning system to atmosphere. A cooling tower shall cool condenser water to within 2 °C to 3 °C of the ambient wet-bulb temperature, with modern cooling towers even achieving approach as low as 1 °C. Therefore, a water-cooled system operates at a condenser temperature that could be more than 20 °C in a corresponding air-cooled system, resulting in considerably improved efficiency and significantly reduced energy consumption.

Where make-up water is expensive, or not available at all or in limited quantities only, the use of an adiabatic cooler should be considered. An adiabatic cooler allows the use of water-cooled air-conditioning plant with water consumption 70 percent to 90 percent lower than that of a conventional cooling tower.

Certain amount of water is lost from circulating water in the cooling tower, as given below:

a) *Evaporation loss* — It is approximately 1 percent of the rate of water circulation per 6 °C of range.

b) *Drift loss* — The drift loss shall be below 0.1 percent of the rate of water circulation.

c) *Blow-down/bleed-off* — The amount of blow-down shall be below 0.8 percent of the total water circulation. If simple blow-down is inadequate to control scale formation, chemicals may be added to inhibit corrosion and limit microbiological growth.

Provision shall be made to make-up for the loss of circulating water. Provision for make-up water tank to the cooling tower shall be made. Make-up water tank to the cooling tower shall be separate from the tank serving drinking water. Makeup water should be sourced from treated water from sewage treatment, wastewater treatment plant, or from rain water harvesting.

Make-up water having contaminants or hardness, which shall adversely affect the refrigeration plant life, shall be treated. Treated water where hardness as ppm of $CaCO_3$ is reduced to 50 ppm or below is recommended for air conditioning applications. Water with pH value less than 5 shall also need to be treated. For treatment of water for cooling towers good practice [D-3(20)] shall be referred.

Cooling tower should be so located as to eliminate nuisance from drift to adjoining structures. Cooling tower approach and minimum efficiency shall be as per Table 26.

Table 26 Cooling Tower Approach and Minimum Efficiency

(*Clause* 10.1.2.2)

Sl No.	Building	Chiller	HWT	CWT	WBT	Efficiency
		kWr	ºC	ºC	ºC	kW/LPS
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	All others	Any	36.4	30.8	28.3	0.35
ii)	24 × 7 facilities	Any	35.6	30.0	28.3	0.35

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10.1.2.3 *Installation of cooling tower*

The cooling tower shall be mounted on a set of four or six numbers of reinforced cement concrete pillars (structural foundation) as per manufacturer's recommendations. Height of these pillars shall be not less than 1 m, actual height is decided at site as per space required to install a pot strainer below the water level in cooling tower sump, drain pipe and valve for complete drainage of sump, and to permit maintenance of slab upon which structural foundation is installed.

Cooling tower should be located at a well-ventilated place, preferably on the terrace of the building, in consultation with the structural consultant. Dynamic structural loading on the terrace shall be considered. Cooling tower shall be installed in such a way that its dynamic load is transferred directly to the building structural columns, for which necessary mild steel I-section may have to be provided. Anticorrosive coating such as epoxy coating shall be applied required for these mild steel I-sections. Suitable thickness of vibration isolation pads shall be placed between the tower and the I-sections to avoid transfer of vibration to building structure. Sufficient space shall be left all around the cooling tower support structure for efficient operation of the cooling tower.

When cooling tower is installed at ground level, contiguous to the utility services block, great care has to be exercised to prevent users and visitors from coming in close proximity to the cooling tower. This is necessary to avoid their exposure to legionellae bacteria which shall hibernate in the cooling tower sump, if operator does not follow strict instructions for regular bleed-off and chemical treatment of condenser water.

Also, the bleed-off tap should be given in the return line to cooling tower, instead of only providing in the sump to ensure the desired water quality.

10.1.2.4 *Safety aspects* (*while designing tower installation*)

a) Access to and from maintenance access doors, top of tower access platform with handrail system should be provided;

b) Ladders (either portable or permanent) to gain access to the discharge level or maintenance access doors should be provided;

c) Surrounding area should be clear;

d) Provision for lockout of mechanical equipment should be provided;

e) Safety cages around ladders should be provided;

f) Cooling tower shall be with appropriate electrical earthing;

g) Motor terminals shall be provided with appropriate enclosure for appropriate ingress protection; and

h) Bird cages shall be provided from all sides to prevent birds entering into the cooling tower.

10.1.2.5 *Testing of cooling tower*

Upon completion of installation, the cooling tower shall be tested for performance. The entering and leaving water temperatures, the entering air wet-bulb temperature, and the flow rate of water through the condenser water circuit shall be measured. The fan power consumption shall be checked from measurements at the fan motor. The tower capability shall then be calculated using the measured values and the manufacturer’s performance curves given with the technical submittal of the cooling tower and shall not be less than 95 percent.

10.1.2.6 *Critical parameters for cooling tower*

For cooling tower system following are the critical parameters:

a) Water flow rate;

b) Water temperature:

    1) *Inlet temperature* — Measures the temperature of the water entering the tower; and

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2) *Outlet temperature* — Measures the temperature of the water leaving the tower.

c) Cooling range measures the difference between inlet and outlet water temperatures;

d) Wet-bulb approach measures the difference between the outlet water temperature and the ambient wet-bulb temperature;

e) Fan power consumption monitors the energy used by the fan;

f) Water level;

g) *p*H level;

h) Conductivity/Total dissolved solids(TDS); and

j) Drift rate.

10.1.2.7 *Water quality management in HVAC system*

The objective of cooling water treatment is to:

a) increase production;

b) reduce downtime;

c) lower operating and chemical costs; and

d) reduce your operation's impact on the planet

Treatment of cooling water will be different depending upon the kind of system in use. Here are the basic types:

1) Once-through;

2) Open recirculating;

3) Closed recirculating; and

4) Specialized.

NOTE — A specialized cooling system might utilize compression or absorption-type refrigeration or air conditioning systems or it might include the use of industrial air washers in which air is filtered, sprayed and then forced through a series of mist eliminators.

Water quality is crucial in HVAC systems to prevent scaling, corrosion, and microbiological growth, which shall lead to reduced efficiency, equipment damage, and health risks.

Water treatment should be considered to prevent scaling, corrosion, and biological fouling of the condenser and circulating system.

Large system shall be provided with fixed continuous-feeding chemical treatment system in which chemicals, including acids for *p*H control, are diluted, blended and pumped into the condenser water system.

Corrosion-resistant materials should be required for the treatment of system components that come in contact with these chemicals. In piping system design, provision for feeding the chemicals, blow down, drain, and on-line testing should be included.

Treatment system design should incorporate mainstream filtration without separate pumping system.

Additionally, side stream filtration incorporation in the system design should be considered especially when the primary make-up water is from an un-clarified water source (bore well-tanker water, STP effluent etc) that is high in suspended solids and/or iron.

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10.1.2.8 *Recommended methods to control scale formation*

a) *Elimination at source* — Limit the concentration of scale-forming minerals by controlling cycles of concentration, or by removing the minerals before they enter the system;

b) *Monitoring cycle of concentration* — The ratio of makeup water rate to the sum of blow down and drift rate. The cycle of concentration shall be monitored by calculating the ratio of chloride ion, which is highly soluble in the system water, to that in the makeup water;

c) Mechanical changes in the system, like increasing water flow and providing exchanger with larger surface area, to reduce the chances of scale formation;

d) Feed acid to keep the common scale forming minerals, like, calcium carbonate, in dissolved state. Organic acid based specialty chemical formulations (*p*H reducers) are best suited for *p*H reduction in cooling water systems in terms of reducing the risk of acid induced corrosion; and

e) Treat with chemicals designed to prevent scale. (for example, scale inhibitors, dispersants and crystal modifiers).

For treatment of water for cooling towers, good practice [D-3(20)] shall be referred.

10.2 Closed-Loop Water System Treatment

Cooling and heating systems harness the power of water and refrigerant to transfer heat. Open circuits use cooling towers, while closed loops enclose water in pipes, cooling it through tubes and refrigerant, ensuring efficient temperature control in three precise steps.

Closed-loop systems have a reduced chance of contamination, but they are not maintenance free. Neglecting maintenance of a closed system promotes the growth of sludge and deposits. The most common problem with these systems is black magnetic iron oxide mud deposits. Over time, magnetic iron oxide particles bind together and collect on narrowed parts of the system. The most common place for this sludge is narrowed pipes, heat-transfer surfaces, cooling or heating coils and AHU and fan coils

The *p*H level of the water drops leads to bacterial growth or a system leak. Bacteria shall lead to pinhole leaks in the pipes, which shall affect both the water levels and chemistry. In addition to leaks, bacteria or mineral deposits shall reduce the ability of the system to transfer heat by coating the surfaces of the parts. Regular care of your components through water testing and chemical maintenance prevents the corrosion of the interior components of the system. In the closed system, effect of corrosion shall not be diagnosed.

While open systems need monitoring of water levels and watching for particulate matter from the environment in the water, closed circuit systems need control of the water's chemistry.

10.2.1 *Chemical Treatment of Closed Loop Systems*

To prevent corrosion in carbon steel components, the water shall maintain a high, or alkaline, *p*H. To keep the correct chemical balance, water treatment professionals have several options at their disposal:

a) *Polymers* — Prevent corrosion and scale by dispersing harmful components in water, without environmental impact;

b) *Corrosion inhibitors* — Form a protective film on system surfaces, reducing corrosion, buffering *p*H, and reacting with oxygen; and

c) *Biocides* — Eliminate bacteria, preventing organic growth, biofilms, and Legionella bacteria, which shall contribute to corrosion.

10.3 Chilled and Condenser Water Pumps

Radial flow centrifugal pumps are recommended for use in HVAC systems for circulation or transfer of water or water/glycol solutions. Direct coupled pump assembly and inline pump should be used for smaller flow

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applications. Higher flow rate requiring motor size above 7.5 kW, pumps shall be coupled with high efficiency (IE3 and above) motors. Mono-block pumps shall be used up to 7.5 kW.

The split case horizontal pump shall be used in larger applications. Pumps shall be provided with the tapping on bearing housing for mounting of Vibration and temperature sensors, which shall be used for condition monitoring. For these pumps minimum IE3 (high efficiency class) motors are recommended.

Cavitation shall be avoided by selecting suitable location of pump with respect to the cooling tower, so as to always meet the net positive suction head (NPSH) requirement of condenser water pump.

10.3.1 *Selection Criteria and Types of Pumping System*

Pump shall be selected for optimized efficiency over the load profile, to operate at or near the best efficiency point (BEP) not more than 5 percent from the maximum efficiency curve to achieve energy efficiency. Pump shall be selected for optimized efficiency over the load profile, to operate at or near the best efficiency point (BEP) not more than 5 percent from the maximum efficiency curve to achieve energy efficiency. Wherever there is variable speed application, the pumps shall be with motor mounted VFDs or integrated drives with inbuilt intelligent IOT controls. IoT based controls shall have pump predictive analysis function with alert mechanism through SMS/email for various operational parameters.

Pump motor shall be energy efficient, having minimum IE3 (high efficiency class) motors, totally enclosed, fan-cooled, Class-F insulation and suitable for operation on AFD. Motor shall be specially designed for quiet operation. The motor rating shall be such as to ensure non overloading of the motor throughout its capacity range. Motor shall be suitable for 3-phase 415 percent + 10 percent volts, variable frequency power supply.

For water pumps, available net positive suction head (NPSH) shall exceed required NPSH to avoid pump cavitation.

The possible types of chilled water recirculation pumps are as given below:

a) Constant speed pumping system;

b) Variable speed pumping system (VSPS):

   1) Parallel VSPS configuration;

   2) Zoned VSPS configuration; and

   3) Primary secondary tertiary pumping system (P-S-T).

c) Primary only variable speed pumping system (PVF).

In order to improve energy efficiency of larger systems, where pumping energy amounts to 5 percent to 9 percent of total energy consumption in a building, glass flake coatings for large size pumps may be considered, based on life cycle cost assessment as it reduces friction improves and sustain efficiency.

Chilled water circulation system having pump motor larger than 3.7 kW rating are generally designed for variable fluid flow to offer large savings in operating cost.

10.3.2 *Installation of Pump*

The vertical in-line pumps do not require concrete pump foundation as they are of pipe mounted design. They become integral part of the piping system when installed as per manufacturer's instructions. Installation of efficient suction guide and triple duty valves shall also eliminate many piping accessories, resulting smaller installed footprint, as well as lowest embodied and life cycle carbon.

The horizontal base mounted pump base frame shall be mounted on concrete block which in turn shall be mounted on machinery isolation cork or any other equivalent isolation material. More than one pump set shall not be installed on a single base or on a single cement concrete block. Foundation bolts are required, shall be embedded correctly. Before the bolts are grouted and the coupling bolted, the base frame level shall be checked before proceeding with work.

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The pump motor shall then be mounted on base frame, alignment checked and shall then be connected to the pump with flexible coupling and with guard, both for the condenser and chilled water pumps.

The insulation for chilled water pump shall be carried out in a manner so that it allows maintenance of the pump without causing damage to the insulation. After installation of the complete system and before testing, the pump shall be lubricated in strict accordance with the manufacturer's instructions.

10.3.3 *Testing of Pump*

Upon completion of installation, capacity of the pump shall be checked by measuring water flow, using the balancing valve in fully open position, motor current and pressure differential between the inlet and outlet. The readings shall be compared with actual performance identified in the technical submittal of the pump.

10.3.4 *Critical Parameters for Pumping System*

a) Pumps for condenser/chilled water:

1) Water flow rate as established from pump curves based on suction/discharge pressure;

2) *Head pressure* — Measures the pressure generated by the pump;

3) *Current and power consumption* — Monitors the current drawn and energy used by the pump;

4) *Vibration* — Tracks the mechanical vibration of the pump;

5) *Temperature* — Monitors the pump's and motor's operating temperature;

6) *Discharge pressure* — Measures the pressure at the pump outlet;

7) *Suction pressure* — Measures the pressure at the pump inlet; and

8) *Efficiency* — Calculates the pump's efficiency based on flow rate and power consumption.

10.4 Air Handling Unit (AHU)

All-air system is commonly used for comfort, healthcare, pharma, process applications. The provisions do not apply to AHUs used for data-center application.

10.4.1 *Selection Criteria*

The designer shall select the air handling unit on the basis of supply air temperature and volume; outdoor air requirement; desired space pressure; heating and cooling coil capacity; humidification and dehumidification capacity; return, relief, and exhaust air volume requirement; filtration levels, and the corresponding pressure capability of the fan(s). Controls may be added as required for project specific requirements.

Air handling unit shall be as per accepted standard [D-3(21)] of AHU. It should be verified or certified for the compliance of the standard through an third part certifying agencies for compliance as per the accepted standard [D-3(21)]. Selection criteria should include the sound levels of the AHU like casing radiated, supply and return to help acoustic engineers.

10.4.2 *Fan*

Fan selection should be based on efficiency and sound power level throughout the anticipated range of operation, as well as on the ability of the fan to provide the required flow at the anticipated static pressure.

Fans used in AHUs, with motor power exceeding 0.37 kW shall be of minimum mechanical efficiency and minimum fan motors efficiency requirements as specified in below table or as per ESCBC whichever is stringent:

System Type	*Fan Type*	*Mechanical Efficiency*	*Motor Efficiency* {*As per* [D-3(22)]}
(1)	(2)	(3)	(4)
Air- Handling unit	Supply, return and Exhaust	65 percent	IE3 and above

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In addition, all fans used in AHUs having shaft power 2.5 kW or higher shall meet or exceed the FEI requirements of > 1.1.

a) Fan speed modulation control should be considered to save energy using duct static pressure signal; and

b) The power consumed by the AHU to be declared in the selection output and that should be part of the critical parameter for validation and measurement.

10.4.3 *Cooling Coil*

Cooling coil shall be designed as per the sensible and latent load. Number of rows of coils shall be determined as per the dehumidification requirements. Provisions shall be made to modulate the chilled water flow rate in the cooling coil for achieving high energy efficiency.

10.4.4 *Reheat Coil*

Reheat coil is heating coil placed downstream of a cooling coil. Reheat system is strongly discouraged, unless recovered thermal energy is used. Reheat coil is used to provide precise humidity control, which is generally not required for comfort conditions in most applications. Either reheat or desiccant is usually required to dehumidify outdoor air.

Reheating is necessary for specific applications like, laboratory, health care, or similar applications where temperature and relative humidity shall be controlled accurately. Hot-water coil, which provides a very controllable source of reheat energy, and thereby accurate relative humidity control is the preferred option for reheat coil. Condenser water recirculation through reheat coils may be considered for energy saving.

10.4.5 *Humidifier*

Humidifier shall be installed as part of the air handling unit only where close humidity control of selected spaces is required. For comfort installations requiring humidity control, moisture shall be added to the air by mechanical atomizer or point-of-use electric or ultrasonic humidifier placed in the conditioned area.

10.4.6 *Air to Air Energy Recovery Devices*

All hospitality and healthcare occupancies with energy recovery systems shall have air-to-air heat recovery equipment with minimum 60 percent recovery effectiveness at design conditions.

To prevent the wheel media from transferring exhaust air to the supply air duct, the heat wheel shall be fitted with an adjustable purging sector, with adjustable angle provision. The center of the wheel media shall consist of a hub with a shaft and bearings with efficient seal provided in the clearance between the rotor and the casing to minimize leakage between the supply air and exhaust air. Recommended higher face velocity limit is 3.5 m/s.

The outdoor air correction factor (OACF) and exhaust air transfer ratio (EATR) have direct impact on the energy consumption of the fans. The OACF should be in the range of 0.9 to 1. The EATR > 5 percent should not be acceptable.

10.4.7 *Fan Coil Unit* (*FCU*)

FCU shall be in accordance with accepted standard [D-3(21)].

10.4.8 *Air Filters*

Air filters used in AHUs shall be in accordance with accepted standards [D-3(15)], [D-3(16)], [D-3(17)] and [D-3(18)]. It is recommended to use ISO ePM1 50 percent in combination with ISO coarse and ISO ePM1 80 percent as second stage, for comfort applications (apart from critical applications like healthcare and cleanroom etc).

AHU filters shall be tested for filter bypass leakage in accordance with the accepted standard [D-3(21)].

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10.4.9 *Vibration Isolation*

Where floor mounted fans are used, the AHU shall have an internal vibration isolation system by mounting fan, motor and drive assembly on suitable deflection type anti-vibration mountings as well the fan discharge shall be connected to the AHU casing through canvas connection to prevent vibration transfer.

10.4.10 *Dampers*

The exhaust air damper/s shall not allow inflow of outdoor air under any circumstances. Dampers should be modulated via an automated control system.

10.5 Installation of Air Handling Unit (AHU)

Following provisions to be considered of installation of air handling units:

a) Floor mounted air handling unit is generally installed on a set of precast PCC blocks to raise it off the mounting surface to permit easy drainage of the AHU drain pan and cleaning of the mounting surface. A set of 4 or 6 numbers of 0.20 m × 0.20 m × 0.20 m blocks are generally used for AHUs up to capacity of 10 000 m^3/h airflow, and 6 or more 0.30 m × 0.30 m × 0.30 m blocks for higher capacity AHU;

b) Floor trap shall be provided in the AHU room for disposal of condensate which accumulates in the drain pan during operation of AHU. AHU room floor should slope in the direction of floor trap to avoid the accumulation of water in AHU room. The condensate drain piping shall be connected with U-trap of the floor drain to avoid odour carry over with the return air;

c) AHU location shall be marked on the AHU floor as per approved shop drawings/manufacturer's details. Co-ordination with contractors for civil works and other services shall be checked prior to installation;

d) Easy accesses and sufficient clearance shall be ensured for servicing and maintenance, that is, for cleaning of filters, maintenance of strainer/valve packages, tightening of fan belts, and repair as well as possible replacement of fan motor;

e) Duct flexible connection made of fire-proof material, shall be fixed on air outlet of the AHU, and if possible, also in perpendicular direction in main ducts within AHU room, to avoid vibration transmission along the ducts beyond the AHU room;

f) The valve package and piping connections shall be completed as per approved shop drawings;

g) Installation of ceiling suspended air handling unit shall be done with rod and fasteners as per the procedure stated above, barring the PCC blocks required for floor mounted AHU, and that insulated condensate drain pipe shall be laid in slope within ceiling space terminating into the U-trap of the nearest floor drain; and

h) Since the AHUs have the tendency to vibrate, both floor mounted and ceiling suspended AHUs shall be isolated from the structure by suitable rubber or spring-based isolators.

10.5.1 *Installation of Air Washer Unit (AWU)* – Air washer unit (AWU) components are similar to those of AHU, except for water spray section with in-line recirculation pump, which replaces the cooling coil. Installation of AWU shall follow the same steps as described above for AHU. Ceiling suspended AWU should be avoided.

10.6 Thermal Insulation

10.6.1 Air conditioning and water distribution systems, carrying chilled or heated fluids/air shall be thermally insulated to prevent undue heat gain or loss and to prevent internal and external condensation. Vapour seal shall be provided on chilled water pipes to avoid possibility of condensation.

10.6.2 The thermal insulation material shall be selected based on following physical characteristics:

a) *Fire properties* — Insulating materials shall be fire resistant and, in case of fire, shall not produce noxious smoke and toxic fumes;

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b) Materials and their finishes should inherently prohibit rotting, mould and fungal growth, attack by vermin, and should be non-hygroscopic;

c) Material should not give rise to objectionable odour at the temperature at which they are to be used;

d) It should not cause a known hazard to health during application, while in use, or on removal, either from particulate matter or from toxic fumes;

e) It should have a low thermal conductivity throughout the entire working temperature range;

f) It should have good mechanical strength and rigidity, otherwise it should be cladded for protection; and

g) The insulation material selected should be non-hygroscopic and naturally resist the ingress of water vapour without any vapour barriers.

10.6.3 *Material*

Selection of material shall be as per design requirement, such as, closed cell flexible elastomeric foams, expanded/extruded polystyrene (EPS/XPS) and phenolic foam. Insulation should be flexible in natural to ease of handling, should be able to take contours of the surface on which it is installed, and thickness of insulation should be calculated for each project. For additional information special publication may be referred. The fire rating of insulation material for Class 0 for fire propagation test and Class 1 for surface spread of flame test may be referred from special publication for additional information.

NOTE — Special publication maybe DIN EN 12667 and EN ISO 8497 for testing thermal conductivity, EN 13501 and BS 476 Part 6 : 1989 for fire rating Class 0 for fire propagation test and BS 476 Part 7, 1987 for fire rating Class 1 for surface spread of flame test.

Insulation should possess the self-extinguishing property and it should not drip or spread the flames. Insulation should have zero ozone depletion potential, zero global warming potential, dust and fibre free. Insulation should have good resistance to ozone, oil and chemical. Insulation material should be compatible to various covering options like metal, polymeric, glass cloth, silver polymeric laminate etc.

The guidelines for insulating with fibre glass are given below; for other insulation materials, manufacturers' recommendations for installation should be followed.

10.6.4 *Thermal Insulation of Duct*

Insulation material for ducts shall be anti-microbial to ensure the indoor air quality. For microbiological growth on insulation surface and bacterial resistance special publications may be referred.

NOTE — Special publications maybe ASTM G-21 for Microbiological growth and ASTM 2180 or EN ISO 846 Method A and Method C for bacterial resistance.

The insulation materials shall be phenolic foam {as per accepted standard [D-3(23)]} closed cell flexible elastomeric foam/ fibre glass based. The insulation materials should be non-hydroscopic. PUF/Polyurethane shall not be used.

Elastomeric foam tubes, due to its vulnerability to fire, should be used only with full protection fire against with full cladding to smaller size pipes, and not on ducts.

The thermal insulation material should be wrapped around the duct with facing on outer side. Joints of insulation should be properly sealed with either same type of material or tape of 50 mm width on all longitudinal/transverse joints. Finally, straps should be fixed at suitable interval to ensure that the insulation is properly fixed with the ducts. Thermal insulation of the ducts, surface of duct, on which the external thermal insulation is to be provided, shall be thoroughly cleaned with wire brush and rendered free from all dust and grease. Then, one coat of cold-setting adhesive, should be applied over the duct surface and one coat of adhesive to be applied on insulation.

The facing of the insulation should be determined based on the site conditions. Facings can be plain, alufoil, polymer based, Glass cloth, PVC based or non-metallic composite cladding in case of flexible elastomeric foams

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depending on application area. In case of fiber glass insulation, metal claddings after wrapping polyethylene as vapor barrier is to be used to prevent fiber migration and also regulate the water vapor ingress. Fiber Glass with only alufoil should not be used due to vulnerability of foil which is very thin and can be damaged during installation causing water vapor ingress and increased thermal conductivity over time.

The thermal insulation material should be installed around the duct with facing on outer side. Joints of insulation should be properly sealed with either same type of material or tape of 50 mm width on all longitudinal/transverse joints. Finally, PVC straps should be fixed at suitable interval to ensure that the insulation is properly fixed with the ducts in case of fiber glass insulation is being used.

10.6.5 *Acoustic Lining of Duct*

Acoustic lining of duct should be carried out as follows:

a) The inside surface of duct on which the acoustic lining is to be provided should be thoroughly cleaned with wire brush and rendered free from all dust and grease;

b) The materials to be used for duct lining should be 25 mm thick resin bonded fiberglass having density of 48 kg/m^3. Open cell flexible elastomeric foam having density of minimum 140 kg/m^3 specially formulated only for sound attenuation not for inside duct surfaces, due to its poor fire and smoke emission risks;

c) The insulation should be fixed inside the duct using suitable adhesive and covered with fibre glass tissue paper. Open cell flexible elastomeric Foam should be installed with eco-friendly low VOC adhesive elastomeric foam should pass the tests (for test procedure special publications may be referred) for 50 kW/m^2 exposure;

NOTE — Special publications may be ISO 5659-2.

d) The plain insulation materials used should have an air erosion test certified so as no particles/fibres are dislodged with high velocity air and mix with conditioned air compromising indoor air quality. Materials used should have antimicrobial properties;

e) The insulation should then be covered with 0.5 mm thick perforated aluminium sheet with at least 20 percent to 40 percent perforation;

f) The insulation and aluminium sheet should be secured with cadmium coated bolts, nuts and cup washers/steel screws;

g) Finally, the ends should be sealed completely, so that no lining material is exposed; and

h) The lining of initial length of the duct may have to be done as per the requirement at site.

10.6.6 *Acoustic Lining in Equipment Room*

Acoustic treatment in equipment room to prevent noise transmission to adjacent occupied areas should be provided on the walls and ceiling of equipment room with acoustic lining of thermal insulation material. Acoustic lining shall be provided with performance levels adequate to achieve effective sound absorption and sound insulation, ensuring compliance with the acoustic comfort and noise control requirements of the space.

Acoustic lining of equipment may be carried out as follows:

a) A 610 mm × 610 mm frame work of 25 mm × 50 mm × 25 mm or 50 mm × 50 mm × 50 mm ‘U’ shape channel, for 25 mm for open cell flexible elastomeric foam or and 50 mm thick fiber glass acoustic lining respectively, made of 0.6 mm thick galvanized steel sheet may be fixed on to walls leaving 610 mm gap above floor (to prevent damage from flooding) by means of rawl plug in walls. Similar frame work may also be fixed on ceiling by means of dash fasteners;

b) Resin bonded glass wool/ Open Cell Elastomeric foam as specified, cut to size may be fitted in the frame work and covered with fibre glass tissue paper;

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c) Surfaces may be finished by covering with 0.5 mm thick perforated aluminium sheet having perforation 20 to 40 percent with brass screws;

d) All horizontal and vertical joints may be covered with at least 25 mm wide, 1 mm aluminium strips held in position by steel or brass screws; and

e) For, Open Cell Elastomeric Foams, metal frame work is not required. 1m x 1m sheets of insulation to be directly applied to wall with suitable adhesive and finally two galvanized stainless steel metal strips of 0.6mm to be fixed in diagonally crossing each other with fasteners.

10.6.7 *Insulation of CHW/HW Refrigerant Pipes*

Pipe insulation Standard material should be EPS/XPS/PUF/closed cell flexible elastomeric foam/fibre glass as per requirement, specified with suitable density and thickness. Adhesive used for setting the insulation should be non-flammable, vapour proof, cold-setting, eco-friendly compound.

The insulation should then be finished as per the specific requirement of the site, as given below:

a) *Inside the building* — Insulation over the pipe work exposed in the building should be finished with specified thickness of aluminium sheet cladding, over a vapour barrier, with 50 mm overlap and tied down with lacing wire. For flexible elastomeric foams, suitable covering for mechanical protection can be used;

b) *Outside the building* — Insulation over the pipe work exposed to weather should be finished with vapour barrier, and 12 mm thick cement-sand plaster in two layers of 6mm thick each, followed by curing of minimum 48 h. For flexible elastomeric foams, suitable covering for mechanical protection can be used for UV resistance as per specialist literature;

NOTE — Specialist literature maybe DIN EN 4892-2 Method A artificial weathering test.

c) *Buried pipe insulation* — For pipes outside the building and laid underground, the insulation should be covered with suitable gauge polythene faced hessian, (the polythene facing outward), with 50 mm overlap. All joints should be sealed with bitumen. A layer of maximum 0.50 mm × 20 mm GI wire mesh netting should be provided over it butting all joint, and it should be laced down with GI wire. A 20 mm thick cement-sand plaster (1 : 4) should be provided in 2 layers of 10 mm thickness each and should be waterproofed by applying hot bitumen and fixing tar-felt over the plaster. It should be finally finished with a coat of hot bitumen;

d) *Pump insulation* — Chilled water pump should be insulated to the same thickness as the pipe to which they are connected, and application should be same as above. Care should be taken to apply insulation in a manner as to allow the dismantling of pumps without damaging the insulation;

e) *Insulation of valves and fittings in chilled water line* — All valves, fittings, strainers, etc, should be insulated to the same thickness and in the same manner as for the respective piping, taking care to allow operation of valves without damaging the insulation; and

f) The thermal insulation of VRF system should be flexible elastomeric rubber insulations with UV resistance.

10.7 Thermal Energy Storage for Demand Management

Thermal storage may be used for limiting maximum demand, by controlling peak electricity load through reduction of chiller capacity, and by taking advantage of high system efficiency during low ambient conditions. Thermal storage will also help in reducing operating cost by using differential time-of-the day power tariff, where applicable. TES system may be designed in accordance with specialist literature.

NOTE — Specialist literature maybe API-650/AWWA D-100.

TES systems should be carefully designed and installed, considering factors like:

a) *Location* — Central plant TES location shall be determined in consultation with the air conditioning engineer, ensuring optimal performance and efficiency;

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b) *Structural Integrity* — Adequate structural provisions to accommodate TES system loads, open-area surface installations shall consider vertical system options, complete with approach ladders for manholes etc;.

c) *Buried Installations* — Designs shall account for vehicular loads and movements above the installation area. The tanks may be rectangular or Circular with RCC construction; and

d) *Insulation* — To meet the thermal performance specifications, the tank to be provided with adequate insulation and cladding.

Thermal storage tank should be technically evaluated for tank material selection, insulation, and sizing, as well as the selection of suitable thermal energy storage media like water, ice, or phase-change materials. System design and controls should also be optimized, including charging and discharging strategies, temperature control, and integration with building management systems. TES systems should be designed with scalability and flexibility, allowing for modular expansion and integration with various HVAC systems.

10.8 Thermal Energy Storage for Critical Facilities

During power outage, chilled water to be made available for the duration the DG set starts and chillers ramp up. TES tanks are to be installed in line with the chillers, so that chilled water flows through the TES tanks then to the load, this to ensure that the tanks are always in charged condition.

TES tanks to be pressurized cylindrical vertical, all welded CS vessels with upper and lower ellipsoidal dish heads. For designing, manufacturing, certification and testing of tanks special publications maybe referred.

NOTE — Special publication may be ASME Section VIII Div.1.

Pressure vessels TES tanks to be fitted with radial disk diffusers to maintain stratification of water to ensure that the chilled water is delivered at the designed temperature and duration.

Designing of TES system and radial disk diffusers may be referred from special publications.

NOTE — Special publication may be ASHRAE Handbook, HVAC Systems and Equipment, Chapter 51.

Pressure vessels to be adequately insulated to meet the thermal performance specifications. Insulation to be protected with cladding.

System controls should also be optimized for charging and discharging strategies, temperature monitoring, and integration with building management systems.

11 HEATING

The efficiency of a heating equipment shall never be more than 100 percent, while a refrigeration system for heating usage shall have the coefficient of performance (COP) than its cooling mode.

Heating Systems are mainly used for hot water generation and space heating for comfort applications and also for Industrial use. The various applications where heating shall be effectively used are:

a) sanitary hot water generation for residential, commercial and hospitality industry;

b) space heating for residential, commercial and industrial sector in winters/as required depending on location and climatic conditions; and

c) hot water generation for industrial requirements.

11.1 Various Heating Equipment/Systems

Various heating equipment/systems are described under **11.1.1** to **11.1.7**. These heating equipment/systems shall be used for the building space and water heating applications based on their effectiveness, efficiency, and life cycle cost and installation process.

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11.1.1 *Heat Pump – Air to Water and Air to Air and Water to Water Type*

There are two types of air source heat pumps. It extracts heat from the air and then transfers heat to either the inside or outside depending on the season is called air to air heat pump. The air-to-air heat pump shall be as per accepted standard [D-3(6)], [D-3(24)] or [D-3(25)] based on its capacity and type (*see* Fig. 3). The air to water heat pump shall be as per best practices given special publications. Water to water heat pump shall be as per standard [D-3(24)] (*see* Fig. 4).

NOTE — Special publication may be ISO 21978.

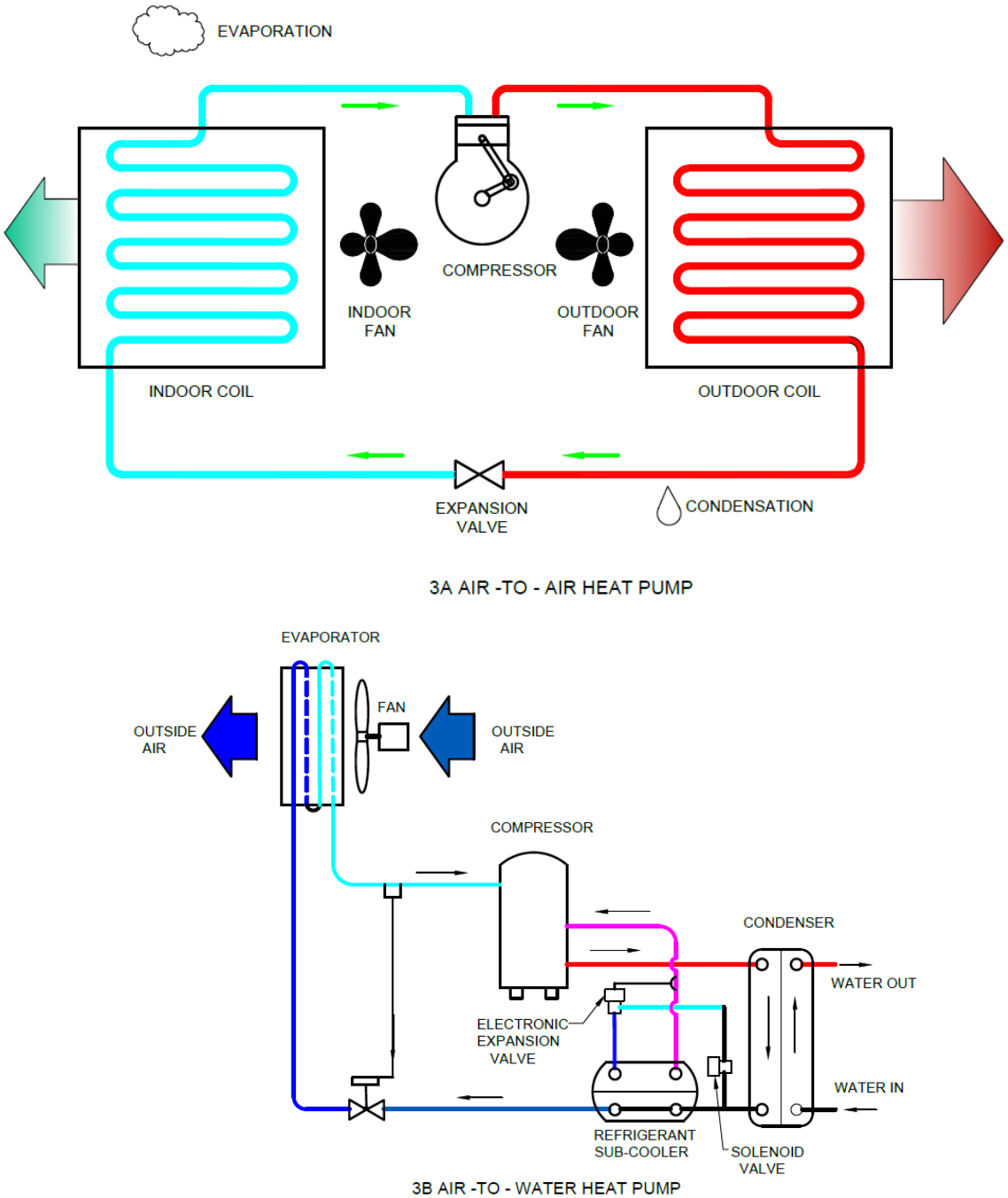

FIG. 3 AIR TO AIR AND AIR TO WATER HEAT PUMP

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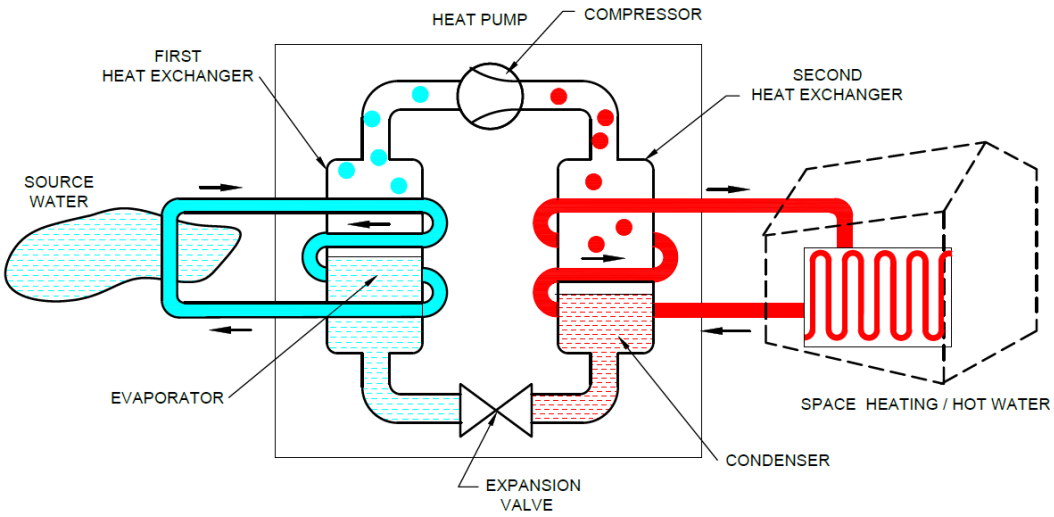

FIG. 4 WATER TO WATER HEAT PUMP

11.1.2 *Heat Pump – Ground Source*

Ground source heat pump uses the earth, or ground water, or both as the source of heat in the winter, and as the sink for heat removed from the conditioned areas in the summer. Heat is removed from the earth by using groundwater or an antifreeze solution; the liquid's temperature is raised by the heat pump; and the heat is transferred to indoor air. For year-round air conditioning, the process is reversed during summer months, heat is taken from indoor air and transferred to the earth, by the ground water. Fig. 5 illustrates the schematic of ground source heat pump. This shall be effectively used in locations having low temperature also.

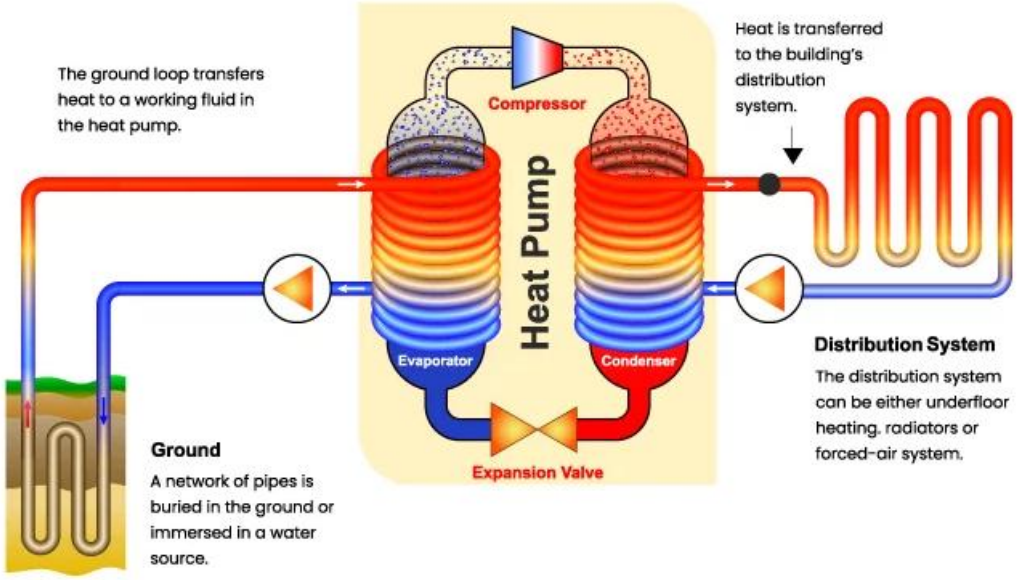

FIG. 5 GROUND SOURCE HEAT PUMP

11.1.3 *Reverse Cycle Systems*

Air conditioner window and split type, VRF system and DX package units, these systems are available with reverse cycle operation mode which shall supply cold air for cooling in summer and hot air for heating in winter. The performance of window air conditioners shall be as per accepted standard [D-3(4)], the split air conditioners shall be as per accepted standard [D-3(6)], the ducted split air conditioners shall be as per accepted standard [D-3(25)]. The variable refrigerant flow systems shall be as per accepted standard [D-3(26)] and chillers shall be

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as per accepted standard [D-3(24)]. The following Fig. 6 shows the reversible heat pump both in heating and cooling mode of operation.

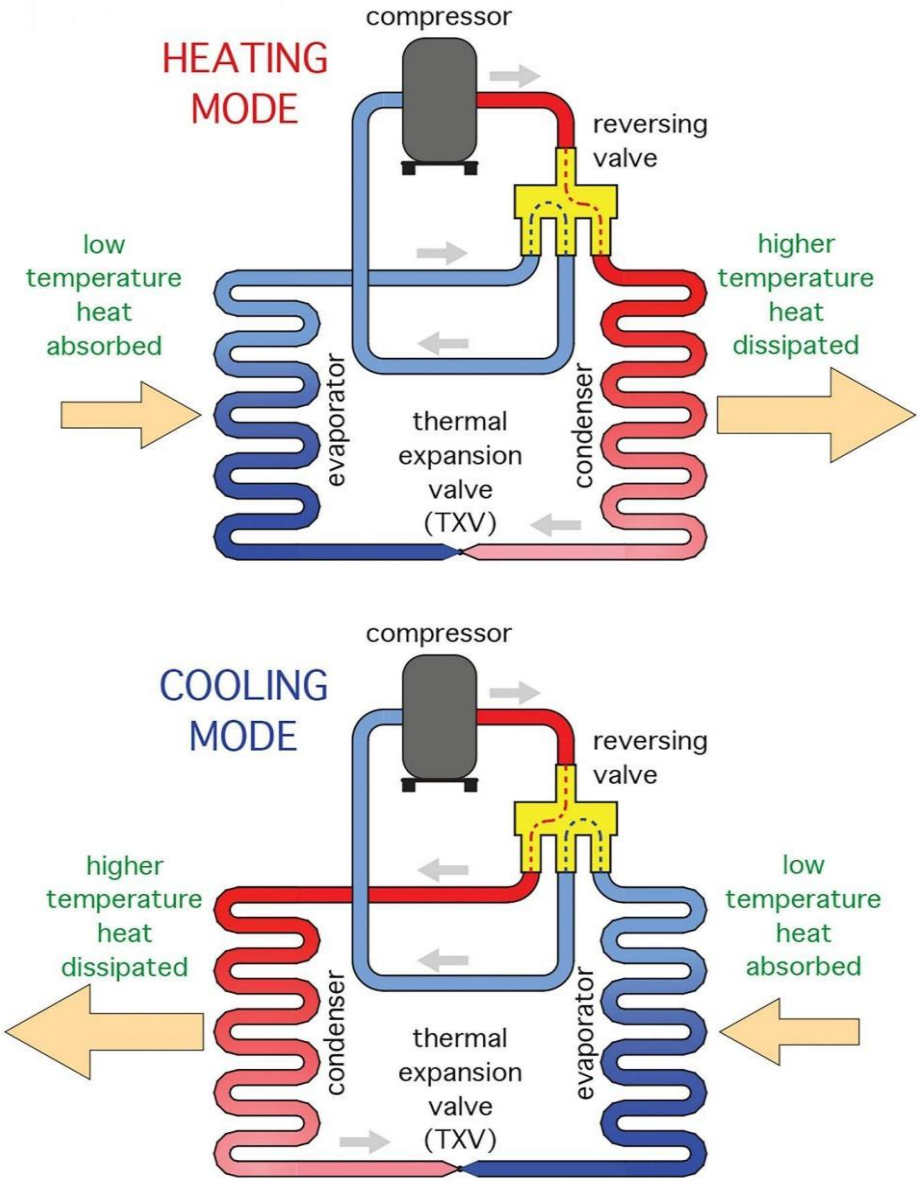

FIG. 6 REVERSIBLE HEAT PUMP

11.1.4 *Solar Water Heating* (*SWH*) *System*

SWH system converts energy content of solar radiation into heat energy for water heating using a solar thermal collector. In a close-coupled SWH system, the hot water storage tank is horizontally mounted immediately above the solar collectors on the roof. No pumping is required as the hot water naturally rises into the tank through thermal siphon flow. In a pump circulated system, the storage tank is ground or floor mounted and is below the level of the collectors; a circulating pump moves water or heat transfer fluid between the tank and the collectors.

SWH systems are designed to deliver hot water for most times of the year. However, in winter/monsoon, sometimes there may not be sufficient solar heat gain to deliver sufficient hot water. Therefore, alternative back up system is recommended to be used to meet hot water requirements.

Residential solar thermal installations fall into two groups; passive systems (sometimes called compact) and active systems (sometimes called pumped). Both typically include an auxiliary energy source (electric heating element or gas connection for the hot water storage tank, or fuel oil fired central heating system or heat pump) which is activated when the water in the tank falls below a minimum temperature setting such as 55 °C. However, it is

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recommended to use heat pump in active as well as passive systems to reduce carbon footprint and protect environment hence, hot water is always available. The combination of solar water heating and using the back-up heat from heat pump to heat water shall enable a hot water system to work all year round in cooler climates.

The amount of heat delivered by a solar water heating system depends primarily on the amount of heat delivered by the sun at a particular place, that is, the insolation. In tropical places, the insolation shall be relatively high, for example, 7 kWh/m^2 per day, whereas the insolation shall be much lower in temperate areas where the days are shorter in winter, for example, 3.2 kWh/m^2 per day. Even at the same latitude the average insolation shall vary a great deal from location to location due to differences in local weather patterns and the amount of overcast. The design, installation and performance evaluation of solar heating systems shall be in accordance with the good practice.

11.1.5 *Condenser Heat Recovery System*

Condenser heat recovery system captures energy that would otherwise be wasted in the atmosphere and converts this energy into useful heat. It is possible to capture this heat from the condenser and use it to generate hot water. By capturing this heat, overall system efficiency is considerably improved. Such a system should be used, wherever there is heating requirement concurrent with cooling demand. In a well-designed system this improves the performance of the cooling or refrigeration

11.1.6 *Solar Air Heating* (*SAH*) *System*

SAH system converts energy content of solar radiation into heat energy for air heating using a solar thermal collector. SAH systems shall be once through or of recirculating type. In the once through system fresh outdoor air is heated to a higher temperature of around 60 °C to 65 °C and supplied indoors through insulated ducting. This air mixes with the conditioned space air to maintain the indoor at a comfortable temperature typically between 18 °C to 22 °C. In the recirculating type, the conditioned space air is recirculated through the roof or wall integrated solar air heaters. In this case the air delivery temperatures shall be moderate at around 30 °C to 45 °C. Electric fans or blowers are used to enable circulation of the air. Solar air heaters shall offer solar collector efficiency in the range of 50 percent to 80 percent. Reversible air-to-air heat pumps powered with grid electricity shall be used as backup.

11.1.7 *Electric Heating*

Electric heating system are highly energy consuming and should be applied to specific application where other efficient Heating system shall not be applied due to technical/ location constraints. With all electric heating, care should be taken to preclude the risk of fire under abnormal conditions of operation, by the use of a suitably positioned temperature sensitive trip of the manual reset type, to cut off the electric supply in case of temperature rise beyond the specified limit.

It is recommended to avoid electrical heating to maximum extent possible for the building space or water heating applications.

12 BUILDING TYPOLOGY RELATED CONSIDERATIONS

The general guidance, for various selected building typologies, for the factors that usually influence the selection of the type, design and layout of the air conditioning or ventilating system, to be used are given in this section. The primary objective of these is to define the special provisions required for the air conditioning system, to ensure comfort conditions or defined conditions as the case may be for occupants in the respective applications.

These are the following typical building typologies normally envisaged in construction for different applications based on the usage factors:

a) Residential buildings;

b) Office buildings;

c) Campus buildings;

d) Hospitality buildings;

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e) Healthcare buildings;

f) Underground metro stations;

g) Airport buildings;

h) Shopping complex buildings;

j) Industrial buildings; and

k) Tall buildings.

The following criteria shall be common to most of the building typologies:

1) *Building Layout and Orientation* — North-south orientation is often preferred to minimize direct sun exposure. The building orientation to be optimized to reduce heat gain. The design floor plans shall facilitate natural ventilation, air circulation and daylighting avoiding deep floor plans that limit these measures in case of naturally ventilated buildings.

2) *General Considerations* — Buildings may include both the outer and inner zones. The outer zone may be considered as extending from approximately 4 m to 6 m inwards from the outer wall of the building and is generally subjected to wide load variation owing to daily and annual changes in outside temperature and solar radiation. Ideally, the system(s) selected to serve an outer zone should be able to provide summer cooling and winter heating. During intermediate seasons, the outer zone of one side of the building may require cooling and at the same time, the outer zone on another side of the building may require heating. The main factors affecting load are usually window area and choice of shading devices.

   The other important factors are the internal gain owing to people, light, and other equipment loads. The choice of system may be affected by requirements to counteract down-draughts and chilling effects due to radiation associated with single glazing during winter. Cooling load for the inner zone is generally entirely from the heat gain from people, lights, and equipment, which is generally uniform throughout the year.

   Other important considerations in building applications may include requirements for individual room control, partitioning flexibility serving multiple tenants or residents, and the requirement of operating selected areas outside of normal working hours.

3) *Building Envelope* — The building envelope shall be designed to minimize energy use. Materials with low thermal transmittance (U-value) for walls, roofs, and selection of glass following a detailed study of solar heat gain coefficient (SHGC), U-value and visible light transmittance (VLT) shall be selected. For additional information on high-efficiency insulation materials, special publication may be referred.

   NOTE — Special Publication may be Energy Conservation and Sustainability Building Code (ECSBC) 2024

4) *Ventilation* — Minimum outdoor airflow rate based on occupancy and area requirements shall be provided as detailed in **3**. Comprehensive mechanical ventilation system with usage of energy/heat recovery system and CO_2 monitoring and control system to adjust airflow following indoor air quality norms shall be utilised. Also refer to **5.2.5** of Part D 'Building Services, Section 1 Lighting and Natural Ventilation' of this NBCS.

5) *Indoor Air Quality* (*IAQ*) *and Thermal Comfort* — For threshold values related to indoor air quality and requirements for thermal comfort, article on 'Basis of Design' to be referred.

12.1 Residential Building Typology

This classification helps in understanding the different types of residential buildings based on their design, usage, and structure.

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12.1.1 *Room-Specific Design*

a) *Bedrooms* — Quiet AC operation and individual temperature control for better thermal comfort shall be ensured. Outdoor unit of the air-conditioner shall not be installed towards the room/living spaces/balconies. Hot air of the outdoor unit shall be directed toward open spaces/ambient.

b) *Living rooms* — Design of AC in living room shall be appropriate considering peak occupancy. For better thermal comfort and energy savings, AC and ceiling fan both shall be installed in living room.

c) *Kitchens* — Ventilation hoods to remove excess heat and gaseous contaminants shall be installed.

12.1.2 *Insulation and Thermal Mass*

a) *Insulation* — High-quality insulation in walls, roofs, and floors to reduce cooling loads shall be entertained.

b) *Thermal mass* — Materials with high thermal mass (for example brick) to stabilize indoor temperatures shall bring in better energy efficiency.

12.1.3 *Window Design and Shading*

a) *Glazing* — Glazing in residential houses refers to the installation of glass in windows, doors, skylights, and other transparent or translucent building components. The choice of glazing impacts energy efficiency, aesthetics, security, and comfort. Glass preferably of lower SHGC based on climatic zone shall be selected. Ratio of VLT/SHGC shall be more.

b) *Shading devices* — Install external permanent/movable shading devices (for example, shade, awnings, louvers) to block direct sunlight. Consider the use of trees and vegetation for natural shading. For large dwelling/projects, optimising shading shall lead to reduced cost and more benefits. Facade shall be designed with specific shading devices/solutions.

c) *Window placement* — Strategically placement of windows to maximize natural light while minimizing heat gain shall be encouraged.

12.1.4 *Ventilation*

a) *Natural ventilation* — Cross-ventilation by aligning windows and openings to allow air to flow through the building shall be envisaged. For a building to be naturally ventilated, it shall have operable windows that occupants shall adjust to maintain their thermal comfort. These windows may include dynamic components like louvers to regulate the amount of air exchange. Open door/window and operation of exhaust fan to ventilate during night, to cool the spaces and remove the heat that traps during daytime shall be worked out.

b) *Mechanical ventilation* — Mechanical ventilation systems shall be designed to complement AC systems, providing fresh air without compromising energy efficiency.

12.1.5 *Sustainability Measures*

a) *Passive cooling* — Passive cooling strategies such as orientation, providing buffer spaces, thermal chimneys, evaporative cooling, and night purging to reduce reliance on AC shall be included in the design.

b) *Landscaping* — Strategic landscaping (for example, planting trees, creating windbreaks) to naturally cool the building and reduce AC load shall be used.

12.1.6 *Cultural and Climatic Adaptations*

a) *Regional design adaptations* — Building design shall adapt to local climatic conditions, such as high humidity areas requiring enhanced dehumidification.

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b) *Cultural preferences* — Cultural preferences in building layout and AC usage, such as preferred room temperatures and ventilation styles shall be investigated and included during design.

12.1.7 *Adaptive Reuse and Retrofitting*

a) *Historic buildings* — When retrofitting historic buildings, the preservation of architectural features with the integration of modern AC systems shall be balanced.

b) *Older homes* — Upgrading insulation, windows, and ductwork to improve the efficiency of new AC systems shall be envisaged.

12.2 Office Building Typology

Important considerations in office building applications may include requirements for individual room control, partitioning flexibility serving multiple tenants, and the requirement of operating selected areas outside of normal office hours. Areas such as conference rooms, board rooms, shall teens, etc., will often require independent systems.

12.2.1 *Specific Guidelines for Large/Small Office Buildings*

a) *Centralized HVAC systems* — Centralized HVAC systems shall be specifically considered for their high efficiency and flexibility in handling variable loads. Centralized systems shall provide cooling and heating based on the specific needs of different zones, enhancing overall energy efficiency;

b) *Demand-controlled ventilation (DCV)* — Implementing demand controlled ventilation (DCV) should be considered to optimize ventilation rates based on real-time occupancy and indoor air quality. This shall reduce energy consumption while maintaining a comfortable environment;

c) *Indoor air quality monitoring (IAQ)* — IAQ sensors shall be considered to continuously monitor and maintain optimal indoor air quality levels. These sensors shall measure parameters such as CO_2 levels, humidity, and volatile organic compounds (VOCs), there by maintaining and monitoring to ensure a healthy indoor environment;

d) *Air purification technologies* — Advanced air purification technologies such as UV-C light/bipolar ionization/other passive air purification methods should be used to reduce airborne contaminants of their levels exceed the threshold values given in **3.6.2**. These technologies shall be particularly beneficial in reducing the spread of airborne diseases and improving overall air quality;

e) *Predictive maintenance* — Predictive maintenance using IoT and smart sensors should be considered. This approach shall identify potential issues before they lead to system failures, reducing downtime and maintenance costs;

f) *Enhanced humidity control* — Desiccant dehumidification systems should manage high humidity levels, particularly in areas with high latent gains. Proper humidity control for maintaining comfort and improving indoor air quality;

g) *Energy recovery ventilation* (*ERV*) — ERV systems to improve indoor air quality inclusion shall enhance energy efficiency by recovering energy from exhaust air. ERVs shall significantly reduce the load on heating and cooling systems by pre-conditioning incoming fresh air. For additional information, special publication may be referred for the Energy recovery system;

NOTE — Special publication maybe ISO 16494.

h) *Advanced zoning strategies* — Implementing advanced zoning strategies for large office spaces should be considered by dividing office spaces into detailed zones based on occupancy and usage patterns and use of automated systems to adjust HVAC settings dynamically in different zones shall lead to energy efficiency to systems;

j) *Building management systems (BMS) and IoT integration* — HVAC systems should be integrated with building management systems (BMS) for centralized control and monitoring and utilizing IoT devices

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to enable real-time data collection and automated adjustments, shall optimize energy efficiency and system performance;

k) *Noise reduction measures* — Advanced soundproofing materials and design techniques to minimize the operating noise levels of HVAC equipment and further ensuring low noise levels enhances occupant comfort, especially in open office environments. Noise control measures shall be as per Part D 'Building services, Section 4 Acoustics, Sound Insulation and Noise control' of this NBCS; and

m) *Green building practices* — Green building practices such as incorporating renewable energy sources (for example, solar panels) to power HVAC systems and using sustainable building materials should be considered. This aligns with global trends towards environmental responsibility and sustainability.

12.3 Campus Building Typology

The provisions related to HVAC requirements for a large campus (facility consisting of multiple single or multi-use buildings or structures within a premise), including residential and (or) non-residential educational institutions, IT/ITES parks are covered. The design and implementation of heating, ventilation, and air conditioning (HVAC) systems for campus projects shall meet several key requirements to ensure efficient, effective, and sustainable operation.

12.3.1 *General Requirements*

These guidelines help in categorizing and designing buildings within a campus based on their function, layout, and structural needs.

a) *Scalability and flexibility* — The system design shall allow for future expansion as well as varying nature of usage of spaces by designing modular components for easy upgrades to ensure flexibility to adapt;

b) *Energy efficiency* — Central HVAC systems with advanced controls, with predictive maintenance and energy system for optimum energy use shall be designed. Centralized air-conditioning system with a diligent feasibility/viability study of a particular system invariably leads to better energy efficiency solutions. In case of mixed used buildings (residential, office, laboratories, etc) in the campus, the projects should consider choosing district cooling system for better resource efficiency and sustainability. The system design feasibility for district cooling systems or alternate energy cooling systems shall be referred in detail from **6** and **7**. Variable speed drives for motors and fans shall be used.

Life cycle analysis shall further support to demonstrate business case of selecting a particular system. Minimizing the ecological footprint of HVAC systems and use environmentally friendly refrigerants, implementation of systems that conserve water and other resources should be considered;

c) *Heating systems* — Heat pumps/high efficiency central heating system as detailed in **11** for space heating as well as water heating Integrate heating systems with building management/optimization systems (BMS) for optimal control;

d) *Zoning and control* — Multiple zones for different buildings or areas use advanced control systems for precise temperature and humidity levels and incorporate programmable thermostats and building management systems (BMS). Advanced zoning strategies for large campuses by dividing campus buildings into detailed zones based on occupancy and usage patterns, automated systems to adjust HVAC settings dynamically in different zones shall be standard practices. Occupancy diversity into zoning for better control and energy savings as well as thermal control strategies based on space type and usage shall be considered. For more details on building automation and zoning control refer to **15**;

e) *Occupancy and lighting schedules* — HVAC and lighting schedules with occupancy to optimize energy use shall be aligned. Automated lighting systems with daylight harvesting and occupancy sensors and scheduling HVAC operations before occupancy starts for optimal usage is preferred; and

f) *Urban heat island* (*UHI*) — Urban heat island (UHI) causes discomfort and increases energy consumption of air-conditioners. Mitigation measures to reduce the impact of UHI and its associated impacts shall be considered. Proper placement of HVAC equipment to avoid UHI and manage distance

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between equipment (especially air-cooled outdoor equipment) to release the heat and avoid creating local heat spots need a due consideration.

12.3.2 *Operation and Maintenance (O&M)*

These ensure the effective management, upkeep, and long-term performance of campus buildings and their systems.

a) *Energy management* — Energy management strategies within the BMS to minimize energy consumption by scheduling HVAC operations to match occupancy patterns and utilizing energy-efficient modes during non-peak hours and similarly system designed to showcase performance levels (square foot/TR) shall lead to better energy management;

b) *Maintenance* — As the energy consumption in the large campuses is huge, the predictive maintenance and cloud monitoring for advanced energy efficiency may be considered as part of the system for effective monitoring and for taking proactive measures. Advanced monitoring systems to track performance in real-time and scheduled maintenance based on predictive analytics will lead to lower down times. Detailed logs using a computerized maintenance management system (CMMS) shall be maintained; and

c) *Retro/re-commissioning* — Analysing HVAC system performance after one year of operation to compare design with actual performance. Necessary retro-re/commissioning to improve performance based on load profiles of several components for example fan/pump/motor, etc (following over/under load conditions) shall be undertaken.

12.3.3 *Specific Requirements for Campus Project*

These requirements address the unique operational needs and considerations for designing and managing campus buildings.

a) *Climate adaptation* — Implement HVAC system modifications for different climatic zones (hot and dry, warm and humid, composite, temperate, cold);

   Use adaptive thermal comfort models to enhance occupant comfort and energy savings.

b) *Water conservation* — Emphasize water-efficient HVAC systems, especially in water-scarce regions. Encourage the use of condensate recovery systems to reuse water in cooling towers or irrigation. Promote the use of water-efficient fixtures and fittings in all campus buildings;

c) *Sustainability practices* — Campus buildings are encouraged to use sustainability practices (green building guidelines) and sustainability standards shall follow for enhanced sustainability. Promote the use of recycled and sustainable materials in HVAC installations;

d) *Resilience and reliability* — HVAC systems that shall handle frequent power outages and voltage fluctuations shall be envisaged. The inclusion of backup systems to ensure continuous operation during power failures. Robust disaster recovery plans to maintain HVAC operations during emergencies shall be included; and

e) *Testing and commissioning* — Thorough testing, balancing, and commissioning procedures shall be followed. Standardized protocols for verifying system performance before handover shall be compulsory. For detailed guidelines refer **17**.

12.3.4 *Educational Campus Buildings*

Special attention for the design of the HVAC systems shall be paid to meet the needs of every age group in this type of buildings. The equipment should be easy to operate and maintain and the design should provide no drafts. These facilities have two distinct occupant zones: (a) the floor level, where younger children play, and (b) normal adult height, for the teachers. The administrative and teachers' offices shall be considered as a separate zone.

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Special consideration shall be given to operating schedule for setback. Supply air outlets should be positioned to avoid drafts. Proper ventilation and exhaust shall be provided for controlling odours and to prevent the spread of diseases. University and college campus having large diversity in cooling/heating loads, should be provided with large central utility plant or smaller mechanical rooms serving a cluster of buildings. The central utility plant shall supply chilled/hot water depending on the zonal requirement. The designer should consider site constraints, including geographic location. In addition to accommodating the mechanical and electrical equipment, central utility plant may also house engineering, operation and maintenance personnel. A central control room shall be provided for energy monitoring.

12.4 Hospitality Buildings Typology

It is critical to focus on guest comfort, energy efficiency, and system reliability. Each guest room or each zone shall be provided with not less than one thermostat capable of being set from 20 °C to 30 °C and capable of operating the system's cooling and heating. The thermostat or control system, or both, to have an adjustable dead band, the range of which includes a setting of 12 °C between cooling and heating, where automatic changeover is provided. Wall mounted temperature control shall be mounted preferably on an inside wall and shall meet the requirements given in **15**.

12.4.1 *Guest Rooms*

Guest room systems are required to be available for operation on a continuous basis. The room may be unoccupied for most of the day and therefore provision for operating at reduced capacity or switching off. Low operating noise level, reliability and ease of maintenance shall be taken care. Treated fresh air (TFA) is introduced through an independent TFA system, it is generally balanced with the bathroom extract ventilation, to ensure air circulation into the bathroom. Fan coil unit is generally found to be the most suitable for this kind of application with speed control for fan and motorized/modulating valve for chilled water control for cooling.

12.4.2 *Restaurant, Cafeteria, Bar and Night Club*

These applications have several factors in common; highly variable loads, with high latent gains (low sensible heat factor) from occupants and meals, and high odour concentrations (body, food and tobacco smoke odours) requiring adequate control of fresh air extract volumes, direction of air movement for avoidance of draughts and make up air requirement for associated kitchens to ensure an uncontaminated supply. This type of application is generally best served by the all-air type of system preferably with some reheat or return air bypass control, to limit relative humidity. Either self-contained packaged unit or split system, or air handling unit served from a central chilled system, may be used. Sufficient control flexibility to handle adequately the complete range of anticipated loads.

12.4.3 *Specific Criteria to be Adhered for Hospitality Buildings*

a) *Occupant (guest) comfort* — Air-conditioning system to maintain consistent temperature and humidity control in guest rooms, lobbies, restaurants, and common areas. There shall be individual temperature and ventilation controls in guest rooms for personalized comfort. Ensure rapid response to temperature adjustments for good comfort conditions;

b) *Energy efficiency* — Energy-efficient HVAC equipment such as high-efficiency chillers/cooling system, boilers, and heat pumps shall be needed. Occupancy sensors and smart thermostats reduce energy use in unoccupied rooms. Integrating energy recovery ventilation systems to reclaim and reuse waste heat or cooling shall bring in additional energy efficiency. Heat recovery system shall be sized based on floor/occupancy loading;

c) *Zoning and control* — HVAC systems cater to multiple zones with different activity areas of the hotel, such as guest rooms, dining areas, and conference rooms. Advanced control systems for precise temperature and humidity regulation as well as building management system (BMS) for centralized monitoring and control of HVAC operations shall be designed and used as detailed in **15**;

It shall be necessary to avoid mixing of air of various type of zoning (corridor, guest rooms, guest areas where smoking allowed, kitchen ventilation, etc), designate smoking and non-smoking areas by pressure differentials between zones;

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d) *Noise control* — Low-noise HVAC equipment shall be used to ensure a quiet environment. Necessary sound attenuation measures shall be installed in ductwork and mechanical rooms to reduce noise. Proper acoustic insulation in guest rooms and other sensitive areas for ensuring low/nil cross talk between areas shall be initiated. Noise control measures shall be as per Part D 'Building services, Section 4 Acoustics, Sound Insulation and Noise control' of this NBCS;

e) *Sustainability* — Integrating passive and active heating/cooling system to minimize greenhouse gas emissions and developing the hotel/hospitality project to incorporate sustainable design practices shall be followed;

f) *Reliability and maintenance* — Durable and reliable HVAC equipment to minimize downtime and maintenance issues shall be needed as the systems are generally required to function round the clock throughout the year. Systems should have easy-access for maintenance and repairs and a preventive maintenance schedule to ensure long-term system reliability and performance shall be implemented;

g) *Aesthetic integration* — HVAC design shall coordinate with the hotel's interior design to minimize visual impact and use discreet and aesthetically pleasing diffusers, grilles, and other HVAC components without compromising on functional effectiveness and air distribution patterns. HVAC components shall be selected to seamlessly integrated into the overall architectural design;

h) *Environmental impact* — The ecological footprint of HVAC systems shall be minimised by using environmentally friendly refrigerants and materials. Water conservation measures, particularly in cooling towers and other water-intensive components shall be a priority. Use of treated water for cooling tower and designing systems to reduce overall energy consumption and waste shall be adhered. Calculate environmental impacts of refrigerants used in air-conditioning/fire suppression system (calculate ODP – ozone depleting potential if applicable and GWP – global warming potential). Project to utilise new age refrigerant/natural refrigerant to minimize or avoid negative impact of refrigerants. For more details, refer to **5**;

j) *Guest room control systems* — User-friendly interfaces for guests to control room temperature, ventilation, and other comfort settings shall be provided. Integrating with hotel management systems to optimize energy use based on occupancy and guest preferences and by offering customizable settings enhance the guest experience and also accommodates individual needs;

k) *Operation and maintenance of HVAC system* — Comprehensive training for facility managers and maintenance staff on the operation and maintenance of HVAC systems shall be provided. Ongoing support and service agreements with HVAC vendors for timely repairs and updates and constant skill upgradation for staff on energy-saving practices and the proper use of HVAC control systems shall be followed. Make provision to clean ducts periodically to offer hygiene conditions to guest, staff/occupants;

m) *Scalability* — HVAC systems shall be designed to accommodate future expansions or renovations, use modular components for easy upgrades and modifications. Ensure the system shall adapt to varying occupancy rates and seasonal changes; and

n) *Specialty areas* — HVAC systems shall be designed for specialty areas such as spas, kitchens, and conference rooms for meeting specific requirements. Adequate ventilation and humidity control in spas, pools, and fitness centres and robust exhaust systems in kitchens to manage odors, heat, and smoke effectively shall be provided.

12.5 Healthcare Building Typology

HVAC Systems in healthcare facilities provide a broad range of services in support of people who are vulnerable to an elevated risk of health, fire and safety hazard.

12.5.1 *Basic Classification of Health Care Facilities*

Health care facilities vary widely in the nature and complexity of services they provide and the relative degree of illness or injury to the patients treated-like clinic, diagnostic centers, medical centers, specialty hospitals, super

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specialty hospitals, etc. Environmental control requirements and the role of HVAC system in life safety and infection control becomes very important with the medical services provided.

Ventilation in healthcare buildings is crucial for maintaining air quality, controlling infections, and ensuring the comfort and safety of patients, staff, and visitors. Healthcare facilities have unique ventilation requirements due to the need to manage airborne pathogens, chemical contaminants, and varying needs of different areas.

12.5.2 *Design Criteria*

While designing HVAC for a healthcare facility, Patient therapy shall be the prime consideration, the plan shall include the following parameters which shall be taken into consideration:

a) temperature and humidity requirements of various spaces;

b) ventilation requirements/air changes requirements;

c) filtration requirements for contamination control;

d) restriction on air movement between adjoining spaces;

e) permitted tolerance on environmental conditions;

f) redundancy/backup;

g) fire and life safety;

h) efficiency bench marking on the equipment;

j) guidelines for parameters;

k) standards/ good practices; and

m) ease of installation and Maintenance friendly.

12.5.3 *Key Considerations*

These considerations ensure that healthcare buildings are designed to meet the specific functional, safety, and regulatory requirements for patient care and medical operations.

a) *Comfort conditioning* — Across health care facilities, health care practices often expose patients and staff to conditions that dictate unique environmental requirements. As in any other building, comfort of occupants is fundamental to overall well-being and productivity also it has a significant role in facilitating healing and recovery;

b) *Therapeutic conditioning* — Certain Medical functions, treatments or healing processes demand controlled environmental temperature and relative humidity conditions that deviate from the requirements for personal comfort. Operating rooms and other key areas require a range of room temperature spanning several degrees regardless of the season to best facilitate a given procedure or patient condition;

c) *Infection control* — Medical facilities are places where relatively high levels of pathogens are generated and concentrated by an infected patient population or by procedures that handle infected human tissues and bodily fluids. Filtration levels and air changes per hour (ACH) play a vital role in controlling the risk;

d) *Pressure differentials* — Implement negative pressure in airborne infection isolation (AII) rooms to contain airborne pathogens and positive pressure in operating rooms (OR)/protective environment (PE) rooms to protect patients from outside contaminants;

e) *Life safety* — HVAC systems are required to support special building compartmentation, opening protection, smoke control and smoke detection systems. Containment is facilitated by smoke and fire dampers and some cases restricting cross overs between smoke zones; and

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f) *Noise control* — Noise control is of high importance because of negative impact of high noise levels on the patients and the need to safeguard patient privacy. Noise control measures shall be as per Part D 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of this NBCS.

12.5.4 *Energy Efficiency/Sustainability Considerations*

These guidelines focus on optimizing energy use and incorporating sustainable practices in the design and operation of buildings to reduce environmental impact.

a) *Role of building envelope* — The building envelope in healthcare facilities is a critical component that affects energy efficiency, indoor environmental quality, and overall functionality. Given the unique needs of healthcare environments, the building envelope shall be designed with stringent requirements to ensure patient safety, comfort, and operational efficiency;

b) *Energy-Efficient Window* — Windows with low solar heat gain may be used in order to minimize heat loss and gain shall be used. Windows shall have proper seals to prevent air infiltration;

c) *Air Tightness* — Building envelope shall be well-sealed to prevent air leaks by providing proper sealed building envelope. This shall be done for controlling indoor air quality and maintaining the efficacy of HVAC systems;

d) *Testing and Commissioning* — Apart from the procedures listed in**,** additionally shall conduct blower door tests and infrared thermography tests during commissioning to identify and rectify any air leakage points;

e) *Natural Light and Views Daylighting* — The building envelope shall be designed to maximize natural light, reducing the need for artificial lighting and creating a more patient friendly environment. This includes the strategic placement of windows, skylights, and light wells; and

f) *Glare Control* — Shading devices, low-E glass, or other technologies shall be incorporated to control glare and excessive solar heat gain, enhancing comfort and reducing cooling loads.

Guidelines for the above parameters for various functional spaces in a health care facility are given in Table 27 and Table 28.

Table 27 Guidelines for Parameters to be Considered for HVAC System Design for Health Care Facilities

(*Clauses* 12.5.4 *and* 12.5.5)

Sl No.	Area/Functional Space	Temperature	Relative Humidity	Minimum Total Air Changes per Hour	Minimum Air Changes of Outdoor Air per Hour	Air Pressure in Relation to Surrounding Area/ All Room Air Directly Exhausted to Outdoors
		°C	percent			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Operating theatres	20 to 24	20 to 60	20	4	Positive/NR
ii)	Cath labs	21 to 24	*Max* 60	15	3	Positive/NR
iii)	Delivery rooms	20 to 24	20 to 60	20	4	Positive/NR
iv)	Recovery room, ICU, treatment rooms	21 to 24	*Max* 60	6	2	Equal/NR
v)	Endoscopy, bronchoscopy	20 to 23	*Max* 60	12	2	Negative/NR
vi)	Patient rooms	21 to 24	*Max* 60	6	2	Equal/NR

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Table 27 (*Concluded*)

Sl No.	Area/Functional Space	Temperature	Relative Humidity	Minimum Total Air Changes per Hour	Minimum Air Changes of Outdoor Air per Hour	Air Pressure in Relation to Surrounding Area/ All Room Air Directly Exhausted to Outdoors
		°C	percent			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
vii)	Toilets	–	–	–	10	Negative/Yes
viii)	Protective environment rooms (Immuno suppressed patients)	21 to 24	*Max* 60	12	2	Positive/NR
ix)	Isolation room (for patients with infectious disease)	21 to 24	*Max* 60	12	2	Negative/Yes
x)	Corridors	–	–	2	2	Negative/NR
xi)	X-ray/Radiology	21 to 24	*Max* 60	15	3	Positive/NR
xii)	Laboratories (other than biochemistry and serology)	22 to 26	*Max* 60	6	2	Negative
xiii)	Biochemistry and serology labs and pharmacy	22 to 26	*Max* 60	6	2	Positive/NR
xiv)	Admission/waiting rooms	22 to 24	*Max* 60	6	2	NR/NR
xv)	Diagnostic/treatment OPD	21 to 24	30 to 60	12	2	NR/NR
xvi)	Sterilizer equipment room	NR	NR	10	–	Negative/Yes
xvii)	Sterilizer storage	22 to 26	*Max* 60	4	2	Positive/NR

Table 28 Guidelines for Minimum Filter Efficiency Requirement in Health Care Facilities

(*Clause* 12.5.4)

Sl No.	Category	Area/Designation	Filter Class (Efficiency)	
			Filter Bed 1	Filter Bed 2
(1)	(2)	(3)	(4)	(5)
i)	Category 1	a) Orthopedic OT b) Bone marrow transplant OT c) Organ transplant OT d) PE rooms including Burn Units	ISO Coarse 60 percent	ISO ePM2.5 80 percent and HEPA at outlets

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Table 28 (*Concluded*)

Sl No.	Category	Area/Designation	Filter Class (Efficiency)	
			Filter Bed 1	Filter Bed 2
(1)	(2)	(3)	(4)	(5)
ii)	Category 2	a) General OT delivery rooms b) ICU, patient care rooms	ISO Coarse 60 percent	ISO ePM2.5 80 percent
iii)	Category 3	a) Treatment rooms b) Diagnostic areas	ISO Coarse 60 percent	Not required
iv)	Category 4	a) Laboratories b) Sterile storage	ISO Coarse 60 percent	Not required
v)	Category 5	a) Food preparation b) Laundry c) Admin, etc	ISO Coarse 60 percent	Not required

12.5.5 *Air Distribution System*

The fresh air changes per hour as well as the total air changes shall be minimum as per the guidelines given in Table 27 above.

For critical care areas, variable air volume systems shall be used for energy conservation by controlling supply, exhaust and return air and maintaining the pressure relationships as per standards and inside design conditions without any compromise. Critical areas in general are operating theatres, ICUs, isolation rooms, sterile areas, post-operative patient care; any place which houses medical surgical procedures and some of the laboratories.

For patient rooms and non-critical areas, variable air volume system shall be considered for energy conservation. However, when variable air volume systems are used, care should be taken to ensure that minimum ventilation requirements are not compromised and pressure balance is maintained even at minimum flow.

Active smoke control systems shall be used along with fire and smoke partitions to limit the spread of smoke in the event of fire. Smoke and fire management should be done in accordance with Part F 'Fire and Life Safety' of this NBCS and **19**. For health care facilities which provide ambulatory care to patients, safety from fire and smoke is a paramount design consideration and should be provided in accordance with Part F 'Fire and Life Safety' of this NBCS.

A separate exhaust system shall be provided for removal of anaesthesia gases from the operation theatre. Alternatively, proper isolation dampers may be provided in the air circulation system for removal of anaesthesia gases or fumigation effect if this system of fumigation is followed in health care.

Air handling devices shall be designed to prevent water intrusion and permit access for inspection and maintenance. Draw through air handling systems shall be used as moisture ingression is minimized in these systems. Lower face velocity across the coil in the range of 1.27 m/s to1.52 m/s shall be considered for better heat transfer.

When humidifiers are provided, they shall be located with-in the air handling unit or duct work in such a way that moisture accumulation on downstream components do not take place. Evaporative pan type humidifiers shall not be used.

Fibrous acoustic insulating material shall not be used as duct lining for critical spaces. Supply air ducts shall be externally insulated as required.

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Multiple direct drive plenum fans may be used in air handling units serving critical areas. This provides redundancy and minimizes shut down of critical areas in case of single fan failure.

For critical areas, both supply air and return air shall be ducted. Ducts shall be sized for medium velocity and medium pressure drop 12 m/s and 4 mm for 10 m maximum. For applications like operation theatres and intensive care units, the preferred material for ductwork should be of corrosion resistive metal sheets.

Ultraviolet germicidal irradiation is recommended for air handling units serving health care facilities. Lamps may be installed either upstream or downstream of the evaporator coil but away from the filter media.

12.5.6 *Air Flow and Filtration*

Outside air intakes shall be located minimum 8 m away from exhaust stacks, cooling tower and/or any other polluting source. Bottom of an outdoor air intake shall not be located less than 2 m above ground level and 1 m above any roof terrace level.

Exhaust outlets shall be located at a minimum height of 3 m away from ground level and away from doors, occupied areas and operable windows. Locating exhaust outlets above the roof, projecting upwards, is preferred.

While installing filters, care shall be taken to see that there is no scope for leakage between frame and filters and between filter segments. Filters shall be as per tested to accepted standards [D-3(15)], [D-3(16)], [D-3(17)] and [D-3(18)].

All openings in ducting/diffusers collars shall be sealed to prevent infusion of dust and dirt. All slab openings shall be terminated in enclosed rooms and airflow systems shall be designed and balanced to create positive or negative air pressure with-in specified areas.

It is recommended that supply air outlets shall be located at or near the ceiling and return/exhaust is collected near the floor level. This is to ensure that clean conditioned air moves through breathing and working space to the floor area, for return/exhaust.

For operating room and procedure room, where patients are highly susceptible to infection, such as orthopaedic and cardiac operating theatres, laminar air flow system shall be considered. A unidirectional air flow pattern at a max velocity of 0.13 m/s to 0.18 m/s should be aimed for to prevent the thermal plume at surgical site getting disturbed. A vertical laminar flow system which will wash the patient on the operating table and flow downwards, to be collected near floor level, shall be chosen for such rooms. The area of laminar flow grid shall extend by a minimum of 0.450 m beyond the footprint of the operating table on all sides. If required, additional supply diffusers may be provided for achievement of required temperature and humidity.

Minimum two (2) exhaust grilles shall be provided at opposite corners of the room at approximately 0.200 m above the finished floor level.

12.5.7 *Pressure Differential*

Operating rooms where highly infectious patients are treated and isolation is required, an anteroom shall be provided between the operating room and external area. Anteroom shall be maintained at positive pressure with respect to both the operating room and the surrounding areas.

All air from operating rooms shall be recirculated with adequate fresh air changes and Total air changes per hours and filtration as per tables above or exhausted after energy recovery. Similarly, from all airborne infection isolation rooms, all air shall be exhausted directly to outdoors through high efficiency particulate air (HEPA) filters. Such rooms shall be maintained at a minimum negative pressure of 2.5 N/m^2 with respect to surrounding areas.

Protective environment rooms, such as, bone marrow transplants and organ transplants, shall be maintained at a positive pressure of 2.5 N/m^2 with respect to surrounding spaces.

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12.5.8 *Conditioning Equipment*

Cooling equipment shall be central or local chilled water systems, direct expansion type condensing units or variable refrigerant flow systems. Indirect cooling systems using chilled water are preferred and, if direct cooling systems are used, required safety measures should be adopted. Heating equipment shall include heat pumps and heat exchangers.

Sizing and arrangement shall give adequate consideration to minimum loading and standby facility for critical areas. It shall be possible for the facility to operate even when one of the systems is under break down or maintenance.

Where specific areas are to be maintained at a low temperature coupled with low humidity, an additional direct expansion coil may be introduced downstream of the regular evaporator coil. In such cases, the control strategy shall ensure that the DX coil is energized only after the main evaporator coil is at full load.

When variable refrigerant flow systems are used, care shall be taken to see that minimum air change and pressure differential considerations are not compromised.

12.5.9 *Installation and Maintenance*

The air distribution system shall be provided with access panels to allow inspection and cleaning. Duct systems shall be cleaned of construction debris before commissioning.

Surfaces of air terminals shall be suitable for cleaning.

Access to equipment rooms shall be planned so as to avoid intrusion of maintenance personnel into critical care areas. Equipment room layout shall allow easy access to equipment for its operation and maintenance.

Operation and maintenance records shall include indoor temperature and pressure requirements as well as permitted tolerances for all spaces. It shall also include standard operating procedures for emergencies, such as power failure, equipment breakdown and fire situation.

Pressure differentials of operating rooms, protective environment rooms, and air borne infection isolation rooms with respect to surrounding areas, shall be verified and recorded semi-annually.

HEPA filters shall be replaced periodically based on pressure drop. Filters of fan coil units and air handling units (AHU) shall be cleaned according to a regular maintenance schedule. AHU/fan coil drain pans shall be of stainless-steel construction and shall be cleaned monthly.

Supply and return air ducts for critical areas shall be tested for air leakage and an air blow down process shall be undertaken before loading of filters. All areas served by the AHU shall be cleaned and mopped before the AHU is started. Filters shall be loaded in sequence. Pre-filters shall be loaded first followed by microvee or fine filters and finally HEPA filters. AHU shall be run with each set of filters for 24 h and the conditioned area shall be cleaned and mopped each time before the next set of filters is loaded.

After air balancing, and adjusting of air quantity, a validation process shall be carried out by recording temperature, humidity and pressure differentials. For critical areas, validation process shall be repeated and recorded at least once every year.

For operating rooms where validation is needed the air handling devices shall be run 24 h. However, the system deliverables shall be limited to maintaining minimum pressure differentials considerations with turndown procedures to control and limit contamination (unoccupied turn down is permitted subject to maintaining pressure differentials).

12.6 Underground Metro Station Buildings

A typical underground metro station generally consists of three underground levels i.e. concourse level, platform level and undercroft level. The first level at minus 1 being the concourse with a height ranging from 4.8 m to 5.5 m followed by Platform level at minus 2 of height varying from 4.5 m to 5 m. The third level that is undercroft level provided below the platform having minimum clear height of 1.8 meter is mainly used for the services like cables, fire pipes, escalator pits, seepage and sewage sumps etc. The ancillary building at metro stations is also provided outside the station building to house either cooling towers, air cooled chillers, water cooled chillers, etc.

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The underground metro station is provided with environment control system (ECS). The ECS system shall serve following function:

a) station public area and ancillary room air conditioning;

b) mechanical ventilation of plant rooms;

c) smoke management system; and

d) staircase Pressurisation

12.6.1 *Station Public Area and Ancillary Room Air Conditioning*

12.6.1.1 *Station air conditioning design philosophy*

The underground stations of the metro corridor shall be designed to provide forced ventilation for removal of the large quantity of heat dissipated from train equipment, station electrical accessories and equipment, passenger body heat, obnoxious odours, and harmful gases such as CO_2. The station heat load shall be assessed by taking into account the provision of platform screen doors (PSDs) at the station. PSDs, which act as barriers between the station platform and the trackway, are provided for enhancing passenger safety, improving indoor air quality, and achieving energy savings. PSDs may be of two types, full Height PSD or half Height PSD, and their installation significantly influences the overall heat load profile of the station. The station heat load generally consists of a combination of unsteady train heat loads, passenger heat load, lighting and miscellaneous equipment loads, fresh air loads, transmission heat loads, and infiltration/exfiltration loads. The station heat load shall be considered as

a) *Unsteady heat load due to train movement* — The unsteady heat load at a station due to train movement is almost negligible when the full height PSD are provided between station trackway and station platform. In case of no PSD or half height PSD the unsteady heat load is the major source of heat for the station is from the train air conditioning systems and the train traction and braking systems. The air that gets pushed in to the tunnel due to the piston effect gets exhausted through separate gravity dampers provided at the top of tunnel. The simulation studies also evaluate the tunnel temperatures during the normal operation of the train movements. The underground stations with provision of full height PSD doesn't allow the cool air of the station to go into the tunnel and the tunnel temperatures tends to be higher. The simulation studies inform the amount of tunnel cooling required for normal and congested operation of the train in the tunnel sections.

b) *Steady heat load*:

   1) *Passenger heat load* — The passenger occupancy at station is taken from peak hour peak direction traffic (PHPDT) data given in detail project report (DPR). Passenger heat gain shall be computed from the above data;

   2) *Lighting and miscellaneous equipment load* — It is based on lighting in public area and equipment like lifts, escalators and AFC Gates contributing to the heat load;

   3) *Fresh air loads* — Fresh air is supplied to the platform and concourse to meet the physiological requirements of the passengers. Fresh air quantity shall be calculated as per **3**;

   4) *Transmission heat loads* — The transmission of heat through the station walls between public and non-public areas, through concourse floor slab and heat transmission through PSD glass doors to be considered; and

   5) *Infiltration and exfiltration heat load* — Infiltration or ex-filtration of air at platform takes place through PSD doors from the trackway to platform and vice versa. The source of heat on trackway is heat rejected from train condenser, traction, braking, and airflow due to train piston effect. In order to maintain the required conditions in the station, the loss of cooling at station platform due to infiltration/exfiltration of air may be considered in station heat load estimation

12.6.1.2 *Design criteria*

Since the passengers stay in the stations only for a short period, a reasonable degree of comfort conditions, just

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short of discomfort conditions are considered appropriate. Station air conditioning system shall be designed to maintain specific design conditions.

Station air conditioning system design conditions are:

a) Platform, Concourse : 27 °C at 55 percent relative humidity

b) Outdoor : Summer and monsoon condition as per location

12.6.1.3 *System description*

The station environment control shall be by a central air conditioning system. Station shall have provision of fresh air intake and exhaust shaft. The station shall be supplied with conditioned air to concourse and concourse area via ductwork from air handling unit (AHU) located in plant room either at concourse or platform level. AHU shall be supplied with chilled water from water cooled/air-cooled chillers and its associated pumping system. The AHU shall be as per accepted standard [D-3(21)] and the liquid chillers shall be as per accepted standard [D-3(24)].

The trackway exhaust system shall be installed in the trainways of each station to capture both excessive tunnel airflows and the heat rejected by the vehicle propulsion/braking/air-conditioning systems as the train dwells in the station. An over track exhaust (OTE) duct is normally utilized to capture heat that is rejected from the vehicle propulsion/braking as well as the heat that is rejected from the above car area rooftop mounted air-conditioning units. An under platform exhaust (UPE) duct can also be utilized to capture heat from the train's undercarriage heat sources if the heat generated is significant. Openings in the OTE and UPE shall be located to be near the heat generating sources on the train.

For systems designed without PSD or half height PSD, the extracted air from the station trackway is used as a return air for the air-conditioning system during the close mode of operation. For stations with full height PSDs, the heat extracted through station trackway can be directly exhausted to the atmosphere or can also be used as return air as per the system requirements.

12.6.1.4 *Modes of operation*

There are namely two types of mode of operation:

a) *Open mode operation* — In open mode, 100 percent outside air is circulated in the stations. It is an economical mode of operation when the outside air enthalpy is relatively low and favourable for the inside condition (the best-case scenario is when the outside air enthalpy is same as the design AHU coil leaving air enthalpy). AHU shall draw the air directly from outside via fresh air shaft and deliver the air at platform level and concourse level. Trackway exhaust fans (TEF) shall extract the air from OTE and UPE and discharge it outside directly via exhaust shaft. The centralized chillers units shall remain shut down in this mode. This mode is known as 'Economiser Cycle' and is generally available during winter season;

b) *Closed mode operation* — In close mode, air is extracted from the public areas of the station and returned to the air handling units to be cooled and delivered back to the platform and concourse. Closed mode operation is proposed when the outside air temperature and humidity are high. In this operation, AHU shall recirculate the air of OTE and UPE with the addition of fresh air, brought in by fresh air fans (FAF). This mode is generally used during summer and monsoon season; and

c) During close mode operation in station with full height PSDs, the return air is taken from the station concourse and public areas and then again recirculated by the AHUs provided in the ECS plant rooms.

12.6.2 *Mechanical Ventilation of Plant Rooms*

The back of house area rooms are provided with mechanical ventilation supply, ventilation exhaust or both according to their use and particular requirements.

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12.6.2.1 *Ancillary area air conditioning*

Air conditioning of back of the house areas and ancillary areas, that are occupied by staff and non-travelling persons, who are going to stay in these areas for considerable duration, shall be same as air conditioning system for commercial buildings.

12.6.3 *Smoke Management System*

The and trackway exhaust fans (TEF) are used for concourse and platform public areas either TEF can be used or separate smoke extract fans can be provided. In case of full height PSD as TEF is not available for concourse and platform smoke extraction, separate smoke extraction ducts and fans are compulsorily required for these areas. The fans with related equipment shall be suitably located at each end of the station. Where a smoke extract ducting passes through protected areas, it shall be rated to the same fire resistance as the walls of the compartments. Station smoke removal fans to provide a positive indication of the fan operation at the station control rooms (SCR) as well as operations control centres (OCC).

12.6.4 *Staircase Pressurization*

Pressurization of the firemen's staircase and emergency staircase should be done in accordance with Part F 'Fire and Life Safety' of this NBCS.

12.7 Airport Buildings

HVAC systems for airports shall address unique requirements due to the complexity, scale, and diverse usage of these facilities. The key considerations for airport typology as given below shall be followed for energy efficient and sustainable building.

12.7.1 *Passenger Comfort*

These recommendations focus on maintaining optimal air quality, temperature, and humidity levels to enhance the comfort and experience of passengers in airport terminals:

a) *Temperature control* — Consistent and comfortable temperatures to provide thermal comfort in passenger areas, considering high traffic and varying external conditions as detailed in **3** shall be ensured;

b) *Humidity control* — Optimal humidity levels to enhance comfort and protect electronic equipment shall be ensured. (*see* **3**); and

c) Indoor air quality shall be as per the requirements as specified in **3**.

12.7.2 *Energy Efficiency*

The equipment like variable air volume (VAV) Systems, energy recovery ventilation (ERV) systems, and BMS as specified in **15**, should be considered.

12.7.3 *Ventilation and Air Exchange*

The ventilation and air exchange rate shall refer to the **3** and **8**.

12.7.4 *Load Management*

These guidelines focus on optimizing energy consumption and ensuring efficient operation of HVAC systems in response to fluctuating passenger traffic and varying environmental conditions:

a) *Peak load handling* — Systems shall be designed to handle peak loads during busy periods without compromising comfort; and

b) Demand control ventilation should be implemented to adjust ventilation rates based on occupancy to reduce energy use during off-peak hours.

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12.7.5 *Redundancy and Reliability*

These considerations ensure the continuous, uninterrupted operation of HVAC systems by incorporating backup systems and fail-safe mechanisms to handle critical airport operations:

a) *Backup systems* — Backup HVAC systems and power supplies shall be incorporated to ensure continuous operation during power outages or system failures as the systems are expected to operate continuously all 365 days of the year; and

b) *Maintenance access* — Easy access to HVAC components for regular maintenance and emergency repairs shall be envisaged.

12.7.6 *Special Considerations for Specific Areas*

For the following specific areas, special considerations should be taken:

a) *Control towers* — HVAC system shall be designed for precise temperature and humidity control along with high air quality. Design should be fail safe system with redundancy;

b) *Baggage handling areas* — Maintain moderate temperatures to protect mechanical systems and baggage handling equipment; and

c) *Retail and Dining Areas* — Adequate ventilation and temperature control to ensure comfort for patrons and staff shall be provided.

12.7.7 *Noise Control*

These recommendations focus on minimizing noise pollution from HVAC systems to ensure a quiet and comfortable environment for passengers and staff in airport terminals:

a) The acoustic design of HVAC system should be considered to lower the noise level;

b) *Sound attenuation* — Sound attenuators and low-noise equipment to control noise levels in critical areas should be used; and

c) Noise control measures shall be as per Part D ‘Building Services, Section 4 Acoustics Sound Insulation and Noise control’ of this NBCS.

12.7.8 *Advanced HVAC Technologies*

These technologies aim to enhance energy efficiency, air quality, and overall system performance, ensuring a more sustainable and comfortable environment for passengers and staff.

a) *Smart sensors* — Occupancy and air quality sensors to optimize HVAC operations dynamically should be used;

b) *Advanced controls* — Advanced control systems to automate and optimize HVAC performance based on real-time data should be implemented **15**; and

c) *High volume low speed fans* (*HVLS fans*) — These fans should be used in conjunction with air conditioning systems to provide better thermal comfort in high ceiling areas there by enhancing passenger comfort and energy efficiency.

12.7.9 *Scalability*

The system should be designed with flexibility in mind to accommodate future expansion needs. This includes providing sufficient capacity, space, and infrastructure to allow for easy integration of additional components, equipment, or systems as the airport's operations grow. It should also consider scalability in terms of power, cooling, and airflow requirements, ensuring that the system can be upgraded or modified without significant disruption.

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12.8 Shopping Complex Buildings

HVAC systems for shopping complex buildings like malls shall be designed to handle the unique demands of large, complex spaces with varying loads and occupancy levels.

For a small shop and store, unitary split type air conditioning system shall offer many advantages, including low initial cost, minimum space requirement and ease of installation. For large department store a very careful analysis of the location and requirement of individual department shall be required as these may vary widely, for example, for lighting department, food halls, restaurants, etc. Some system flexibility to accommodate future changes should be attempted in design.

Generally, internal loads from lighting and people are predominate considerations shall be given to initial and operating costs, system space requirements, ease of maintenance and type of operating personnel operating the system.

The economical options of all-air type of system, with variable volume distribution from local air handling unit, shall be considered. Facilities to take all outside air, for 'free cooling' under favourable conditions, should be provided.

a) *Load Calculations* — The following considerations should be taken into account for load calculation:

   1) *Diverse spaces* — Malls include various spaces such as retail shops, food courts, fine dining restaurants, cinemas, play zones and common areas, each with different HVAC needs;

   2) *Peak occupancy* — Systems shall accommodate peak load times, such as weekends and holidays; and

   3) *Heat loads* — Due consideration for heat loads from lighting, equipment, and occupants shall be accounted.

b) *Zoning* —Proper zoning is required for ensuring optimal comfort and energy efficiency in HVAC systems which shall be ensured by adhering to following:

   1) *Multiple zones* — Separate zones for different areas to ensure comfort and efficiency shall be designed. For example, food courts, theatres, and individual stores should have their own control zones served by common or individual air handlers with distinct functioning options; and

   2) *Independent controls* — Each zone should have independent temperature and humidity controls.

c) *Ventilation* — The following considerations should be taken into account for ventilation:

   1) *Fresh air requirements* — Adequate ventilation to ensure indoor air quality, with proper intake of fresh air as detailed in **3** shall be followed; and

   2) *Exhaust systems* — Effective exhaust systems for areas with specific requirements, such as food courts and restrooms, shall be needed for controlling odour, and pollutants.

d) *Air Distribution* — Effective air distribution is crucial for maintaining consistent comfort and air quality across all areas of the space:

   1) *Even distribution* — The system should be designed for uniform air distribution; and

   2) *Diffusers and grilles* — These shall be appropriately selected and placed for efficient air distribution.

e) *Energy Efficiency* — The system should be designed for energy-efficient operation, aiming to minimize energy consumption while maintaining optimal comfort levels. Proper system sizing, effective load management, and routine maintenance practices to ensure the HVAC system operates at peak efficiency, reducing overall energy costs and environmental impact;

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f) *Humidity Control* — The following considerations should be considered for humidity control:

1) *Dehumidification* — Proper dehumidification to maintain comfort and prevent mould growth shall be planned in humid climates or areas located in zones with high humid ambient conditions; and

2) *Humidification* — In colder climates, additional humidification strategies in air handlers shall be added to maintain comfort.

g) *System Redundancy* — To ensure system redundancy following recommendations to be considered:

1) The design should consider backup systems for critical components to reduce downtime; and

2) The system design should be for easy maintenance access.

h) *Building Management Systems* (*BMS*) — The design of BMS should focus on centralizing control and monitoring of various building systems to enhance operational efficiency and energy management by adhering to following:

1) *Integrated control* — BMS should be planned for centralized control and monitoring and integrating various operating HVAC systems and other systems such as lighting controls, lift management, water pumping systems, DG sets and MCC panels as well as fire alarm system to provide comprehensive and energy efficient operations; and

2) Real-time monitoring should be incorporated for feedback on the performance and provide opportunity for necessary alterations to achieve energy efficiency goals.

i) *Noise Control* — Systems should be designed to minimize noise as well as sound transfer from one zone to another, especially in common areas and near sensitive zones like screens in multiplex, conference areas etc;

j) *Monitoring and Diagnostics* — Should implement predictive maintenance strategies using data analytics to reduce downtime and maintenance costs;

m) *Commissioning and Re-Commissioning* — Thorough initial commissioning as well as ongoing recommissioning shall be carried out as detailed in **17**;

n) *Climate Resilience* — The systems shall be designed to withstand and operate efficiently during extreme weather conditions as per the weather data provided in this NBCS;

p) *Water Management* — Water management systems should be designed to optimize water usage, enhance efficiency, and support sustainability within the building's HVAC operations and overall facility management which shall be ensured through:

1) *Condensate management* — This shall be ensured by efficiently managing and reusing condensate water from air conditioning systems; and

2) *Cooling towers* — Principally all types of cooling towers need make up water as well as constant replenishment and to achieve better system efficiency lower approach, designing of cooling towers may be referred from special publication.

NOTE — Special publication may be Energy Conservation and Sustainability Building Code 2024 (ECSBC).

q) *Operational Training* — Operational training to ensure that maintenance and operational staff are well-equipped, to manage the HVAC systems efficiently and respond effectively to emergencies and following may be adhered:

1) *Staff training* — Comprehensive training shall be provided for maintenance and operational staff on system use and troubleshooting; and

2) *Emergency procedures* — Emergency procedures shall be established with clear procedures for HVAC-related emergencies, such as system failures or fire/smoke instances.

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r) *Tenant Coordination* — Effective coordination with tenants to ensure that their HVAC needs are addressed while maintaining overall system efficiency. The following points outline key aspects of this coordination:

1) *Tenant integration* — Coordinate with tenants shall be done to ensure their HVAC needs are met without compromising overall system efficiency; and

2) *Tenant fit-out* — Proper guidelines shall be provided for tenant fit-out to maintain compatibility with the central HVAC system installed.

s) *Other requirements* — Other requirements such as safety, system type and components, should be as per Part F 'Fire and Life Safety' of this NBCS. HVAC should be designed flexible to accommodate future expansion:

1) The design shall ensure thermal comfort as defined in **3**. (Adaptive controls – Adaptive control algorithms that respond to real-time occupancy and environmental data should be incorporated);

2) Demand control ventilation (DCV) should be considered as reference to the thermal comfort and Indoor air quality requirements defined in this section; and

3) *Backup power* — Critical HVAC systems shall have backup power to maintain operation during power outages.

12.9 Industrial Facility Buildings

12.9.1 *Zoning*

Zoning of different spaces shall be planned according to the functionality. Based on the hazard classification of different entities, compartmentation measures and safe distances shall be maintained. Emergency exits and assembly points shall be planned in line with the local regulations.

Planning shall consider adequate ventilation and natural light ingress into majority of the working spaces.

12.9.2 *Indoor Conditions*

Indoor conditions of different spaces shall be planned in line with the functional requirements of the spaces in general. Temperature, relative humidity and air quality shall be planned as per guidelines.

Ventilation and air conditioning shall be planned based on the functional requirements of the industrial buildings in line with basis of design brought out in **3**.

In industrial buildings, acceptable working conditions shall be ensured rather than comfort as providing comfortable conditions in huge volumetric spaces will not be efficient in terms of energy usage and cost economics. However, the ancillaries and office spaces shall be planned for comfort conditions in line with the guidelines.

The ventilation systems may contain chemical compounds or toxic substances in concentrations crossing prescribed safe limits. Necessary precautionary arrangements shall be made to remove, contain, exhaust and maintain the hazardous pollutants within acceptable limits in occupied spaces.

Emergency preparedness includes fire safety measures, with designated smoke extraction and pressurization systems integrated for safe evacuation and emergency response capabilities. Additionally, industrial zones shall be equipped with specialized HVAC systems, ensuring operational continuity within sensitive areas such as equipment rooms, control centers, and personnel amenities.

12.9.3 *Energy Efficiency and Conservation*

Energy-saving initiatives such as variable air volume (VAV) systems in public and operational zones, optimizing airflow and energy consumption based on real-time demand, variable frequency drives (VFDs) control AHUs, pumps, air compressors and chillers, optimizing operational efficiency during fluctuating production cycles,

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enthalpy economizer cycle in 100 percent Fresh air scenario and adaptive thermal comfort approach should be considered.

12.9.4 *Fire Safety and Electrical Integration*

It should be as defined in the Part F 'Fire and Life Safety' of this NBCS.

12.10 Tall Buildings Typology

12.10.1 *General*

Tall buildings are defined as structures with a height greater than 100 m. Buildings that exceed 300 m are classified as super tall buildings. Furthermore, buildings taller than 600 m are categorized as mega tall buildings.

Important considerations for tall/super tall/mega tall buildings are:

a) The effect of ambient air temperature over the height of buildings especially for super tall and mega tall buildings;

b) Facades for tall Buildings, leakage rates and pressure resistance;

c) Natural ventilation for tall buildings;

d) Energy consumption/conservation and new trends in HVAC design for tall/super tall/mega tall buildings;

e) Stack effect; and

f) Green/Sustainable tall buildings.

12.10.2 *Architectural Consideration*

Following key points outline key aspects of architectural consideration:

12.10.2.1 *Core design*

Design of core areas determine the projects floor to floor heights. This reflects in the building cost and architectural as well as HVAC design. An important consideration for architecture shall be the core design comprising of the three commonly used cores – Central Core/Double Core/Single sided (or offset) core. For hot and humid as well as temperate climates the core is suggested to be located on the east and west facades to insulate the interior zones from ambient conditions. Also, the cooling loads are found to be minimal when the double core configuration with glazing is used on north south and south facade and core on east and west facades. The core incorporates the following minimum entities:

Fire escape stairs/vertical transportation elements/rest rooms/electrical closets/communication closets/local fan rooms/shafts for HVAC risers/shafts for HVAC and plumbing systems/electrical distribution and building management and fire alarm system cabling.

12.10.2.2 *Facade systems*

The orientation influences the either increased or decreased infiltration rates and solar loads through facades. This is specifically important for mega tall and super tall buildings as infiltration from wind loads shall be significant for very tall buildings since there may not be adjacent buildings to mitigate high winds.

A high-performance facade needs to be planned to minimize solar cooling load and allow for efficient performance of air-conditioning systems while maintaining thermal comfort.

Facade is to be designed to minimize solar gain to 10 percent to 20 percent of the incident radiation. A double skin facade with fan coil/chilled ceiling/chilled beam cooling systems with return air directed to the floor of the perimeter and up between exterior and interior windows could be used.

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Different types of multi skin facades such as one story faced module/corridor facade/multiple story facade and shaft box facade shall be designed

12.10.3 *Shading Strategies*

Shading strategies are important especially for cooling load dominated climates. It is better to minimize window to wall ratio as shall be seen the difference between 40 percent window to wall ratio and 65 percent window to wall ratio as seen in most modern buildings (*see* Fig. 7).

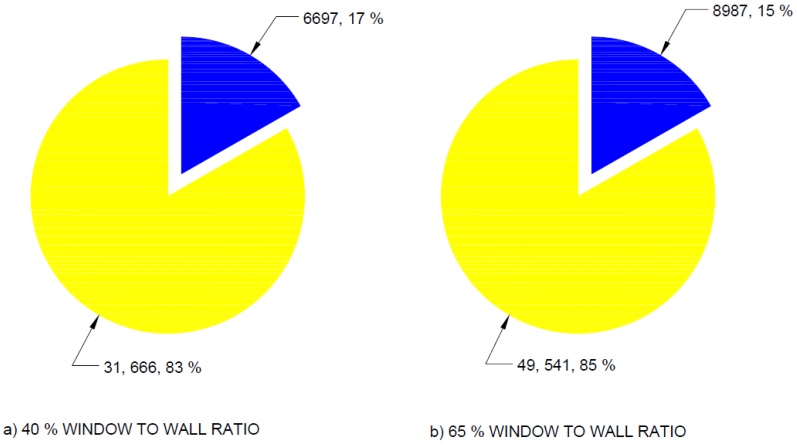

FIG. 7 IN 40 PERCENT THE HEAT TRANSFER THROUGH THE GLAZING IS 83 PERCENT OF THE LOAD TO THE SPACE AND IN 65 PERCENT IT IS 85 PERCENT TO THE SPACE.

12.10.4 *Facade Leakage Rates*

Envelope leakage depends on HVAC system operation. In pressurized buildings when HVAC systems operate the infiltration leakage could be very low. In accordance with the best practices of special publications recommended air leakage test of the completed building shall be with a leakage rate of not exceeding 2.0 l/s.m^2 at 75 Pa pressure differential.

As per special publication the recommended leakage rate value is 9.0 l/sm^2 at 75 Pa pressure differential.

The following are the two options as recommendations either as per special publications:

a) 2.0 l/s.m^2 at 75Pa; and

b) 9.0 l/s.m^2 at 75 Pa.

NOTE — Special publications maybe International Energy Conservation Code (IECC) and ASHRAE 90.1.

The leakage rate for tall building however shall vary with height. If the maximum leakage rate is achieved at a particular height, then at any height above this there will be facade leakage as infiltration load (*see* Fig. 8).

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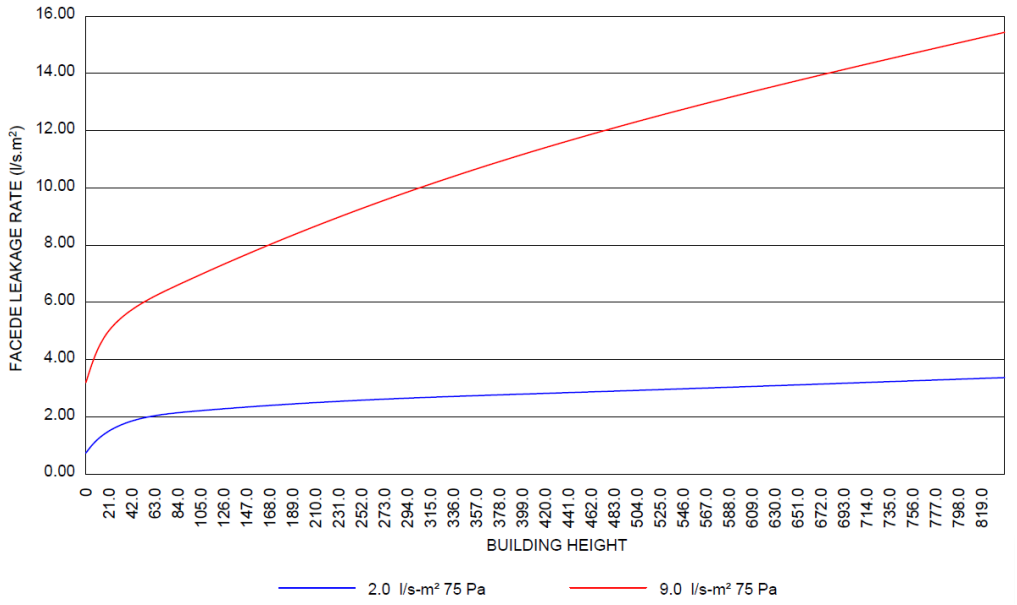

FIG. 8 CALCULATED LEAKAGE RATES FROM WIND SPEED IN CFM(L/S) OF FACADE AREA FOR TALL/MEGA TALL BUILDING

12.10.5 *Climate Data*

Generation of climate data at upper elevations is a shall. It could be achieved through:

a) Remote sensing technologies or ballon releases; and

b) Model using weather forecasting techniques.

Following are some of the calculation methods:

1) To obtain external temperature at different building heights use:

$$T = T_g - 0.006\,49\,h$$

where

T = temperature at height h (m);

T_g = Temperature at ground level F (°C); and

h = height from ground level (m).

2) External Pressure vertically with the building height is

$$P = 101\,325(1 - 2.255\,77 \times 10^{-5} \times h)^{5.255\,9}$$

where, P = pressure (kPa)

3) Density of air vertically with the height of the building shall be

$$\rho = \frac{P_{abs}}{0.286\,9\,(T\ + 273.1)}$$

where

T = absolute temperature (K);

P_{abs} = absolute pressure (Pa); and

ρ = air density (kg/m^3).

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4) Wind speed and pressure are generally obtained from meteorological stations located away from urban environments. This wind speed shall be corrected for terrain conditions and for building height relative to wind measurement at that height. Approximate correction factor is:

$$v_z = v_m k Z^a$$

where

v_z = wind speed at the building height (m/s);

v_m = wind speed measures in open country at a height of 10 m (m/s);

Z = building height (m); and

k and a = constants dependent on terrain as per table below:

Wind speed terrain constants:

Sl No.	*Terrain Category*	*k*	*a*
(1)	(2)	(3)	(4)
i)	Open, flat country	0.68	0.17
ii)	Country with scattered wind breaks	0.52	0.20
iii)	Urban	0.35	0.25
iv)	City	0.21	0.33

12.10.6 *Stack Effect*

By convention, the stack pressure differences are positive when building is pressurized relative to outdoors which causes flow out of building.

When indoors is warmer than outdoors the base building is depressurized, and top is pressurized relative to outdoors. When the indoors is cooler than outdoors then the reverse becomes true. At some elevation in building the pressure indoors is equal to the outdoors and this height is known a neutral pressure level (NPL). NPL is influenced by leakage distribution and not necessarily at mid height of building.

The location of NPL (h) is expressed by:

$$h = H/(1 + (A_1/A_2)^2 T_i/T_o)$$

where

A_1 and A_2 = lower and higher leakage areas;

T_o and T_i = outdoor and indoor absolute temperatures; and

H = Building height.

12.10.7 *Heating and Cooling Loads*

Cooling and heating loads shall be calculated by dividing the building into sections. For example, splitting the building as 100 m sections and calculate heating and cooling loads in view of variable outside temperature, density and pressure over the building height as compared to constant parameters for other building typologies.

12.10.8 *Indoor Air Quality and Thermal Comfort*

The procedures and standards mentioned in **3** shall be followed. If this ventilation procedure does not yield adequate results to contain a specific contaminant or if the contaminant levels shall be attained with lower ventilation rates, then as an alternative indoor air quality procedure (IAQP) may be used.

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12.10.9 *HVAC Systems*

All HVAC system options available for any building typology shall be applicable for use in Tall Buildings. These include:

a) All air variable air volume (VAV) systems;

b) Low temperature air VAV systems;

c) Underfloor air systems;

d) Air-water systems;

e) Radiant ceilings;

f) VRF drive fan coil units; and

g) VRF fan coils with 100 percent outdoor air ventilation.

12.10.10 *Exhaust Fan Pressures*

There will be considerable wind pressures at the air intake and exhaust locations shall be calculated as follows:

P_s intake = C_p intake $[\frac{\rho_a U_H^2}{2g_c} / 2.152]$

P_s exhaust = C_p exhaust $[\frac{\rho_a U_H^2}{2g_c} / 2.152]$

(P_s intake – P_s exhaust) + $\Delta P_{fan} = F_{Sys} \frac{\rho Q^2}{A_L^2 gc}$

$\Delta_{P_{wind}}$ = (C_p intake - C_p exhaust) $[\frac{\rho_a U_H^2}{2g_c} / 2.152]$

where

ρ_a = outdoor air density at height h;

U_H = approach wind speed at upwind height h (m/s);

F_{Sys} = system flow resistance;

A_L = flow leakage area and; and

Q = system volume flow rate.

12.10.11 *Water Distribution Systems*

A major consideration in the design of a piping system in a tall building is the hydrostatic pressure created by the height of the building. The design of piping shall take static pressure on the piping system due to the height of into consideration. The piping network is divided into zones vertically separated by pressure breaks and served by heat exchangers and pumps with main chiller located at the utility complex in basement or an adjacent service building. The building pressure break shall be at equal interval at different heights separated using heat exchangers and tertiary pumps. It is needed that consideration to be given for different vertical zones in chilled water temperatures at the inlet to heat exchangers in each zone. In a typical scenario of 4 zones to serve chilled water at 6 °C at top of building following temperatures at each Heat exchanger will have to be maintained:

I Zone	1.5 °C
II Zone	3.0 °C
III Zone	4.5 °C
IV Zone	6.0 °C

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Suggested piping materials shall be steel pipes schedule 40 with standard wall thickness for pipes up to 250 mm in diameter and for pipes 300 mm or larger a wall thickness of 9.5 mm. This by and large would accommodate the working pressures in tall buildings. However, a cross verification with accepted standard [D-3(27)] is preferred. Based on the working pressure valves and fittings also need to be selected. For steam condensate piping or for condenser water piping where corrosion is a possible concern pipe with heavier wall thickness shall be considered.

12.10.12 *Expansion and Contraction in Piping*

Design of piping shall take other factors including expansion and contraction and static and dynamic loads of the piping should be taken into consideration.

13 SPECIAL PLACES IN BUILDINGS

13.1 Cleanroom

The basic considerations in a cleanroom design are:

a) Cleanroom class;

b) Temperature;

c) Relative humidity;

d) Sound level;

e) Vibration;

f) Light spectrum; and

g) Electrostatic charge/static electricity.

NOTE — Number d, e, f and g are important for only selective cleanroom applications such as semiconductor, electronics and others.

13.1.1 *General Requirement*

a) Areas surrounding the cleanroom shall be less pressured than the cleanroom to avoid ingress of non-clean air to classified areas;

b) Airlock rooms shall be provided before clean room to maintain cleanroom integrity and reduce entry of contamination in classified areas:

   1) Separate change rooms shall be provided for male and female workers. multiple change rooms should be designed in series as per criticalness of application with primary change rooms designed as controlled not classified (CNC) and secondary change rooms (opening in cleanroom areas) designed under classified category; and

   2) A suitable door interlocking shall be used to ensure that both doors of airlock do not open “simultaneously” during usual operation time (except during emergency situations).

c) Air shower shall be used to reduce particles entry during human movement;

d) Dedusting tunnels or pass box should be used to reduce particles entry during material movement;

e) Existing Windows, cleanroom wall/ceiling panel joints shall be closed permanently using suitable sealants to avoid cross contamination;

f) Good smooth and scratch resistant flooring with skirting shall be provided;

g) All Corners and edges (ceiling to wall, wall to wall and wall to floor) shall be provided with coving to avoid dust accumulation and for easy cleaning;

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h) The room shall be considered a restricted area. Only authorized personnel shall be allowed to enter during operation;

j) No paper products/cotton buds shall be allowed inside the cleanroom;

k) All personnel entering the clean room facility shall use 'cleanroom compatible gowning and shoes';

m) All personnel/visitors shall wear cleanroom garments while entering cleanroom; and

n) Cleanroom garments shall be stored properly in a laminar air flow storage cabinet:

1) The cleanroom cleaning protocol shall be designed as per the product nature and contaminations to be removed. The cleaning agents shall also be compatible with cleanroom architecture; and

2) Movement of materials from and to the cleanroom shall be as optimum as possible.

13.1.2 Selection of airborne particulate cleanliness classes for cleanrooms and clean zones as per special publication is given in Table 29.

Table 29 Airborne Particulate Cleanliness Classes for Cleanrooms and Clean Zones

(*Clause* 13.1.2)

Sl No.	ISO Classification Number	Maximum Concentration Limits (Particles/m^3 of Air) for Particles Equal to and Larger than the Considered Sizes Shown below:					
		≥ 0.1 µm	≥ 0.2 µm	≥ 0.3 µm	≥ 0.5 µm	≥ 1 µm	≥ 5 µm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	ISO Class 1	10	2	–	–	–	–
ii)	ISO Class 2	100	24	10	4	–	–
iii)	ISO Class 3	1 000	237	102	35	8	–
iv)	ISO Class 4	10 000	2 370	1 020	352	83	–
v)	ISO Class 5	100 000	23 700	10 200	3 520	832	29
vi)	ISO Class 6	1 000 000	237 000	102 000	35 200	8 320	293
vii)	ISO Class 7	–	–	–	352 000	83 200	2 930
viii)	ISO Class 8	–	–	–	3 520 000	832 000	29 300
ix)	ISO Class 9	–	–	–	35 200 000	8 320 000	293 000

NOTE — Special publication may be ISO 14644-1.

13.1.3 The meanings of the cleanrooms classification is given in Table 30.

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Table 30 Meanings of the Cleanrooms Classification

(*Clause* 13.1.3)

Sl No.	Class	Description
(1)	(2)	(3)
i)	Class 1	This Cleanrooms class is mainly used within the microelectronic industry when manufacturing integrated circuits which requires submicron resolution.
ii)	Class 10	This Cleanroom class is mainly used within the semiconductor industry using band widths below 2 micrometer.
iii)	Class 100	This cleanroom class is, according to many, the most useful critical cleanliness class. Cleanrooms class 100 are often, incorrectly, known as sterile rooms and are used when > bacterial free < and /or > particle free < environments are required. Cleanroom class 100 is used in aseptic manufacturing within the pharmaceutical industry, for example. This cleanroom class is frequently used during the manufacture of integrated circuits; and also during isolation and treatment of patients who are especially sensitive to bacterial infections, for example, after bone marrow transplantation.
iv)	Class 1 000	This cleanroom class is mainly used when producing high quality optics; When carrying out mounting work and testing of gyroscopes for aircrafts; and also, when mounting high quality miniature bearings.
v)	Class 10 000	Clean rooms of class 10 000 are used for mounting procedures in hydraulic or pneumatic equipment and on some occasions are also used within the food and beverage industry. Class 10 000 cleanrooms are also commonly used within the pharmaceutical industry.
vi)	Class 100 000	This classroom class is used by many industries, for example when working with optical products, when building large electronic systems based on smaller components, when building hydraulic and pneumatic systems and also within the food and beverage industry. The pharmaceutical industry also makes frequent use of this class of cleanrooms.

13.1.4 Air velocities and air changes in cleanrooms is given in Table 31.

Table 31 Air Velocities and Air Changes in Cleanrooms

(*Clause* 13.1.4)

Sl No.	Class of Cleanroom	Airflow Type	Average Velocity (m/h)	Air Changes per h
(1)	(2)	(3)	(4)	(5)
i)	ISO 8 (100 000)	N/M	18 to 146	5 to 48
ii)	ISO 7 (10 000)	N/M	183 to 274	60 to 90
iii)	ISO 6 (1 000)	N/M	457 to 732	150 to 240
iv)	ISO 5 (100)	U/N/M	732 to 1 463	240 to 480
v)	ISO 4 (10)	U	914 to 1 646	300 to 540
vi)	ISO 3 (1)	U	1 097 to 1 646	360 to 540
vii)	Better Than ISO 3	U	1 097 to 1 829	360 to 600

NOTES

1 Air Changes per hour = Average airflow velocity × room area × 60 min/h

2 Room Volume

3 N=non unidirectional; M= mixed flow room; U= Unidirectional flow.

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13.1.5 The classification of filters given in Table 32 should be applicable.

Table 32 Classification of Filters

(*Clause* 13.1.5)

Sl No.	Filter Class	Overall Value Efficiency (percent)	Overall Value Penetration (percent)	Leak Test Efficiency (percent)	Leak Test Penetration (percent)
(1)	(2)	(3)	(4)	(5)	(6)
i)	H 10	85	15	–	–
ii)	H 11	95	5	–	–
iii)	H 12	99.5	0.5	–	–
iv)	H 13	99.95	0.05	99.75	0.25
v)	H 14	99.995	0.005	99.975	0.025
vi)	U 15	99.999 5	0.000 5	99.997 5	0.002 5
vii)	U 16	99.999 95	0.000 05	99.999 75	0.000 25
viii)	U 17	99.999 995	0.000 005	99.999 9	0.000 1

13.1.6 Schedule of tests to demonstrate continuing compliance is given in Table 33.

Table 33 Schedule of Tests to Demonstrate Continuing Compliance

(*Clause* 13.1.6)

Sl No.	Test Parameter	Class	Maximum Time Interval
(1)	(2)	(3)	(4)
i)	To demonstrate compliance by particle counting	≤ ISO 5	6 months
		> ISO 5	12 months
ii)	Schedule of additional	All Classes	12 months
iii)	Air flow velocity or volume		
iv)	Air pressure difference	All Classes	12 months
v)	Schedule of optional tests	All Classes	24* months
vi)	Installed filter leakage		
vii)	Airflow visualisation	All Classes	24* months
viii)	Recovery	All Classes	24* months
ix)	Containment leakage	All Classes	24* months

* = Suggested time interval

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13.2 Refrigeration for Cold Stores

13.2.1 *Key Elements and Components of Cold Room*

a) *Product quality* — Design and operation of cold storages is governed by the level of quality control parameters as per the individual products.

b) *Temperature of cold room* — During the entire storage period, the temperature should remain as constant as possible:

1) In case of some produces the rate of cooling for the freshly cooled products shall be considered, as per recommended cool down period. (Respiration loads, mainly from fruits and vegetables).

2) Shall avoid putting into a room a large amount of goods at a temperature too different from that of goods already in the room. The cold-production equipment should be checked to make sure it shall handle this extra load. Within one room the temperature should be as uniform as possible, as this affects not just products that are sensitive to temperature variations, but also those with recommended temperatures near 0 °C. These optimum conditions shall be approachable without risk of freezing.

3) Dead zones and regular drafts shall be avoided. Temperature sensors should be placed around the room on the basis of the accuracy, as indicated by the manufacturer, of the automatic devices. Cold store temperature shall be either recorded or read at regular intervals. Thermometers should be protected from impact and yet be easily accessible. Temperature should be read at more than one location. Moreover, the temperature of the products themselves should be taken.

c) *Measurement of temperature of food* — A thermometer/temperature measurement device that shall measure the internal temperature of food, like one with a probe that shall be inserted into the food is required. Food internal temperature shall be measured as the surface temperature may be warmer or cooler than the temperature of the rest of the food. The thermometer shall be accurate to ±0.5°C. The thermometer/temperature measurement device should be cleaned and sanitized before inserting it into food. The probe should be washed in warm water and detergent, sanitized according to the sanitizer instructions or the instructions that thermometer accompanies, and the probe should be allowed to air dry or thoroughly dried with a disposable towel.

For further details, refer [D-3(50)].

13.2.2 *Typical Design Inputs for a Standard Cold Room*

The criteria involved in designing a cold room are similar to any warehouse, that is, storage capacity, facilities for receiving and dispatching goods, interior operating space, location of cold room, selection and location of refrigeration units. While designing cold room, the difference between room temperature and product temperature should be kept at a minimum value.

13.2.3 *Heat Loads*

Refrigeration load includes:

a) Transmission load, which is heat transferred into the refrigerated space through its surfaces;

b) Product load, which is heat removed from and produced by products when these are brought into and kept in the refrigerated space;

c) Internal load, which is heat produced by internal sources (for example, lights, electric motors, defrost mechanism and people working in the space);

d) Infiltration air load, which is heat gain associated with air entering the refrigerated space; and

e) Equipment related load. For example, Air-cooling unit fan motors, fork lifts, etc.

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The first four segments of load constitute the net heat load for which a refrigeration system is to be provided; the fifth segment consists of all heat gains created by the refrigerating equipment itself. Thus, net heat load plus equipment heat load is the total refrigeration load.

While other loads are quite similar to loads in regular HVAC system design, the product load includes the primary refrigeration loads from products brought into and kept in the refrigerated space, which includes:

a) Heat that shall be removed to bring products to storage temperature. In case of some produces the rate of cooling for the freshly cooled products shall be considered, as per recommended cool down period.

b) Heat generated by produces in storage such as respiration loads, mainly from fruits and vegetables.

In addition, another new aspect in heat load is the heat from defrosting where the refrigeration coil operates at a temperature below freezing and shall be defrosted periodically, regardless of the room temperature. In order to avoid system oversizing, and to take full advantage of load diversity, hour-by-hour load calculation or simulation method should be used.

13.2.4 *Considerations for Cold Room Selection*

The conditions within a closed refrigerated chamber shall be maintained to preserve the stored product. This refers particularly to seasonal, short shelf life, and long-term storage.

The four major concerns for product compatibility are temperature, moisture, ethylene, CO_2 and odour. Specific considerations include:

a) Uniform temperatures as much as possible in empty condition as well as with product loaded condition;

b) Length of air blow and impingement on stored product;

c) Effect of relative humidity;

d) Effect of air movement on employees working in cold store;

e) Controlled ventilation, if necessary;

f) Product entering temperature;

g) Expected duration of storage;

h) Required product shipping temperature when leaving cold store;

j) Traffic in and out of storage area;

k) Design of storage bins; and

m) Size of food product (L × W × H) or volume.

Rack systems are mostly related to retail store refrigeration and are not considered as part of building system.

13.2.5 *Installation and Maintenance of Cold Room*

All panels for thermal insulation of cold storage shall be as per the accepted standard [D-3(28)].

Refrigeration system has to be selected for a particular application based on a particular refrigerant keeping in mind environmental issues. Thus, the refrigerant shall be a natural refrigerant like ammonia, carbon dioxide, hydrocarbons, or synthetic refrigerants, with very low GWP. System shall have either a) unitary system or b) DX systems or c) integrated single or d) two-stage system depending on the application temperature. The entire design has to be done as per proper standards.

Refrigeration system shall be assembled as per proper specifications to ensure that no refrigerant leakage. It should have proper emergency measures in case of any accidental leaks. The building structure shall be designed

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with adequate safety factors and the thermal insulation has to be protected properly from any possible occurrence of fire. Emergency alarms should be provided in the cold store with switches in each chamber.

Safety is critical in the design, construction and operation of refrigeration systems for cold storage, especially with ammonia systems. Refrigeration system's safety standards shall meet requirements relating to safe design, construction, installation, and operation of refrigeration systems by establishing safeguards for life, limb, heath and property as per the applicable safety standards. This includes, but is not limited to, occupancy classification, restriction on refrigerant use, installation restrictions, design and construction of equipment and systems, and operation and testing. Equipment selection and their placement should be such so as to ensure safe and easy maintenance. A safety review of the engineered design and equipment layout is recommended with participation from the owner's site operations and maintenance (O&M) team. Personnel safety measures are required as part of the facility design. The designer should prepare a system safety plan with full hazard analysis.

13.2.6 *Cold Room Safety*

The cold temperatures inside a low temperature cold room shall cause increase in blood viscosity and risk to life unless proper precautions are taken. An audio alarm should be installed outside the cold room, powered through a UPS and the switch should be fixed prominently and within reach, inside the cold room. This will help any person trapped inside to alert those outside, for help.

The following safety provisions should be kept/taken care of, at the cold room site:

a) Firefighting equipment;

b) Safe handling of refrigerant leaks;

c) Safety devices, controls and alarm systems;

d) Emergency lighting in the cold chambers;

e) Lightning arrestor;

f) First aid kit;

g) Air filters/breathers;

h) Emergency assembly points;

j) Regular safety drills and training;

k) Water shower in ammonia plants; and

m) Avoiding ramps as they become slippery when wet or frozen.

13.2.6.1 *Precautions against getting trapped in freezing room*

In order to facilitate getting out of a person who may accidentally get locked in a cold room, emergency exits shall be provided. These shall have facility to be opened from inside, even when they are locked from the outside. In all cases, following shall be installed in the freezing room:

a) Doors which shall open manually both from the inside and the outside (for functioning during power shortages, etc). In case of rooms with large dimensions say more than 25 m, it is advisable to provide emergency doors with UPS/battery lit exit sign at both ends of the freezing room for easy exit;

b) A signage system outside the freezing room with a steady or blinking light, and a siren or buzzer, activated from the inside by pressing a UPS-lit button. This button should also be connected to the caretaker's apartment, where a monitoring board shows where the button has been pressed. These visible and audible alarms should always be connected to a self-contained electric circuit, operated with a permanently charged battery. The same circuit should also connect to an independent, battery-operated emergency lighting system or a phosphorescent signalling system, all the way to the nearest emergency exit from the area; and

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c) Electric or pneumatic sliding or manual doors, capable of being operated both from outside and inside by push button or pull cords, easily accessible, in case of large freezing rooms, to the persons inside/outside.

13.2.6.2 *Precautions against refrigerant leaks*

Safety measures shall be taken against leak of liquid or gaseous refrigerant. Consideration should also be given to installing gas detectors and shut-off valves. The safety of the people should be considered by installing in traffic and public areas with which the refrigerant supply shall be cut long before the refrigerant concentration reaches the level which would affect the people or the stored products. The gaskets around the cold storage door should be periodically inspected and corrected for any damage.

In refrigeration applications with ammonia (if used) as per standard practice, there is a risk of a high concentration accumulating in an enclosed room. With 15 percent to 28 percent by volume, and an ignition source (of 582 °C), it is possible to create a fast-burning process which could be something like an explosion. So, a rapid dilution/containment system or an expulsion system that is emergency ventilation should be installed as per relevant standards.

Self-contained breathing apparatuses and protective clothing for entering a building with a concentration of ammonia greater than 50 ppm. Ammonia clouds shall be neutralized with dry ice (CO_2) or transformed by fog nozzle, but there is then a risk of water pollution. For safety requirements for cold stores as also for refrigerant gas related safety, relevant standards shall be followed.

13.2.7 *Cold Room in Various Segments and Requirements*

The recommended temperature ranges for various applications/product categories to be stored in modular cold rooms are given below (temperature range is to be finally decided based on the product intended to be stored):

Sl No.	*Application/Product Category*	*Recommended Temperature Range*
(1)	(2)	(3)
i)	Horticulture (fruits and vegetables)	+ 2 ºC to + 8 ºC
ii)	Floriculture	+ 2 ºC to + 6 ºC
iii)	Hotels, restaurants, fast food chains	+ 2 ºC to + 6 ºC
iv)	Pharmaceuticals	+ 8 ºC to – 25 ºC
v)	Dairy	+ 4 ºC to – 25 ºC
vi)	Ice cream	– 20 ºC to – 25 ºC
vii)	Ripening	+ 12 ºC to + 20 ºC
viii)	Controlled Atmosphere	+ 1 ºC to + 3 ºC

The above temperature ranges are indicative only, and may tend to vary, based on specific application requirements and other conditions. The relative humidity in most of the cases are above 85 percent to 90 percent range except pharmaceuticals, seeds, dry products and frozen products, or as required for a specific case by the user.

13.2.8 *Refrigeration Technologies for Cold Storage*

The prime considerations for selection should be life cycle cost, ease of maintenance and controls. Designers may select unitary or centralized systems that comprise unitary off the shelf products, DX units, centralized refrigeration system - air cooled or water-cooled.

13.2.9 *Ammonia Refrigeration System*

Ammonia is one of the most efficient applications, with the application range from high to low temperatures. With the ever-increasing focus on energy consumption, ammonia systems are a safe and sustainable choice for the future.

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Ammonia is the most environmentally friendly refrigerant. It belongs to the group of so called "natural" refrigerants, and it has both global warming potential (GWP) and ozone depletion potential (ODP) equal to zero.

Ammonia is a toxic refrigerant, and it is also flammable at certain concentrations. That is why it has to be handled with care, and all ammonia systems have to be designed with safety in mind. At the same time, unlike most other refrigerants, it has a characteristic odour that shall be detected by humans even at very low concentrations. That gives a warning sign even in case of minor ammonia leakages. In case it is necessary to reduce ammonia charge, combination of ammonia and CO_2 (as cascade or as brine) could be a good and efficient option. For ammonia refrigeration system, good practice [D-3(29)] to be referred.

13.2.10 *Freon Refrigeration System*

The refrigeration system shall be unitary and centralised systems. Condenser cooling may be either water-cooled and air-cooled.

13.3 Supermarket Refrigeration

Supermarket refrigeration systems include various types of equipment and condensing units designed for both remote and direct applications. The further clauses cover the different systems and components used in supermarket refrigeration.

13.3.1 *Type of Supermarket Refrigeration Equipment*

The following types of refrigeration equipment are commonly used in supermarkets, offering various configurations such as remote and plug-in systems:

a) Open multideck chillers, with remote refrigeration system;

b) Glass door upright freezers and chillers with remote refrigeration system;

c) Display cold room (Wall replaced with glass doors);

d) Plug and play solutions;

e) Serve-over counters, plug-in type;

f) Self-service counters, plug-in type;

g) Stainless steel fish counters, plug-in type;

h) Plug-in island freezers;

j) Visi-coolers – plug-in type;

k) Visi-freezers – plug-in type;

m) Confectionery displays or cake showcase;

n) Four-sided visi-tower;

p) Four-sided visi-frozen tower/visi freezer; and

q) Glass top freezers with sliding glass (plug-in type).

13.3.2 *Remote Condensing Units for Remote Application*

Various types of condensing units are listed and explained below:

a) *Rack system for supermarkets* — The multi-compressor rack system comes with various types of reciprocating, scroll, or screw compressors. It should be compact, solidly built, and enhance performance with minimal pipe work. Also, the addition of an inverter in the rack enhances its efficiency and increases the life of the system;

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b) *Individual condensing units* — Glass-door cold rooms, supermarket open or closed-door chillers and freezers shall be connected with a variety of condensing units. Their selection is based on cold room size, temperature and usage. The selection of these units is critical and should be verified ahead of installation.

Various types of Compressors are used in the condensing units as listed below:

1) *Air cooled systems* — These are generally for small to industrial applications, excessive pipe run or vertical lift distances and speciality blast chilling and freezing applications. They are highly efficient and perform tirelessly; and

2) *Water cooled systems* — These are generally for medium to industrial applications, these types of units are very effective in malls, where units are required to be installed in the basement or in a hidden area, were fresh air and exhaust facilities in not available. These are also suitable for chilling and freezing applications. They are highly efficient but need treated water and regular maintenance.

See accepted standard [D-3(7)] for more details.

13.4 Data Centre

13.4.1 *Location*

a) *Seismic considerations*:

1) *Seismic zone mapping* — Consult the latest seismic zone map of India {*see* accepted standard [D- 3(30)]} to accurately assess the risk level of the proposed location; and

2) *Structural design* — Engage qualified structural engineers experienced in seismic design for data centres. Adhere to the latest codes and standards, incorporating base isolation or energy dissipation systems if necessary.

b) *Proximity to utilities*:

1) *Power grid stability* — Evaluate the historical reliability and voltage stability of the local power grid. Prioritize locations with minimal outages and voltage fluctuations;

2) *Redundant power sources* — Having access to two independent power feeds from different substations for enhanced reliability;

3) *Water availability* — Assess water availability throughout the year, accounting for seasonal variations. Consider water recycling and rainwater harvesting to reduce dependency on municipal supply; and

4) *Distance to utilities* — Minimize the distance between the data centre and power/water sources to reduce transmission losses and infrastructure costs.

c) *Connectivity*:

1) *Carrier diversity* — Ensure access to at least two diverse fibre paths from different carriers to avoid single points of failure;

2) *Latency* — Consider the proximity to major internet exchange points (IXPs) and content delivery networks (CDNs) for low latency connections; and

3) *Future expansion* — Plan for future connectivity needs by choosing locations with ample capacity for additional fiber optic cables.

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d) *Environmental factors*:

Flood risk — Refer to flood zone maps and avoid areas prone to flooding. If unavoidable, implement appropriate flood mitigation measures (elevated platforms, watertight barriers):

1) *Cyclone and wind risk* — Consider the historical cyclone tracks and wind speeds in the region. Design the building to withstand wind loads as per local codes;

2) *Air quality* — Analyse the ambient air quality data to understand the levels of particulate matter (PM), dust, and other pollutants. Employ high-efficiency air filtration systems to protect sensitive equipment if required;

3) *Electromagnetic interference (EMI)* — Evaluate potential sources of EMI (power lines, radio towers, etc.) and implement shielding if necessary; and

4) *Environmental clearances* — Understand and comply with all environmental impact assessment (EIA) and pollution control norms relevant to data center construction and operation.

e) *Temperature and humidity*:

1) *Climate zone analysis* — Refer to India's climatic zone map (as per Part D 'Building Services, Section 1 Lightning and Ventilation' of this NBCS) to identify regions with favourable temperature and humidity profiles for data centre operations;

2) *Microclimate considerations* — Within a climatic zone, local variations shall exist. Investigate microclimates around the proposed site, accounting for factors like proximity to water bodies, elevation, and prevailing wind patterns;

3) *Historical weather data* — Analyze at least 10 years of historical temperature and humidity data for the location. Pay close attention to peak summer temperatures and humidity levels, which will drive cooling requirements;

4) *Wet-bulb temperature* — Evaluate wet-bulb temperature data as a critical indicator of evaporative cooling potential. Higher wet-bulb temperatures limit the effectiveness of evaporative cooling technologies;

5) *Climate change projections* — Consult climate change models and projections for the region to anticipate future shifts in temperature and humidity patterns. Factor these projections into long-term planning and design; and

6) *Adaptive cooling strategies* — Explore the potential for free cooling or hybrid cooling systems that shall leverage favourable ambient conditions to reduce energy consumption.

f) *Accessibility and logistics*:

1) *Transportation infrastructure* — Evaluate the quality and capacity of road networks, proximity to airports/railway stations, and availability of reliable freight transport for equipment delivery and maintenance;

2) *Manpower access* — Consider the ease of commute for staff and the availability of skilled IT professionals in the region. Plan to be in vicinity of a public transport infrastructure or provide common shuttle service; and

3) *Expansion space* — Ensure sufficient space for future expansion of the facility or campus, including considerations for power and network infrastructure upgrades.

g) *Security and risk mitigation*:

1) *Physical security* — Evaluate the overall security environment of the location, including crime rates and potential threats. Implement robust physical security measures for the data centre premises;

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2) *Cybersecurity* — Consider the proximity to potential cybersecurity risks and implement stringent network security protocols to protect data; and

3) *Disaster recovery* — Develop a comprehensive disaster recovery plan that considers natural disasters, power outages, and other disruptions.

13.4.2 *Redundancy for Cooling Infrastructure*

a) *Chillers*:

1) Implement N+1 redundancy for chillers, ensuring that the remaining chillers shall handle the full cooling load even if one unit fails. Consider 2N redundancy for critical facilities or those in hot climates;

2) Size chillers based on peak cooling load with a safety margin to accommodate future expansion or equipment upgrades; and

3) Implement preventive maintenance schedules and conduct regular inspections to ensure optimal performance and reliability.

b) *Precision air handling units* (*PAHUs*):

1) Deploy N+1 redundancy for PAHUs, ensuring sufficient airflow even if one unit is offline for maintenance or repair;

2) Consider zoning the data center and assigning dedicated PAHUs to each zone for better control and redundancy; and

3) Equip PAHUs with variable speed drives (VSDs) to optimize airflow based on real-time cooling demands, improving energy efficiency.

c) *Power distribution for cooling*:

1) Provide redundant power feeds (A+B) to critical cooling equipment, including chillers, PAHUs, and pumps;

2) Utilize dedicated PDUs for cooling infrastructure with branch circuit monitoring to track power consumption and identify potential issues; and

3) Implement emergency power off (EPO) functionality to safely shut down cooling systems in emergencies.

d) *Additional considerations for cooling redundancy*:

1) If the climate permits, explore the use of free cooling (air-side or water-side economizers) to reduce reliance on mechanical cooling and improve energy efficiency;

2) Design chilled water and condenser water piping systems with redundancy to prevent single points of failure and ensure continuous circulation;

3) Implement N+1 redundancy for cooling towers or consider alternative cooling technologies like dry coolers or adiabatic coolers for water-scarce regions; and

4) Deploy redundant chilled water and condenser water pumps with automatic switchover capabilities in case of a pump failure.

13.4.3 *Water Leak Detection* (*WLD*)

a) *Comprehensive coverage* — Install a water leak detection system with adequate coverage in all areas prone to leaks, such as under raised floors, near cooling systems, piping, and water entry points. Tailor the coverage to the specific layout and potential risks of each data centre;

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b) *Sensor types* — Utilize a combination of sensor technologies to ensure comprehensive detection:

1) *Spot Sensors* — Rope sensors or point sensors for localized detection in critical areas like under racks and near equipment; and

2) *Zone sensors* — For broader coverage in areas like underfloor plenums or around piping systems.

c) *Sensitivity and response time*

1) *Sensor selection* — Choose sensors with high sensitivity and rapid response times to enable early detection and minimize potential damage;

2) *Calibration* — Regularly calibrate sensors and adjust sensitivity levels based on environmental conditions and potential risk factors;

3) Alarms and Notifications;

4) *On-site alerts* — Implement visual and audible alarms within the data centre to immediately notify onsite personnel of a leak; and

5) *Remote Notifications* — Utilize remote notifications via email, SMS, or dedicated monitoring systems to alert responsible personnel even when they are off-site.

d) *BMS integration*

1) *Centralized monitoring* — Integrate the WLD system with the BMS for centralized monitoring and control, enabling real-time visualization of leak locations and status; and

2) *Automated responses* — Configure the BMS to trigger automated responses to leaks, such as shutting off water valves or activating backup systems.

13.4.3.1 A few additional considerations to be taken are:

a) *Regular testing and maintenance* — Conduct periodic testing and maintenance of the WLD system, including sensor checks, cleaning, and calibration;

b) *Documentation* — Maintain detailed documentation of the WLD system, including sensor locations, alarm thresholds, and maintenance records; and

c) *Emergency response procedures* — Develop and regularly review clear emergency response procedures for water leaks, ensuring staff are trained and prepared to act swiftly to mitigate damage

13.4.4 *Inside Acceptable Temperature and RH Condition*

a) *Temperature*:

1) Maintain a temperature range between 18 °C to 27 °C for optimal performance and longevity of IT equipment;

2) Consider higher temperature setpoints (closer to 27 °C) where possible to improve energy efficiency, ensuring equipment compatibility; and

3) Minimize temperature fluctuations and avoid hot spots or cold spots through effective airflow management and cooling strategies.

b) *Relative humidity* (*RH*):

1) Keep RH within the range of 8 percent to 60 percent to prevent condensation on equipment and electrostatic discharge (ESD) that shall cause damage;

NOTE — The upper limit may be lower (50 percent or even 35 percent) depending on the presence of specific corrosive gases in the environment.

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2) Monitor dew point temperature and ensure a safe margin between the dew point and the lowest surface temperature in the data centre; and

3) Employ humidification or dehumidification systems as needed to maintain RH within the desired range, especially in regions with fluctuating humidity levels.

c) *Monitoring and control*:

1) *Real-time visibility* — Implement a monitoring system that provides real-time visibility into all critical infrastructure components, including power, cooling, security, and environmental conditions.

2) *Data granularity* — Capture and store granular data at frequent intervals to enable in-depth analysis and trend identification.

3) *Multi-protocol support* — Ensure compatibility with various communication protocols (SNMP, Modbus, BACnet) for seamless integration of diverse equipment and systems.

4) *Centralized management*:

i) *Unified platform* — Deploy a centralized management platform (BMS, DCIM) to aggregate data from all monitored systems, enabling holistic oversight and control of the data center environment;

ii) *Remote access* — Provide secure remote access to the management platform, empowering authorized personnel to monitor and manage the data center from anywhere, anytime; and

iii) *User-friendly interface* — Choose a platform with an intuitive and user-friendly interface for easy navigation and efficient operation.

5) *Advanced analytics*:

i) *Predictive analytics* — Leverage AI-powered analytics to analyze historical and real-time data, enabling predictive maintenance, anomaly detection, and optimization of resource utilization;

ii) *Machine learning* — Utilize machine learning algorithms to learn from data patterns and proactively identify potential issues or inefficiencies; and

iii) *Data visualization* — Employ data visualization tools to present complex information in a clear and concise manner, facilitating decision-making and troubleshooting.

6) *Automated control*:

i) *Threshold-based actions* — Configure the system to trigger automated actions based on predefined thresholds or events, such as adjusting cooling setpoints, initiating failover procedures, or sending notifications; and

ii) *Workflow automation* — Streamline routine tasks through workflow automation, reducing manual intervention and human error.

7) *Alarms and notifications*:

i) *Prioritized alerts* — Implement a multi-tiered alarm system to prioritize critical events and ensure prompt attention to potential issues;

ii) *Multiple notification channels* — Utilize multiple communication channels (email, SMS, phone calls, mobile app) to ensure timely notifications reach relevant personnel; and

iii) *Escalation procedures* — Define clear escalation procedures for critical alarms to ensure swift and appropriate action.

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8) *Additional Recommendations*:

i) *Cybersecurity* — Implement robust cybersecurity measures to protect the monitoring and control systems from unauthorized access and potential threats;

ii) *Data retention and analysis* — Retain historical monitoring data for long-term analysis and trend identification, aiding in capacity planning and optimization efforts; and

iii) *Training and skill development* — Provide comprehensive training to data center staff on the use and management of monitoring and control systems.

13.4.5 *Air Distribution Pattern with Positive Pressure*

a) *Hot/Cold aisle containment*:

1) *Mandatory implementation* — Implement hot/cold aisle containment systems for all data centers to ensure efficient cooling and prevent hot air recirculation;

2) *Containment types* — Choose between physical barriers (for example, aisle doors, curtains, or rigid panels) or chimney rack systems based on space constraints, future flexibility requirements, and desired level of containment efficiency; and

3) *Bypass airflow control* — Minimize bypass airflow (air leakage around containment systems) to the lowest achievable level, ideally below 5 percent. Employ blanking panels, brush strips, and proper sealing to achieve optimal containment.

b) *Positive pressure*:

1) *Pressure differential* — Maintain a slight positive pressure differential of 2.5 Pa to 5 Pa between the data centre and surrounding areas. This effectively prevents dust, pollutants, and other contaminants from entering the data centre;

2) *Airlock systems* — Implement airlock systems at all entrances to further enhance pressure control and minimize air infiltration during door openings; and

3) *Pressure monitoring* — Continuously monitor pressure differentials using differential pressure sensors and integrate them with the BMS for automated control and alarms in case of deviations.

c) *Computational fluid dynamics (CFD) analysis*:

1) *Design optimization* — Utilize CFD modelling during the design phase to comprehensively optimize airflow patterns, identify potential hot spots, and ensure adequate cooling for all equipment under various operating scenarios; and

2) *Validation and troubleshooting* — Use CFD analysis to validate the effectiveness of the implemented containment and airflow management strategies. It shall also aid in troubleshooting cooling issues and optimizing airflow distribution as the data centre evolves and equipment densities change.

13.4.5.1 Following are some additional considerations to be taken for airflow management:

a) *Raised floor plenum* — Design the raised floor plenum with appropriate airflow tiles and perforated tiles strategically placed to distribute cold air efficiently to IT equipment intakes;

b) *Cable management* — Implement meticulous cable management within racks and under raised floors to avoid airflow obstructions and maximize cooling efficiency; and

c) *Equipment placement* — Consider the airflow requirements of different equipment types during rack layout and placement within the data centre to ensure optimal cooling for all components.

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13.4.6 *Commissioning and Retrofitting Guidelines for Data Centres*

a) *General principles*:

1) *Adherence to standards* — Follow the commissioning process and relevant industry standards for commissioning and retrofitting processes;

2) *Documentation* — Maintain thorough documentation throughout the project, including design intent, test plans, procedures, and results;

3) *Independent commissioning agent* (*CxA*) — Engage a qualified and independent CxA to oversee the commissioning or retrofitting process. The CxA should be involved from the early design stages to ensure that the project meets its intended performance and efficiency goals; and

4) *Collaboration and communication* — Foster effective collaboration and communication among all stakeholders, including the owner, design team, contractors, and CxA.

b) *Commissioning phases*:

1) *Factory acceptance testing* (*FAT*):

i) *Purpose* — Verify that equipment and systems meet specified requirements before shipment to the site;

ii) *Scope* — Conduct functional and performance tests on major equipment (for example, chillers, UPS systems, generators, PAHUs) at the manufacturer's facility; and

iii) *Documentation* — Document test procedures, results, and any identified issues for resolution before shipment.

2) *Site acceptance testing (SAT)*:

i) *Purpose* — Verify that installed equipment and systems function correctly and meet performance specifications on-site;

ii) *Scope* — Conduct comprehensive testing of individual systems and components (electrical, mechanical, controls, fire protection) after installation but before integration; and

iii) *Documentation* — Document test procedures, results, and any deficiencies for rectification before proceeding to the next phase.

3) *Integrated system testing* (*IST*):

i) *Purpose* — Verify the proper interaction and performance of all systems and components as an integrated whole under various operating conditions;

ii) *Scope* — Conduct tests under normal, peak load, and simulated failure scenarios to assess system redundancy, failover capabilities, and overall performance; and

iii) *Documentation* – Document test procedures, results, and any identified issues for resolution before final handover.

13.4.6.1 *Specific guidelines for retrofitting*

a) *Thorough assessment* — Conduct a detailed assessment of the existing data centre infrastructure, including its current performance, energy efficiency, capacity limitations, and potential risks;

b) *Clear objectives* — Define clear objectives for the retrofitting project, focusing on areas such as energy efficiency improvements, capacity upgrades, reliability enhancement, or technology modernization;

c) *Phased approach* — Consider a phased approach to minimize disruption to ongoing operations, allowing for gradual implementation and testing of new systems while maintaining service continuity;

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d) *Compatibility and integration* — Ensure that new equipment and systems are compatible with existing infrastructure and shall be seamlessly integrated into the current environment; and

e) *Thorough testing* — Conduct rigorous testing of all retrofitted systems and components, both individually and in an integrated manner, to validate performance and ensure compliance with design intent.

13.4.6.2 A few additional recommendations for retrofitting are:

a) *Energy efficiency focus* — Prioritize energy-efficient technologies and design strategies during commissioning and retrofitting to reduce operational costs and environmental impact;

b) *Monitoring and control* — Implement comprehensive monitoring and control systems to enable real-time visibility, proactive management, and optimization of data centre performance; and

c) *Documentation and training* — Provide detailed documentation and training to data centre staff on the operation and maintenance of new or retrofitted systems.

13.4.7 *Electrical Safety*

a) *Earthing and bonding* — Effective earthing and bonding are crucial for personnel safety and equipment protection:

1) *Earth resistance* — Achieve low earth resistance as per good practice [D-3(31)] for effective fault current dissipation. The specific requirements depend on voltage levels and earthing methods. Use multiple earth electrodes and ground enhancement techniques if needed. Regularly test and inspect the earthing system;

2) *Automatic disconnection of supply* — Fault loop impedance of every circuit shall be lower enough to ensure automatic disconnection of supply as per good practice [D-3(31)]. If fault loop impedance is higher than the requirement of OCPD, RCDs shall be used. For equipment with 1 phase VFD's Type F RCD shall be used and for equipment with 3 phase VFD's Type B RCDs shall be used;

3) *Bonding* — Ensure proper bonding of all conductive elements to create an equipotential environment and prevent electrical hazards. Use low-impedance bonding conductors and regularly inspect connections;

4) *Lightning protection* — Protect your data centre from lightning strikes with a robust system complying with accepted standard [D-3(32)]. The LPS should include air terminals, down conductors, and earth termination networks. Install surge protection devices (SPDs) to safeguard sensitive equipment and ensure effective equipotential bonding for shielding effectiveness; and

5) *Water pipes* — Avoid using water pipes as earth electrodes. Use of multiple earth electrodes are in violation to the recommendation of good practice [D-3(31)] and shall be avoided.

b) *Circuit protection* — Prevent overcurrent's and short circuits with appropriate circuit protection devices:

1) *Circuit breakers and fuses* — Install appropriate circuit protection devices (MCBs, MCCBs, fuses) with suitable ratings to protect against overloads and short circuits;

2) *Selective coordination* — Ensure selective coordination of devices to minimize disruptions caused by faults; and

3) *Arc flash protection* — Conduct an arc flash hazard analysis and implement appropriate protective measures including appropriate personal protective equipment (PPE) and arc-resistant switchgear (for example, arc-resistant switchgear, personal protective equipment) to safeguard personnel from arc flash incidents.

c) *Regular inspections* — Regular inspections are vital for identifying and addressing potential hazards.

1) *Scheduled inspections* — Conduct comprehensive inspections at least annually. Depending on the criticality of the equipment;

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2) *Thermography* — Utilize thermography to identify hotspots and potential issues; and

3) *Corrective actions* — Address any identified deficiencies or potential hazards promptly to maintain a safe electrical environment.

13.4.7.1 Some of the additional considerations to be taken for electrical safety are:

a) *Design and installation* — Engage qualified professionals for design and installation with accepted standards [D-3(33)] and [D-3(34)] and the National Building Construction Standards;

b) *Power quality* — Monitor and maintain power quality parameters (voltage, current, harmonics) within acceptable limits;

c) *Emergency power off (EPO)* — Implement EPO systems for critical areas; and

d) *Training and awareness* — Provide regular electrical safety training to staff, including arc flash safety and lockout/tagout procedures.

13.4.8 *Periodic Maintenance/Predictive Maintenance*

a) *Periodic maintenance*:

1) *Comprehensive schedule* — Develop and adhere to a comprehensive preventive maintenance schedule for all critical equipment, including:

i) *Electrical systems* — UPS, generators, switchgear, PDUs;

ii) *Mechanical systems* — Chillers, cooling towers, pumps, CRAC/CRAH units;

iii) *Fire suppression systems* — Sprinklers, gas suppression systems, fire alarm panels; and

iv) *IT equipment* — Servers, storage arrays, network switches.

2) *Frequency* — Base the maintenance frequency on manufacturer recommendations, equipment criticality, and operating conditions. Generally:

i) *Quarterly or as per OEM recommendations* — CRAC/CRAH units, air filters, UPS batteries;

ii) *Semi-annually or as per OEM recommendations* — Generators, electrical switchgear; and

iii) *Annually or as per OEM recommendations* — Chillers, cooling towers, fire suppression systems.

3) *Qualified technicians* — Engage qualified and certified technicians for maintenance activities to ensure proper procedures are followed and equipment warranties are maintained.

4) *Documentation* — Maintain detailed records of all maintenance activities, including dates, tasks performed, and any observations or issues encountered.

b) *Predictive maintenance*:

1) *Sensor deployment* — Install sensors on critical equipment to monitor parameters such as vibration, temperature, humidity, current, and power quality;

2) *Data collection and analysis* — Collect and analyse sensor data using advanced analytics platforms and machine learning algorithms to identify trends, anomalies, and potential failures;

3) *Early warning system* — Set up alerts and notifications to proactively identify equipment degradation or impending failures; and

4) *Proactive maintenance* — Schedule maintenance activities based on predictive insights, minimizing unplanned downtime and optimizing equipment lifespan. Adhere to recommended maintenance intervals or as per OEM recommendations.

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c) *Thermal imaging*:

1) *Regular inspections* — Conduct periodic thermal imaging inspections of electrical connections, switchgear, and IT equipment to identify hotspots and potential overheating issues;

2) *Qualified thermographers* — Engage certified thermographers to perform inspections and interpret results; and

3) *Corrective action* — Address any identified hotspots promptly to prevent equipment damage and potential fire hazards.

13.4.8.1 Some additional considerations to be taken for maintenance are:

a) *Spare parts inventory* — Maintain an adequate inventory of critical spare parts onsite to enable quick repairs and minimize downtime;

b) *Vendor support* — Establish strong relationships with equipment vendors and leverage their expertise for troubleshooting and support;

c) *Remote monitoring* — Utilize remote monitoring and management tools to gain real-time insights into equipment health and performance; and

d) *Training* — Provide ongoing training to data centre staff on maintenance procedures and predictive maintenance tools.

13.4.8.2 The specific considerations for the Indian context are:

a) *Dust and pollution* — In regions with high dust and pollution levels, increase the frequency of air filter replacements and AHU maintenance;

b) *High temperatures and humidity* — Pay close attention to the performance and maintenance of cooling systems during peak summer months; and

c) *Power fluctuations* — Implement measures to protect equipment from power fluctuations and surges, which shall impact equipment lifespan.

13.4.9 *Design for Future Expansion and Technology*

To consider for the future expansions scalability in below dimensions to be considered:

a) *Capacity planning*:

1) Conduct a detailed capacity planning exercise, factoring in:

i) Projected IT load growth based on business forecasts and technology roadmaps;

ii) Anticipated storage requirements, including data growth rates and retention policies;

iii) Network bandwidth demands considering increasing traffic and application needs; and

iv) Time horizon for expansion planning (typically 5 years to 10 years).

2) Utilize industry-standard tools and methodologies for capacity planning, such as data centre infrastructure management (DCIM) software and power/cooling modelling.

b) *White space and power provisioning*:

1) Design the data centre with adequate white space to accommodate future rack installations and expansions:

i) Consider factors like anticipated growth rate, rack densities, and desired aisle widths; and

ii) Leave room for future power and cooling distribution infrastructure.

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2) Provision power capacity based on projected IT load growth and power densities:

i) Factor in the power requirements of new technologies and potential increases in rack densities; and

ii) Account for inefficiencies in power distribution and cooling systems.

c) *Modular power and cooling*:

1) Implement modular UPS systems, PDUs, and cooling units that shall be easily scaled up as IT load increases. This allows for incremental expansion and avoids upfront overinvestment; and

2) Consider using modular power skids and containerized cooling solutions for flexibility and rapid deployment.

d) *Network infrastructure*:

1) Design a flexible and scalable network architecture with ample capacity for future bandwidth requirements:

i) Evaluate the need for higher-speed network technologies to accommodate future demands.

2) Deploy high-density fiber optic cabling and modular network switches to facilitate seamless upgrades and expansions.

14 VENTILATION SYSTEMS

Ventilation is the process of changing air in an enclosed space. A portion of the air in the space shall be continuously withdrawn and replaced by fresh air drawn from outside to maintain the required level of air purity, health, comfort and safety of building occupants.

Ventilation shall be done either by mechanical systems or through natural means. Mechanical ventilation usually consists of fans, filters {accepted standards [D-3(15)], [D-3(16)], [D-3(17)] and [D-3(18)]}, ducts, air diffusers and outlets for air distribution within the building. Natural ventilation and natural exhaust are covered in Part D 'Building Services, Section 1 Lighting and Ventilation' of this NBCS. The scope is therefore restricted to mechanical ventilation.

14.1 Types of Fans

Fans are broadly categorised as:

a) Axial fan; and

b) Centrifugal.

In axial fans, the direction of air flow is parallel to the fan's axis of rotation and in centrifugal fans, this direction is perpendicular. Each category encompasses further designs for example in centrifugal – forward curved, backward curved/inclined, aerofoil fans, plug/plenum fans and in axial – tube axial, vane axial and propellers. Fans have also been classified in terms of their application and special design for example roof ventilator, inline fan, jet fan, spark resistant fan, fume extract fan to name a few. These types may be available in both centrifugal and axial designs.

Recent advances in fan technology have led to the development of mixed-flow fans. These fans combine the high-pressure capability of centrifugal fans with the high flow rate of axial fans.

14.1.1 *Application*

Table 34 provides a general guideline on selecting the type of a fan for a given application, for example for kitchen exhaust, a backward curved centrifugal fan, for basement smoke ventilation, a high temperature rated fan and for laboratory ventilation, a fume extract fan.

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Table 34 General Guideline for Fan Type and its Application

(*Clause* 14.1.1)

Sl No.	General Fan Selection Guide	Double Inlet Centrifugal			Single Inlet Centrifugal			Plenum	Tube Axial	Vane Axial	Propeller	Mixed Flow	Tubular Centrifugal	Roof Ventilator	Spark Resistant Construction	Fume Extract Fan	Jet Fan	Powerless Roof Ventilator	High Volume Low Speed (HVLS)
	Application	FC	BC/ BI	AF	FC	BC/ BI	AF												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
i)	Air handling units - static less than 70 mm	X	X	X				X											
ii)	Air handling unit - static above 70 mm		X	X				X											
iii)	Fan filter units	X	X	X				X											
iv)	Cabinet fans	X	X	X				X											
v)	Basement ventilation-supply fans	X	X	X				X	X	X									
vi)	Basement ventilation-exhaust fans		X			X			X	X		X							
vii)	Ductless basement ventilation																X		
viii)	Kitchen exhaust					X	X	X	X										
ix)	Smoke extraction		X			X		X	X	X		X		X					
x)	Chemical fume extraction								X	X						X			
xi)	Wall mounted exhaust								X	X	X								
xii)	Roof exhaust													X				X	

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Table 34 (*Concluded*)

Sl No.	General Fan Selection Guide	Double Inlet Centrifugal			Single Inlet Centrifugal			Plenum	Tube Axial	Vane Axial	Propeller	Mixed Flow	Tubular Centrifugal	Roof Ventilator	Spark Resistant Construction	Fume Extract Fan	Jet Fan	Powerless Roof Ventilator	High Volume Low Speed (HVLS)
	Application	FC	BC/ BI	AF	FC	BC/ BI	AF												
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
xiii)	Toilet exhaust (Ducted)											X	X						
xiv)	Toilet exhaust (Unducted)										X			X					
xv)	Ventilation of explosive environment														X				
xvi)	Ventilation of nuclear facilities		X	X				X	X										
xvii)	Ventilation of dusty environment		X			X		X	X										
xviii)	Tunnel ventilation								X	X							X		
xix)	Large volume recirculation																		X

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14.1.2 Selection and Operation

A fan consumes most of the energy in a mechanical ventilation system. To meet a given requirement of air flow rate and system pressure drop, the primary fan selection criterion shall be the overall fan system power consumption and efficiency, that is by the fan, the drive train, the motor and any electric controller such as a variable frequency drive (VFD). This is shown schematically in Fig. 9.

The fan energy index (FEI) is a measure of the overall fan system efficiency and relates the electric power input to the fan motor (or to the motor drive) with the aerodynamic power imparted to the air by the fan (for additional information special publication may be referred). FEI is an index (ratio) that compares the overall energy performance of the selected fan to that of a reference fan. The reference fan is a conceptual fan capable of producing the required airflow and fan pressure at a specified shaft input power using a V-belt drive and a 4-pole IE3 efficiency classification electric motor. The reference fan does not include speed control. FEI of a selected fan at a desired duty point is defined as:

FEI = (Reference Fan Electrical Input Power)/(Selected Fan Electrical Input Power)

NOTE — Special publication maybe ISO12759-6 : 2024 'Efficiency Classification for Fans, Part 6 – Calculation of the Fan Energy Index'.

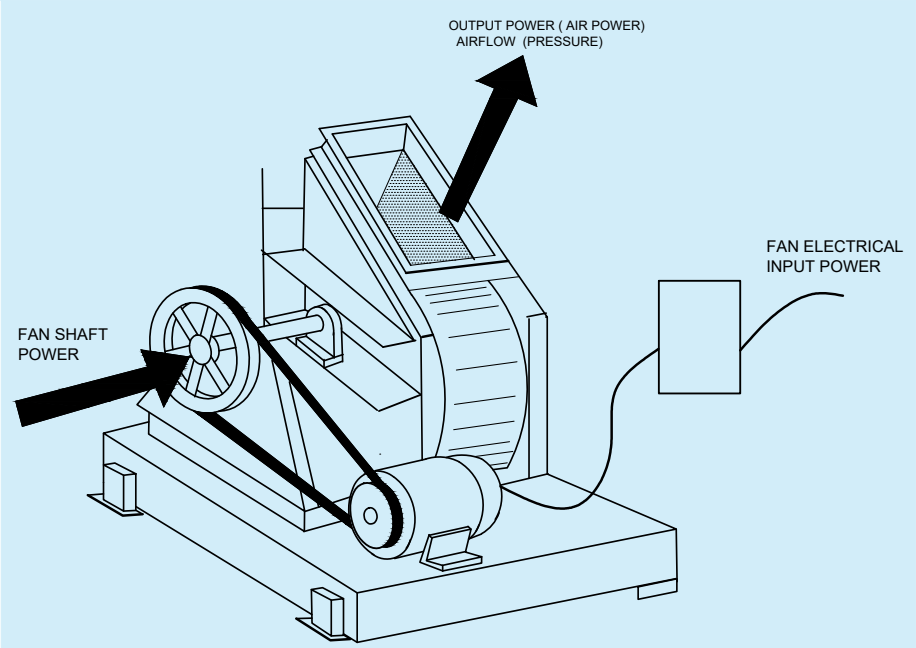

FIG. 9 FAN INPUT (ELECTRIC) POWER TO FAN OUTPUT (AIR) POWER

14.1.2.1 *Reference fan*

The Reference fan is a conceptual fan whose input power and efficiency values for a given duty point (flow rate Q and pressure P) are predefined and are used as a reference to calculate the FEI of any fan. The same reference fan is used to calculate FEI of various types of fans for a given duty point (Q, P).

Reference fan shaft power ($H_{i,ref}$) at a given duty point of flow rate Q and Pressure P is defined as:

For Ducted Outlet Fans $H_{i,ref} = (Q + 0.118) \times (P_t + 100)/660$ kW

For Free Outlet Fans $H_{i,ref} = (Q + 0.118) \times (P_s + 100)/600$ kW

where Q is in m^3/s and P_t is total pressure, P_s is static pressure, both in Pascals.

Reference transmission efficiency ($\eta_{t,ref}$) is defined as a function of reference fan shaft power $H_{i,ref}$ as:

$$\eta_{t,ref} = \frac{0.96}{[H_{i,ref}/(H_{i,ref} + 1.64)]^{0.05}}$$

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Combining fan shaft power with transmission efficiency, the Reference motor output power shall be calculated as:

$$= H_{i,ref/}\eta_{t,ref}$$

Basline motor efficiency ($\eta_{m,ref}$) shall be calculated from the Reference motor output power from the graph in Fig. 10.

By reading the value of Reference motor efficiency corresponding to the reference motor output power, the reference motor input power (or Reference fan electric power input) shall be calculated as under:

$$= H_{i,ref}/(\eta_{t,ref} \text{ x } \eta_{m,ref})$$

The reference electric power input at a given duty point is the same irrespective of fan type and shall be used to calculate the FEI for any fan selected for the given duty point.

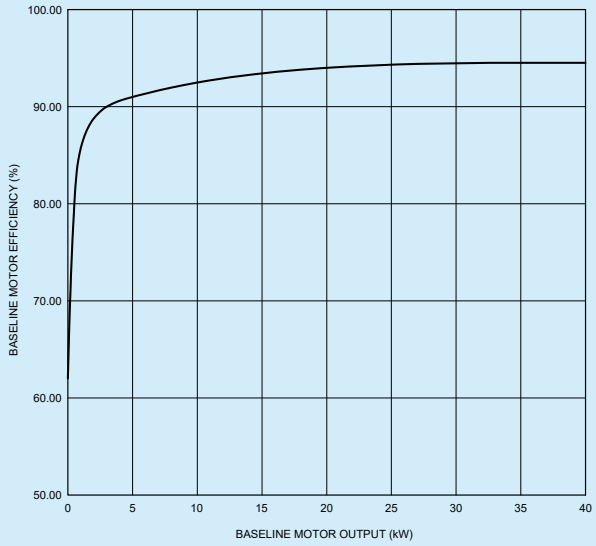

FIG. 10 MECHANICAL AND MOTOR EFFICIENCY REQUIREMENTS (MINIMUM) FOR FANS IN ECSBC BUILDINGS

14.1.2.2 *Fan selection criteria*

The following selection criterion shall be used to select fan for various type of mechanical ventilation applications for a new building:

a) For axial fans requiring a shaft power of 2.0 kW or more, its FEI shall be 1.00 or more;

b) For centrifugal fans and mixed flow fan requiring a shaft power of 2.0 kW or more, its FEI shall be 1.10 or more; and

c) The above prescribed minimum FEI values shall be applicable for all the duty points the fan is selected to operate at.

The choice of a fan type and its drive arrangement also depends on the nature of air to be handled and the type of application. If the fan has to handle dust laden or contaminated air, for example, industrial exhaust or kitchen exhaust, the fan drive arrangement (motor, pulleys, bearing and belts) shall be kept outside the air stream. The same applies to the temperature of air to be handled. For higher-than-normal air temperatures, for example in smoke ventilation, the fan shall be rated for high temperature application.

If fan noise is a concern, it shall be addressed by specifying acceptable limits of certified fan sound power ratings and not by arbitrary limits on fan speed or fan outlet velocity. Specifying fan noise in terms of fan sound pressure levels shall be discouraged.

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14.2 Industrial Ventilation

In Industrial buildings, ventilation is needed not only to provide oxygen rich fresh air normally required for health and hygiene and to mitigate against thermal loads due to equipment, people and building heat gains, but also to remove and maintain the hazardous industrial pollutants within safe limits.

14.2.1 *Ventilation for Heat Control*

The required ventilation flow rate shall be calculated both for the sensible and latent heat load. In majority of cases the sensible heat load far exceeds the latent heat load, so the design rate usually shall be calculated on the basis of sensible heat alone. The sensible heat load includes solar heat gain, occupancy, lighting load, equipment load as well as other particular sources, if any.

The ventilation flow rate shall be calculated using the following equation:

$$Q_s = 3.462 \times \frac{H_s}{\Delta T}$$

where

Q_s = air volume flow rate, in m^3/h;

H_s = sensible heat load, in kcal/h; and

ΔT = allowable temperature rise, in °C.

Ventilation system shall be designed for air to flow through the hot environment in a manner that will effectively control the excess heat.

14.2.2 *General (Dilution) Ventilation Versus Local Exhaust Ventilation*

General exhaust ventilation (dilution ventilation) is appropriate when,

a) emission sources contain materials of relatively low hazard (*see* note);

b) emission sources are primarily vapours or gases, or small, respirable size aerosols (those not likely to settle);

c) emissions occur uniformly;

d) emissions are widely dispersed;

e) moderate climatic conditions prevail;

f) heat is to be removed from the space by flushing it with outside air;

g) concentrations of vapours are to be reduced in an enclosure; and

h) portable or mobile emission sources are to be controlled.

NOTE — The degree of hazard is related to toxicity, dose rate, and individual susceptibility.

Local exhaust ventilation is appropriate when:

1) emission sources contain materials of relatively high hazard;

2) emitted materials are primarily larger diameter particulates (likely to settle);

3) emissions vary over time;

4) emission sources consist of point sources;

5) employees work in the immediate vicinity of the emission source;

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6) the plant is located in a severe climate; and

7) minimizing air turnover is necessary.

Local exhaust ventilation normally requires lower air flows than general (dilution) ventilation.

Dilution ventilation is used to reduce the concentration of vapours from a given liquid solvent in the air to a safe level known as the threshold limit value (TLV) of the solvent expressed in ppm (parts per million). For a given solvent, the volume of air required to dilute its vapour concentration to below TLV shall be calculated by the following equation:

$$\text{Air volume in m}^3 \text{ per kg of evaporation} = \frac{(24 \times 10^6 \times k)}{M \times TLV}$$

where

k = constant varying from 3 to 10 depending on the solvent, uniformity of air distribution, dilution of vapours in air and location of exhaust hood; and

M = molecular weight of the solvent.

A local exhaust ventilation system normally consists of a hood, a duct system, air cleaner, a fan and an exhaust stack. Such a system captures the contaminants at the point of generation through a properly mounted exhaust hood. The exhaust flow rate is determined from the area of the hood opening and capture velocity sufficient to prevent outward escapement of the contaminant. Table 35 lists the recommended range of capture velocity for various types of industrial contaminants.

Table 35 Recommended Capture Velocities for Industrial Contaminants

(*Clause* 14.2.2)

Sl No.	Condition of Dispersion of Contaminant	Process Example	Recommended Capture Velocity m/s
(1)	(2)	(3)	(4)
i)	Released with practically zero velocity into still air	Evaporation from pickling tank, degreasing tank	0.25 to 0.5
ii)	Released at low velocity into moderately still air	Spray booth, intermittent container filling, welding, plating, low speed conveyor transfer	0.5 to 1.0
iii)	Active generation into zone of rapid air motion	Spray painting in shallow booth, barrel filling, conveyor loading, crushers	1.0 to 2.5
iv)	Released at high initial velocities into zone of very rapid air motion	Grinding, abrasive blasting, tumbling	2.5 to 10

The sizing of the ducts shall be determined considering the volume of air required and recommended duct velocity necessary to convey the contaminants with minimum possible pressure drop keeping in mind economics of installation and operation. Recommended duct velocity for exhaust ventilation system is given in Table 36.

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Table 36 Recommended Duct Velocity for Exhaust Ventilation Systems

(*Clause* 14.2.2)

Sl No.	Nature of Contaminants	Examples	Recommended Duct Velocity m/s
(1)	(2)	(3)	(4)
i)	Vapours, gases, smoke	All vapours, gases and smoke	5 to 10
ii)	Fumes	Welding	10 to 12.5
iii)	Air laden with very fine dusts	Litho powder, wood flour, cotton lint	12.5 to 15
iv)	Dry dust and powders	Fine rubber dust, moulding powder dust, cotton dust, jute lint, soap dust, leather shaving	15 to 20
v)	Average industrial dusts	Grinding dust, general material handling, clay dust, brick cutting, lime stone dust, asbestos dust in textile industry, dry buffing lint, granite dust, silica flour, shoe dust	17.5 to 20
vi)	Heavy dusts	Metal turnings, saw dust, sand blast dust, C.I. boring dust, lead dust, foundry tumbling barrels and shakeout	20 to 22.5
vii)	Heavy and moist dusts	Lead dust with small clips, moist cement dust, sticky buffing lint, quick lime dust	22.5 and above

The selection, installation and operation of fan shall be in accordance with the nature of contaminants. For dust and other industrial contaminant laden air, the drive arrangement (motor, belts and pulleys) shall be kept outside the air stream.

14.3 Underground Car Park Ventilation

14.3.1 *Requirement*

Ventilation in enclosed car parking areas to dilute the level of toxic gases such as carbon monoxide (CO), oxides of nitrogen (NOx), presence of petrol/diesel fumes and smoke from engine exhaust. The ventilation rate will be such so as to ensure that the CO level is maintained within 40 mg/m^3 (35 ppm) for 1 h exposure, with a maximum of 29 mg/m^3 (25 ppm) for an 8 h exposure (as per best practices of special publication).

NOTE — Special publication may be ISO 10121-2.

14.3.2 *Ventilation Rate Requirement of Mechanically Ventilated Underground Car Parks*

For enclosed underground car parks without provision for natural ventilation, a minimum ventilation rate of 6 air changes per hour (ACH) shall be provided to keep contaminants within acceptable hygiene limits. In large basements, each compartment shall be independently ventilated at the minimum rate of 6 ACH.

14.3.3 *System Requirement*

The underground car park ventilation system shall be classified as supply-only, exhaust-only or a combination of the two. A system of ducts or impulse/induction fans (jet fans) may also be used for proper distribution of air in the car park.

For underground car parking, the fans and the ventilation system used for normal CO level ventilation are also used for smoke ventilation during a fire. The extraction fans, ancillaries and the system should therefore be rated

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for high temperature operation including air changes per hour requirement, as specified in Part F 'Fire and Life Safety' of this NBCS.

14.3.4 *Demand Control Ventilation Based on CO Level*

The ventilation air flow rate shall be varied according to CO level in order to conserve energy during off peak hours when vehicular movements is much lower than during peak hours. In multilevel basements as well as in large single level structures, independent fan system with individual control is required to take care of fire compartmentation requirements (*see* also Part F 'Fire and Life Safety' of this NBCS).

14.3.5 *Location of Sensors*

The sensors for car park ventilation shall be placed in the following manner:

a) Maximum distance of any corner in the car park to the nearest sensor should be less than 25 m;

b) Sensors should be grouped according to the zone covered by the exhaust fan. The coverage area of each sensor should typically be 400 m^2; and

c) Sensors should ideally be located between 0.9 m and 1.8 m above floor level. However, for practical reasons (in order to avoid vandalism), the sensors may be installed at just above 1.8 m height from floor.

14.4 Commercial Kitchen Ventilation

The basic purpose of a kitchen ventilation system (KVS) is to provide a comfortable environment in the kitchen and to ensure the safety of the people working in the kitchen and other building occupants, by effective removal of effluents which may include gaseous, liquid and solid contaminants produced by the cooking process and products of fuel and food combustion.

Heat and grease are the primary ingredient of kitchen effluents. 50 percent to 90 percent of the appliance energy input is released in the form of a rising convective thermal plume above the cooking surface; balance is released into the surrounding space through radiation. The exhaust hood shall be of sufficient size and placed at proper height to capture the whole plume. The hood exhaust flow rate shall be slightly higher than the plume flow rate. Extra exhaust capacity may be required to resist cross drafts.

14.4.1 *Hood Exhaust Flow Rate*

Kitchen hoods have been classified as two types, Type I and Type II. Type I hoods are used to collect and remove grease, smoke, steam and heat. Type II hoods only remove steam and heat. Thus, Type I hoods are fitted with some kind of grease collection device such as grease filters, baffles and a fire suppression system but a Type II hood typically does not have these devices. Appliances such as cooking ranges, fryers, broilers and griddles require Type I hoods whereas ovens, steamers and dishwashers shall work with Type II hoods.

Hood exhaust flow rates for different types of cooking equipment and exhaust hoods per linear meter of hood length shall be calculated as per Table 37. If more than one duty category appliance is placed under one hood, the hood exhaust flow shall be calculated on the basis of the heaviest duty appliance.

For Type II hoods, the prescribed exhaust flow rates are from 150 liters per second per linear meter of hood length to 460 liters per second per linear meter of hood length for oven hoods, and 460 liters per second to 770 liters per second for condensate hood.

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Table 37 Hood Exhaust Flow Rates by Appliance Category

(*Clause* 14.4.1)

Sl No.	Appliance Category Surface Temperature °C	Light 200 °C	Medium 200 °C	Heavy 315 °C	Extra Heavy 370 °C
(1)	(2)	(3)	(4)	(5)	(6)
i)	Cooking equipment	a) Electric/gas ovens	a) Hot top/element Ranges	a) Open burner ranges	Appliances using solid fuels for example, wood, charcoal briquettes
		b) Electric/gas steamers		b) Broilers	
		c) Cheese melters	b) Griddles	c) Wok ranges	
		d) Pizza ovens	c) Fryers		
		e) Food warmers	d) Pasta cookers		
			e) Conveyor ovens		
			f) Grill		
			g) Rotisseries		
ii)	Plume velocity (m/s)	0.25	0.43	0.75	0.93
iii)	Hood type	Hood exhaust flow rates per linear meter of hood length (litres per second)			
	a) Wall mounted canopy	309	463	618	850
	b) Single island	618	772	927	1080
	c) Double island (per side)	386	463	618	850
	d) Back shelf	463	463	618	–

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14.4.2 *Good Hood Design and Installation Practices*

Wherever feasible, the following good hood design and installation practices shall be adhered to:

a) Increasing hood overhang increases capture volume which aids capture and prevents spillage. A minimum overhang of 150 mm on all open sides for all canopy hoods is prescribed. Increasing front overhang and use of inclined side panels (instead of side overhang) significantly reduces capture flow rates;

b) Deployment of side panels improves hood performance significantly. Side panels prevent the plume from spilling at the side, prevent cross drafts and increase velocity at the hood front;

c) Under a wall canopy hood, pushing the appliance towards the back wall significantly improves hood performance in two ways, increased front overhang and reduction in gap between the appliance and the back wall;

d) When using multiple duty category appliances in line under a single hood, the lowest capture rates are achieved when light duty appliance are at the end of the line. Therefore, hood performance is best when heavy duty appliances are placed in the middle of the line; and

e) Hood shall be mounted at as low a height as practical above the appliance surface.

14.4.3 *Oil/Grease Removal*

The removal of oil/grease from the exhaust airflow is a very important part of commercial kitchen operation. Collection of grease in the duct system, in the fan, in roof top equipment and its emission in the environment poses not only pollution problems but is also a serious fire hazard. Grease shall be effectively removed in the hood exhaust system through the use of proper filtration device. The design and selection of proper filtration device shall ensure that the exhaust air is clean and in accordance with the applicable pollution control norms.

14.4.4 *Exhaust Duct Design, Installation and Maintenance Practices*

Kitchen exhaust ductwork carries hot grease laden air. The following general guidelines shall be followed in their design, installation and maintenance:

a) Ducts should be round or rectangular;

b) Ducts shall be grease tight and should be free of traps that shall hold grease;

c) Minimum sheet gauge should be (16 gauge) mild steel or 18 gauge stainless steel;

d) All joints and seams shall be fully welded and made grease tight;

e) Ductwork shall lead directly to building exterior and should not be interconnected with any other type of building ductwork;

f) Horizontal duct runs should be minimized and pitch towards the hood or an approved reservoir for continuous drainage of liquid grease and condensate. The slope should be 2 percent for runs under 23 m. For horizontal runs greater than 23 m, 8 percent slope should be provided. A grease drain outlet shall be provided in form of a leg under a vertical riser;

g) Maximum velocities are limited by pressure drop and noise and should normally not exceed 12.5 m/s;

h) The minimum air velocity for exhaust ducts should be 2.5 m/s;

j) For new single speed fan system, a design duct velocity of 7.5 m/s to 9 m/s is appropriate;

k) Ducts should be as per the requirements given in Part F ‘Fire and Life Safety’ of this NBCS;

m) Access doors duly nut bolted with lead/fire rated gasket shall be provided for scavenging/grease removal during maintenance. This should be marked/provided in drawings as well as in actual duct work, so that nothing is built to block access to them; and

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n) It is recommended that duct cleaning at regular intervals be carried out so that the grease film thickness inside ducts (measured with a wet film thickness gauge or equivalent device) does not exceed 180 microns. This will avoid accidental grease sparks and fire.

14.4.5 *Fan for Kitchen Exhaust*

Kitchen exhaust consists of hot, grease laden air with some solid particulate matter also. Fan shall be capable of handling this air and the motor and the drive train (shaft, bearings, belts, etc) shall be kept outside the air stream. The kitchen exhaust fan shall consist of a backward centrifugal impeller or backward SISW centrifugal impeller to capture grease particles.

14.4.6 *Terminations of Kitchen Exhaust System*

Kitchen exhaust systems shall be terminated so that:

a) Discharge direction shall be such as to minimize re-entry into fresh air intake. This not only requires a minimum separation between exhaust and fresh air intake but also knowledge of prevailing winds;

b) Grease shall be collected and drained into a closed container (a fire safety precaution);

c) Rainwater shall be kept out of the grease container;

d) Grease shall not be allowed to drain down the side of the building;

e) Discharge shall not be directed downward or towards pedestrian areas;

f) Roof top discharge shall de released a minimum 4 m above the roof surface; and

g) For discharge from building sides, it shall be ensured that the discharge air is clean, free from odours and in accordance with the applicable pollution control norms.

14.4.7 *Replacement* (*Make-up*) *Air Considerations*

The air exhausted through a kitchen hood shall be replaced 100 percent with clean outside air. Kitchen room pressure shall be maintained slightly lower than the adjoining building space (for example, dining room) to allow conditioned air to transfer into the kitchen and to contain heat and odours within the kitchen. For kitchens adjacent to a building exterior wall, the kitchen pressure shall be slightly higher than outside to prevent ingress of dust, heat and insects.

14.4.8 *Energy Management Considerations*

Significant energy savings are possible with demand control ventilation (DCV) because the power consumed by a fan is proportional to the third power of its speed. Exhaust and supply air flow rates shall be controlled to cater to peak and off-peak periods by installing variable frequency drives (VFD) on the fan motors.

14.5 Laboratory Ventilation

Most laboratories are the source of chemical and biological contaminations which may be very harmful for the occupants. Effective ventilation shall be provided to control the air quality and remove contaminants to protect the health and safety of laboratory personnel and surrounding environment.

14.5.1 *Ventilation of Chemical Laboratories*

a) The laboratory rooms shall have mechanically operated supply and exhaust air system. Exhaust air shall not be recirculated or short cycled through make up air;

b) Chemical laboratories shall have a minimum of 6 air changes per hour (as per best practices of special publication);

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c) Fume hoods (*see* Fig. 11) and/or local extractors shall be deployed for effective exhaust from localized processes. Face velocity at fume hood sash shall be sufficient to maintain the maximum allowable escape of contaminants at 0.01 ppm. This shall be verified by tracer gas tests post commissioning;

d) Laboratories shall be maintained at negative pressure with respect to surrounding corridors or less hazardous areas;

e) Ventilation system shall be capable of shutting down in case of fire;

f) Exhaust duct air velocity shall be maintained at 5 m/s to 10 m/s to prevent condensation of fumes or accumulation of solid contaminants;

g) Eddies and cross drafts in the vicinity of fume hoods shall be minimized;

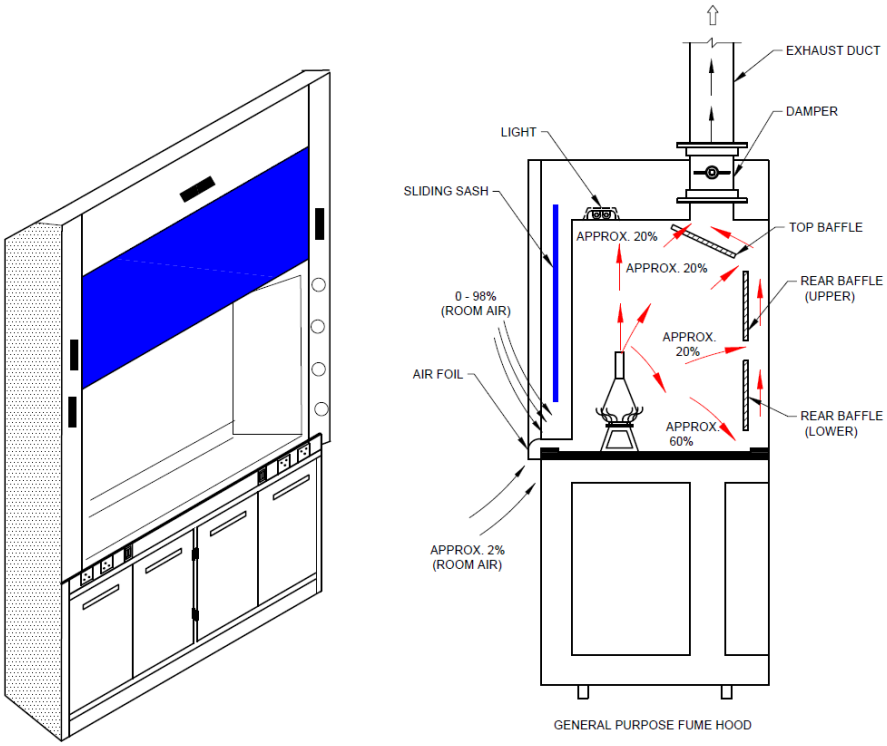

FIG. 11 GENERAL PURPOSE LABORATORY FUME HOOD

h) Certain minimum level of ventilation shall be provided even when the laboratories are not functional to evacuate the vapours generated from the chemicals in the laboratory;

j) Openable windows shall be prohibited to maintain containment and negative pressure in laboratory rooms;

k) Exhaust duct shall not be internally insulated for thermal or acoustic purpose. Sound attenuators or external insulation should provide adequate sound transmission class (STC) and weighted sound reduction index (R_w) ratings to ensure better isolation. Sound attenuators or external insulation may have STC and $R_w \geq 50$ dB for better isolation;

m) Fume hood using heated perchloric acid shall be designed to have the entire exhaust path in spark and corrosion resistant construction as well as with a washing system to avoid explosion hazard;

n) Adequate makeup air shall be provided to compensate the air exhausted by the hoods or other exhaust system; and

p) Air flow direction shall be from low hazard to high hazard areas.

NOTE — Special publication may be ISO 10121-2.

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14.5.2 *Ventilation of Biological Laboratories*

Depending upon level of hazard and requirement of protection, biological labs are generally classified into four bio-safety levels (BSL), further categorized into BSL1, BSL2, BSL3 or BSL4 based on combination laboratories practices and techniques, safety equipment and laboratory facilities. General ventilation requirements of BSL3 labs are as prescribed below:

a) Minimum rate of 6 air changes per hour shall be maintained at all times;

b) Laboratories shall be maintained at negative pressure of 12.5 Pa or lower with respect to adjoining corridors, areas, other containment or pressure zones. Monitoring and control devices shall be installed to ensure that pressure differential is maintained at all time;

c) Ventilation system shall effectively remove heat, contaminants and odour from all equipment and laboratory spaces;

d) Visual readout devices and alarm should be provided at entry to containment space, in ante rooms and at entry to other individual rooms within the containment area;

e) Dedicated exhaust air system shall be provided. This system may not be connected to a common system or any other system serving the spaces outside the biocontainment space;

f) Exhaust system shall be provided with variable frequency drive with necessary airflow sensors and a standby fan for redundancy;

g) All duct work shall be with welded joints and in stainless steel construction;

h) It is highly recommended to provide the exhaust system for a BSL3 lab with high efficiency particulate air (HEPA) filters {accepted standard [D-3(19)], [D-3(35)], [D-3(36)], [D-3(37)] and [D-3(38)]}. This filtration shall be provided as close as possible to the biocontainment area. The filtration system shall include bag-in/bag-out type filter replacement system so as to replace the filters without shutting down the exhaust system. Necessary arrangement shall be provided for full face scanning of HEPA filter integrity;

j) Necessary equipment such as laminar flow units, bio safety cabinets of required class, glove box etc. shall be used to ensure the protection of biologically delicate material or to contain bio hazard material during the experiment; and

k) The airflow direction shall be from the clean area to the biocontainment spaces.

14.5.3 *Ventilation of Animal Research Labs*

Properly designed ventilation system provides an adequate amount of oxygen to the lab personnel and animals, removes thermal load generated by animals, removes biological contaminants including allergens and airborne pathogens, controls the humidity of animal housing systems, dilutes the gaseous contaminations, maintains pressure differential between adjoining spaces, maintains micro environment in primary enclosure (housing cage) and maintains animal health.

Animal research facility shall be classified as under with respect to housing system:

a) Conventional animal facility with open type pan; and

b) Modern animal facility with individually ventilated animal housing system.

14.5.3.1 *Animal lab with conventional system*:

a) Shall be provided with minimum of 10 to 15 outside air changes per hour for animal biosafety level (ABSL) 1 and ABSL 2 labs and higher for ABSL 3 facility. System should be once through. Recirculation of air is generally not permitted;

b) Both, supply and exhaust air system shall be provided with HEPA filter to protect the animal from outside contamination and also to protect the environment from biological contamination;

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c) System shall be designed to maintain required hygroscopic conditions as per animal requirement; and

d) High velocity draft shall be avoided near animal housing pans to protect animals from wind chill effect.

14.5.3.2 *Animal lab with individually ventilated housing system*:

a) Shall be provided with fresh air supply depending upon the total cage volume and number of air changes required by the system;

b) Necessary adjustment factor shall be considered while designing the HVAC system as the relative humidity in close cage will be 8 percent to 10 percent higher than in the room;

c) Shall ensure no air movement from contaminated area to clean area; and

d) Ventilated caging system shall be selected and pressure gradients shall be adjusted in system itself according to different ABSL level requirements.

14.5.3.3 *In addition*:

a) The direction of air flow shall be from clean corridor to animal room to the service corridor. Necessary pressure gradient shall be maintained to ensure this all the time;

b) Both, supply and exhaust systems shall be designed for redundancy and shall be in operation all the time;

c) Animal experiment room shall be maintained under negative pressure with respect to clean area. Animal quarantine room and healthy animal rooms shall be maintained under positive pressure;

d) Use necessary isolation equipment to protect surrounding environment from infected animal or to protect immune compromised animals from surrounding environment.

14.6 Tunnel Ventilation

14.6.1 *General*

The tunnel ventilation system (TVS) for underground metro network is intended to provide:

a) An acceptable environment in the tunnel and station trackway for the operation of trains;

b) Pressure relief produced by the piston effect of train movement during normal operation;

c) Heat removal during congested/maintenance operation; and

d) An effective means of controlling smoke flows during emergency conditions for safe evacuation of passengers

14.6.2 *Operation Philosophies*

There are three design operating conditions for the tunnel ventilation system that is normal operation, congested operation and emergency operation.

During normal operation, that is when trains are running as per scheduled headway the main source of ventilation for the tunnel is airflow generated due to piston effect produced by moving train. Tunnel ventilation fans are not operated during train movement in tunnel. The trackway exhaust system (TES) at the station extract the heat from train air-conditioning or braking equipment when train is dwelling at the stations. The air extracted from the TES is either exhausted to the atmosphere or shall be used to recirculate to the station air-conditioning system as per the requirement. The trackway exhaust fans are generally provided with variable frequency drives to operate the fan at optimal speed to save energy.

In congested operation, the tunnel ventilation fans (TVFs) are activated for preventing the accumulation of warm tunnel air around idling train in the affected tunnel section. The tunnel ventilation design condition for congested train operation is maximum stratified tunnel air temperature (approximately 50 °C) as per the design of the rolling stock.

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In emergency operation, the TVS is set to operate to control the movement of smoke and provide a smoke-free path for safe evacuation of the passengers and for firefighting purposes. The ventilation system is operated in a 'push-pull' supply and exhaust mode with tube axial flow fans/nozzles. This enables driving tunnel air flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction. A typical ventilation system in tunnel during fire on a train is shown in Fig. 12.

One of the most important factors in selection of the system is to generate the minimum critical velocities of air flow in the tunnel to prevent back-layering of smoke laden air in the tunnel.

14.6.3 *System Description*

The tunnel ventilation system (TVS) consists of tunnel ventilation fans (TVFs), trackway exhaust fans (TEFs), tunnel booster fans (TBFs), tunnel ventilation dampers (TVDs), tunnel ventilation nozzles and sound attenuators provided in the tunnel ventilation plant rooms at each end of the station and connected to both trackways and to outdoors through ventilation shafts.

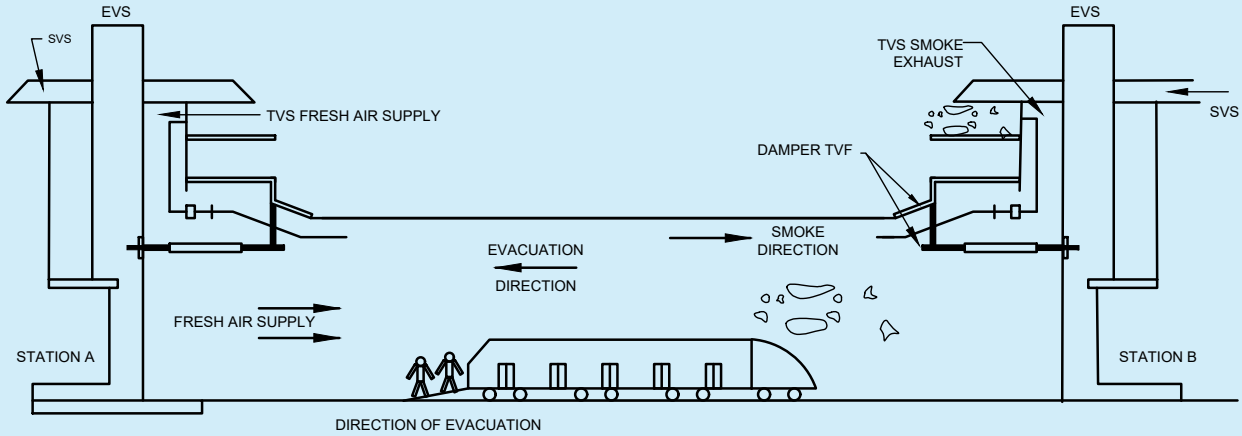

FIG. 12 VENTILATION IN TUNNEL DURING FIRE ON A TRAIN

Each tunnel ventilation installation has two fully reversible tunnel ventilation fans with fan isolation dampers. These dampers are closed when the fan is not in operation. In addition, there is a bypass duct with isolation dampers around the fan room, which acts as a pressure relief shaft when open during normal conditions and enables the flow of air to bypass the TVFs, allowing air exchange between tunnel and outdoor with flows generated by train movement.

The tunnel booster fans are installed at the crossover locations/at portals that is, where the train moves from underground to overground to provide thrust and to direct the flow in desired direction during congestion and emergency scenarios.

The trackway exhaust fans are located in separate plant rooms at each end of the station and connected to station trackway through under platform exhaust and over track exhaust ducts and to the outdoors through exhaust ventilation shafts, to enable heat removal from train AC system and braking system. The TEFs shall also be utilized for smoke extraction from the concourse/platform public areas with the help of dampers connecting the ducting system.

All the components of the tunnel ventilation system are rated minimum for 250 ºC for one hour. The fire rating of the system shall be increased based on the requirements.

The specialized software tools such as subway environment simulation (SES), IDA tunnel software, computational fluid dynamics (CFD) analysis are used to evaluate the requirement and efficacy of the tunnel ventilation system.

A typical schematic of the TVS system installed at platform level is shown in Fig. 13.

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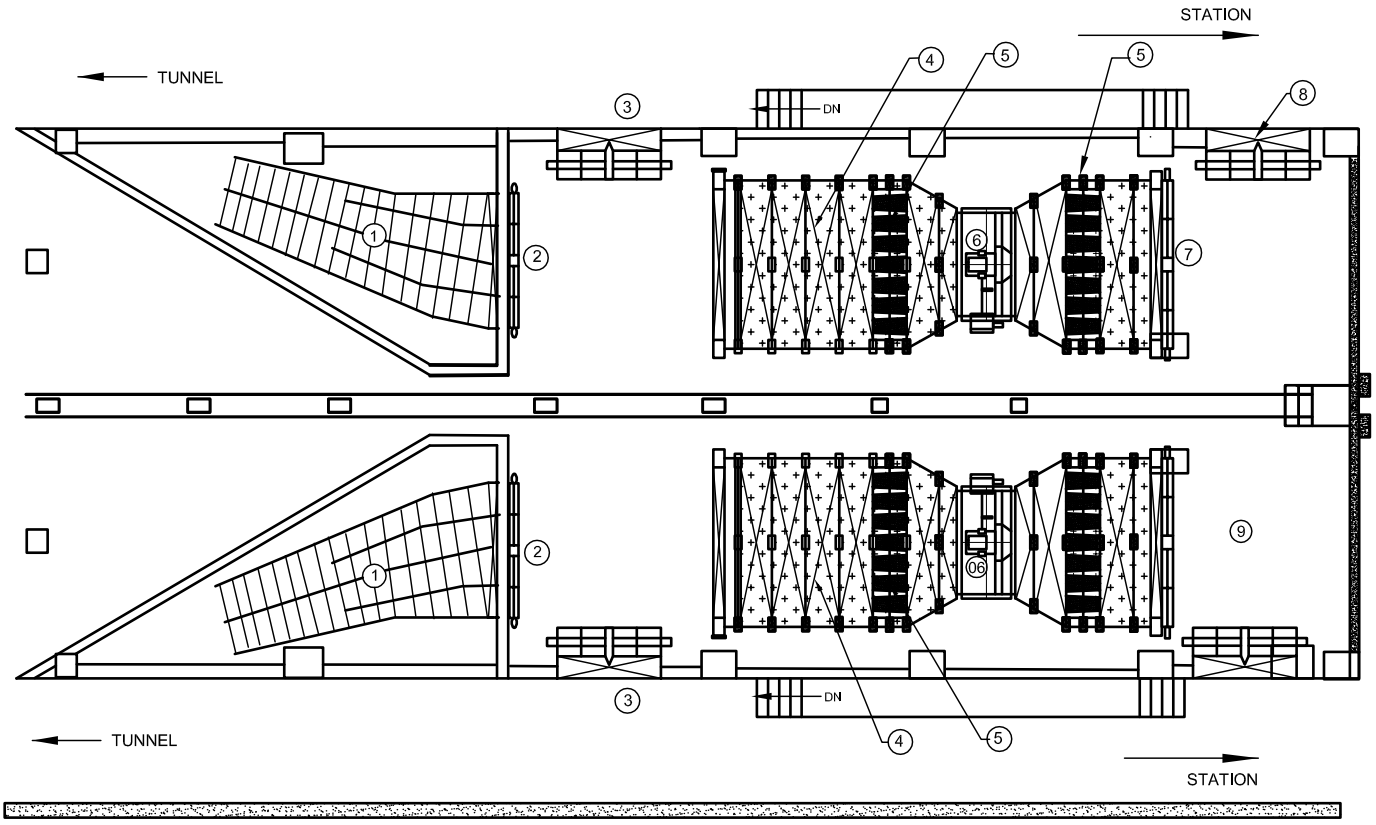
14.6.4 *Control and Monitoring of TVS*

The TVS system shall be equipped with provisions for automatic, manual, local and remote controls so that the fans and damper motors shall be operated from a station control room (SCR) or from the operations control centre (OCC). At OCC, an integrated supervisory control and data acquisition system (SCADA), should be employed to control and monitor the TVS plant in each station, as the same are generally not attended locally.

The operation of the tunnel ventilation fans during congestion are integrated with the signalling system to identify the affected tunnel section or the ventilation zone. The fans shall be operated automatically or semi-automatic as per the requirements.



1. NOZZLE
2. NOZZLE DAMPER
3. TVD (SCHEMATIC)
4. DUCT
5. ATTENUATOR
6. TVF
7. FID
8. DRD
9. SD ABOVE

FIG. 13 TYPICAL SCHEMATIC OF THE TVS PLANT ROOM AT PLATFORM LEVEL

In case of unattended train operation, suitable means shall be provided to locate the fire on train for deciding the direction of operation of the ventilation system.

The SCADA for TVS shall be designed with a minimum safety integrity level that is SIL-2. The redundancy shall be provided for communication, processor and power supply.

14.7 General Ventilation Rates for Non-Air-Conditioned Areas

In non-air-conditioned areas, ventilation may be provided through natural or mechanical means to maintain acceptable indoor air quality and thermal comfort. The design may consider climatic conditions, building orientation, effective opening area, and occupancy pattern to ensure adequate air movement and dilution of indoor

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pollutants. For more details, refer to **5** of Part C 'Structural Design, Section 1 Loads and Load Effects' of this NBCS.

15 AUTOMATION AND CONTROLS

In commercial buildings, there are various equipment and systems that consume a lot of energy in applications while delivering occupant comfort and achieving their functionalities. There are multiple aspects for operating these systems to deliver design conditions due to which automation and controls become inevitable. Systems are supposed to function at the set parameters throughout the year whereas ambient conditions vary throughout the operating hours of the building. Systems and equipment normally get designed for peak loads and demands but they operate at part load conditions for a majority of their operating hours. This aspect of operations under various outside as well as inside conditions impacts the operating efficiencies of these systems. To maintain various functionalities within the design conditions, systems should have proper controls incorporated in design as well as in operations. Nowadays equipment come with a lot of built in intelligence and it becomes very necessary to integrate them to a higher level of BMS to ensure owners and end users shall monitor and control the various systems to achieve operating efficiencies, safety, comfort and health of the building and its occupants. In addition to these aspects, the speed with which the digital technology is moving forward, internet of things (IoT) is becoming an integral part of equipment. Buildings shall incorporate futuristic design aspects of BMS in building design. The various aspects of automation and control elements in a building for the various systems are addressed below.

15.1 Roles and Requirements of Automation and Controls in a Building for Various Systems

Given below are the required roles for automation and control in building for various system:

15.1.1 *Heating, Ventilation and Air Conditioning Systems (HVAC)*

Automation and Controls should be designed for:

a) *Monitoring* — Should monitor air quality and thermal comfort parameters as specified in section;

b) *Control* — Controls shall switch on/off of the various equipment based on demand, and open/close or modulate valve actuators and HVAC dampers based on time schedule, occupancy or control parameters like temperature or RH or pressure or flow based on the application;

c) *Energy data management* — Should Provide energy consumption data to monitor and help create energy saving strategies;

d) *Alarm management* — Should Provide better monitoring, control and early notification for predictive and preventive maintenance, optimize operational efforts and reduce downtime of the system; and

e) *Building parameter data management* — Should provide historical data for analysis of system performance.

15.1.2 *Fire and Life Safety*

There is a lot of data exchange required between the fire alarm system and HVAC system for monitoring and controlling the pressurization systems in a building from the BMS. Life safety systems are always stand-alone systems but monitoring of all these systems from the BMS should be deployed critical for proper operation and monitoring of the buildings:

a) Automation for fire and life safety in commercial buildings, residential communities, public places and FAS and BMS should be seamlessly integrated:

   1) *Monitoring* — Shall monitor status of various equipment - water tank levels, primary pumps, diesel pumps, jockey pumps, fire sensors, smoke sensors, pressure across the system, leakages, fire-panel alerts and diesel fuel tank level, fire extinguishers;

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2) *Control* — It should have controls for automatic filling of water in fire tanks independently and proactive steps for managing alerts from the fire panel. should include predictive and preventive maintenance scheduling via automation for various components; and

3) The Wired or wireless technology for automation should be deployed based on the overall implementation of that project and budget.

b) Automation for life safety systems and monitoring of systems with interlinked logics and sharing of information with fire responders.

Application in buildings, communities, cities and towns, public places, industries, data centres, hospitality and hospitals, etc.

1) *Monitoring of fire alarm panels* – status monitoring – ON/OFF, alarm status/normal status this should be covered over IoT (Via Wi-Fi/4G/3G or wired). - Intend of this application – To have status monitoring locally and remote capability via IOT which shall be seen by fire responders;

2) *Monitoring of hydrant system* – Pressure in hydrant pipes should be continuously monitored and remotely displayed, Change of Pump switch from auto/manual or vice versa, change in ON/OFF status of pumps. Calls and SMS/Or mail alerts at all levels with escalation matrix defined; and

3) The Wired or wireless technology for automation should be deployed based on the overall implementation of that project and budget.

For real life saving impact, we need to look at early detection methods. Wired and wireless technology shall be employed. Wireless IoT sensors and applications should be programmed to provide 'Notifications' of critical events in small and medium sized buildings that do not have a complete BMS system.

15.1.3 *Electrical*

The following sub systems should be connected with the BMS for monitoring purposes. BMS should monitor:

a) critical parameters of diesel generator (DG);

b) fuel levels of day fuel tank;

c) electrical breakers for risk free operation of the system;

d) various parameters from energy meters to ensure that energy consumption levels are trended and logged for proper analysis of the usage of energy and taking corrective action at the appropriate time to save the energy consumption levels in buildings; and

e) vertical and horizontal transportation (VHTs) from a single platform.

The integrated building management system (IBMS) should create necessary dashboards for easy access to the operating personnel.

Medium size buildings should use independent wireless IoT based energy monitoring device to monitor and control energy usage of VRF and ducted split units.

15.1.6 *Controls Requirement for Significant Components of Building*

Based on the above details of requirements of various systems for control and monitoring functionalities, following Table 38 defines compliance requirements for significant components of BMS at equipment level and system level.

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Table 38 Controls Compliance Requirement for Significant Components of Building

(*Clauses* 15.1.6, 15.2.1(1) *and* 15.2.3)

Sl No.	Discipline	Control and Monitoring Level	Equipment/System	Control/Monitoring Base Level	Control/Monitoring Energy Intensive Buildings	Control/Monitoring for Critical Buildings
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	HVAC					
i)	HVAC	Equipment level	DX IDU/ODU	Stand alone	Stand alone	Stand alone
ii)	HVAC	Equipment level	DX VRF	Stand alone	Stand alone	Provide networked controllers
iii)	HVAC	Equipment level	CHW FCU	Stand alone	Individual time clock control using controller	Provide networked controllers
iv)	HVAC	Equipment level	CHW AHU	Stand alone	Individual time clock control using programmable controller	Provide networked controllers
v)	HVAC	Equipment level	CHW Pumping	Stand alone	Provide group controls for all the pumps	Provide networked controllers
vi)	HVAC	Equipment level	Cooling tower fan	Stand alone	Stand Alone - as per ECSBC	Provide networked controllers
vii)	HVAC	Equipment level	Extract fan	Stand alone	Stand alone	Provide networked controllers
viii)	HVAC	Equipment level	Pressure Control (Air side)	Stand alone	Stand Alone	Provide networked controllers
ix)	HVAC	Equipment level	CT Level Control	Stand alone	Stand alone	Provide networked controllers
x)	HVAC	Equipment level	Basement ventilation	Stand Alone - as per ECSBC	Stand Alone - as per ECSBC	Provide networked controllers with all monitoring points in the dashboard screens
xi)	HVAC	Equipment level	Energy recovery (Airside)	Stand Alone - as per ECSBC	Stand Alone - as per ECSBC	Provide networked controllers
xii)	HVAC	System level	CHW pumping	Stand alone	Stand alone	Provide networked controllers
xiii)	HVAC	System level	Variable air volume	Stand alone	Stand alone	Provide networked controllers

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Table 38 (*Continued*)

Sl No.	Discipline	Control and Monitoring Level	Equipment/System	Control/Monitoring Base Level	Control/Monitoring Energy Intensive Buildings	Control/Monitoring for Critical Buildings
(1)	(2)	(3)	(4)	(5)	(6)	(7)
xiv)	HVAC	System level	Pressure control	Stand alone	Stand-alone	Provide networked controllers
xv)	HVAC	System level	Demand control ventilation	Stand alone as detailed in ECSBC	Stand alone as detailed in ECSBC	Provide networked controllers
xvi)	HVAC	System level	Economizer	Provide controls as per ECSBC	Provide controls as per ECSBC	Provide networked controllers
xvii)	HVAC	System level	Chillers and chiller plant control	Chiller plant control as per ECSBC details	Chiller plant control as per ECSBC details	Provide networked controllers with data for analysis
	LIGHTING					
xviii)	Lighting	Equipment level	Lux level control	as per details given in ECSBC	as per details given in ECSBC	as per details given in ECSBC
xix)	Lighting	System level	Lighting Management System (LMS)	-	-	Integrate LMS with BMS; share occupancy/unoccupancy mode data; based on based on which, VAVs to switch to occupied/unoccupied modes
	ELECTRICAL AND VERTICAL TRANSPORTATION					
xx)	Electrical and vertical transportation	Equipment level	Transformers, breakers, VHT	-	-	Monitor healthy status of the equipment
xxi)	Electrical and vertical transportation	Equipment level	Energy meters	Record energy value at all meters for monitoring purposes for all utilities	Digitally connect all utility energy meters; track energy consumption for analysis	Digitally connect all utility energy meters; track power and energy consumption data for analysis

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Table 38 (*Concluded*)

Sl No.	Discipline	Control and Monitoring Level	Equipment/System	Control/Monitoring Base Level	Control/Monitoring Energy Intensive Buildings	Control/Monitoring for Critical Buildings
(1)	(2)	(3)	(4)	(5)	(6)	(7)
xxii)	Electrical and vertical transportation	System level	Building level	-	Comply as per ECSBC	Comply as per ECSBC
	WATER MANAGEMENT					
xxiii)	Water management	Unit/equipment level	PHE Equipment	Provide stand-alone control for equipment functioning	Provide stand-alone control for equipment functioning	Track parameters at the dashboards
xxiv)	Water management	Equipment level	STP System	Stand-alone control	Stand-alone control	Track parameters at the dashboards
xxv)	Water management	Equipment level	Water Meters	Recording of Water Consumption data;	Recording of Water Consumption data;	Recording and trending of water consumption data

NOTE — Details of for abbreviations mentioned in column under equipment/system are provided below - this matrix is part of Chapter 13 of ECSBC and shall be referred also from ECSBC.

DX IDU/ODU	DX Split Unit
DX VRF	DX Variable Refrigerant Flow Unit
CHW FCU	Chilled water Fan Coil Unit
CHW AHU	Chilled Water Air Handling Unit
CHW Pumping	Chilled water Pumping
CT Level Control	Cooling Tower Level Control
PHE equipment	Public Health and Engineering equipment
VHT	Vertical and Horizontal Transportation

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15.2 Building Management System (BMS) and Internet of Things (IoT)

The following points outline the various components and functionalities associated with BMS and IoT in modern buildings

15.2.1 *BMS System Architecture*:

a) Control Systems in a building shall have a system architecture that ensures control and monitoring of various operating parameters at the following levels:

   1) Unit/equipment Level for equipment performance, monitoring, control and energy optimization as per the control logic developed to achieve the design objective. Necessary and appropriate field devices shall be used at this level to capture various parameters that need to be controlled and monitored (*see* Table 38);

   2) System and automation level shall ensure coordinated and integrated control logic between the various sub systems as per the design intents; and

   3) Management Level shall contain necessary workstations with software and dashboard screens provide macro level parameters of various high-level systems to monitor trend and analyse the various data.

b) System shall bring in all mechanical, electrical and public health engineering (MEP) equipment and systems under its architecture;

c) Control system shall be constructed to achieve energy optimization based on the level of intelligence and functionalities in-built in the equipment;

d) A matrix of equipment and parameters that shall be controlled and monitored shall be drawn (*see* Table 38 for various building systems). In addition to Table 38, critical parameters namely, temperature, pressure, voltage, current, energy, and others shall be recorded and monitored and shall be made available for the operations team for corrective action either through stand-alone controls or networked controls;

e) Based on point (d) above, detailed Input/output point summary (IOP Summary) shall be developed;

f) Control schematics and sequence of operation shall be developed for various control loops based on the respective design philosophy and intent of the building by the concerned design team; and

g) The controls system architecture shall be developed to effectively integrate and manage various building systems and technologies. The key requirements shall include:

   1) Scalability and flexibility – Allowing for future expansion and adaptation;

   2) Interoperability;

   3) Real-time data acquisition and analysis;

   4) Security and privacy;

   5) Redundancy and fault tolerance;

   6) Energy efficiency and sustainability; and

   7) Centralized management for control and monitoring.

15.2.2 *Protocols*

All unit level and system level controls shall have industry standard open protocols adopted for connecting various equipment/controllers/third party devices that have built-in intelligence in their controllers and factory installed field devices/equipment like chillers, diesel generating sets, energy meters, and variable speed drives. Other industry standard open and accepted protocols such as open platform communications (OPC), message queuing

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telemetry transport (MQTT), zigbee, Wi-Fi, modbus, meter-bus (M-Bus), global system for mobile communication/general packet radio services (GSM/GPRS), Z-wave, device language message specification (DLMS) shall be used for connecting devices.

15.2.3 *Controllers*

For various applications, controllers with built-in logic or programmable control logic shall be used to achieve the desired design intents.

Depending upon the building application and criticality, networked controls shall be used.

a) All networked controller systems shall comply with **15.2.2** for protocols used; and

b) Critical parameters namely, temperature, pressure, voltage, current, energy, and others shall be made available for effective monitoring and control of the system through networked centralized control system. (Table 38 shall be referred for various parameters to be considered based on the application.)

15.2.4 *Internet of Things* (*IoT*)

IoT devices and automation optimize building performance by providing data on core building operational systems and enabling automatic control of the building's main operating functions. IoT devices, when implemented, shall be able to connect via standard building and industry protocols as mentioned in **15.2.2**.

For IoT devices to be accessed and configured on the field and/or remotely shall have hardware interface and software or wireless interface for remote configuration.

Integrating IoT with BMS represents a significant advancement in building management, offering improved efficiency and enhanced user experiences. While implementing systems with IoT enabled controls, following aspects have to be taken care of in the design:

a) *Interoperability* — This is to ensure different IoT devices and systems work together seamlessly. For medium sized buildings, all applications for devices should be accessible from the same screen. Use of higher-level local servers running continuously are to be considered to achieve interoperability when stated in OPR;

b) *Data privacy* — Safeguarding the personal data collected by loT devices is important. Use of VLAN and Privacy Levels to be as per requirement detailed in OPR. For medium sized buildings WPA/WPA2 will otherwise be the minimum level;

c) *Scalability* — Ensure the system is scalable and adaptable to changing needs within the same platform; and

d) *Security* — Protect the system from cyber threats by ensuring that remote access to all IP and other applicable devices have USER configured usernames. Default usernames and passwords shall not be retained and device shall not be accessed by use of default username and password. Security levels to be as per requirement detailed in OPR. For medium sized buildings WPA/WPA2 otherwise accepted as the minimum level.

15.2.5 *Cyber Security*

Vulnerabilities in the IT based systems are diverse. Due to their physical location across all parts of a facility and connectivity with open protocols, systems are prone to technical and physical attacks at all architectural levels. System shall take care of all aspects of cyber security.

15.2.6 *Software*

The BMS workstation software that brings in all the data and the graphics including all the functionalities and sequence of operation and logic to the operator workstation shall have the following options depending upon the

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criticality and application of the building and also based on owner's project requirements (OPR).

a) Computer workstation software or server based software depending upon the number of data points for monitoring and control.

b) Optional server based on premise or remote depending upon the scale and application of the building.

c) IoT and cloud based system as per OPR.

15.2.7 *Integrators/Gateways*:

a) High level integrators/gateways shall be used to ensure conversion of various protocols mentioned under **15.2.7 (c)**.

b) Protocol conversion for 3rd party devices integration of various equipment in a building shall happen when various equipment is connected through soft link to bring in the various parameters residing at the equipment to the BMS platform without installing any additional field devices.

c) Conversion from one protocol to another protocol:

1) BACnet MSTP to BACnet/IP;

2) MODBus RTU– BACnet/IP;

3) MODBus TCP/IP - BACnet/IP;

4) M-Bus to BACnet-IP; and

5) MODBus – GSM/GPRS.

NOTE — The above are not exhaustive and other conversions may also be required as per the equipment and protocols installed.

15.2.8 *Dashboard*

High level parameters of various sub systems shall be captured on the dashboard screen and customized based on the OPR.

a) HVAC;

b) Electrical;

c) Energy management – consumption, generation;

d) Water management – levels, volume, consumption;

e) Sewage treatment plant;

f) Lighting management – power consumption, circuits status, luminaire fused status circuits status, luminaire fused status;

g) Fire – status of alarms/alerts;

h) IEQ/IAQ;

j) Waste management;

k) Occupancy status; and

m) UPS/battery management.

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15.3 Instrumentation and Field Devices

Instrumentation in automation and controls shall be provided to measure various parameters and communicate the same to the next level in the system architecture:

a) *Monitoring* — Status monitoring of multiple aspects of buildings like,

   Utilities (water, lighting, energy, gas), water quality (WTP, STP, ETP), air quality, ventilation (HVAC, mechanical), VHT (lifts, elevators, escalators, travellators), fire and life safety, UPS (power consumption, battery management), DG set, parking, security (cameras, boom barriers, access control, intrusion detection), plumbing etc;

b) Control of critical/non-critical areas as defined in OPR;

c) *Instrumentation considerations* — These devices range from field devices, loggers, aggregators, controllers - sensors, PLCs, controllers (PID, IoT), mechanical (actuators, valves, dampers etc.), internal and external communication devices and any special purpose instruments. These shall be of analogue or digital type. Communication protocols like analogue (V, A), digital, serial, TCP/IP etc. based on the application shall be considered; and

d) *Technology* — A combination of wired and wireless field devices shall be used based on the overall application of the project and OPR.

15.4 Sequence of Operation and Control Logic

Sequence of operation and the control logic of any control loop shall be developed in the BMS based on the design logic of that particular discipline and application. This is to be developed by the concerned design team and the same will be used in developing the Input/output point summary as well as for determination of necessary field devices to be installed for capturing the parameters to be controlled and/or monitored.

15.5 Data Gathering for Analysis and Performance Improvements

This is a very important part of the BMS where all the data that are gathered through the field devices as well as those processed at the controllers, data stored through various trending and logging from the various equipment and system shall be stored in a PC workstation or a server depending upon the number of data points.

This data shall be made available for analysis by the facilities and operations team for making performance improvements in the system as well as comparing through a range of time spans to understand the behaviour of the building. These data will also be useful in making informed decisions like the life of the equipment, for drawing up replacement schedules, comparing performances for various buildings etc.

15.6 Energy Savings — Optimization for Decarbonization

To effectively use the data from the BMS for measuring the sustainable level of operations of a building, following dashboard screens, at the minimum shall be made in addition to those listed under **15.2.6**. These will not only help the facilities and operations team for trending and analysis but also for measuring the carbon footprint of the building and the decarbonisation levels of the building. These will help the owner in understanding the carbon emissions and help in migrating towards net zero goals.

Dashboard screens shall be developed for the following:

a) Energy;

b) Environment;

c) HVAC system;

d) Lighting control system;

e) Water management system; and

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f) Electrical and VHT systems.

For example, energy consumption data to monitor and help create energy saving strategies, energy dashboards shall provide energy data to building and asset management team in graphical form for easy understanding and implementation.

15.7 Installation and Commissioning of Control Systems

15.7.1 *Field Devices*

Field Devices like temperature sensors, RH Sensors, pressure transmitters, flow meters and transducers, level sensors and switches, IAQ Sensors shall be installed as per manufacturers installation manual and recommendations. Necessary precautions shall be taken during installation of the field device for measuring the parameter that is detailed in the input/output point summary and the sequence of operation and control logic diagrams.

15.7.2 *Enclosure Panels*

The controllers, integrators and other components of BMS shall be housed in an enclosure panel that is appropriately rated (electrically) for the ambient conditions at which they are surrounded by so that the control components are neither damaged nor communicate incorrect data to the system. Since most of the controllers and field devices operate with 240V a.c./24V a.c./24V d.c. (as per manufacturers data sheets and installation manuals), necessary transformers have to be installed in the enclosure panel to supply the voltage as per the requirements. The transformers shall be rated to take care of the necessary VA ratings of the field devices and the relays being operated by the controller. Proper earthing etc, shall be provided as per the relevant sections of the accepted standard [D-3(39)] and Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS. These enclosure panels shall be suitably IP rated depending on their installation environment.

Relevant sections concerning electrical components in NBCS shall be followed for proper compliance.

15.7.3 *UPS Power Supply*

Necessary uninterrupted power supply shall be provided to the controllers and other control components of the BMS through proper electrical distribution system. Necessary earthing etc, shall be provided as per the relevant sections of the accepted standard [D-3(39)].

Relevant sections concerning electrical components in accepted standard [D-3(39)] shall be followed for proper compliance.

15.7.4 *Field Cabling and Containment*

Field cabling shall be provided between the various control components like the field devices, sensors, transducers, controllers, starter panels, 3rd party equipment for integration as per the relevant sections of this NBCS and as per the recommendations of the manufacturer of the control system. Control cables, integration cables and field cables shall be screened, twisted, shielded and the sizing shall be as per the recommendations of the controls' contractor and OEM. There shall be a detailed cable schedule drawn up based on the input/ output point summary before carrying out this work. Necessary earthing etc, shall be provided as per the relevant sections of the accepted standard [D-3(39)]. Containment of cabling shall be carried out as per the relevant sections of the accepted standard [D-3(39)] and as per the details of the projects approved documents. Necessary drawings have to be made for the entire system and approvals taken from concerned Engineer-in-charge

15.7.5 *BMS PC Workstation/Server*

The PC Workstations or servers, depending upon the number of data points and based on the application of the building and OPR, shall be installed in an air-conditioned room. These along with either the monitoring station or display units shall be accessible by the facilities and operations team. UPS power supply shall be provided for these components since these will have to handle data from the entire BMS online and have to store data as well for use.

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Necessary network components like network switches and accessories shall be installed based on the control manufacturers recommendations and drawings.

15.7.6 *Programming and Commissioning of BMS*

The entire BMS system shall be properly installed, field cabling all checked for continuity prior to the commissioning of the system.

Based on the control logic and the applications, necessary programming shall be developed by the controls contractor and the same shall be downloaded to the various controllers or configured based on the type of control system (wireless or wired).

Various control parameters that are measured through the field devices are to be mapped onto the controllers and checked for consistency. Various set points need to be determined based on the applications and the programs have to be test run and observed for proper operations and necessary fine tuning needs to be done on various control parameters like – PID gains, range etc, for trouble free and accurate operation of the programs.

With all the above completed and as-built drawings, the BMS system needs to be handed over to the end user with as-built drawings and all IOMs for the entire system.

16 HYDRONIC PIPING SYSTEMS

This NBCS establishes uniform standards for the design, installation and maintenance of hydronic and refrigerant piping used in heating, ventilation and air conditioning (HVAC) systems. By adhering to these standards, practitioners shall enhance system performance, reduce operational risks and meet regulatory compliance.

The provisions for material selection, sizing criteria, installation practices, testing procedures and maintenance guidelines for HVAC and refrigerant piping are specified.

16.1 General Hydronic Piping Systems

In HVAC systems, piping systems play a crucial role in transporting fluids such as water and refrigerants throughout the building. Some general type of hydronic systems commonly found in HVAC system are:

a) *Chilled Water Piping System* — Network of pipes designed to distribute chilled water from a central plant to various points of use within a building or facility. Primarily used for air conditioning, refrigeration, and industrial cooling applications;

b) *Hot Water Piping System* — Network of pipes designed to distribute heated water from a central heating source to various points of use within a building or facility. Primarily used for space heating, domestic hot water supply, industrial processes, and other applications requiring heated water;

c) *Condenser Water Piping System* — Network of pipes designed to circulate water between a chiller's condenser and a cooling tower or other heat rejection equipment. It's a crucial part of a water-cooled HVAC system, commonly used in large commercial buildings for air conditioning and refrigeration; and

d) *Condensate Drain Piping System* — Network of pipes designed to collect and remove condensate water generated by cooling equipment, such as air conditioners, refrigerators, and dehumidifiers. Condensate forms when warm, moisture-laden air comes into contact with a cold surface, causing the water vapor in the air to condense into liquid water.

16.1.1 *Open and Closed HVAC Piping Systems*

a) *Open and closed system* — An open system is one in which the water enters a reservoir that is exposed to the atmosphere such as collecting tanks, air washers, and cooling towers. A closed system is one in which the water flow is never exposed to the outside environment except at expansion tank part; and

b) *Once – thru and recirculating* — Piping system shall be once through that is, when water is released from system, it only goes through the machinery once. Water circulates in a recirculating system by

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going through the refrigeration equipment, the heat exchanger, and back again instead of being discharged.

16.1.2 *Selection of Pipe and Fitting Materials*

Selection of right HVAC pipe material shall be done considering fluid type, pressure and temperature range, system layouts, space constraints and special requirements if any (flexibility/corrosion resistance):

a) *Material options for HVAC pipe*:

1) *Steel pipe* — Carbon steel or stainless-steel pipes should be used in HVAC systems for their strength, durability, and resistance to corrosion. They are suitable for high-pressure applications such as chilled water, hot water, and steam distribution;

2) *Copper pipe* — Copper pipes have excellent thermal conductivity, corrosion resistance, and ease of installation. They should be used for refrigerant lines, domestic water supply, and hydronic heating systems;

3) *Polyvinyl chloride (PVC) pipe* — PVC pipes are lightweight, cost-effective, and resistant to corrosion. They may be used for low-pressure applications such as drainage, venting, and condensate lines in HVAC systems;

4) *Cross-linked polyethylene (PEX) pipe* — PEX pipes are flexible, durable, and resistant to corrosion and scale buildup. They may be used for radiant heating systems, and hydronic piping systems in HVAC; and

5) *High-density polyethylene (HDPE) pipe* — HDPE pipes are highly resistant to corrosion, abrasion, and chemical damage, making them suitable for outdoor or underground applications in HVAC systems, such as geothermal heat pump systems and chilled water distribution.

b) *Pipe fittings terminology*:

1) *Elbows* — Elbows are used to change the direction of flow in a piping system. They are available in various angles (for example, 45°, 90°) to accommodate different piping layouts;

2) *Tees* — Tees create branch connections in a piping system, allowing fluid to flow in multiple directions;

3) *Reducers* — Reducers connect pipes of different sizes, allowing for a smooth transition between different sections of the piping system;

4) *Couplings* — Couplings join two pipes together end-to-end, providing a leak-tight connection;

5) *Flanges* — Flanges connect pipes to valves, fittings, or equipment. They provide a secure and leak-proof connection and allow for easy disassembly when required; and

6) *Unions* — Unions are similar to couplings but allow for easy disassembly of pipe joints for maintenance or repairs.

A significant portion of the pressure drop in the piping system is caused by elbows. Elbows with a longer radius shall be provided wherever feasible. Whenever possible, 45° elbows shall be provided over 90° elbows when arranging offsets.

c) *Piping connection methods*:

1) *Soldering/brazing* — Soldering or brazing is commonly used to join copper pipes and fittings together in HVAC systems. It involves heating the joint and applying solder or brazing material to create a strong and leak-free connection;

2) *Threaded connections* — Threaded connections are used with threaded pipes and fittings, allowing for easy assembly and disassembly without the need for soldering or welding. This is usually recommended for low pressure system up to 6.9 kPa. (*see* Fig. 14);

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3) *Grooved connections* — Grooved connections use grooved pipes and fittings with rubber gaskets to create a tight seal. They are quick and easy to install and are commonly used with steel pipes in HVAC systems. (*see* Fig. 14);

4) *Flanged connections* — Flanged connections use flanges to connect pipes to valves, fittings, or equipment. They provide a secure and leak-proof connection and allow for easy disassembly when required. (*see* Fig. 14); and

5) *Welding* — Welding is used to create permanent connections between pipes and fittings in HVAC systems. It involves melting the edges of the pipe and fitting and fusing them together with heat. This type of fitting is recommended on high pressure system and larger diameter pipes.

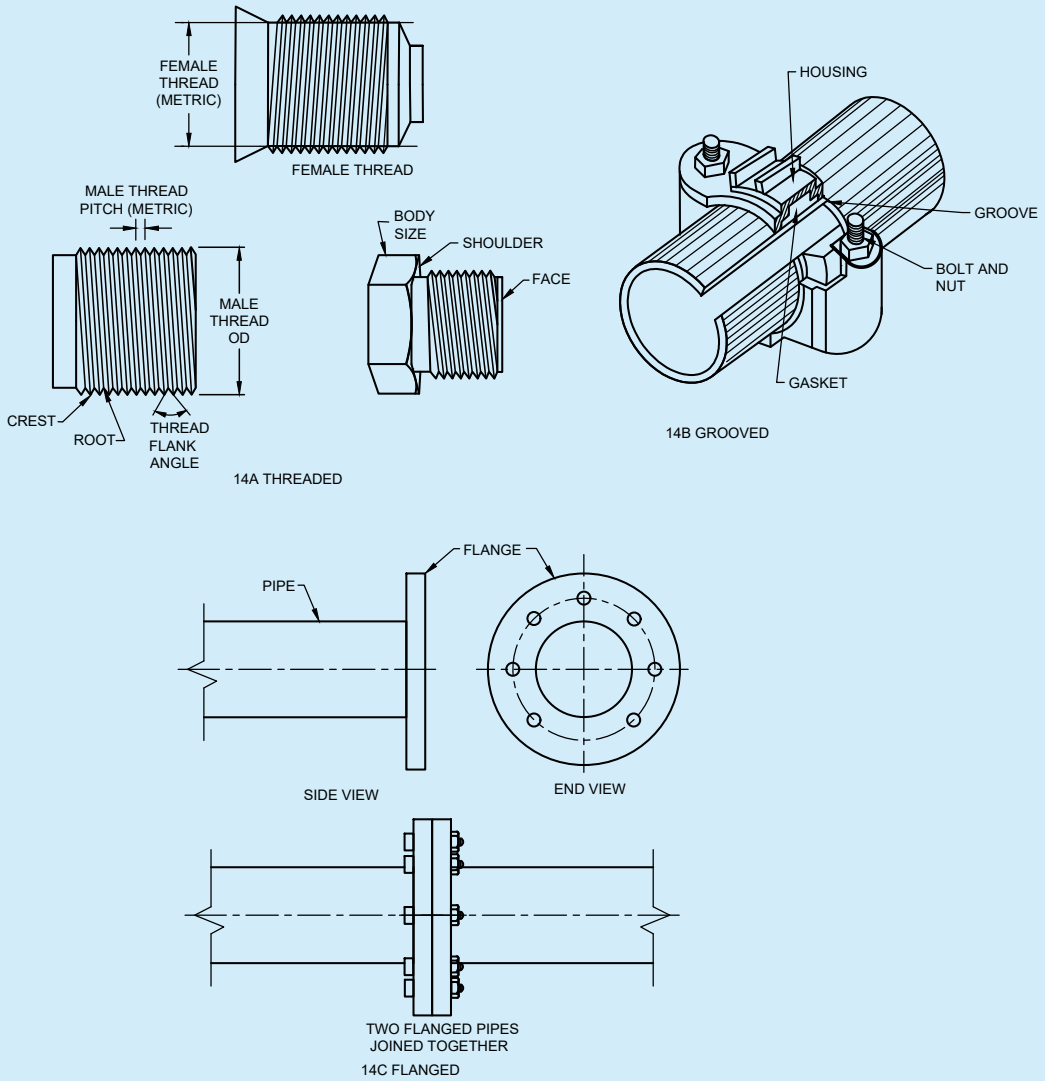

FIG. 14 PIPING CONNECTION METHODS

16.1.3 *Piping Supports*:

a) Pipe supports shall be selected to ensure strong anchoring, absorbing vibrations, providing flexibility and reducing noise transmission;

b) Rigid supports/spring hangers and supports/neoprene pads and inserts/ vibration isolators shall be selected based on load capacity to bear the combined weight of the insulation, pipe, fittings, valves, and fluid in the pipe accounting for static and dynamic loads;

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c) Manufacturer's guidelines and specifications should be referred for recommended support type based on pipe material, size and system dynamics; and

d) Consultation with HVAC engineers, vibration specialists or manufacturers to tailor support selection is recommended for specific project requirements.

16.1.4 *Expansion Loops*:

a) Expansion loops should be installed in straight runs of pipe or at points where significant temperature changes occur, such as near equipment or in outdoor installations. They prevent damage to piping, equipment, and surrounding structures caused by thermal expansion; and

b) Expansion loops shall be fabricated from standard piping fittings such as elbows and tees, or they shall be custom-designed to meet specific project requirements.

16.1.5 *Valves – Types and Applications*:

a) *Gate valve* — Gate valves control flow by raising or lowering a gate (wedge-shaped disk) to allow or restrict fluid passage. When fully open, the gate is lifted entirely out of the flow path, minimizing flow restriction. Gate valves may be used for ON/OFF control in HVAC systems where full flow or shut-off is required. They may also be provided for isolating equipment/piping sections for maintenance;

b) *Globe valve* — Globe valves feature a globe-shaped body with a movable plug (the 'disc') that regulates flow by moving up and down. As the disc moves, it alters the size of the flow opening, allowing for precise flow control. Globe valves may be used for pressure balancing, throttling or regulating flow in HVAC systems, such as controlling the flow of water or steam in heating and cooling applications. They may also be used for isolation of equipment/piping sections;

c) *Ball valve* — Ball valves feature a spherical disc (the 'ball') with a hole through the center that controls flow. The ball rotates within the valve body to open or close the flow path. Ball valves may be used for on/off control, isolation, and emergency shut-off;

d) *Butterfly Valve* — Butterfly valves use a circular disc (the 'butterfly') mounted on a shaft to control flow. The disc rotates perpendicular to the flow direction to open or close the valve. Butterfly valves should be used for large-diameter pipes in HVAC systems for ON/OFF control;

e) *Check Valve* – Check valves allow fluid to flow in one direction only, preventing backflow or reverse flow. They typically consist of a movable disc or flap that opens to allow forward flow and closes to prevent reverse flow. Check valves should be used in HVAC systems to prevent damage to equipment, maintain system efficiency, and ensure proper flow direction in piping systems;

f) *Balancing Valve* — Balancing valves should be used in hydronic systems to achieve proper flow distribution and maintain system balance;

g) *Control Valve* — Control valves regulate fluid flow based on signals from a control system, such as a thermostat or building automation system. They modulate the flow by adjusting the position of a valve plug, disc, or ball in response to changing system conditions. Control valves should be used in HVAC systems for precise temperature control, flow modulation, and energy management in heating, cooling, and air distribution systems;

h) *Pressure Independent Control Valve (PICV)* — A PICV is an advanced type of control valve used in HVAC (Heating, Ventilation, and Air Conditioning) systems for precise flow control and temperature regulation. It combines the functions of a control valve, differential pressure regulator, and flow limiter into a single device. This is recommended to be used to replace balancing and control valve in the system. (*see* Fig. 15); and

j) *Triple Duty Valve* — A triple duty valve is a multifunctional valve and combines the functions of a check valve, balancing valve and an isolation valve into a single unit. Use of these valves simplify installation, save space and improve system efficiency. These are recommended to be used in hydronic chilled water and hot water systems (*see* Fig. 16).

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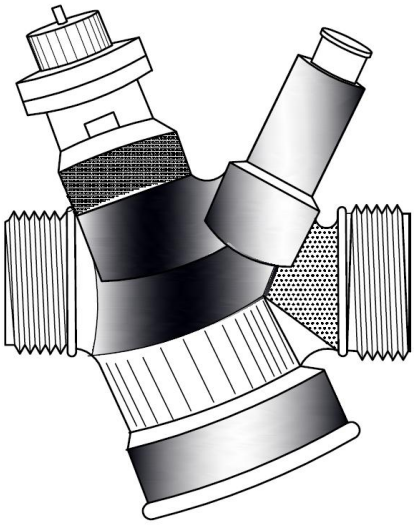

FIG. 15 PICV VALVE

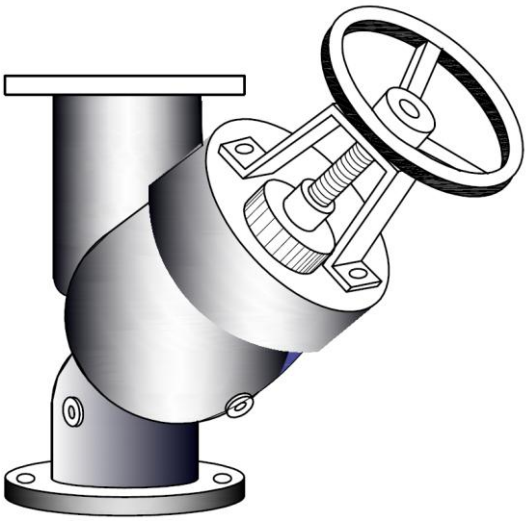

FIG. 16 TRIPLE DUTY VALVE

16.1.6 *Buried Piping Systems*

The following points cover the key aspects of buried piping systems:

a) *Design considerations* — Thermal expansion, corrosion protection and accessibility should be considered in buried piping design. Corrosion-resistant materials like HDPE, steel with protective coatings, ductile iron, or PVC should be selected. These materials shall withstand corrosive environments and prolong the service life of the piping system. Access points like valve boxes, manholes, or cleanouts should be planned along the pipeline route for maintenance;

b) *Material options* — These are material options recommended to be used:

   1) *High-Density Polyethylene* (*HDPE*) — HDPE pipes may be used for buried piping due to their lightweight nature, flexibility, and excellent resistance to corrosion, abrasion, and chemical damage;

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2) *Steel* — Steel pipes with corrosion-resistant coatings like epoxy or polyethylene may enhance their longevity in buried applications; and

3) *Polyvinyl Chloride* (*PVC*) — PVC pipes are lightweight, cost-effective, and resistant to corrosion, making them ideal for low-pressure applications in buried piping systems.

c) *Installation considerations* — Proper installation is crucial to ensure the efficiency, safety, and longevity of systems and equipment. The following points highlight key considerations for installation:

1) *Trenching* — Excavation of trenches shall be carried out to the required depth and width to accommodate the piping system. Trench dimensions should be determined based on factors such as pipe size, soil conditions, and local building codes;

2) *Bedding and backfilling* — A layer of bedding material such as sand or gravel should be placed at the bottom of the trench to provide support and stability for the pipes. After installation, the pipes to be backfilled with soil, compacted in layers to prevent settling, and ensure proper support;

3) *Protection* — Buried pipes may be wrapped with protective materials such as geotextile fabric or insulation to shield them from damage due to abrasion, soil movement, or external forces. This protective layer helps preserve the integrity of the piping system over time; and

4) *Marking and identification* — Buried piping systems shall be marked and identified with durable markers or tape along the pipeline route to indicate the location, type of pipe, and purpose of the system. This facilitates future reference, maintenance, and repair activities.

16.1.7 *HVAC Piping in High Rise Buildings- Design Considerations*

Designing of HVAC Piping systems for high rise buildings should consider efficiency, reliability and safety aspects. Material selection shall be suitable for building's structural and environmental conditions. Factors such as corrosion resistance, thermal expansion and fire safety ratings should be considered. HVAC piping in high rise buildings should be designed to handle the required pressure ratings. Accounting for pressure drops due to friction losses, fittings and changes in elevations. Design should facilitate ease of maintenance and future expansion. Few recommendations are:

a) Ensure valve controls and access points are easily available for servicing and repair;

b) Implement measures to mitigate noise and vibration transmission through HVAC piping; and

c) Comply with fire safety regulations by using fire rated materials and design pipe routes to minimize fire spread and maximize compartmentation.

16.1.8 *HVAC Piping in Radiant Cooling Systems-Design Considerations*

Designing piping systems for radiant cooling involves several critical considerations:

a) *Pipe material selection and sizing* — Piping with high thermal conductivity such as cross-linked polyethylene, copper or specialized composite pipes should be used. Select pipe sizes based on flow rates required to meet cooling/ heating demands. Zoning strategies should be implemented to allow different areas to be heated or cooled independently based on occupancy and usage patterns;

b) *Floor construction and thermal mass* — The type of floor construction should be assessed (for example, concrete/wood) to determine its conductivity for efficiency of radiant system. Ensure proper insulation beneath the radiant pipes to minimize heat loss downward;

c) *Integration with building design* — Radiant piping layout to be coordinated with other services like electrical, plumbing and structural components; and

d) *Maintenance and accessibility* — Access to manifold stations and control valves should be planned for maintenance and repair.

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16.1.9 *HVAC Piping Testing, Commissioning and Maintenance Guidelines*

Testing, commissioning, and regular maintenance of HVAC piping systems to ensure proper functioning and long-term reliability. The following points outline the guidelines for these processes:

a) *Testing procedures* — The periodic testing procedures recommended to ensure efficiency, longevity and reliability of HVAC piping system shall include pressure testing to check integrity of piping joints and connections; leak detection tests to identify and repair any leaks; flow tests to measure flow rates to check they meet design specifications and adjust as necessary.

b) *Balancing and commissioning process* — The piping system shall be balanced for even distribution of flow and pressure across all the branches. Verify system performance against design criteria and operational requirements. The commissioning procedure shall involve flushing, purging and filling the system with appropriate fluids.

c) *Regular inspection and maintenance* — A regular maintenance schedule should be established based on manufacturers recommendations and operational demands:

   1) This shall include but not limited to visual inspection for signs of corrosion, damage or leaks. Periodic cleaning of pipes should be done to remove any debris or build up to maintain optimal flow and efficiency; and

   2) Valves operation shall be tested to ensure proper functioning and prevent sticking or seizing. Inspect and adjust pipe supports and hangers for any sagging or stress in joints.

d) *Documentation* — Maintain comprehensive documentation of testing, balancing, commissioning activities including test results.

16.2 Refrigerant Piping

The following points outline key considerations for the design, installation, material, and maintenance of refrigerant piping

16.2.1 *Considerations in Refrigerant Piping*

The refrigerant when flowing through these pipes, imposes friction with the inner piping wall due to the velocities. The friction reduces the system efficiencies and as such shall be maintained as low as possible. The norm is to maintain the pressure drops in these pipes, not exceeding an equivalent of 1.10°C which for most of the commonly used refrigerant works out to 1.3 kPa to 1.9 kPa for suction line and 4.0 kPa to 6.0 kPa for hot gas and liquid lines. This shall however be verified with the refrigerant pressure-temperature charts.

The second consideration is oil migration during operation. When refrigerant flows out of the compressor in vapor form, some amount of compressor lubrication oil escapes along with the refrigerant. The piping system shall be designed to ensure that the escaped oil is made to return back to the compressor after travelling through the system to ensure that the oil levels in the compressor is maintained. Following practices should be followed to achieve this objective:

a) The refrigerant velocities in suction line as well as hot gas line be maintained high enough so that it impels oil to move along the direction of the flow. The velocities in horizontal pipes should be minimum 3.8 m/s and that in vertical lines be maintained at a minimum of 7.6 m/s;

b) The suction line and hot gas line in horizontal traverse should be pitched downwards in the direction of the flow to ensure that the oil does not flow back. The recommended gradient is 1 : 200;

c) When the suction line and hot gas line traverse in vertical direction, the U-shaped trap shall be provided at the bottom and inverse U-shaped trap shall be provided at the top. The bottom trap provides holding space for the oil in vertical pipe and not allowing it to travel backward. The top trap prevents the oil that has reached the top from traversing back;

d) In the event of vertical pipe for suction line or hot gas line travelling upwards exceeds 3.5 m, a U-shaped oil trap should be installed at every 3.5 m;

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e) In the event the compressor has part load operation capabilities, the piping velocities in vertical risers may not be possible at the lowest capacity operations. In such events, a double suction riser should be installed in vertically upward pipes. One riser should be sized for the minimum capacity and the second riser should be sized for the balance capacity; and

f) Since liquid refrigerant is perfectly miscible with the oil, the refrigerant velocity is not needed for transportation of oil. However, sudden closing of refrigerant flow shall result in liquid hammer effect. To minimize this impact and consequent damage to the piping system, the refrigerant velocities in liquid line should not exceed 1.5 m/s.

16.2.1.1 The third consideration is migration of liquid refrigerant during the system off cycle. When the system is not operational, the piping layout shall ensure that the liquid does not migrate either to the evaporator or the compressor.

a) When the relative position of compressor is at lower elevation than the condenser, the inverted U-shaped riser should be provided at an elevation higher than the condenser;

b) When the evaporator is at the lower elevation than the condenser, once again a similar inverted U-shapes riser should be employed. It is also a good practice to employ controls such that the system is switched on only after a time delay after the evaporator pump/fan is switched on; and

c) Pump down control may be employed, particularly on the larger systems to shut off the flow of refrigerant by installation of solenoid valve so that when the system is off cycle, the most of the liquid refrigerant is stored in condenser or receiver.

16.2.2 *Piping Material*

Since the refrigerant in the system operate at high pressures, the piping material and thicknesses should be complaint with the subjected pressures. Following materials could be used for refrigerant piping.

a) Steel tubes and pipes;

b) Copper tubes and pipes;

c) Aluminium tubes; and

d) Copper alloy tubes.

NOTE — For copper tubes and pipes, When the pipes are laid in an environment where pipes may be subjected to damage, soft annealed copper tubes should be avoided.

Any other proprietary material may be used provided they are rated for the subjected pressures as well as the verified data of pressure drops is well documented.

Post installation of piping the entire piping system should be pressure tested at 1.5 times the operating high pressure and joints tested for leaks. Post the pressure testing the system should be vacuumized to a pressure of 500 microns with holding of vacuum for the period of 4 h to 6 h to ensure that all non-condensable vapours are removed from the system and any trace of remaining moisture is removed.

The suction line pipes shall be adequately insulated. The insulation thickness should be calculated minimize the heat loss as well as to avoid condensation over the surface. Hot gas line insulation may not be deployed unless the pipes are laid in an environment where the hot gas temperatures may cause burns to occupants. Liquid lines may not be insulated. However, if the equipment is with reversible cycle such as heat and cool mode, all pipes need to be insulated. The insulated pipes should be protected from possible damages as well as the ultra violet exposures.

The piping system should be adequately supported. The supporting system should not damage or compress the insulation system integrity. Alternatively, the piping may be rested on well supported continuous trays.

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16.2.3 *Refrigerant Piping Accessories*

The piping system should incorporate accessories which will either aid in proper operation of the system or may assist in trouble shooting:

a) *Oil separators* — Oil separators may be mounted in the hot gas line at the outlet of the compressor when piping lengths are excessively high or when the refrigerant velocities are on the border line. The refrigerant piping velocities however, should not be compromised;

b) *Receivers* — Receivers should be installed where the condenser volume is not adequate to store the entire refrigerant charge of the system. Receivers should be properly designed so that no flash vapor shall enter the liquid line;

c) *Filter dryers* — Filter dryers should be installed in the liquid line to ensure that all solid impurities are arrested prior to the entry of refrigerant in the expansion device. These devices also aid in removing minor amount of water vapor from the piping system that may have been left behind;

d) *Sight glass* — Sight glass may be installed in the liquid line to visualize the adequate flow of refrigerant as well as for to view adequate system dryness; and

e) *Isolation valves* — Isolation valves either in form of hand shut-off valve or solenoid valve may be installed upstream and downstream locations of filter dryer for maintenance works.

17 INSTALLATION AND COMMISSIONING OF HVAC SYSTEMS/EQUIPMENT

The installation and commissioning of HVAC systems are critical to ensuring the system operates efficiently, safely, and in compliance with design specifications. The following points outline the objectives and planning considerations for the installation and commissioning process.

17.1 Objectives

The objectives for the installation and commissioning of HVAC systems and equipment shall be to fully meet the owner's project requirements. The installation process must prioritize optimal energy efficiency, ensuring the systems operate reliably and maintain high-quality standards. Safety is a top priority, with all installations executed to the highest safety standards. Timeliness to meet project deadlines, while also ensuring the optimum life cycle cost is achieved. In addition, the systems should be designed and commissioned to minimize noise and vibration, providing a comfortable and efficient environment.

a) Shall fully meet owner's project requirements;

b) Optimal energy efficiency;

c) Reliability/Quality;

d) Safety;

e) Speed/Timeliness;

f) Optimum life cycle cost; and

g) Minimum noise and vibration.

17.2 Planning the Installation

Meticulous planning results in a trouble-free installation at optimum time and cost with little chance of wastage and rework. Planning ensures safety during installation and commissioning.

Following factors are common across all types of equipment/systems:

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17.2.1 Location of installation shall be selected with care. Location shall be such that there is adequate space to mount the equipment as well as to operate, service and maintain it. It shall be as close to the area to be served as possible. Good ventilation and natural lighting are important.

Where the installation is large, a separate utility block should be considered along with a service tunnel to house chilled and condenser water piping, electrical and control cabling and communication systems.

Equipment room floor shall be light coloured and finished smooth but non-slippery with epoxy paint coating. Where required, water proofing of plant/equipment room floor shall be done.

17.2.2 Noise generated by the equipment shall not be objectionable to surrounding spaces and any vibration generated shall not be transmitted to the building structure. Noise levels to be as per CPCB norms.

17.2.3 Equipment rejecting heat to surroundings shall be mounted in such a way that there is no obstruction to heat rejection and good ventilation and adequate top and side clearances are provided.

17.2.4 Location shall be such that proper access to material handling equipment such as crane, forklift etc is available not only during installation but also for its removal and replacement at a later date. When equipment has to be located in the basement of the building, service ramps or removable hatches shall be provided for this purpose.

17.2.5 Structure should be able to take the static and dynamic load of the equipment and transfer it to the ground.

17.2.6 Location shall be dust free and clean.

17.2.7 Equipment which needs drainage shall have the facility. For basement installations, provision shall be kept to pump out excess water from sumps provided. These sumps shall be coupled to alarms in case water level rises beyond set point. In no case shall the condensate water be left out in the open. It shall either be connected to the building drainage and if the installation is large, options for condensate recovery and re use shall be explored.

17.2.8 Locations of shafts, wall openings etc shall be planned in advance so that breakage/rework shall be avoided. Pipes may be supported from floor or ceiling slab as specified by designer. All floor and ceiling support for pipes, cable trays, ducts etc shall be suitably isolated from building structure to prevent transmission of vibration. The openings around service shafts shall be closed as specified. Openings in structural elements (beam, slab etc) shall not be made without the approval of structural engineer.

17.2.9 Equipment foundations shall be structurally designed and concrete foundation blocks shall be protected by epoxy coated angle nosing. Inertia blocks and seismic restraints shall be used where specified. Floor finish/slope shall be such that any water spillage does not stagnate around equipment foundations.

17.2.10 Fresh air intakes shall be planned taking into consideration required distance from exhaust outlets as well as other sources of contamination. All such intakes and exhausts which open outside the building shall be provided with wire mesh and bird screen on inside and louvres with rain protection or cowl piece on the outside. Where specified, intake air filters shall be used. When any duct is terminated on the roof, it shall have a swan's neck to prevent rain ingress.

17.2.11 Access to equipment rooms shall be through double leaf doors or rolling shutters of adequate width and height and fan room doors shall be airtight. Doors shall open outside and a sill provided to prevent water ingress.

17.2.12 It shall be possible to isolate equipment rooms in case of fire or distress. For provisions for compartmentation in case of fire, *see* **19**. Escape routes shall be planned and clearly marked on site.

17.2.13 All equipment/materials delivered to site shall be compared with the documented and approved specifications and found correct. Test certificates shall be sought and verified for physical properties such as thickness, malleability, test pressure etc. Where independent testing is specified, third party test reports from labs [D-3(40)] accredited shall be produced. Agreed lot sizes shall be inspected at site before use. Where factory inspection is specified, same shall be carried out as provided in contract. Agreed quality assurance plan (QAP) shall be specified and test results recorded suitably. All instruments and gauges shall be calibrated, and valid calibration certificates shall be available.

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17.2.14 All equipment's, materials and sub systems shall be cleaned prior to use. Installed sub systems such as duct and pipe work shall be cleaned as per an approved Standard operating procedure and shall be kept with all open ends suitably closed. All equipment shall be kept covered with tarpaulin /canvas cloth till they are ready to be commissioned. Shafts of electric motors and other rotating equipment, if stored for a long time, shall be rotated by hand once a fortnight so that grease applied on them do not solidify.

17.2.15 Testing of sub systems shall be carried out in sections as per an approved schematic drawing. Applicable standards and test pressures/duration of test shall be approved by the owner. Testing schedules shall be prior intimated to owner and tests shall be witnessed by owner's representative or by commissioning authority (CxA). Owner shall have the right to approve contractor's testing personnel regarding qualification and experience.

17.2.16 Number of test points for duct and pipe work shall be pre agreed between owner/CxA and the contractor. Once testing of individual sections are completed (with suitable isolation), the entire system shall be tested as a whole. Power and control cabling shall be tested as one single unit.

17.2.17 Receiving of equipment at site, its unloading, shifting to place of installation or interim storage shall be done with care and by using suitable tools and tackle. This requires advance planning and providing adequate lifting and shifting equipment at site. This is of special significance in case of heavy and bulky equipment such as chillers, fans etc to be installed in basement or building terrace. To the extent possible, heavy equipment shall be received at site only after its location of installation is fully ready and at the first instance the equipment should be located at the right place of installation. Multiple shifting of heavy equipment shall be avoided.

17.2.18 Source of power and water shall be provided as close to point of use as possible and shall be terminated with an isolator/valve. All electrical systems shall be properly grounded and electrical protections such as surge protectors/circuit breakers installed as required. When remote start/stop or control is specified, adequate provisions shall be made.

17.3 Specific Requirements for Equipment/Systems

17.3.1 *Room* (*Window*) *Air Conditioner*

There shall be an opening of adequate size in the outer wall of the room (can be a window) and a wooden frame of suitable size shall be fitted therein. The air conditioner unit shall be placed inside the frame with its outer casing firmly fitted inside the wooden frame with metal screws keeping a slope of 6 mm to 10 mm for drainage of condensate. Drain line of adequate size shall be fitted to the back of the unit. Unit shall be properly levelled and any gap between the frame and wall/window shall be sealed off. Adequately rated electric power socket with on/off switch shall be provided close to the unit. Before fixing the front grill on the unit, it shall be ensured that supply and return air openings are properly isolated and short cycling of air does not happen (*see* Fig. 17, Fig. 18 and Fig. 19).

In addition, the installation shall be as per the manufacturer specified installation requirements and instructions. In absence of manufacturer's installation instruction and requirement.

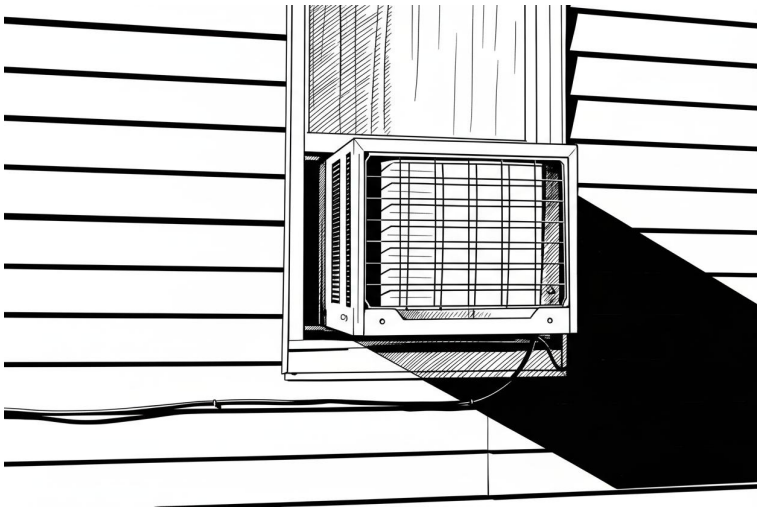

FIG. 17 ROOM AC INSTALLATION – WALL MOUNTED

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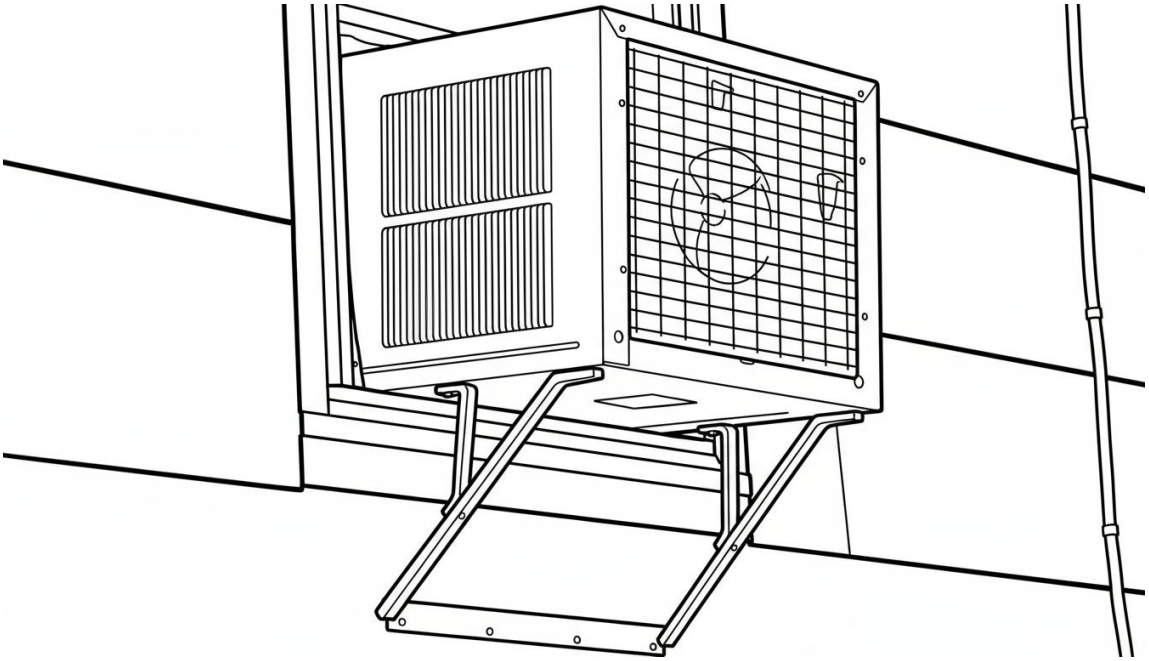

FIG. 18 ROOM AC INSTALLATION – SUPPORTED ON BRACKETS

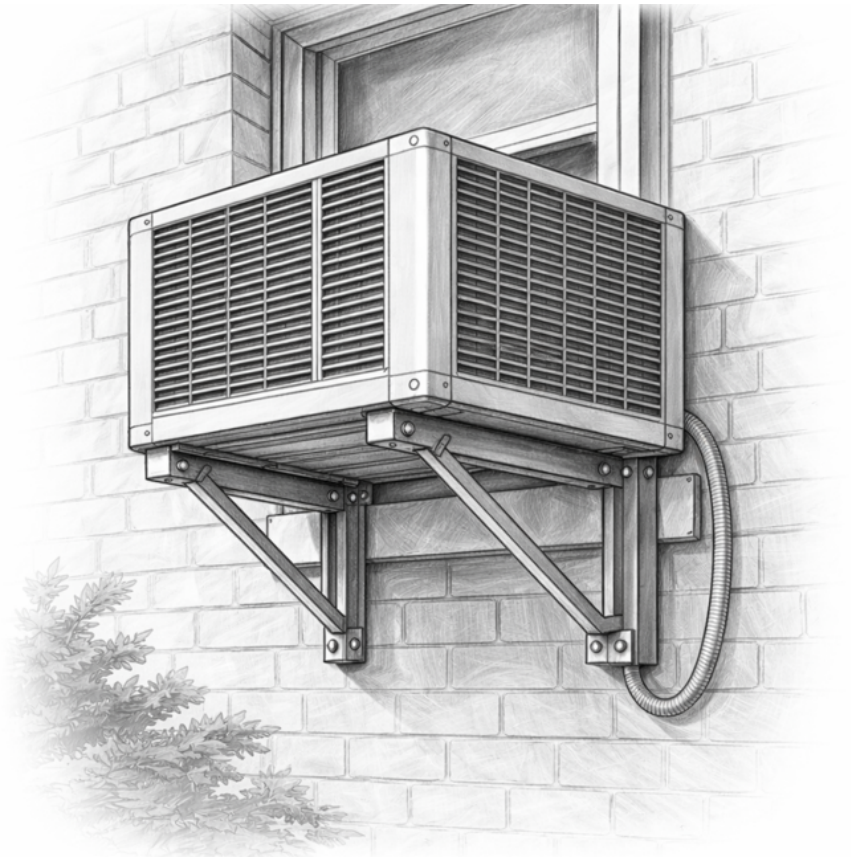

FIG. 19 WINDOW AIR CONDIONING UNIT INSTALLATION

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17.3.2 *Split Air Conditioner*

The indoor unit (IDU) shall be located in the conditioned space at a suitable location away from any obstacles to airflow. IDU shall be accessible for regular filter cleaning and maintenance. Drilled holes in the wall to locate the IDU are best located with a template and a spirit level. A hole of adequate diameter shall be drilled in the wall close to the unit (adjacent to the refrigerant pipe connection side of the unit) through which supply and return refrigerant piping (both insulated), drain pipe to remove condensate water and power cabling to the outdoor unit (ODU) shall be carried. A PVC sleeve may be used to carry the lines and the annular space between the wall and the sleeve shall be filled with caulking material or sealant (*see* Fig. 20 and Fig. 21).

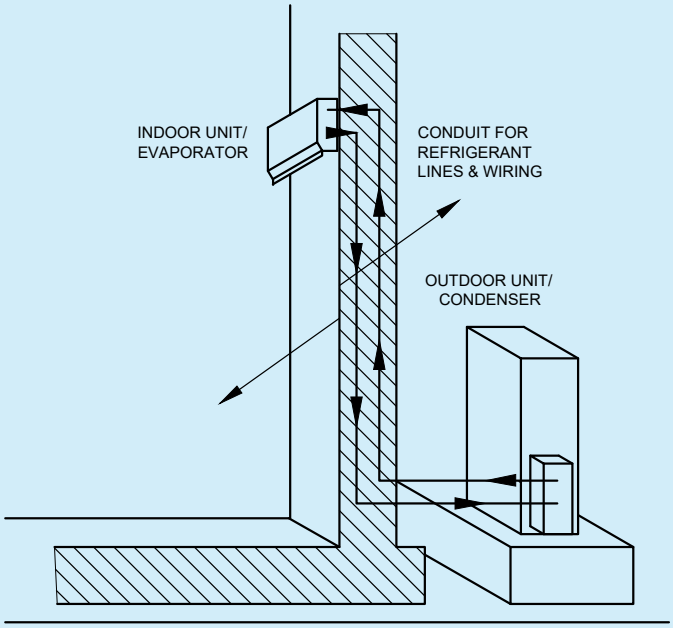

FIG. 20 TYPICAL SPLIT AC UNIT PIPING

FIG. 21 TEMPLATE FOR LOCATING SPLIT INDOOR UNIT (IDU)

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Refrigerant piping between the IDU and ODU shall be of copper with minimum number of bends and the minimum radius of each bend shall be 10 mm. Maximum piping length between IDU and ODU, difference in height between IDU and ODU and any additional refrigerant charge/lubricating oil charge that may be required shall all be specified by the equipment supplier. In cases where the IDU is located at the same level or above the ODU level, the suction line shall rise to the top of the IDU. This prevents the refrigerant liquid from migrating to the compressor during off cycle. Horizontal suction lines shall be either straight or slightly sloped towards the ODU. A refrigerant trap shall be installed at the bottom of the vertical riser (*see* Fig. 22 and Fig. 23).

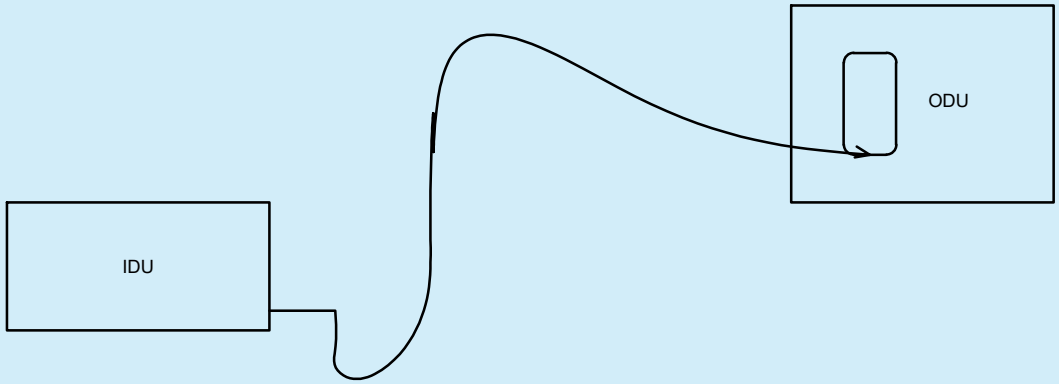

FIG. 22 SUCTION PIPE WITH U TRAP

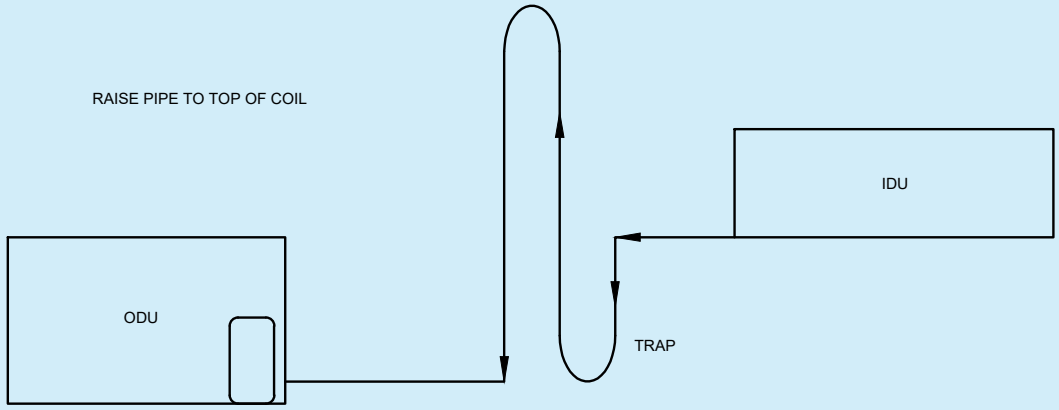

FIG. 23 SUCTION PIPE WHEN ODU IS BELOW IDU LEVEL

Where the ODU is located above the level of the IDU, a trap shall be installed at the bottom of the suction riser immediately after the IDU.

Pipes shall not be in direct contact with the building structure to prevent vibration transmission. Pipes shall be clamped to walls at suitable intervals and separation may be kept between pipe and clamp to prevent bi-metallic erosion.

ODU shall be placed on a flat firm surface which shall take the load of the unit. Vibration isolators or serrated rubber pads shall be placed below the unit. The ODU shall be located where air for cooling shall flow freely through the condenser coil. As far as possible, ODU shall not be exposed directly to sunlight. ODU shall be easily accessible for servicing. Where multiple ODUs are located, they should not face one another, and an adequate arrangement shall be made to prevent short cycling.

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Once the piping between the ODU and IDU is completed, it shall be pressure tested at 21×10^4 Kg/m^2 on the high side and 10×10^4 Kg/m^2 (or 1.5 times the maximum operating pressure) on low side for minimum 6 h. Thereafter, the system shall be evacuated and a vacuum of 500 microns of Hg shall be maintained for 6 h before refrigerant is charged. Refrigerant charge/oil charge shall be as recommended by the manufacturer.

Condensate drain from the indoor unit tray shall be planned, routed and connected to the designated drain point (*see* Fig. 24).

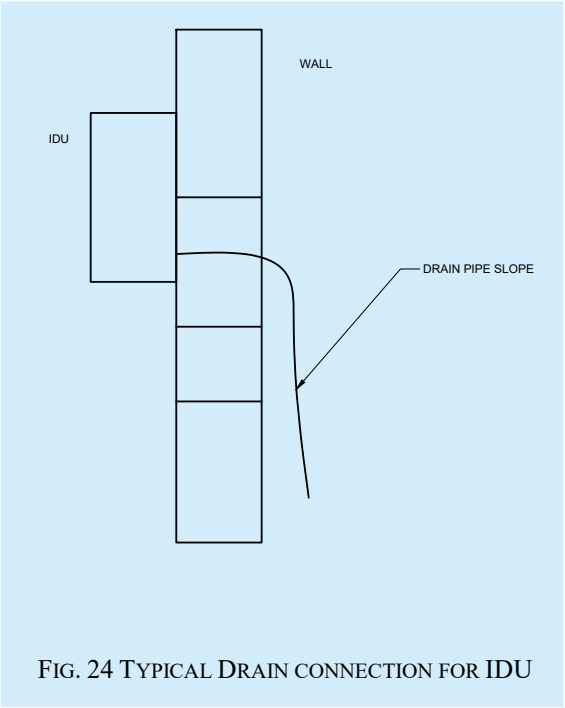

FIG. 24 TYPICAL DRAIN CONNECTION FOR IDU

Unit shall be started only by the supplier's authorised service personnel. All installation and start up checks shall be as per the manufacturer's/supplier's documented SOP.

In addition, the installation shall be as per the manufacturer specified installation requirements and instructions. In absence of manufacturer's installation instruction and requirement.

17.3.3 *Variable Refrigerant Flow (VRF) Systems or Multi Split Units*

All requirements detailed in **17.3.2** shall apply (*see* Fig. 25).

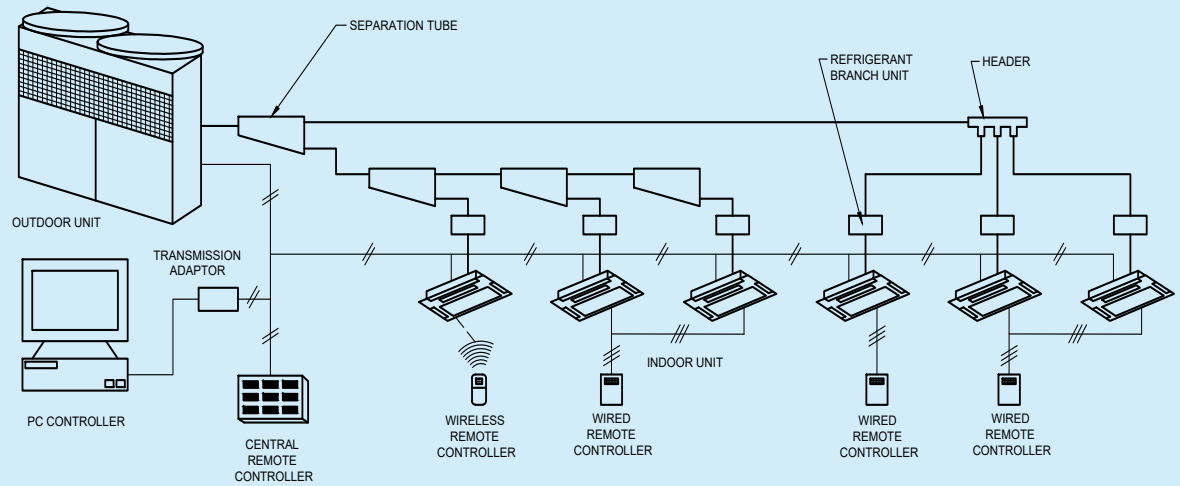

FIG. 25 TYPICAL VRF CONFIGURATION.

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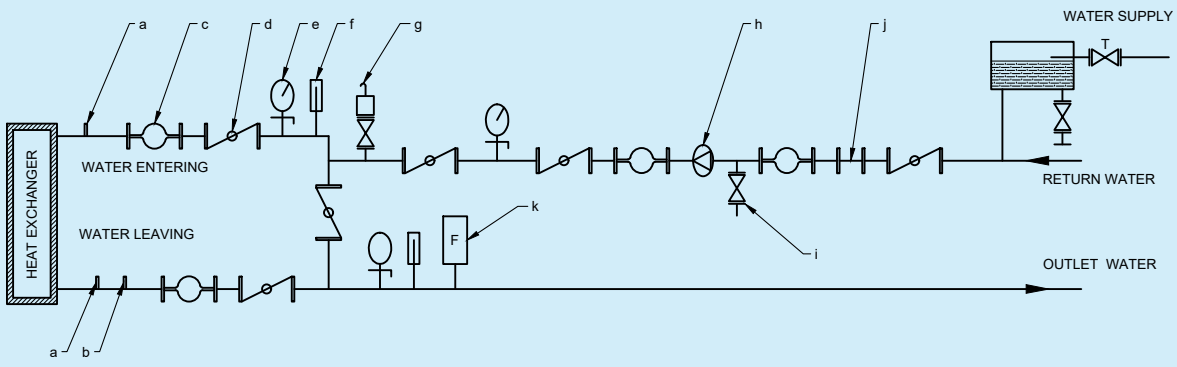
Since the same (set of) outdoor units serves multiple indoor units with varying lengths of piping, charging the correct amount of refrigerant and lubricating oil is important and manufacturer's instruction shall be followed. Communication wiring between all indoor units and the corresponding ODU shall be connected as per the manufacturer's instructions and communication cable shall be away at a distance minimum 300 mm to avoid interference.

Allowable length of refrigerant piping and height between various IDUs and between IDU and ODU shall follow manufacturer's specification. Ball valves shall be installed for zoned refrigerant isolation. Evacuation shall be possible at each IDU and ODU. Start up by manufacturer/installer's authorised personnel shall include configuring and setting up of all control devices.

17.3.4 *Chiller* (*Air Cooled and Water Cooled*)

Chillers are heavy and built with either rotating or reciprocating equipment. adequate foundation system shall be provided to transfer the load to ground thru beams/columns and this shall be done in consultation with structural specialist. Dynamic loading shall be considered while designing the structure and shall be as per the accepted standard [D-3(41)]. Vibration isolation mounts or serrated rubber pads (as recommended by manufacturer) shall be placed between the chiller frame and the foundation. Where open type compressors are used, the alignment of the compressor with its motor shall be checked with a dial gauge (*see* Fig. 26).

Piping connections to the chiller shall be made only after the chiller is finally located in place and levelled. Piping ends shall have offsets for flexibility and piping shall be supported independent of the chiller. Coolers and condensers shall be connected through victaulic/equivalent couplings and suitable flexible connections as recommended by the manufacturer. Provision for fixing temperature sensor and pressure gauges shall be made immediately after the condenser and cooler at a distance of minimum 150 mm from the outlet.



a	TEMP. SENSOR	b	THERMO SWITCH	c	SHOCKPROOF JOINT
d	BUTTERFLY VALVE	e	PRESSURE GAUGE	f	THERMOMETER
g	AUTOMATIC AIR RELIEF	h	WATER PUMP	i	DRAIN VALVE
j	Y - SHAPE FILTER	k	WATER FLOW SWITCH		

FIG. 26 TYPICAL CHILLER PIPE CONNECTIONS.

Temperature at the location where chiller is installed shall be within the limits specified by the manufacturer. Where air-cooled chillers are installed open to atmosphere, a suitable cover over the roof panels is recommended. All electrical enclosures in case of open installations shall be IP 55 or higher as per accepted standard [D-3(42)]. Space for air circulation, people movement and maintenance shall be provided on all four sides.

Where the chiller is mounted above grade, a structural steel platform, capable of supporting the dynamic load of the chiller, shall be provided. A maintenance platform providing access to all parts requiring maintenance/ attention shall also be provided. Service space shall include space for tube cleaning or for attaching the tube cleaning device.

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Electrical isolation shall be provided not more than 2 m away from the chiller. Floor drain and water supply point near to the chiller shall be planned. Where accessories to chiller such as expansion tank, air separator unit etc are to be located in the plant room, adequate space for installing and servicing them shall be planned.

Where chillers are located inside the building, floor to floor height of the plant room shall be adequate to house the piping, valves, strainers etc. Height ranging from 3.6 m to 4.5 m is recommended depending on chiller type. A guide rail arrangement is recommended over the chiller for easy removal of components in case of failure. The chiller concrete foundation base should be 150 mm to 200 mm above floor level.

17.3.4.1 Quality of water used for condenser circulation and chilled water make up greatly influences chiller performance as well as chiller life. Make up supply of soft water may be provided at a suitable height above the chiller allowing flow by gravity. Manufacturer's recommendation in this regard shall be strictly followed even for the water used for pressure testing and commissioning. The Table 39 should be referred for the water quality requirements.

Table 39 Water Quality Requirements

(*Clause* 17.3.4.1)

Sl No.	Properties	Limit	Circulating Chilled Water	Make up Water (Chiller)	Condenser Water
(1)	(2)	(3)	(4)	(5)	(6)
i)	Total hardness as CaCo3	*Max*	80	50	200
ii)	Total alkalinity as CaCo3	*Max*	100	80	100
iii)	Chloride ion, ppm	*Max*	50	50	200
iv)	Iron as Fe, ppm	*Max*	0.3	0.3	1.0
v)	Silica as SiO2, ppm	*Max*	30	30	50
vi)	Ammonia, ppm	*Max*	0.2	0.2	1.0
vii)	*p*H	*Min* to *Max*	7.2 to 8.5	6 to 8	7.2 to 8.5

17.3.5 *Packaged Air Conditioner (Air Cooled and Water Cooled)*

Installation of water-cooled packaged air conditioners (PAC) shall be similar to installation of water-cooled chiller whereas installation of air-cooled chiller shall generally follow the installation guidelines for split air conditioners as detailed in **17.3.2**. Following additional points are specific to PAC installation

a) While lifting and hoisting the unit with a sling, spreader bars shall be used to prevent damage to sides and top;

b) In respect of air-cooled PAC where piping length is more than 7 m, additional refrigerant/oil may require to be charged;

c) Unit connections shall be through reinforced flexible connector;

d) Condensate drain with a water trap shall be installed next to the access panel of the unit; and

e) Pre-filters shall be anti-bacteria and shall be washable. Unit shall not be operated without filter in place.

17.3.6 *Pumps*

17.3.6.1 Pump base frame shall be mounted on an adequately sized concrete block and there shall be cork or serrated rubber pads or anti-vibration mounts between the concrete block and plant room floor and shall be as per the accepted standard [D-3(41)]. Load shall be transmitted to beam or column as per advice of structural engineer.

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17.3.6.2 More than one pump shall not be installed on a single base frame or concrete block. Factory supplied pumping systems mounted on common base frame is an exemption to this.

17.3.6.3 Foundation bolts where required shall be embedded correctly. Before grouting the bolts, the level of the base frame shall be checked.

17.3.6.4 Pump motor shall be mounted on the base frame, alignment checked and then only coupled with the pump shaft. Pump shall not run without its coupling guard. Pump alignment shall be checked once again after completing the suction and discharge piping in order to ensure that alignment is not disturbed after connecting the piping.

17.3.6.5 Before being test run, the pump shall be lubricated as per manufacturer's instructions.

17.3.6.6 Suction and discharge lines shall be supported independent of the pump and shall be connected to the pump through flexible connectors. Isolation valves shall be provided on both sides (suction and discharge). Provision for pressure gauge connections at the inlet and outlet of the pump shall be made (*see* Fig. 27).

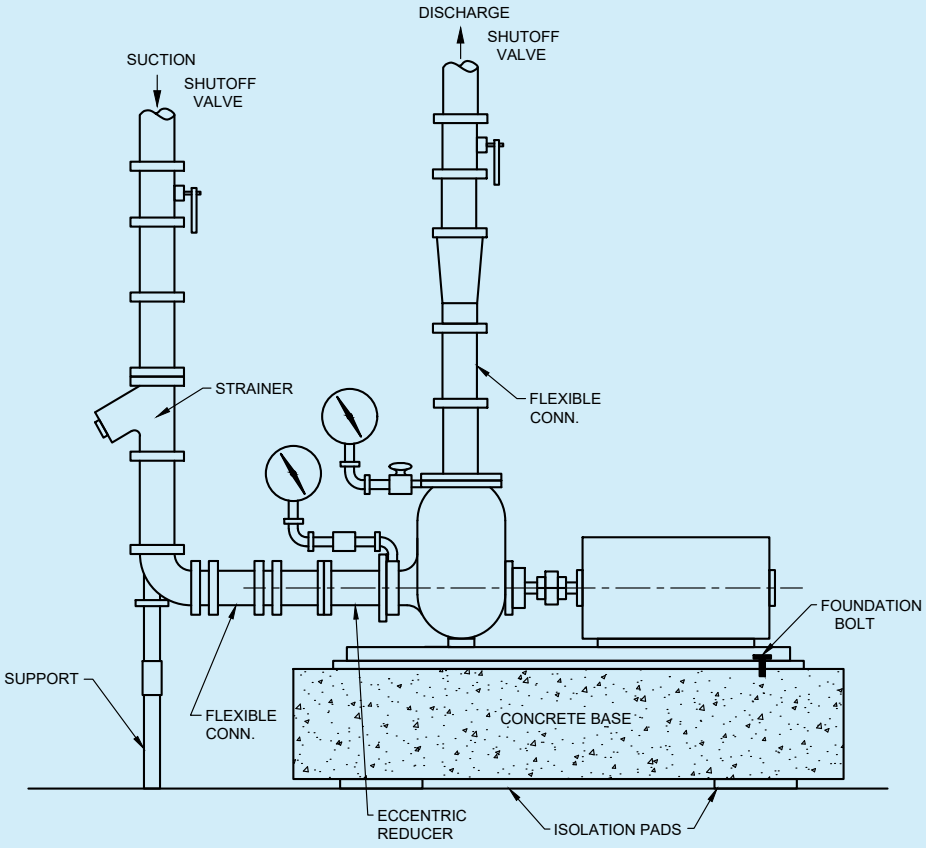

FIG. 27 TYPICAL PUMP INSTALLATION DETAILS.

17.3.6.7 In-line pumps may be installed directly in the piping with pipe hangars adequately sized to handle the load of the pump and piping. For larger size in -line pumps, a flange support or floor support with saddles shall be used. All supports to floor and ceiling shall be vibration isolated.

17.3.6.8 Correct direction of rotation of the pump (which shall be indicated on the housing) shall be checked before start up.

17.3.6.9 A factory installed drain connection with a site fitted installation valve shall be used to drain the pump reservoir.

17.3.6.10 Where low temperatures are encountered, freeze up precautions shall be taken.

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17.3.7 *Cooling Tower*

17.3.7.1 Cooling tower shall be located in such a way that noise as well as water drift are not objectionable. Tower location should not be close to leaf shedding trees.

17.3.7.2 Location shall be open and well-ventilated and manufacturer's instructions regarding side clearances for air circulation shall be meticulously followed.

17.3.7.3 If located on building terrace, the operating load shall be transferred to beams/columns as per advice of structural engineer. Cooling tower shall rest on adequately sized MS I-sections. These I-sections shall be hot dip galvanized to accepted standard [D-3(43)]. All welded joints shall be primer with corrosion resistant coated such as epoxy. Vibration isolation shall be provided between tower and the MS I-Sections.

17.3.7.4 Installation shall be such that the space below the cooling tower shall accommodate a strainer below the water level in the sump as well as a drain pipe with a valve. It shall be possible to completely drain the cooling tower sump when required (*see* Fig. 28).

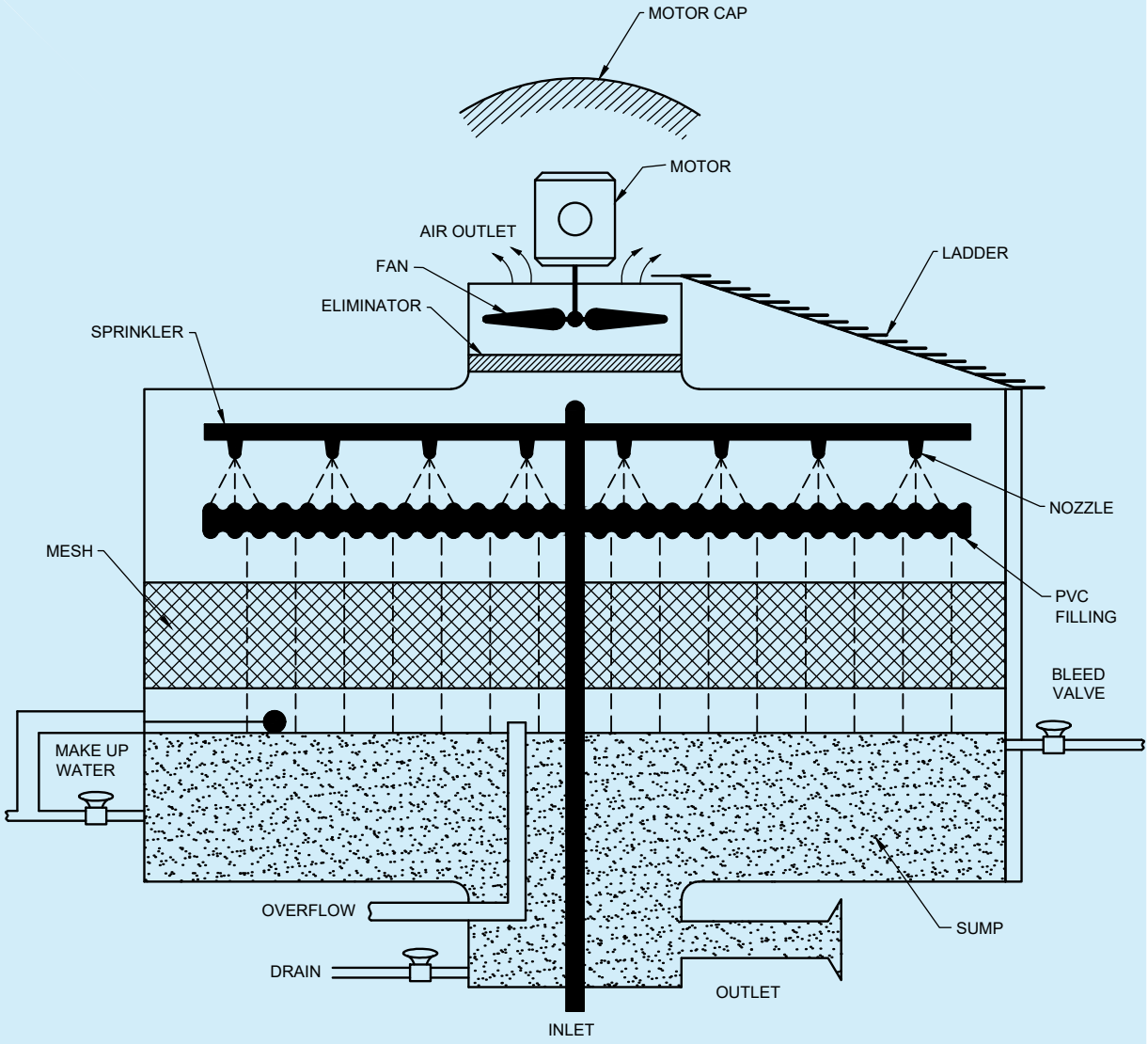

FIG. 28 TYPICAL COOLING TOWER INSTALLATION

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17.3.7.5 A service platform may be constructed beside the tower so that all parts requiring cleaning or maintenance are easily accessible. Slope of the floor below the tower shall be such that water does not stagnate below the tower.

17.3.7.6 Make up and quick fill connections shall be done and uninterrupted water supply shall be made available. For water quality, water treatment and bleed off, refer 7.4.

17.3.7.7 In case of multiple cooling tower installation at the same location, equaliser connections shall be provided. In case the pumps are at the same location as the cooling tower, the cooling tower sump shall be minimum 300 mm above the pump suction to ensure positive pressure while starting the pump. The cooling tower basin shall be leak tested by filling up with water and holding it for minimum two hours.

17.3.8 *Air Handling Units* (*AHU*)/ *Heat Recovery Units* (*HRU*)/ *Fan Coil Units* (*FCU*)

Air handling units shall be either floor mounted or ceiling mounted. AHUs and FCUs shall be located close to or with in the area to be air conditioned so that duct runs are minimum. Location shall take into consideration the feasibility of running ducts, taking back return air to the unit (either through return air ducts, above the false ceiling or directly into the unit as well as provision of chilled water connections, provision of humidifiers, fresh air inlet as well as drain connections.

In a multi-storied building, it is advisable to locate the AHUs on above the other on each floor so that piping shall rise through the same shaft.

From fire safety considerations, individual AHUs shall not serve more than one floor. Similarly, it is advisable to have exclusive AHU for each fire compartment. In case, these are not possible, fire and smoke dampers shall be fitted on both the supply air and return air paths where floor crossing or fire compartment crossing takes place. Provision for pressure gauge and thermometer connections shall be made at inlet and outlet piping connections.

AHU/FCU shall be mounted in such a way that both the mechanical noise as well as the air noise does not disturb the occupants. This is specially emphasised for ceiling-suspended units. Duct mounted silencers and acoustic lining of supply air duct may be provided as specified. AHU/FCU shall not be mounted above electrical or IT rooms where water leakage shall lead to serious problems.

Adequate maintenance and service space shall be provided around AHU/FCU and trap doors for convenient access shall be available. Lamps inside the unit, belt guards, sight glass and door interlocks shall be ensured (*see* Fig. 29).

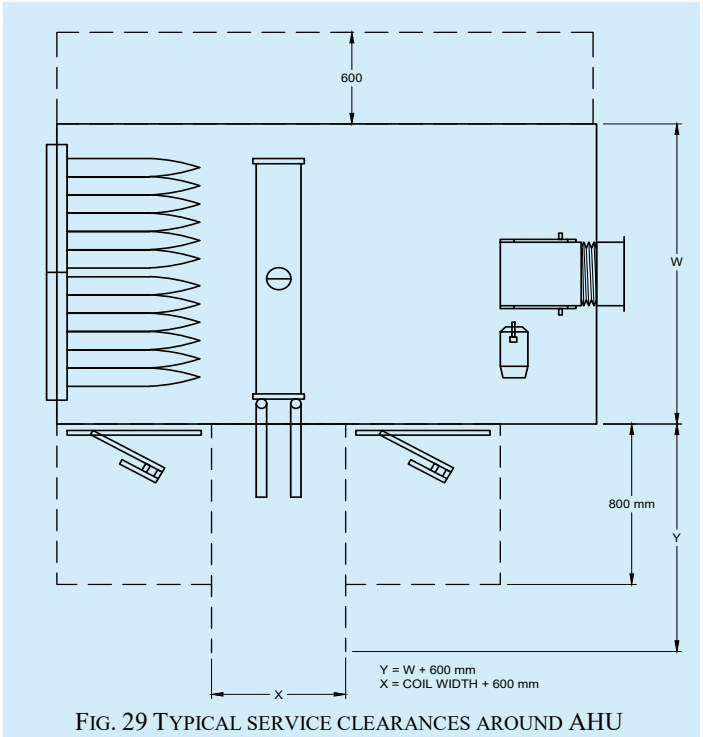

FIG. 29 TYPICAL SERVICE CLEARANCES AROUND AHU

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Floor mounted AHU/heat recovery unit shall be mounted on top of pre-cast concrete block to permit easy drainage of condensate and to facilitate cleaning below the unit. Such supports shall be adequate in number and also located suitably so that transfer of dynamic load to structure safely takes place. Serrated rubber pads or other vibration isolation material shall be placed between the AHU/HRU frame and the concrete support. Insulated condensate drain connection shall be with a U- trap and the floor slope shall be towards the floor drain. Slope of the drain pan connection shall also be towards the drain pipe connection. Chilled water piping to AHU shall have a manual air vent at the top most point in the coil circuit and a drain plug at the bottom of the coil (*see* Fig. 30).

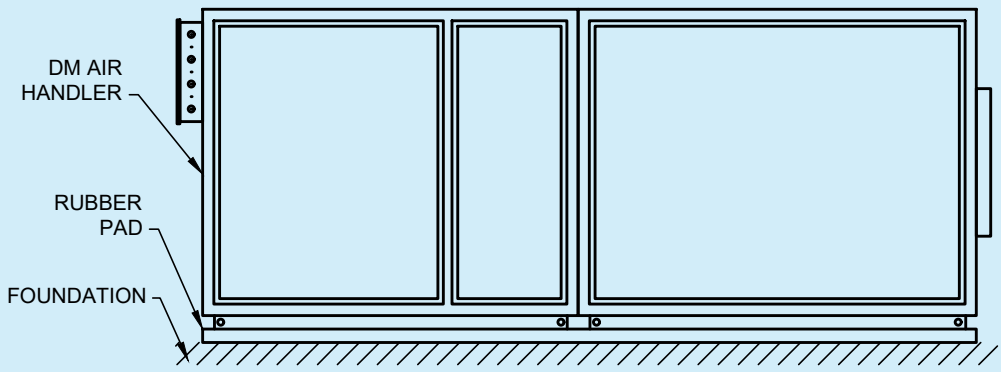

FIG. 30 AHU LOCATED ON FOUNDATION

Ducts shall be connected to the AHU/HRU with fire-proof connections to prevent transmission of vibration. Ceiling suspended AHUs/FCUs shall be hung from the ceiling with adequately sized rod and fasteners and shall be isolated from the structure by rubber or spring isolators. Illumination near the unit, drain point, water supply point and floor drain shall be provided.

17.3.9 *Air Washer Units* (*AWU*) *and Evaporative Cooling Units* (*ECU*)

Installation of AWU and ECU are similar to that of floor mounted AHU/HRU. They will have additional water connections to the spray- section with in-line recirculating pumps. Air washer units shall be preferably located on the summer wind-ward side. They shall be painted with reflective coating or thermally insulated. Large size air washers may be constructed with concrete basin. These shall have leak proof access doors as specified and basin shall be tested for water proofing integrity.

17.3.10 *Fans – Centrifugal, Axial Flow and Cabinet Type*

Fan performance is influenced by inlet and outlet conditions. 'Fan System Effect' which is the impact on fan performance due to inlet and outlet conditions as well as ways to mitigate them are described in **14**.

While rigging and hoisting heavy fans, manufacturer's instructions shall be carefully followed since the load is not uniformly distributed around the periphery.

Dynamic load of the fan, its distribution at different supporting points, vibration and noise shall be taken into account while designing the fan foundation.

Outlet connection to a duct (if provided) shall be by means of flexible fire-retardant connections.

17.3.10.1 *Centrifugal fans*

Where foundation bolts are provided, they shall be securely placed along with base plates while foundation is cast. Alternatively, fan may be mounted on suitable channel frame.

Vibration isolation base for fan and motor shall be an integral unit and shall be mounted on concrete foundation with anti-vibration mounts.

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Safety screen shall be provided on fan suction side. Belt guard/coupling shall be provided and fan shall not be started without these protective devices.

17.3.10.2 *Axial flow fans*

Removable safety screens shall be provided on either side of the fan. Fans shall be properly grouted on the walls with vibration isolation material. Where the fan is suspended from the ceiling, vibration isolators shall be used.

17.3.10.3 *Cabinet fans*

A door interlock switch which shuts off the fan and switches on a bulk-head lamp mounted within the cabinet shall be provided. A water drain point shall also be provided within the cabinet. Transparent inspection windows of minimum 150 mm dia shall be provided.

17.3.10.4 For all type of fans, the sound generated is a major consideration which shall be taken care during the design/selection stage itself. Additionally, as specified by the fan manufacturer or system designer, acoustic silencers shall be mounted at inlet and outlet of the fan. Bird screen shall be provided at fresh air intake points and at exhaust outlet.

In all cases, adequate space for service and maintenance including removal and replacement of motor shall be provided.

Direction of rotation shall be verified on startup and field balancing shall be done where required. An electrical isolator or a push button switch shall be provided adjacent to the fan.

17.3.11 *Air Distribution and Ducting*

17.3.11.1 *Duct supporting/hanging systems*

Duct hanging system shall have three parts: Upper attachment to the building, the Hanger and Lower attachment to duct.

Upper attachments shall be concrete inserts which are cast into the structure, threaded concrete fasteners which are inserted into the cast slab or structural steel fasteners. Upper attachment method shall be selected with care and a safety factor of 5 is recommended. In case of steel structure, careful selection of primary and secondary supporting to be done on case-to-case basis.

Hangars shall be strips of galvanized steel or threaded round steel rods. Threaded portion of the rods shall be painted after installation.

Lower attachment is the connection between the hangar and duct section. Fasteners that penetrate the duct shall be sheet metal screws or rivets. All nuts, bolts and washers shall be zinc plated steel. Rivets shall be galvanized or made of magnesium-aluminium alloy.

Where ducts shall not be supported from the ceiling, wall brackets or other suitable support arrangements may be used.

Neoprene or other vibration isolation material of minimum 6 mm thickness shall be inserted between the ducts and the angle iron supports/brackets. Vertical ductwork shall be supported at each floor by suitable structural steel members.

Plenums where provided shall have access doors of 450 mm × 450 mm. Support details for different duct section is given in Fig. 31.

Supporting details for rectangular ducting for static pressure up to 750 Pa are given in Table 40 and for static pressure above 750 Pa are given in Table 41. Supporting details for low pressure (Up to 750 Pa) rectangular ducting system are given below:

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Table 40 Supporting Details for Low Pressure (Up to 750 Pa) Rectangular Ducting System

(*Clause* 17.3.11.1)

Sl No.	Larger Side of Duct	Supporting Angle	Vertical Rod Diameter	Maximum Spacing between Supports
	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)
i)	Up to 900	40 × 40 × 5	8	2 400
ii)	901 to 1 500	40 × 40 × 5	8	2 400
iii)	1 501 to 2 400	40 × 40 × 5	10	2 400
iv)	2 401 and above	65 × 65 × 5	12	2 400

Table 41 Supporting Details for High Pressure (Above 750 Pa) Rectangular Ducting System

(*Clause* 17.3.11.1)

Sl No.	Larger Side of Duct	Supporting Angle	Vertical Rod Diameter	Maximum Spacing between Supports
	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)
i)	Up to 1 250	50 × 50 × 5	12	2 400
ii)	1 251 to 2 100	65 × 65 × 5	12	2 400
iii)	2 101 and above	75 × 75 × 5	15	2 400

Alternatively, slotted galvanized brackets attached to the top two bolts of the four-bolt duct connector shall be used.

For round, oval and flexible ducts, galvanized steel straps, wire or rods shall be used and support details shall be as provided by manufacturer/installer and approved by Engineer-in-Charge.

Sheet metal ducts shall be fabricated from galvanized iron sheets with minimum 180 GSM zinc coating and of lock forming quality. Fabrication of ducts shall be carried out at a factory from coil stock or at site from cut sheets. Where the overall duct area for the project exceeds 600 m^2 or where the external static pressure exceeds 250 Pa, lock forming machines shall be used for fabrication.

17.3.11.2 *Pre-insulated ducts*

Pre-Insulated duct made of polyisocyanurate sandwich panels comprising of a rigid foam board faced on both sides by stucco embossed aluminium foil shall be joined with tiger connectors or with male-female jointing system up to 500 mm. Higher sizes shall be joined by cover corners which has a holding pin which goes inside the flange. Ducts shall have suitable fixtures made of polymer plastic or extruded aluminium for jointing as well as for fixing of accessories such as grills, diffusers etc. Duct work shall be installed using supports as specified by the manufacturer.

17.3.11.3 *Fabric ducting*

Tools and accessories for installation shall be provided by the Fabric duct supplier. Fabric duct shall be connected to fan/AHU with GI duct connectors. While laying the duct, care shall be taken to prevent twisting of the fabric. A ratchet strap may be used to secure the fabric to duct connector.

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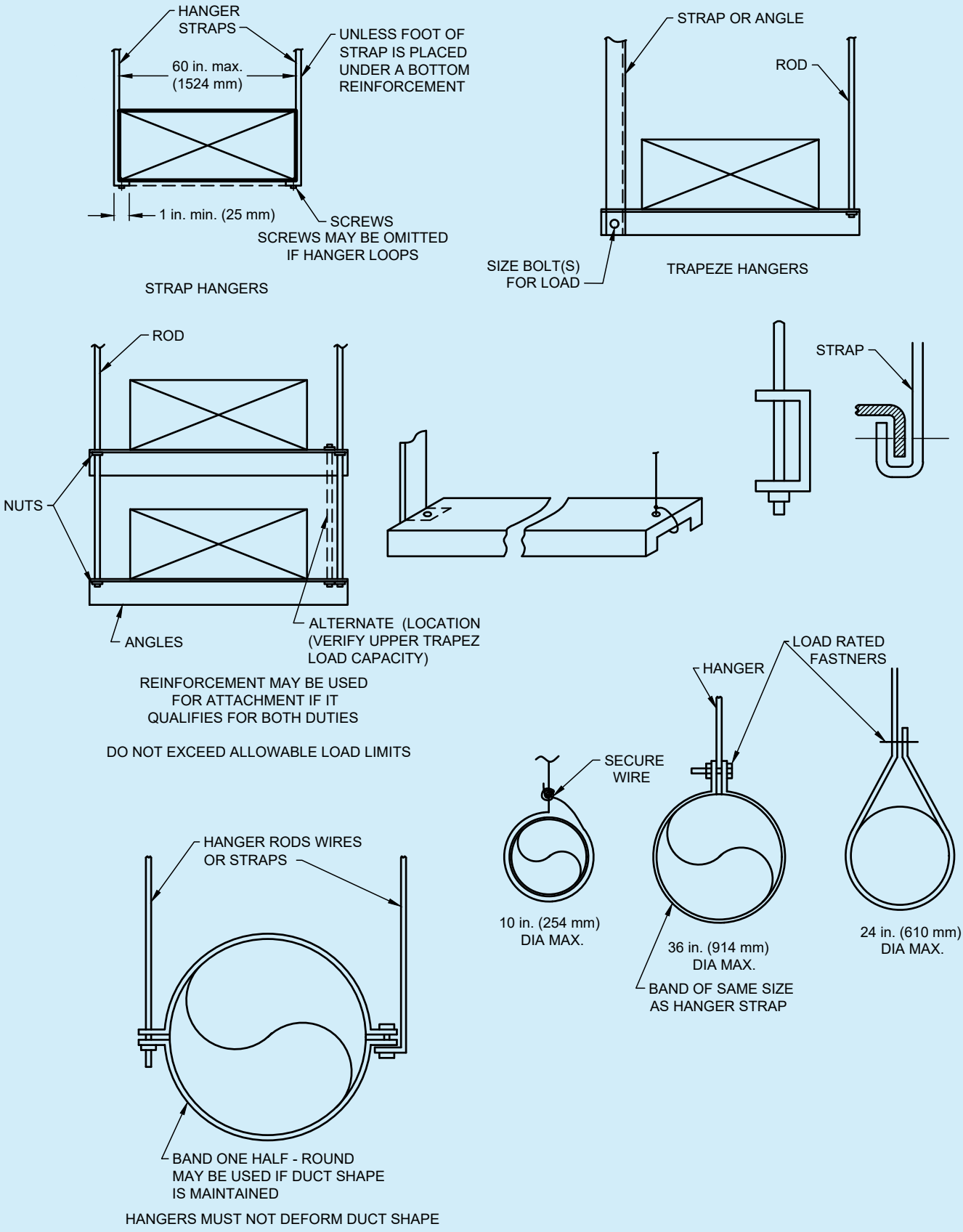

FIG. 31 SUPPORT DETAILS FOR DIFFERENT DUCT SECTIONS

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17.3.11.5 Where duct penetrates brickwork or masonry openings, treated wooden framework shall be provided within the opening and the crossing duct shall be provided with heavy flanged collars on either side of the wooden frame so that the duct crossing is made leakproof. Alternatively, the duct section passing through the structure may be suitably wrapped so that vibration is not transmitted to the structure. Where duct passes through a fire compartment barrier, a fire barrier shall be created by installing a fire cum smoke damper.

17.3.11.6 When fans feed into a duct system, uniform straight flow conditions shall be ensured. Fan manufacturer's recommendation in regard to straight length of connecting duct both at inlet and outlet of the fan to obtain optimum fan performance needs to be followed. Similarly, pressure loss in a duct elbow or a volume control damper is minimum when air approaching the elbow/damper has a uniform velocity profile and positioning the elbow/damper after an adequate straight piece of duct is recommended. All elbows shall have adequate number of turning/guide vanes to ensure uniform air flow over the entire cross-section.

17.3.11.7 When duct is connected to an air handler or a fan, flexible connections made of rubberised canvas and 100 mm long shall be used between duct and AHU/fan and shall be securely bonded and bolted to the unit casing as well as the duct to prevent air leakage.

17.3.11.8 Turning vanes shall be provided at supply air outlet collars and at branch take-offs. They shall be fabricated from minimum 0.8 mm galvanized steel sheet and equally spaced on side runner and riveted or bolted to the duct (*see* Fig. 32).

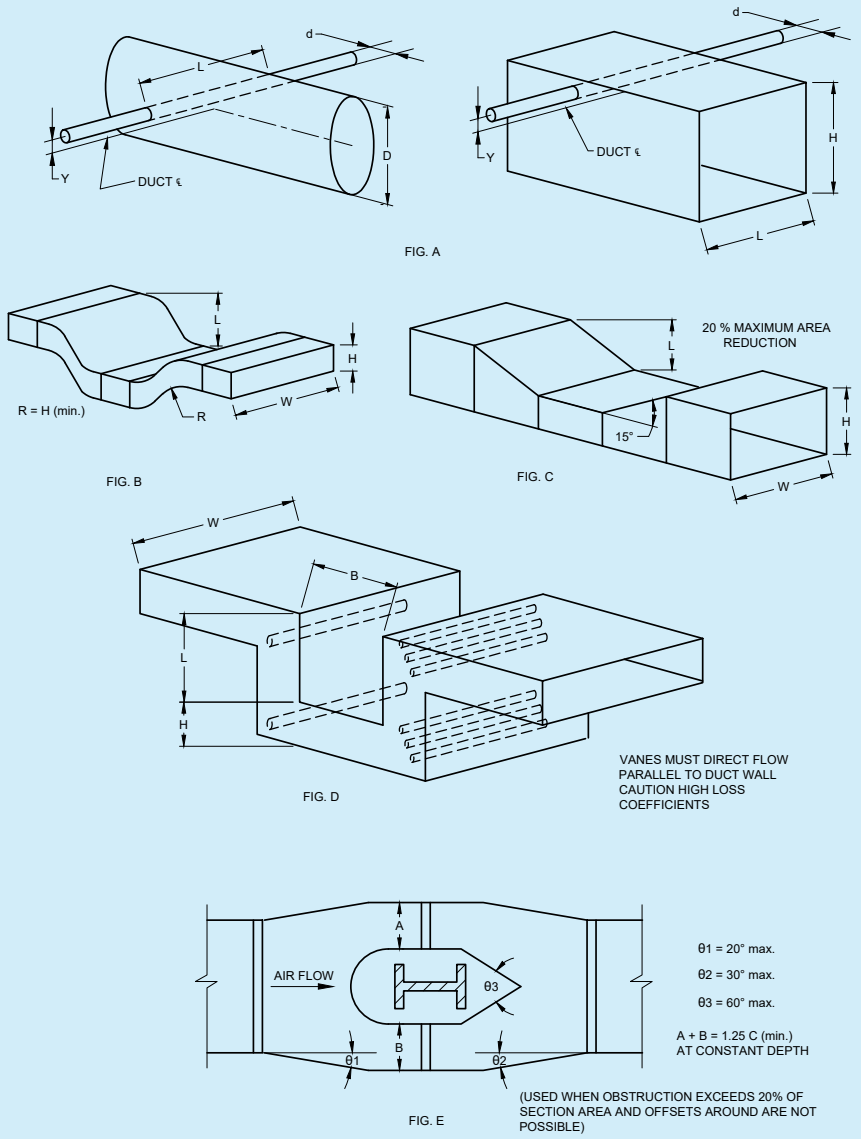

FIG. 32 TYPICAL TURNING VANES

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17.3.11.9 Take offs allow air from main duct to be diverted to branch ducts and take offs are fitted into circular or rectangular openings cut into the wall of the main duct and small metal tabs cut at the start of the take-off are bent to connect the take off to main duct. Alternatively, a snap-in attachment with an adhesive foam gasket shall be used, outlet of the take-off connects to branch duct.

17.3.11.10 Dampers shall be manually controlled or automatic. Dampers shall be rated for operation against 1.5 times the rated pressure class of ducting. Suitable links, levers and quadrants shall be provided for proper operation, control and setting of the dampers. Linkages shall be blade to blade and concealed in a jamb out of the airstream. Every damper shall have an indicating device showing the damper position and a locking device. Where Dampers are operated via an external gear train, these are to be constructed out of engineering polymers with self-lubricating properties, and, located out of the air stream. Leak resistant access doors next to the dampers shall be provided to facilitate attending to the dampers and duct cleaning.

17.3.11.11 Splitter dampers shall be installed in branches where a split takes place. They shall be made of aerofoil blades of minimum 1.6 mm thickness and hinged at downstream edge. Operation rod shall be accessible from outside with an airtight hub and locking screw. Splitter damper shall be enclosed in sheet steel ducting with flange at both ends and shall be aligned with the main ducting. Damper section shall be made of one size higher thickness than the upstream duct.

17.3.11.12 Louvre dampers shall be provided in all branches they shall be multiblade type of aerofoil construction or in triple vee grove construction, rotating in lubricated ball/roller bearings/delrin bushes. Blades shall be connected by a linkage for simultaneous operation by a rod extending outside the duct and terminating in a locking quadrant with damper position indicator. Damper shall be enclosed in sheet steel box made of one size thicker than upstream duct and shall have flanges at both ends for connecting to main duct.

17.3.11.13 Fire dampers and combination fire and smoke dampers shall be installed wherever a fire compartment barrier exists. They shall be installed in ducts, return air passages and at all floor crossings. Access door shall be provided for each fire damper. Fire dampers may be motorized (activated by an electrical impulse from the fire alarm panel or a thermal trip element) or operate on a fusible link and shall shut off airflow completely. Wiring from AHU panel to the damper (in case of electrically operated damper) shall be carried out by damper installer. Dampers shall be suitable for vertical or horizontal mounting. Damper shall be installed maintaining fire integrity of the partition and all dampers at wall/floor crossings shall have a factory fitted sleeve. In such cases, the damper shall be a free float and the annular space shall be free to allow for expansion through a smoke seal. *See also* Part F 'Fire and Life Safety' of this NBCS.

17.3.11.14 Any type of electrical heaters shall not be mounted inside ducts. The electrical heaters shall be allowed to be installed in locations identified and approved by competent authority.

17.3.11.15 Variable air volume (VAV) boxes shall be installed at specified locations. They may be supported from floor, wall or ceiling as specified and may be mounted in vertical or horizontal direction. Boxes shall be factory set for minimum airflow of 10 percent and maximum airflow of 110 percent of design flow. Access to the box shall be from below and shall be completely sealed but easily removable. Electrical supply point with an isolator shall be provided by others and step-down transformer wherever needed shall be part of the unit.

17.3.11.16 Grilles, diffusers and registers act as terminal units for supplying air from the duct system to the room or for collecting back air from the room either to exhaust or for return to AHU/fan. Terminal units may be fitted with air filters. Square or rectangular wall outlets shall have a flanged frame with outside edges turned and fitted with a flexible gasket between the concealed face of the flanges and the finished wall face. Core of supply air register shall have adjustable front loves parallel to the longer side capable of deflection and adjustable back louvres parallel to shorter side to achieve horizontal spread of air up to 45°. Outer framework shall be made of 1.6 mm minimum thickness of aluminium sheet and louvres shall be of aero foil design of extruded aluminium section with minimum thickness of 0.8 mm. The vane ratio (ratio of gap between the vanes and vane depth) should not be less than 1 and should not exceed 1.2.

17.3.11.17 Square and rectangular ceiling outlets /intakes shall have a flange flush with the ceiling on which it is fitted. Outlets shall have an outer ring with duct collar and removable core assembly. Inner as well as outer rings shall be minimum 1.1 mm thick and diffuser assembly shall be 0.8 mm thick extruded aluminium section. Circular ceiling outlets shall be either flush or with an outer cone. Flush cones shall have the lower edge not more than 5 mm below the finished ceiling. All outlets/inlets shall be designed to reduce dirt deposit on the ceiling adjacent to the outlet.

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17.3.11.18 Linear diffusers shall have a flanged frame with the outer edge turned 3.5 mm and shall have 1 to 8 slots as specified in design. These shall be constructed out of 1.6 mm thick extruded aluminium sheet. All supply air outlets shall have volume control device made of extruded aluminium.

17.3.11.19 Locations of air outlets and intakes shall be shown in the drawing and necessary openings and the wooden framework for fixing the grilles/diffusers shall be provided by the contractor.

17.3.11.20 While installing fresh air intakes, no fixing device shall be visible from the face of the frame. Where louvres are to be fixed to brick, masonry or concrete, fixing shall be with expanding plugs or raw plugs. Where louvres are to be fixed to wood or metal, nonferrous screws or bolts shall be used. A flanged frame made of rolled steel sections shall be provided on the front face to cover the gap between the louvres and the adjoining wall face. Frame shall be structurally rigid and corners shall be welded. Where the louvre length exceeds 1 250 mm additional intermediate and equally spaced supports shall be provided to prevent sagging/vibration. Louvres shall be made of 1.6 mm thick 100 mm wide extruded aluminium sections and fitted in an extruded aluminium frame. A bird screen made of 12 mm mesh in 1.6 mm steel wire held in angle or channel frame shall be fixed to the rear face of the louvre frame. Louvres shall be fixed 45 degrees to vertical and shall provide 60 percent minimum net opening. Louver design and spacing shall ensure that there is no water ingress and the lowest louver shall be suitably overlapped to prevent water being drawn in.

17.3.11.21 Test probes which shall be installed at every fan discharge and suction duct shall be of heavy-duty zinc alloy casting. Expansion plugs shall be neoprene and capable to withstand 80 °C and 300 kPa pressure.

17.3.11.22 Kitchen exhaust ducting shall be of 16 G MS CRCA sheets and shall be of welded construction. Access doors shall be provided at 3 m intervals and the duct shall have a mild slope towards the kitchen hood. Laundry and dish washer extract ducts shall be of air and watertight construction and shall be of Aluminium sheets in accordance with accepted standard [D-3(44)]. Gasket used to be fire rated. Access doors to be provided at regular intervals and at critical points. The ducting shall be wrapped with high temperature grade EPDM, nitrile rubber or with fire wrap.

17.3.12 *Filters and Air Cleaning Devices*

The installation and commissioning of filters and air cleaning devices require strict adherence to these guidelines to ensure optimal performance and safety.

17.3.12.1 Filter elements shall be kept stored in original packing till they are ready to be installed with all upstream areas such as AHU rooms and upstream ducting is cleaned and made dust free.

17.3.12.2 Filters shall be installed with directional arrows pointing towards air flow direction. Filters shall be tightly fitted in the frames provided using gaskets with no gap between the filter and the frame.

17.3.12.3 Differential pressure gauge/switch is recommended to be installed across filters. After initial running of 48 h, if required, replace the filters (In case of pre filters only).

17.3.12.4 HEPA filters shall be handled with special care since the media is fragile and shall be installed with the gasket side of the filter facing the frame.

17.3.12.5 ESP filters shall be firmly fitted in a specially fabricated frame and wiring of the ESP filters shall be as per manufacturer's recommendation. A clear sticker 'Caution – High Voltage Filters' shall be prominently displayed in front of ESP filters.

17.3.12.6 While installing ultra violet germicidal irradiation (UVGI) lamps, the layout provided by the manufacturer shall be followed. In AHUs, UVGI lamps may be installed downstream of cooling coil. Mounting frame for UVGI lamps may be at a distance of 300 mm from the cooling coil for optimum performance. After installation, the lamp surface shall be cleaned with a wick wetted with spirit.

17.3.12.7 Ballast of the lamps may be accommodated with in the UVGI electrical panel or may be tied to the UVGI mounting brackets as per manufacturer's recommendation and IP rating of ballasts.

17.3.12.8 Follow manufacturer's instruction for any shielding of drain pan, cable sheaths and conduits.

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17.3.12.9 Safety guidelines provided by manufacturer shall be closely followed. If for any reason, AHU door needs to be opened while the lamps are 'ON' person/s in AHU room shall wear PPE kit and protective goggles. Bare eye or skin shall not be exposed.

17.3.12.10 Upper zone irradiation units may be mounted on walls or hung from ceiling well above occupied zone (minimum 2.2 m from floor level). Baffles/ louvres shall be directed in such a way that the rays are not directed towards occupied zone. In respect of upper zone irradiation units, the occupied zone UVGI shall be measured periodically to ensure that it does not exceed 1 000 UV/m^2 to 2 000 UW/m^2.

17.3.13 *Installation of Piping Works*

The following are key points for the proper installation of pipeworks, ensuring alignment, sealing, support, and compliance with safety:

17.3.13.1 It shall be verified that pipes of correct specifications such as pipe class, length, thickness, straightness and surface finish are received at the project site. Pipe routing as per 'Good for Construction' drawing shall be verified at site and pipes may be cut to required lengths.

17.3.13.2 Edges of pipes shall be bevelled by grinding to make a 'butt' joint. Welding shall be done exactly to specifications (for example, accepted standard [D-3(45)]. Fabrication of supports shall be as per site requirements and specifications. Spacing between supports shall be as specified.

17.3.13.3 Overhead piping may be supported on walls/ columns with appropriately sized brackets or may be suspended from ceiling/roof truss with MS suspension rods or hangars. Anchor fasteners of adequate sizes shall be used for pipe supports. Vertical risers shall be supported by horizontal supports mounted at regular intervals.

17.3.13.4 Vertical pipes passing through floors shall be parallel to the wall and shall be straight (as verified with a plumb line).

17.3.13.5 Where pipes pass through floor slab or walls, gaps between the pipe and floor/wall opening should be sealed as detailed in Part F 'Fire and Life Safety' of this NBCS.

17.3.13.6 Chilled water piping shall be supported on PUF or wooden gutties. Single gutties shall be used for horizontal runs and double gutties for vertical risers. While installing insulated pipes, care shall be taken that insulation is not unduly compressed.

17.3.13.7 Condenser water piping shall be placed on serrated rubber pads at each support and held in place by U-clamps.

17.3.13.8. Piping shall have expansion joints as required. Fittings, valves and instruments shall be as per approved drawings. Drain points and air vents shall be provided as required. Auto purge valves shall be provided at the highest point in each pipe loop with discharge piped out to nearest drain or sump. While T connections shall be permitted on suction side of pump, shoe connections shall be provided on the discharge side. Elbows/bends shall be minimum and reducers shall be eccentric type. Welding scale shall be removed before applying red oxide primer. Readymade fittings to specifications are recommended. Welder shall be competent and hydraulic pressure testing with 1.5 times the working pressure shall be done for 24 h (*see* Fig. 33, Fig. 34 and Fig. 35).

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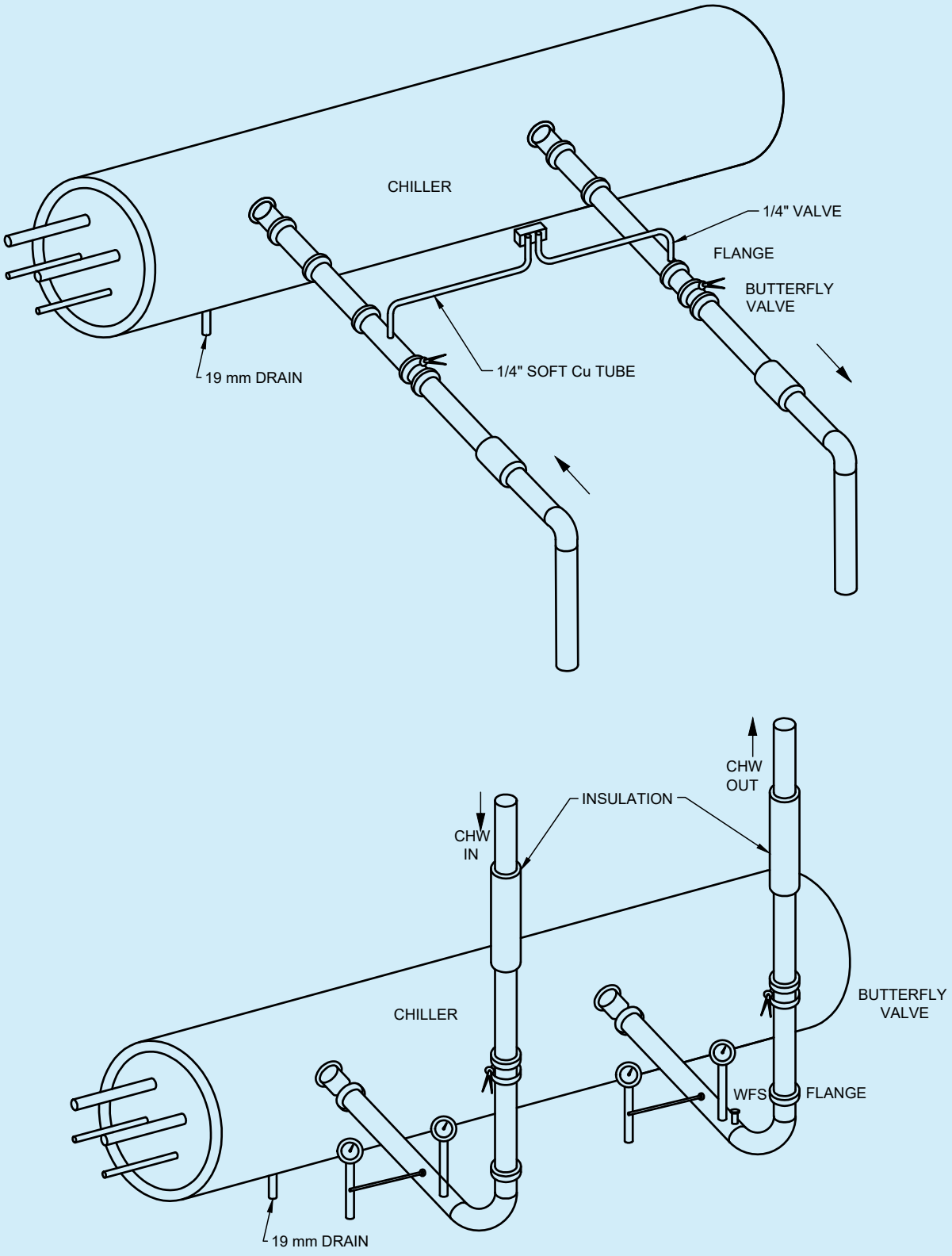

FIG. 33 TYPICAL CHILLER CONNECTIONS

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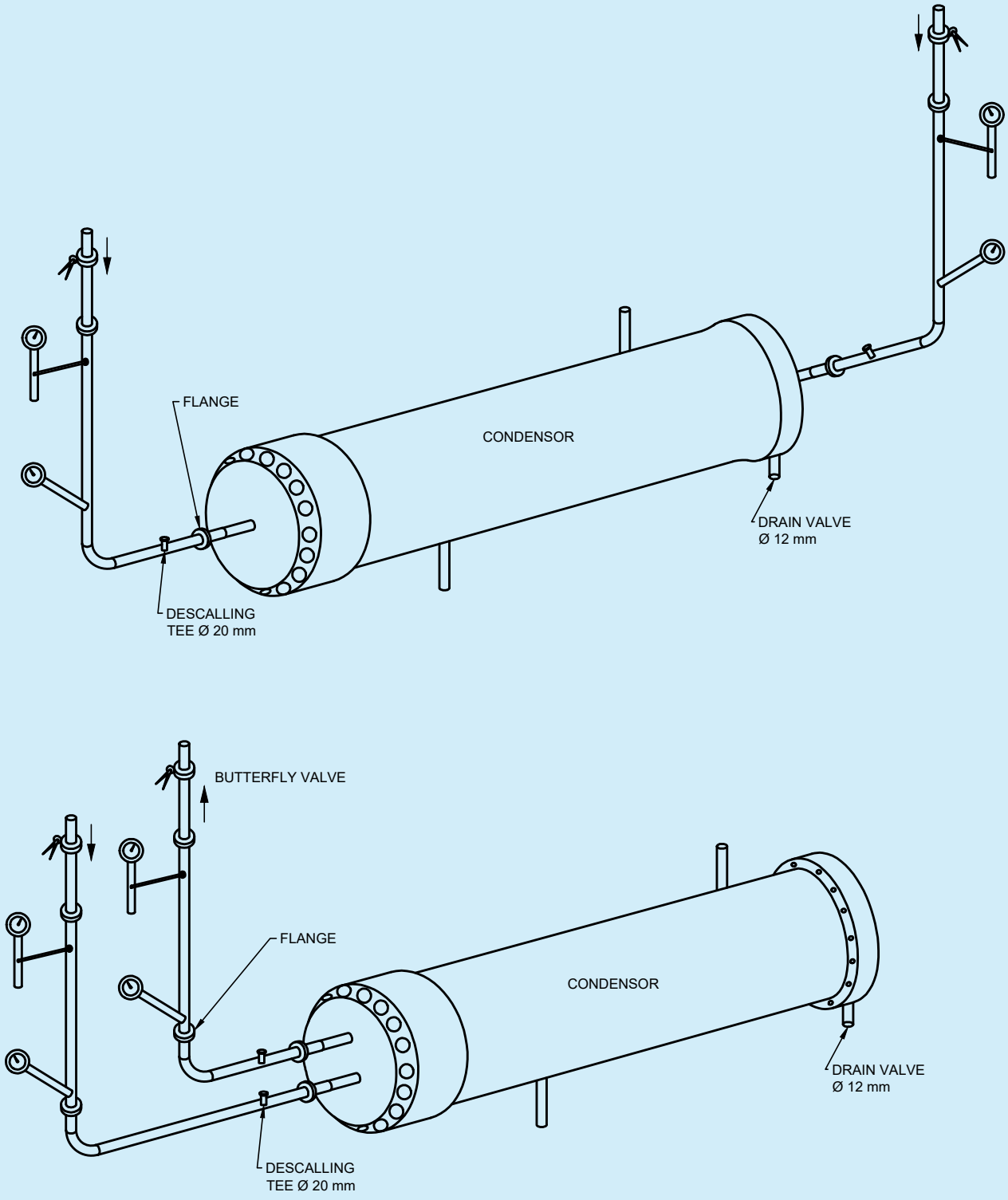

FIG. 34 TYPICAL WATER COOLED CONDENSER CONNECTIONS

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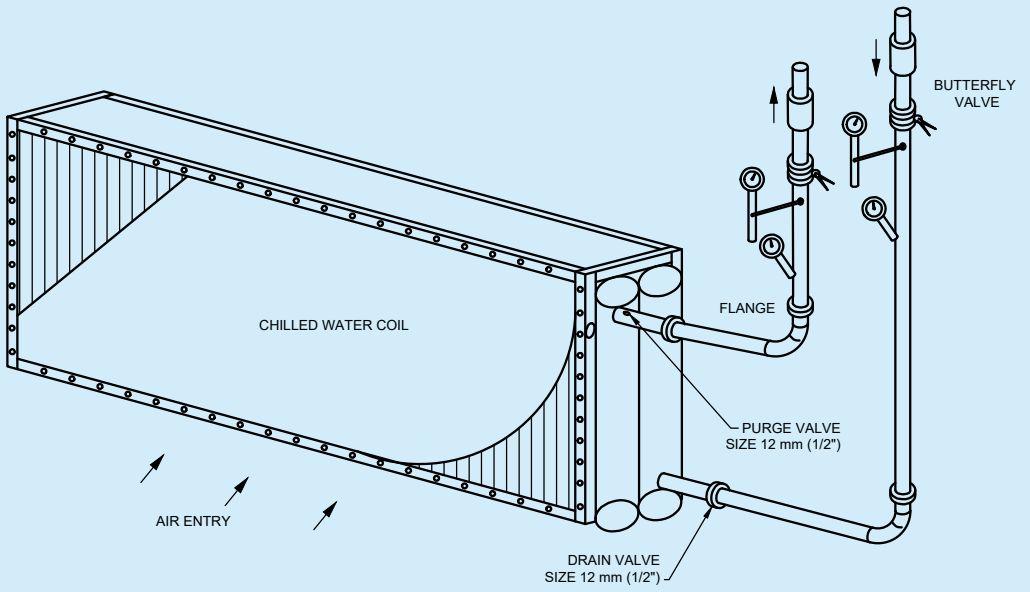

FIG. 35 TYPICAL COIL CONNECTIONS

17.3.13.9 Flanges shall be provided near each equipment connection and all flanges shall be with gaskets.

17.3.13.10 During installation process, open pipe ends shall be always kept closed.

17.3.14 *Insulation Works*

The following are key points for the proper installation of insulation works, ensuring correct material selection, proper fitting, and adherence to safety and performance.

17.3.14.1 *Thermal insulation of sheet metal ducts*

Duct surface shall be cleaned with wire brush to remove dust and grease. Two coats of cold setting fire resistant adhesive compound shall be applied over the duct surface. GI stick pins shall be used in case of glass wool/rock wool. Thermal insulation shall be wrapped around the duct with aluminium foil facing the outer side. All transverse and longitudinal joints to be sealed with aluminium tape. PVC strips shall be fixed at suitable intervals so that insulation remains in place. Insulation shall be covered with GI wire mesh (0.63 mm thick × 19 mm) netting on the outside where duct is open and exposed to weather and shall be additionally protected with tar felt or two coats of 10 mm sand cement plaster followed by two coats of water proofing chemical.

17.3.14.2 *Duct made of pre insulated boards*

Pre-insulated duct boards may be used for efficient air distribution with reduced energy loss and improved installation speed (*see* Fig. 36) providing both thermal insulation and structural stability.

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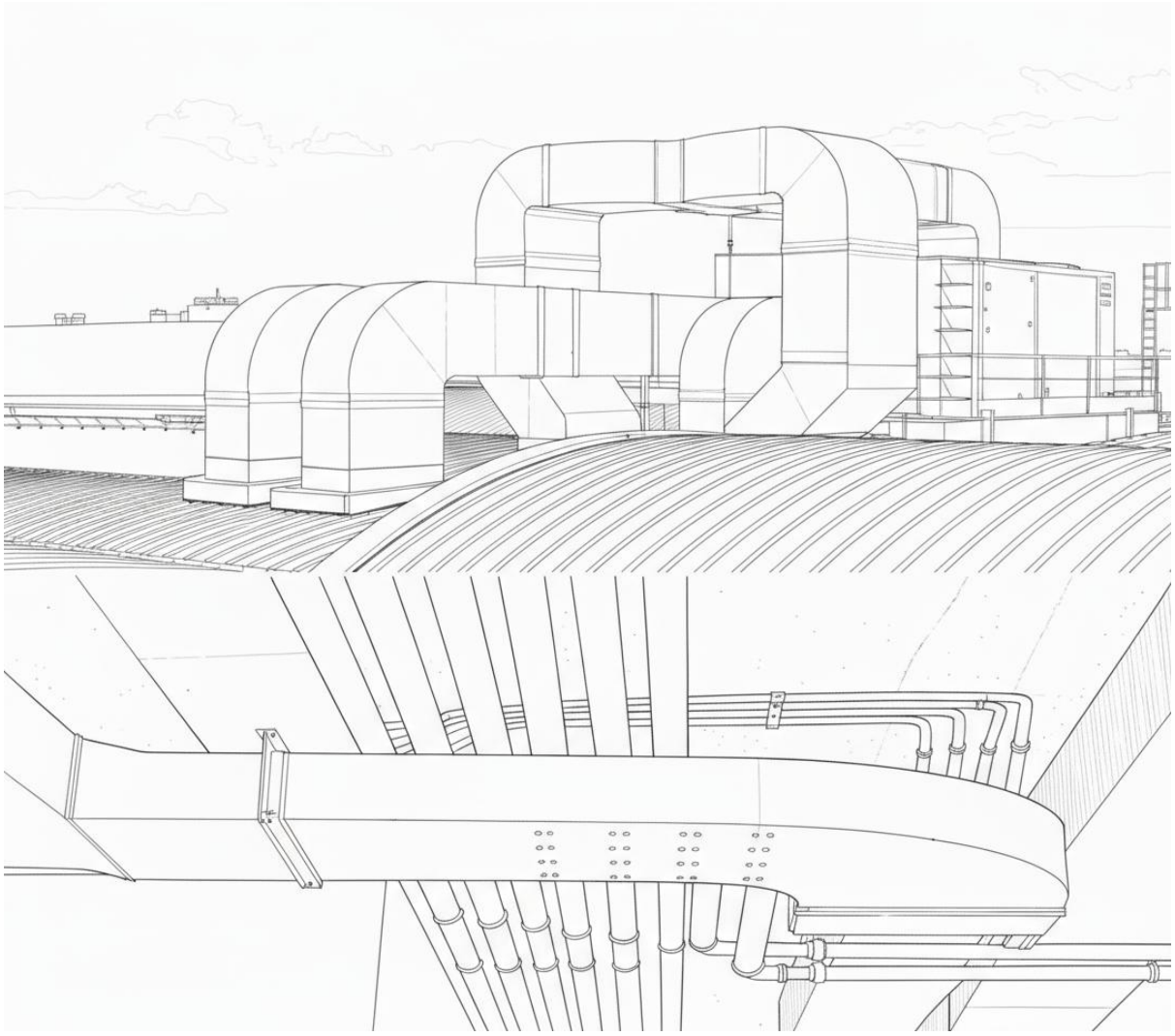

FIG. 36 PRE INSULATED DUCTS.

17.3.14.3 *Acoustic lining of duct*

Inside surface on which lining is to be provided shall be cleaned of dust and grease. Material used shall be 12 mm/25 mm thick resin bonded fibre glass/rock wool rigid board with 48 kg/m^3 density. Board shall be fixed inside duct using fire retardant adhesive and covered with tissue paper. Insulation shall be covered with 0.5 mm thick perforated Aluminium sheet having polysurlyn lamination on inner side with minimum 20 percent perforation. Insulation board and aluminium sheet shall be secured with Cadmium coated bolts, nuts, cup washers and steel screws. Ends shall be securely sealed so that no lining material is exposed. Length of lining shall be as per approved drawing.

As an alternative to the above, open cell elastomeric foams of fire-retardant type specially formulated for sound attenuation may be used. These shall be fixed inside the duct with fire retardant cold setting adhesive (*see* Fig. 37).

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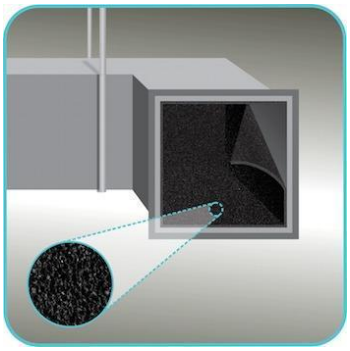

FIG. 37 ACOUSTIC INSULATION OF DUCT WITH OPEN CELL ELASTOMERIC FOAM.

17.3.14.4 *Acoustic lining of equipment rooms*

Where specified in drawings, inside walls and ceilings of equipment rooms may be lined with acoustic insulation. Surface to be cleaned with a wire brush. A frame work of U-shaped channel with height equal to proposed lining thickness made of 0.63 mm thick GI sheet shall be fixed to the walls by means of raw plugs. Similar frame work shall be fixed to ceiling by means of dash fasteners (*see* Fig. 38).

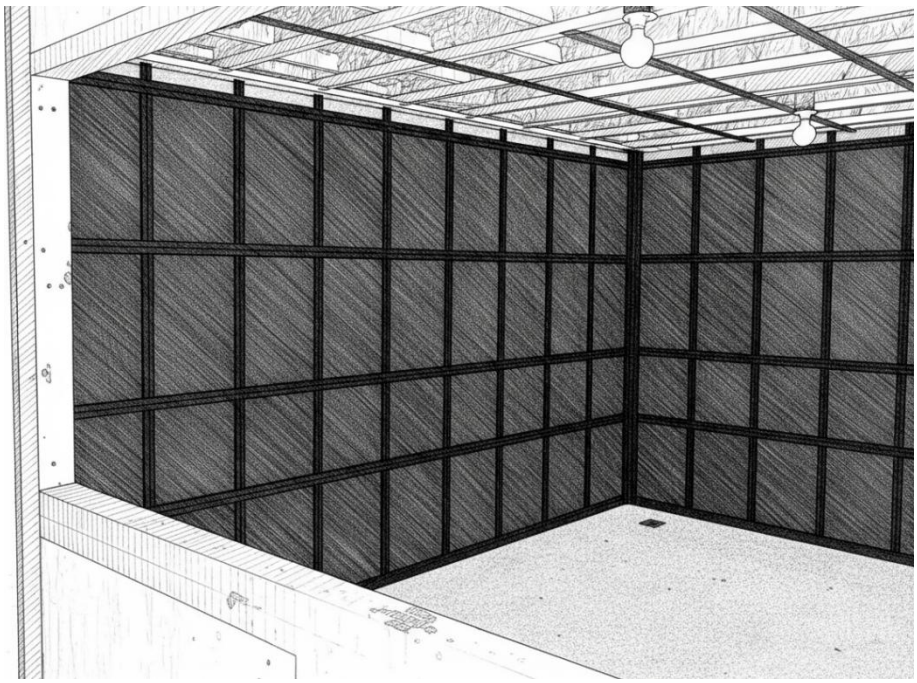

FIG. 38 PLANT/AHU ROOM ACOUSTIC INSULATION.

Resin bonded glass wool/rockwool cut to size shall be fitted in the framework and covered with tissue paper. Surface shall be covered with 0.5 mm thick perforated (minimum 20 percent perforations) aluminium sheet with polysurlyn lamination on the inside. These shall be fixed with brass screws.

17.3.14.5 *Pipe insulation*

Insulation of pipes shall be carried out with specified material. Pipe insulation material is available in pre-moulded half sections.

Pipe surface shall be cleaned of dust, rust and grease with wire brush. One coat of red oxide primer and two coats of cold setting, fire retardant adhesive compound shall be applied. After tightly fixing the insulation sections, joints shall be sealed with adhesive compound.

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Piping within covered space shall be covered with aluminium cladding of specified thickness having polysurlyn lamination on the inside over a vapor barrier. Cladding shall have 50 mm overlap and shall be tied down with lacing wire.

Piping outside the building and exposed to weather shall be finished with vapor barrier and GI or Aluminium sheet cladding with polysurlyn lamination on inner side. Two layers each of 6 mm thick sand cement plaster each cured for minimum 48 h followed by two coats of water proofing chemicals or fixed with bitumen membranes with hot bitumen adhesive or cold quick setting fire resistant mastic compound.

Buried piping shall be covered with suitable gauge polythene faced hessian cloth (with polythene facing outward) with 50 mm overlap. Joints shall be sealed with bitumen. A layer of 0.5 mm × 20 mm thick sand cement plaster (1:4) shall be applied and water proofed by applying hot bitumen or cold quick setting fire resistant mastic compound with a layer of tar felt over the plaster. Final finishing shall again be with hot bitumen or cold mastic compound.

Alternatively, the insulation sections shall be protected with a 3 mm to 5 mm thick HDPE sheet cladding hot air welded and sealed at all joints.

In respect of pre insulated pipe sections, manufacturer's instructions shall be followed. For pipes inside the building, the factory provided Aluminium foil lamination shall suffice both as vapor barrier and also as finishing material. Otherwise, GI or aluminium cladding shall be provided with 1.016 mm (40 mil) polysurlyn coating on inside. After application with adhesives, all joints shall be sealed with Aluminium tape.

17.3.14.6 *Insulation of pumps, valves, expansion tank, fittings and pipe supports*

Pumps, valves, fittings and strainers in the chilled water line shall be insulated to the same thickness and using the same as the pipeline. Care shall be taken to apply the insulation in such a way that it shall be possible to dismantle the pumps and operate the valves without damaging the insulation. Moulded PUF insulation in sections may be used where access is desired. These shall be easily reset/ reinsulated after dismantling. Option is available to use pre insulated valves and flanges.

Expansion tanks shall be insulated with 50 mm thick TF quality expanded polystyrene or 40 mm thick polyurethane or poly-isocyanurate foam as specified. Surface shall be cleaned and two layers of hot bitumen or fire resistant cold adhesive compound shall be applied. Insulation slabs shall be placed abutting one another and joints sealed with same compound. Slabs shall be covered with 0.63 mm thick × 20 mm GI wire mesh netting to be fixed with brass/GI screws. Final finishing shall be with 0.5 mm thick Aluminium cladding with polysurlyn coating on inner side.

Chilled water pipe supports shall be insulated with high density (120 kg/m^3) phenolic foam of thickness equal to pipe insulation. Supports shall have same shape as the outside surface of the pipe. Shape/ dimensions of pipe supports shall be as specified.

Pipe bends shall be insulated with sections cut into bevelled lags and applied over the bends with fire retardant cold adhesive compound and all joints sealed with cut insulation pieces or factory-made shaped bends in two halves fixed with fire retardant cold adhesive compound and tied with lacing wire. Vapor barrier similar to that used for pipes shall be applied and the whole assembly may be clad with Aluminium sheet having 1.016 mm (40 mil) polysurlyn lamination on inner side. Cladding to have same thickness as pipe cladding. Joints in the cladding shall be grooved joints fixed with screws and sealed with aluminium tape or mastic compound.

17.3.14.7 *Under deck and over deck insulation*

Underdeck roof insulation shall be with phenotherm 35 kg/m^3 or polyisocynurate foam 32 kg/m^3 or resin bonded glass wool or rock wool 48 kg/m^3. Thickness shall be as specified and method of application same as that of acoustic insulation for equipment rooms (*see* **17.3.14.4**).

Overdeck insulation shall be with polyurethane foam 40 kg/m^3 to 45 kg/m^3 of specified thickness sprayed in multiple layers to form a jointless homogeneous surface. Geo – textile cloth shall cover the insulation followed by plaster and suitable water proofing system. Alternatively, extruded polystyrene slabs or polyurethane/ poly-isocynurate foam slabs shall be fixed over fully dried roof surface with fire resistant mastic and joints sealed with adhesive compound.

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17.3.15 *Thermal Storage System*

Storage tanks shall be fabricated out of carbon steel of adequate thickness, hydraulically tested for 1.5 times the design pressure and shall be positioned at the location ensuring that its operating load is safely transferred. Tanks may also be fabricated on-site. Red oxide primer as per the accepted standard [D-3(46)] shall be applied to all exposed welds and edges. Tank shall be able to withstand freezing of water inside through repeated cycles without damage. Tank shall be thoroughly cleaned and flushed before use. External surface shall be insulated similar to that of expansion tank.

Where multiple tanks are installed adjacent to one another, minimum clearance of 600 mm shall be kept. Adequate height to allow for piping (minimum 1 m) shall be available above the tank. Each pair of manifold inlet/outlet connections shall include a shutoff valve to isolate the unit. Bypass circuit shall be installed with a 3-way modulating valve. Thermometer/pressure gauge shall be installed at inlet and outlet. Before start up, air shall be completely purged out from the system for which air bleed valves shall be located at the uppermost points in the piping network.

When glycol is used as the storage medium, add inhibitors as recommended by the manufacturers.

When tanks are located in the open outside the building, insulation shall be covered with a layer of 26 gauge aluminium cladding.

17.3.16 *Smoke Management Systems*

Purpose of smoke management is:

a) Inhibit smoke from entering stairwells and other means of egress, refuge spaces, elevator lobbies, elevator shafts etc;

b) Maintain tenable environment in refuge areas and egress paths during evacuation;

c) Provide conditions to enable emergency response teams to fight fire and conduct rescue operations; and

d) Protect life and property.

Smoke control systems should be as per **19** as well as Part F 'Fire and Life Safety' of this NBCS.

Installation aspects of smoke and fire dampers is covered in **17.3.11.13** and installation of fans and ducting is covered in **17.3.10** and **17.3.11**.

17.3.17 *Installation of Electrical Systems*

These are the key provisions for the installation of electrical systems in electrical rooms and switchboards.

17.3.17.1 All the equipment used in the electrical room shall be of sufficient current rating for its normal duty as well as during the fault current. The equipment shall be of sufficient mechanical strength to withstand the fault condition to ensure human safety.

17.3.17.2 Every switch board of medium or high voltage shall comply the following provisions:

A clear space of not less than 1 meter in width shall be provided in front of the switch board. If there is any attachment at the back of the switchboard, the space shall be either less than 20 cm or more than 750 mm in width from the farthest outstanding part of the switchgear. If the space behind the switchboard exceeds 75 cm in width, there shall be passage-way from either end of the switchboard clear to height of 1.8 meters.

All disconnect switches are to be identified and labelled stating the source of the circuit and the equipment/circuit it is feeding.

17.3.17.3 Insulation mat as per the accepted standard [D-3(47)] of proper grade to be used in front of 415 V and above electrical switchgears. All panel doors shall be locked, made vermin proof by sealing entry holes specially from cable entry points.

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17.3.17.4 Bus coupler panel and its cubicle shall be handled with utmost care. Red painting of bus coupler, adaptor panel and tie feeder panel from all sides (front, top and back) for easy identification and treat Adaptor panel as a part of bus coupler.

17.3.17.5 Incoming barrier of power supply and phase barrier inside the switchgear panel to be ensured.

17.3.17.6 There should not be any loose wirings, exposed joints, distribution box or junction box in cover open condition in the workplace. No switchgear which has been kept disconnected, for period of six months or more for any maintenance job shall be energized without testing.

17.3.17.7 Over current protection to be provided to disconnect the supply automatically if the rated current of the equipment, cable or supply line is exceeded for a time which the equipment, cable or supply line is not designed to withstand. Earth fault or earth leakage protection to disconnect the supply automatically if the earth fault current exceeds the limit of current for keeping the contact potential within the reasonable value.

17.3.17.8 The operation of all electrical and mechanical interlocks on the switchgear shall be checked to ensure that they operate in a positive manner. All electrical connections shall be proved for mechanical integrity that is terminal tightness, shrouding etc. The panels, relays and control modules shall be visually inspected to ensure freedom from debris and mechanical damage.

17.3.17.9 Proper illumination in work area shall be ensured and no lone working shall be allowed inside HV/LV switch gear room

17.3.17.10 Refer to Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS for installation of all electrical equipment including motors and switch/control gear.

17.3.18 *Installation of Electric Motors*

These are the key provisions for the installation of electric motors

17.3.18.1 Motors shall be installed at a location compatible with its enclosure type as well as the ambient conditions.

17.3.18.2 Before installation, the insulation resistance shall be checked by applying 500 V (d.c.). If insulation resistance is low, the windings shall be dried out till the resistance increases to 5 megaohms. While doing this, the frame shall be grounded and winding discharged against frame immediately after measurement.

17.3.18.3 Foundation details and bolting arrangements shall be as specified by the manufacturer.

17.3.18.4 For belt drives, the sheave pully shall be mounted close to motor housing and clearance may be provided for end-to-end movement of motor shaft. Drive shafts shall be parallel and belt tensions may be checked periodically during the first 24 hours of operation.

17.3.18.5 Lubrication shall be done with grease recommended by the manufacturer.

17.3.18.6 Terminal housing shall be of adequate size to allow minimum terminal spacing as per article 430 of accepted standard [D-3(39)]. Adequate earthing shall be provided. Minimum earth wire permitted is No. 14 standard wire gauge (SWG).

17.3.18.7 All motor connections and protections shall comply with accepted standard [D-3(39)].

17.3.19 *Installation of Instrumentation/Controls/BMS/IOT*

These are the key provisions for the installation of Instrumentation/Controls/BMS/IOT

17.3.19.1 Field devices such as temperature and RH sensors, pressure transmitters, flow meters etc shall be installed as per manufacturer's instructions. Components of the BMS System shall be housed in an enclosure suitable for the location where they are installed in respect of temperature, RH and IP rating. Where required, suitable transformers shall be installed in the enclosure and adequate earthing shall be provided. Uninterrupted power supply shall be provided to the BMS system.

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17.3.19.2 Field cabling and containment shall be as per Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS. Kept at a minimum distance of 300 mm from power cables. Field cabling shall be carried out with screened cables in conduits work stations/servers shall be installed in clean and dust free rooms.

17.3.19.3 While installing IoT – Wireless field devices, availability of repeaters to form a mesh network shall be ensured.

17.3.19.4 Method statement for installation and commissioning shall be provided by the supplier/installer and pre-approved by the Engineer-in-Charge. If energy dashboard is part of the scope of supply, all screens shall be pre-approved by the Engineer-in-Charge. Where specified, IoT interface for specified equipment shall be provided and these shall be tested as part of the commissioning process.

17.3.19.5 All back up data for restoring the system functionally, in case of any failure, shall be provided and these shall be safely stored separately.

17.3.19.6 System shall be protected from cyber threats by ensuring that all remote access is password protected. Default user names/passwords shall not be retained.

17.4 Vibration Isolation and Seismic Protection

These are the key provisions to be considered for vibration isolation and seismic protection.

17.4.1 When machinery with moving parts rests on any support or foundation, vibration gets transmitted usually accompanied by noise. Objective of vibration isolation is to minimize the effect of the dynamic forces generated by the moving parts being transmitted to surrounding structure. When a resilient material is introduced between the machine and its foundation, it deflects due to the static load and by so doing establishes the natural frequency of the isolation system. Natural frequency f_n of the machine set on resilient material is a function of the static deflection of the resilient material under the imposed load.

This shall be expressed as:

$$f_n = (946.5/V) - d$$

where

d is the static deflection in mm; and
V is the velocity in m/s.

The disturbing frequency f_d of the machine is defined by the operating characteristics of the equipment. Efficiency of isolation (percentage of vibration isolated) may be calculated as:

$$E = 100.1 - 1/(f_d/f_n)^2\text{-}1$$

E represents the amount of reduction in the amplitude of the transmitted mechanical vibration. Based on the graph below (Fig. 39) the static deflection required to attain the desired isolation efficiency shall be ascertained.

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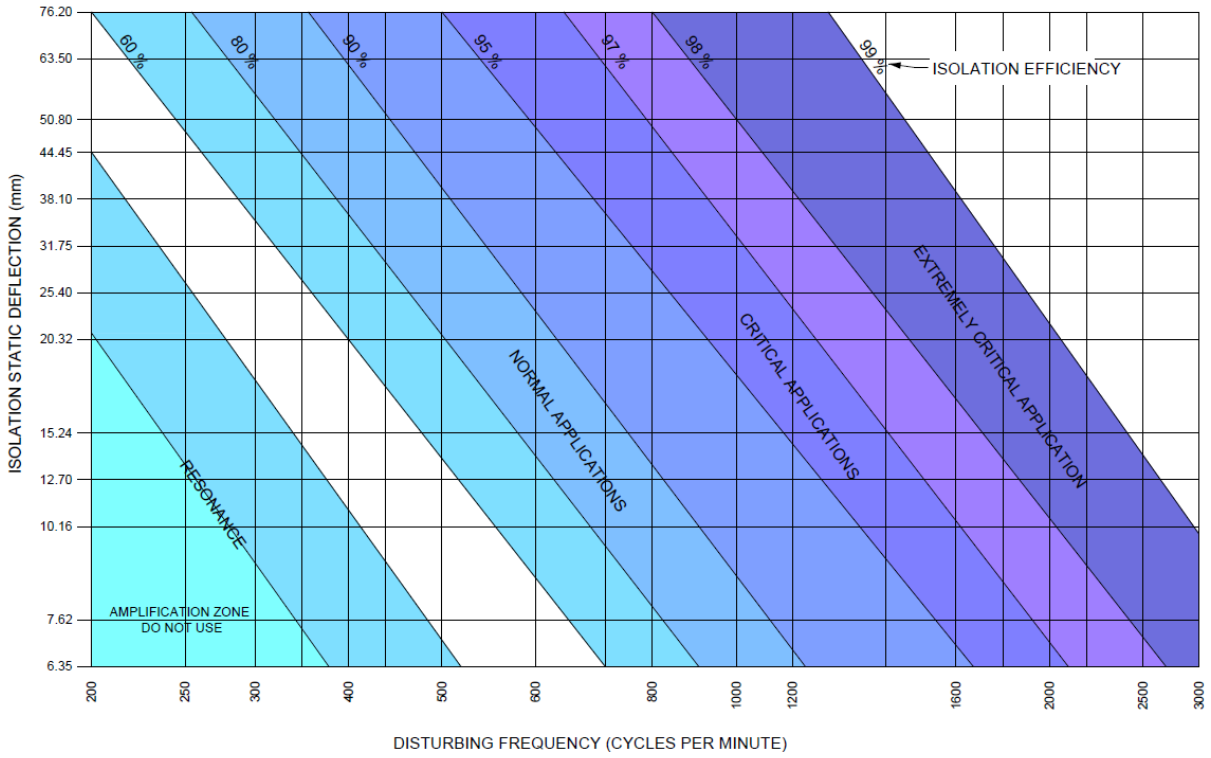

FIG. 39 STATIC DEFLECTION REQUIRED FOR DESIRED ISOLATION EFFICIENCY

17.4.2 Selection of isolator in a particular situation depends on:

a) Weight to be supported;

b) Disturbing frequency; and

c) Rigidity of supporting structure.

17.4.2.1 Anti vibration mounts (AVMs) are generally elastomer based, springs, or fluid based. These need to be selected and positioned carefully since incorrect use shall worsen the problem.

17.4.2.2 *Selection of suitable AVMs involves the following steps*:

a) Estimating the weight distribution at each support which depends on its position relative to the centre of gravity of the total mass. This is best done by a computer program. If the equipment is placed on suspended supports, same shall be factored into the selection program;

b) Selecting the appropriate AVM based on type of equipment being supported, its operating speed, nature of supporting structure, environmental conditions and space availability;

c) The load rating of the mount shall be determined based on isolation efficiency derived from charts available for that purpose; and

d) Usually, the AVM is selected for the next higher load rating than the one determined in (c) above.

17.4.3 *Seismic Isolation of Non – Structural Components*

These are the key provisions to be considered for Seismic Isolation of non- structural components

17.4.3.1 The non-structural components in the building which shall be affected by earthquake effects include:

a) Mechanical systems and components;

b) Electrical systems;

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c) Fire protection systems; and

d) Plumbing systems.

17.4.3.2 Seismic protection of the above systems shall ensure

a) The components are securely attached to the supporting structure;

b) Life safety equipment such as emergency lighting and fire suppression systems continue to function; and

c) For critical applications, non-structural components continue to operate. Critical applications shall include:

1) Health care facilities;

2) Airports;

3) Emergency response centres;

4) Critical defence installations; and

5) Data centres.

17.4.3.3 Performance objectives for seismic protection of non-structural components and how the objectives shall be met shall be as indicated below:

a) *Position retention* — Non-structural components shall retain their position under design level earthquake demands without consideration of frictional resistance produced by effects of gravity. This shall be validated by analysis of seismic calculations and such analysis shall also validate the non- structural anchorage, force resisting skeleton and attachments shall have position retention capacity equal to or greater than project specific design level demand for the installation location. Both, strength design and allowable stress design approaches shall be accepted in such calculations. This shall be done in accordance with good practice [D-3(48)].

The use of earthquake experience data may be used to establish non-structural position retention capacity. Seismic simulation testing may be used to establish non – structural position retention capacity.

b) *System interactive avoidance* — Unwanted interaction, under design level earthquake demands, between the non-structural systems and anything else that might be located in the vicinity shall be taken into account. This is to ensure that failure of one system or contact between systems shall not cause consequential damage to system. This may also be validated through visual inspection.

c) *Active operation* — Following application of design level earthquake demands, active operational functionality of mechanical and electrical equipment and electrical distribution system shall be maintained.

17.5 Painting and Colour Codes

The following are guidelines for painting and colour coding in air conditioning installations:

17.5.1 All surfaces to be painted shall be thoroughly cleaned with a wire brush. One coat of zinc chromate primer shall be applied and after the prime coat is completely dry finish painting shall be done. Second coat of finish painting shall be done just before hand over with permission from Engineer-in-Charge. Galvanized steel ducts may be painted without a prime coat. Dry film thickness (DFT) of finished painting shall be 250 microns minimum.

17.5.2 Colour code shall be used for easy identification of various items in an air conditioning installation for correct interpretation and identification.

17.5.3 Colour band shall be 150 mm wide, superimposed on ground colour to distinguish type and condition of fluid. The spacing of band shall not exceed 4.0 m.

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17.5.4 Further identification may also be carried out using lettering and marking direction of flow.

17.5.4.1 The scheme of colour code for painting of pipe work services for air conditioning installation shall be as indicated in Table 42.

17.5.4.2 In addition to the colour bands specified above, all pipe work shall be legibly marked with black or white letters to indicate the type of service and the direction of flow, as identified below:

Hot water	:	HW
Chilled water	:	CHW
Condenser water	:	CDW
Steam	:	ST
Condensate drain	:	CN

Table 42 Scheme of Colour Code of Pipe Work Services for Air Conditioning Installation

(*Clause* 17.5.4.1)

Sl No.	Description	Ground Colour	Lettering Colouring	First Colour Band
(1)	(2)	(3)	(4)	(5)
i)	Cooling water	Sea green	Black	French blue
ii)	Chilled water	Sky Blue	Black	Black
iii)	Central heating	Dark Blue	Black	Canary yellow
iv)	Condensate drain pipe	Black	White	
v)	Vents	White	Black	
vi)	Valves and pipe line fittings	White with black handles	Black	
vii)	Belt guard	Black yellow diagonal strips		
viii)	Machine bases, inertia bases and plinth	Charcoal grey		

17.6 Testing and Balancing

17.6.1 *Air System Balancing*

Air distribution system shall be balanced so that air quantities measured at fan discharge and at various outlets shall be within ±10 percent of the design airflows. Branch duct adjustments shall be permanently marked after the balancing is complete. Throttling losses in the system shall be minimum. Tests shall be carried out for each fan and AHU. All dampers after adjustment shall be set and locked in position. All air and static pressure measurements shall be done with probe type meters. After balancing the fan speed shall be suitably adjusted. Duct leakages shall be tested and validated as specified.

17.6.1.1 Airflow balancing shall be carried out by adjusting the flow at each diffuser to match the right percentage of total airflow in the ductwork. Balancing shall be done based on the ratio between measured and designed flow rate. Following steps may be followed for proportional balancing:

a) Ensure all VCD, VAV and fire dampers are in fully open position.

b) Adjust the damper of each diffuser proportionately to the same ratio in each branch duct.

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c) Adjust each branch duct VCD in each main duct so that each branch duct has the same proportion of airflow.

d) Adjust each main duct VCD.

e) Adjust fan speed (through VFD or belt pully) or the main VCD after the AHU to ensure that each diffuser has the right airflow rate.

f) Measure and record airflow rate at each diffuser and compare it with design airflow (within $\pm$ 10 percent)

17.6.2 *Water System Balancing*

The following are guidelines for testing and balancing in air and water systems:

17.6.2.1 Water balancing (of chilled water/brine) shall be done as under:

a) Keep all balancing, control and isolating valves in fully open position;

b) Measure the water flow across each balancing valve and compare it with design flow;

c) Identify the index value (lowest flow ratio) in each branch;

d) Keep index valve fully open;

e) Throttle the farthest valve to the same ratio and after that every valve in the branch starting from the lowest ratio;

f) Monitor index valve percentage after throttling each valve gradually. By the time the last valve is completed, the flow is balanced at all valves including the index valve; and

g) Record the reading at all valves.

17.6.2.2 Where pressure independent balancing and control valves (PIBCV) are used, the proportional balancing described above is not required. Each valve may be set to correct water flow rate as per manufacturer's instructions.

17.7 Cleaning/Flushing of Duct/Pipe work

The following are guidelines for cleaning and flushing of duct and pipe work:

17.7.1 In duct work, access doors shall be provided next to dampers and these access doors shall be used to clean the duct work. Prior to commissioning of the system, entire duct shall be cleaned. Where specified, such cleaning shall be done by duct cleaning systems using robots. Otherwise, the fans shall be run with only pre-filters in place (to protect coils) and the entire dust shall be blown off. After the cleaning, pre filters shall be replaced.

17.7.2 Pipe work shall be cleaned and flushed before commissioning. Flushing of system shall be done bypassing sensitive parts such as chiller and heat exchanger tubes. Before filling up the system with clean water, all shut off and control valves shall be kept fully open. Continuous air venting shall be done. Pump shall be started only after filling up and air venting is completed. Additional flushing pumps may be used over and above system pumps and the primary pump strainer basket mesh shall not be less than 3 mm when flushing starts. Flushing velocity from 1.0 m/s to 1.25 m/s is recommended. Pressure drop across pumps shall be monitored during the process so that pump cavitation is avoided.

17.7.2.1 Dynamic flushing in several steps is recommended. First the primary ring main may be flushed, thereafter the main pipes and lastly the horizontal mains in each floor. After each round of flushing, the strainer basket shall be changed. Each loop needs to be flushed till the water is clean and the strainer basket does not collect sediments. Flushing of horizontal main pipes shall start at the topmost floor and finish at the lowest floor. After flushing in sections is completed, full system flushing shall be carried out. After flushing is complete, the water sample shall be analysed to determine successful flushing.

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17.8 Commissioning, Testing and Balancing, Performance Validation, System Handover

The following are guidelines for effective commissioning, testing and balancing, performance validation, and system handover to ensure that all systems operate as per design intent and meet performance requirements:

17.8.1 Commissioning shall mean putting an equipment or a system into active service as intended by the owner.

17.8.1.1 In respect of unitary equipment such as room (window air conditioners), Non – ducted split units, package units or VRF, this process shall involve connecting the unit (after installation) to a suitably sized power outlet, switching on the unit and recording the temperature/RH/ air movement/air quality in different locations in the conditioned space. The process shall also involve whether the unit's contracted features are operational and whether the compressor switches off once the set temperature is achieved. Air flow from the unit as well as noise level shall be appropriately measured and recorded. Capacity/power consumption is verified with factory issued test certificates.

17.8.1.2 For a central air conditioning plant or a mechanical ventilation system, the process of commissioning shall follow a structured and documented process. This shall comply with special publication.

NOTE — Special publication may be ISHRAE Standard 10003-2020.

17.8.1.3 The commissioning flow chart given below in Fig. 40 sets out the stages of this process.

17.8.1.4 Initiating the process. Owner shall designate commissioning authority (CxA) at the start of the process. CxA shall either be a member of the owner's project team or an independent agency appointed for this specific purpose. CxA shall have adequate knowledge and experience to guide the project through various stages of the process. Engagement of CxA shall be for a minimum period extending to one year from date the building/facility is put to use. It shall be the responsibility of CxA that all non-conformances, warranty issues, seasonal and occupancy related performance issues are fully resolved during her tenure with the project.

Owner shall be responsible for defining scope of the commissioning plan, incorporating CxA into the project team and establishing the commissioning budget.

Role of CxA and contractual requirements for commissioning shall be a part of all sub contracts including contracts with architects/consultants.

17.8.1.5 Owner's project requirements (OPR) shall include all functional requirements of the project and owner's expectation regarding its use and operation.

17.8.1.6 Commissioning plan shall be a written document scheduling the commissioning activities. This shall include scope, resources required at each stage, agreed timelines and roles and responsibilities of each member of the project team.

17.8.1.7 Basis of design document details design team's approach to meet OPR.

17.8.1.8 Commissioning specifications shall be established for all equipment and systems.

17.8.1.9 Commissioning design review shall involve verifying that all equipment and systems meet OPR. This shall not be a peer review of the design.

17.8.1.10 Testing shall involve preparation of check lists, test procedures and report forms which shall be agreed by all concerned. Person responsible for executing test protocols shall be identified.

17.8.1.11 Functional performance testing shall involve recording the operation, then initiating a change in one or more parameters and recording the changes in performance. This shall be done in auto mode with functional BMS and controls.

17.8.1.12 All information required to operate, maintain and if required, modify the system in future. Systems manual shall be approved by owner and kept updated.

17.8.1.13 Operation and maintenance training shall be documented. Evaluation and feedback are important.

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17.8.1.14 Final commissioning report shall summarize the entire process and shall have owner's acceptance.

17.8.1.15 Post occupancy commissioning shall include all delayed and seasonal tests, warranty actions/records and resolution of all non-conformances with owner's specific approval.

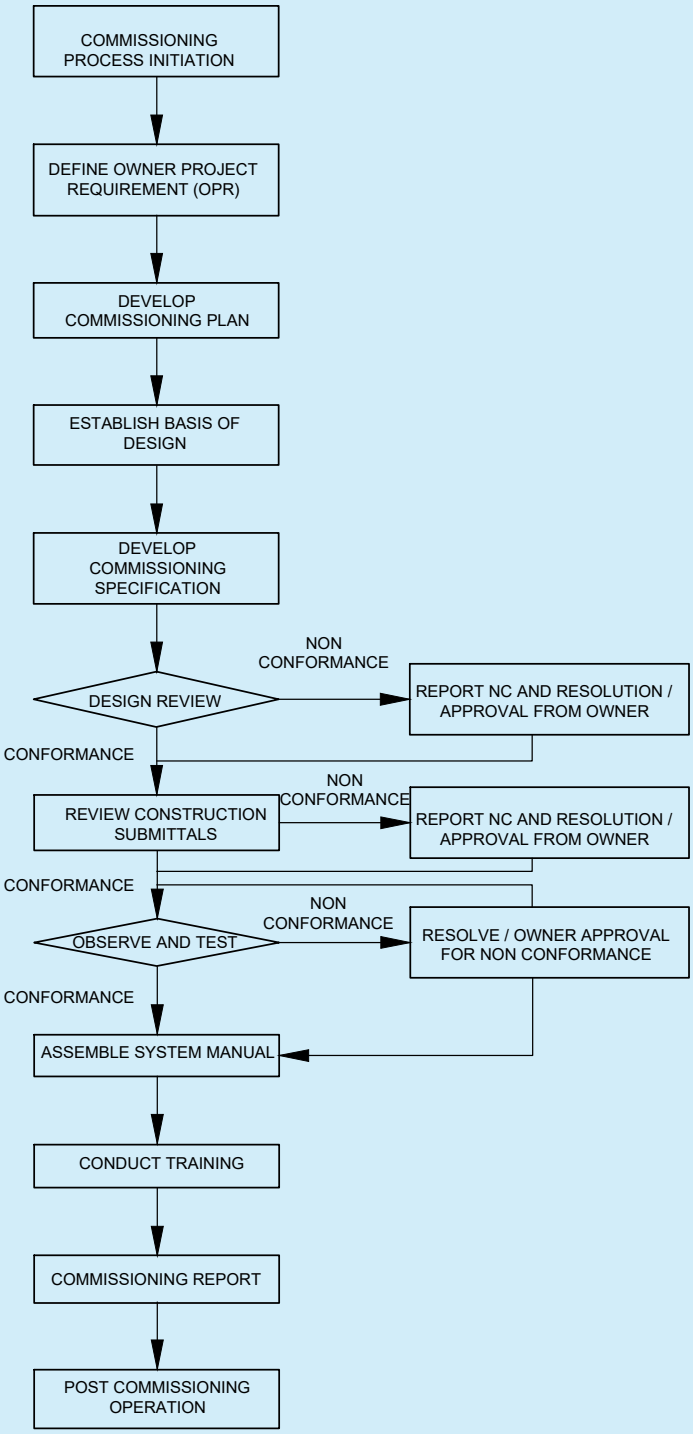

FIG. 40 FLOW CHART FOR HVAC COMMISSIONING

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17.8.2 For testing of equipment, receipt and inspection at site, safe storage and handling at site, refer 17.2. For each piece of equipment, sub system and system check lists shall be made use of for delivery, installation, start up and readiness of commissioning. Sample check lists available in special publication may be suitably adapted for use.

NOTE — Special publication maybe ISHRAE Standard 10003-2020.

17.8.3 Individual pieces of equipment, sub systems shall be considered ready for testing only when the complete installation is over, pressure testing/leak testing (as specified) are completed and required utility connections are made to the satisfaction of CxA. It shall be verified that all blank offs, shipping bolts etc have been removed. Where specified, manufacturer/supplier shall inspect and certify that the equipment/system is ready to start.

17.8.4 Testing of all equipment/ systems shall be in line with the documented protocol which is agreed between the manufacturer/vendor, CxA, design consultant, project management consultant and any other agency who may have jurisdiction over the project. Check lists, reporting formats and standards applicable shall all be agreed in writing beforehand.

17.8.5 Training and documentation for data collection leading to energy analysis shall form part of the process. It is recommended that all individual loads greater than 15 KW be monitored for energy management.

17.8.6 Static inspections that verify proper installation (for example, belt tensions, coupling alignments, oil levels, labelling, gauges and instrumentation in place, sensors calibrated etc) shall be submitted by the vendor to CxA with the request for startup.

17.8.7 Pre-commissioning cleaning of the installed ducting and leak testing of the ducts (where specified) shall be carried out prior to staring of AHU/Fans.

17.8.8 Activities where the equipment is initially energized, tested and operated shall be completed before functional performance testing (FPT) (*see* 17.8.1.11). FPT shall involve testing under dynamic situations such as low load, full load, varying ambient, power outage, distress and emergency conditions etc. FPT shall establish that the equipment/system performs as designed under all these conditions. Systems shall be operated integrally through all specified operation sequences. Each step of FTP shall be planned in advance, agreed between vendor and CxA, performed under supervision and results tabulated in a pre-agreed format. In case FPT shall not be performed due to any reason (such as ramp up period) before the equipment /plant is put to beneficial use, same shall be recorded and owner's approval taken.

17.8.9 Operation of all controls and safety cut outs shall be demonstrated and recorded. All measuring instruments shall have valid calibration certificates which shall be part of the record.

17.8.10 Handover documentation shall include all information owner/user will need to operate, maintain and if required, modify the system at a later date. Hand over documents shall include the following as a minimum requirement:

a) Updated and approved (by owner) systems manual;

b) Final commissioning report;

c) Set of as built drawings;

d) Full set of design calculations;

e) Spare parts lists/ordering procedure;

f) Warranty records, escalation matrix;

g) List of non-conformance with resolution records;

h) List of accessories/tools/spare parts supplied with system;

j) Operation and maintenance manuals provided by equipment supplier; and

k) List of spares and escalation matrix.

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17.9 Safety Points Specific to HVAC Systems

The following are safety guidelines specific to HVAC systems to ensure safe operation and maintenance:

17.9.1 Persons working on installation of HVAC Systems, large and small, are exposed to the same risks applicable to any construction activity such as bodily injuries, fall from height, electrical shocks etc. It is of prime importance to follow all safety requirements mandated by national as well as local codes, rules and regulations, including but not limited to, the safety provisions of Indian electricity act and rules framed thereunder and fire safety regulations prescribed by authority having jurisdiction (AHJ).

17.9.2 Following are the safety guidelines specific to HVAC Systems:

17.9.2.1 Nature and level of smoke hazard from the type of insulation material used in the system shall be carefully evaluated and proper ventilation and smoke management provisions shall be made dep, ending on the type and scalability of potential smoke generation.

17.9.2.2 Refrigerant gas being heavier than air, shall cause suffocation in enclosed spaces. Personnel shall use prescribed (by the refrigerant supplier) safety equipment while handling refrigerants and the plant room shall be well ventilated. Refrigerant cylinders shall be stored in upright position. Appropriate safeguard shall be in place based on manufacturer supplied information with respect to physical and chemical health hazards as well as storage and handling information.

17.9.2.3 While pressure testing systems, the following precautions shall be taken:

a) Obtain necessary work permit;

b) Barricade the area;

c) Use calibrated instruments and gauges;

d) Store gas cylinders in covered area and in upright position. Use colour codes to identify the gas inside the cylinder. Avoid exposing cylinders to sunlight;

e) Isolation/relief valves shall be provided appropriately;

f) Air shall be completely purged from water systems before pressure testing. identify drain valves and drainage routes/sumps; and

g) Have documented SOP approved by engineer-in-charge before work is taken up. Maintain appropriate records.

18 POST OCCUPANCY OPERATION AND MAINTENANCE

Proper maintenance schedules, regular inspections, and timely repairs are critical to optimizing system functionality and extending equipment lifespan. These practices also contribute to energy efficiency and occupant comfort in the building.

18.1 Operation and Maintenance Procedures

The following guidelines for post occupancy operation and maintenance to ensure long-term performance, safety, and efficiency of the HVAC systems after installation.

18.1.1 *Operating Plan*

The operating plan is given below:

a) Facility operating plan shall describe the intended use of this facility to ensure safety to the users, maintain thermal comfort, optimize resources efficiency, monitoring and data collection of the systems being operated in the facility;

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b) Key focus of this plan to ensure safety, reliability, comfort and healthy environment for the users/occupants;

c) During the post occupancy phase of operations, the facility shall develop a systems operations manual;

d) This manual shall comprise the owner's project requirements (OPR) and also the current facility requirements (CFR);

e) These documents shall be maintained throughout the operations of the facilities and shall update the changes in the operational procedures and functions of the facility;

f) Maintaining the information for the facility/building operators to understand, operate and maintain the building systems for entire life cycle of the facility as per design;

g) Operations and maintenance staffs shall effectively utilize the procedures for documenting and tracking of information on any updates, modifications to systems that occurred during occupancy and post occupancy of the facility;

h) The document shall include the modifications performed and the reasoning for the modification to the building operations;

j) As part of the operating plan the facility/operations team shall ensure all the safe operational practices recommended by the original equipment manufacturers (OEM); and

k) The facility/operations team shall ensure that the design documents like basis of design (BOD), as built drawings/documents updated time to time, are kept intact to ensure the intended operations of the systems in the facility/building.

18.1.2 *Facility Layouts*

This includes simple line diagrams (schematics) capturing the facility site/building plan, floor layouts and locations of major equipment and systems, control centers (like, electrical power isolations points), utility shut off points (like, dampers, isolation valves) to assist orientation/training of operators.

18.1.3 *Data Logging*

Maintain daily log of each system operations, record values as per OEM checklist for daily readings and record any abnormalities like sound, vibration, leakages, etc.

18.1.4 *Scheduling of Operation*

Operating hours for the facility to be described and listed and this should be the basis to perform more detailed scheduled and operational sequences.

18.1.5 *Roles and Responsibilities*

The building owner/operator shall describe their facility team/operating staff on the requirements of the building operations.

18.1.6 *Minimum Qualifications for the Building HVAC Operators*

The minimum qualifications for the HVAC Operators should be:

a) The operator should be having a required education qualification of reading operating manuals, standard operating procedures in the language that written with;

b) *Engineering-in-Charge* — Degree or diploma in electrical/mechanical/HVAC with not less than 5 years of experience respectively in operating and maintaining the HVAC systems;

c) *Supervisor* — Diploma in electrical/ mechanical/ HVAC with 3 years of experience or ITI or equivalent in HVAC with 5 years of experience;

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d) *Technician* — Diploma in electrical/mechanical/HVAC with minimum 1 year of experience or ITI or equivalent in HVAC with 3 years of experience;

e) *Operator* — Should have passed 10th Class/Intermediate from a state board of education [like CBSE or higher secondary education (HSC)]. Also, operator should have minimum technical qualification of certificate course or refrigeration and air-conditioning from an institute having reputation with state board of technical education (like ITI/NCVT/ AICTE); and

f) *Trainee* — Anybody not meeting the above qualifications may be inducted as a Trainee attached to any of the above positions. He/she may not be allowed to operate systems without supervision or support during their training period of minimum one year.

18.1.7 *Building and Equipment Operating Schedules, Set Points and Ranges*

The following guidelines for building and equipment operating schedules, set points, and ranges are designed to maintain optimal system performance and energy efficiency:

a) List and describe the planned/intended operating hours of the facility/building;

b) Building owner/operator shall define the initial operating schedules, anticipated occupancy, desired temperatures in the occupied zones;

c) All the set points of equipment with their safe operational requirements/adjustments shall be listed and provided to the operations team to perform their tasks;

d) The list shall comprise safe operating set point values, acceptable ranges and limitations; and

e) Any change to be implemented on the set points shall be recorded and implemented with reason for changing the set values to eliminate human errors.

18.1.8 *Sequence of Operations and Limitations*

The sequence of operations and limitations are listed as follows:

a) List out and provide operational sequences of all equipment to be operated in language and format that is understandable to the operating staffs;

b) The operators shall be briefed on the occupied and un occupied mode of operations of system and components; and

c) The operators shall be briefed on the safe shutdown of plant and equipment.

18.1.9 *Start-Up and Shut Down Procedures/Actions*

Start-up procedures shall be adopted as stated in **18.1.10** to **18.1.12**. The maintenance procedure shall be as laid down in **18.1.15**.

18.1.10 Before starting the plant, the operator shall ensure that:

a) All the valves in the refrigeration system, condenser water lines and chilled water lines are kept open, except those of the standby items of equipment;

b) Adequate water in the cooling tower basin and the make-up water system is working satisfactorily;

c) The make-up water system to the expansion tank of the chilled water circuit is working and there is a regular water supply. Water is lost from the chilled water system through pump gland drips/leaky mechanical seal. If the level in the expansion tank is not maintained, air shall enter the chilled water system, affecting the system performance substantially. It shall even lead to system/plant breakdown;

d) All the air filters and water strainers are clean. Any dirty filter and/or the blocked strainer shall be cleaned periodically;

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e) All doors and windows of the air conditioned/refrigerated area are closed;

f) The crankcase of the compressor is warm (to the physical touch). If it is not warm, defects in the crankcase heater and/or circuit should be checked fully. The compressor shall not be started until the defect is rectified and the crankcase warms up, else it will result to poor lubrication, thereby substantially reducing the life of the bearings of the compressor; and

g) The supply voltage is within permissible limits. The windings of the motors shall get affected, if run on low voltage conditions.

18.1.11 The starting sequence shall be as follows:

a) Switch 'ON' the mains. Observe the voltage. If it is less than the permissible level, do not start any component of the system;

b) Start air handling unit motors (all dampers have to be checked based on their specific application);

c) Start condenser water pumps. Check that sufficient water pressure is obtained;

d) Start cooling tower fan;

e) Start chilled water pumps and check the pressure;

f) Switch 'ON' the compressor control switch; and

g) Start the compressor motor.

18.1.12 Following aspects require special attention:

a) In the compressor with oil pump, the compressor oil pressure should build up as the compressor is started. Check that corrects net oil pressure is built up;

b) Check the oil level in the oil sight glass of the compressor. The oil level should be about 40 to 50 percent of the sight glass. In operation, certain amount of oil gets entrained in the refrigerant vapor in the compressor and is carried to the system along with the refrigerant;

c) After the plant operation has stabilized, check all the pressures and temperatures and ensure that the system is working satisfactorily;

d) Record periodically the readings of temperature, pressure, current and other required data in the log sheet;

e) Check for any unusual noise/vibration in the plant. If something unusual is noticed, trace out the reason for it and rectify the cause; and

f) During the operation of the system, if any major component stops suddenly, trace out its reason, before starting the component/system again.

18.1.13 The stopping sequence of the system shall be as follows:

a) Switch off the compressor on the low-pressure switch, as the system gets pumped down;

b) Switch off the power supply to compressor;

c) Check that the crankcase electric heater comes on as soon as compressor stops and ensure that the heater is working;

d) Stop chilled water pumps;

e) Stop air handling units; and

f) Stop condenser water pumps and cooling tower fans.

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18.1.14 Following are standard operating instructions which the operator should follow:

a) In case stand-by chiller, pumps, etc, are provided, systematically change over the stand-by components, periodically. This will ensure uniform wear and tear of the system. Further, this also helps in ensuring that all equipment is in good shape and the stand-by is in working condition;

b) Do not switch off the main switch on the main electrical board or switch off any component of the system, when the plant is in operation;

c) All the water valves in the system shall be kept open and need not be closed, unless specifically instructed by designer. But it shall be done to close and open each valve periodically to ensure that the valves work and are not stuck by scale formation or dirt accumulation; and

d) Keep the plant room clean. Do not use the plant room, particularly the air handling unit rooms for storage.

NOTE — An automatic sequence of operation shall be covered under Chapter 15 - Building Management System.

18.1.15 *Maintenance Procedures, Check Points and Records*

Procedure for establishing and maintaining effective maintenance practices, ensuring comprehensive inspection points, and maintaining accurate records for facility management.

18.1.15.1 *Preventive maintenance*

The preventive maintenance is:

a) The goal of preventive maintenance is to prevent equipment failure caused normal wear and necessary action by replacing worn out components prior to actual failure of an equipment;

b) Maintenance activities shall include partial or complete overhauls at specified periods and shall include oil changes, lubrication of components, minor adjustments and so on;

c) Operators shall record equipment deterioration by inspection to facilitate the replacement or repair of worn-out parts prior to any system failures;

d) Implement preventive maintenance of installations and equipment to maintain efficient working of building HVAC system and its components;

e) Implement periodic inspection schedule, testing and maintenance throughout their life cycle;

f) Conduct periodic maintenance and testing, servicing, checking, calibration, overhauls and certification, annual inspection, testing, witness regular test and certification;

g) Perform overhauling or replacement at a certain usage (as recommended by OEM) or due to specific causes. This shall be outlined specifically in a preventive maintenance program;

h) Implement preventive maintenance program (PMP) and shall include the methodology and record for all action that are necessary to maintain the efficient working order of the HVAC system;

j) The maintenance procedures shall be unique to each property and the installations and equipment within these facilities;

k) Conduct preventive maintenance in accordance with statutory requirements. (pressurization system, smoke control system, fire alarm interlock with air handling units are few example);

m) Conduct preventive maintenance and overhauls with clear maintenance schedule, instruction and procedures;

n) Ensure O&M personnel induction training on safety, statutory requirements and performance target and work manner;

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p) Adopt condition based/reliability-based maintenance where appropriate;

q) Conduct a regular review of all procedures/standards;

r) Conduct a regular update of relevant procedures/standards against the latest statutory requirements, good industrial practices, maintenance records and fault history by a working/facility team comprising competent personnel; and

s) Adopt a web based/mobile application-based performance monitoring system for maintenance that is contracted out.

18.1.15.2 *Maintenance schedule*

18.1.15.2.1 *Day-to-day maintenance schedule*

a) *Clean the air filters* — Dirty filters cause poor air flow through air handlers and results in thermal discomfort. Unattended filters could result in damage to the filtering media and the unfiltered air shall pass through them and settle on the cooling coils. This results in poor heat transfer and impacts the efficiency of the air handler system and total efficiency of the HVAC system as a cascading effect;

b) *Leak testing for refrigerant leaks* — Check physically for oil traces, which is indicates source of refrigerant leaks. Perform leak testing using soap bubble or electronic leak detectors. Refrigerant leaks impact the system operation and leads to breakdown of system. Refrigerant leaks impact our environment due to global warming potential of the refrigerants being used in the HVAC system;

c) *Water pump (packed) glands* — Certain amount of water should drip through the gland which is necessary to keep the gland cool. However, if the drip develops into a flow of water, then, it is an indication of leak gland. This should be attended by tightening the gland nuts to reduce the water leaks or gland packing to be replace to prevent loss of water from the distribution system. Unattended gland water leaks shall result in loss of water and facilitates air entry into to the system which could result in abnormality in the chilled water distribution system; and

d) Check and monitor any abnormal noise or vibration.

18.1.15.2.2 *Weekly maintenance schedule*:

a) *Belt Tension of belt drives* — Check the belt tensions and tighten whenever necessary if found loose. A loose belt reduces the transmission efficiency, reduced air volume of the air handlers and thus affects the thermal comfort. Loose belts cause noisy air handlers and results disturbance to the building occupants;

b) *Check the cooling coil drain tray* — Check and ensure the drain tray is clean from dirt and debris to prevent mould growth or water leakage due to drain block;

c) *Check the lubrication* — Check the lubrication of bearings to ensure smooth operation and prevent breakdowns due to worn out bearings;

d) *Check the Cooling tower* — Check the cooling tower sumps to keep them clean from debris (tree leaves if the towers are located at ground level). The towers are kept open to ambient and dust from the air shall settle on the fills, sumps and requires cleaning to ensure proper operation of the cooling towers which are very critical for a water-cooled system efficiency and performance; and

e) Conduct water quality test for cooling towers periodically.

18.1.15.2.3 *Monthly Maintenance Schedule*:

a) Replace the air handling unit filters with a set of replacement filters kept under stock;

b) Check the starters and check loose connections of cables and ensure tightness;

c) Check the operation of automatic blow down system for cooling towers;

d) Check and clean the Y-strainers and Pot Strainers;

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e) Check the preventive maintenance schedule of components and equipment and conduct maintenance activities; and

f) Check and tighten all base bolts to prevent breakdown due to vibration.

18.1.15.2.4 *Quarterly maintenance schedule*:

a) Perform pre scheduled preventive maintenance activities equipment and components;

b) Check the log book and conduct thorough study of equipment to ensure healthiness of its operation;

c) Check and lubricate all the moving parts;

d) Check and clean the cooling tower sumps;

e) Check and clean all the strainers and pot strainers;

f) Check and replace belts if necessary;

g) Check the safety interlock of all air handling units;

h) Check and replace defective instruments like pressure gauges, thermometers etc;

j) Check and rectify any refrigerant leaks; and

k) Check and replace any defective/malfunctioning components of the system.

18.1.15.2.5 *Half year maintenance schedule*:

a) Perform all the activities listed under quarterly maintenance schedule;

b) Check the conditions of the cooling tower fills and clean them;

c) Check and clean the air handling unit blowers from dust/dirt accumulation; and

d) Check the operation of cooling tower blow down system (automatic) and chemical dosing system.

18.1.15.2.6 *Yearly Maintenance Schedule*:

a) Perform all the activities listed under half yearly maintenance schedule;

b) Collect oil sample from the chiller system and send them for laboratory test to analyze presence of metal particles, viscosity etc;

c) Post lab results replace the oil to ensure safe operation of the compressors to enhance the life cycle;

d) Check and clean the condenser tubes of the water-cooled system to improve heat transfer. If, required only, conduct de-scaling of the tubes. Frequent de-scaling is not recommended and cause potential damage to the copper tubes;

e) Check the operation of auto tube cleaning system if it is in place and ensure its components are intact or replace if required;

f) Conduct vibration test of all major equipment and record the test readings for further comparisons till life cycle of the equipment;

g) Witness maintenance of all the electrical starter panels, switch gears, earthing conductors and perform interlock testing for safe operations of the total system; and

h) Conduct indoor air quality test and if required perform duct cleaning procedures to ensure good indoor air quality.

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18.1.15.2.7 *Check points*:

a) Compare the previous maintenance log and record any abnormalities;

b) Conduct necessary actions to rectify or replace component/equipment as noticed on abnormalities;

c) Ensure O&M personnel induction training on safety, statutory requirements and performance targets; and

d) Conduct and analyze on operating costs due to lack of maintenance and ensure corrective actions.

18.1.15.2.8 *Records*:

a) Good maintenance records for ensuring that a piece of equipment is performing in line with OEM recommendations, warranties and thus help to determine an equipment preventive maintenance schedule;

b) Maintenance records to be maintained to assist the service matter experts, (SME's) service technicians for diagnosing any repeat problems with or within the plant or its equipment;

c) Maintain paper records of all maintenance related activities including testing and commissioning certificates, test records, as-built documents, statutory approved submission documents, water quality test reports, oil quality test report, indoor air quality reports, calibration certificates of instruments;

d) Maintain emergency call/fault attendance reports, fault history etc;

e) Maintain records of usage of refrigerants;

f) Maintain soft copies of all the documents listed under paper records;

g) Assign designated persons/s responsible to review and update routine maintenance inspection schedule, emergency call/fault attendance reports etc, on a monthly basis and the findings shall be documented for future reference;

h) Set up record system able to automatically provide alerts for outstanding shutdown notices and annual maintenance renewal etc; and

j) Digitize all documents and records with a standardized file naming system in a reliable database server for easy retrieval. (Facility management system/manager shall perform this activity).

18.1.15.2.9 *Training*:

a) Provide training to equip staff with knowledge to work safely and without risk to health;

b) To Ensure maintenance plans are followed correctly, facility managers and building owners should provide sufficient periodical training to all maintenance technicians. Good sources of trainings are:

   1) An experienced technician or facility staff member;

   2) OEM's training;

   3) Technical and community colleges; and

   4) Videos, seminars and short-term courses by professional associations like ISHRAE.

c) The minimum training content delivered should generally include below:

   1) Basis of design or design brief;

   2) Documentation requirements;

   3) Operating procedures such as startup and shutdown procedures;

   4) Basic diagnostic instructions; and

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5) Fire, life safety and emergency procedures.

18.1.15.10 *Spare parts inventory management*:

a) Managing spare parts in an optimal way is an inherent and substantial part of O&M aimed at ensuring that spare parts are available in a timely manner for corrective maintenance in order to minimize the downtime of a system or equipment;

b) Maintain a spare parts list for plant and equipment;

c) Maintain an updated contact list of suppliers with lead time details of each spare;

d) Review constantly the quality and quantity of spare parts in stock and restock when necessary;

e) Maintain the log of spares utilized;

f) Assign designated person/s responsible for regular updates of any changes in spare parts inventory;

g) Monitor the condition of spare parts to ensure their quality is maintained;

h) Identify long lead items/components for early procurement; and

j) Identify discontinued items (obsolete) for sourcing an alternative parts or upgrade of system.

18.2 Predictive Maintenance

a) Predictive maintenance is a planned maintenance basis diagnosis of equipment condition;

b) Measurements that detect the onset of a degradation mechanism, thereby allowing causal stressors to be eliminated or controlled prior to any significant deterioration in the component physical state;

c) Predictive maintenance techniques may include vibration analysis, thermography, oil analysis, motor current analysis, Eddy current testing and pressure measurement etc; and

d) Performance trending.

18.2.1 *Emergency Operating Procedures*

a) Emergency event requires planning, preparation and practice;

b) Regardless of type of risk, every facility shall have a risk event plan or emergency management in place to minimize the damage and danger to following:

1) Building occupants;

2) Documents and assets within facility;

3) Building, IAQ and surrounding community, air and water; and

4) Establish and implement environmental management systems and safety management systems. For additional information special publications may be referred.

NOTE — Special publication maybe ISO 14001 for Environmental Management Systems and OHSAS 18001 or ISO45001 for Safety Management Systems.

18.2.2 *Performance Based Operation and Maintenance Contracts*

a) Performance based or output based operation and maintenance contracts gaining traction;

b) The advantages of performance-based O&M contracts are;

c) Payment for actual performance or usage;

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d) Contractor responsibility for full package;

e) Continuous improvement/Innovation; and

f) Reduced risks due to lower capital costs.

18.2.3 User feedback mechanisms for optimizing maintenance schedules or identifying:

a) Metering and sub-metering of energy and resource use is a critical component of a comprehensive O&M program;

b) Metering provides the information that when analyzed allows the building operations staff to make informed decisions on how to best operate mechanical/electrical systems and equipment:

1) Metering approaches;

2) One time/spot measurement;

3) Run time measurement;

4) Short term monitoring;

5) Long term monitoring;

6) Measure, verify, and optimize equipment performance; and

7) Identify improvement opportunities on environmental (especially energy, water efficiency) and safety aspects.

18.3 Computerized Maintenance Management System (CMMS)

CMMS is a computerized maintenance management system, which is a software application that helps controlling, monitoring and analysing operation of HVAC system. The centralized CMMS would help in optimization of cost, resources, and information at one place.

Benefits that the CMMS shall provide to the facility during operation and maintenance shall include

a) *Electronic records* — Use of electronic records reduces the amount of time spent by office personnel entering data, which improves the efficiency of the maintenance department;

b) *Reduced repair costs* — A CMMS shall store and provide easy access to equipment records. When historical records are easily accessible, they shall be used to determine the most economical decision for a piece of equipment: repair or replace;

c) *Personnel management* — Records for each employee shall be stored and easily accessed and updated. Electronic personnel records shall include, but are not limited to, training and certifications earned by each employee, pay scales, and hire dates;

d) *Asset management* — A CMMS shall be used to store electronic records for any type of asset, including equipment and supplies;

e) *Process automation* — When a CMMS is set up correctly, preventive and predictive maintenance work orders, parts and supply reordering, and other notifications shall be automated, saving time and increasing the efficiency of the maintenance team;

f) *Improved work control* — CMMSs provide increased ability to manage work orders and prioritize and schedule work;

g) *Increased budget accountability* — Accurate records of labour hours and inventory items increase the accuracy of expenses and budgets; and

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h) *Increased ability to measure performance and service* — When data are available, performance shall be determined for a period of time, such as that required to complete a specific type of maintenance activity or respond to a service call.

CCMS Modules shall be considered for facility operations are as below:

1) *Asset management* — Its asset operations, monitoring and control, repair and PM history;

2) *Work order management* — Helpdesk ticket end-to-end user complaint to closure of calls;

3) *Procurement* — Inventory management, parts ordering; and

4) *Dashboard reporting* — This module allows you to generate reports on a variety of maintenance metrics, such as downtime, costs, and asset health.

18.3.1 Broad CMMS selection process that shall be considered as follows:

a) *Team involvement* — To include the facility managers, clients, property management team, consultants and technicians shall be involved during the planning phase to select the suitable CMMS software, scope of working of CMMS and integration requirement with other third-party systems (BMS, EMS and AI); and

b) When selecting the software, the following shall be part of the process:

1) Continued focus and understanding of the true need for the CMMS; and

2) Clear understanding of how the CMMS implementation will support maintenance best practices desired by the organization.

18.3.1.1 Process of selection given below shall be followed:

a) For planning:

1) Establish a CMMS selection task force;

2) Perform interviews with all members of the facilities team who will use the CMMS;

3) Determine the needs, wants, reporting features, and goals for the CMMS;

4) Determine what CMMS outputs are needed to meet the goals;

5) Determine input data that shall be collected;

6) Evaluate the value of data versus the cost of collecting, inputting, and maintaining the data within the CMMS;

7) Integration of third-party software data to CMMS;

8) Determine available budget;

9) Determine CMMS modules needed;

10) Write CMMS specification;

11) Prepare for CMMS vendor meetings;

12) Meet with vendors and participate in vendor demonstrations;

13) Prepare bid package;

14) Develop a continual implementation plan;

15) Determine if a phased implementation plan is needed; and

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16) Develop a phased implementation plan (if needed).

b) CMMS software/ CMMS module selection shall fulfil the operational needs of facility and shall address the following:

1) Areas for improvement in current maintenance practices (for example, reduced downtime, improved preventive maintenance);

2) Advanced features and functionalities (for example, mobile access, work order management, reporting);

3) Strong asset management, work order creation and tracking, preventive maintenance scheduling, and inventory control;

4) Consider advance features like AI-based functionalities for predictive maintenance, asset analysis from R and M, PM perspective, dash-board reporting, mobile capabilities for Equipment operative team;

5) Integration with any existing software you use;

6) Options for future scalability;

7) Requirements towards company where CMMS to be installed IT/data security and compliance with relevant regulations;

8) Implementation costs, licensing fees (one time and recurring), availability of software key, and ongoing software support; and

9) Strong after sale service and customer support.

18.3.2 *Implement a CMMS, Going-Live Phase*

a) Select a CMMS;

b) Collect input data;

c) Input data into CMMS;

d) Determine how users will be trained;

e) Implement training;

f) Go live and cut over:

1) Going live is the transition between setting up a system and using the CMMS for daily maintenance activities. This project phase reveals how successful the planning and implementation processes were. Before going live, the CMMS shall be tested and checked to ensure correct system configuration.

g) Implement continual implementation plan; and

h) Create standard operating procedures (SOPs) for using the CMMS.

18.3.3 *Integration of CMMS with Building Automation Systems (BAS) for Data Collection and Analysis*

a) Integrating of CMMS with a building automation system (BAS) will be an intense tool for property and facility management engineering team. The BAS regularly monitors and collects data on several characteristics of a building's management systems;

b) Integration complexity shall be looked during planning phase for example, specific software and desired functionality, shall ensure that both the systems communicate with each other properly;

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c) To protect sensitive building information, a common IT security protocol, proper data security protocol shall be ensured;

d) It shall be ensured that periodic data export from the BAS and import into the CMMS be established or worked during RFP phase. Make certain consistent data formats and naming principles between the CMMS and BAS for seamless integration; and

e) Protocol for two-way communication between both the systems, allowing for real-time data exchange shall be established.

18.3.4 *Automation and Integration of Chiller plant and Pumps*

Following systems shall be considered for automation and integration in the BMS and CMMS. Refer to relevant guidelines/best practices ('Handbook on Asset and Facility Management in Buildings') for further details.

a) Building automation system (BAS);

b) Chiller plant manager; and

c) Sensors, VFD, communication system/PLCs .

18.4 Controls to Measure and Monitor Building Energy Performance

18.4.1 *System for Data Collection and Analysis*

Building controls such as CMMS and BMS systems shall consists of following metering systems, controls and monitoring systems for data collection and analysis:

a) Main meters for sources of energy used by facility;

b) Submetering for applications that represent 10 percent or more of the total building consumption such as chillers, pumps, cooling towers, AHU's, ventilation systems, hotel rooms (cumulative), lighting and UPS systems;

c) Data collection systems: collecting data from energy meters, sub-meters on pumps, cooling towers, AHU feeders;

d) Building Automation System (BAS);

e) Chiller plant manager; and

f) Sensors, VFD, communication system/PLCs.

NOTE — Refer to relevant guidelines/best practices ('Handbook on Asset and Facility Management in Buildings') for further details.

18.4.2 *Maintenance Strategy and Controls Including Integration of CMMS with Building Automation Systems* (*BAS*)

a) *Predictive maintenance* — Using CMMS/CPM/ BMS, BAS data for example, equipment performance metrics and sensor readings, helps to predict potential breakdowns and shall schedule maintenance before failures occur. CMMS shall be used to analyse this data and initiate work orders;

b) *Condition* — Based Maintenance: BAS/ CMMS shall use this data to prioritize maintenance tasks based on actual equipment condition, optimizing resource allocation;

c) *Preventive maintenance* — CMMS should be used to schedule PM tasks based on OEM recommendations, historical data, and BAS/CMMS/BAS alerts; and

d) A 52 week PPM planner shall be used aligned with checks prescribed in OEM manuals.

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18.4.2.1 Critical systems identification and analysis of efficiency and healthiness checks:

a) AHUs;

b) Compressors;

c) Chiller;

d) Condenser;

e) Cooling towers;

f) CMMS, PLC and controls;

g) Electrical, power distribution network;

h) Water cycle – open and closed circuits;

j) Boilers;

k) PAHUs/PACs, domestic air conditioners; and

m) STPs in case STP water is used in cooling towers.

18.4.2.2 Analysis of efficiency and healthiness checks:

a) ikW and COP test shall be performed with the help of OEM and maintenance agency the analysis report should contain performance designed vs actual;

b) Check for the AHU performance; and

c) A regular health check-up should be conducted by a professional HVAC engineer, preferably on annual basis, the test should be considered during Peak load for example, summer.

Further an equipment wise check shall be conducted using calibrated equipment's.

18.4.2.3 *Selection of maintenance class and transitioning from reactive to proactive maintenance*

To transition from one particular maintenance approach to another, a detailed analysis shall be made to determine what will be the most effective. Table 43 below indicates the type of maintenance to be considered for the systems/facility.

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Table 43 Type of Maintenance to be Considered for the Systems/Facility

(*Clause* 18.4.2.3)

Sl No.	Maintenance Class	Effect of Failure	Desired Result	Analysis Used to Determine Most Effective Maintenance Technique	Implementation of Maintenance Practices
(1)	(2)	(3)	(4)	(5)	(6)
i)	A: Mission Critical	Significant financial, safety and/or operational impact	Risk mitigation and maximize equipment and system availability	Reliability centered maintenance and risk assessment	Preventive and predictive approaches
ii)	B: Optimize life-cycle costs	Minor impact on core business activities	Minimize equipment LCC over time	Reliability centered maintenance and risk assessment	Preventive, predictive and reactive approaches
iii)	C: Minimize short-term costs	No impact on core business activities	Minimize short-term costs	Risk assessment	Risk mitigation measures, visual inspection, and preventive maintenance
iv)	D: Industry standard maintenance	No impact on core business activities	Minimize short-term costs	Risk assessment	RS Means or original equipment manufacturer job plans, preventive maintenance
v)	E: Out-of-Service	No impact oncore business	Ability to operate	Risk assessment	Minimum maintenance

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To select the appropriate maintenance class, the facility mangers to develop an effective maintenance program and shall consider the following:

a) Focus on maintenance that results in the best return on investment (ROI);

b) Make sure results shall be measured;

c) Avoid intrusive maintenance; and

d) Employ an effective management system, such as a computerized maintenance management system (CMMS).

18.4.2.3.1 The Systems to consider for proactive maintenance shall include:

a) AHUs;

b) Compressors;

c) Chiller;

d) Condenser;

e) Cooling towers;

f) CMMS, PLC and controls;

g) Electrical, power distribution network;

h) Water cycle – open and closed circuits;

j) Boilers;

k) PAHUs/PACs, domestic air conditioners; and

m) STPs in case STP water is used in cooling towers.

18.4.2.3.2 Transition from reactive to proactive maintenance shall benefits the facility operation and maintenance and that shall include:

a) Fixing things only when they break is a reactive maintenance, which leads to a sudden failure to equipment, causing down-time, production loss, Impact equipment life span/age and requires more budget/cost to manage;

b) Making a switch towards proactive maintenance for example, prevention over repairs requires time and efforts but helpful enhance equipment life, up-time, reliability, maintenance cost, safety and increased efficiency; and

c) A proactive maintenance should have deep understanding of your assets, thorough study of OEM manuals, drawings, design brief/project reports, regular inspection, analysis of failure history/equipment down-time/break-down historical data, condition monitoring, a regular training to operators understanding various failures code as described in OEM manuals.

18.5 Benchmarking of Building Performance with KPI Index

18.5.1 *Strategies for Implementing the Measurement and Verification* (*M and V*)

M and V strategies/ techniques shall be used by facility owners or energy efficiency project investors for the following purposes:

a) Increase energy savings;

b) Enhance financing for efficiency projects;

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c) Improve engineering design and facility operations and maintenance; and

d) Manage energy budgets.

M and V plan produce verifiable savings reports. An M and V Plan shall be developed for each facility by qualified professional. M and V applies to a wide variety of facilities including existing and new buildings and industrial processes. M and V strategies consist of some or all of the following:

1) Meter installation calibration and maintenance.

2) Submetering for applications such as HVAC (Chillers, Pumps, CT), AHU's, ventilation fans, internal lighting, external lighting and UPS.

3) Data gathering and screening,

4) Development of a computation method and acceptable estimates,

5) Computations with measured data, and

6) Reporting, quality assurance and third-party verification of reports.

M and V options to be followed shall include as below:

i) Option-1 – Retrofit Isolation: key parameter measurement

ii) Option-2 – Whole facility

18.5.1.1 *Option*-1 – *Retrofit isolation: key parameter measurement*

Retrofit isolation techniques are best applied where:

a) Only the performance of the systems affected by the ECM is of concern, either due to the responsibilities assigned to the parties in an energy performance contract, or due to the savings of the ECM being too small to be detected;

b) Interactive effects of the ECM on the energy use of other facility equipment shall be reasonably estimated or assumed to be insignificant;

c) Sub-meters already exist to isolate energy use of systems;

d) Meters added at the measurement boundary shall be used for other purposes such as operational feedback or tenant billing; and

e) Long term testing is not warranted.

18.5.1.2 *Option*-2 – *Monitoring performance of whole facility*

Monitoring of whole facility Involves use of utility meters, whole-facility meters, or sub-meters to assess the energy performance of a total facility. The measurement boundary encompasses either the whole facility or a major section. This option determines the collective savings of all ECMs applied to the part of the facility monitored by the energy meter.

Facility team shall select the M and V options based on the energy metering infrastructure availability and energy conservation measures (ECM) implementation and monitoring of ECM.

a) *Overall HVAC system efficiency for benchmarking*

The overall HVAC systems efficiency shall be measured with the help of submetering as suggested in the M and V section and overall HVAC systems efficiency shall be calculated as overall HVAC energy consumption in kWh and divided by conditioned area of the facility.

$$\text{Overall HVAC systems efficiency} = \frac{\text{overall HVAC consumption (kWh)}}{\text{conditioned area-sq.m}}$$

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b) Scheduled intervals, equipment performance to be measured and monitored and compared with bench marking of efficiency till the end-of-life cycle of the equipment. The equipment performance to be measured on monthly basis in kWh and performance to be tabulated for comparing with benchmarking.

c) Corrective action to ensure performance of the system.

The corrective actions to ensure performance of systems shall be as per Table 44.

Table 44 Potential Corrective Measures List

(*Clause* 18.5.1.2)

Sl No.	Possible Cause	Recommended Corrective Action
(1)	(2)	(3)
i)	General	
	Human error in data collection and analysis	Train staff in data collection and analysis
	Instrumentation error	Check error and calibrate to attain manufacturer recommended level
	Equipment operating schedules	Change equipment operating schedules to more closely follow actual building activities.
	Equipment load	Identify correct plug load and ensure their proper use
ii)	Lighting	a) Fine tune on hours more closely to reflect actual. b) Measure actual lux level and take corrective action to ensure task-based lux level c) Check voltage level to ensure there is no over voltage to avoid over consumption d) Ensure fixture and accessories cleaning to increase lighting efficiency
iii)	HVAC- Chilled Water System	a) Ensure preventive maintenance as per schedule. b) Check DPT function. c) Check pump operates at its best efficiency point. d) Check COP at full load condition.
iv)	Water	a) Check for leak in pipes, fittings. b) Ensure periodical cleaning of the filters provided at the roof for rainwater harvesting. c) Rainwater collection sumps to be have a maintenance plan in place.

d) Measure the indoor air quality, thermal comfort, water performance and energy performance as part of KPI.

Metrics and trends are important parts of maintenance organization. Metrics, also known as key performance indicators (KPIs), shall be used to drive improvement, minimize problems, help set priorities and goals, and help determine milestones and evaluate success.

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To effectively use metrics and trends, reports shall be set up and generated using the CMMS. There are two basic types of reports

1) *KPIs and measures reports* — Reports that contain key performance indicators, trends, and measurements that identify systems and equipment, processes, other maintenance management topics that need the most attention.

2) *Functional reports* — Reports used Measure the indoor air quality, thermal comfort, water performance and energy performance.

18.6 HVAC System Life Expectancy Comparison

a) Comparison of HVAC systems to check the end of life/replacement of systems:

   1) The typical lifespan of an HVAC system is known. Nevertheless, after years of regular use, the efficiency and performance of an HVAC system naturally decreases overtime;

   2) There are few signs that signal this decrease are:

      i) Increase in breakdown frequency;

      ii) Increased energy use;

      iii) Performance degradation; and

      iv) Unusual noise.

   3) Risk based approach to plan and schedule replacement works in accordance with spare parts availability as well as any specific law and safety requirements, etc.

b) Performance based approach to analyse the HVAC systems life served including the factor affecting the HVAC systems lifespans:

   1) Output based approach to understand the life of HVAC system;

   2) Factors that affect the HVAC systems lifespan are:

      i) Quality of installation;

      ii) Utilization time of equipment;

      iii) Location; and

      iv) Operation and maintenance.

19 SMOKE MITIGATION – FIRE AND LIFE SAFETY

Smoke mitigation towards fire and life safety is towards providing human life safety with tenability to enable the occupants ideally to exit from event (fire incident) zone or in some occupancies to have occupants towards defend in place.

Compartmentation to ensure space by space integrity to prevent the spread of fire. Such spaces enable occupants to proceed to exits and to be provided with aspects of smoke mitigation though ideally pressurization or in some cases with smoke ventilation.

Smoke ventilation predominately post fire incident to enable reducing smoke concentration levels for firefighters and emergency responders shall more effectively check reoccurrence of fires and rescue occupants from the defend in place safe zone to exits. This also helps in reducing property damage by purge of smoke post fire incident in the fire incident area/ spaces.
The various strategies and spaces shall be identified to enable designers to adopt the required strategy of smoke mitigation and also have specific design, systems provided and its functions on respective occupancy of the project.

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Technical, design, performance aspects with integration to fire alarm system and also importantly evacuation strategy are specified.

Aspects of pressurization (Pascals) for defend in place [One door open], phased evacuation [Three door open], assisted firefighting shaft [Three door open] shall be detailed in the smoke mitigation aspects towards life safety.

The power supplies, fire rating, interlocking of the smoke mitigation system on mechanical systems, equipment, elevators, lobby compartmentation, damper control shall be included for successful implementation of the smoke mitigation system.

19.1 Smoke Mitigation – Sub Structure

19.1.1 *Car Parking in Sub Structure*

19.1.1.1 *Basement car parking non-mechanical*

In case of smoke exhaust and pressurization of areas below ground, each basement shall be separately ventilated. Vents with cross-sectional area (aggregate) not less than 2.5 percent of the floor area spread evenly round the perimeter of the basement shall be provided in the form of grills, or breakable stall board lights or pavement lights or by way of shafts.

19.1.1.2 *Basement car parking stack/ mechanical*

In case of smoke exhaust and pressurization of areas below ground, mechanical ventilation system be provided with following requirements:

a) Mechanical ventilation system shall be designed to permit 12 ACPH in case of fire or distress call. However, for normal operation, air changes schedule shall be as given in **3**;

b) In multi-level basements, independent air intake and smoke exhaust shafts (masonry or reinforced concrete) for respective basement levels and compartments therein shall be planned with its make-up air and exhaust air fans located on the respective level and in the respective compartment. Alternatively, in multi-level basements, common intake masonry (or reinforced cement concrete) shaft may serve respective compartments aligned at all basement levels. Similarly, common smoke exhaust/outlet masonry (or reinforced cement concrete) shafts may also be planned to serve such compartments at all basement levels. All supply air and exhaust air fans on respective levels shall be installed in fire resisting room of 120 min. Exhaust fans at the respective levels shall be provided with back draft damper connection to the common smoke exhaust shaft ensuring complete isolation and compartmentation of floor isolation to eliminate spread of fire and smoke to the other compartments/floors;

c) Due consideration shall be taken for ensuring proper drainage of such shafts to avoid insanitation condition. Inlets and extracts may be terminated at ground level with stall board or pavement lights as before. Stall board and pavement lights should be in positions easily accessible to the fire brigade and clearly marked ‘AIR INLET’ or ‘SMOKE OUTLET’ with an indication of area served at or near the opening;

d) Smoke from any fire in the basement shall not obstruct any exit serving the ground and upper floors of the building;

e) The smoke exhaust fans in the mechanical ventilation system shall be fire rated, that is, 250 °C for 120 min;

f) The smoke ventilation of the basement car parking areas shall be through provision of supply and exhaust air ducts duly installed with its supports and connected to supply air and exhaust fans. Alternatively, a system of impulse fans (jet fans) may be used for meeting the requirement of smoke ventilation complying with the following:

    1) Structural aspects of beams and other down stands/services shall be taken care of in the planning and provision of the jet fans;

    2) Fans shall be fire rated, that is, 250 °C for 120 min;

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3) Fans shall be adequately supported to enable operations for the duration as above;

4) Power supply panels for the fans shall be located in fire safe zone to ensure continuity of power supply;

5) Power supply cabling shall meet circuit integrity requirement in accordance with accepted standard [D-3(39)];

6) The jet fan system may be validated through final computational fluid dynamics (CFD) analysis of the basement; and

7) The jet fan system after commissioning may be verified by Smoke Gun Test for at least one compartment.

The smoke extraction system shall operate on actuation of flow switch actuation of sprinkler system. In addition, a local and/or remote 'manual start-stop control/switch' shall be provided for operations by the fire fighters. Visual indication of the operation status of the fans shall also be provided with the remote control. Smoke exhaust system having make-up air and exhaust air system for areas other than car parking shall be required for common areas and exit access corridor in basements/underground structures and shall be completely separate and independent of car parking areas and other mechanical areas supply air shall not be less than 5 m from any exhaust discharge openings.

19.1.1.3 *EV Car Parking*

The aspect of smoke ventilation for EV car parking shall be as above in **19.1.1.2**.

19.1.2 *Habitat Spaces in Substructure*

Smoke exhaust system having make-up air and exhaust air system for areas other than car parking shall be required for common areas and exit access corridor in basements/underground structures and shall be completely separate and independent of car parking areas and other mechanical areas.

19.1.3 *Services Spaces in Substructure*

Smoke exhaust system having make-up air and exhaust air system for areas other than car parking shall be required for common areas and exit access corridor in basements/underground structures and shall be completely separate and independent of car parking areas and other mechanical areas.

19.2 Smoke Mitigation – Super Structure/Above Ground

19.2.1 *Group A* (*Residential Buildings*) *to Group G* (*Industrial Buildings*)

For the residential buildings (Group A), all kitchen exhaust fans, where provided shall be fixed to an outside wall or to a duct of non-combustible material, which leads directly to the outside. The ducts shall not pass through areas having combustible materials. However, in case of centralized ducting, the duct shall be provided with adequate protection to limit the spread of fire.

For the industrial buildings (Group G), occupancy requiring undivided floor areas so large that the distances from points within the area to the nearest outside walls where exit doors are 45 m and more, requirements for distance to exits should provide stairs leading to exit tunnels or to overhead passageways. In cases where such arrangements are not practicable, the authority may, by special ruling, permit other exit arrangements for single storeyed buildings with distances higher than distances specified in **4**, if completely automatic sprinkler protection is provided and if the heights of ceiling curtain boards and roof ventilation are such as to minimise the possibility that employees will be overtaken by the spread of fire or smoke within 1.8 m of the floor level before they have time to reach exits, provided, however, that in no case may the distance of travel to reach the nearest exit exceed 65 m where smoke venting is required as a condition for permitting distances of travel to exits in excess of the maximum otherwise allowed.

Additional precautions for smoke mitigation are as follows:

a) In any room in which volatile flammable substances are used or stored, no device generating a glow or

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flame capable of igniting flammable vapour shall be installed or used, such a room shall be provided with a suitably designed exhaust ventilation system; and

b) Storage buildings, such as for warehouses, natural draft smoke venting shall utilize roof vents or vents in walls at or near the ceiling level; such vents shall be normally open, or, if closed, shall be designed for automatic opening in case of fire, by release of smoke sensitive devices.

19.3 Smoke Mitigation of Exits - Natural/ Mechanical

19.3.1 *Staircases and Exits Passageways*

19.3.1.1 *Smoke control of exits*:

a) In building design, compartmentation plays a vital part in limiting the spread of fire and smoke. The design should ensure avoidance of spread of smoke to adjacent spaces through the various leakage openings in the compartment enclosure, such as cracks, openings annular gaps around pipes ducts, airflow grills and doors;

b) The pressurization of staircases and lift lobbies shall be adopted:

1) The pressure difference for staircases shall be minimum 50 Pa; and

2) Pressure differences for lobbies (or corridors) shall be between 25 Pa and 30 Pa. Further, the pressure differential for enclosed staircase adjacent to such lobby (or corridors) shall be 50 Pa. For enclosed staircases adjacent to non-pressurized lobby (or corridors), the pressure differential shall be 50 Pa.

c) Equipment and ductwork for staircase pressurization shall be in accordance with one of the following:

1) Directly connected to the stairway by ductwork enclosed in non-combustible construction; and

2) If ducts used to pressurize the system are passed through shafts and grills are provided at each level, it shall be ensured that hot gases and smoke from the building shall not ingress into the staircases under any circumstances.

d) The normal air conditioning system and the pressurization system shall be designed and interfaced to meet the requirements of emergency services. When the emergency pressurization is brought into action, the following changes in the normal air conditioning system shall be affected:

1) Any re-circulation of air shall be stopped and all exhaust air vented to atmosphere;

2) Any air supply to the spaces/areas other than exits shall be stopped;

3) The exhaust system may be continued, provided:

i) The positions of the extraction grills permit a general air flow away from the means of egress;

ii) The construction of the ductwork and fans is such that, it will not be rendered inoperable by hot gases and smoke; and

iii) There is no danger of spread of smoke to other floors by the path of the extraction system which shall be ensured by keeping the extraction fans running.

e) For pressurized stair enclosure systems, the activation of the systems shall be initiated by signalling from fire alarm panel;

f) Pressurization system shall be integrated and supervised with the automatic/manual fire alarm system for actuation;

g) Wherever pressurized staircase is to be connected to unpressurized area, the two areas shall be segregated by 120 min fire resistant wall. Such as, in high-rise office buildings, a pressurized staircase can discharge into an unpressurized ground-level lobby or covered parking floor, provided that the staircase itself remains protected as a smoke-free escape path up to the point of final exit; and

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h) Fresh air intake for pressurization shall be away (at least 4 m) from any of the exhaust outlets/grille.

19.3.1.2 In case of smoke exhaust and pressurization of areas above ground, corridors in exit access (exit access corridor) are created for meeting the requirement of use, privacy and layout in various occupancies. These are most often noted in hospitality, health care occupancies and sleeping accommodations. Exit access corridors of guest rooms and indoor patient department/areas having patients lacking self-preservation and for sleeping accommodations such as apartments, custodial, penal and mental institutions, etc, shall be provided with 60 min fire resistant wall and 20 min self-closing fire doors along with all fire stop sealing of penetrations. The fire doors shall be as per the accepted standard [D-3(49)].

Smoke exhaust system having make-up air and exhaust air system or alternatively pressurization system with supply air system for these exit access corridors shall be required. Smoke exhaust system having make-up air and exhaust air system shall also be required for theatres/auditoria. Such smoke exhaust system shall also be required for large lobbies and which have exit through staircase leading to exit discharge. This would enable eased exit of people through smoke-controlled area to exit discharge. All exit passageway (from exit-to-exit discharge) shall be pressurized or naturally ventilated. The mechanical pressurization system shall be automatic in action with manual controls in addition. All such exit passageway shall be maintained with integrity for safe means of egress and evacuation. Doors provided in such exit passageway shall be fire rated doors of 120 min rating.

Smoke exhaust system where provided, for above areas and occupancies shall have a minimum of 12 air changes per hour smoke exhaust mechanism. Pressurization system where provided shall have a minimum pressure differential of 25 Pa to 30 Pa in relationship to other areas. The smoke exhaust fans in the mechanical ventilation system shall be fire rated, that is, 250 °C for 120 min. For naturally cross-ventilated corridors or corridors with operable windows, such smoke exhaust system or pressurization system will not be required.

19.3.2 *Lift Lobby*

Smoke control of exits – pressure differences for lobbies (or corridors) shall be between 25 Pa and 30 Pa.

Firefighting shaft (fire tower) is an enclosed shaft having protected area of 120 min fire resistance rating comprising protected lobby, staircase and fireman's lift, connected directly to exit discharge or through exit passageway with 120 min fire resistant wall at the level of exit discharge to exit discharge.

19.3.3 *Hoist Way*

If the lift lobby is not provided at any of the levels in air-conditioned buildings or in internal spaces where funnel/flue effect may be created, lift hoist way shall be pressurized at 50 Pa.

19.3.4 *Fire Tower/Firefighting Shaft*

Firefighting shaft (Fire tower) is an enclosed shaft having protected area of 120 min fire resistance rating comprising protected lobby, staircase and fireman's lift, connected directly to exit discharge or through exit passageway with 120 min fire resistant wall at the level of exit discharge to exit discharge.

If lift lobby shall not be provided at any of the levels in air-conditioned buildings or in internal spaces where funnel/flue effect may be created, lift hoist way shall be pressurized at 50 Pa.

19.3.5 *Egress and Evacuation Strategy*

Staircase and fire lift lobby of a firefighting shaft shall be smoke controlled. It is recommended that the pressurization requirement for staircase in firefighting shaft and for other fire exit staircases in buildings greater than 60 m in height be evaluated to limit the force required to operate the door assembly (in the direction of door opening) to not more than 133 N to set the door leaf in motion. The aspect of pressurization, door area/width and door closure shall be planned in consideration to the above.

19.4 Smoke Mitigation – Special Occupancy and Spaces

19.4.1 *Atrium*

Given below are the requirements for atrium concerning with the smoke prevention and management for

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occupancy and spaces:

a) Atrium in business occupancy shall be planned with 6 ACPH while atrium in hotels and assembly occupancy shall be planned with 8 ACPH smoke extraction system. Such air changes shall be planned in atrium for a height of 15 m from the top;

b) Smoke exhaust fans shall be capable of operating effectively at 250 °C for 120 minutes;

c) Makeup air supply points shall be located beneath the smoke layer and on the lower levels connected by the atrium. Makeup air shall be provided by fans, openings to outside to allow infiltration, or the combination thereof;

d) It is recommended that makeup air be designed at 85 percent to 95 percent of the exhaust flow rate, not including the leakage through these small paths. The makeup air shall not cause door-opening force to exceed allowable limits. The makeup air velocity shall not exceed 1.02 m/s where the makeup air could come in contact with the plume unless a higher makeup air velocity is supported by engineering analysis; and

e) Atrium smoke management system fans shall be provided with emergency power. If so, required by the authority, an engineering analysis should be performed which demonstrates that the smoke system for the atrium is designed to keep the smoke layer interface 1 800 mm above the highest occupied floor level of exit access, open to the atrium, for a period equal to 1.5 times the calculated egress time or 20 min, whichever is greater.

19.4.2 *Commercial Kitchens*

Given below are the requirements for fire separation for commercial kitchens:

a) Where the flue or exhaust duct passes through the compartment wall or floor, the flue or duct shall be encased by non-combustible construction and no damper shall be permitted to be installed in such flue or duct. Also, such flue or ductwork shall be clear from combustible materials; and

b) It is advisable to locate the kitchen/cooking operations on the external periphery of the building so that in the event of mechanical ventilation failure, it shall be naturally ventilated.

19.4.2.1 *Exhaust ventilation system*

Following guidelines shall be ensured for proper functioning of exhaust ventilation system for cooking equipment:

a) Provision of cleaning of the kitchen exhaust every six months to ensure that the carbon soot accumulated in the exhaust duct is cleaned to avoid the chances of outbreak of fire shall be made;

b) Independent exhaust ducts shall be provided for equipment using dry fuel like wood/ charcoal which produce spark and are likely to ignite the grease which might have accumulated in the common duct; and

c) Alternatively, approved spark arrestors may be provided before the duct from equipment using dry fuel meets the main duct. These spark arrestors shall be so provided that these are easily accessible and removable for cleaning.

19.4.2.2 *Cooking equipment*

Following procedures shall be adopted for handling of cooking equipment:

a) Any penetrations to the outside of a hood, be either welded or fit with a sealing device in accordance to the relevant Indian standard for not allowing cooking grease, oil to migrate to the outer portion of the hood. The fitment arrangements shall be of approved type. Gaskets for the panels shall be certified to withstand a temperature of 815.6 °C;

b) Grease strip shall be readily available for efficient and regular cleaning of concrete or paved floors of kitchen and restaurant and also the drainage areas;

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c) The hood or that portion of a primary collection means designed for collecting cooking vapours and residues shall be constructed of and be supported by steel not less than 1.09 mm in thickness or stainless steel not less than 0.94 mm in thickness or other approved material of equivalent strength and fire and corrosion resistance;

d) All seams, joint, and penetrations of the hood enclosure that direct and capture grease-laden vapours and exhaust gases shall have a liquid tight continuous external weld to the hood's lower outermost perimeter;

e) Grease filters shall be of steel rigid construction that will not distort or crush under normal operation handling and cleaning conditions. They shall be so arranged that all exhaust air passes through the grease filters. Filters shall be easily accessible and removable for periodic cleaning;

f) Grease filters shall be installed at an angle not less than 45° from the horizontal;

g) Grease filters shall be equipped with a grease drip tray beneath their lower edges and shall have a suitable minimum depth needed to collect grease. The grease drip trays shall be pitched to drain into an enclosed metal container having a capacity not exceeding 3.8 1itre; and

h) The exhaust ducts shall be constructed of and supported by carbon steel not less than 1.37 mm in thickness or stainless steel not less than 1.09 mm in thickness.

19.4.2.3 *Rooftop terminations — Exhaust systems*

The exhaust system shall terminate either outside the building with a fan or duct or through the roof or to the roof from outside with minimum 3 m of horizontal clearance from the outlet to the adjacent buildings, property lines and air intakes. There shall be a minimum of 1.5 m of horizontal clearance from the outlet (fan housing) to any combustible structure. There shall be a vertical separation of 1.0 m below any exhaust outlets for air intakes within 3.0 m of the exhaust outlet.

19.4.3 *Auditoriums and Cinemas*

Smoke exhaust and pressurization of areas above ground – smoke exhaust system having make-up air and exhaust air system shall also be required for theatres/auditorium.

19.4.4 *Multilevel Car Parking* (*MLCP*) *Non-Mechanical*

Open parking structures (including multi-level parking and stilt parking) specifies the degree to which the structure's exterior walls shall have openings. Parking structures that meet the definition of the term open parking structure provide sufficient area in exterior walls to vent the products of combustion to a greater degree than an enclosed parking structure.

A parking structure having each parking level wall openings open to the atmosphere, for an area of not less than 0.4 m^2 for each linear metre of its exterior perimeter shall be construed as open parking structure. Such openings shall be distributed over 40 percent of the building perimeter or uniformly over two opposing sides. Interior wall lines shall be at least 20 percent open, with openings distributed to provide ventilation, else, the structure shall be deemed as enclosed parking structures.

NOTE — A car park located at the stilt level of a building (not open to sky) shall be considered an open or an unenclosed car park if any part of the car park is within 30 m of a permanent natural ventilation opening and any one of the following is complied with towards the permanent natural ventilation requirement: i) 50 percent of the car park perimeter shall be open to permanent natural ventilation. ii) At least 75 percent of the car park perimeter is having the 50 percent natural ventilation opening.

19.4.5 *Multilevel Car Parking Stack/ Mechanical*

For enclosed multilevel car parking structures utilizing stack or mechanical systems, provisions for smoke ventilation should be considered to enhance safety during fire incidents. Smoke ventilation systems may include natural or mechanical ventilation strategies to ensure the rapid removal of smoke and hot gases. Such systems should comply with the applicable fire safety standards and guidelines, as detailed in Part F 'Fire and Life Safety' of this NBCS.

For smoke ventilation requirement of car parking, *refer* **19.1.1.2**.

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19.5 Aspects of Pressurization (Pascals) Smoke Mitigation

Smoke ventilation systems should be designed in line with the principles of pressurization to manage smoke spread effectively. These include:

a) *Defend in Place* (*One Door Open*) — Maintaining a pressure differential to protect occupants who remain within the structure;

b) *Phased Evacuation* (*Three Doors Open*) — Ensuring controlled evacuation by balancing pressurization for multiple door openings;

c) *Firefighting Shaft* (*Three Doors Open*) — Providing safe access for firefighters with maintained pressure differentials;

d) *Pressure Differential Measurement* — Ensuring pressure is appropriately maintained in staircases, lift lobbies, and lifts; and

e) *Door Opening Force Measurement* — Verifying door operation under pressurized conditions to allow safe egress.

19.6 Aspects of Ventilation for Smoke Mitigation

Ventilation systems play a crucial role in maintaining occupant safety during fire emergencies by controlling smoke spread and ensuring adequate air changes per hour (ACPH). Proper compartmentalization, isolation of air handling units, and adherence to fire resistance standards for ducts and dampers to prevent smoke infiltration and maintain safe evacuation routes. These units ensure effective fire containment and support emergency response operations.

19.6.1 *Air Handling Unit*

From fire safety point of view, separate air handling units (AHU) for each floor shall be provided so as to avoid the hazards arising from spread of fire and smoke through the air conditioning ducts. The air ducts shall be separate from each AHU to its floor and in no way shall interconnect with the duct of any other floor. Within a floor it would be desirable to have separate air handling unit provided for each compartment. Air handling unit shall be provided with effective means for preventing circulation of smoke through the system in the case of a fire in air filters or from other sources drawn into the system and shall have smoke sensitive devices for actuation in accordance with best practices.

Shafts or ducts, if penetrating multiple floors, shall be of masonry construction with fire damper in connecting ductwork or shall have fire rated ductwork with fire dampers at floor crossing. Alternatively, the duct and equipment should be installed in room having walls, doors and fire damper in duct exiting/entering the room of 120 min fire resistance rating. Such shafts and ducts shall have all passive fire control meeting 120 min fire resistance rating requirement to meet the objective of isolation of the floor from spread of fire to upper and lower floors through shaft/duct work.

NOTES

1 Zoned and compartmented HVAC systems are encouraged with an approach to avoid common exhaust shafts and fresh air intake shafts which will limit the requirement of such passive measure and fire rated duct work and dampers.

2 The air filters of the air handling units shall be made of non-combustible materials.

3 The air handling unit room shall not be used for storage of any combustible materials.

19.6.2 *Duct Work*

Air ducts serving main floor areas, corridors, etc, shall not pass through the exits/exit passageway/ exit enclosure. Exits and lift lobbies, etc, shall not be used as return air passage.

As far as possible, metallic ducts shall be used even for the return air instead of space above the false ceiling.

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Wherever the ducts pass through fire walls or floors, the opening around the ducts shall be sealed with materials having fire resistance rating of the compartment. Such duct shall also be provided with fire dampers at all fire walls and floors unless such ducts are required to perform for fire safety operation; and in such case fire damper may be avoided at fire wall and floor while integrity of the duct shall be maintained with 120 min fire resistance rating to allow the emergency operations for fire safety requirements.

The ducting within compartment would require minimum fire resistance rating of 30 min. If such duct crosses adjacent compartment/floor and not having fire dampers in such compartment/floor, it shall require fire resistance duct work rating of 120 min. The requirements of support of the duct shall meet its functional time requirement as above.

The materials used for insulating the duct system (inside or outside) shall be of non-combustible type. Any such insulating material shall not be wrapped or secured by any material of combustible nature.

Inspection panels shall be provided in the ductwork to facilitate the cleaning accumulated dust in ducts and to obtain access for maintenance of fire dampers. For more information, special publications may be referred.

NOTE — Special publication may be UL 2079 'Tests for Fire Resistance of Building Joint Systems'.

19.6.3 *Fire or Fire/Smoke Dampers*

These dampers shall be evaluated to be located in supply air ducts, fresh air and return air ducts/passages at the following points:

a) At the fire separation wall;

b) Where ducts/passages enter the vertical shaft;

c) Where the ducts pass through floors; and

d) At the inlet of supply air duct and the return air duct of each compartment on every floor.

Damper shall be so installed to provide complete integrity of the compartment with all passive fire protection sealing. Damper should be accessible to maintain, test and also replace, if so required. Damper shall be integrated with fire alarm panel and shall be sequenced to operate as per requirement and have interlocking arrangement for fire safety of the building. Manual operation facilities for damper operation shall also be provided.

19.6.4 *Glass Facade*

Openable panels shall be provided on each floor and shall be spaced not more than 10 m apart measured along the external wall from centre-to-centre of the access openings. Such openings shall be operable at a height between 1.2 m and 1.5 m from the floor and shall be in the form of openable panels (fire access panels) of size not less than 1 000 mm × 1 000 mm opening outwards. The wordings, 'FIRE OPENABLE PANEL — OPEN IN CASE OF FIRE, DO NOT OBSTRUCT' of minimum 25 mm letter height shall be marked on the internal side. Such panels shall be suitably distributed on each floor based on occupant concentration. These shall not be limited to cubicle areas and shall be also located in common areas/corridors to facilitate access by the building occupants and fire personnel for smoke exhaust in times of distress.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this NBCS. The standards listed may be as a guide in conformance with the requirements of the referred clauses in this NBCS.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Section of this NBCS.

	IS No.	*Title*
(1)	IS 3615 : 2024	Glossary of terms used in refrigeration and air conditioning (*third revision*)
(2)	IS16656 : 2017/ ISO 817 : 2014	Refrigerants — Designation and safety classification
(3)	IS 7896 : 2023	Air conditioning outdoor design conditions data for Indian cities (*second revision*)
(4)	IS 1391 (Part 1) : 2023	Room Air Conditioners Specification Part 1 Unitary air conditioners (*fourth revision*)
(5)	IS 60335-2-40 : 2018/ IEC 60335-2-40	Household and similar electrical appliances — safety: Part 2-40 Particular requirements for electrical heat pumps air-conditioners and dehumidifiers
(6)	IS 1391 (Part 2) : 2023	Room air conditioners specification: Part 2 Split air conditioners (*fourth revision*)
(7)	IS 18689 : 2024	Household and similar electrical appliances — Safety — Particular requirements for commercial refrigerating appliances and ice-makers with an incorporated or remote refrigerant unit or motor-compressor (IEC 60335-2-89 : 2019, MOD)
(8)	IS 16678 (Part 1) : 2018/ ISO 5149-1 : 2014	Refrigerating systems and heat pumps safety and environmental requirements: Part 1 Definitions, classification and selection criteria
(9)	IS 16678 (Part 2) : 2018/ ISO 5149-2 : 2014	Refrigerating systems and heat pumps — Safety and environmental requirements: Part 2 Design, construction, testing, marking and documentation
(10)	IS 16678 (Part 3) : 2018/ ISO 5149-3 : 2014	Refrigerating systems and heat pumps — Safety and environmental requirements: Part 3 installation site
(11)	IS 16678 (Part 4) : 2024/ ISO 5149-4 : 2022	Refrigerating systems and heat pumps — Safety and environmental requirements: Part 4 Operation, maintenance, repair and recovery (*first revision*)
(12)	IS 5610 : 2025	Refrigerants — Specification (*third revision*)
(13)	IS 3315 : 2024	Direct evaporative air cooler — Specification (*fourth revision*)
(14)	IS 655 : 2006	Air ducts — Specification (*second revision*)
(15)	IS 17570 (Part 1) : 2021/ ISO 16890-1:2016	Air Filters for general ventilation: Part 1 Technical specifications, requirements and classification system based upon particulate matter efficiency (ePM)
(16)	17570 (Part 2) : 2025	Air Filters for general ventilation: Part 2 Measurement of fractional efficiency and air flow resistance (ISO 16890-2 : 2016, MOD)

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	IS No.	*Title*
(17)	IS 17570 (Part 3) : 2021/ ISO 16890-3 : 2016	Air Filters for general ventilation: Part 3 Determination of the gravimetric efficiency and the air flow resistance versus the mass of test dust captured
(18)	IS 17570 (Part 4) : 2025/ ISO 16890-4 : 2016	Air Filters for general ventilation: Part 4 Conditioning method to determine the minimum fractional test efficiency
(19)	IS 16753 (Part 1) : 2022/ ISO 29463-1 : 2017	High efficiency filters and filter media for removing particles from air Part 1 Classification, performance, testing and marking (*first revision*)
(20)	IS 8188 : 1999	Treatment of water for cooling towers — Code of practice (*first revision*)
(21)	IS 18794 : 2024	Air handling units — Specification
(22)	IS 12615 : 2018	Line operated three phase a.c. motors (IE CODE) "efficiency classes and performance specification" (*third revision*)
(23)	IS 13204 : 2024	Rigid phenolic foam for thermal insulation — Specification (*first revision*)
(24)	IS 16590 : 2023	Liquid chilling package units — Specification (*first revision*)
(25)	IS 8148 : 2018	Specification for packaged air conditioners (*second revision*)
(26)	IS 18728 : 2024	Multiple split-system air conditioners and air-to-air heat pumps (VRF air conditioners) — Specification
(27)	IS 3601 : 2006	Steel tubes for mechanical and general engineering purposes — Specification (*second revision*)
(28)	IS 661 : 2019	Thermal insulation of cold storage — Code of practice (*fourth revision*)
(29)	IS IS 17773 : 2022	Closed-circuit ammonia refrigeration system — Code of practice for design and installation (ANSI/IIAR 2 : 2014, NEQ)
(30)	IS 1893 (Part 1) : 2025	Design for earthquake hazard and criteria for earthquake-resistant design of structures: Part 1 General provisions (*seventh revision*)
(31)	IS 3043 : 2018	Code of practice for earthing (*second revision*)
(32)	IS/IEC 62305-4 : 2010	Protection against lightning: Part 4 Electrical and electronic systems within structures
(33)	IS 732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
(34)	IS 1255 : 1983	Code of practice for installation and maintenance of power cables up to and including 33 kV rating (*second revision*)
(35)	IS 16753 (Part 2) : 2018/ ISO 29463-2 : 2011	High-Efficiency filters and filter media for removing particles in air: Part 2 aerosol production, measuring equipment and particle — Counting statistics
(36)	IS 16753 (Part 3) : 2018/ ISO 29463-3 : 2011	High-Efficiency filters and filter media for removing particles in air: Part 3 testing flat sheet filter media
(37)	IS 16753 (Part 4) : 2018/ ISO 29463-4 : 2011	High-Efficiency filters and filter media for removing particles in air: Part 4 testing method for determining leakage of filter elements — Scan method

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	IS No.	*Title*
(38)	IS 16753 (Part 5) : 2024/ ISO 29463-5	High-efficiency filters and filter media for removing particles in air: Part 5 Test method for filter elements (*first revision*)
(39)	SP 30 : 2023	National Electrical Code of India 2023 (*second revision*)
(40)	IS 17025 : 2017/ ISO/IEC 17025 : 2017	General requirements for the competence of testing and calibration laboratories (*second revision*)
(41)	IS 13301 : 1992	Vibration isolation for machine foundations — Guidelines
(42)	IS/IEC 60529 : 2001	Degrees of protection provided by enclosures (IP Code)
(43)	IS 4759 : 1996	Hot — Dip zinc coatings on structural steel and other allied products — Specification (*third revision*)
(44)	IS 737 : 2024	Wrought aluminium and aluminium alloy sheet and strip for general engineering purposes — Specification (*fourth revision*)
(45)	IS 10234 : 1982	Recommendations for general pipeline welding
(46)	IS 2075 : 2017	Ready mixed paint, stoving, red oxide zinc chrome, priming — Specification (*third revision*)
(47)	IS 15652 : 2006/ IEC 61111	Insulating mats for electrical purposes — Specification
(48)	IS 1946 (Part 2) : 2025	Fixing devices in walls, ceilings and floors of solid construction: Part 2 Design of post-installed anchorage to concrete — Code of practice (*first revision*)
(49)	IS 3614 : 2021	Fire doors and doorsets — Specification (*first revision*)
	IS 61439-1 : 2020/ IEC 61439-1:2020	Low-voltage switchgear and controlgear assemblies Part 1: General rules (*first revision*)
(50)	IS 2370: 2014	Walk-in cold rooms — Specification

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 4 ACOUSTICS, SOUND INSULATION AND NOISE CONTROL

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part D/Section 4) covers the acoustical, sound insulation and noise control requirements in buildings. Emphasis is laid on planning of buildings *vis-a-vis* its surroundings to reduce noise, and in addition, sound insulation aspects of different occupancies are covered for achieving acceptable noise levels.

This Section was first published in 1970 as part of the National Building Code of India and was subsequently revised in 1983, 2005 and 2016. Some of the important changes in the 1983 version included: specifying of approximate measured noise levels due to various types of traffic (air, rail and road) conditions; elaboration of planning and design features of buildings against outdoor noise; modification of impact sound insulation in residential buildings and hearing damage risk criteria in industrial buildings; recommendations regarding planning of open plan schools against noise; planning and design aspects of hotels and hostels, laboratories and test houses, and other miscellaneous buildings, and planning of office buildings with light weight partitions; and elaboration of the public address system to cover public address system at passenger terminals.

Some of the important changes in the 2005 version included: addition of large numbers of important definitions in line with the existing international practice of usage of terms in the field of acoustics, sound insulation and noise control; inclusion of a new clause on highway noise barrier under provisions on planning and design against outdoor noise; deletion of the clause on public address system; addition of a new clause on cinema; and deletion of existing appendices on 'Constructional measures for sound insulation of buildings' and 'Sound Insulation values for various types of materials and construction'; and addition of eight new informative annexes on noise calculations, specification of sound insulation, noise rating, outdoor noise regulations in India, special problems requiring expert advice, airborne and impact sound insulation, basic design techniques for noise control in HVAC and suggested equipment noise data sheet.

The significant changes that were incorporated in the 2016 revision included the review and update of definitions of various existing terms, along with the introduction of new terms such as noise criteria, sound level difference, ground-borne noise, and structure-borne noise. A new clause on construction noise was introduced, while the provision relating to noise control in open-plan schools was deleted. For auditoria and theatres, a provision for the effective isolation of mechanical equipment, such as lifts, from the building structure was included to prevent noise transmission. Additionally, in auditoria and theatres, a requirement was introduced for adequate damping under lightweight metal roofs, along with an additional lightweight under-deck noise barrier to reduce noise generated by rainfall. The reverberation time of assembly halls in schools, corresponding to 'Maximum for noise control (empty)', was modified, and the reverberation times of classrooms were also revised. The requirement for insulation (R_w) for walls or partitions between rooms in hospitals was modified, as also the recommended maximum reverberation times for very large offices and canteens. The recommended sound isolation value (D_w) between one room and another room in office was modified, and a similar modification was made for clerical offices where noise does not constitute a major nuisance. The provisions for assembly for partitions in hotels, including those between guest rooms as well as between rooms, corridors, and floors, were also modified. Examples of common types of wall and floor construction with sound insulation were reviewed and updated as required. Additionally, the provisions were updated to address the requirements of persons with disabilities.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

This revision has been brought out to incorporate changes based on the experience gained during usage of the last version of this Section. Following significant changes have been made in this revision:

a) Provisions for open plan offices have been updated to address concerns regarding data theft and protection of sensitive information;

b) Provisions have been added for noise control in specific industrial occupancies;

c) A new clause has been included for neighbourhood acoustic shielding during infrastructure development to reduce noise impact on nearby areas;

d) Provisions on traffic noise barriers has been introduced;

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e) A new Annex F has been introduced detailing the design requirements and performance evaluation of noise barriers to ensure effective noise mitigation;

f) Provisions on the integration of noise barriers and noise abatement measures in zonal and urban planning have been included in Annex E; and

g) Room criteria (RC) has been added in Annex J for rating the heating ventilation and air-conditioning system-related noise in buildings.

There are two types of noises, that is, air-borne and structure-borne noise. To reduce the intensity of air-borne noise, sound absorbent materials may be used. An absorbent material is one which reduces the intensity of sound reflected from its surface. It may be applied to walls, floors, ceilings or used as furnishings to reduce the sound level by absorption. However, the materials selected for sound absorption shall be consistent with fire safety requirements of the buildings.

To reduce the transmission of air-borne noise, sound insulating materials may be used. Sound insulating materials block the passage of noise through them by virtue of their mass and physical properties. The extent of noise reduction provided by a single homogeneous panel is proportional to the logarithm of mass per unit area. For high values of sound insulation, normally heavy panels are required. Thin sheets of materials do not have adequate mass for providing any appreciable sound transmission loss by themselves. However, when thin sheet materials are used in a double panel construction with an intervening air cavity, this special construction can give extremely high sound transmission loss values considering the mass of the partition, if designed properly. Porous materials lack the mass required to provide any appreciable sound transmission loss, and readily allow sound at most frequencies to be transmitted through them.

To reduce the transmission of structure-borne noise (such as noise generated by impacts) special construction methods and elastic discontinuity in the structure may be used. Structure-borne noise reduction is effected by corner joints, changes in cross-section, changes in materials, etc, in construction. The reduction by these construction methods is, however, not appreciable especially when a large amount of noise reduction is required over a short distance. In such cases, introduction of an elastic discontinuity in the structure can result in a very large amount of noise reduction. The noise transmission is affected only above a certain lower frequency which depends on the material thickness and the elastic properties of the material. Bonded fibrous materials, rubber elastomers, cork, etc, are suitable for curtailing structure-borne noise transmission.

This Section is largely based on the following standards:

IS 1950 : 1962	Code of practice for sound insulation of non-industrial buildings
IS 3483 : 1965	Code of practice for noise reduction in industrial buildings
IS 4954 : 1968	Recommendations for noise abatement in town planning
IS 11050 (Part 1) : 2023	Rating of sound insulation in buildings and of building elements: Part 1 Airborne sound insulation (*first revision*)
IS 11050 (Part 2) : 2023	Rating of sound insulation in buildings and of building elements: Part 2 Impact sound insulation (*first revision*)

Assistance has also been drawn from the following publication, in the formulation of this Section:

BS 8233 : 2014	Code of practice for sound insulation and noise reduction for buildings

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

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For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **"accepted standard"** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/ Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [D-4(1)] refers to the Indian Standard(s) given at serial number (1) of the list of standards given at the end of this Part D/Section 4, that is, IS 11050 (Part 1) : 2023 'Rating of sound insulation in buildings and of building elements: Part 1 Airborne sound insulation (*first revision*)'.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 4 ACOUSTICS, SOUND INSULATION AND NOISE CONTROL

1 SCOPE

This NBCS (Part D/Section 4) covers requirements and guidelines regarding planning against noise, acceptable noise levels and the requirements for sound insulation in buildings with different occupancies.

2 TERMINOLOGY

For the purpose of this Section, the definitions given below shall apply.

2.1 Ambient Noise — The sound pressure levels associated with a given environment. Ambient noise is usually a composite of sounds from near and far sources, none of which are particularly dominant.

2.2 Audible Frequency Range — The range of sound frequencies normally heard by the human ear. The audible range spans from 20 Hz to 20 000 Hz.

2.3 A-Weighted Sound Pressure, p_A — Value of overall sound pressure, measured in pascal (Pa), after the electrical signal derived from a microphone has been passed through an A-weighting network.

NOTE — The A-weighting network modifies the electrical response of a sound level meter with frequency in approximately the same way as the sensitivity of the human hearing system.

2.4 A-Weighted Sound Pressure Level, L_{pA} — The quantity of A-weighted sound pressure, in decibels (dB), is given by the following formula:

$$L_{pA} = 10\log_{10}\left(p_A/p_0\right)^2$$

where

p_A = A-weighted sound pressure, in pascal (Pa); and

p_0 = reference sound pressure (20 μ Pa).

NOTE — Measurements of A-weighted sound pressure level can be made with a meter and correlate roughly with subjective assessments of loudness, and are usually made to assist in judging the effects of noise on people. The size of A-weighting in 1/3 octave bands, is shown in Annex A (*see* **A-5**). An increase or decrease in level of 10 dBA corresponds roughly to a doubling or halving of loudness.

2.5 Background Noise — The sound pressure levels in a given environment from all sources excluding a specific sound source being investigated or measured.

2.6 Break-in — Unwanted sound transmission into a duct or a quiet environment, from outside.

2.7 Break-out — Unwanted sound transmission from the inside of a duct or a noisy enclosure, to the outside.

2.8 Broad Band Noise — Spectrum consisting of a large number of frequency components, none of which is individually dominant.

2.9 Cross-talk — Unwanted sound transmission between one room and another room or space, *via* a duct.

2.10 C_{tr} — Correction term applied against the sound insulation single-number values (R_w, D_w, and $D_{nT,w}$) to provide A-weighting against low frequency performance.

NOTE — The reference values used within the C_{tr} calculation are based on urban traffic noise.

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2.11 Decibel — Ten times the logarithm (to the base 10) of the ratio of two mean square values of sound pressure, sound power or sound intensity. The abbreviation for decibel is dB.

2.12 Effective Perceived Noise Level, in Decibel (EPN dB) — The number for rating the noise of an individual aircraft flying overhead is the effective perceived noise level in decibels (EPN dB). The effective perceived noise decibel value takes into account the subjectively annoying effects of the noise including pure tones and duration. In principle, it is a kind of time-integrated loudness level.

2.13 Equivalent Continuous A-Weighted Sound Pressure Level, $L_{Aeq.T}$ — Value of the A-weighted sound pressure level in decibels (dB) of a continuous, steady sound, that within a specified time interval, *T*, has the same mean squared sound pressure as the sound under consideration that varies with time, and is given by the formula:

$$L_{Aeq.T} = 10 \log_{10} \left[\frac{1}{T} \int_0^T \frac{P_A{}^2(t)}{p_0^2} dt \right]$$

where

$p_A(t)$ = instantaneous A-weighted sound pressure, in pascals (Pa); and

p_0 = reference sound pressure (20 μ Pa).

NOTE — Equivalent continuous A-weighted sound pressure level is mainly used for the assessment of environmental noise and occupational noise exposure.

2.14 Equivalent Sound Absorption Area of a Room, *A* — Hypothetical area of a totally absorbing surface without diffraction effects, expressed in square metres (m^2) which, if it were the only absorbing element in the room, would give the same reverberation time as the room under consideration.

2.15 Facade Level — Sound pressure level measured 1 m to 2 m in front of the facade.

NOTE — Facade level measurements of L_{pA} are usually 2 dB to 3 dB higher than corresponding free-field measurements.

2.16 Free-Field Level — Sound pressure level measured outside, far away from reflecting surfaces.

NOTE — Measurements made 1.2 m to 1.5 m above the ground and at least 3.5 m away from other reflecting surfaces are usually regarded as being free-field measurements. To minimise the effect of reflections the measuring position should be at least 3.5 m to the side of the reflecting surface (that is, not 3.5 m from the reflecting surface in the direction of the source). Estimates of noise from aircraft overhead usually include a correction of 2 dB to allow for reflections from the ground.

2.17 Frequency — The number of cyclical variations per unit time. Frequency is generally expressed in cycles per second (cps) and is also denoted as Hertz (Hz).

2.18 Impact Sound Pressure Level, L_i — Average sound pressure level in a specific frequency band in a room below a floor, when it is excited by a standard tapping machine.

2.19 Indoor Ambient Noise — Pervasive noise in a given situation at a given time, usually composed of noise from many sources, inside and outside the building, but excluding noise from activities of the occupants.

2.20 Insertion Loss (L_{IL}) — Insertion loss is generally defined as the difference, in decibels, between two sound pressure levels (or power levels or intensity levels) which are measured at the same point in space before and after a muffler or any other noise control device is inserted between the measurement point and the noise source.

2.21 Noise — Unwanted sound which may be hazardous to health, interferes with communications or is disturbing.

2.22 Noise Exposure Forecast (NEF) — The noise exposure forecast at any location is the summation of the noise levels in EPN dB from all aircraft types, on all runways, suitably weighted for the number of operations during day time and night time.

2.23 Noise Criteria — Numerical indices used to define design goals for the maximum allowable noise in a given space.

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2.24 Noise Rating (NR) — Graphical method for rating a noise by comparing the noise spectrum with a family of noise rating curves.

NOTE — Noise rating is described in Annex B.

2.25 Noise Reduction Coefficient (NRC) — A single figure descriptor of the sound absorption property of a material. It is the arithmetic mean of the sound absorption coefficients at 250 Hz, 500 Hz, 1 000 Hz and 2 000 Hz rounded off to the nearest multiple of 0.05.

2.26 Normalized Impact Sound Pressure Level, L_n — Impact sound pressure level normalized for a standard absorption area in the receiving room.

NOTE — Normalized impact sound pressure level is usually used to characterize the insulation of a floor in a laboratory against impact sound in a stated frequency band (*see* Annex C).

2.27 Octave Band — Band of frequencies in which the upper limit of the band is twice the frequency of the lower limit.

2.28 Percentile Level, $L_{AN,T}$ — A-weighted sound pressure level obtained using time-weighting '*F*', which is exceeded for *N* percent of a specified time interval.

Example:

$L_{A90,1h}$ is the A-weighted level exceeded for 90 percent of 1 h.

NOTE — Percentile levels, determined over a certain time interval cannot accurately be extrapolated to other time intervals. Time-weighting '*F*' or '*S*' can be selected on most modern measuring instruments and used to determine the speed at which the instrument responds to changes in the amplitude of the signal. Time-weighting '*F*' is faster than '*S*' and so its use can lead to higher values when rapidly changing signals are measured.

2.29 Pink Noise — Sound with an uninterrupted frequency spectrum and a power which is steady within frequency band and proportional to centre frequency. An example is constant power level per octave band.

2.30 Pure Tone — A sound emitted at a single frequency.

2.31 Rating Level, L_{Ar},T_r — Equivalent continuous A-weighted sound pressure level of the noise, plus any adjustment for the characteristic features of the noise.

NOTE — This definition is used for rating industrial noise, where the noise is the specific noise from the source under investigation.

2.32 Reverberation Time, *T* — Time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped.

NOTE — Reverberation time is usually measured in octave or third octave bands. It is not necessary to measure the decay over the full 60 dB range. The decay measured over the range 5 dB to 35 dB below the initial level is denoted by T_{30}, and over the range 5 dB to 25 dB below the initial level by T_{20}.

2.33 Sound — A vibrational disturbance, exciting hearing mechanisms, transmitted in a predictable manner determined by the medium through which it propagates. To be audible the disturbance shall have to fall within the frequency range of 20 Hz to 20 000 Hz.

2.34 Sound Exposure Level, L_{AE} — Level of a sound, of 1 s duration, that has the same sound energy as the actual noise event considered.

NOTES

1 The L_{AE} of a discrete noise event is given by the formula:

$$L_{AE} = 10\log_{10}\left(\frac{1}{t_0}\int_{t_1}^{t_2}\frac{p_A^2(t)}{p_0^2}dt\right)$$

where

$P_A(t)$ = instantaneous A-weighted sound pressure in pascals (Pa);

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$t_2 - t_1$ = stated time interval in seconds (s) long enough to encompass all significant sound energy of the event;

p_0 = reference sound pressure level (20 μ Pa); and

t_0 = reference time interval (1 s).

2 L_{AE} is also known as L_{AX} (single-event noise exposure level).

2.35 Sound Level Difference, *D* — Difference between the sound pressure level in the source room and the sound pressure level in the receiving room.

NOTE — *D* is given by the following formula:

$$D = L_1 - L_2$$

where

L_1 = average sound pressure level in the source room; and

L_2 = average sound pressure level in the receiving room.

2.36 Sound Power — The acoustic power of a sound source, expressed in Watts.

2.37 Sound Power Level (L_w) — The acoustic power radiated from a given sound source as related to a reference power level (typically 10-12 watt) and expressed in decibel as:

$$L_p = 10log_{10}\left\{\frac{W}{10^{-12}}\right\}$$

or

$$L_w = 10log\ W + 120$$

where

W = acoustic power, in watts.

By definition, 1 W therefore corresponds to 120 dB for L_w.

2.38 Sound Pressure, *p* — Root-mean-square value of the variation in air pressure measured in pascal (Pa), above and below atmospheric pressure, caused by the sound.

2.39 Sound Pressure Level, L_p — Quantity of sound pressure, in decibel (dB), given by the formula:

$$L_p = 10\ log_{10}(p/p_0)^2$$

where

p = root mean square sound pressure in pascals (Pa); and

p_0 = reference sound pressure (20 μ Pa).

NOTE — The range of sound pressures for ordinary sounds is very wide. The use of decibels gives a smaller, more convenient range of numbers. For example, sound pressure levels ranging from 40 dB to 94 dB correspond to sound pressures ranging from 0.002 Pa to 1 Pa. A doubling of sound energy corresponds to an increase in level of 3 dB.

2.40 Sound Receiver — One or more observation points at which sound is evaluated or measured. The effect of sound on an individual receiver is usually evaluated by measurements near the ear or close to the body.

2.41 Sound Reduction Index, *R* — Laboratory measure of the sound insulating properties of a material or building element in a stated frequency band.

NOTE — For further information *see* Annex C.

2.42 Sound Source — Equipment or phenomena which generate sound. Source room is the room containing sound source.

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2.43 Spectrum — A quantity expressed as a function of frequency, such as sound pressure versus frequency curve.

2.44 Standardized Impact Sound Pressure Level, L'_{nT} — Impact sound pressure level normalized to that in a receiving room having a reverberation time of 0.5 s.

NOTE — Standardized impact sound pressure level is used to characterize the insulation of floors in buildings against impact sound in a stated frequency band (*see* Annex C).

2.45 Speech Interference Level (SIL) — A descriptor for rating steady noise according to its ability to interfere with conversation between two people. SIL is the arithmetic average of the sound pressure levels in the three octave bands with centre frequencies at 500 Hz, 1 000 Hz and 2 000 Hz.

2.46 Standardized Level Difference, D_{nT} — Difference in sound level between a pair of rooms, in a stated frequency band, normalized to a reverberation time of 0.5 s.

NOTE — Standardized level difference takes account of all sound transmission paths between the rooms (*see* Annex C).

2.47 Structure-borne Noise and Ground-borne

NOTE — When elements of a structure vibrate they radiate noise and, if the vibration is high enough, this noise can be audible. Ground-borne and structure-borne noises are rarely an issue outside buildings or structures.

2.47.1 *Ground-borne Noise* — Audible noise caused by the vibration of elements of a structure, for which the vibration propagation path from the source is partially or wholly through the ground.

NOTE — Common sources of ground-borne noise include railways and heavy construction work on adjacent construction sites.

2.47.2 *Structure-borne Noise* — Audible noise caused by the vibration of elements of a structure, the source of which is within a building or structure with common elements.

NOTE — Common sources of structure-borne noise include building services plant, manufacturing machinery and construction or demolition of the structure.

2.48 Transient Sound — Sound which is audible for a limited period of time, for example sound from over flight of an airplane.

2.49 Third Octave Band — Band of frequencies in which the upper limit of the band is $2\frac{1}{3}$ times the frequency of the lower limit.

2.50 Threshold of Hearing — The lowest continuous sound pressure level which will create an auditory sensation for the average human ear. Any sound below these levels will be inaudible and any sound above the threshold will vary in loudness dependent on intensity.

2.51 Vibration Isolation — Reduction of force or displacement transmitted by a vibratory source, often attained by use of a resilient mount.

2.52 Wavelength — The length in space of one complete cycle of a sound wave given by.

$$\lambda = \frac{Speed\ of\ Sound}{frequency} = \frac{C}{f}$$

2.53 Weighted Level Difference, D_w — Single-number quantity that characterizes airborne sound insulation between rooms but which is not adjusted to reference conditions.

NOTE — Weighted level difference is used to characterize the insulation between rooms in a building as they are; values cannot normally be compared with measurements made under other conditions {*see* good practice [D-4(1)]}.

2.54 Weighted Sound Reduction Index, R_w — Single number quantity which characterizes the airborne sound insulating properties of a material or building element over a range of frequencies.

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NOTE — The weighted sound reduction index is used to characterize the insulation of a material or product that has been measured in a laboratory (*see* Annex C).

2.55 Weighted Standardized Impact Sound Pressure Level, $L'_{nT,w}$ — Single number quantity used to characterize the impact sound insulation of floors over a range of frequencies.

NOTE — Weighted standardized impact sound pressure level is used to characterize the insulation of floors in buildings (*see* Annex C).

2.56 Weighted Standardized Level Difference, $D_{nT,w}$ — Single-number quantity, which characterizes the airborne sound insulation between rooms.

NOTE — Weighted standardized level difference is used to characterize the insulation between rooms in a building (*see* Annex C).

2.57 Weighted Normalized Impact Sound Pressure Level, $L'_{n,w}$ — Single number quantity used to characterize the impact sound insulation of floors over a range of frequencies.

NOTE — Weighted normalized impact sound pressure level is usually used to characterize the insulation of floors tested in a laboratory (*see* Annex C).

2.58 White Noise — A noise whose spectrum (level) density is substantially independent of frequency over a specified range and has equal power for any range of frequencies of constant band width.

3 PLANNING AND DESIGN AGAINST OUTDOOR NOISE

3.1 General

Planning against noise should be an integral part of town and country planning proposals, ranging from regional proposals to detailed zoning, and three-dimensional layouts and road design within built-up areas. Noise nuisance should be fully recognized in zoning regulations.

3.1.1 Noise is either generated by traffic (road, air and surface and underground railway) or it arises from zones and buildings within built-up areas (industry, commerce, offices and public buildings), and from public gatherings and social activities. For planning, the noise survey should examine all the possible causes of noise and consider the various factors causing actual nuisance.

3.1.2 Noise by night, causing disturbance of sleep, is more of a nuisance than noise by day. For this reason, housing colonies that adjoin areas with heavy traffic movement during the night are liable to cause serious complaints. Also, the factories that work by night are liable to cause serious complaints if housing estates adjoin them. While planning, care should be taken that housing colonies are adequately set back from busy airports, state and national highways, factories, main railway lines and marshalling yards.

3.1.3 There are two aspects of defence by planning. The first is to plan so as to keep the noise at a distance. Under this aspect comes the separation of housing from traffic noise by interposing buffer zones, and the protection of schools and hospitals by green belts, public gardens, etc. The second is the principle of shading or screening. This consists of deliberately interposing a less vulnerable building to screen a more vulnerable one or by providing a solid barrier, such as a wall, between the source and the location to be protected.

3.2 Traffic Noise Levels

3.2.1 *For Air Traffic*

For guidance, approximate noise levels due to various types of aircrafts, measured on ground, when the aircrafts fly overhead at a height of 450 m, are given in Table 1.

3.2.2 *For Rail Traffic*

Noise levels of some typical railway traffic are given in Table 2.

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3.2.3 *For Road Traffic*

The level of noise generated by road traffic depends upon such factors as the number of vehicles passing per hour, the type of traffic, the preponderance of heavy vehicles, average speed, gradient and smoothness of traffic flow. The smoothness of traffic flow also affects variability of the noise and is governed by such features as roundabouts and traffic lights, and the volume of traffic and pedestrian movement with their effects on stopping, starting, overtaking and honking. The level of traffic noise fluctuates continuously and the way it does, has a considerable effect on the nuisance caused. For assessing traffic noise, noise is measured in dBA. Because of the fluctuating nature of traffic, noise levels due to different volumes of traffic flow with a varying mix of vehicles are given in Table 3.

Table 1 Typical Noise Levels of Some Aircraft Types

(*Clause* 3.2.1)

Sl No.	Type of Aircraft	Flyover Noise Levels at 450 m with Take-off Thrust EPN dB
(1)	(2)	(3)
i)	Boeing 737	107
ii)	Boeing 747 to 200	103
iii)	Airbus A300	101

Table 2 Typical Noise Levels of Railway Trains

(*Clause* 3.2.2)

Sl No.	Type of Train	Noise Level at 30 m, Measured on the Side or in the Direction of Train dBA
(1)	(2)	(3)
i)	Steam train, 60 km/h	85
ii)	Diesel train, 60 km/h	83
iii)	Electric train, 60 km/h	77

Table 3 Typical Noise Levels Due to Free-Flowing Road Traffic

(*Clause* 3.2.3)

Sl No.	Type of Traffic	L_{10} 30 m from Edge of Road dBA
(1)	(2)	(3)
i)	5 000 vehicles per 18 hour day (10 percent heavy vehicles), 50 kmph	65
ii)	10 000 vehicles per 18 hour day (20 percent heavy vehicles), 60 kmph	70
iii)	10 000 vehicles per 18 hour day (40 percent heavy vehicles), 80 kmph	75
iv)	20 000 vehicles per 18 hour day (40 percent heavy vehicles), 80 kmph	77

NOTE — The values are applicable to free flowing traffic without honking.

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3.3 Outdoor Noise Regulations

The outdoor noise regulations in force from time to time shall be complied with (*see* Annex D).

3.4 Planning and Design

3.4.1 *For Air Traffic*

Near airports two sources of aircraft noise should be considered.

a) *Flyover Noise* — Flyover noise is that which occurs under flight paths close to airports and is the most serious and common problem. As the aircraft passes overhead the noise level at any particular location rises to a peak and then decreases; and

b) *Ground Noise* — The noise emitted by an aircraft during ground operations is less variable in direction than flyover noise, but is usually of a longer duration.

3.4.1.1 Aircraft noise may disturb sleep, rest and communication, and as such may be considered potentially harmful to health. It is important that no new development is carried out within areas where the expected noise levels will cause mental and physical fatigue or permanent loss of hearing. In case development in such areas is essential, adequate sound insulation shall be provided for the building.

3.4.1.2 As the problems caused by aircraft noise have become more acute, a number of methods have been devised for evaluating noise exposure in the vicinity of airports. They all combine many factors into a single number evaluation. A commonly used criterion is the noise exposure forecast (NEF). The NEF is used primarily to develop noise contours for areas around airports. It has been accepted generally that noise exposure forecast levels greater than NEF 40 are unacceptable to people while levels less than NEF 25 are normally acceptable. Levels between NEF 25 and 40 may lead to subjective complaints.

3.4.1.3 While it is theoretically possible to provide sufficient insulation to achieve an acceptable indoor noise environment in the area of very high outdoor noise, there is a level above which aircraft noise seriously affects living conditions no matter how much sound insulation has been applied to the dwelling unit. For this reason, it is recommended that no residential development be allowed beyond the NEF 35 level.

3.4.1.4 During summer months, the windows are normally kept open for adequate ventilation. In view of this, no matter how much sound insulation is provided for the building structure, the noise level inside the room can never be less than 10 dB below the outdoor noise level. For very critical buildings, such as buildings necessary for maintaining and supplementing the airport services, and for commercial development, such as hotels, it is possible to provide sealed windows and to centrally air-condition the entire building. However, it is not feasible for most of the residential developments in the country. In such cases proper zoning regulations and siting of vulnerable buildings away from aircraft noise are of vital importance.

3.4.2 *Rail Traffic*

This is a very serious source of noise in built-up areas, both by day and by night. Railway cuttings reduce the spread of noise, whereas embankments extend it. The elevated railway on viaducts or embankment is very common in built-up areas. The elevation increases exposure to noise but in addition the construction of the viaduct may affect the propagation of noise. In this respect solid embankments are preferable to built-up arches, which tend to act as sound boxes. Worst of all are the steel bridges, which greatly magnify the noise due to vibration. Uphill gradients are another feature tending to increase noise, especially of heavy goods trains.

3.4.2.1 Wherever possible, no residential or public building zone should abut onto railway lines, especially on the marshalling yards which is particularly objectionable because of the shrill, clanging and intermittent noise they generate, often at night. The appropriate zones alongside railway lines are industrial and commercial buildings other than office buildings. Where these precautions are not practicable and housing has to abut on to railway lines, every attempt may be made to house as few people as possible in the vicinity of the railway lines.

3.4.2.2 Underground transportation system can be a major cause of disturbance for the neighbouring community. Very high noise levels are propagated to long distances by the underground high speed railway, as a result of

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wheel-rail interaction. Both airborne noise and ground or structure-borne vibrations are potential sources of complaints. Noise control measures, therefore, need to be considered for the following:

a) In stations, where high noise levels are produced at the arrival and departure of trains;

b) In tunnels, during high speed train movement;

c) Where an underground rail transit system passes close to existing structures or high rise buildings, adequate attention should also be paid to the problem of ground vibration transmitted to the building, and proper isolation should be provided for critical areas;

d) Wherever elevated railway tracks are provided, adequate measures should be taken to avoid the spread of noise in the surrounding built up areas; and

e) In transit cars, where sound insulation is of vital importance to provide comfortable conditions for the commuters.

3.4.3 *Road Traffic*

3.4.3.1 Convoys of long-distance heavy trucks at night moving past through built-up areas cause serious noise complaints. On busy roads, the noise of continuous traffic may be a worse nuisance than that of railways. At least the same precautions may, therefore, be taken in the planning of dwellings in relation to arterial and trunk roads as with railways. Care may be taken that local housing roads do not provide short cuts for heavy traffic through residential areas. Hilly roads present the additional noise of gear changing. Trees with heavy foliage planted on both sides of carriageway help slightly to muffle the noise, provided the foliage extends for a considerable distance (30 m or above).

3.4.3.2 Road traffic may give rise to serious nuisance particularly on busy thoroughfares, between continuous high buildings in main streets, at the traffic lights, near bus stops, on steep slopes and in parking spaces and enclosed yards.

3.4.3.3 For zoning and planning of new buildings in urban areas, it is recommended that external L_{A10} be limited to a maximum of 70 dBA when the dwellings are proposed to have sealed windows and 60 dBA when the dwellings are proposed to have open windows. Indeed, it is desirable to confine major new residential development to locations subject to L_{A10} levels substantially lower than those given above.

It is recognized, however, that within the large urban areas, the use of sites where the external L_{A10} is greater than 60 dBA to 70 dBA cannot always be avoided. In that case it is suggested to utilize such design solutions as barrier blocks in order to reduce external L_{A10} noise levels to at least 60 dBA to 70 dBA at any point 1.0 m from any inward looking facade. When the orientation of site and the density of development are such that this cannot be fully achieved some form of dwelling insulation will have to be provided. It should be appreciated that where open windows are necessary, the occupants would have to put up with discomfort if the above conditions are not met.

3.4.3.4 Certain other methods can often be utilized to provide economical and effective protection from noise, as follows:

a) Methods should be adopted to improve the smoothness of flow and reduce number of stopping and starting. This leads to an improvement even, if it leads to increased flows. Flow linking of traffic lights, for example, may reduce noise nuisance;

b) Use of roads passing through residential areas should be prohibited to heavy commercial vehicles. An alternative would be to limit use by commercial vehicles to certain times of the day;

c) Use of honking shall be prohibited near sensitive buildings, such as hospitals and the like; and

d) Barriers shall be provided to shield sites from noise.

3.4.4 *Construction Noise*

3.4.4.1 Construction activities relating to building and infrastructure facilities cause noise disturbance to occupants in existing built facilities located around the site.

Construction noise involves both stationary and mobile sources. Common activities and sources of concern in case of construction noise include excavation and site clearing activities, blasting, piling, operation of batching

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plants, concrete mixers, pumping, running of diesel generators, drilling and chipping, loading/unloading activities, and truck and other vehicular movement.

The source noise intensity and spectrum is primarily characterized by the type of construction activity, equipment used, ground conditions and associated vehicular movement. Apart from the source characteristics, community noise impact is influenced by the time and sequence of construction related activities.

3.4.4.2 Noise control can be done at the source or in the noise propagation path. While it is preferable to adopt noise control at the source, it may not be practically possible to implement it for some of the construction equipment. Given the diversity of noise sources, mitigation strategies in case of construction noise have to be dealt with appropriately depending on the spectral characteristics of sources.

Source noise control strategies include providing acoustic enclosures for sources like diesel generators, choosing less noisy construction machinery and selecting alternative construction practices which involve lesser noise generation.

Noise control in the propagation paths primarily involves provision of noise barriers around the construction sites.

Positioning of major fixed construction equipment/installations such as batching plants and diesel generators have a significant impact on the noise spectrum and its impact. Also, time of operation and duration of noisy construction activities have significant impact on the resultant annoyance.

3.4.4.3 Due consideration for environmental noise regulation should be given while scheduling and sequencing noisy construction activities.

3.5 Zoning

The zoning of the different cities shall be done by the town planning authorities, taking into account besides other aspects, the noise levels from different occupancies. Wherever necessary, experts in the field may be consulted. For detailed information on noise reduction for town planning schemes, reference may be made to good practice [D-4(2)]. Details regarding the integration of noise barriers and noise abatement measures in zonal and urban planning are provided in Annex E.

3.6 Green Belts and Landscaping

Where relief from noise is to be provided by means of green belts these may be of considerable width and be landscaped. In case of railway tracks, a minimum distance of 50 m to 70 m may be provided between the buildings and the tracks. The extent of relief that may be derived from the above may be estimated only after considering other environmental factors. Only thick belts of planting (greater than 30 m) are of real value. Strong leafy trees may be planted to act as noise baffles. Shrubs or creepers may also be planted for additional protection between tree trunks; artificial mounds and banks should be formed where practicable. As little hard paving and as much grass as possible may be used. The creation of green belt is particularly advisable on the perimeter of aerodromes, along railway lines and arterial roads, through or past built-up areas and adjoining noisy industrial zones.

3.7 Highway Noise Barriers

Barriers are often the most effective means of reducing traffic noise around residential areas. They have the great advantage that they generally protect most or all of the site. In nearly all situations, a well-designed barrier of even a modest height (say 3 m) can at least ensure that all areas of open space are free from excessive noise levels.

There are two types of barriers that can be built to protect sites; one which are built solely for the purpose of reducing noise and the other which form part of the building complex (barrier blocks). Free standing walls and artificial mounds are typical examples of the first type while single and multi-storeyed utility buildings and garages are the most common form of the second.

Of the two types, laying out barrier blocks of a complex in an appropriate fashion is a better option because they are cheaper and also tend to form a more effective barrier overall because of their greater height and width. Barrier walls or mounds are more limited in their effect than barrier blocks for they protect little more than the area of the site close to ground level essentially because of the lack of height, as continuous walls much higher than 3m are often difficult to construct.

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3.8 Use of Acoustic Barriers for Residential, Educational and Hospital Buildings along Highways on City Outskirts (Approximately 4 m to 5 m in Height)

3.8.1 Noise barriers can be constructed from a wide variety of materials and designs, but the basic purpose of all the noise barriers is to reduce noise levels at noise sensitive receptors.

3.8.2 A reduction in noise levels up to 10 dBA can be obtained at ground level in an area that is close behind a barrier of considerable height with sufficient insulation value and absorption value. Noise barriers are relatively ineffective at more than 250 m distance from the road.

3.8.3 Innovative combinations, including perforated metal sheeting on one side with the inclusion of absorptive material and a corrugated profile, should be utilized to enhance the insertion loss provided by the barrier.

3.8.4 Noise barriers may be constructed from a variety of materials, including but not limited to earth, concrete, masonry, metal and wood. Conventional concrete or masonry structures should be considered the best practicable option for highway noise barriers due to their long-term stability and maintenance-free service characteristics. Laminated glass requires frequent cleaning due to accumulation of dirt, while polycarbonate sheets become opalescent over time as it can absorb water. Plastics are prone to damage from fire and vandalism, and some, such as polyethylene, become brittle after prolonged exposure to sunlight.

3.8.5 The application of multiple-edge noise barriers, also known as profiled noise barriers, should be implemented in specific applications where enhanced acoustical performance is required to effectively screen a single noise source.

3.8.6 The noise barriers, although highly effective in reducing highway noise levels by significant extent, are subject to certain limitations. To ensure effectiveness, noise barriers shall be designed to be of sufficient height and length to block the view of the road. Barriers are less effective for homes on hillsides or buildings that rise above the barrier.

3.8.7 The design of noise barriers (*see* Annex F) should take into account the following factors:

a) Visual impact;

b) Maintenance requirements; and

c) Cost implications.

3.8.8 The noise barriers may also have negative impacts on the surrounding environment, such as blocking views or creating shadows, which should be taken into account during the design process.

3.8.9 Transparent barriers are associated with lower perceived loudness and noise annoyance compared to opaque barriers, contributing to improved user satisfaction.

3.8.10 The utilization of waste materials, such as plastic, rubber, and bottom ash, is recommended for achieving high noise attenuation with improved cost efficiency.

3.9 Special Problems Requiring Expert Advice

The purpose of noise control is to ensure that people are neither harmed nor disturbed by noise. In addition to provisions given in this Section, special advice may be required for more complex situations, such as those listed in Annex G.

4 PLANNING AND DESIGN AGAINST INDOOR NOISE

4.1 Acceptable Indoor Noise Levels in Buildings

The generally acceptable noise levels inside buildings are given in Table 4.

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Table 4 Acceptable Indoor Noise Levels for Various Buildings

(*Clause* 4.1)

Sl No.	Location	Noise Level dBA
(1)	(2)	(3)
i)	Auditoria and concert halls	20 to 25
ii)	Radio and TV studios	20 to 25
iii)	Cinemas	25 to 30
iv)	Music rooms	25 to 30
v)	Hospitals	35 to 40
vi)	Apartments, hotels and homes	35 to 40
vii)	Conference rooms, small offices and libraries	35 to 40
viii)	Court rooms and class rooms	40 to 45
ix)	Large public offices, banks and stores	45 to 50
x)	Restaurants	50 to 55

4.2 Vulnerable Buildings

Some buildings or parts of buildings are especially vulnerable to noise, for example, recording and radio studios, hospitals and research laboratories. These should not be sited near loud noise sources. Most vulnerable buildings contain some areas which are themselves noisy and in such buildings, the less vulnerable elements should be planned to act as noise buffers. Most noisy buildings also contain quiet accommodation, which equally may be planned to act as a buffer between the noisy part of the building and adjoining vulnerable buildings.

4.3 The details of site and internal planning and insulation requirements are covered under individual occupancies (*see* **5** to **12**) as applicable to the respective character and sources of noise in different buildings.

4.3.1 *Equitable Inclusion of Hearing Impaired Persons in Public Place*s

People with hearing impairments have particular difficulty in making out sounds and words in noisy environments. Therefore, adequate sound insulation would minimise noise from both outside and inside the building. Also, low reverberation times are more suitable for hearing impaired persons and should thus be planned while designing the size and shape of the room.

Persons using hearing aids may require quiet areas with induction loops in very noisy information counters or where announcements are made. Induction loops may also be provided in all areas where there are verbal inputs provided, such as conference halls, auditoria, class rooms and cinema halls.

4.4 Sound Insulation of Non-Industrial Buildings by Constructional Measures

The desired (acceptable) noise levels and the recommended insulation values for the various areas may be achieved by providing sound insulation treatments by constructional measures. The details of the same are given in Annex H. The recommendations given in Annex H are applicable to non-industrial buildings like residences, educational buildings, hospitals and office buildings.

4.5 Special Problems Requiring Expert Advice — *See* **3.9** and Annex G.

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5 RESIDENTIAL BUILDINGS

5.1 Sources of Noise Nuisance

5.1.1 *Outdoor Noise*

The main sources of outdoor noise in residential areas are traffic (aeroplane, railways, roadways), children playing, hawkers, services deliveries, road repairs, blaring loud-speakers, various types of moving machinery in the neighbourhood and building operations, and captive power generation machinery.

5.1.2 *Indoor Noise*

5.1.2.1 As far as indoor noises are concerned, conversation of the occupants, footsteps, banging of doors, shifting of the furniture, operation of the cistern and water closet, playing of radio, television, music system, cooling and ventilation machinery, etc, contribute most of the noise emanating from an adjacent room or an adjacent building. Noise conditions vary from time to time and noise which may not be objectionable during the day may assume annoying proportions in the silence of the night when quiet conditions are essential.

5.1.2.2 In the case of flats the main sources of noise are from other flats and from stairs, lifts and access balconies. Plumbing noise is another cause. In semi-detached buildings, outdoor noises from streets are noticed more than indoor noises from neighbours.

5.2 Recommendations

5.2.1 *Site Planning*

The most desirable method is to locate the residential buildings in a quiet area away from the noisy sources like the industrial areas, rail tracks, aerodromes, roads carrying heavy traffic, etc.

5.2.1.1 To minimize ground reflection, the dwellings should be surrounded by the maximum amount of planting and grassed areas and the minimum amount of hard surfacing. This applies particularly to high density areas. Where for maintenance reasons a large amount of hard paving is necessary, it should be broken up by areas of planting and grassing. Narrow hard paved courts should be avoided between adjacent tall buildings.

5.2.1.2 Roads within a residential area should be kept to a minimum both in width and length, and should be designed to discourage speeding. Area-wise planning, with zones from which vehicular traffic is altogether excluded will greatly help to reduce noise. Roads with through traffic should be excluded from residential areas, but where sites have to be developed adjacent to existing major roads the same principles should be observed in the siting of blocks as with railway lines as covered under **3.4.2.1**.

5.2.1.3 Play areas for older children should be sited as far away from dwellings as possible. Special care should be taken with old peoples' dwellings. They should not be placed immediately adjacent to service entries, play spaces, or to any entrances where children may tend to congregate.

5.2.2 *Internal Planning*

The orientation of buildings in a locality should be planned in such a way as to reduce the noise disturbance from neighbourhood areas. The non-critical areas, such as corridors, kitchens, bathrooms, elevators and service spaces may be located on the noisy side and the critical areas, such as bedrooms and living space, on the quiet side.

5.2.2.1 *Windows and doors*

Windows and doors should be kept away from the noisy side of the building as given below, wherever possible:

a) When windows of a building, particularly those of bedrooms in apartments or flats, face roads carrying heavy traffic or other noises where the external noise is of the order of 80 dBA to 90 dBA, the building should be located at a distance of about 30 m from the road, but a distance of 45 m or more, where possible, should be aimed at for greater relief from noise;

b) When the windows are at right angles to the direction of the above type of noise, the distance from the road should be arranged to be about 15 m to 25 m; and

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c) In case another building, boundary wall or trees and plantations intervene between the road traffic and the house/flat further noise reduction is achieved and in such cases the above distances may be reduced suitably.

5.2.2.2 *Layout plans*

It is desirable that rooms adjoining party walls and above/below party floors should be of similar use. By this means, bedrooms are not exposed to noise from adjoining living rooms, and there is less risk of disturbance of sleep.

In semi-detached houses, the staircase, hall and kitchen should adjoin each other on each side of the party wall, thus providing a sound baffle between rooms requiring quiet conditions.

Bedrooms should not be planned alongside access balconies, and preferably not underneath them. Where the approach is by an internal corridor, a sound baffle may usefully be provided by arranging internal passages and bathrooms between the corridor and the living room or bedrooms.

Kitchens and water-closets should not be planned over living rooms and bedrooms, whether within the same dwelling or over other dwellings. Soil pipes should not be carried in ducts which adjoin living rooms or bedrooms unless the side of the duct next to these rooms is a solid wall containing no inspection openings. Refuse chutes should not be planned next to living rooms or bedrooms.

5.2.3 *Sound Insulation*

5.2.3.1 *Reduction of airborne noise*

The weighted sound reduction index, R_w, of partitions between individual rooms or apartments of a building unit shall be as given in Table 5. These values may, however, be suitably increased, where required, for critical areas.

Table 5 Sound Insulation between Individual Rooms (Airborne)

(*Clause* 5.2.3.1)

Sl No.	Situation	R_w dB
(1)	(2)	(3)
i)	Between the living room in one house or flat and the living room and bed-rooms in another	50
ii)	Elsewhere between houses or flats	45
iii)	Between one room and another in the same house or flat	35

NOTES

1 Where communicating doors are provided, all doors should be so designed as to provide recommended insulation between the rooms.

2 There are cases when a set of houses or flats have to be built for the people who work at night and sleep during the day. It is desirable to consider the design of at least one such room in each of the houses or flats which will provide an insulation of about 45 dB in that room.

3 The insulation values referred to are applicable with doors and windows shut.

5.2.3.2 *Suppression of noise at the source itself*

All items of equipment that are potentially noisy should be selected with care. Water-closet cisterns should not be fixed on partitions next to bedrooms or living rooms. Plumbing pipes should be isolated from the structures. Lift motors should be mounted on resilient supports. Access doors from machine rooms to internal staircases should be well fitting and of solid construction. Special noise control measures may be required for electrical and mechanical services such as diesel generators, outdoor air conditioning units, cooling towers, etc.

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5.2.3.3 *Reduction of airborne noise transmitted through the structure*

Reduction of airborne noise requires the use of rigid and massive walls, or acoustically designed dry walls, without any openings. Openings are the major cause of penetration of noise through a barrier. While designing it should be borne in mind that all components should provide a sound transmission compatible with that of the rest of the barrier so that an equivalent amount of sound energy is transmitted through each portion of the barrier.

Ventilating ducts or air transfer openings where provided should be designed to minimise transmission of noise. For this purpose, sound attenuating devices having necessary insertion loss may be installed in these openings.

All partitions should be sealed effectively where they butt against rest of the structure. All doors and windows should be properly gasketed where a high degree of sound insulation is desired.

5.2.3.4 *Reduction of structure-borne noise*

This requires the use of discontinuous or non-homogeneous materials in the construction of the structure.

5.2.3.5 *Reduction of impact noise*

The floor of a room immediately above the bed room or living room shall result in an impact sound pressure level ($L'_{nT,w}$) not greater than 60 dB. Typically, a 150 mm thick concrete floor with thick carpet (12 mm) covering would satisfy this requirement.

5.2.3.6 Main staircases in blocks of flats are often highly reverberant. Some of the surfaces at least (for example, the soffits of stairs and landings) should be finished with sound absorbent materials, wherever required.

6 EDUCATIONAL BUILDINGS

6.1 Sources of Noise Nuisance

6.1.1 *Outdoor Noise*

The outdoor sources of noise produced on school premises, which cause disturbance within the school, include the noise arising from playgrounds, playing fields and open-air swimming pools. Though playgrounds are used mainly during break periods, they are also used for games and physical education at times when teaching is in progress in the adjoining class rooms.

6.1.2 *Indoor Noise*

Indoor sources of noise are as follows:

a) Singing, instrumental and reproduced music which may take place in class rooms and in dining and assembly halls particularly in primary schools. In secondary schools, specialized music rooms are generally provided;

b) Movement of chairs, desks and tables at the end of one period may disturb a class engaged in a lesson in a room below;

c) Shutting and openings of doors and windows which may occur at any time during teaching periods;

d) Audio-visual presentations in class rooms;

e) Wood and metal workshops, machine shops (engineering laboratories), typing rooms, etc that produce continuous or intermittent sound of considerable loudness;

f) Practical work carried out in general teaching areas;

g) Gymnasia and swimming pools;

h) School kitchens and dining spaces where food preparation and the handling of crockery and utensils persist for the greater part of the school day;

j) Corridors and other circulation spaces; and

k) Plumbing and mechanical services.

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6.2 Recommendations

6.2.1 *Site Planning*

Where outdoor noise nuisance exists from local industry, busy roads, railway, airfields, sport grounds or other sources beyond the control of the school authority, school buildings should be sited as far away from the sources of noise, as possible.

6.2.1.1 Rooms should be planned in a manner so that the minimum amount of glazing is placed on the side facing the external noise.

6.2.1.2 Noises arising from the activities of a school and from the use of the buildings after school hours may constitute a nuisance to occupants of surrounding property; therefore, it is desirable to place playgrounds, workshops, swimming pools, music rooms, assembly halls and gymnasia as far away as possible from buildings which require a quiet environment.

6.2.2 *Internal Planning*

The following principles should be observed in the detailed planning of educational buildings:

a) *Grouping* — Noisy rooms should be separated from quiet ones, if possible. In general, it is desirable that rooms should be grouped together in accordance with the classification given in **6.2.4.1**;

b) *Windows and ventilators* — Windows of noisy and quiet rooms should not open on to the same courtyard or be near to one another. Skylights and ventilators over noisy rooms should be avoided, if they are likely to be a source of nuisance to adjacent upper floors;

c) *Doors* — Swing doors into rooms should only be used where no problem of sound transmission exists. Reduction of insulation between rooms and corridors due to doors shall be borne in mind. The type and method of fitting of doors is important and necessary care should be paid in this respect;

d) Sliding partitions, if used, should be acoustic operable partitions. Pass-through doors, if provided, should be acoustic doors with drop seals;

e) *Open planning and circulation areas* — Where open planning is used to permit spaces, such as assembly halls, dining rooms or entrance halls to be used in association with each other or for circulation, the degree of disturbance caused by interfering noise to teaching areas needs careful consideration; traffic through such areas should be strictly controlled; full use should be made of sound absorbent treatments to reduce the spread of noise from one space to another (*see* **6.2.3**);

   If rooms have large glazed panels or ventilation openings facing directly on the circulation areas, human traffic passing by the rooms should be controlled. Preferably baffled ventilation system or double windows should be used. Fan-lights over doors should be fixed and glazed; and

f) *Furniture* — In all educational buildings, regardless of the character of the floor finish, rubber buffers should be fitted to the legs of chairs and tables.

6.2.3 *Noise Reduction within Rooms*

Sound absorbent materials play a useful part in reducing the built-up or air-borne noise at source. In rooms, such as class-rooms, assembly halls and music rooms, a fairly short reverberation time under occupied conditions is one of the requirements of the acoustic design. The maximum reverberation times permissible for this purpose are usually short enough to give adequate noise control but in addition, the reverberation time should not be excessive under empty conditions, because noise may occur in these rooms with very few occupants. Table 6 gives the reverberation times often arranged in occupied rooms for acoustic reasons and the maximum times recommended in the empty rooms for noise reduction; the times given are for a frequency of 500 Hz, but they should not be greatly exceeded at any frequency. When rooms are used for a variety of purposes, the reverberation period appropriate to the major use should be adopted.

6.2.3.1 Special attention should be given to noise reduction in schools for the hearing impaired and schools for the visually impaired. Hearing impaired children are taught by means of hearing aids which cannot be used satisfactorily in high noise levels or in reverberant conditions. Visually impaired children depend on good hearing for understanding speech and for detecting changes in environment. In both these types of schools, noise levels should be kept low and reverberation times short. As an example, the reverberation times in empty class-rooms should not exceed 1.0 s in schools for the visually impaired or 0.5 s in schools for the hearing impaired.

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Table 6 Reverberation Times in Schools

(Clause 6.2.3)

Sl No.	Room	Reverberation Time s	
		Usual for Acoustic Reasons (Full)	Maximum[1)] for Noise Control (Empty)
(1)	(2)	(3)	(4)
i)	Assembly halls	1.0 to 1.25 according to size	1.5 to 2.0 according to volume of hall
ii)	Music teaching rooms	0.75 to 1.25	1.5
iii)	Gymnasia and indoor swimming pools	—	1.5
iv)	Dining rooms	—	1.25
v)	Classrooms	0.6	1.1
vi)	Headmasters room and staff rooms	0.5 to 1.00	1.0

[1)] Shorter reverberation times are desirable for noise control, whenever possible.

6.2.4 *Sound Insulation*

6.2.4.1 *Airborne noise*

For purposes of sound insulation, rooms in educational buildings may be classified as follows:

Class A	Noise Producing	a) Workshops b) Kitchens c) Dining Rooms d) Gymnasiums e) Indoor Swimming Pools
Class B	Noise producing but needing quiet at times	a) Assembly halls b) Lecture halls c) Music rooms d) Typing rooms
Class C	Average	a) General class rooms b) Practical rooms c) Laboratories d) Offices
Class D	Rooms needing quiet	a) Libraries b) Studies
Class E	Rooms needing privacy	a) Medical rooms b) Staff rooms

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6.2.4.2 The recommended minimum sound reduction (D_w) between rooms of the same class is as follows:

Class A	—	25 dB
Class C or D	—	35 dB
Class B or E	—	45 dB

6.2.4.3 Where a room is likely to have a dual use, for example, a dining room to be used as a class-room, the higher sound insulation value should be used.

6.2.4.4 The recommended minimum sound reduction (D_w) between rooms in different classes is 45 dB subject to the following:

a) In schools or institutes with a technical bias where noisy activities, such as sheet metal work, plumbing and woodwork, are likely to be practised extensively in normal hours, workshops should be regarded as a special category requiring more than 45 dB isolation (D_w) from rooms of any other class;

b) Assembly halls and music rooms are special cases in that, as well as producing noise, they also require protection from it and may need more than 45 dB isolation (D_w) from rooms in Class A, if the latter are very noisy;

c) Circulation spaces may vary from a long and frequented corridor to a small private lobby and it is therefore difficult to give precise recommendations to cover them. For partitions between rooms in Class C and most corridors, an R_w of 35 dB for the partition itself is adequate. For partitions between rooms in other classes and corridors, more or less insulation may be necessary, depending upon the specific usage; and

d) The problem of noise in circulation areas is as a rule greatly mitigated in schools by the fact that classes usually change rooms together at regular times. In colleges and evening institutes, however, this is much less true and in such buildings particular attention should be paid to insulation between rooms and corridors.

6.2.4.5 *Impact noise*

In the case of schools, the concrete floor of the room immediately above the teaching rooms shall provide an impact sound pressure level, $L'_{nT,w}$ not greater than 70 dB. For example, a covering of 6 mm linoleum or cork tiles on concrete floor (hollow or solid) weighing not less than 220 kg/m^2 will usually meet the above requirement.

7 HOSPITAL BUILDINGS

7.1 General

Problems of noise control vary from hospital to hospital but the principles outlined below apply to all types. A quiet environment in hospitals is desirable for patients who are acutely ill. Staffs require quiet conditions for consultations and examinations and also in their living and sleeping quarters. There have been rapid rises in noise levels in hospitals due to the higher levels of outdoor noise, increasing use of mechanical and mobile equipment (some of which is now brought much nearer to the patient in order to facilitate nursing procedure) and the introduction of loudspeaker, radio, television and call systems. Noise control in the hospital is made much more difficult by the extensive use of hard washable surfaces which reflect and intensify the noise. In most hospitals, windows to the open air and fanlights to corridors are usually open for the purpose of ventilation, admitting noise from outside and allowing it to spread through the building.

7.2 Sources of Noise Nuisance

7.2.1 *Outdoor Noise*

This may be classified into two main categories:

a) Noise from sources outside the hospital premises, for example, traffic and industrial noises; and

b) Noise from sources outside the building but usually within the control of the hospital authority, for example, ambulances, motor-cars and service vehicles, fuel and stores deliveries, laundries, refuse collection, trucks and trolleys.

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7.2.2 *Indoor Noise*

A hospital is a complex building with many services and the numerous internal sources of structure-borne and airborne noises are grouped into three main categories:

a) Noise consequent upon hospital routines. This category includes sources which transmit noise through both structure-borne and air-borne paths, many of which may be quite near to patients particularly those in wards, such as the following:

   1) Wheeled trolleys of various kinds, for food and medical supplies;
   2) Sterilizing equipment;
   3) Sluice room equipment including bedpan washers;
   4) Ward kitchen equipment;
   5) Footsteps;
   6) Doors banging;
   7) Handling of metal or glass equipment;
   8) Noises caused during maintenance and overhaul of engineering services; and
   9) Vacuum cleaners, mechanical polishers, etc.

b) Loudspeaker, radio or television, audible call system, telephone bells and buzzers, and other air-borne noises, such as loud conversation; and

c) Noises from fixed or mobile equipment and services not directly concerned with hospital routines. These include all the fixed services as given below:

   1) Plumbing and sanitary fittings;
   2) Steam, hot and cold water and central heating pipes;
   3) Ventilation shafts and ducts;
   4) Fans
   5) Boilers;
   6) Pumps;
   7) Air compressors;
   8) Pneumatic tubes;
   9) Electrical and mechanical motors and equipment;
   10) Lifts;
   11) Laundry equipment; and
   12) Main kitchen equipment (refrigerators, mixers, steam boilers, etc).

7.3 Recommendations

7.3.1 *Site Planning*

Hospital sites with their high degree of sensitivity to outside noise should be as far away from outside sources as may be compatible with other considerations, such as accessibility and availability of services. The building should be so arranged on the site that sensitive areas like wards, consulting and treatment rooms, operating theatres and staff bedrooms are placed away from outdoor sources of noise, if possible, with their windows overlooking areas of acoustic shadow.

7.3.2 *Detailed Planning*

There is a very large number of unit and room classification in hospital design and in planning the units in relation to each other and to the common services, (such as X-ray departments, operating theatre suits and main kitchens), noise reduction in the sensitive areas should be weighed carefully against other design factors. Special care in

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overall planning and internal planning against noise is required in the planning within the building of units which are themselves potential noise sources, for example, children's wards and outpatients' departments, parts of which require protection against noise.

7.3.2.1 Unloading bays, refuse disposal areas, boiler houses, workshops and laundries are examples of service units which should be as far from sensitive areas as possible.

7.3.2.2 The kitchen is a constant source of both air-borne and structure-borne noise and should preferably be in a separate building away from or screened from the sensitive areas. If this is not possible and the main kitchens shall form part of a multi-storey building, noise control is easier if they are placed below and not above the wards and other sensitive rooms so as to facilitate the insulation of the equipment and machinery in order to reduce the transmission of structure-borne noise to a minimum.

7.3.2.3 In ward units, the kitchens, sluice rooms, utility rooms, sterilizing rooms and other ancillary rooms, need to be placed quite near to the beds if they are to fulfil their purposes, which are all sources of noise. Some form of noise baffling between open wards and rooms of this kind will be needed.

7.3.3 *Reduction of Noise at Source*

In view of the difficulty of suppressing noise in hospital buildings, it is important to eliminate noise at its source, wherever possible.

7.3.3.1 *Use of resilient material*

Mats of rubber or other resilient material on draining boards and rubber-shod equipment will greatly reduce noise from utility rooms, sluice rooms and ward kitchens. The use of plastics or other resilient materials for sinks, draining boards, utensils and bowls would also reduce the noise. Many items of equipment especially mobile equipment, such as trolleys, beds and movable furniture, may be silenced by means of rubber-tyred wheels and rubber bumper and the provision of resilient floor finishes (*see* **7.3.4.1**). The latter also reduces footstep noise. Silent type curtain rails, rings and runners should be used. Lift gates and doors should be fitted with buffers and silent closing gear. Fans and other machinery should be mounted on suitable resilient mountings to prevent the spread of noise through the structure.

7.3.3.2 *Other measures*

Noise from water or heating pipes may be reduced by installing systems which operate at comparatively low pressure and velocities. Silencing pipes and specially designed flushing action reduce water closet noise at source and make structural measures easier to apply. The ventilation system should be designed so as not to create a noise problem. Silent closers should be fitted to doors.

7.3.4 *Reduction of Noise by Structural Means*

7.3.4.1 *Insulation*

Since the various departments or units may be planned in many ways, only general guidance on the insulation values for walls and partitions is as given below:

a) It is recommended that walls or partitions between rooms should normally have an R_w of at least 45 dB. Higher values of R_w of at least 50 dB are necessary where a noisy room is adjacent to one requiring quiet conditions. Doors should be solid with close fitting in the frames;

b) There is little insulation value in double swing doors and where these are fitted to a noisy room the opening should be planned so that it is screened from areas requiring quiet by a baffle lobby lined with absorbent material. Very high insulation values may be necessary in special cases and exceptional measures may be required;

c) Solid floors with floating finishes and resilient surfaces are necessary particularly between wards and other parts of the building. Ordinary timber board on joist floors should never be used; and

d) Conduits, ventilation ducts, chases etc, should be constructed so as not to form easy by-pass for disseminating noise about the building, and should be provided with sufficient sound insulation. Pipe

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ducts should be completely sealed around the pipes where they pass through walls or floors. Ducts carrying waste or water pipes should be lined with sound insulating material to prevent noise from the pipes passing through duct walls into the rooms through which they pass.

7.3.4.2 *Absorption*

Most surfaces in hospitals should be easily cleanable, so as to prevent the build-up of bacteria which may cause cross-infection. Many sound absorbent materials of a soft nature and difficult to clean are unsuitable for use in some hospital areas and lose much of their effectiveness, if painted for hygienic reasons.

Some porous materials with very thin non-porous coverings (like mineral wool covered with thin plastic sheets) have good sound absorption and when covered with a perforated sheet metal facing can be used in most areas requiring a washable acoustical treatment. In noisy areas, such as corridors and waiting rooms, however, a wider choice of absorbents is available.

In the ward, bed curtains, window curtain, etc, add to the absorbent properties of the room and help reduce reverberation in otherwise hard surfaced surroundings.

7.3.5 Sensitive areas such as operation theatres, doctors' consultation rooms, intensive care units (ICU) require special consideration against noise control. Apart from outdoor noise, a common problem is the transmission of sound between the consulting room and the waiting room. To ensure silence, a sound isolation D_w of 45 dBA, between the rooms shall be provided. If the doors are directly connected by a single communicating door it will not be possible to achieve these values of isolation D_w. To obtain 40 dBA to 45 dBA insulation between communicating rooms, it is necessary to provide two doors separated by an air gap, such as a lobby or corridor.

8 OFFICE BUILDINGS

8.1 General

Modern office buildings are often noisier than older buildings due to the use of thinner and more rigid forms of construction, harder finishes, more austere furnishings and use of business machines.

8.2 Sources of Noise Nuisance

8.2.1 *Indoor Noise*

Main sources of indoor noise include the following:

a) Office machines, such as keyboards, typewriters, and printers;

b) Telephonic conversation;

c) Noise from the public admitted to the building;

d) Footsteps, voices and slamming of doors in circulation spaces, lift doors and gates;

e) Sound reproduction in staff training rooms, conference rooms and recreation rooms, etc;

f) Handling of crockery and utensils in canteens and kitchens; and

g) HVAC and lift machinery.

8.3 Recommendations

8.3.1 *Site Planning*

Rooms demanding quiet conditions should be placed on the quiet side of the site. Even on quiet thoroughfares, these rooms should also not be planned at street level. They should also not be planned on enclosed yards used for parking of cars, scooters, etc. Where, however, the problems cannot be resolved by planning, the provision of double windows may be necessary.

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8.3.2 *Detailed Planning*

8.3.2.1 *Noise reduction within rooms*

The reverberation time should not exceed 1.0 s in all general offices of the types listed in **8.3.2.2** to **8.3.2.6**. In small private offices, the reverberation time should not exceed 0.75 s, in very large offices the reverberation time may be increased to 1.0 s. For canteens, the recommended maximum reverberation time is 1.0 s.

NOTE — All reverberation times are specified for a frequency of 500 Hz.

8.3.2.2 *Large general offices*

The grouping of departments and machines together in one room should be avoided, wherever possible. Where supervision is necessary the provision of glazed screens carried up to the ceiling should be considered. If it is essential to the work of an office for machine operators and clerks to work side by side in the same room, the machines should be enclosed by panels or low screens lined with absorbent material and the ceiling should be sound absorbent. In addition, the machines should be as quiet as possible in operation and mounted on suitable resilient mountings.

NOTE — A quiet area should be planned for prolonged telephonic conversation.

8.3.2.3 *Light weight construction*

Modern construction methods and economy dictate the use of light weight construction for many office buildings. While the lightweight materials lead to fast fabrication and erection and also effect considerable economy in the building structure, they may lead to tremendous sound insulation problems between adjacent offices and areas. Light weight construction is also frequently employed for the subdivision of large space into executive cabins and secretarial areas. Where such construction is considered desirable, efforts should be made to provide a double-skin panel. The panels should be isolated from each other as far as possible either by the use of separate framing or by the use of elastic discontinuities in the construction, and a sound absorbing material may be introduced in the air cavity between the panel. The partitions should be full height up to the bottom of the roof above and any openings required for air movement should be provided with sound attenuators compatible with the rest of the partition.

When light weight floors are provided in multi-use buildings, adequate attention should be paid to the question of air-borne and structure-borne noise transmission from the upper floors to the floors below. For effective reduction of air-borne noise, a double panel hollow floor construction may be employed with some heavy sound damping material introduced between the panels and the panel isolated from each other. The sound damping material could be sand, mineral wool, etc. In case impact noise isolation is also required, the upper panel should be effectively isolated from the rest of the floors and building structure. The choice of the isolation layer would of course depend upon the lowest frequency of interest.

Another point to be kept in mind when going in for light weight construction is to ensure that the light weight panels are not in resonance with the natural frequencies of any mechanical equipment installed inside the building. Lightweight materials have high natural frequencies well within the audio range and may resonate or vibrate due to an applied vibratory force. This vibratory force is caused by mechanical equipment, road traffic, rail traffic, etc. Special measures also need to be taken to isolate either the source or the building so as to reduce the amount of vibration transmitted to the building structure.

8.3.2.4 *Open plan offices*

A new concept in office planning is the use of open plan offices. Large open floor spaces are converted into an office area with senior executives, junior executives and secretarial staff all seated within the same area without the use of any partitions or walls. While this method of planning is appreciated, it leads to a problem of inadequate acoustical privacy between adjacent work spaces. Speech privacy in open plan offices is defined by the speech interference level of intruding noise. Speech privacy between two adjacent rooms or spaces is, therefore, a function of two key parameters; noise reduction of the intervening partition and background noise levels.

Special design measures are, therefore, required to reduce the level of intruding sounds at work places to acceptable low value so that people are not disturbed and adequate privacy is maintained. Some special measures which might be considered for such open plan offices are the use of an acoustical ceiling together with partial

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height barriers between work spaces, all designed to provide adequate privacy between adjacent work spaces. In addition, use may have to be made of an electronic background masking noise system which provides a constant level of a generally acceptable background noise in the entire office area. The masking noise system is a very useful concept in open plan office design because by raising the background level at every workplace, intruding noises are made less disturbing. A background music system cannot serve as a noise masking system because the music does not have a constant spectrum or sound level. In fact, the background noise masking system shall be introduced gradually without the knowledge of employees. The air-conditioning system can also be used to generate background masking noise if the noise level from the fans, ducts and grills is suitably tailored to generate the desired frequency spectrum. However, it is not simple to predict the noise level of air-conditioning components accurately. On the other hand, the electronic system enables both the level and the spectrum of the background noise to be accurately adjusted to suit individual job requirements.

8.3.2.4.1 In addition to comfort, speech privacy and sound insulation play a critical role in preventing data theft or leakage of sensitive information. Improper acoustical design can lead to unauthorized access to confidential conversations, especially in organizations handling financial data, legal matters or classified projects. Speech leakage across open-plan offices occurs when sound waves are transmitted either directly or indirectly through reflective surfaces, openings, or poorly isolated barriers. The sound control measures given below should be employed to mitigate this risk and ensure information security.

a) *Control of direct and indirect sound paths*

   Partial-height barriers alone are often insufficient to block sound transmission, as sound can travel over the barriers and reflect off ceilings, windows, or walls. To prevent sound leakage, barriers between workstations should be designed with sound-absorptive materials to reduce reflections. In high-security zones, barriers should ideally reach ceiling height to limit the direct path of sound waves. Additional sealing measures, such as acoustic baffles or sound-blocking panels near ceilings, can help to further contain sound within specific zones;

b) *Masking noise for speech concealment*

   Even with physical barriers in place, speech masking systems play a crucial role in enhancing speech privacy by rendering conversations unintelligible beyond a specific range. These systems should generate uniform background noise across the entire office, tuned to a frequency spectrum that aligns with typical human speech, thereby reducing the clarity of overheard conversations. Care should be taken to avoid variations in masking noise across different zones, as uneven noise profiles can inadvertently create ‘quiet spots’ where speech becomes more easily discernible;

c) *Acoustic zoning for sensitive areas*

   Workspaces dealing with confidential or sensitive data should be zoned acoustically to limit sound propagation beyond their intended boundaries. These zones can be created through sound-dampening partitions, low-noise areas, and placement of workstations away from high-traffic zones. Additionally, team discussions or meetings involving classified topics should occur in acoustically treated rooms with sealed doors and walls to avoid inadvertent sound leakage into adjacent spaces;

d) *Control of reflective surfaces*

   Reflective surfaces such as glass partitions, metal ceilings, and large windows can amplify sound reflections, making speech intelligible at greater distances. Such surfaces shall be treated with sound-absorbing films, acoustic panels, or curtains to minimize reflection. Flooring materials such as carpets or rugs may also be used to reduce the transmission of footfall noise, which could otherwise interfere with the effectiveness of masking systems; and

e) *Air-conditioning systems and noise control*

   Although air-conditioning systems can generate a degree of background noise, it is critical to ensure that the noise they produce remains predictable and stable. Inconsistent air-conditioning noise can undermine masking systems, creating intermittent quiet periods that increase the risk of speech leakage. Ducts, grilles, and vents shall be designed and placed carefully to maintain a uniform noise level throughout the office area, ensuring no unintended listening opportunities arise.

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8.3.2.5 *Office equipment rooms*

It is important that machines like keyboards, typewriters, printers, etc, should be quiet in themselves and also be fitted with resilient pads, to prevent the floors or tables on which they stand from acting as large radiating panels. It is desirable to locate machines further apart and to apply sound absorbent treatment to the ceiling.

8.3.2.6 *Banking halls*

If banking halls are large and lofty, noise nuisance tends to be aggravated. It is advisable to avoid high reflective ceilings. The worst effects may be reduced by segregating the noise from the quiet operations and screening one from the other and by applying sound absorbent materials to the surfaces of the ceilings, screens and nearby walls. Resilient flooring is also recommended.

8.3.2.7 *Public offices and waiting spaces*

Noise nuisance may be minimised by the provision of resilient flooring, sound absorbent ceilings and heavy full height screens between the public space and the clerical office.

8.3.2.8 *Canteens*

The provision of a sound absorbent ceiling, resilient flooring and the use of plastics/wooden trays and tables with quiet tops are recommended.

8.3.2.9 *Circulation spaces*

The effective length of long corridors should be limited by providing swing doors at intervals. Hard floor finishes and board and batten floors in corridors should be avoided. The provision of a sound absorbent ceiling in corridors is recommended. Floor ducts should be planned on one side of corridors.

The noise from slamming of doors may be reduced by fitting automatic quiet action type door closers. Door buffers are useful but may reduce insulation of air-borne sound due to the inevitable gaps between buffers. Continuous soft, resilient strip let into the door frames is preferable. The use of quiet action door latches is recommended.

Staircases and lifts should be isolated from quiet rooms and should have silent type doors.

8.3.3 *Requirement of Sound Insulation*

With open window (single or double) the sound reduction (D_w) will be 5 dB to 10 dB, and with sealed double windows it will be 40 dB to 45 dB. Intermediate values are obtainable with closed openable windows (single or double) but only, of course, at such times as ventilation may be dispensed with. Having to choose between ventilation and noise exclusion is a serious handicap to efficient working in offices. In large office blocks on noisy sites, consideration should be given to the provision of sealed double windows and mechanical ventilation at least in the offices on the sides of the building exposed to noise.

8.3.3.1 The insulation necessary between adjoining rooms, both horizontally and vertically, depends upon the amount of noise created within the rooms, the amount of intruding noise and whether it is important that conversation should not be overheard between rooms. Generally, a sound isolation value (D_w) of 40 dB between one room and another room in office is recommended.

8.3.3.2 The following list may be considered as broad classification of noise producing rooms and rooms requiring quiet though many offices fall into both categories. Where rooms in opposing categories are planned adjacent to each other, a sound reduction (D_w) of at least 45 dB should be provided between them.

Sl No.	*Noise Producing Rooms*
(1)	(2)
i)	Entrance and reception halls, staircases and corridors used by the public
ii)	Lifts and lift halls

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Sl No.	*Noise Producing Rooms*
(1)	(2)
iii)	Motor and plant rooms
iv)	Lavatories
v)	Public offices
vi)	Canteen and kitchens
vii)	Office machine rooms and typing pools
viii)	Recreation rooms
ix)	Large general offices
x)	Cinemas and projection rooms

Sl No.	*Rooms Requiring Quiet Conditions*
(1)	(2)
i)	Executive's rooms, Conference rooms and Board rooms
ii)	Interview rooms
iii)	Offices for one or two persons
iv)	Medical officer's rooms
v)	Sick rooms
vi)	Rest rooms
vii)	Libraries
viii)	Telephoning rooms

The recommended sound reductions (D_w) are as follows:

a)	Rooms requiring quiet (as listed above) on a quiet site where privacy is required	45 dB
b)	Rooms requiring quiet (as listed above) but on a noisy site or where a lower degree of privacy is tolerable	40 dB
c)	Clerical offices in which noise does not constitute a major nuisance	30 dB

8.3.3.3 It is recommended that the minimum sound reduction index, R_w for floors should be 45 dB, and the floors should have a resilient finish.

9 HOTELS AND HOSTELS

9.1 General

Hotels and hostels are primarily used as dwelling units, and hotels also provide for public entertainment. The most serious risk, of course, is disturbance to sleep, and adequate care, therefore, needs to be taken to protect the occupants from being disturbed by outdoor and indoor noise.

9.1.1 *Outdoor Noise*

Hotels near railway stations, airports, highways and those situated in highly urbanized areas are especially vulnerable to outdoor noise. The outdoor noise in many of the areas is of a high level even late at night and in the early morning. The noise could also be due to other types of activities such as building construction activity

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(pile driving, concrete mixing, etc) and various types of portable utility equipment, such as compressors or generators.

9.1.2 *Indoor Noise*

Insofar as indoor noise is concerned, the noise could be due to the occupants themselves, which is transmitted from one room to the other. It could also be due to public functions and late night use of restaurants located in the hotel, as also due to miscellaneous utility equipment installed for providing and maintaining the services in the hotel, such as air-conditioning equipment, pumping equipment, power laundry and kitchen. Sometimes hotels equipped with standby generators are a potential source of noise. Another source which could lead to disturbance to the occupants is the plumbing system.

9.2 Recommendations

9.2.1 *Site Planning*

While it is desirable to locate the hotel, or hostel away from an area where there is a high ambient noise level, many a time these have to be located in noisy areas for public convenience. Hotels near airports and railway stations are becoming popular because they are convenient for passengers in transit. Hotels located in the commercial areas of a city are also a commercially viable proposition and many a time this factor outweighs the other problems associated with such a location. When a reasonably quiet location is not possible, it is desirable that adequate measures be considered to provide a comfortable acoustical environment for the occupants.

9.2.2 *Internal Planning*

Where a hotel is located in a noisy environment, the provision of sealed windows (single or double) and provision of an air conditioning system is desirable for rooms exposed to noise. The requirements for the windows would of course depend upon the level and character of noise in the area.

The general recommendations for satisfactory acoustical design of hotels and hostels are given in **9.2.2.1** to **9.2.2.7**.

9.2.2.1 Hotels of all classes should by necessity provide good protection against indoor noise. Since hotels can be considered as flats, the standards of protection recommended for flats are also applicable to hotels. Partition between guest rooms and between rooms, corridors and floors should not be less than 230 mm brick wall plastered or equivalent (R_w = 50 dB). The floors should have proper impact insulation. Special attention should be paid to built-in wall cupboards as these are potential areas of sound leakage. These will not serve as sound insulating partitions and may not be relied upon to increase the insulation value of partitions against which they may be built. In fact, partitions between adjoining rooms should be continuous behind the cupboards. Use of silent type door gear and cupboard catches is also highly desirable.

9.2.2.2 Door openings on opposite sides of corridors should be staggered and doors shall be provided with gaskets on head, sides and threshold. As an alternative to thresholds, drop seals may be provided. Inter-communicating doors should be double doors, fully gasketed. Doors should also have quiet action latches. Whenever possible, rooms should be entered through a baffle lobby. Wherever possible, corridor walls should not have ventilators unless they are double glazed and non-openable.

9.2.2.3 Corridors and staircases may have resilient floor coverings and sound absorbent ceilings are desirable unless the corridor is fully carpeted. Staircases and lift wells may be cut off from corridors by means of swing doors and, if possible, isolated from guest rooms by linen stores or similar rooms. Room service pantries on floors can also be a source of noise and may be separated from corridors by baffle lobbies, unless the rooms themselves have baffle lobbies.

9.2.2.4 Except within the same suite, bathrooms should not be planned next to bedrooms. Where this is unavoidable, internal pipe shafts with heavy walls, unpierced on bedrooms' side may be used as means of separation. It is important to choose quiet type of sanitary fittings and to design the plumbing system so as not to create noise, that is, by avoiding sharp bends, restrictions of flow, quick-action valves that might cause water hammer, etc.

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9.2.2.5 Air-conditioning system should be quiet in operation. Care should also be taken that the air-conditioning ducts do not lead to a cross-talk problem between rooms. Suitable acoustical lining should be provided in the ducts consistent with the fire safety requirements of the buildings.

9.2.2.6 Large hotels often have banquet halls and conference halls which are separately hired out for public and private functions. Late night restaurants and night clubs are also popular and functions in all these areas may go on well into the night. It is therefore essential that these rooms be effectively isolated from bedrooms and effective insulation from all possible noise sources is considered. Here it is not only necessary to consider the air-borne sound insulation but it is also necessary to consider the question of structure-borne and impact noise transmitted from areas where there might be dancing late into the night. Floating floors may be considered for structure borne sound isolation for dance floors and loudspeakers.

9.2.2.7 While most of the noise problems encountered in hotels are applicable to hostels, the latter are normally of more economical construction and, therefore, cannot cater for special sound insulation provisions. However, as far as possible, precautions should be taken to provide comfortable conditions in hostel rooms. This is especially true for student hostels where each room is also a living room. Students might play music or have loud discussions late into the night.

This may disturb sleep or study of other students. Proper precautions should, therefore, be taken to provide satisfactory conditions.

10 INDUSTRIAL BUILDINGS

10.1 General

Industrial buildings are primarily producers rather than receivers of noise. The level of industrial noise commonly exceeds that from any other source with the exception of aircraft. As compared with traffic noise, its effects are less widespread but it is often more annoying in character.

10.1.1 Many industrial noises contain very strong high frequency whines, screeches and clatter - these components are relatively more attenuated by passage through the air and by the insulation of light structure than are lower frequencies.

10.1.2 Intermittent noises are either isolated explosions or reports, or noises of a periodic nature, such as those of pressure relief valves of blow off, or the noises of work occurring at random intervals, for example, hammering, grinding and sawing operations; the latter class may be especially irritating because of high frequency components.

10.2 Sources of Industrial Noise

10.2.1 Noises in industrial buildings are mainly of indoor origin. Noise in factories and workshops is generally caused by machine tools and by operations involved in making and handling the product and they are classified into the following groups, depending upon how the noise energy is generated.

10.2.1.1 *Impact*

Noise caused by impact is the most intense and widespread of all industrial noises. It is normally coupled with resonant response of the structural members connected to the impacting surface. Common sources of this type of noise are forging, riveting, chipping, pressing, tumbling, cutting, weaving, etc. Intense impact noise may also be produced during handling of materials as in the case of sheared steel plates falling one over another in collecting trays in a steel factory. Impact noise is usually intermittent and impulsive in character, but it may also be continuous as in the case of tumbling.

10.2.1.2 *Friction*

Most of the noise due to friction is produced in such processes as sawing, grinding and sanding. Friction also occurs at the cutting edge on lathes and other machine tools and in brakes and from bearings. The spectrum of frictional noise often predominates in high frequency and is very unpleasant in character.

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10.2.1.3 *Rotation and reciprocation*

A rotating or reciprocating machine generates noise due to unbalanced forces and/or pressure fluctuations in the fluids inside the machines. In many cases, the moving surfaces radiate noise directly and in other cases, the pressure fluctuations are transmitted to the outer casings of the machine from where they are radiated as noise. Interaction of rotating component with the fluid stream can also give rise to pure tone components, such as the whine in a turbine. Since most machine casings have radiation efficiencies of unity in the higher frequency range, the amount of sound radiated is often substantial.

10.2.1.4 *Air turbulence*

Noise may be generated by rapid variation in air pressure caused by turbulence from high velocity air, steam or gases. Common examples are the exhaust noise from pneumatic tools and air jets. The noise is intense, and broad based in character and the frequency criteria depends on the size of the jet. The intensity increases rapidly with the velocity of the air stream.

10.2.1.5 *Noises with pure tone components*

Whining noise from turbines and humming noise from transformers come under this group.

10.3 Noise Criteria

10.3.1 *Hearing Damage – Risk Criteria*

Continuous exposure to high noise levels may result in permanent noise induced hearing loss in the course of time. Damage-risk criteria specify the maximum levels and duration of noise exposure that may be considered safe. Generally accepted damage-risk criteria for exposure to continuous, steady broad band noise are shown in Table 7. Whenever the sound levels at the worker's position in a factory exceed the levels and the duration suggested, feasible engineering controls shall be utilized to reduce the sound to the limits shown. If such controls fail to reduce sound levels within the levels of Table 7, personal hearing protection equipment shall be provided and used to reduce sound levels within the level shown.

Table 7 Permissible Exposure Limits for Steady-State Noise

(*Clause* 10.3.1)

Sl No.	**Sound Level (Slow Response)** dBA	**Time Permitted,** *T* h : min
(1)	(2)	(3)
i)	85	16 : 00
ii)	86	13 : 56
iii)	87	12 : 08
iv)	88	10 : 34
v)	89	9 : 11
vi)	90	8 : 00
vii)	91	6 : 58
viii)	92	6 : 04
ix)	93	5 : 17
x)	94	4 : 36
xi)	95	4 : 00
xii)	96	3 : 29
xiii)	97	3 : 02

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Table 7 (*Concluded*)

Sl No.	Sound Level (Slow Response) dBA	Time Permitted, *T* h : min
(1)	(2)	(3)
xiv)	98	2 : 50
xv)	99	2 : 15
xvi)	100	2 : 00
xvii)	101	1 : 44
xviii)	102	1 : 31
xix)	103	1 : 19
xx)	104	1 : 09
xxi)	105	1 : 00
xxii)	106	0 : 52
xxiii)	107	0 : 46
xxiv)	108	0 : 40
xxv)	109	0 : 34
xxvi)	110	0 : 30
xxvii)	111	0 : 26
xxviii)	112	0 : 23
xxix)	113	0 : 20
xxx)	114	0 : 17
xxxi)	115	0 : 15

NOTES

1 Where the table does not reflect the actual exposure times and levels, the permissible exposure to continuous noise at a single level shall not exceed the time *T* (in h) computed from the formula:

$$T = \frac{16}{2^{[0.2(L-85)]}}$$

where

L = work place sound level measured in dBA.

2 When the daily noise exposure is composed of two or more periods of different levels, their combined effect should be considered rather than the individual effect of each. The combined levels may not exceed a daily noise dose, D of unity where D is computed from the formula:

$$D = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots\ldots + \frac{C_n}{T_n}$$

where, C_1, C_2 …… C_n indicate the total duration of exposure (in hour) at a given steady-state noise level; and T_1, T_2,…,T_n are the noise exposure limits (in hour for the respective levels given in the table or computed by the equation in Note 1). Exposure to continuous noise shall not exceed 115 dBA regardless of any value computed by the formula for the daily noise dose, *D* or by the equation in Note 2.

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10.3.2 *Interference with Communication*

In factories where audible warning signals are used, or where an operator follows the operation of his machine by ear, the background noise should not be so loud as to mask the signal or desired sound (the information sound) to be heard. Noise may be the cause of accidents by hindering communication or by masking warning signals.

10.4 Methods of Reducing Noise

10.4.1 *Noise Control by Location*

Machines, processes and work areas which are approximately equally noisy should be located together as far as possible. Areas that are particularly noisy should be segregated from quiet areas by buffer zones that produce and may tolerate intermediate noise levels.

10.4.2 *Noise Reduction by Layout*

The office space in a factory should be as far as possible located preferably in a separate building. This building should not have a wall common with the production area. Where a common wall is unavoidable, it should be heavy with few connecting doors and no permanent openings.

10.4.3 *Noise Reduction at Source*

10.4.3.1 *Selection of machinery*

Noise should be reduced as near the source as possible. While the operational processes in a factory may be fixed and may have no quieter alternative, careful selection of the machine tools and equipment to be used may considerably help attaining lower noise levels in the machine shop.

10.4.3.2 *Reducing noise from potential sources*

Impact that is not essential to a process should be quietened. Noise from handling and dropping of materials on hard surface may be reduced by using soft resilient materials on containers, fixing rubber tyres on trucks, trolleys, etc. Machine noise may be kept to a minimum by proper maintenance. Proper lubrication reduces noise by friction conveyors, rollers, etc.

10.4.3.3 The noise from the radiating surfaces may be reduced by reducing the radiating area. For example, if the area is halved, the noise intensity will be reduced by 3 dB and at low frequencies the reduction will be much greater.

10.4.3.4 Supporting structures for vibrating machines and other equipment should be frames rather than cabinets or sheeted enclosures. If an enclosure is used, precaution should be taken to isolate it and line it on the inside with sound-absorbent material. Penetration through the enclosure should be adequately sealed. The noise radiated by machinery guards can be minimised by making them of perforated sheet or of wire mesh.

10.4.3.5 *Reducing transmission of mechanical vibration*

A vibrating source does not usually contain a large radiating surface but the vibration is conducted along mechanically rigid paths to surfaces that can act as effective radiator. If the rigid connecting paths are interrupted by resilient materials, the transmission of vibration and consequently the noise radiated may be greatly reduced. The reduction depends on the ratio of the driving (forcing) frequency of the source to the natural frequency of the resilient system. The natural frequency may be determined from static deflection under actual load as given in Fig. 1. The higher the ratio between the two frequencies, the lesser is the transmissibility, which is defined as the ratio of the force transmitted through the resilient isolator to the exciting force applied to it. Transmissibility and the equivalent noise reduction for various frequency ratios are given in Fig. 2. For satisfactory operation, a ratio of 3 : 1 or more between the driving and natural frequencies is recommended.

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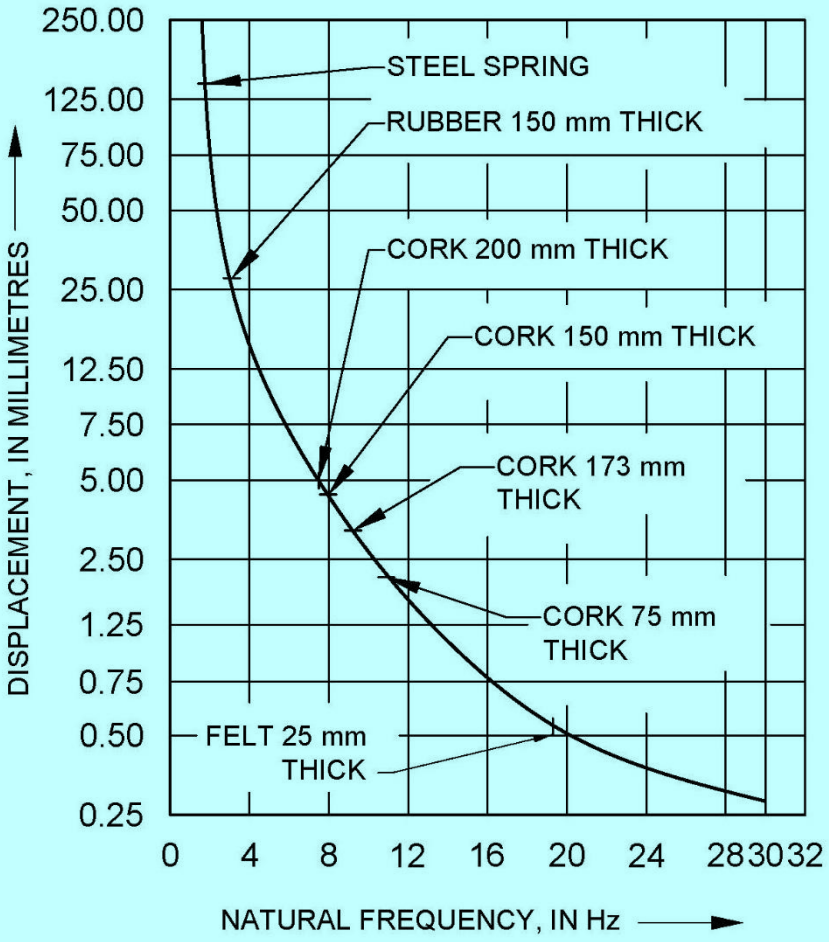

FIG. 1 RELATION BETWEEN STATIC DEFLECTION AND NATURAL FREQUENCY

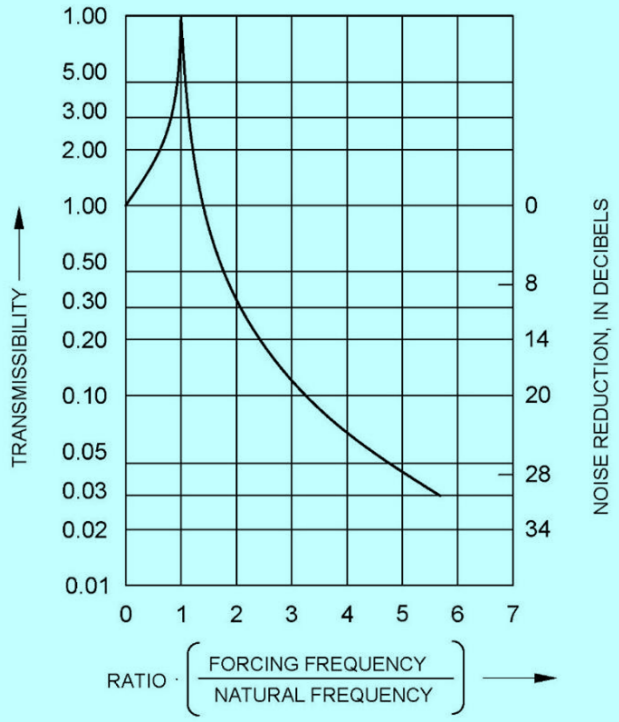

FIG. 2 TRANSMISSIBILITY AND EQUIVALENT NOISE REDUCTION FOR DIFFERENT RATIOS OF FORCING AND NATURAL FREQUENCIES

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Materials for isolators and their position are given below:

a) *Material for isolators* — Vibration isolators are usually made of resilient materials like steel in the form of springs and rubber:

   1) Because of the large range of deflections obtainable in coil springs, they may isolate vibrations over a large spectrum of low frequencies. Metal springs transmit high frequency (from about two hundred to several thousand c/s) very readily. Transmission of these frequencies can be reduced by eliminating direct contact between the spring and the supporting structure. Rubber or felt pads may be inserted between the ends of the spring and the surfaces to which it is fastened;

   2) Rubber in the form of pads may be used to isolate very effectively engines, motors, etc. It may be used in compression or in shear. Some rubber mountings use rubber-in-shear as the primary elastic elements and rubber-in-compression as a secondary element which furnishes snubbing action if the mounting is subjected to an overload; and

   3) Felt or cork or both may be used as resilient mats or pads under machine bases. The load per unit area shall be chosen to produce enough deflection for the isolation required; and shall be such that at this deflection, it is not loaded beyond its elastic limit.

b) *Position of isolators* — The normal position of the isolators is between the machine and its foundation. However, if the forcing frequency of the machine is low (less than 10 Hz) and vibration isolators with the requisite deflection for this location are not available, the machine may be bolted directly to an independent heavy inertia concrete base and the available vibration isolators used below the concrete base.

   1) Large press and drop hammers which create serious impact vibration in heavy machine shops may be mounted rigidly on very massive blocks of concrete having weights several times greater than the weights of the supported machines. The inertia blocks may, in turn, be isolated from the building structure by large wooden blocks and with thick pads of cork;

   2) In critical installations (*see* Note), attempt should be made to locate the resilient mounts in a plane which contains the centre of gravity of the mounted assembly. It is also preferable to locate the mounts laterally as far away as possible from the centre of the machine;

      NOTE — Critical installations are those installations where transmission of vibration from these installations seriously hamper the normal working.

   3) Rigid mechanical ties between vibrating machine and building structure, short-circuit or reduce the effectiveness of isolators. Loose and flexible connections should be inserted in all pipes and conduits leading from the vibrating machine. Where flexible connections are impracticable, bends should be inserted into the pipes or the pipes themselves should be supported on vibration mounts for a considerable distance from the source; and

   4) *Flexibility of foundation* — The effect of flexibility of the foundation on the isolator transmissibility shall be considered in the selection of practical vibration isolating mountings. The simplified vibration isolation theory assumes a completely rigid foundation. However, in practice, this can never be achieved. The foundation is never actually completely rigid. Generally, the relatively low stiffness of the isolation system permits the assumption of the foundation to be rigid. However, if the stiffness of the isolator is allowed to become comparable to the foundation stiffness (or greater), the deflection of the isolator will become smaller and the foundation will also deflect with increased transmissibility and decreased isolator efficiency. In a dynamic sense, supporting foundation or floors should have natural frequency as high and be as stiff as possible compared to the system being isolated. Good design practice requires that the isolators should be designed assuming a rigid foundation with the stipulation that the selected machine isolation system frequency should be well below the foundation frequency. This point should specially be kept in mind when installing machines at upper levels in buildings because supported slabs generally have lower natural frequencies (low stiffness) than slabs on grade in basement or ground floor locations.

10.4.4 *Noise Reduction by Enclosures and Barriers*

10.4.4.1 *Enclosures*

Airborne noise generated by a machine may be reduced by placing the machine in an enclosure or behind a barrier. The enclosure may be in the form of close-fitting acoustic box around the machine such that the operator performs

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his normal work outside the box and thus is not subjected to the high noise levels of the machine. The enclosure may be made of sheet metal lined inside with an acoustical material.

Where size of the machine, working area and the operation do not permit close-fitting enclosures, the machine may be housed in a room of its own. The inside of the enclosure should be lined with sound-absorbing materials to reduce the noise level of the contained sound. The bounding walls of the enclosures should also have adequate transmission loss to provide desired noise reduction.

10.4.4.2 *Barriers*

A partial reduction of noise in certain directions may be obtained by barriers or partial enclosures or partial height walls. Two-sided or three-sided barrier, with or without a top and invariably covered on the machine side with acoustic absorption material should face a wall covered with sound-absorbing material. If the top of the enclosure is open, the reduction may be increased by placing sound-absorbing material on the ceiling overhead.

10.4.5 *Acoustical Absorption Devices*

10.4.5.1 *Acoustical treatment of ceilings and side walls*

In order to reduce the general reverberant noise level in machine shops, acoustical material may be provided on as much of the available area on the ceiling and side walls. With this treatment 3 dB to 6 dB reduction of middle and high frequency noise may be achieved. While the noise level at the source, affecting the operator, may not be reduced materially, the treatment would bring down the built-up noise level away from the source in reverberant field.

10.4.5.2 *Functional sound absorbers*

For efficient noise reduction functional sound absorbers may be clustered as near the machines as possible. These units may be suspended and distributed in any pattern to obtain lower noise levels within the machine shop. Compared on the basis of equal total exposed surface areas, functional sound absorbers have higher noise reduction coefficients (NRC) than conventional acoustical materials placed directly on ceilings and walls.

10.5 Noise Control in Specific Industrial Occupancies

10.5.1 *Manufacturing and Heavy Machinery Industries*

10.5.1.1 Industrial units with high-noise equipment such as stamping presses, crushers, and rolling mills should install vibration isolation platforms or resilient mounts to control structure-borne noise.

10.5.1.2 Machines producing significant noise should be enclosed in acoustic enclosures to prevent noise propagation within the facility and reduce exposure to workers.

10.5.1.3 Partition walls between noisy production areas and quieter zones (such as offices or break rooms) should incorporate sound-insulating materials or be designed with adequate thickness to ensure minimal noise transfer.

10.5.2 *Chemical and Pharmaceutical Plants*

10.5.2.1 Noise-generating equipment such as pumps, compressors, and centrifuges should be fitted with mufflers or acoustic casings to minimize sound emissions.

10.5.2.2 Mechanical rooms containing heating, ventilation, and air conditioning systems and other service units should be acoustically treated and isolated from production spaces to prevent noise transmission.

10.5.2.3 Noise-sensitive spaces such as laboratories and quality control areas should either be located away from noisy zones or separated by floating floors or soundproof partitions to ensure operational efficiency.

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10.5.3 *Food Processing Units*

10.5.3.1 Equipment such as blenders, grinders, and packaging machines should use vibration-isolating mounts to control structure-borne noise.

10.5.3.2 Temporary sound barriers may be installed around seasonal operations like bulk-loading zones during periods of high activity.

10.5.3.3 Control rooms and staff areas should be acoustically insulated to ensure noise relief, with soundproof partitions and doors installed where necessary.

10.5.4 *Power Plants and Utilities*

10.5.4.1 Power plants should install noise barriers or walls around high-noise zones such as turbine halls and generator rooms to minimize sound emissions beyond facility boundaries.

10.5.4.2 Cooling towers and exhaust stacks should be equipped with noise control devices like silencers to mitigate low-frequency noise emissions.

10.5.4.3 Control rooms and operational centres should be designed to maintain appropriate noise levels conducive to work, with double-wall partitions or air gaps considered for turbine or engine rooms.

11 LABORATORIES AND TEST HOUSES

11.1 Sources of Noise

11.1.1 *Outdoor Noise*

In a test house or laboratory, where research workers and scientists are engaged in performing sophisticated experiments, the external noise is mostly contributed by noise emitting buildings (workshops, machine rooms), airports, railway stations and general traffic noises. The outdoor sources of noise in a college laboratory include noises produced in a playground as well.

11.1.2 *Indoor Noise*

The following sources mainly contribute to indoor noises in research institutions/college laboratories:

a) Workshops, machine rooms, cafeteria, etc;

b) Air conditioning and exhaust fans;

c) Noise produced within the test house or laboratory while performing experiments; and

d) Typing or other machine noises, telephone service, lift, sanitary services, etc.

11.2 Recommendations

11.2.1 *Site Planning*

While planning for a laboratory or test house, care should be taken in the design that no noise emitting installations should exist in its neighbourhood. However, where outdoor noises exist, such as from local factory, heavy traffic airports, railway lines, sport grounds or busy markets, buildings should be kept as far away as possible from the source of noise.

11.2.1.1 The window and door openings towards the noise sources should be minimum. Minimum amount of glazing should be placed on walls directly facing the noise sources.

11.2.2 *Internal Planning*

11.2.2.1 Noisy places should be kept separate from the quiet ones. The location of laboratories or test houses should be so chosen that it is cut off from the noisy zones. Where there are offices attached to a laboratory,

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provision should be made to treat the offices and to use acoustical partitions, to achieve a sound isolation D_w of at least 35 dB.

11.2.2.2 In a laboratory, mostly hard reflecting surfaces and bare furnishings are found, which produce very reverberant conditions. The noise condition still deteriorates when noise producing instruments are switched on or a heavy object is dropped on the floor. Under these conditions, sound absorbing treatment of the space is very essential. Sound absorbing ceilings are recommended to deaden such noises. Rubber buffers may also be fitted to the legs of furniture.

11.2.2.3 In large span laboratories or test houses where scientists and researchers are engaged in work and/or simultaneously busy in calculations or desk work requiring high degree of mental concentration, use of sound absorbing screens is recommended.

11.2.2.4 Noise reduction between the test house or laboratory and corridors or general circulation space should be well kept in mind and due care should be taken of the type of doors and the manner of their fittings, etc. Transmission of noise through service ducts, pipes, lifts and staircases should also be guarded.

Telephones should preferably be placed in a separate small enclosure or acoustically efficient telephone booth.

11.2.2.5 To isolate a laboratory or a test house from structure-borne noises originating from upper floor, sandwich type floor construction is recommended.

11.2.2.6 Wherever the provision of double glazed windows is necessary to reduce the heat losses, care should be taken to provide sealed double windows rather than double glazing in a single window.

NOTE — Double glazed windows for sound insulation should have a minimum gap of 100 mm between the two glasses.

12 MISCELLANEOUS BUILDINGS

12.1 Law Courts and Council Chambers

It is important that law courts and council chambers be protected from the intrusion of outdoor noise and from indoor noise arising both from ancillary offices and circulation spaces. The general recommendations on site planning given in **3** apply to law courts and municipal buildings, but in the larger buildings at least, further protection against outdoor noise can be obtained by planning offices and other rooms around the court rooms or chambers, and separating the offices from the central rooms by means of corridors. This arrangement is usually convenient to the function of the buildings.

12.1.1 The wall between the corridors and the central rooms should have a sound reduction index, R_w of not less than 50 dB (for example 230 mm brick) to insulate against airborne noise in the corridors. Entrances from halls or corridors into court rooms or council chambers should be through baffle lobbies with two sets of quiet action doors. Sound absorbing treatment on ceilings and upper parts or walls or entrance lobbies is recommended.

12.1.2 The whole of the floor of the court room or chamber including steps and seating areas set aside for the public should have a resilient floor finish to reduce the noise of footsteps and shuffling of feet. Any tip-up seats should be quiet in action.

12.1.3 Sound absorbing treatment applied for acoustic purposes serves also to reduce the build-up of noise within the room. It is desirable to provide sound absorbing ceiling in the court room.

12.2 Libraries, Museums and Art Galleries

Quiet conditions for reading and study are essential in these types of buildings and, since their occupancy is not noise producing, intruding noise is more noticeable and distracting. Every opportunity therefore should be taken to plan for noise defence, both in respect of siting of the building and internal planning. When possible, stack rooms, store rooms and administrative offices should be planned to screen reading rooms, print rooms and lecture rooms from noise sources. In public libraries, the reference library and lecture rooms should receive first consideration; the lending library, newspaper and periodical rooms have a higher background noise and are secondary in importance.

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12.2.1 In large libraries, museums and art galleries echoes from lofty, large domed or concave ceilings are often a nuisance. Small noises such as footsteps, coughs, chair scraping and closing of books are reinforced by reverberation, and concave surfaces even when treated with a sound absorbent may focus these noises. Treated flat ceilings, if not too high, obviate these troubles. Books on shelves in libraries constitute a valuable wall absorbent.

12.2.2 Floor finishes are important. The impact noise of footsteps on marble, terrazzo or wood block flooring, and especially on hardwood strip and batten flooring, can be disturbing both within the room in which the noise is generated and the rooms below. On solid floors, resilient floor finishes, such as rubber, cork and linoleum on an underlay, are highly desirable. In the children's sections of libraries and museums they are essential. In existing buildings, rubber linoleum or vinyl asbestos tiles laid over the floor in the traffic areas are often a solution to the problem.

12.2.3 Reference libraries in universities, research establishments, office buildings and science buildings having machines and testing benches, should be planned in a quiet part of the building. Walls enclosing the library should normally have a sound reduction index, R_w of not less than 50 dB (for example 230 mm brick) and baffle lobbies should be planned between the library and halls and corridors. Walls facing on to corridors or other noisy areas should not have fanlights unless they are double glazed and non-operable.

12.3 Auditoria and Theatres

The sources of noise that have to be considered in concert halls, opera house, theatres and similar auditorium buildings are as follows:

a) Outdoor noise entering through walls, roofs, doors, windows or ventilation openings;

b) Noise from any other hall in the same building, especially if let out separately for revenue;

c) Noise from foyers, service rooms and other ancillary rooms, particularly rehearsal rooms;

d) Noise from air conditioning plant, etc, and the cross-transmission of other internal noises via ventilating duct system; and

e) Impact generated noise due to rainfall on light weight metal roofs.

12.3.1 Because of greatly increased outdoor noise, all auditorium buildings now need more care in siting than formerly. For listening to speech or music, a very low background noise level is desirable; in concert halls especially, the quietest possible conditions should be provided because the pauses and moments of silence which are an essential element of music cannot otherwise be given full value. Therefore, sites at cross-roads or close to steel railway bridges, religious places or near churches where bell ringing is practiced, should be avoided unless very high standards of structural sound insulation are contemplated. Sites adjoining underground railways may also prove unsatisfactory at basement levels owing to low-pitched noise or rumble transmitted through the ground; special isolation measure need to be adopted for isolating large buildings from ground vibration of this sort.

12.3.2 Whenever possible, for concert halls and theatres on city sites a noise survey of the site should be made; a suitable sound reduction value for the structure of the building can then be chosen so as to keep down to certain maximum noise levels within the auditorium. The maximum octave-band sound pressure levels (SPL) recommended are given in Table 8.

Table 8 Maximum Sound Pressure Levels (dB) Due to External and Mechanical Equipment Noise in Auditoria

(*Clause* 12.3.2)

Sl No.	Type of Auditorium	Centre Frequency Hz							
		63	125	250	500	1 000	2 000	4 000	8 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Concert halls [dB*A*-25]	51	39	31	24	20	17	14	13
ii)	Drama theatres and Cinemas [dB*A*-30]	55	44	35	29	25	22	20	18

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12.3.3 The minimum standard of sound reduction index, R_w likely to be required for the envelope of an auditorium in a city to protect it against external noise is of the order of 65 dB for a concert hall or 55 dB to 60 dB for a theatre. This reduction should be provided on all sides, but it would be reasonable to make the R_w for the roof 5 dB to 10 dB less provided the building is not unduly exposed to noise from aircraft in flight. Surrounding the auditorium with ancillary rooms and foyers is an obvious and invaluable planning method of obtaining the required insulation against outdoor noise.

12.3.4 Ventilation intakes and returns are vulnerable features in the defence against external noise. They should be positioned so as to avoid exposure to noise, and in addition sufficient length of both inlet and outlet ducts should be provided with carefully designed silencers. The ventilation system should also be designed to avoid transmitting or adding to internal noise.

12.3.5 The most serious internal noise problem arises when there are two halls meant for separate use in the same building, especially if one of them is a concert hall. The latter is a very loud potential source of noise and requires a high standard of protection against extraneous noise. In these circumstances it is doubtful whether a 'single' wall can be adequate for insulating the two halls unless it is designed with a wide unbridged cavity. Separation by planning is preferable.

12.3.6 Other sources of internal noise are rehearsal rooms, scenery bays and workshops, stages of other halls where rehearsals or erection of stage sets might be in progress and foyers and bars where loud conversation might occur. The insulation of the internal walls should be adequate to protect the auditorium from these noise sources and the insulation should not be by-passed by openings, doorways, etc. The general noise due to banging of doors also needs to be taken care of and soft sealing materials should be provided for all doors to ensure quiet closing.

12.3.7 Mechanical equipment such as lifts shall be effectively isolated from the building structure to help avoid noise transmission.

12.3.8 Adequate damping should be provided under light weight metal roofs with an additional light weight under deck noise sound barrier to reduce rainfall generated noise.

12.3.9 For detailed acoustical design of auditoria and conference halls reference may be made to good practice [D-4(3)].

12.4 Cinemas

The main objective of the design should be to control noise from adjacent screens, the projection area, the foyer, and outside the cinema. The first of these, controlling noise from adjacent screens, is likely to be the most difficult with modern digital sound systems. As most cinemas are air-conditioned, there will be some noise from services. To ensure reasonable listening conditions, this should be limited to 30 dBA. This will provide some masking of the noise from adjacent screens, but a high performance partition will still be essential. Masonry or lightweight construction may be used, and a typical performance specification for a lightweight wall separating two screens is given in Table 9. Cinema design, however, normally requires specialist acoustic advice.

Table 9 Typical Sound Insulation Specification for Wall Separating Two Cinema Screens

(*Clause* 12.4)

Sl No.	Octave band Hz	Sound Reduction Index, R dB
(1)	(2)	(3)
i)	63	38
ii)	125	44
iii)	250	50
iv)	500	61
v)	1 000	57
vi)	2 000	58
vii)	4 000	57
viii)	8 000	55

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13 NOISE FROM BUILDING SERVICES

13.1 Mechanical, electrical, air conditioning, heating and mechanical ventilation, and other services are provided in almost all large buildings including residential, commercial and industrial buildings. Noise control measures should be incorporated during the design and installation of such services to adhere to the recommended outdoor and indoor noise criteria for the kind of occupancy. For detailed design of noise control for services, specialist advice should be sought.

Some basic design techniques for noise control in air conditioning, heating and mechanical ventilation system are given in Annex J.

13.2 Control of noise from mechanical equipment can also be done by specifying noise control requirements while purchasing the equipment (*see* Annex K).

14 NEIGHBOURHOOD ACOUSTIC SHIELDING DURING INFRASTRUCTURE DEVELOPMENT

14.1 General

Infrastructure development projects often generate substantial noise that can adversely affect the well-being of residents. Prolonged exposure to noise pollution may lead to health issues such as sleep disturbances, hearing impairments and stress. Hence, effective acoustic shielding of neighbourhood is required to minimize such impacts. The following outlines the provisions for noise control during infrastructure development.

14.2 Pre-Development Noise Assessment

14.2.1 A baseline noise assessment should be conducted prior to the commencement of construction activities to determine ambient noise levels and identify noise-sensitive receptors (NSRs), including residential areas, schools, and healthcare facilities.

14.2.2 Noise modelling should be performed to predict noise levels for each phase of construction. The model shall take into account equipment type, frequency and duration of activities, and the topography of the site.

14.2.3 Predicted noise levels shall be compared with the limits prescribed. If expected levels exceed the permissible limits, additional mitigation measures should be proposed.

14.3 Noise Mitigation Planning

14.3.1 A noise mitigation plan (NMP) should be prepared prior to the commencement of any construction work. The NMP shall include:

a) Identification of potential noise sources and their expected noise levels;

b) Location of noise-sensitive receptors and baseline noise levels;

c) Proposed noise control measures and their implementation timelines;

d) Monitoring strategies for continuous noise assessment; and

e) Community engagement strategies and complaint management procedures.

14.3.2 Construction activities that generate high levels of noise should be scheduled during permissible hours. Noise-intensive operations should be avoided during night time hours unless specific approval is obtained.

14.4 Noise Barriers

14.4.1 Temporary noise barriers should be installed at the perimeter of construction sites to shield NSRs from construction noise. Barriers should be designed to achieve a minimum noise reduction of 10 dBA. The height of the barriers should be at least 2.5 m or as determined by site-specific acoustic analysis.

14.4.2 Permanent noise barriers, such as earth berms, concrete walls, or vegetative buffers, may be considered for long-term infrastructure projects with expected noise impacts exceeding permissible limits.

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14.4.3 Recommended guidelines for the design and performance evaluation of noise barriers are given in Annex F.

14.5 Low-Noise Equipment and Practices

14.5.1 Low-noise equipment, such as electric or hydraulic machinery, should be used wherever feasible. Equipment should be fitted with silencers, mufflers or acoustic enclosures to reduce emissions.

14.5.2 Construction techniques that minimize noise generation, such as hydraulic splitting instead of pneumatic hammering for concrete demolition, should be employed wherever possible.

14.6 Maintenance of Equipment

14.6.1 A maintenance schedule for all construction equipment should be implemented to ensure optimal operating conditions and minimize noise emissions.

14.6.2 All equipment should be inspected regularly for defects, such as worn-out parts, loose fittings or damaged mufflers, that may increase noise levels. Defective equipment should be repaired or replaced immediately.

14.7 Noise Monitoring and Compliance

14.7.1 Continuous noise monitoring should be conducted at designated locations near NSRs throughout the construction period. Monitoring equipment should be as per accepted standard [D-4(4)].

14.7.2 Noise levels should be logged at regular intervals. The logged data shall be reviewed daily to ensure compliance with the permissible noise levels.

14.7.3 If noise levels exceed permissible limits, corrective actions, such as modifying work practices, deploying additional noise barriers, should be implemented within 24 h.

14.7.4 A noise monitoring report should be maintained throughout the project, including logged data, incidents of exceedances, corrective actions taken, and community complaints received.

14.8 Community Engagement and Communication

14.8.1 A community noise management plan should be established as part of the noise management plan, outlining strategies for engaging with the local community, informing them about construction activities, expected noise impacts, and mitigation measures.

14.8.2 A public contact point should be established for residents to report noise concerns. All complaints should be logged, investigated, and resolved promptly.

14.9 Vegetative Buffers

14.9.1 Where feasible, vegetative buffers consisting of dense rows of trees or shrubs should be planted around the construction site to serve as supplementary noise barriers.

14.9.2 Vegetative buffers should have a minimum width of 5 m and be composed of mixed species with dense foliage for optimal sound absorption.

14.10 Post-Construction Noise Assessment

14.10.1 Upon completion of construction activities, a post-construction noise assessment should be conducted to verify that ambient noise levels have returned to pre-development conditions or meet permissible limits.

14.10.2 Temporary noise barriers should be dismantled and disposed of responsibly. If permanent barriers or vegetative buffers were installed, they should be integrated into the final landscape design.

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15 TRAFFIC NOISE BARRIERS

Noise barriers are one of the most effective ways to mitigate road traffic noise. Noise barriers can reduce the A-weighted noise levels depending on their design and height. If the barrier surface density exceeds 20 kg/m^2, a reduction of 5 dB can be achieved by having a barrier tall enough to break the line of sight from the road to the receiver and an additional 1.5 dB reduction can be achieved for each additional metre of height. The efficiency of noise barrier largely depends upon its geometry. Besides the height of the barrier and its top element form, the cross section of the barrier contributes to its performance. Recommended guidelines for the design and performance evaluation of noise barriers are given in Annex F.

ANNEX A

(*Clause* 2.4)

NOISE CALCULATIONS

A-1 GENERAL

Some of the simpler types of noise calculation are described in this annex.

A-2 ADDITION OF TWO NOISE LEVELS

To determine the combined sound pressure level (L_c) resulting from the sound pressure levels of two or more noise sources (L_1, L_2, etc), it is necessary to calculate and add the mean square values of their individual sound pressures and then convert this back to a sound pressure level. This can be done using the following formula:

$$L_c = 10\, log_{10}(10^{L_1/10} + 10^{L_2/10})$$

As the individual sound pressure levels are logarithms of the mean square sound pressures, they cannot simply be added arithmetically. Fig. 3 shows a graphical method for adding the sound pressure levels from two independent sources to obtain the combined sound pressure level at a particular place. This graph may also be used for multiple sources by combining sources two at a time to produce virtual sources that can then be combined. The most accurate approach is to start with the lowest levels and work towards the highest.

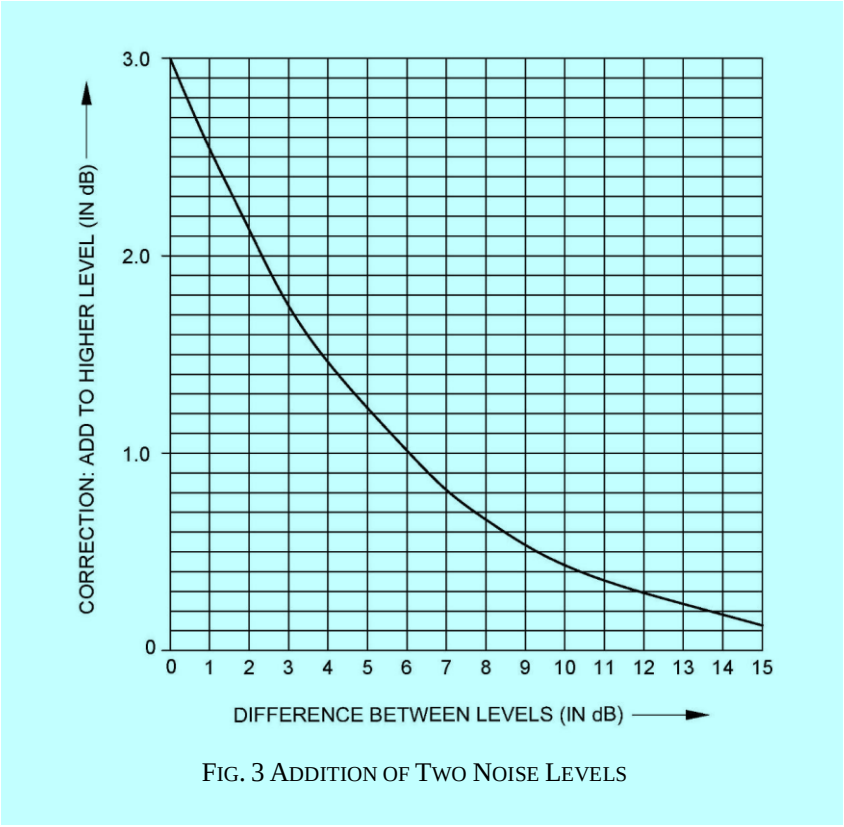

FIG. 3 ADDITION OF TWO NOISE LEVELS

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The graph should be used with caution where the noise sources are not independent. For example, the sound pressure level from two large transformers fed with currents in phase will be very sensitive to the receiving position. This is because the effect of the constructive and destructive interference of the sounds from the two sources is very dependent on position.

A-3 SUBTRACTION OF TWO NOISE LEVELS

When measuring noise from a source, the true noise level of the source alone will be less than that shown by the meter if the level of extraneous noise is less than about 10 dB below the total noise level. An estimate of the true source level can be obtained from Fig. 4.

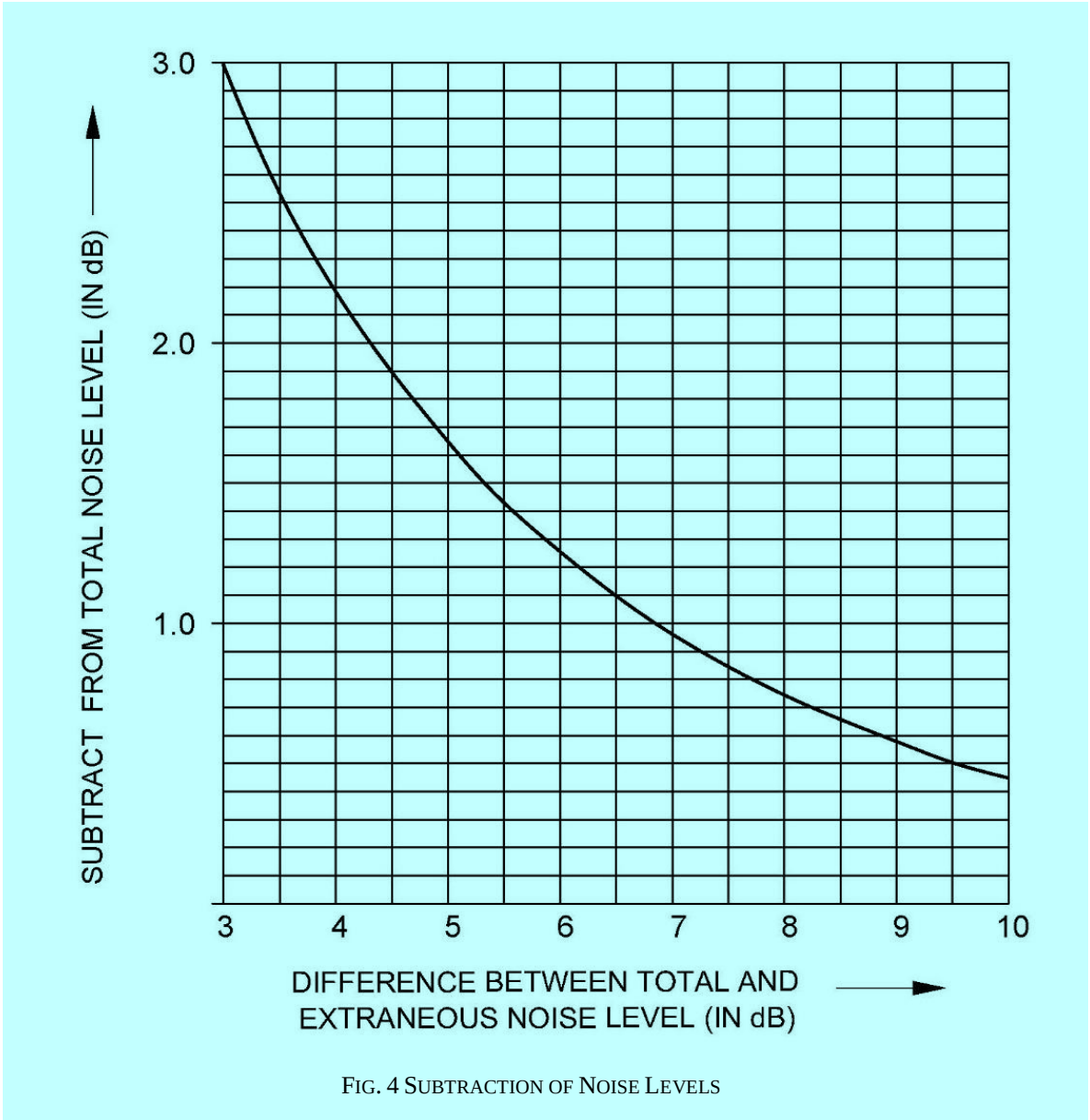

FIG. 4 SUBTRACTION OF NOISE LEVELS

A-4 NON-UNIFORM COMPOSITE PARTITIONS

Figure 5 provides for calculating the overall sound insulation of a composite partition consisting of two parts having different sound-insulating properties, for example, a window in a wall. It may also be used to give an indication of the effect of gaps or holes in a partition by assigning a sound insulation value of 0 dB to the aperture.

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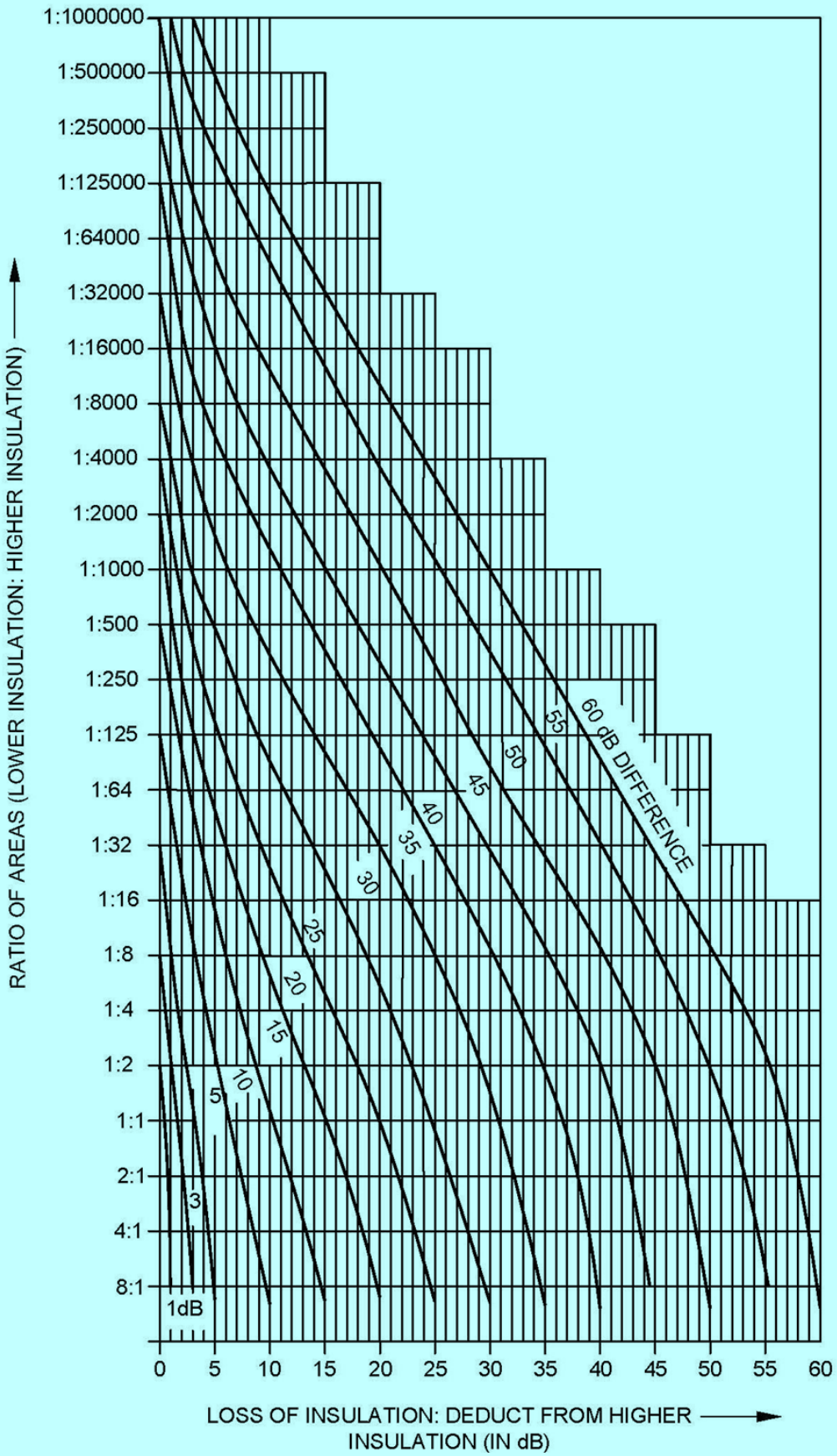

FIG. 5 SOUND INSULATION OF NON-UNIFORM PARTITIONS

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A-5 A-WEIGHTING CALCULATIONS

The equivalent A-weighted level is often required when data on a noise source is available as a set of octave band or one-third octave band levels. The conversion can be done manually, using the standard A-weighting values (*see* Table 10) and the graph for combining levels (*see* Fig. 3). For all but the simplest situations it is more convenient to use a computer spreadsheet to do the conversion.

Table 10 Standard A-Weighting Values (dB)

(*Clause* A-5)

Sl No.	Third Octave Band Centre Frequency	A-Weighting	Third Octave Band Centre Frequency	A-Weighting
	Hz	dB	Hz	dB
(1)	(2)	(3)	(4)	(5)
i)	10	- 70.4	500	-3.2
ii)	12.5	- 63.4	630	-1.9
iii)	16	- 56.7	800	-0.8
iv)	20	- 50.5	1 000	0
v)	25	- 44.7	1 250	0.6
vi)	31.5	- 39.4	1 600	1.0
vii)	40	- 34.6	2 000	1.2
viii)	50	- 30.2	2 500	1.3
ix)	63	- 26.2	3 150	1.2
x)	80	- 22.5	4 000	1.0
xi)	100	- 19.1	5 000	0.6
xii)	125	- 16.1	6 300	-0.1
xiii)	160	- 13.4	8 000	-1.1
xiv)	200	- 10.9	10 000	-2.5
xv)	250	- 8.6	12 500	-4.3
xvi)	315	- 6.6	16 000	-6.6
xvii)	400	- 4.8	20 000	-9.3

A-6 REVERBERATION TIME CALCULATION

An estimate of the reverberation time (T) of a room can be obtained from the Sabine formula:

$$T = \frac{0.16\,V}{\sum A_i}$$

where

V = volume of the room in cubic metres (m^3); and

A_i = equivalent sound absorbing area in the room, in square metres (m^2).

The A_i are the absorbing areas of each surface, or other permanent fixture in the room. Each A_i is determined by multiplying the area of that surface in square metre (m^2) by its absorption coefficient α_{si}. The surface of each significant fixture or feature of the room should be considered as well as the walls, ceiling and floor.

The total absorption is obtained by summing the individual A_i values. As the values of α_{si} are frequency dependent, this calculation should be repeated for each octave band of interest.

An allowance should also be made for people and furnishings in the room.

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ANNEX B

(*Clause* 2.24)

NOISE RATING

B-1 Noise rating (NR) is a graphical method for assigning a single number rating to a noise spectrum. It can be used to specify the maximum acceptable level in each octave band of a frequency spectrum, or to assess the acceptability of a noise spectrum for a particular application. The method was originally proposed for use in assessing environmental noise, but was later also found suitable for describing noise from mechanical ventilation systems in buildings. To make a rating, the noise spectrum is superposed on a family of NR contours; the NR of the spectrum corresponds to the value of the first NR contour that is entirely above the spectrum. The data for drawing NR contours (from NR 0 to NR 75) is given in Table 11 for the frequency range 31.5 Hz to 8 kHz.

Table 11 Noise Rating Values

(*Clause* **B-1**)

Sl No.	**Noise Rating**	**Octave Band Centre Frequency**, Hz **For Sound Pressure Levels dB$_{re}$ 20 µPa**								
		31.5	63	125	250	500	1 000	2 000	4 000	8 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	NR75	106	95	87	82	78	75	73	71	69
ii)	NR70	103	91	83	77	73	70	68	66	64
iii)	NR65	100	87	79	72	68	65	62	61	59
iv)	NR60	96	83	74	68	63	60	57	55	54
v)	NR55	93	79	70	63	58	55	52	50	49
vi)	NR50	89	75	66	59	53	50	47	45	43
vii)	NR45	86	71	61	54	48	45	42	40	38
viii)	NR40	83	67	57	49	44	40	37	35	33
ix)	NR35	79	63	52	45	39	35	32	30	28
x)	NR30	76	59	48	40	34	30	27	25	23
xi)	NR25	72	55	44	35	29	25	22	20	18
xii)	NR20	69	51	39	31	24	20	17	14	13
xiii)	NR15	66	47	35	26	19	15	12	9	7
xiv)	NR10	62	43	31	21	15	10	7	4	2
xv)	NR5	59	39	26	17	10	5	2	– 1	– 3
xvi)	NR0	55	35	22	12	5	0	– 4	– 6	– 8

B-2 For computational methods, the curves are defined by the equation:

$$L = a + bN$$

where

L = octave band sound pressure level corresponding to NR level N; and

a and b = constants for each frequency band, as given in Table 12.

NOTE — NR values cannot be converted directly to dBA values but the following approximate relationship applies:

NR = dBA – 6

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B-3 Although the NR system is currently the preferred method for rating noise from mechanical ventilation system, other methods which are more sensitive to noise at low frequencies are available, but they are not yet widely accepted. Low frequency noise may be disturbing or fatiguing to occupants, but may not have much effect on the dBA or NR value.

Table 12 Values of a and b

(*Clause* B-2)

Sl No.	Octave Band Centre Frequency Hz	*a*	*b*
(1)	(2)	(3)	(4)
i)	31.5	55.4	0.681
ii)	63	35.4	0.790
iii)	125	22.0	0.870
iv)	250	12.0	0.930
v)	500	4.2	0.980
vi)	1 000	0.0	1.000
vii)	2 000	- 3.5	1.015
viii)	4 000	- 6.1	1.025
ix)	8 000	- 8.0	1.030

ANNEX C

(*Clauses* 2.26, 2.41, 2.44, 2.46, 2.54, 2.55, 2.56 *and* 2.57)

SPECIFICATION OF SOUND INSULATION

C-1 GENERAL

Sound insulating elements work mainly by reflecting sound energy back into the source room, not by absorbing it. The methods of measurement and the terms used are described in **C-2** to **C-4**.

C-2 INSULATION AGAINST AIRBORNE SOUND

As per the standard tests, the insulation between a pair of rooms is measured either in third octave bands having centre frequencies which cover at least the range 100 Hz to 3 150 Hz, or in octave bands which cover at least the range 125 Hz to 4 000 Hz. The noise is produced by a loudspeaker in one of the rooms (called the source room) and at each frequency the average noise levels are measured in the source room (L_S) and in the adjacent receiving room (L_R). The difference between these two levels (D) is a measure of the sound insulation between the rooms regardless of the transmission path(s) the sound energy followed to travel between the rooms. The equation is as follows:

$$D = L_S - L_R$$

The actual level in the receiving room depends on the following:

a) Sound insulation of the separating wall or floor;

b) Area of the separating wall or floor;

c) Volume of the receiving room;

d) Amount of flanking transmission (that is the importance of transmission paths other than the separating wall or floor); and

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e) Amount of absorbing material (for example furniture) in the receiving room.

For field measurements, apart from the amount of absorption, these factors are a property of the building and should be taken into account by the measurement procedure. As the amount of absorbing material (for example soft furniture) in the room at the time of measurement is arbitrary, it should be allowed for separately. This is achieved by measuring the reverberation time (T) of the room in seconds (s), which is a measure of how long it takes a sound to die away after the source has been switched off. As the sound energy is dissipated as heat in the absorbing material (T), it is related to the total amount of absorption in the room. The receiving room level may then be corrected to the level it would be if the room had a standard reverberation time (T_0) which is typical of furnished rooms, and is taken to be 0.5 s. The corrected level difference is known as the standardized level difference, which has the symbol D_{nT} and is calculated using the following equation:

$$D_{nT} = L_S - L_R + 10log_{10}(T/T_0)$$

For laboratory measurements, the insulation of the separating wall or floor being tested is required in a way which is independent of the actual measuring laboratory. For this reason, laboratories are designed to have minimal flanking transmission and a different correction is applied to account for the other factors. This correction is $10 \log_{10} (S/A)$.

where

S = common area of the separating wall or floor, in m^2; and

A = equivalent absorption area in the receiving room, in m^2.

The laboratory corrected level difference at each frequency is known as the sound reduction index, which has the symbol R and is calculated using the following equation:

$$R = L_S - L_R + 10\ log_{10}(S/A)$$

If the test wall or floor is mounted in a realistic way in the laboratory and flanking transmission will be low in the field, the sound reduction index may be used to predict its performance in the field. The relation between D_{nT} and R is given by the following equation:

$$D_{nT} = R - 10\ log_{10}(3S/V)$$

where

S = area of the separating wall or floor in the field, in m^2; and

V = volume of the receiving room in the field, in m^3.

This equation shows that if the source and receiving rooms have different volumes, D_{nT} will depend on which is used as the source room; using the larger room as the source room will give lower value.

C-3 INSULATION AGAINST IMPACT SOUND

The procedure to measure the impact insulation of floors is rather different. Instead of a loudspeaker, a machine containing five small hammers is placed on the floor. While the hammers strike the floor at a rate of 10 blows a second, the resulting noise level (L_i) is measured in the receiving room below at each of the same frequency bands used for airborne insulation. In the field, the receiving room levels are again 'corrected' to a standard reverberation time (T_0) of 0.5 s to give the standardized impact sound pressure level, L_{nT}, which is calculated as follows:

$$L_{nT} = L_i - 10\ log_{10}(T/T_0)$$

In the laboratory, the noise level depends mainly on the characteristics of the floor being tested and the amount of absorption (A m^2) in the laboratory. It is therefore appropriate to correct the noise level to a standard area of absorption. The area used is 10 m^2. The resulting normalized impact sound pressure level is given the symbol L_n and calculated as follows:

$$L_n = L_i + 10log_{10}(A/10)$$

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C-4 RATING SOUND INSULATION

Measurements of insulation against both airborne and impact sounds yield values in a number of frequency bands. To make this information more manageable, rating methods such as those in accordance with [D-4(1)] are used to reduce the frequency band values to single figure ratings. These single figure ratings should be good predictors of subjective assessments of insulation. However, this is not always the case and it is prudent to examine the full measurement data in critical situations. The impact insulation measured on a floor with a carpet is likely to be overestimated by this method.

The more common indices used to describe sound insulation are summarized in Table 13.

Table 13 Common Indices Used to Describe Airborne and Impact Sound Insulation

(*Clause* C-4)

Sl No.	Airborne (*A*) Impact (*I*)	Lab (*L*) Field (*F*)	Measured Values		Single Number Quantity	
			Name	Symbol	Name	Symbol
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	*A*	*F*	Standardized level difference	D_{nT}	Weighted standardized level difference	$D_{nT,w}$
ii)	*A*	*L*	Sound reduction index	*R*	Weighted sound reduction index	R_w
iii)	*I*	*F*	Standardized impact sound pressure level	L'_{nT}	Weighted standardized impact sound pressure level	$L'_{nT,w}$
iv)	*I*	*L*	Normalized impact sound pressure level	L'_n	Weighted normalized impact sound pressure level	$L'_{n,w}$

ANNEX D

(*Clause* 3.3)

OUTDOOR NOISE REGULATIONS IN INDIA

D-1 Government notifications are issued from time to time on the allowable ambient noise levels in general and specifically in different zones of various metropolitan cities of India.

D-2 Noise regulations and notifications are also issued from time to time specifying the maximum permissible sound levels from equipment commonly used in and around the residential areas and around sensitive buildings, specifically with regard to noise levels from electricity generating sets, construction equipment and HVAC utility equipment installed outdoors.

D-3 These regulations should be referred to by the designer for the design of measures for control of external noise.

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ANNEX E

(*Clause* 3.5)

INTEGRATION OF NOISE BARRIERS AND NOISE ABATEMENT MEASURES IN ZONAL AND URBAN PLANNING

E-1 APPLICABILITY

E-1.1 These provisions establish requirements for incorporating noise barriers and noise abatement measures in the preparation of zonal plans to control noise pollution in urban and semi-urban areas.

E-1.2 The provisions apply to all zonal plans developed by municipal corporations, urban development authorities, and town planning bodies.

E-2 IDENTIFICATION AND SEGREGATION OF ZONES

E-2.1 Noise-Sensitive Zones (NSZs)

Zonal plans should identify noise-sensitive zones that include residential areas, educational institutions, healthcare facilities, and public parks, among others.

E-2.2 Noise-Generating Zones (NGZs)

Zonal plans should also identify noise-generating zones that include industrial areas, major transportation corridors, commercial zones, and recreational spaces prone to high noise levels.

E-2.3 Buffer Zones

Buffer zones should be established between NSZs and NGZs to minimize noise impacts. Buffer zones may include green belts, mixed-use developments, or other suitable land uses. The width and nature of buffer zones should be defined based on local conditions and practical feasibility.

E-3 NOISE BARRIERS

E-3.1 Requirement for Noise Barriers

Noise barriers should be required along major transportation corridors, such as highways and railway lines, adjacent to NSZs. The need for noise barriers should be determined based on the predicted noise levels and potential impact on NSZs.

E-3.2 Design criteria for noise barriers may be as per Annex F.

E-3.3 Placement of Noise Barriers

Noise barriers should be placed as close as possible to the noise source or the boundary of NSZs to maximize effectiveness.

E-4 NOISE ABATEMENT MEASURES IN ZONAL PLANS

E-4.1 Noise Mapping and Assessment

Zonal plans should include noise mapping to identify areas with high noise levels and predict future noise impacts based on planned developments.

E-4.2 Green Belts and Vegetative Buffers

Zonal plans should integrate green belts and vegetative buffers as supplementary noise reduction measures wherever feasible. These green belts should consist of dense rows of trees or shrubs and should be positioned strategically to serve as natural sound barriers.

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E-4.3 Building Design Considerations

For buildings located in or near NGZs, zonal plans should encourage the use of noise-reducing building materials and construction techniques, such as double-glazed windows, soundproofing walls, and appropriate building orientation. For detailed information on noise reduction for town planning schemes, reference may be made to good practice [D-4(2)].

E-5 REGULATION OF NOISE EMISSION SOURCES

E-5.1 Construction Noise Control

Zonal plans should specify noise control measures for construction sites, including the use of low-noise equipment, temporary barriers, and restricted working hours in NSZs.

E-5.2 Industrial and Commercial Noise Control

Zonal plans should regulate emissions to ensure that industries and commercial establishments comply with noise limits, monitored periodically for compliance.

E-6 MONITORING AND COMPLIANCE

E-6.1 Noise Monitoring Provisions

Zonal plans should include provisions for noise monitoring to assess compliance with noise standards. Monitoring stations should be established in key locations within each zone to regularly measure noise levels.

E-6.2 Review and Enforcement

Zonal plans should be reviewed periodically to ensure the effectiveness of noise abatement measures. Non-compliance with noise regulations should result in penalties, including fines or mandatory implementation of additional noise control measures as per local regulations.

E-7 COMMUNITY ENGAGEMENT AND PUBLIC AWARENESS

E-7.1 Public Consultation

The preparation of zonal plans should involve public consultation to incorporate community concerns related to noise pollution and to inform stakeholders about proposed noise abatement measures.

E-7.2 Awareness Programs

Zonal plans should include provisions for public awareness programs to educate residents and businesses on noise pollution control practices and compliance requirements.

ANNEX F

(*Clauses* 3.8.7, 14.4.3, 15 *and* E-3.2)

DESIGN REQUIREMENTS AND PERFORMANCE EVALUATION OF NOISE BARRIERS

F-1 DESIGN AND GEOMETRY REQUIREMENTS

F-1.1 The barrier should be built as close as possible to either the source or receiver. Noise barriers should be tall enough and long enough to avoid degradations in barrier performance.

F-1.2 Barriers do not necessarily have to be of constant height as varying the height of the barrier may also help to alleviate the monotonous appearance of long length of barriers.

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F-1.3 The 'line of sight' between the source and receiver should be cut off completely by the barrier. Barrier design also plays a major role where effective noise barriers should be high and long enough to break the line-of-sight between the sound source and the receiver.

F-1.4 Capped barriers of same height as conventional barriers may offer greater noise reductions than conventional barriers. A specified noise reduction may be achieved by a capped barrier of lower height than a conventional barrier. If high quality absorptive materials are available, the relative screening performance of cylinder-profile and mushroom-profile caps can be improved by up to 8 dBA relative to a plane screen of the same overall height. T-profile caps exhibit similar improvement when the uppermost surfaces are treated with the same absorptive materials. Double cylinder-profile caps are comparatively more efficient than single cylinder-profile caps. When absorptive, these provide equivalent average screening performance to T-profile configurations with the same overall height. A 3 m high T-shaped barrier provides the same performance as a 10 m high plain barrier.

F-2 MATERIALS AND CONSTRUCTION

F-2.1 Barriers should be constructed using solid, non-porous materials having minimum density of 20 kg/m^2.

F-2.2 The materials used for fabrication of noise barriers include

a) Steel (painted, galvanized, stainless);

b) Aluminium;

c) Plastics or polymer sheet concrete;

d) Brick or glass fibre reinforced concrete (GFRC);

e) Proprietary-made acoustic panels; and

f) Landscaped earth berms.

F-2.3 Sound absorbing material may be applied on the source side of the barrier to reduce the build-up of sound pressure level. An absorptive treatment may be appropriate to reduce the impact of reflected noise.

F-3 DESIGN MORPHOLOGY AND ADDITIONAL CONSIDERATIONS

F-3.1 Strategic planting may be considered to reduce the monotonous appearance of long length of barriers. The design morphology for noise barriers is shown in Fig. 6.

F-3.2 The height of a noise barrier is directly proportional to its noise reduction capacity, wherein higher barriers result in greater levels of noise reduction.

F-3.3 The insertion loss for barriers of heights between 3 m to 6 m typically ranges between 5 dB to 12 dB.

F-3.4 Barriers with a thickness exceeding 3 m shall be classified as thick barriers.

F-3.5 Noise barriers may become part of the surrounding landscape over time and can have potential impacts on ecosystems, road users, and residents living alongside the road. The loss of sunlight and visual impact should also be considered while designing the noise barriers.

F-3.6 Special attention should be given to the selection of materials used in the construction of noise barriers, particularly in areas experiencing extreme weather conditions.

F-3.7 The design of noise barriers should ensure minimal maintenance, except for routine cleaning or repairs due to damage, over the intended lifespan.

F-3.8 The Insertion loss can be estimated by using the Kurze and Anderson model given by the following equation:

a) $IL = 5dB + 20log\left(\frac{\sqrt{2\pi N}}{tanh\sqrt{2\pi N}}\right) dB\ upto\ N = 12.5$

b) IL = 20 dB for $N > 12.5$, N is the Fresnel number

Maekawa's curve is one of the most established methods for predicting the insertion loss behind the barriers.

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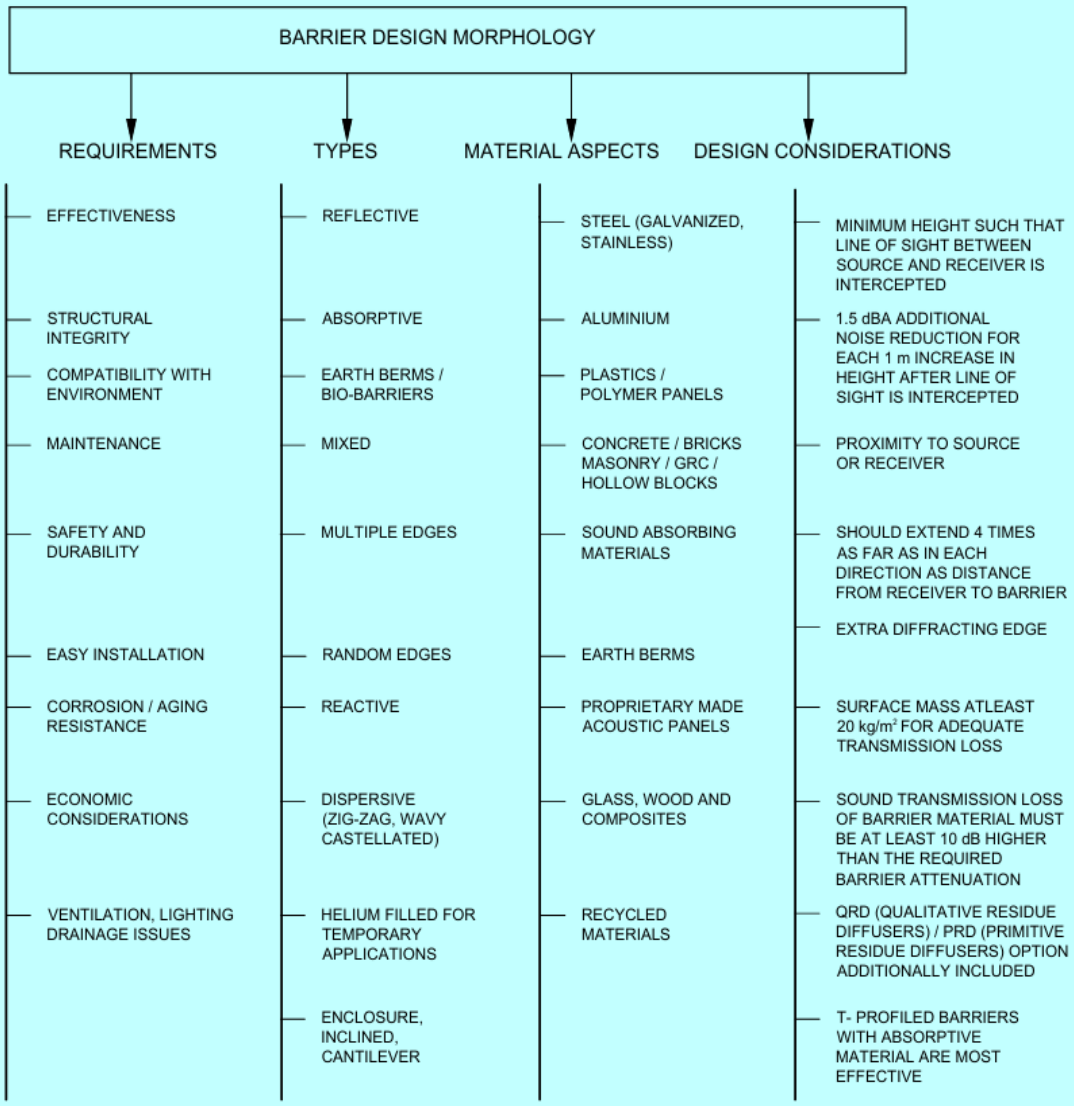

FIG. 6 DESIGN MORPHOLOGY FOR NOISE BARRIERS

F-4 PERFORMANCE EVALUATION OF NOISE BARRIERS

F-4.1 To ensure the effectiveness of a noise barrier, thorough testing should be conducted to verify its performance. The intrinsic acoustic properties of the noise barriers are tested as follows.

F-4.1.1 *Diffuse Sound Field Method for Testing Sound Absorption*

This method is based on the change of reverberation time inside a reverberation chamber after installing a noise barrier testing sample at the room's surface. This testing method is characterized by a single-number rating of the sound absorption evaluation $DL_{\alpha,\,NRD}$, which is described by the following equation:

$$DL_{\alpha,\,\mathrm{NRD}} = -10\log_{10}\left[1 - \frac{\sum_{i=1}^{18} \alpha_{\mathrm{NRD,i}} 10^{0.1L_i}}{\sum_{i=1}^{18} 10^{0.1L_i}}\right]$$

where, α_{NRD} is the absorptance of the test sample and L_i is the relative A-weighted sound pressure levels (dB) of the normalized traffic noise spectrum. The classification of $DL_{\alpha,\,\mathrm{NRD}}$ shall be done on the basis of Table 14.

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Table 14 Categories of the Absorptive Performance

(*Clause* F-4.1.1)

Sl No.	Category	$DL_{\alpha,\ NRD}$
(1)	(2)	(3)
i)	A0	Not determined
ii)	A1	< 4
iii)	A2	4 to 7
iv)	A3	8 to 11
v)	A4	12 to 15
vi)	A5	> 15

The value of $DL_{\alpha,\ NRD}$ ranges from 0 to 20. $DL_{\alpha,\ NRD}$ value greater than 8 is required for most highway projects. Close 'corridors', high barriers (> 3 m), and reverberant locations require noise barriers with $DL_{\alpha,\ NRD}$ greater than 12. Figure 7 represents the normalized traffic spectrum in one-third octave band. The spectra is normalized to an overall value of 0 dB as its shape is more important rather than the absolute value.

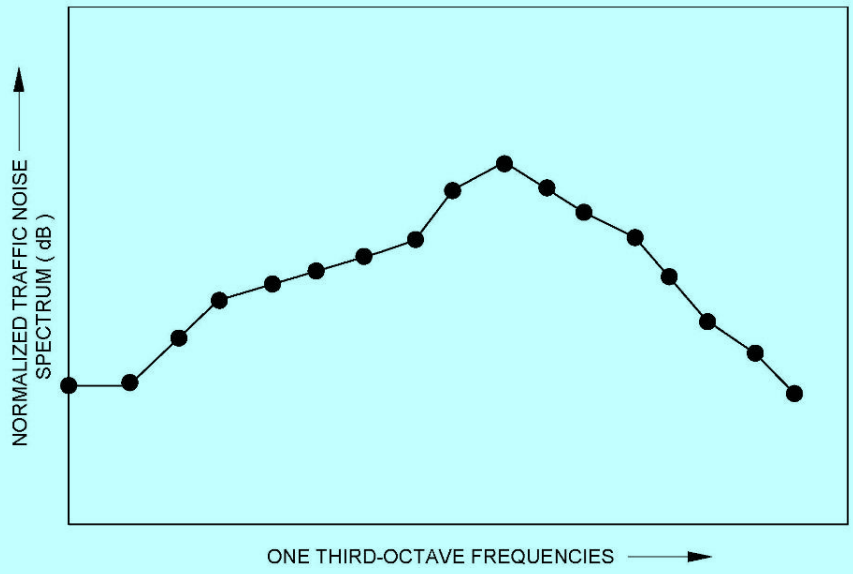

FIG. 7 NORMALIZED TRAFFIC NOISE SPECTRUM (IN DB) AT ONE THIRD OCTAVE FREQUENCY BAND

F-4.1.2 *Diffuse Sound Field Method for Testing Airborne Sound Insulation*

In this method, the noise barrier testing sample is inserted in an opening between two adjacent reverberation rooms, the 'source room' and the 'receiving room'. This testing method is characterized by a single number rating, DL_R for summarizing the airborne sound insulation in third-octave bands and can be given by:

$$DL_R = -10\log_{10}\left[\frac{\sum_{i=1}^{18} 10^{0.1L_i}\, 10^{-0.1R_i}}{\sum_{i=1}^{18} 10^{0.1L_i}}\right]$$

where, R is the airborne sound insulation of the test specimen. Table 15 represents the classification of DL_R.

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Table 15 Categories of the Airborne Sound Insulation Performance

(*Clause* F-4.1.2)

Sl No.	Category	DL_R
(1)	(2)	(3)
i)	B0	Not determined
ii)	B1	= < 15
iii)	B2	15 to 24
iv)	B3	= > 24

B3 is required for the majority of highway developments. B2 may be acceptable for low barriers (less than 2 m), however, the rating level of at least 20 dB is required.

F-4.1.3 *Direct Sound Field Method for Testing Sound Reflection*

This method is based on a comparison between the sound energy reflected from the noise barrier and the sound energy emitted towards it. The third-octave band values are then averaged and weighted according to the standardized traffic noise spectrum L_i, to get a single number rating for the NRD, DL_{RI} as:

$$DL_{RI} = -10\log_{10}\left[\frac{\sum_{i=1}^{18} RI_i 10^{0.1L_i}}{\sum_{i=1}^{18} 10^{0.1L_i}}\right]$$

where, RI_i is the reflectance in i-th third-octave bands

F-4.1.4 *Direct Sound Field Method for Testing Airborne Sound Insulation*

This testing method is based on a comparison between the sound energy arriving at the microphone positions with and without the noise barrier. This testing method is characterized by a single number rating, DL_{SI}. The single-number rating by a weighted average with the standardized traffic noise spectrum L_i is described by:

$$DL_{SI} = -10\log_{10}\left[\frac{\sum_{i=1}^{18} 10^{0.1L_i}\, 10^{-0.1SI_i}}{\sum_{i=1}^{18} 10^{0.1L_i}}\right]$$

F-4.2 These single-number ratings can be used for the performance evaluation of noise barriers or noise reducing devices. The *in-situ* method is comparatively more reliable and yields more realistic values than the laboratory method and additionally facilitates fault detection and ascertains the acoustic durability of the NRD.

ANNEX G

(*Clauses* 3.9 *and* 4.5)

SPECIAL PROBLEMS REQUIRING EXPERT ADVICE

G-1 GENERAL

Certain design problems require reliable advice of a kind which is not easy to find in published material. The advice of an expert should be sought for these kinds of problems, some examples of which are given in **G-2** to **G-9**.

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G-2 ACOUSTIC TEST ROOMS

The design of rooms in which acoustic measurements are carried out, such as reverberation chambers, free-field anechoic rooms and audiometric test rooms, usually requires the advice of an expert.

G-3 PERFORMING SPACES

The design of theatres, opera houses, concert halls and similar performing spaces usually requires expertise in room acoustics and noise control. The intrusion of quite low levels of noise may seriously interfere with the enjoyment of the performance and distract the performers. The requirements for low noise levels often mean that more room has to be allocated for low velocity ventilation ductwork and the impact on the design of the ventilation system is often substantial.

G-4 BROADCASTING AND RECORDING STUDIOS

Broadcasting and recording studios have requirements similar to those of performing spaces. For some infrequent intrusive noises, the requirements are sometimes relaxed on the grounds that a retake of a recording can be done, but this can result in higher operating costs.

G-5 AIRCRAFT NOISE

As there are many variables affecting the level of aircraft noise heard on the ground, expert advice is almost always required. Contours of daytime $L_{Aeq,T}$ levels are available from most major airports. Where measurements of façade insulation are necessary a standard test method may be referred.

G-6 GROUND-BORNE NOISE

Projects involving ground-borne noise from underground trains usually require expert advice.

G-7 LOW-FREQUENCY NOISE

Projects involving low-frequency noise usually require expert advice as accurate measurement is difficult and there is a shortage of reliable data below 100 Hz.

G-8 ACTIVE NOISE CONTROL

Active noise control is the reduction of noise by cancellation with a similar noise (anti-noise) generated by electro-acoustic means. The technique is still under development, but commercial systems are available which successfully reduce low frequency noise from mechanical ventilation systems.

G-9 NOISE SURVEYS

Noise surveys are carried out for a variety of reasons, for example:

a) Before construction, to establish the existing noise climate at the site of a proposed development where reliable prediction is impracticable, as an aid to the design of the building envelope, either to protect against external noise or contain internally produced noise;

b) During construction, to monitor noise from building activity, either to assess the likely nuisance to the local community or the risk of hearing damage to the work force;

c) At the end of a building contract to check the insulation of the building envelope, or the noise levels produced by the services;

d) As part of a planning requirement; and

e) To provide objective evidence to support or defend a legal action.

The expense of carrying out a comprehensive noise survey of any kind is likely to be high, so the cost-effectiveness of a full or partial survey should be weighed against alternatives such as prediction. A survey will generally be more accurate and can take account of factors such as prevailing wind conditions.

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ANNEX H

(*Clause* 4.4)

AIRBORNE AND IMPACT SOUND INSULATION

H-1 GENERAL

Airborne sound refers to sources which produce sound by directly setting the air around them into vibration. Impact sound refers to sources which produce sound by impulsive mechanical excitation of part of a building (for example by footsteps, electric light switches, slamming doors). Many sources of impact sound also produce significant levels of airborne sound. The term structure-borne sound has no very precise meaning as the structure can be excited by both airborne and impact sources; it is often used to refer to sound that travels for long distances *via* the structure, especially in connection with vibrating machinery linked directly to the structure.

H-2 DIRECT AND INDIRECT TRANSMISSION

Figure 8 shows diagrammatically a pair of rooms in a house where the construction consists of solid walls, etc, bonded together. Sound travelling from room 1 to room 2 may travel *via* the direct path a-a and by the many indirect, or flanking, paths shown. The term flanking transmission is usually used to mean transmission paths involving the structure, while the term indirect transmission includes flanking paths and airborne paths through gaps and ducts, etc. The indirect paths may limit the sound insulation attainable no matter how much the direct sound is reduced by the separating wall or floor. The indirect transmission can be reduced by measures such as the following:

a) Increasing the mass of the flanking walls;

b) Increasing the mass of the partition and bonding it to the flanking walls;

c) Introducing discontinuities in the indirect paths;

d) Erecting independent wall linings adjacent to the flanking walls to prevent energy entering the flanking construction; and

e) Sealing any air gaps and paths through ducts.

Figure 9 shows a number of indirect paths that have been found in offices.

It is important to remember that standard test laboratories are designed to minimise transmission by all paths other than the direct path. This makes it difficult to relate the results of laboratory measurements to those likely to be obtained in the field.

H-3 AIRBORNE SOUND INSULATION

H-3.1 General

The sound insulation of structural elements such as walls and floors always varies with frequency, the insulation rising in general as the frequency rises.

H-3.2 Terminology

Results from field measurements are usually expressed in terms of the weighted standardized level difference, while laboratory measurements are usually expressed in terms of the sound reduction index. In the absence of significant flanking transmission, the numerical difference between the weighted standardized level difference and the sound reduction index of a wall or floor is usually small for furnished rooms in dwellings, and so either quantity may be used in considering principles; for this purpose, it is, therefore, convenient to use the general term insulation.

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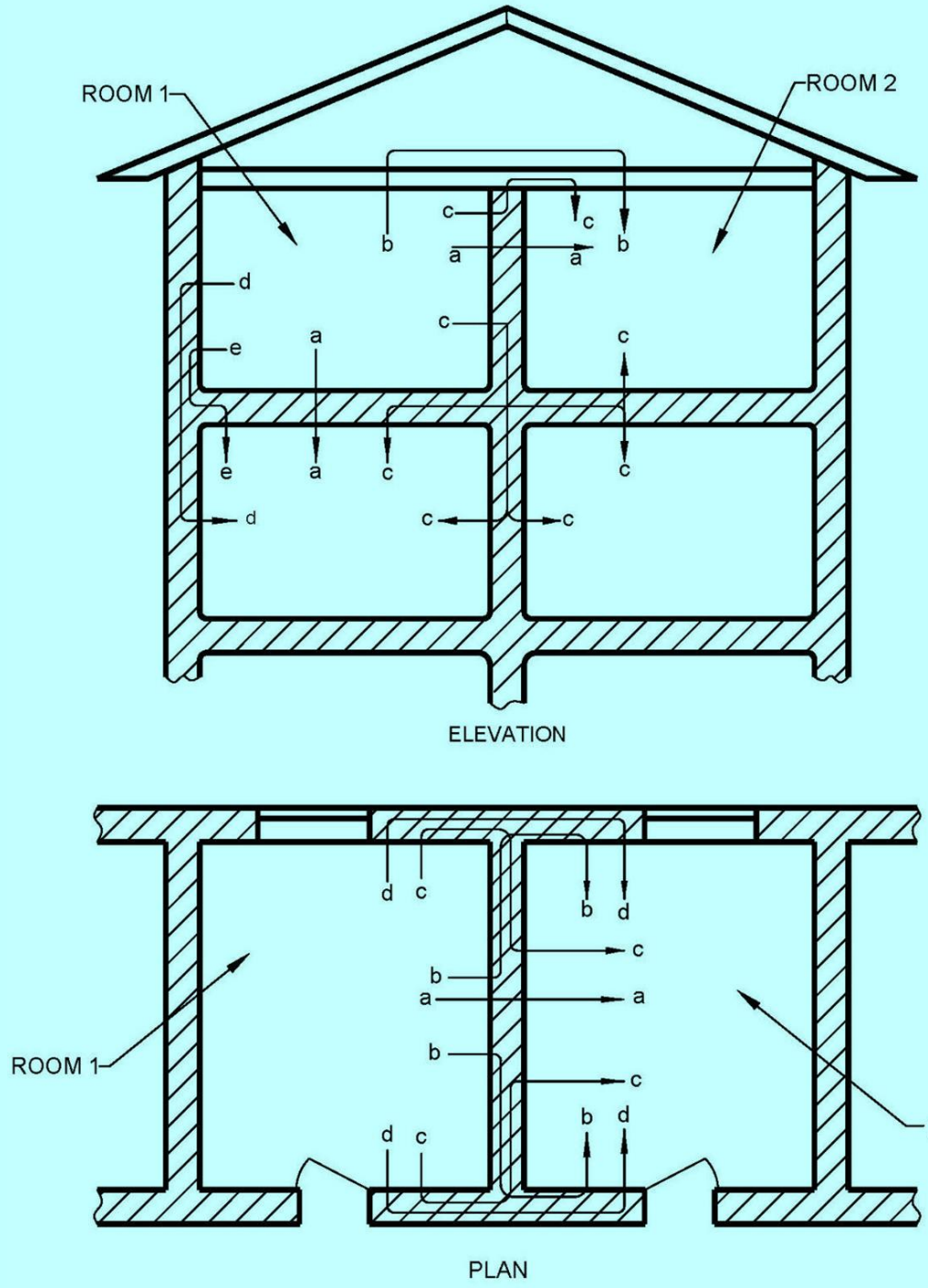

FIG. 8 TRANSMISSION PATHS (VIA THE STRUCTURE) OF NOISE ORIGINATING IN ROOM 1 (DIAGRAMMATIC)

H-3.3 Mass Law

An approximate empirical relationship has been established between sound insulation and mass for single leaf constructions as shown in Fig. 10. This so called 'Mass Law' gives a useful first approximation to the behaviour of a single sheet or plate. In practice, the sound insulation predicted by the mass law may not be attained because of factors such as the coincidence effect, which is outlined in **H-3.4**. Results for specific materials vary around the value given by the Mass Law relationship, and so measured data should be used when available.

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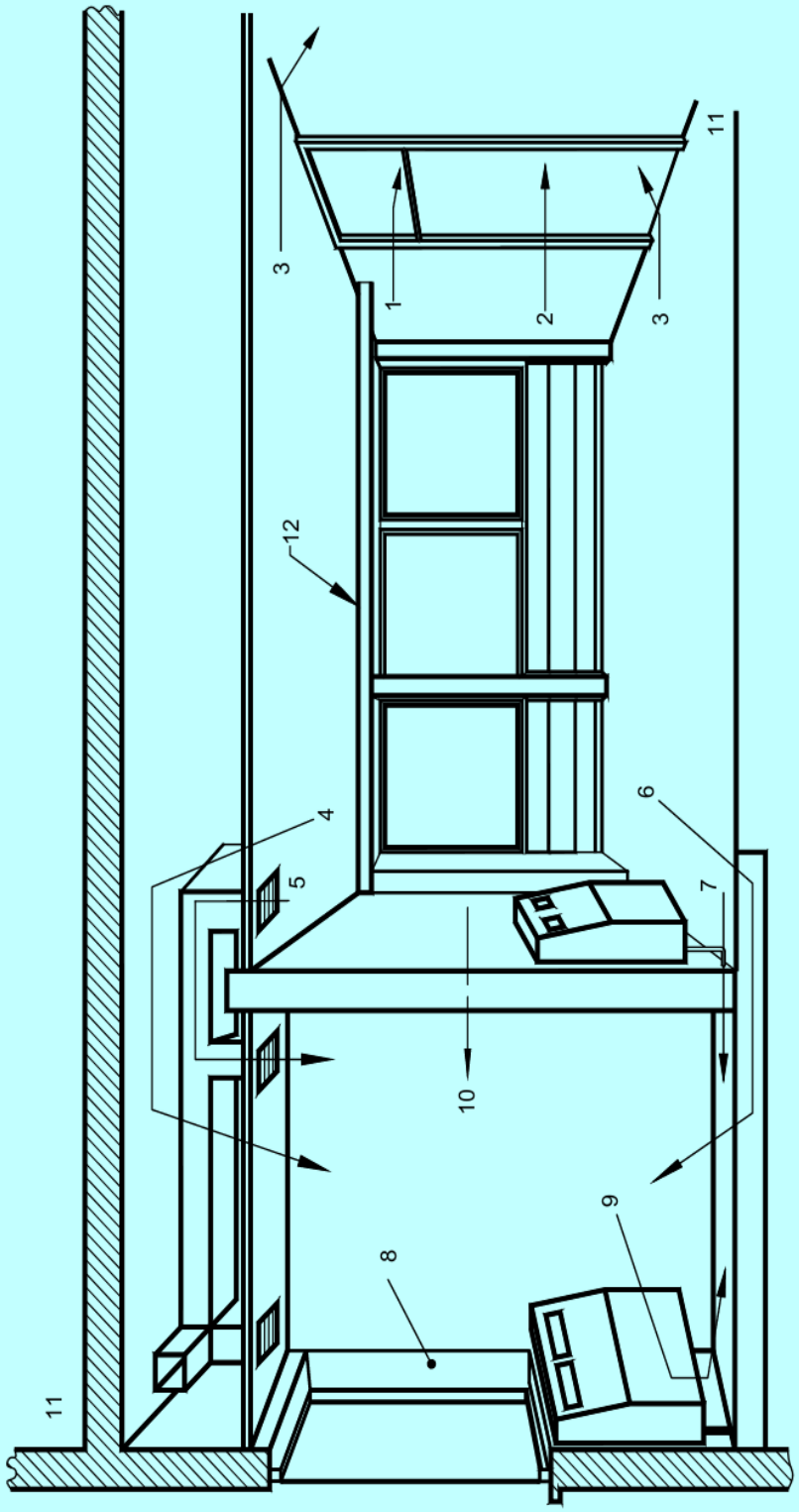

FIG. 9 INDIRECT SOUND LEAKAGE PATHS

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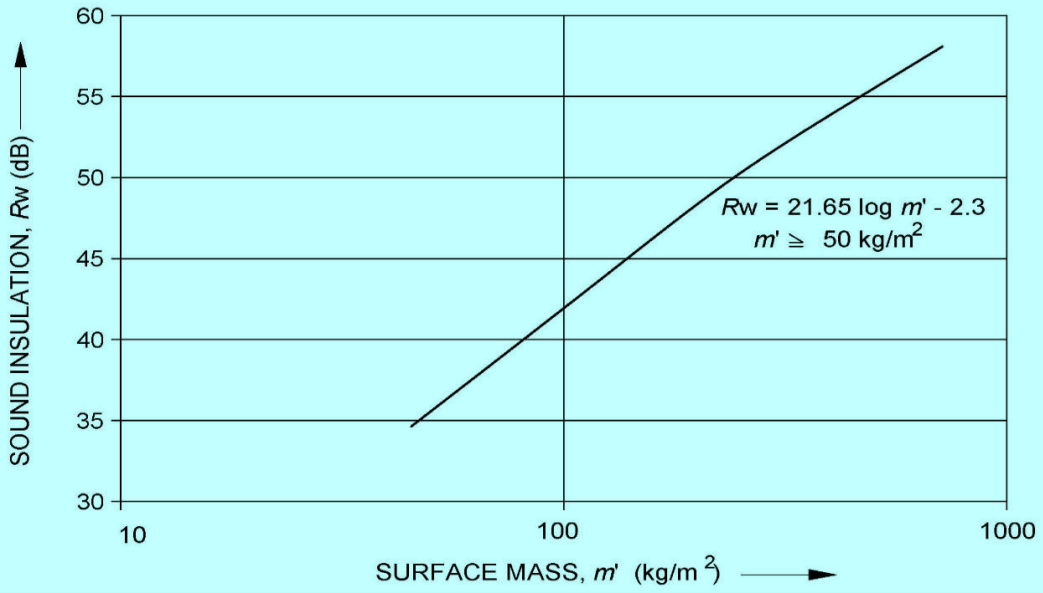

FIG. 10 MASS LAW CURVE

H-3.4 Coincidence Effect

The coincidence effect occurs when the wavelength of the wave impressed on the panel by the incident sound wave is close to the wavelength of free bending waves in the panel. The effect of coincidence is to lower the sound insulation of a construction by as much as 10 dB below the level expected from its mass per unit area over a limited frequency range. The coincidence effect can be pronounced with thin light weight partitions, resulting in loss of insulation at middle and high frequencies. Reducing the stiffness without a corresponding reduction of mass can raise the critical frequency above 3 150 Hz, and so improve the insulation over the important 100 Hz to 3 150 Hz range. An increase of stiffness will have the reverse effect.

It is possible to design lightweight stud partitions so that they perform to their maximum effect in the speech frequency region between 250 Hz and 2 000 Hz, that is between the mass-spring-mass and coincidence regions respectively.

The worst coincidence dips occur in materials such as plate glass and rigid metal sheets. Heavily damped materials such as lead sheets are least affected.

H-3.5 Mass-Spring-Mass Frequency

A double leaf wall can perform better than a single leaf wall of similar mass because the sound has to pass through two barriers. If the two leaves are not connected to each other, the insulation values of the two leaves may be added together. However, in practice the leaves are often connected by ties or studs, and the full insulation cannot be achieved. Even where the two leaves are isolated from each other, the full benefit can only be obtained above a certain frequency that depends on the cavity width. This is because the air in the cavity behaves like a spring connecting the leaves together, and causes a resonance at the mass-spring-mass frequency. Below this frequency, the two leaves behave more like an equivalent single leaf.

Making the cavity width wide can reduce the mass-spring-mass frequency, as in the case of sound insulating secondary glazing. The mass-spring-mass frequency (F_0) may be estimated from the following equation:

$$F_0 = 59.6 \sqrt{\frac{1}{d}\left(\frac{1}{m_1}+\frac{1}{m_2}\right)}$$

where

m_1 and m_2 = surface masses of the two leaves, in kilograms per square metre (kg/m^2); and

d = cavity width, in metres (m).

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H-3.6 Impact Sound Control

A structure that receives an impact or has a vibrating source in contact with it behaves more like an extension of the source rather than an intervening element between source and listener. For this reason, a relatively small amount of impact energy may produce a loud sound and, if the structure is continuous, the sound may travel a long distance. Control is usually obtained by inserting a resilient surface at the point of contact with the source (for example laying a carpet on a floor) or by introducing a structural discontinuity.

Floating floors, which are an example of the latter approach, are a common method of controlling impact sound from footsteps. However, it should be noted that an effective floating floor may result in increased sound from impacts on the source side of the floor.

H-4 AIRBORNE INSULATION VALUES OF WALLS AND AIRBORNE AND IMPACT INSULATION VALUES OF FLOORS

Table 16 and Table 17 give examples of common types of wall and floor construction with sound insulation in the ranges shown. The insulation indices are for field measurements accessed in accordance with good practice [D-4(5)]. The insulation values given are necessarily approximate since examples of nominally identical constructions may show variations of several decibels. All the figures represent values expected in the field, that is, in actual buildings. Many are based directly on field measurements, though other (in the absence of representative field measurements) have been assessed from laboratory data, with an allowance for typical flanking conditions in normal buildings. Variation in the amount of indirect transmission may affect significantly the insulation between two rooms separated by a given barrier. For example, the sound insulation of some types of floor may be reduced by indirect transmission along the walls supporting them, particularly if these walls are of lightweight masonry and carried past the floor.

Table 16 Airborne Sound Insulation of Walls and Partitions

(*Clause* H-4)

Sl No.	Sound Insulation $D_{nT,w}$ dB	Type of Wall or Partition
(1)	(2)	(3)
i)	26 to 33	a) 1 mm steel sheet panels fixed to steel frame members to form demountable partition units 50 mm overall thickness. Mineral wool cavity insulation b) Plywood or wood fibre board 12 mm thick nailed both sides of 50 mm × 50 mm timber framing members spaced at 400 mm centres c) Paper faced strawboard or wood wool 50 mm thick panels plastered both sides d) Chipboard hollow panels 50 mm thick tongued and grooved edges, hardboard faced. Joints covered with wood trim
ii)	33 to 37	a) Lightweight masonry blockwork. Plaster or drylining on at least one side. Overall mass per unit area not less than 50 kg/m^2 b) Laminated plasterboard at least 50 mm thick fixed to timber perimeter framing, any suitable finish. Approximate mass per unit area 35 kg/m^2 c) Timber stud partitions any size timbers greater than 50 mm × 50 mm, 400 mm centres, cross noggins, 9.5 mm plasterboard lining on both sides, any suitable finish d) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 18 kg/m^2 e) 50 mm lightweight masonry blockwork, plastered both sides to 12 mm thickness or drylined with 9.5 mm plasterboard

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Table 16 (*Continued*)

Sl No.	Sound Insulation $D_{nT,w}$ dB	Type of Wall or Partition
(1)	(2)	(3)
iii)	37 to 43	a) Lightweight masonry blockwork, plaster or dry lining on at least one side. Overall mass per unit area not less than 75 kg/m^2 b) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. 25 mm mineral fibre quilt hung between studs. Approximate mass per unit area 18 kg/m^2
iv)	43 to 50	a) Masonry wall, joints well filled. Either plaster or dry lining on both sides. Overall mass per unit area not less than 150 kg/m^2 b) 100 mm metal stud partition, `C' section studs not greater than 600 mm spacing, not less than nominal 50 mm web depth. Clad on both sides with two layers of plasterboard of not less than 25 mm combined thickness. Mineral fibre quilt hung between studs. Approximate mass per unit area 35 kg/m^2 c) 75 mm x 50 mm timbers framing using staged studs at 300 mm spacing with 25 mm stagger forward and back. Frame clad with two layers of 12.5 mm of plasterboard on both sides. Mineral fibre quilt hung between studs. Approximate mass per unit area 36 kg/m^2; d) 50 mm × 25 mm timber stud partition to form a 25 mm cavity, clad on both sides with minimum 38 mm wood wool slabs having their outer faces screeded or plastered; and e) Solid autoclaved aerated concrete block 215 mm thick plaster or dry lined finish on both sides, blockwork joints well filled. Overall mass per unit area not less than 160 kg/m^2
v)	50 to 54	a) Two separate frames of timber studs not less than 89 mm × 38 mm, or boxed metal studwork with 50 mm minimum web depth studs at 600 mm maximum centres. A 25 mm mineral wool quilt suspended between frames. Frames spaced to give a minimum 200 mm overall cavity. Clad on outside of each frame with a minimum of 30 mm plasterboard layers (for example 19 mm plus 12.5 thickness). Approximate mass per unit area 54 kg/m^2 [1)] b) Either in situ or pre-cast concrete wall panel not less than 175 mm thick and not less than 415 kg/m^2. All joints well filled [1)] c) Brick wall nominal 230 mm thickness, weight (including plaster) not less than 380 kg/m^2. Plaster or dry-lined finish both sides. Brick work joints well filled [1)] d) 'No fines' concrete 225 mm thickness, weight (including plaster) not less than 415 kg/m^2. Plaster or dry-lined finish both sides [1)] e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m^3) with 75 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m^2 [1)] f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides.

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Table 16 (*Concluded*)

Sl No.	Sound Insulation $D_{nT,w}$ dB	Type of Wall or Partition
(1)	(2)	(3)
		Joints in block work well filled. Overall mass per unit area not less than 415 kg/m^2 [1)]
		g) Autoclaved aerated concrete block cavity wall consisting of two leaves, 100 mm blocks not less than 75 mm apart, with wall ties of the butterfly type. Plaster or dry line finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 150 kg/m^2 [1)]
vi)	54 to 60	a) Two separate frames of timber studs not less than 100 mm × 50 mm spaced at 600 mm maximum centres. A 50 mm mineral wool quilt in each frame between studs. Frames spaced to give a minimum 300 mm overall cavity. Each frame clad on outside with three layers of 12.5 mm plasterboard nailed to framing. Approximate mass per unit area 51 kg/m^2 [1)] b) Two separate frames of boxed 'C' section galvanized nominal 150 mm steel studs 100 mm apart with a 400 mm overall cavity. 50 mm mineral wool quilt fixed to the back of one frame, each frame clad on outside with three layers of 12.5 mm plasterboard by self drilling or tapping screws. Approximate mass per unit area 47 kg/m^2 [1)] c) Solid masonry with an overall mass per unit area of not less than 700 kg/m^2 fully sealed both sides [1)] d) Dense aggregate concrete block solid wall 215 mm thick plaster finish to both surfaces. Overall mass per unit area not less than 415 kg/m^2 [1)] e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m^3) with 75 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m^2 [1)] Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides Joints in blockwork well filled. Overall mass per unit area not less than 415 kg/m^2 [1)]

NOTES

1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

2 Where plasterboard is specified it is assumed that the surface mass will be at least 6.5 kg/m^2 for 9.5 mm thick board, at least 8.5 kg/m^2 for 12.5 mm thick board, and at least 14.5 kg/m^2 for 19 mm thick board. If less dense plasterboard is used, the thickness should be increased.

[1)] When considering these constructions for separating walls, expert advice should be sought.

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Table 17 Airborne and Impact Sound Insulation of Floor Constructions

(*Clause* H-4)

Sl No.	Sound Insulation dB	Type of Floor Construction
(1)	(2)	(3)
i)	$D_{nT,w}$ = 49 to 54 $L'_{nT,w}$ = 56 to 65	a) A concrete floor having mass per unit area not less than 365 kg/m2, including any screed or ceiling finish directly bonded to the floor slab; together with a floating floor or resilient floor covering equivalent to rubber or sponge rubber underlay or thick cork tile (for example carpet and underlay or sponge rubber backed vinyl flooring) b) A solid floor consisting of: 1) a solid slab; or 2) concrete beams and infilling blocks; or 3) hollow concrete planks; together with a floating floor. A ceiling finish is required for a beam and block floor. In each case the slab should have a mass per unit area of at least 300 kg/m^2, including any screed or ceiling finish directly bonded to it Where a floating floor is laid over a floor of beams and hollow infill blocks or hollow beams along the top of the structural floor, it should be sealed and levelled before the resilient layer is put down. It is also essential to have due regard for conduits and pipework which should be laid and covered so as to prevent any short circuit of the floor's isolating properties If precast units are used as a structural floor, it is essential that the joints are filled to ensure that the sound insulation performance is maintained The resilient material is laid to cover completely the structural floor and turned up against the surrounding wall along all edges. The resilient layer is usually of mineral fibre, or a special grade of expanded polystyrene. When the screed is laid, it is important that none of the mix finds its way through the resilient layer to the structural floor, as this will short circuit the isolation between the two decks and significantly reduce the sound insulation A floor consisting of boarding nailed to battens laid to float upon an isolating layer of mineral fibre capable of retaining its resilience under imposed loading. With battens running along the joists, a dense fibre layer can be used in strips. The ceiling below to be of metal lath and plaster not less than 29 mm thick, with pugging on the ceiling such that the combined mass per unit area of the floor, ceiling and pugging is not less than 120 kg/m^2. This construction will only give values for $D_{nT,w}$ of 50 dB to 53 dB, and a value for $L'_{nT,w}$ of 75 dB c) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard laid on battens running parallel to the joists and supported on 25 mm thick mineral wool of about 90 kg/m^3 to 140 kg/m^3 density; 100 mm of fibre

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Table 17 (*Concluded*)

Sl No.	Sound Insulation dB	Type of Floor Construction
(1)	(2)	(3)
		absorbent (as used for insulation in roof spaces) laid between the joists on top of the plasterboard ceiling [1)]
		d) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard floating on a 25 mm thick mineral wool layer of about 60 kg/m^3 to 80 kg/m^3 density; this on a 12.5 mm plywood platform; 100 mm of fibre absorbent laid between the joists on top of the plasterboard ceiling [1)]; and
ii)	$D_{nT,w}$ = 32 to 36 $L'_{nT,w}$ = 80 to 85	Timber joist floor consisting of 22 mm tongued and grooved floor boarding or equivalent fixed directly to floor joists. Ceiling of 12.5 mm plasterboard and skim with no floor covering

NOTES

1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

2 Where plasterboard is specified it is assumed that the surface mass will be at least 8.5 kg/m^3 for 12.5 mm thick board, and at least 14.5 kg/m^2 for 19 mm thick board. If less dense plasterboard is used, the thickness should be increased.

[1)] In these types of floor construction, the ceiling may be 19 mm plus 12.5 mm plasterboard. It is imperative that the resilient layer is not punctured by nails.

In many cases, simple solid partitions give insulation values according to their mass (*see* **H-3.3**). Moreover, with partitions of this type there is usually little variation between field and laboratory test results unless the laboratory insulation exceeds 45 dB. Exceptions may occur in buildings that have not been specially designed to minimise common cavities and strongly coupled elements in lightweight panelling. The examples given are not exhaustive. Flanking structures are not listed since these can vary widely and are often dependent upon other factors such as thermal insulation, which are outside the scope of this NBCS.

ANNEX J

(*Clause* 13.1)

BASIC DESIGN TECHNIQUES FOR NOISE CONTROL IN AIR CONDITIONING, HEATING AND MECHANICAL VENTILATION SYSTEM

J-1 When selecting fans and other related mechanical equipment and when designing air distribution systems to minimise the sound transmitted from different components to the occupied spaces that they serve, the following recommendations should be considered:

a) Design the air distribution system to minimise flow resistance and turbulence. High flow resistance increases the required fan pressure, which results in higher noise being generated by the fan. Turbulence increases the flow noise generated by duct fittings and dampers in the air distribution system, especially at low frequencies;

b) Select a fan to operate as near as possible to its rated peak efficiency when handling the required quantity of air and static pressure. Also, select a fan that generates the lowest possible noise but still meets the required design conditions for which it is selected. Using an oversized or undersized fan that does not operate at or near rated peak efficiency may result in substantially higher noise levels;

c) Design duct connections at both the fan inlet and outlet for uniform and straight air flow. Failure to do this may result in severe turbulence at the fan inlet and outlet and in flow separation at the fan blades. Both of these may significantly increase the noise generated by the fan;

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d) Select duct silencers that do not significantly increase the required fan total static pressure;

e) Place fan-powered mixing boxes associated with variable volume air distribution systems away from noise-sensitive areas;

f) Minimise flow-generated noise by elbows or duct branch take-offs, whenever possible, by locating them at least four to five duct diameters from each other. For high velocity systems, it may be necessary to increase this distance to up to ten duct diameters in critical noise areas;

g) Keep airflow velocity in the duct as low as possible (7.5 m/s or less) near critical noise areas by expanding the duct cross-section area. However, do not exceed an included expansion angle of greater than 15°. Flow separation, resulting from expansion angles greater than 15°, may produce rumble noise. Expanding the duct cross-section area will reduce potential flow noise associated with turbulence in these areas;

h) Use turning vanes in large 90° rectangular elbows and branch take-offs. This provides a smoother transmission in which the air can change flow direction, thus reducing turbulence;

j) Place grilles, diffusers and registers into occupied spaces as far as possible from elbows and branch take-offs;

k) Minimise the use of volume dampers near grills, diffusers and registers in acoustically critical situations;

m) Vibration isolates all vibrating reciprocating and rotating equipment if mechanical equipment is located on upper floors or is roof-mounted. Also, it is usually necessary to vibration isolate the mechanical equipment that is located in the basement of a building as well as piping supported from the ceiling slab of a basement, directly below tenant space. It may be necessary to use flexible piping connectors and flexible electrical conduit between rotating or reciprocating equipment and pipes and ducts that are connected to the equipment;

n) Vibration isolates ducts and pipes, using spring and/or neoprene hangers for at least the first 15 m from the vibration-isolated equipment;

p) Use barriers near outdoor equipment when noise associated with the equipment will disturb adjacent properties if barriers are not used. In normal practice, barriers typically produce no more than 15 dB of sound attenuation in the mid-frequency range; and

q) Table 18 lists several common sound sources associated with mechanical equipment noise. Anticipated sound transmission paths and recommended noise reduction methods are also listed in the Table 19. Airborne and/or structure-borne sound can follow any or all of the transmission paths associated with a specified sound source.

Table 18 Sound Sources, Transmission Paths and Recommended Noise Reduction Methods

[*Clause* J-1(q)]

Sl No.	Sound Source	Path No. (*see* Table 19)
(1)	(2)	(3)
i)	Circulating fans, grilles, registers, diffusers, unitary equipment in room	1
ii)	Induction coil and fan-powered VAV mixing units	1, 2
iii)	Unitary equipment located outside of room served; remotely located air-handling equipment, such as fans, blowers, dampers, duct fitting, and air washers	2, 3

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Table 18 (*Concluded*)

Sl No.	Sound Source	Path No. (*see* Table 19)
(1)	(2)	(3)
iv)	Compressors, pumps, and other reciprocating and rotating equipment (excluding air-handling equipment)	4, 5, 6
v)	Cooling towers; air-cooled condensers	4, 5, 6, 7
vi)	Exhaust fans; window air conditioners	7, 8
vii)	Sound transmission between rooms	9, 10

Table 19 Sound Transmission Paths and Recommended Noise Reduction Methods

[*Clause* J-1(q) *and* Table 18]

Sl No.	Path No.	Transmission Paths	Noise Reduction Methods
(1)	(2)	(3)	(4)
i)	1	Direct sound radiated from sound sources to ear Reflected sound from walls, ceiling and floor	Direct sound can be controlled only by selecting quiet equipment Reflected sound is controlled by adding sound absorption to the room and to equipment location
ii)	2	Air and structure-borne sound radiated from casings and through walls of ducts and plenums is transmitted through walls and ceiling into rooms	Design duct and fittings for low turbulence; locate high velocity ducts in noncritical areas; isolate ducts and sound plenums from structure with neoprene or spring hangers
iii)	3	Airborne sound radiated through supply and return air ducts to diffusers in room and then to listener by Path 1	Select fans for minimum sound power; use ducts lined with sound-absorbing material; use duct silencers or sound plenums in supply and return air ducts
iv)	4	Noise transmitted through equipment room walls and floors to adjacent rooms	Locate equipment rooms away from critical areas; use masonry blocks or concrete for equipment room walls and floor
v)	5	Vibration transmitted via building structure to adjacent walls and ceilings, from which it radiates as noise into room by Path 1	Mount all machines on properly designed vibration isolators; design mechanical equipment room for dynamic loads; balance rotating and reciprocating equipment

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Table 19 (*Concluded*)

Sl No.	Path No.	Transmission Paths	Noise Reduction Methods
(1)	(2)	(3)	(4)
vi)	6	Vibration transmission along pipes and duct walls	Isolate pipe and ducts from structure with neoprene or spring hangers; install flexible connectors between pipes, ducts, and vibrating machines
vii)	7	Noise radiated to outside enters room windows	Locate equipment away from critical areas; use barriers and covers to interrupt noise paths; select quiet equipment
vii)	8	Inside noise follows Path 1	Select quiet equipment
ix)	9	Noise transmitted to an air diffusers in a room, into a duct, and out through an air diffuser in another room	Design and install duct attenuation to match transmission loss of wall between rooms
x)	10	Sound transmission through, over, and around room partition	Extend partition to ceiling slab and tightly seal all around; seal all pipe, conduit, duct and other partition penetrations

J-2 Room Criteria (RC)

Room Criteria (RC) is the rating methodology specifically intended for rating the heating ventilation and air-conditioning system-related noise in buildings and estimate the subjective response of an occupant. The subjective character or quality of the spectrum is determined by a calculation of the Quality Assessment Index (QAI). The QAI is a measure of the degree to which the shape of the spectrum under evaluation deviates from the shape of the RC reference curve.

NOTE — The ASHRAE-developed HVAC noise rating method, RC Mark II rating is a two-dimensional expression, which takes the form, RC xx(yy). The first term, 'xx', is the value of the RC reference curve corresponding to the arithmetic average of the levels in the 500 Hz, 1 000 Hz, and 2 000 Hz octave bands; it is a quantitative descriptor, in the sense that it identifies the level of the spectrum in the principal speech frequency region. The second term, 'yy', is a qualitative descriptor that identifies the character of the sound as perceived by the listener: (N) for neutral, (LF: 16 Hz to 63 Hz) for low-frequency dominant (rumble), (MF: 125 Hz to 500 Hz) for mid-frequency dominant (roar), and (HF: 1 000 Hz to 4 000 Hz) for high-frequency dominant (hiss). There are also two sub-categories of the low-frequency descriptor: (LF_A), denoting a substantial, clearly noticeable degree of sound-induced vibration of room surfaces in lightweight interior building construction, and (LF_B), denoting a moderate, but perceptible degree of sound-induced vibration.

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ANNEX K

(*Clause* 13.2)

SUGGESTED EQUIPMENT NOISE DATA SHEET

K-1 It is recommended that an equipment noise data sheet be furnished to intending bidders of mechanical equipment such as air conditioning, heating and mechanical ventilation machinery or diesel generating units specifying noise requirements at the time of request for quotation. Following is a sample noise data sheet suggested for the purpose:

SAMPLE OF EQUIPMENT NOISE DATA SHEET FOR NOISE SPECIFICATION TO BE SENT TO SUPPLIERS

Equipment Description _____ **Type** _____ **Item No.** _____

Octave-Band Centre Frequency Hz	**Desired Sound Pressure Level,** L_p	**Supplier to Complete**		
		Actual	Special Design	Special Noise Control Measures Recommended
(1)	(2)	(3)	(4)	(5)
63				
125				
250				
500				
1 000				
2 000				
4 000				
8 000				

NOTES

1 The measurements of SPL shall be at a distance of 1.0 m from the equipment and 1.5 m above grade or floor. The measurement method shall be described and the point of maximum levels furnished.

2 Complete column 3 for actual levels of standard equipment.

3 Complete column 4 for special design for low noise (if such alternative is available).

4 Complete column 5 for noise control measures such as enclosure.

5 Indicate if the equipment meets the specified noise levels without modification (Yes/No).

6 If no, additional costs required :

For Column 4 _____

For Column 5 _____

It will be observed from the col (3), col (4) and col (5) that the buyer would get quotation for supply of standard equipment at a price P-1, whose noise characteristics would be as per col (3). Col (4) would indicate acoustical performance for a special design at a price P-2. Col (5) would indicate the acoustical performance if the owners were to provide special noise control measures for the installation (whose broad details and approximate estimated cost is also furnished by the vendor).

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used for conformance with the requirements of the referred clauses in this NBCS. In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	IS 11050	Rating of sound insulation in buildings and of building elements
	(Part 1) : 2023	Airborne sound insulation *(first revision*)
(2)	IS 4954 : 1968	Recommendations for noise abatement in town planning
(3)	IS 2526 : 1963	Code of practice for acoustical design of auditoriums and conference halls
(4)	IS 15575	Electroacoustics — Sound level meters
	(Part 1) : 2016/ IEC 61672-1 : 2013	Specifications (*first revision*)
	IS 15575	Electroacoustics — Sound level meters
	(Part 2) : 2023/ IEC 61672-2 : 2013	Pattern evaluation tests (*second revision*)
(5)	IS 11050	Rating of sound insulation in buildings and of building elements
	(Part 1) : 2023	Airborne sound insulation (*first revision*)
	(Part 2) : 2023	Impact sound insulation (*first revision*)

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 5 INSTALLATION OF LIFTS, ESCALATORS, MOVING WALKS AND POWER-DRIVEN PARKING SYSTEMS

5A LIFTS

BUREAU OF INDIAN STANDARDS

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FOREWORD

This NBCS (Part D/Subsection 5A) deals with the requirements for planning, design, installation, operation, maintenance and inspection of lifts (passenger lifts, goods lifts, hospital lifts, service lifts and dumb waiter) so as to ensure safe movement of people with satisfactory performance in buildings.

This Section was first published in 1970 and was subsequently revised in 1983, 2005 and 2016 as part of National Building Code of India. This Section covers the requirements for installation and maintenance of lifts and escalators in buildings. This Section should be read with Part F ôFire and Life Safetyô of this NBCS from fire safety requirements point of view. The major changes in the first revision of 1983 were addition of outline dimensions of different types of lifts and requirements of escalators in buildings. Emphasis was laid on coordination between the engineer/architect and the lift manufacturer to arrive at the number and position of lifts for attaining optimum efficiency in serving the building with safety.

The significant changes incorporated in the 2005 revision included addition of new clauses/recommendations on building management system; addition of new clauses on firemanôs lift, infrared light curtain safety, and braille button for the visually impaired people and the updation of provisions as per the revised Indian Standards on lifts on which this section was based.

In the 2016 revision, the erstwhile Section 5 on lifts and escalators was divided into two subsections namely:

5A Installation of lifts

5B Installation of escalators and moving walks

The significant changes incorporated in the 2016 revision included the introduction of high-speed lifts and lifts for tall buildings, the use of lifts for fire-fighting and emergency evacuation, machine room less (MRL) lifts, the introduction to destination control system, seismic resistance aspects in lifts, performance measurements for lifts and introduction of new clause on operation and maintenance of lifts.

In this revision, publication has been renamed as National Building Construction Standards (NBCS). As a result of experience gained since the implementation of the 2016 version of this NBCS and feedback received as well as revisions of Indian Standards on which this Section was based, a need was felt to revise this Section.

The significant changes incorporated in this revision (Subsection 5A) include the following:

a) Definitions of various terms relating to energy dissipation and accumulation types, compensation means, hydraulic and electric systems, and safety mechanisms have been included to enhance clarity in performance measurement, seismic considerations, and maintenance aspects of lifts;

b) Additions have been introduced in the planning and design guidelines to address factors such as absenteeism in office buildings, provision of cafeterias and specialty facilities, population considerations for residential and hotel buildings in **4**;

c) Additions have been made in the earthing provisions to elaborate on system earthing methods (TN, TT, IT), their sub-classifications, applications, and the importance of protective equipotential bonding and earth fault protection, in **6.2.3**;

d) Provisions on flood sensors have been introduced for installation in lift pits to enable early detection of water ingress, alarm activation and safe shutdown of lifts, in **8.7**;

e) Provisions of destination control systems (DCS) for call assignments, improving passenger flow and operational efficiency have been included, in **9.11**;

f) Introduction of double-deck lift systems, with two cabins arranged one above the other, optimizing shaft use and improving efficiency in high-traffic areas and for two independent lift cabins in a single shaft solution to address up-peak and inter-floor traffic demands, in **11.7**;

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h) Introduction of passenger evacuation strategies (in **11.8.1** and **11.8.2**) for both independent and joined cabin systems, enhancing safety during emergencies; and

j) Expanded requirements for machine room levels based on lift speed and shaft dimensions.

The information contained in this Section is largely based on the following Indian Standards:

IS No.	*Title*
IS 14665	Electric traction lifts:
(Part 1) : 2000	Guidelines for outline dimensions of passenger, goods, service and hospital lifts
(Part 2/Sections 1) : 2000	Code of practice for installation, operation and maintenance, Section 1 Passenger and goods lifts
(Part 3/Sections 1) : 2000	Safety rules, Section 1 Passenger and goods lifts
(Part 5 : 1999)	Specification ð Inspection manual
IS 14671 : 1999	Code of practice for installation and maintenance of hydraulic lifts
IS 15330 : 2020	Requirements of lifts for persons with disabilities (*first revision*)
IS 15785 : 2007	Installation and maintenance of lift without conventional machine rooms ð Code of practice

Assistance has also been derived from the following publications in preparation of this Subsection:

Other Standards/Other Publication	*Title*
ISO 8100-30 : 2019	Lifts for the transport of persons and goods ð Part 30: Class I, II, III and VI lifts installation
ISO 4190-5 : 2006	Lift (elevator) installation ð Part 5: Control devices, signals and additional fittings
ISO 3008-2 : 2017	Fire-resistance tests ð Part 2: Lift landing door assemblies
ISO 3864-1 : 2011	Graphical symbols ð Safety colours and safety signs ð Part 1: Design principles for safety signs and safety markings
ISO 8100-33:2022	Lifts for the transport of persons and goods Part 33: T-type guide rails for lift cars and counterweights
ISO 18738-1 : 2012	Measurement of ride quality ð Part 1: Lifts (elevators)
ISO/TS 18870 : 2014	Lifts (elevators) ð Requirements for lifts used to assist in building evacuation
EN 81-20 : 2020	Safety rules for the construction and installation of lifts ð Lifts for the transport of persons and goods ð Part 20: Passenger and goods passenger lifts
EN 81-77 : 2022	Safety rules for the construction and installations of lifts ð Particular applications for passenger and goods passenger lifts ð Part 77: Lifts subject to seismic conditions
EN 81-50 : 2020	Safety rules for the construction and installation of lifts ð Examinations and tests ð Part 50: Design rules, calculations, examinations and tests of lift components
CIBSE Guide D: 2015	Transportation Systems in Buildings 2015, The Chartered Institution of Building Services Engineers, London, U.K.

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Other Standards/Other Publication	*Title*
CTBUH 2020	Emergency Evacuation: Elevator Systems Guidelines, Council on Tall Buildings and Urban Habitat, Illinois, USA

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 2022 ôRules for rounding off numerical values (*second revision*)õ. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to ó**good practice**ô in relation to design, constructional procedures or other related information, and where reference is made to '**accepted standard**' in relation to material specification, testing or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [D-5A(1)] refers to the Indian Standard given at serial number (1) of the List of Standards given at the end of this Part D/Subsection 5A, that is, IS 17900 (Part 1) : 2022 ólifts for the transport of persons and goods Part 1: Safety Rulesô

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 5 INSTALLATION OF LIFTS, ESCALATORS, MOVING WALKS AND POWER-DRIVEN PARKING SYSTEMS

5A LIFTS

1 SCOPE

1.1 This NBCS (Part D/Subsection 5A) covers the requirements for planning, design, installation, operation, maintenance and inspection of lifts (passenger lifts, goods lifts, hospital lifts, automobile lifts, service lifts and dumbwaiters) so as to ensure safe movement of people and goods with satisfactory performance.

1.2 This Subsection gives information that should be exchanged among the architect/engineer, the consulting engineer and the lift manufacturer from the stage of planning to installation including maintenance.

NOTE ð The provisions given in this Subsection are primarily for electric traction lifts; however, most of these provisions are also applicable to hydraulic lifts {*see* good practice [D-5A(1)] and [D-5A(2)}.

2 TERMINOLOGY

2.0 For the purpose of this subsection, the following definitions shall apply.

2.1 General Terms Relating to Lifts

2.1.1 *Accessibility* ð Accessibility in the context of this standard is the quality of a building or structure or a lift which enables all people irrespective of their age, gender, or abilities to access it and use its features equally and independently.

2.1.2 *Apron* ð Smooth vertical part extending downwards from the sill of the landing or car entrance.

2.1.3 *Automatic Rescue Device* (*ARD*) ð Device that operates automatically in case of failure or loss of power supply to move the lift car to a nearest landing.

2.1.4 *Automobile Lift* ð A lift designed primarily for the transport of vehicles which may however, carry a lift attendant and/or occupants of the vehicle.

2.1.5 *Available Car Area* ð Area of the car, which is available for passengers or goods during operation of the lift.

2.1.6 *Bottom Car Run-by* ð The distance between the car buffer striker plate and the striking surface of the car buffer when the car is in level with the bottom terminal landing.

2.1.7 *Balancing Weight* ð Mass which saves energy by balancing all or part of the mass of the car.

2.1.8 *Bottom Counterweight Run-by* ð The distance between the counter weight buffer striker plate and the striking surface of the counterweight buffer when the car is in level with the top terminal landing.

2.1.9 *Buffer* ð A device designed to stop a descending car or counter weight beyond its normal limit of travel by storing or by absorbing and dissipating the kinetic energy of the car or counterweight.

The buffer shall be one of the following types:

a) Energy dissipation type; and

b) Energy accumulation type:

   1) Linear type

   2) Non-Linear type

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2.1.9.1 *Energy dissipation type* ð These are usually hydraulic buffer that dissipate the energy of the impact in the form of heat during the travel of the buffer. The hydraulic buffer falls in this category.

These types of buffers may be used whatever may be the rated speed of the lift. For example, oil buffer.

2.1.9.1.1 *Oil buffer stroke* ð The oil displacing movement of the buffer plunger or piston, excluding the travel of the buffer plunger accelerating device.

2.1.9.2 *Energy accumulation type* ð These can take the form of simple mechanical springs or polymer buffers which store the absorbed energy of the impact in the form of strain energy.

Energy accumulation type buffers, with linear and non-linear characteristics, shall only be used if the rated speed of the lift does not exceed 1 m/s.

2.1.9.2.1 *Spring buffer load rating* ð The load required to compress the spring by an amount equal to its stroke.

2.1.9.2.2 *Spring buffer stroke* ð The distance, the contact end of the spring can move under a compressive load until the spring is compressed solid.

2.1.10 *Call Indicator* ð A visual and audible device in the car to indicate to the attendant the lift landings from which calls have been made.

2.1.11 *Car Bodywork* ð The enclosing bodywork of the lift car which comprises the sides and roof and is built upon the car platform.

2.1.12 *Car Door Electric Contact* ð An electric device, the function of which is to prevent operation of the driving machine by the normal operating device of the lift unless the car door is in the closed position.

2.1.13 *Car Frame* ð The supporting frame or sling to which the platform of the lift car, its safety gear, guide shoes and suspension ropes are attached.

2.1.14 *Car Platform* ð The part of the lift car which forms the floor and directly supports the load.

2.1.15 *Control* ð The system governing starting, stopping, direction of motion, acceleration, speed and retardation of moving member.

2.1.15.1 *Variable voltage motor control* (*Generator generator field control*) ð A system of control which is accomplished by the use of an individual generator for each lift wherein the voltage applied to the driving machine motor is adjusted by varying the strength and direction of the generator field.

2.1.15.2 *Electronic control* ð A system of control which is accomplished by the use of electronic devices for driving the lift motor at variable speed.

2.1.15.3 *Alternating current variable voltage* (*ACVV*) *control* ð A system of speed control which is accomplished by varying the driving and braking torque by way of voltage variation of the power supply to the driving machine induction motor.

2.1.15.4 *Alternating current variable voltage variable frequency* (*ACVVVF*) *control* ð A system of speed control that is accomplished by varying the voltage and frequency of the power supply to the driving machine induction motor.

2.1.15.5 *Solid-state d.c. variable voltage control* ð A solid-state system of speed control which is accomplished by varying the voltage and direction of the power supply to the armature of driving machine d.c. motor.

2.1.16 *Counterweight* ð A weight or series of weights to counterbalance the weight of the lift car and part of the rated load.

2.1.17 *Compensation Means* ð Includes all ropes/coated synthetic belts/elastomeric coated ropes/chain to counterbalance suspension means.

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2.1.18 *Deflector Sheave* ð An idler pulley used to change the direction of a rope lead.

2.1.19 *Door* (*Lift Landing Door and Lift Car Door*) — The door located at each floor entrance of the lift shaft, providing access to the lift car. It remains closed when the lift is not present at that level for safety, which opens and closes in synchronization with the car door, ensuring passengers' safe entry and exit.

2.1.19.1 *Door, centre opening sliding* ð A door which slides horizontally and consists of two or more panels which open from the centre and are usually so interconnected that they move simultaneously.

2.1.19.2 *Door, mid-bar collapsible* ð A collapsible door with vertical bars mounted between the normal vertical members.

2.1.19.3 *Door, multi-panel* ð A door arrangement whereby more than one panel is used such that the panels are connected together and can slide over one another by which means the clear opening can be maximized for a given shaft width. Multipanels are used in centre opening and two speed sliding doors.

2.1.19.4 *Door, single slide* ð A single panel door which slides horizontally.

2.1.19.5 *Door, two speed sliding* ð A door which slides horizontally and consists of two panels, one of which moves at twice the speed of the other.

2.1.19.6 *Door, vertical bi-parting* ð A door which slides vertically and consists of two panels or sets of panels that move away from each other to open and are so interconnected that they move simultaneously.

2.1.19.7 *Door, vertical lifting* ð A single panel door, which slides in the same plane vertically up to open.

2.1.19.8 *Door, swing* ð A swinging type single panel door which is opened manually and closed by means of a door closer when released.

2.1.20 *Door Closer* ð A device which automatically closes a manually opened door.

2.1.21 *Door Operator* ð A power-operated device for opening and closing doors.

2.1.22 *Dumb Waiter* ð A lift with a car which moves in guides in a vertical direction; has a net floor area not exceeding 1 m^2, total inside height of 1.2 m, whether or not provided with fixed or removable shelves; has a capacity not exceeding 250 kg and is exclusively used for carrying materials and shall not carry any person.

2.1.23 *Direct Acting Lift* ð Hydraulic lift where the ram or cylinder is directly attached to the car or its sling.

2.1.24 *Down Direction Valve* ð Electrically controlled valve in a hydraulic circuit for controlling the descent of the car.

2.1.25 *Drive Control System* ð System controlling and monitoring the running of the lift machine.

2.1.26 *Electrical and Mechanical Interlock* ð A device provided to prevent simultaneous operation of both up and down relays or power contactors.

2.1.27 *Electro-Mechanical Lock* ð A device which combines in one-unit, electrical contact and a mechanical lock jointly used for the landing and/or car doors.

2.1.28 *Electrical Anti-Creep System* ð Combination of precautions for hydraulic lifts against the danger of creeping.

2.1.29 *Electric Safety Chain* ð The total of the electric safety devices connected in such a way as to stop the lift when one of them is activated.

2.1.30 *Evacuation Lift* ð A lift designed to be used for the evacuation of persons, in automatic mode, or under the direction of building management, or by trained evacuation person(s).

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2.1.31 *Evacuation Exit Lobby* (*EEL*) ð Destination floor(s) for evacuating persons in the building using lift(s), determined by the fire evacuation plan and which has a safe area(s).

2.1.32 *Existing Lift* ð Lift which is in service at the disposal of its owner.

2.1.33 *Floor Levelling Switch* ð A switch for bringing the car to level at slow speed in case of double speed or variable speed machines.

2.1.34 *Floor Stopping Switch* ð A switch or combination of switches arranged to bring the car to rest automatically at or near any pre-selected landing.

2.1.35 *Full Load Pressure* ð Static pressure exerted on the piping, jack, valve block, etc, with the car and rated load being at rest at the highest landing level.

2.1.36 *Geared Machine* ð A machine in which the power is transmitted to the sheave through worm and worm wheel or spur reduction gearing.

2.1.37 *Gearless Machine* ð A lift machine in which the motive power is transmitted to the driving sheave from the motor without intermediate reduction gearing and has the brake drum mounted directly on the motor shaft.

2.1.38 *Goods Lift* ð Lift mainly intended for the transport of goods and on which only the operator and the persons necessary for loading/unloading of the goods are permitted to ride.

2.1.39 *Guide Rails* ð Rigid components which provide guiding for the car, the counterweight or the balancing weight.

2.1.40 *Guide Rails Fixing* ð The complete assembly comprising the guide rails bracket and its fastenings.

2.1.41 *Guide Shoe* ð An attachment to the car frame or counterweight for the purpose of guiding the lift car or counter weight frame.

2.1.42 *Headroom/Overhead* ð The vertical distance from the level of the top lift landing to the bottom of the machine room slab/ceiling.

2.1.43 *Hoisting Beam* ð A beam, mounted immediately below the machine room ceiling/machinery space ceiling, to which lifting tackle can be fixed for raising or lowering parts of the lift machine.

2.1.44 *Hospital Lift* ð A lift normally installed in a hospital, dispensary or clinic and designed to accommodate one bed or stretcher along its depth, with sufficient space around to carry a minimum of three attendants in addition to the lift operator.

2.1.45 *Hydraulic Lift* ð Lift in which the lifting power is derived from an electrically driven pump transmitting hydraulic fluid to a jack, acting directly or indirectly on the car (multiple motors, pumps and/or jacks may be used).

2.1.46 *Indirect Acting Lift* ð Hydraulic lift where the ram or cylinder is connected to the car or the car sling by suspension means [ropes or coated steel belts (CSBs)].

2.1.47 *Jack* ð Combination of a cylinder and a ram forming a hydraulic actuating unit.

2.1.48 *Home Lift* ð A lift specifically designed for a private home taking into consideration the following:

a) compact design in view of the limitations of space in a private residence and light duty;

b) usage of the lift restricted primarily to the residents of the private home;

c) special facilities to meet the needs of elderly and persons with disabilities, including wheelchair users;

d) quiet, smooth, jerk-free movement of the lift; and

e) controls to have ease of operation.

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2.1.49 *Landing Call Push* ð A push button fitted at a lift landing, either for calling the lift car or for actuating the call indicator.

2.1.50 *Landing Door* ð The hinged or sliding portion of a lift well enclosure, controlling access to a lift car at a lift landing.

2.1.51 *Levelling* ð Operation which achieves the accuracy of stopping at landings.

2.1.52 *Levelling Accuracy* ð Vertical distance between car sill and landing sill during loading or unloading of the car.

2.1.53 *Levelling Devices*

2.1.53.1 *Levelling device, lift car* ð Any mechanism which either automatically or under the control of the operator, moves the car within the levelling zone towards the landing only and automatically stops it at the landing.

2.1.53.2 *Levelling device, two-way automatic maintaining* ð A device which corrects the car level on both under run and over-run and maintains the level during loading and unloading.

2.1.53.3 *Levelling device, two-way automatic non-maintaining* ð A device which corrects the car level on both under run and over run but will not maintain the level during loading and unloading.

2.1.54 *Levelling Zone* ð The limited distance above or below a lift landing within which the levelling device may cause movement of the car towards the landing.

2.1.55 *Lift* ð Lift means a hoisting mechanism equipped with a lift car which moves in a substantially vertical direction, is worked by power and is designed to carry passengers or goods/vehicle or both.

2.1.56 *Lift Car* ð The load carrying unit with its floor or platform, enclosing bodywork and car door.

2.1.57 *Lift Landing* ð That portion of a building or structure used for discharge of passengers or goods or both into or from a lift car.

2.1.58 *Lift Machine* ð Unit which drives and stops the lift, including any motor, gear, brake, sheave and drum (traction or positive drive lift) or comprising the pump, pump motor and control valves (hydraulic drive lift).

2.1.59 *Lift Pit* ð The part of the well situated below the lowest landing served by the car.

2.1.60 *Lift Well* ð Space in which the car, the counterweight or the balancing weight travel. This space is usually bounded by the bottom of the pit, the walls and the ceiling of the well.

2.1.61 *Lift Well Enclosure* ð Any structure which separates the lift well from its surroundings.

2.1.62 *Laminated Glass* ð Assembly of two or more glass layers, each of which is bonded together with one or more plastic or liquid interlayers.

2.1.63 *Load Bearing Member* ð Steel wire rope or steel wire strand inside of an elastomeric coated belt.

2.1.64 *Machine Room* ð Fully enclosed machinery space with ceiling, walls, floor and access door(s) in which machinery as a whole or in parts is placed.

2.1.65 *Machine Room Less Lift* ð This special lift does not need a separate machine room.

2.1.66 *Machinery* ð Equipment such as: control cabinet(s) and drive system, lift machine, main switch(es) and means for emergency operations.

2.1.67 *Machinery Space* ð Volume(s) inside or outside of the well where the machinery as a whole or in parts is placed, including the working areas associated with the machinery.

NOTE ð A machinery cabinet with its associated working area(s) is considered as a machinery space.

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2.1.68 *Maintenance* – All the necessary operations to ensure the safe and intended functioning of the installation and its components after the completion of the installation and throughout its life cycle.

NOTE – Maintenance shall include:

a) Lubrication, cleaning, etc;
b) Checks;
c) Rescue operations;
d) Operations of setting and adjustment; and
e) Repair or changing of components which can occur due to wear or tear and do not affect the characteristics of the installation.

2.1.69 *Minimum Breaking Load* (*MBL*) – Specified value in kN below which the measured breaking load is not allowed to fall in a breaking load test.

2.1.70 *Mast* – Structure that supports and guides the cage.

2.1.71 *Mast Section* – Indivisible piece of mast, between two adjacent mast joints.

2.1.72 *Mast Tie* – Connection system between the mast and any building structure, providing lateral support for the mast.

2.1.73 *Non-Return Valve* – Valve which allows flow in one direction only.

2.1.74 *Operation* – The method of actuating the control of lift machine.

2.1.74.1 *Automatic operation* – A method of operation in which by a momentary activation of a call button the lift car is set in motion and caused to stop automatically at any required lift landing.

2.1.74.2 *Non-Selective collective automatic operation* – Automatic operation by means of one button in the car for each landing level served and one button at each landing, wherein all stops registered by the momentary actuation of landing or car buttons are made irrespective of the number of buttons actuated or of the sequence in which the buttons are actuated. With this type of operation, the car stops at all landings for which buttons have been actuated making the stops in the order in which the landings are reached after the buttons have been actuated but irrespective of its direction of travel.

2.1.74.3 *Selective collective automatic operation* – Automatic operation by means of one button in the car for each landing level served and by up and down buttons at the landings, wherein all stops registered by the momentary actuation of the car button made as defined under non-selective collective automatic operation, but wherein the stops registered by the momentary actuation of the landing buttons are made in the order in which the landings are reached in each direction of travel after the buttons have been actuated. With this type of operation, all ‘up’ landing calls are answered when the car is travelling in the up direction and all ‘down’ landing calls are answered when the car is travelling in the down direction, except in the case of the uppermost or lowermost calls which are answered as soon as they are reached irrespective of the direction of travel of the car.

2.1.74.4 *Single automatic operation* – Automatic operation by means of one button in the car for each landing level served and one button at each landing so arranged that if any car or landing button has been actuated, the actuation of any other car or landing operation button will have no effect on the movement of the car until the response to the first button has been completed.

2.1.74.5 *Group automatic operation* – Automatic operation of two or more non-attendant lifts equipped with power-operated car and landing doors. The operation of the cars is coordinated by a supervisory operation system including automatic dispatching means whereby selected cars at designated dispatching points automatically close their doors and proceed on their trips in a regulated manner.

Typically, it includes one button in each car for each floor served and up and down buttons at each landing (single buttons at terminal landings). The stops set up by the momentary actuation of the car buttons are made automatically in succession as a car reaches the corresponding landings irrespective of its direction of travel or the sequence in which the buttons are actuated. The stops set up by the momentary actuation of the landing buttons may be accomplished by any lift in the group, and are made automatically by the first available car that approaches the landing in the corresponding direction.

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2.1.74.6 *Signal operation* – Same as collective operation, except that the closing of the door is initiated by the attendant.

2.1.74.7 *Continuous pressure operation* – Operation by means of buttons or switches in the car and at the landings any of which may be used to control the movement of the car as long as the button or switch is manually pressed in the actuating position.

2.1.75 *Operating Device* – A car switch, push button or other device employed to actuate the control.

2.1.76 *Overhead Beams* – The members, usually of steel, which immediately support the lift equipment at the top of the lift well.

2.1.77 *Over Speed Governor* – Device which, when the lift attains a predetermined speed, causes the lift to stop, and if necessary, causes the safety gear to be applied.

2.1.78 *One-Way Restrictor* – Valve which allows free flow in one direction and restricted flow in the other direction.

2.1.79 *Passenger Lift* – A lift designed for the transport of passengers.

2.1.80 *Passenger* – Any person transported by a lift in the car.

2.1.81 *Position and/or Direction Indicator* – A device which indicates on the lift landing or in the lift car or both, the position of the car in the lift well or the direction in which the lift car is travelling or both.

2.1.82 *Pawl Device* – Mechanical device for stopping involuntary descent of the car, and maintaining it stationary on fixed supports.

2.1.83 *Positive Drive Lift* – Lift which is directly driven (not reliant on friction) by drum and ropes.

NOTE – In this NBCS, the term ‘positive drive lift’ includes drum drive.

2.1.84 *Preliminary Operation* – Energizing of the machine and the brake/hydraulic valve as preparation to a normal run when the car is in the door zone and doors are not closed and locked.

2.1.85 *Pressure Relief Valve* – Valve that limits the pressure to a pre-determined value by exhausting fluid.

2.1.86 *Programmable Electronic System in Safety Related Applications for Lifts* (*PESSRAL*) – System for control, protection or monitoring based on one or more programmable electronic devices, including all elements of the system such as power supplies, sensors and other input devices, data highways and other communication paths and actuators and other output devices, used in safety-related applications

2.1.87 *Pulley Room* – Room not containing the machine, in which pulleys are located and in which the overspeed governor should also be housed.

2.1.88 *Pulley Space* – Space(s) inside or outside of the well where pulleys are placed.

2.1.89 *Rated Load* (*Lift*) – In a normal operation the maximum load for which the lift car is designed and installed to carry safely at its rated speed.

2.1.90 *Rated Speed* (*Lift*) – In a normal operation the mean of the maximum speed attained by the lift car in the upward and downward direction with rated load in the lift car at the time of normal operation.

2.1.91 *Refuge Space* – An area of refuge is a place on the lift car roof or in the pit within the lift well designed to hold the technician/service person in safety when the car is at its highest or lowest position of the lift well, respectively.

2.1.91.1 *Bottom refuge space* – When the lift car is at its lowest position, at least one clear area on the pit where refuge may be taken.

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2.1.91.2 *Top refuge space* ð When the lift car is at its highest position, at least one clear area on the car roof where refuge may be taken.

2.1.92 *Retiring Cam/Coupler* ð A device which prevents the landing doors from being unlocked by the lift car unless it stops at a landing.

2.1.93 *Roping Multiple* ð A system of roping where, in order to obtain a multiplying factor from the machine to the car, multiple falls of rope are run around sheave on the car or counterweight or both. It includes roping arrangement of 2 to 1, 3 to 1, etc.

2.1.94 *Re-levelling* ð Operation, after the lift has stopped, to permit the stopping position to be corrected during loading or unloading.

2.1.95 *Rescue Operations* ð Specific actions required to safely release persons entrapped in the car and well by competent persons.

2.1.96 *Residual Breaking Load* (*RBL*) ð Measured value of suspension member after normal use at the end of expected life span which is detected when discard criteria have been reached.

2.1.97 *Restrictor* ð Valve in which the inlet and outlet are connected through a restricted passage way.

2.1.98 *Rupture Valve* ð Valve designed to close automatically when the pressure drops across the valve, caused by the increased flow in a pre-determined flow direction, exceeds a pre-set amount.

2.1.99 *Rack and Pinion Lift* ð Lift which uses a toothed rack and pinion as the load suspension system.

2.1.100 *Safety Gear* ð A mechanical device attached to the lift car or counterweight or both, designed to stop and to hold the car or counterweight to the guides in the event of free fall, or, if governor operated, of over-speed in the descending and/or ascending direction. Any anticipated impact force shall be added in the general drawing or layout drawing.

2.1.100.1 *Instantaneous safety gear* ð Safety gear in which the full gripping action on the guide rails is almost immediate.

2.1.100.2 *Progressive safety gear* ð Safety gear in which retardation is effected by a braking action on the guide rails and for which special provisions are made so as to limit the forces on the car, counterweight or balancing weight to a permissible value.

2.1.101 *Service Lift* ð A passenger cum goods lift meant to carry goods along with people.

NOTE ð Typically in an office building this may be required to carry food or stationeries, in a residential building to carry luggage or accommodate a stretcher and in a hotel to be used for food trolleys or baggage. There is a need in such lifts, to take care of the dimensions of the car and the door clear opening in line with the type of goods that may have to be carried based on mutual discussion between the supplier and the customer. Also, such lifts shall have buffer railings in the car at suitable height to prevent damage to the car panels when the goods are transported. Typically, such lifts, if provided with an automatic door, may use some means to detect trolleys and stretcher movement in advance to protect the doors against damage. The car floor load calculations and car area of such a lift is as in the case of a passenger lift except that these are not meant to carry heavy concentrated loads.

2.1.102 *Sheave* ð A rope wheel, the rim of which is grooved to receive the suspension ropes but to which the ropes are not rigidly attached and by means of which power is transmitted from the lift machine to the suspension ropes.

2.1.103 *Slack Rope Switch* ð Switch provided to open the control circuit in case of slackening of rope(s).

2.1.104 *Suspension Ropes* ð The ropes by which the car and counter weight are suspended.

2.1.105 *Safety Component* ð Component provided to fulfil a safety function when in use.

2.1.106 *Safety Integrity Level* (*SIL*) ð Discreet level (one out of a possible three) for specifying the safety-integrity requirements of the safety functions allocated to the programmable electronic safety-related system, where safety-integrity level 3 has the highest level of safety integrity and safety-integrity level 1 has the lowest.

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2.1.107 *Safety Circuit* ð Circuit containing contacts and/or electronic components which is regarded to fulfill demands of an electric safety device.

2.1.108 *Safety Rope* ð Auxiliary rope attached to the car, the counterweight or balancing weight for the purpose of tripping a safety gear in case of suspension failure.

2.1.109 *Shut-off Valve* ð Manually operated two-way valve which may permit or prevent flow in either direction.

2.1.110 *Single Acting Jack* ð Jack in which displacement in one direction is by fluid action and in the other by influence of gravity.

2.1.111 *Special Tool* ð Tool unique to the equipment required in order to keep the equipment in a safe operating condition or for rescue operations.

2.1.112 *Stopping Accuracy* ð Vertical distance between car sill and landing sill at the moment when a car is stopped by the control system at its destination floor and the doors reach their fully open position.

2.1.113 *Suspension Means* ð Includes all ropes/elastomeric coated belts suspending car/counterweight/balancing weight and is engaged to car/counterweight/balancing weight side termination.

2.1.114 *Suspension Member* ð Is one rope/elastomeric coated belt in the system to suspend car/counterweight and is engaged to car/counterweight side terminations.

2.1.115 *Terminal Slow-Down Switch* ð A switch when actuated shall compulsorily cut off the high speed and switch on the circuitry to run the lift in levelling speed before reaching on terminal landings.

2.1.116 *Terminal Stopping Switch Normal* ð Switch for cutting off all the energizing current in case of car travelling beyond the top or bottom terminal landing or a switch that cuts off the energizing current so as to bring the car to a stop at the top or bottom terminal landing level in the respective direction of travel.

2.1.117 *Terminal Stopping Device Final* ð A device which automatically causes the power to be removed from an electric lift driving machine motor and brake, independent of the functioning of the normal terminal stopping device, the operating device or any emergency terminal stopping device, after the car has passed a terminal landing.

2.1.118 *Top Counterweight Clearance* ð The shortest vertical distance between any part of the counterweight structure and the nearest part of the overhead structure or any other obstruction when the car floor is level with the bottom terminal landing.

2.1.119 *Travel* ð The vertical distance between the bottommost and topmost lift landings served by the lift.

2.1.120 *Traction Lift* ð Lift whose suspension means are driven by friction on the driving sheave of the machine.

2.1.121 *Travelling Cable* ð Flexible electric cable containing multiple cores between the car and a fixed point.

2.1.122 *Unintended Car Movement* ð Non-commanded movement of the car with doors open within the door zone away from the landing, excluding movements resulting from loading/unloading operation.

2.1.123 *Unlocking Zone* ð Zone, extending above and below the landing level, in which the car floor has to be, to enable the corresponding landing door to be unlocked.

2.1.124 *User* ð Person making use of the services of a lift installation which includes passengers, persons waiting at the landings and authorized persons.

2.2 Terms Relating to Performance Requirements for Lifts

2.2.1 *A*95 ð Values of acceleration or vibration within defined boundaries or limits, in which 95 percent of found values are equal to or less than.

NOTE ð This value is used statistically to estimate typical levels.

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2.2.2 *Acceleration* – Rate of change of z-axis velocity, attributed to lift motion control.

NOTE – It is expressed in metre per second squared (m/s^2).

2.2.3 *Axis of Measurement* – Orthogonal reference axes for the measurements, where for lifts of conventional configuration:

a) *X-axis* – Axis perpendicular to the plane of the car front door (that is, back to front);

b) *Y-axis* – Axis perpendicular to X and Z (that is, side to side); and

c) *Z-axis* – Axis perpendicular to the car floor (that is, vertical).

2.2.4 *Equivalent Sound Pressure Level (L_{Aeq})* – Average sound pressure level, using frequency weighting A and time weighing "fast", determined within defined boundaries.

2.2.5 *Jerk* – Rate of change of z-axis acceleration, attributed to lift motion control. It is expressed in meter per second cube (m/s^3).

NOTE – The passenger perception of vertical ride quality during jerk is represented by the assessment of vertical vibration during non-constant acceleration.

2.2.6 *Lift Ride Quality* – Sound levels in the car and vibration of the car floor, relevant to passenger perception, associated with lift motion.

2.2.7 *Peak to Peak Vibration Levels* – Sum of the magnitudes of two peaks of opposite sign separated by a single zero crossing.

2.2.8 *Sound* – A-weighted sound pressure level measured in decibels (dB).

2.2.9 *Sound Pressure Level* ($L_{p,A}$) – Sound pressure level using frequency weighting A as defined in Part D "Building Services, Section 4 Acoustics, Sound Insulation and Noise Control" of this NBCS:

$$L_{p,A} = 10 \log (p_A^2/p_0^2) \text{ dBA}$$

NOTES

1 The reference sound pressure level (p_0) is 20 µPa (2×10^{-5} Pa).

2 The measured sound pressure, p_A, is in Pascals (Pa), using frequency weighting A.

2.2.10 *V95* – Value of velocity, within defined boundaries or limits, in which 95 percent of found values are equal to or less than the defined limits.

NOTE – This value is used statistically to estimate typical levels.

2.2.11 *Velocity* – Rate of change of z-axis displacement, attributed to lift motion control.

NOTE – Velocity is reported as speed and direction of travel. It is given in meters per second (m/s).

2.2.12 *Vibration* – Variation with time of the magnitude of acceleration, when the magnitude is alternately greater and smaller than the average acceleration of the lift when no lift motion acceleration is present.

NOTES

1 It is expressed in metre per second squared (m/s^2).

2 The deprecated unit Gal (Galileo) is sometimes used: 1 Gal = 0.01 m/s^2

2.3 Terms Relating to Planning and Design of Lifts

2.3.1 *Door Closing Time* (t_c) – Time period measured from the instant that car doors start to close until the doors are closed.

NOTE – The door closing time is expressed in second (s).

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2.3.2 *Door Opening Time* (t_o) – Time period measured from the instant that car doors start to open until they are open to a specified width.

NOTES

1 Measurement may be completed at the instant that the doors are either 800 mm open or until the doors are fully open.

2 The opening width used shall be reported.

3 The door opening time is expressed in second (s).

2.3.3 *Performance time/Door-to-Door Time* (t_{pref}) – Period of time between the instant the car doors start to close and the instant that the car doors are open to a specified width at the next adjacent floor.

NOTES

1 The performance time is expressed in seconds (s).

2 Measurements may be completed at the instant that the doors are 800 mm open or until the doors are fully open.

2.3.4 *Handling Capacity* (C_h) – Maximum sustainable number of passengers per specified time period that a single lift or a group can transport for a specific traffic mix under specified loading constraints.

NOTES

1 Handling capacity is usually expressed as a number of passengers per five minutes (C_h) or as a percentage of population per 5 min (percent C_h).

2 Typical loading constraints are limiting the number of passengers in the cars and are determined by comfort and/or safety considerations that may reflect cultural and/or national norms.

3 The average waiting time increases rapidly and passengers are constantly left behind the departing lift, when passenger demand exceeds handling capacity.

2.3.5 *Interval* (*INT*) – Time period between successive car arrivals at the main terminal floor with cars loaded to any value.

2.3.6 *Nominal Travel Time/Theoretical Time of Travel* (t_{nt}) – Time period in seconds for a lift to travel from the lowest floor to the highest floor without any stops at rated speed.

NOTE – The nominal travel time is expressed in second (s).

2.3.7 *Passenger Arrival Rate* – Percentage of a buildingôs population arriving within a 5 min period.

2.3.8 *Passenger Transfer Time* (t_p) – Average time for a single passenger to enter or leave the lift car.

NOTES

1 The passenger usually moves out faster than they move in. Transfer time is an average of both of them.

2 The passenger transfer time is expressed in second (s).

2.3.9 *Passenger Waiting Time* (*WT*) – Period of time from when a passenger either registers a call on a landing, or joins a queue, until the responding lift that will accommodate the passenger begins to open its doors at the boarding floor.

NOTES

1 The passenger waiting time continues if a passenger does not enter the responding lift, that is, it is full (a refusal).

2 The passenger waiting time is zero, if the responding lift doors are open or opening when the passenger arrives.

3 There may be difference between waiting times measured at a site and waiting times produced by a simulation due to the difficulty of accurately measuring waiting times at an actual site.

2.3.10 *Round Trip Time* (t_{rt}) – Average period of time for a single lift car trip during up-peak traffic conditions, measured from the time the car doors open at the main terminal until the car doors reopen at the main terminal after serving the registered car calls.

NOTE – The round-trip time is expressed in second (s).

2.3.11 *Single Floor Flight Time* (t_{fl}) – Period of time measured from the instant that the car doors are locked until the lift is level at the next adjacent floor.

2.3.12 *Single Floor Transit Time* (t_v) – Period of time required to transit two adjacent floors at rated speed.

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2.3.13 *Sky Lobby* ð A sky lobby is the main floor for local groups in the upper part of a very tall building.

2.3.14 *Door Closing Delay Time* (t_{cd}) ð Delay after passenger clearance before start of door closing.

NOTE ð The door closing delay time is expressed in second (s).

2.3.15 *Express Zone* — Building zone situated between an entrance floor and served floors where lift travel nonstop.

2.3.16 *Door Pre-Opening Time/Advance Door Opening Time* (t_{pre}) ð Time period measured from the instant that car doors start to open until the lift is level at the landing.

NOTES

1 Door pre-opening may compensate for lift levelling, which is the final (slow) approach of the lift to a landing.

2 The pre-opening time is expressed in second (s).

2.3.17 *Incoming Traffic* ð Component of traffic where passengers travel from entrance floors to the populated floors.

2.3.18 *Inter-Floor Traffic* ð Component of traffic where passengers travel between the populated floors.

2.3.19 *Outgoing Traffic* ð Component of traffic where passengers travel from the populated floors to entrance floors.

2.3.20 *Population* (*U*) ð Maximum population a target building is going to be designed.

2.3.21 *Start Delay Time* (t_{sd}) ð Perion of time from the instant the car doors are close until the lift starts to move.

NOTE ð The start delay time is expressed in second (s).

2.3.22 *Flight Time* (t_f) ð Period of time from the instant the lift starts to move until the lift is level at the next stop floor.

NOTE ð Flight time is usually calculated by assuming ideal lift kinematics based on the rated speed, rated acceleration and jerk.

2.3.23 *Entrance Floor* ð Floor with building entrance or utility floor, that is, restaurant, which attract people from populated floors.

2.3.24 *Entrance Bias* ð Proportion of traffic attributed to a specific entrance floor.

2.3.25 *Transit Time* ð Period of time from when a responding lift begins to open its doors at the boarding floor until the doors begin to open again at the destination floor.

NOTE ð The transit time commences when a passenger arrives, if the responding lift doors are open or opening.

2.4 Terms Relating to Seismic Operation of Lifts

2.4.1 *Design Acceleration* (a_d) ð The horizontal acceleration to be used for calculation of forces (moments acting on lift systems and arising from seismic events).

NOTE ð The value of (a_d) shall be obtained by the lift manufacturer from the building engineer/structural engineer.

2.4.2 *Normal Operation* ð Operation mode in which the lift performs when not in seismic mode or in seismic stand-by mode.

2.4.3 *Retaining Device* ð Mechanical device securely fixed to a structural member of the lift car, counterweight frame designed to retain the lift car and counterweight within its guide rails during seismic activity.

2.4.4 *Seismic Mode* ð Special mode in which the lift operates after detection of seismic trigger level.

2.4.5 *Seismic Stand-By Mode* ð Special mode in which the lift operates after detection of primary earthquake wave without the activation of the seismic detection system.

2.4.6 *Seismic Trigger Level* ð Seismic acceleration which is used to activate a seismic detection system.

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2.4.7 *Snag Point* – The point of interference between flexible elements (for example, ropes, chains, travelling cable, etc) and fixed elements (for example, guide rail brackets, guide rail clip bolts, fishplates, vanes and similar devices).

2.5 Terms Related to Maintenance of Lifts

2.5.1 *Competent Maintenance Person* – Designated person, suitably trained, qualified by knowledge and practical experience, provided with necessary instructions and supported within their maintenance organization to enable the required maintenance operations to be safely carried out.

2.5.2 *Installation* – Completely installed passenger lift or good passenger lift or accessible goods only lift or service lift.

2.5.3 *Installer* – Natural or legal person who takes responsibility for the design, manufacture, installation and placing on the market of lifts.

2.5.4 *Maintenance Organization* – Company or part of company where competent maintenance person(s) carry out maintenance operation on behalf of the owner of the installation.

2.5.5 *Manufacturer* – Natural and legal person who takes responsibility for the design, manufacture and placing on the market either of safety components for lifts or complete lift.

2.5.6 *Owner of the Installation* – Natural or legal person who has the power of disposal of the installation and takes responsibility for its operation and use.

2.5.7 *Inspector* – Inspector means an inspector of lifts or any other officer appointed and approved by State/Union Government to maintain *Lift Act*/*Rules* or any *other Act*/*Rules* connected with safety of lifts and framed by State/Union Government

2.5.8 *Authorized Person* – Person with the permission of the natural or legal person who has the responsibility for the operation and use of the lift, to access restricted areas (machinery spaces, pulley rooms and lift well) for maintenance, inspection or rescue operations.

2.5.9 *License* – A permission granted by competent authority to engage in a business or occupation or in an activity otherwise unlawful.

3 GENERAL

3.1 Conformity with Lifts Act and Rules

3.1.1 The installation shall generally be carried out in conformity with *Lifts Act* and *Rules*, wherever they are in force.

3.1.2 It is the responsibility of the owner of the premises where the lift will be installed, to obtain necessary permission from the Authority before and after the installation of lifts and for subsequent operation of lifts.

3.1.3 A license for public use is a safety provision, issued by state authorities under *Lifts Act* and *Rules*, wherever they are in force and shall be obtained as per the laid down statutory requirement.

3.2 Conformity with *The Electricity Act* and CEA Regulations Thereunder

All electrical work in connection with installation of lifts shall be carried out in accordance with the provisions of the *Electricity Act*, 2003 as amended up-to-date along with the CEA regulations framed thereunder and shall also comply with the other provisions of Part D –Building Services, Section 2 Electrical and Allied Installations– of this NBCS.

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3.3 Conformity with Indian Standards

All materials, fittings, appliances, etc, used in electrical installation shall conform to Indian Standard specifications wherever these exist. In case of materials for which Indian Standard specifications do not exist, the materials shall be approved by the competent authority. For detailed specification for lifts, reference shall be made to accepted standards [D-5A(2)].

3.4 Conformity to Accessibility Requirements

All lifts installed for public use shall meet the accessibility requirements in accordance with good practice [D-5A(3)].

3.5 Conformity with Fire Regulations

The installation shall be carried out in conformity with the state fire acts/local fire regulations, wherever they are in force (*see also* Part F ôFire and Life Safetyô of this NBCS for guidance purpose).

3.6 Considerations for Selection of Lifts

The considerations for selection of lifts shall be based on the following criteria:

a) *The Intended use of lift* ð The number of lifts and their capacities (that is, load and speed) required for a given building shall be suitably decided to meet the intended requirement. The passenger lifts shall meet the requirements of handling capacity and waiting time for passenger, depending on the liftôs expected usage and building type.

b) *System performance* ð System performance criteria shall be based on building type (residential, commercial, hotel, hospital, etc).

c) *Accessibility requirements* ð *See* **3.4**.

d) *Environmental conditions* ð Lifts directly exposed to atmospheric conditions, that is, weather (for example, those meant for external applications), or any other adverse condition shall be appropriately designed and protected for that particular condition.

e) *Type of main drive for lift* ð Whether electric traction, geared or gearless or hydraulic depending on speed, stops/travel height and capacity requirement.

f) *Civil engineering requirements* ð Machinery location that is, machinery to be located in machine room or machinery to be kept inside lift well thereby eliminating conventional machine room.

g) *Seismic considerations* ð Whether the lift is to be protected against seismic forces or whether the lift is to be rescued to a landing on detection of earthquake or both.

3.7 Maintenance

The considerations relating to maintenance shall be as follows:

a) The lift installation shall receive regular cleaning, lubrication, adjustment and adequate servicing by authorized competent persons at such intervals as per type of equipment and frequency of service demand. It is desirable and normal for the lift supplier to be entrusted with the servicing during the guarantee period of new lift.

b) In order that the lift installation is maintained at all times in a safe condition, a proper maintenance schedule shall be drawn up in consultation with the lift manufacturer and rigidly followed. The provision of a log book to record all items relating to general servicing and inspection is recommended for all lifts.

c) Any accident arising out of operation or maintenance of the lifts shall be duly reported to the authority in accordance with the rules laid down.

d) Lifts are required by statutory regulations to be examined at regular intervals as specified by lift acts, by a competent person.

e) The company entrusted with maintenance contract shall have valid licence to maintain the lifts. The persons assigned for maintenance work shall be appropriately qualified and experienced as required by *lLift Acts* and *Rules*.

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3.8 Energy Efficiency and Sustainability

Design options like space restrictions, reliability and safety, riding comfort have been the major market and technological drivers. The following should be encouraged for reducing power consumption and promoting sustainability in buildings:

a) Use of energy efficient a.c. variable voltage variable frequency (VVVF) motor drive or equivalent. Lifts with 1-speed and 2-speed motor control are not recommended for passenger lifts because of high power consumption, poor passenger comfort and tripping hazard;

b) When the lift has answered the last call and stopped at a landing and no further landing call is registered, the car and landing doors shall close. If there is no further landing call after pre-determined period but not less than 90 s, the light and fan inside the car shall both be automatically switched off. Car lights and fan shall switch on automatically before the lift doors start to open or the lift is set in motion;

c) Under normal operating status, at least one lift car of a lift bank shall operate under a standby or sleep mode during off-peak period when the traffic demand on the vertical transportation system is low. During low demand periods, even completely shutting down one or more lifts within a group can be a good energy saving option, without compromising the quality of service;

d) Where a number of lifts are installed together, their controls are interconnected to optimize their operation. By efficiently delivering passengers with the least number of trips, starts and stops, the energy consumed is significantly reduced;

e) Use of energy saving LED lamps for car lighting in place of conventional lamps;

f) Use of gearless type machines to reduce transmission losses;

g) Improvement in total power factor of the motor drive of a lift at the isolator connecting lift to the buildingôs electrical supply circuit;

h) Use of regenerative drives to recycle energy rather than wasting it as heat. The regenerated energy may be used for charging batteries, staircase lighting, lobby lighting, etc;

j) Use of high efficiency motors such as permanent magnet synchronous motors, or induction motors having minimum efficiency class equivalent to IE2 as per accepted standard [D-5A(4)]; and

k) Adoption of materials and practices that are environmentally friendly and sustainable.

4 PLANNING AND DESIGN GUIDELINES

This clause provides guidelines for traffic analysis and minimum vertical transportation requirements; and is not a substitute for detailed understanding of the complex theory and the required practical experience.

4.1 The planning guidelines, design considerations, and precautions to be exercised during design of passenger and goods lifts operated by electric traction are provided hereunder. Manufacturer may be consulted for other types of lifts such as hydraulic, home, automobile lifts, etc.

Design of lifts necessarily calls for coordination among various parties concerned, namely the client, the architect/engineer, the consulting engineers and the lift manufacturer. These guidelines give the information from the stage of planning till the design that should be exchanged between parties. It is essential that all the parties involved in the planning should have a clear understanding of the basis and the theory of planning. All parties involved need to recognize that it is highly impractical to correct badly planned lifts in a building as no changes can be carried out to the building core, if the number of hoist-ways is inadequate or of wrong size or wrongly positioned.

These provisions specify requirements for the architects/engineers, builders/developers and tenderers while finalizing specification of lifts. Two basic considerations, namely, the quantity of service required and the quality of service desired, determine the number and type of lifts to be provided in a particular building. The quantity of service factor, that is, how many people might use the lift system over a defined period of time is represented by the handling capacity. The quality of service factor, that is, how well the lift system deals with its passengers is represented by passenger waiting time and lobby queuing. These factors are interrelated and depend, among other things, on the type of building and its use and on the type of occupier. Both these factors require proper study into the character of the building, extent and duration of peak periods, frequency of service required, type and method of control, type of landing doors, etc.

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Figure 1 shows the flow chart to arrive at a reasonable vertical transportation solution for a building.

The adequacy of the lift group in a building is a major contributing factor to the success or failure of a building. Users of lifts would be intolerant of long queues and long waiting times. The planning and selection of the vertical transportation equipment is a specialized activity. Although the basic calculations are relatively simple, the theory on which they are based is complex. The difficulty in planning a lift installation is not only in calculating its probable performance but also in estimating the passenger demand and usage patterns. The architect/engineer doing the planning work should establish the lift system at a very early stage in consultation with the lift manufacturer/consulting engineer and not after the rest of the building has been designed.

This Subsection defines the calculation approach for conventional two button dispatching and does not define calculation methods for destination control systems or hybrid systems. It also does not define an approach to simulation methods as consensus on how to apply simulation has not been established.

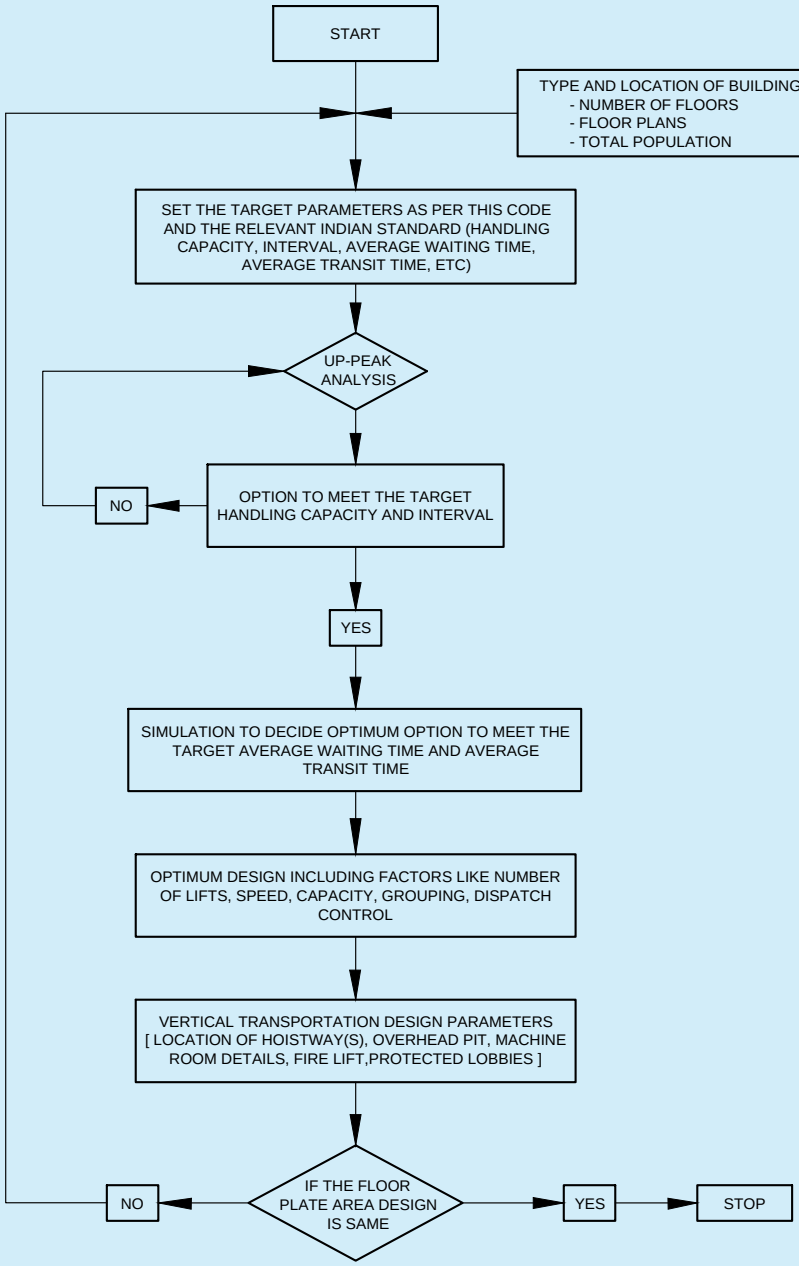

FIG. 1 TYPICAL FLOWCHART ON PRELIMINARY DESIGN OF LIFTS

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4.2 Preliminary Lift Planning

4.2.1 Two models can be used for lift traffic analysis and design:

a) The first model uses a calculation method based on mathematical formulae. This classical model uses the pure up-peak condition as this provides a well-defined, simple traffic pattern amenable to mathematical analysis. These calculations can be carried out manually, using a spreadsheet or by using computer based programme; and

b) The second model is based on discrete digital simulation of the movement of lifts in a building and the passenger dynamics. This simulation model allows very complex situations to be analysed and is generally capable of better evaluations. However, simulation approaches and algorithms vary with software ranging from crude to very sophisticated. With the varied approaches and lack of consensus on simulation approaches and how to apply simulation this standard does not define standards for simulation, however passenger generation for simulation model should be for 120 min and should cover a minimum of 3 intervals (each of 5 min) to co-relate with practical situation.

Generally, if a lift system (using a conventional landing call system) is sized correctly for the up-peak traffic pattern, all other traffic patterns should be adequately served. The notable exceptions to this, are:

1) hotels where check-in/check-out clashes with meal times;
2) hospitals;
3) buildings that open at specified times (example, stock exchanges, movie theatres, stadiums);
4) buildings with 24 Ĭ 7 operation and shift changes (example, BPO/ITES buildings);
5) buildings with amenities located at higher floors (example, roof top restaurant, cafeterias, health clubs);
6) residential buildings (sometimes two-way traffic is considered);
7) buildings with multiple entry levels;
8) parking towers;
9) schools where students change floors or buildings at the beginning and end of classes; and
10) mixed-use buildings.

Methods of calculating the traffic handling capabilities of lifts were first devised for office buildings. In due course detailed modifications were devised to suit other applications without altering the basic principles. The application to office buildings is the most frequently used, and is outlined in **4.2.2** to **4.2.9** as a general approach to lifting.

Subsequently, traffic conditions other than up peak are examined as also building types other than office. It is recommended that calculations based on the classical model should be carried out in order to obtain an understanding of the various factors. A simulation may then be performed in order to cover special situations or to obtain information not provided by the calculation method.

4.2.2 *Population*

4.2.2.1 The first point to be ascertained from the owner/developer or proposed occupier is the total building population. If a definite population figure is not available, then an estimation should be made using floor areas, more specifically, the net usable area (NUA). The NUA excludes circulation areas (stairs, corridors, foyers, etc), structural intrusions (columns, ducts, etc) and facilities (pantry, kitchens, toilets, conference rooms, training rooms, server rooms, storage areas, etc).

4.2.2.2 The number of people occupying the net usable area can vary according to the usage pattern or building type. Because of the criticality of establishing the population, it is recommended that the architect/engineer should prepare a typical test fit to establish an estimate of the population. The test fit estimates can be validated from population counts from buildings with similar usage patterns and types.

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4.2.2.3 *Absenteeism*

While the absenteeism is subjected to input from the developer/tenants, studies have shown that in many office buildings it is unlikely that all the total population is present on any one day. Where this is known to be the case the building population to be used in a design may be reduced by 10 percent to 20 percent on account of persons working from home, holiday, sickness, travelling, vacant posts, etc. It would be impractical to consider absenteeism beyond 20 percent of total population. The designer shall note that the absenteeism shall be applied only for office buildings. Absenteeism factor shall not be considered for residential buildings, hotels or hospitals.

People arriving in morning adopts a bell curve arrival pattern. Designers shall not adopt any additional diversity towards people arriving before peak period/after peak period. The designers need to understand the clear circulation and movement pattern of the occupants (and goods) of a building and design to facilitate the circulation and movement. Table 1 gives typical values for the density of population.

Table 1 Occupancy Area Per Person in Office Buildings

(*Clause* 4.2.2.3)

Sl No.	Building Type	Open Plan/ Hall Seating	Cellular Plan/Cabins
(1)	(2)	(3)	(4)
i)	Premium	10 m^2	12 m^2
ii)	Regular	8 m^2	10 m^2
iii)	Low end	5 m^2	8 m^2

For certain specialized building functions such as BPO, areas ranging from 6 m^2 to 10 m^2 per person may be considered.

4.2.3 *Quantity of Service*

It is measured in terms of the total number of passengers handled during the peak 5 min period of the day. This is calculated by determining the number of trips made by the lifts over the peak 5 min period and then multiplying it by the average number of passengers carried in each trip. The target handling capacity as a percentage of the building population is usually the estimated value of passenger arrival rate for the 5 min up-peak period. The minimum recommended quantity of service for office building is given in Table 2.

This would vary depending on various factors like starting time (fixed or flexi-time), nearness to fast access routes like mass rapid transport systems, express ways, major roads, etc.

Table 2 Recommended Quantity of Service in Office Buildings

(*Clause* 4.2.3)

Sl No.	Type of Occupancy	Quantity of Service
		Percent
(1)	(2)	(3)
i)	Multi tenancy	10 to 15
ii)	Single tenancy	15 to 25

4.2.4 *Quality of Service*

It is very difficult to get real indications of passenger waiting time and lobby queuing from the classic calculation models. Therefore, interval is considered as the measure. During pure up-peak traffic, the interval or the average time between successive arrivals of the lift cars at the main lobby is generally considered as an indicator of passenger waiting time. Table 3 gives the quality of service based on interval for office buildings.

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If interval is used as an indicator of quality of service, it should be noted that passenger average waiting time depends on the car occupancy, the handling capacity *vis-a-vis* the passenger arrival rates, the control systems, etc. The average waiting time approximates 75 percent to 85 percent of the interval for average car occupancy of 80 percent of the actual lift capacity provided the handling capacity is equal to or better than the peak arrival rate. Beyond 80 percent car loading passenger average waiting time increases exponentially and cannot be approximated from interval. Table 4 gives the recommended quality of service measured as average waiting time for office buildings.

Table 3 Recommended Quality of Service in Office Buildings (Based on Interval)

(*Clause* 4.2.4)

Sl No.	Quality of Service	Interval s
(1)	(2)	(3)
i)	Excellent	Less than 25
ii)	Very good	25 to less than 30
iii)	Good	30 to less than 35
iv)	Fair	35 to less than 40
v)	Poor	40 to less than 45
vi)	Unsatisfactory	45 and above

Table 4 Recommended Quality of Service in Office Buildings (Based on Average Waiting Time)

(*Clause* 4.2.4)

Sl No.	Class of Building	Average Waiting Time s
(1)	(2)	(3)
i)	Premium	< 25
ii)	Regular	25 to 35

NOTES

1 The class of building may be as defined by the developer.

2 Service lifts shall be provided in addition to required passenger lifts.

3 Lift designer shall take into consideration the shutdown of lifts for maintenance, especially for office building operating 24 Ĭ 7.

4.2.5 *Traffic Analysis Equations*

The classical method to size a lift installation requires the determination of the time, in second, that it takes for a single lift to make a round trip around the building during the up-peak traffic condition. This is called the round trip time (*RTT*) and is given by:

$$RTT = 2Ht_v + (S+1)(T - t_v) + 2Pt_p$$

where

N = average highest reversal floor = $N - \sum_{i=1}^{N-1}(i/N)^P$;

H = average no of stops = $N\left[1 - \left(1 - \frac{1}{N}\right)^P\right]$;

S = average passengers carried (= 0.8 × maximum actual car capacity);

P = single floor transit time = average inter floor distance/rated speed;

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t_v = single floor transit time = average inter floor distance/rated speed;

T = door operating time (t_c+t_o) + single floor flight time t_f (1); and

t_p = passenger transfer time.

The derivation of the round trip time equation assumes the following:

a) Traffic pattern corresponds to a pure up-peak;

b) Passengers arrive according to a rectangular probability distribution;

c) Lifts, on an average, fill to 80 percent of the actual car capacity by numbers irrespective of the weight of each passenger or the space that maybe occupied;

d) All floors are equally populated;

e) Rated speed is achieved in a single floor jump;

f) Inter-floor heights are equal; and

g) Door dwell time does not exceed the calculated passenger transfer time.

Interval, *INT* = *RTT/L*, where *L* is the number of lifts in a single group.

$$\text{5 min handling capacity, } HC = \frac{300 \times P \times L \times 100/Population}{RTT}$$

or

$$\frac{300 \times P \times 100/Population}{INT}$$

The down peak round trip time is estimated as:

$$RTT_{\text{downpeak}} = Nt_v + (0.5S + 1)(T - t_v) + 2Pt_p$$

The mid-day round trip time is estimated as:

$$RTT_{\text{mid-day}} = 2Ht_v + 2S(T - t_v) + 4Pt_p$$

An estimation of interfloor performance can be obtained using:

$$AWT_{\text{interfloor}} = INT_{\text{uppeak}} + \left(0.22 + 1.78\frac{A_{\text{interfloor}}}{HC_{\text{uppeak}}}\right)$$

where

$A_{\text{interfloor}}$ = number of passengers arriving during the interfloor period.

4.2.6 *Configuration of Lifts*: *Number*

Determination of number of lifts depends on the required quality and quantity of service. It should be noted here that grouping of lifts and location should be given adequate attention.

If a bank of two lifts or more is required to meet the anticipated traffic requirements, they have to be oriented to facilitate grouping. Individual lifts will not achieve the required quantity and quality of service.

4.2.7 *Configuration of Lifts*: *Capacity*

Determination of car capacity depends on the required quality and quantity of service. A larger car, while improving the handling capacity might adversely impact the quality of service.

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4.2.8 *Configuration of Lifts*: *Speed*

In addition to the speeds derived from the calculations for handling capacity and interval, the nominal travel time is used for selecting suitable rated speeds. The higher the building, the faster lifts are needed. The recommended values for nominal travel time in case of an office, commercial or hotel building are given in Table 5.

4.2.9 *Configuration of Lifts: Layout*

The shape and size of a passenger lift car bears a distinct relation to its efficiency in traffic handling. A study of the most suitable proportions for passenger lifts reveals that the width of the lift well entrance is the basic element in the determination of the best proportions. In other words, the width of the car is determined by the width of the entrance and the depth of the car is regulated by the loading per square metre permissible under this standard.

Centre opening doors are the most practicable and the most efficient entrance units for passenger lifts. Given the same door speed, the centre opening is much faster than the side opening type. For passenger lifts, wider cars are preferred as the ingress and egress efficiency is higher. For service/freight/stretcher lifts deeper cars are preferred, so as to easily carry the stretcher/goods.

While sizing the hoist-ways, the possible construction inaccuracies have to be considered. Further, where high speeds lifts are being considered the hoist-ways need to be designed to address the impact of the wind tunnel effect.

Table 5 Recommended Nominal Travel Time for Office, Commercial or Hotel Buildings

(Clause 4.2.8 and Table 11)

Sl No.	Level	Nominal Travel Time s
(1)	(2)	(3)
i)	Excellent	15 to 25
ii)	Good	> 25 to 35
iii)	Satisfactory	> 35 to 45

4.3 Planning for Specific Building Features

4.3.1 *Special Building Facilities*

Facilities like cafeteria, food courts, restaurants, gymnasium, etc in the building impact the circulation patterns in a building and should be considered for lift traffic design.

It is advisable to have cafeteria on ground floor or lower floor with separate access means other than the main lifts. When the cafeteria/food court is located in mid-way or top of the building, the probable number of trips per person is on higher side, lunch peak needs to be analysed considering multiple trips.

For office buildings having specialty restaurants, clubs on higher levels, it is recommended to have dedicated lifts with separate lobby to avoid conflict between the different constituents.

4.3.2 *Basement Service*

Buildings are sometimes designed with car parks or other facilities at basement levels below the terminal floor. Such floors, if they are served by the main lifts have an adverse impact on the up-peak, down-peak and mid-day traffic patterns. During up-peak conditions, this may cause lifts to arrive at the main terminal already partly full causing confusion. In such a situation people have a tendency to push both up and down buttons resulting into deterioration of the lift service.

If basement floors are served by only a part of a lift group, passengers experience difficulty in selecting the correct lifts out of a group that will serve the basement. It is therefore better to provide basement service to the main

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lobby by a separate group of ‘shuttle’ lifts so as to avoid compromising the traffic handling capability of the main lift group.

4.3.3 *Multiple Entry Levels*

Some buildings have main entry points at more than one level. The effect of more than one main terminal is disruptive and adversely impacts effective circulation and movement. If there are more than one entrance levels, means should be provided to bring all the routes to a single terminal floor. If this is not possible, then the lift system planning should take into account the extra times incurred in stopping and loading at multiple entry floors. Another difficulty is in deciding whether the building population will use each entrance equally. In the absence of any guidance, the solution is to assume an entrance bias with an additional 10 percent and size the lifts to meet the additional required handling capacity.

The loss of lift efficiency because of multiple entry levels could be as high as 15 percent per additional entry level. Both basement service and multiple entry level buildings with lifts serving all floors can also impact the security of the building.

4.3.4 *Non-Smoking Buildings*

When buildings are defined as non-smoking buildings, designers need to factor in the additional load put on the lifts on account of the additional trips that smokers make to go outside the building. It is appropriate to provide pressurized smoking zones at the floor level rather than require smokers to make additional trips.

4.3.5 *Reserved Lifts*

When lifts have to be reserved for VIP personal movement, designers should not consider these lifts as part of the lift group.

4.3.6 *Zoning* (*Vertical*)*/Sky Lobbies in Very Tall Buildings*

As the number of floors served increases, the values of *H* and *S* also increase, adversely impacting the round trip time and performance of the lift system. This has led to the concept of zoning in tall buildings. In stacked zoning, a tall building is effectively divided into horizontal layers or stacks. *RTT*, quality and quantity of service can be arrived at separately for each zone. The desired level of service can be attained by adjusting two parameters, in this case – the number of lifts and the number of floors in the zone. The round trip time for each zone is given by:

$$RTT = 2Ht_v + (S + 1)(T - t_v) + 2Pt_p + 2[t_{express} - t_f(1)]$$

where

$t_{express}$ = flight time from the main terminal to the express zone terminal/sky lobby.

The round trip time for shuttle lifts serving only 2 floors – main terminal and sky lobby is given by:

$$RTT = 2T + 2Pt_p$$

4.4 Planning for Specific Building Types

4.4.1 *Residential Buildings*

The peak traffic condition occurs during the morning down-peak when many adults and children are leaving for work and school at the same time. Population assumptions would also need to consider the service staff, drivers of cars, etc. For high rise buildings the delivery of newspapers, milk and disposal of garbage also requires to be considered.

In the luxury housing segment, where the number of ratio of service staff to residents is fairly high, separate service lifts may be required for door deliveries and service staff movement. Typical average daily population for a residential building is given in Table 6.

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The passenger handling capacity shall be as given in Table 7. The target handling capacity for residential building is lower as compared to office building with an understanding that the traffic for residential building would be comparatively less. The absenteeism factor shall not apply to residential buildings. The intervals shall be as per values in Table 8. Table 9 gives the recommended quality of service measured as average waiting time for residential buildings and Table 10 gives the nominal travel times.

Sizing of lifts should consider the requirement to shift the stretchers, heavy material, etc and it is recommended that at least one lift in each building should be a deep car which can accommodate a regular ambulance stretcher.

Table 6 Typical Average Population for Residential Buildings

(*Clause* 4.4.1)

Sl No.	Class of Building	Number of Bedrooms Per Apartment				
		1	2	3	3 With Servant Quarters	4 With or Without Servant Quarters
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	*High end apartments:*					
	a) Residents	2 to 3	3 to 4	5	5	5 to 6
	b) Resident service staff	0	0	0	1	1
	c) Floating service staff	1	2 to 3	3 to 4	3 to 4	4 to 5
ii)	*Mid end apartments:*					
	a) Residents	3	4	5	5	5 to 6
	b) Resident service staff	0	0	0	1	1
	c) Floating service staff	1	1	2 to 3	2 to 3	3 to 4
iii)	*Low end apartments:*					
	a) Residents	4 to 5	5 to 6	NA	NA	NA
	b) Floating service staff	0.5	0.5	NA	NA	NA

NOTE ð Unless separate lifts are provided for service staff, due consideration for service staff shall be given while calculating the required number of lifts. The class of building shall be as defined by the developer.

Table 7 Recommended Handling Capacity for Residential Buildings

(*Clause* 4.4.1)

Sl No.	Class of Building	Handling Capacity Percent
(1)	(2)	(3)
i)	High end building	> 8
ii)	Mid end building	6 to 8
iii)	Low end building	5 to 7

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Table 8 Recommended Quality of Service for Residential Buildings (Based on Time Interval)

(*Clause* 4.4.1)

Sl No.	Class of Building	Interval s
(1)	(2)	(3)
i)	High end building	Ò60
ii)	Mid end building	61 to 80
iii)	Low end building	81 to 100

Table 9 Recommended Quality of Service in Residential Buildings (Based on Average Waiting Time)

(*Clause* 4.4.1)

Sl No.	Class of Building	Average Waiting Time s
(1)	(2)	(3)
i)	High end building	Ò30
ii)	Mid end building	31 to 45
iii)	Low end building	46 to 60

Table 10 Recommended Nominal Travel Time for Residential Buildings

(*Clause* 4.4.1 *and Table* 11)

Sl No.	Level	Nominal Travel Time s
(1)	(2)	(3)
i)	High end building	25 to 35
ii)	Mid end building	36 to 45
iii)	Low end building	46 to 60

NOTE — In case of super tall buildings considering limit of lift speed as 10 m/s, the travel time may be longer than specified above.

The class of building shall be as defined by the developer.

4.4.2 *Service Apartments and Hostel*

Average population as 2 person per flat to 3 person per flat/room may be considered. The quantity and quality of service can be considered as per high end residential building, as the peak demand would be during morning hours as maximum of population would be leaving for office, college, etc. The system shall be designed to cater to a peak arrival rate of 8 percent to 10 percent.

4.4.3 *Hospitals*

Factors to be considered include number of staff and shift patterns, number of visitors and visiting hours, location of operation theatres, facilities, delivery of housekeeping supplies, waste disposal, evacuation procedures and segregation of sterile areas. When carrying out traffic analysis for hospitals, designers should consider establishing average car loading by volume rather than by weight. Arrival rates may approximate 10 percent to 15 percent and interval may be 30 s to 50 s.

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Lifts shall be taken into consideration according to the evacuation strategy of building. Lifts shall be considered when vertical evacuation is planned for patients who need to be evacuated with stretcher.

The sizing of the lift car and doors should be such that a standard hospital stretcher and attendant can be easily accommodated. Where the hospital bed is likely to be moved the lift car should be able to accommodate the standard hospital bed including the auxiliary support equipment like oxygen cylinders, etc.

In addition to passenger lifts, service lifts is required for the movement of housekeeping staff, catering, etc. Dedicated service lift may be considered for movement of medical waste, garbage, etc.

In large hospitals, it is recommended that the lifts for the patients/hospital beds (or stretchers) should be separated from the lifts for staff/visitors.

NOTE — For hospital buildings, designers should also consider that in an emergency a number of patients would require to be evacuated on stretchers.

4.4.4 *Hotels*

4.4.4.1 The most demanding time is during the check-in and check-out period and two-way traffic occurs during this period with guests going to and from rooms and restaurants and in and out of the hotel. Calculations should be made assuming an equal number of up and down stops during this period. Average room occupancy may range from 1.5 persons to 2 persons and arrival rates from 10 percent to 15 percent.

The following shall also be considered in the calculations:

a) Handling capacity > 12 percent;

b) Interval < 40 s; and

c) Average waiting time : 30 s to 40 s (peak check-in/checkout time).

4.4.4.2 Security considerations need to be taken into account whilst establishing the circulation and lift requirements. Escalators should be employed for heavy short range movements such as from the lobby to banquet/ function level. Adequate number of service lifts need to be provided for service movement of housekeeping and room service staff as well as movement of material. Way finding signage shall be helpful to locate lift lobby for guests.

4.4.4.3 While hotel operator guideline should be the base for lift designing, modern hotels that has public amenities like, roof top restaurants, bars, event spaces, casino, etc. There should be dedicated lifts with separate lift lobby to access these levels, this helps in bifurcating the public traffic from hotel resident guests and thus ensure the security and performance of guest lifts.

4.4.4.4 *Banquets and conventional centre*

Escalators shall be an ideal means for the movement of mass people; however, lifts shall need to be considered to cater specially-abled people. The lifts shall be designed to cater to the minimum arrival rate of 12 percent. When escalators are provided, lift shall be designed for a minimum for 30 percent of total capacity for the factors that all the people may not use escalators. For banquets and conventional centres with higher capacities, lifts shall be designed for a fairly larger capacity as people would travel in groups and expected in special attire. It is recommended that the minimum capacity of lifts shall be 1 360 kg/20 pax with minimum door width of 1 000 mm. Freight lifts may be required depending on the functioning and requirements.

4.4.4.5 Consideration has to be given to valet circulation for vehicle retrieval.

4.4.5 *Retail — Malls with Multiplexes*

Pedestrian movement in retail establishments like malls is generally centred on escalators, and lifts do not play a major part. However, provision should be made for movement of shopping trolleys, wheel chairs, perambulators and persons with limited mobility from one level to another. A commonly applied solution is the installation of inclined moving walks. Where lifts are provided, assumptions of lift car sizing should take into account space occupied by trolleys and shopping bags. Where multiplexes are located on the upper floors, the last movie of the day gets over after the mall is closed at which time the escalators might not be available. In such cases the lift provision has to be adequate to handle the egress of the multiplex population with recommended average waiting

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time of below 40 s catering to a demand population of minimum 8 percent for 1/3rd of total screens for exiting at different intervals. Staircase factor can be considered for a simulation model.

4.4.6 *Airports/Railway Stations*

While moving walks and escalators greatly improve the building circulation, the use of lifts has to be considered for persons with limited mobility and for movement of baggage trolleys from one level to another. The RTT equation of 4.2.5 may be used, but care may need to be taken in the assumptions of lift car occupancy levels taking into account space occupied by trolleys.

4.4.7 *Multi-Level Car Parking*

Multi-level car parks may be standalone public car parks or attached to office, retail or residential complexes. These car parks may be fully automated where drivers would leave the cars inside or on a trolley at the entry floor and the car is parked and retrieved automatically. The other alternative would be for the use of car lifts and/or ramps.

When the movement of the cars is dependent on car lifts, detailed study has to be carried out to establish the required number of car lifts ensuring that average car retrieval/parking time does not exceed 2 min. The sizing of the car lifts has to be adequate to fit the largest vehicle that is intended to be transported as well as adequate space to enable opening of the doors to enable evacuation of passengers in the eventuality of an entrapment. Designers will also need to take into account the probability of queues developing and provide for holding lanes. For luxury/ high end residential buildings the car parking provision may exceed the total resident count of building. Where there are no separate shuttle lifts for parking floors, designer need to consider the movement of drivers in passenger lifts. When parking count exceeds the count of residents, the entrance bias should be calculated with assumption of certain percentage of total parking from each entry level.

4.4.8 *Multi-Level Car Parking Passenger Traffic*

When car lifts or ramps are the means for parking the cars, then means would need to be provided for the movement of passengers from and to the parking floors. If the main building lifts also serve the parking floors, it is to be noted that, performance will be adversely impacted due to multiple entry floors. Additional entry floors will also affect the security of the building. It is therefore recommended that separate lifts should be considered to move passengers. If separate parking lifts are provided, the basic *RTT* equation of 4.2.5 may be used. Average vehicle occupancy may be considered as 1.5 per car for office car parks, 4 for airports and retail and 2 elsewhere. For high end residential building or private building, usually drivers would be accessing parking level, hence for such luxury building 1 person (driver) per car can be considered.

4.4.9 *Schools and Other Educational Institutions*

In schools and other educational institutions, the traffic flow would consist of peak demand for short duration that would exist just before the start or after finishing of a class or lecture. It is unlikely that an economical solution can be implemented for such high peak requirements. Therefore, the design of the building has to be such that heavy stair usage is facilitated. Mostly for college buildings, demand time would be before and after each lecture/tutorial or seminar; lifts shall be designed to cater to the demand population of 12 percent to 15 percent with an interval of 30 s to 50 s. A higher staircase factor may be considered for traffic analysis.

4.4.10 *Data Centre*

Building population for data centre is usually low, however data centre has requirement of freight lifts. The design of freight lift shall be based on the input from architect/owner on the class of loading, dimension details and weight of equipment to be taken in freight lifts. As the freight lift hoist-way size is very big and usage is not extensive, the lift car size and door should consider all possible designs to reduce hoist-way sizes and increase saleable area.

4.4.11 *Buildings with* 24 Ĭ 7 *Operations*

In buildings operating 24 Ĭ 7 (round the clock), the peak traffic conditions would not be a typical up-peak but will occur during shift changes. The handling capacity should take into account the incoming, outgoing and shift change traffic as well as cafeteria traffic. Calculations shall be made assuming both up and down stops during this period. Particular attention should be paid while designating the drop off points, these should be assigned to

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a level so as to not increase the burden on the system. Designers need to consider that the lifts in such buildings would have a significantly higher number of starts/stops per hour than a conventional building. Lift designer shall take into consideration the shut-down of lifts for maintenance, especially for office building operating 24 Ĭ 7.

4.4.12 *Observatory*

The height at which the observatory is located and the number of people expected at the observatory level shall decide the speed and the number of lifts. The circulation logic is crucial in locating the observatory lifts. Also, if the observatory is connected with lounge/cafe/souvenir shops, etc, separate service lifts may need to be provided.

4.5 Other Considerations

Designers need to be aware that the door opening and closing times, acceleration and deceleration times, etc would vary between suppliers and equipment types and can impact the overall lift performance. The dispatch algorithms and controller responses would also vary between the suppliers and the equipment types and can impact the actual operational results.

Lifts will breakdown as well as require to be shut-down for regular maintenance and repairs. Lift availability might be hampered during renovation of the building as a lift might be taken up for movement of material and debris. Designers should take into consideration the impact of such non-availability of lifts. The provision of well-located and easily accessible stairs can considerably lessen the demands on the lifts and therefore architect/engineer should consider this aspect in the layout.

4.5.1 *Lift Speed*

For passenger lifts in a building, the general recommendations as given in Table 11 may be followed.

Table 11 Lift Speed

(*Clause* 4.5.1)

Sl No.	No. of Floors	Speed m/s
(1)	(2)	(3)
i)	Up to 6	0.6 to 1.0
ii)	7 to 15	1.0 to 1.5
iii)	16 to 20	1.5 to 1.75
iv)	21 to 30	1.75 to 2.5
v)	31 to 45	3.0 to 4.0
vi)	46 to 60	4.0 to 6.0
vii)	Above 60	6.0 and above

NOTES

1 Above table is considering buildings with average floor height of 3.0 m.

2 For office buildings average floor height is 4.2 m (*see* Table 5 and Table 10).

3 Finalizing the lift speed for any building depends on detailed traffic analysis because number of floors, area per floor, area per person and class of building are crucial factors, which serve as inputs for such traffic analysis.

4 Finalizing the speed for hotel depends on the number of keys per floor and similarly for an observatory depends on the number of expected footfall.

5 For any building, the speed of the lifts will have to be validated against the total population and travel height of the building.

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4.5.2 *Quiet Operation of Lifts*

Every precaution should be taken with passenger lifts to ensure quiet operation of the lift doors and machinery. The insulating of the lift machine and any motor generator from the floor by rubber cushions or by a precast concrete slab with rubber cushions, prevents transmission of most of the noise. In this connection, reference may be made to good practice [D-5A(5)] and Part D ôBuilding Services, Section 4 Acoustics, Sound Insulation and Noise Controlô of this NBCS for some useful recommendations.

5 LIFT ARRANGEMENTS AND PLANNING DIMENSIONS

The appropriate aspect of lift installation shall be discussed during the preliminary planning of the building with all concerned parties, namely, client, architect, consulting engineer and/or lift manufacturer. This enables the lift manufacturer to furnish the architect and/or consulting engineer with the proposed layout or vice-versa.

5.1 Exchange of Information

5.1.1 The guidelines laid down together with Fig. 2 will enable the preliminary scheme for the installation to be established. Figure 2 shows only some of the typical arrangements and variations are possible with respect to number of lifts and the layout of lifts especially when destination control system (DCS) is used instead of conventional group control system.

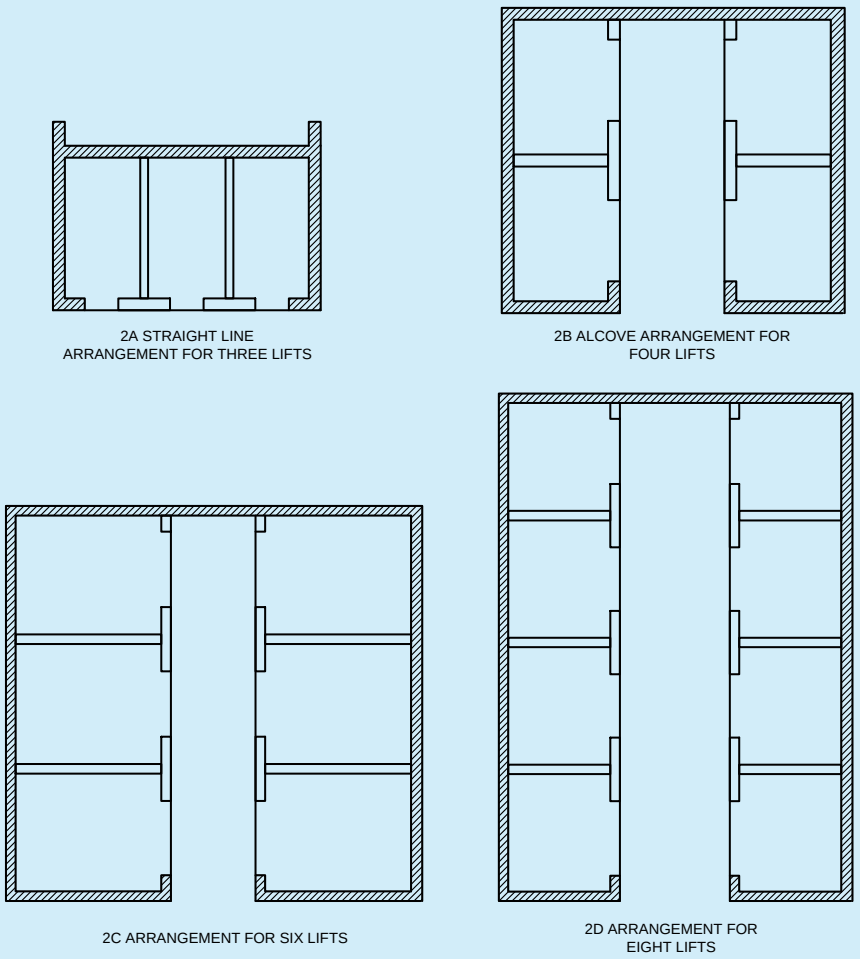

FIG. 2 TYPICAL ARRANGEMENT OF LIFTS

Although the recommended outline for the various classes of lifts enable the general planning details to be determined by the architect/engineer, these should be finally settled at the earliest possible stage by detailed investigation with the purchaserôs representative reaching agreement with the lift manufacturer (where

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necessary) before an order is finally placed. This will enable a check to be made and information to be exchanged on vital matters such as:

a) number, capacity, speed and disposition of the lifts necessary to give adequate lift service in the proposed building;

b) provision of adequate access to the machine room;

c) loads which the lift will impose on the building structure, and the holes to be left in the machine room floor and cut-outs for wall boxes for push-buttons and signals;

d) necessity for and type of insulation to minimize the transmission of vibration and noise to other parts of the building;

e) special requirements of local authorities and other requirements set out in the ópplanning permitô;

f) need for the builder to maintain accuracy of building as to dimensions and in-plumb;

g) periods of time required for preparation and approval of relevant drawings for manufacturing and the installation of the lift equipment;

h) requirements for fixing guide brackets to the building structure;

j) time at which electric power will be required before completion to allow for testing;

k) requirements for electrical supply feeders, etc;

m) requirements for scaffolding in the lift well and protection of the lift well prior to and during installation of equipment; and

n) delivery and storage of equipment.

5.1.2 *Information to be provided by Architect or Engineer*

As a result of preliminary discussions, the drawings of the building should give the following particulars and finished sizes:

a) number, type and size of lifts and position of lift well;

b) particulars of lift well enclosure;

c) size, position, number and type of landing doors;

d) number of floors served by the lift;

e) height between floor levels;

f) number of entrances;

g) total headroom;

h) provision of access to machine room;

j) provision of ventilation and, if possible, natural lighting of machine room;

k) height of machine room;

m) depth of lift pit;

n) position of lift machine, above or below lift well;

p) size and position of any trimmer joists or stanchions adjacent to the lift well at each floor;

q) size and position or supporting steel work at roof levels;

r) size and position of any footings or grillage foundations, if these are adjacent to the lift pit; and

s) in the case of passenger lifts whether the lift cage is required to carry household luggage, such as refrigerator, steel almirah, etc.

5.2 The lift lobby should be designed appropriately since this has bearing on the traffic handling especially when more number of lifts are involved. In a dual line arrangement (lifts opposite to each other) the lobby should be between 1.5 times and 2.5 times the depth of one car. Typically, the greater the number of lifts, the bigger the

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multiplier to be used. As an example, a quadruplex may use 1.5 to 2, where as an octuplet will need 2 to 2.5. For in-line (single line) arrangements, the lobby can be typically half of the above recommendations.

5.3 The architect/engineer should advise the lift manufacturer, if the authority has any special requirements regarding lifts in buildings in the administrative area concerned.

5.4 The architect/engineer should inform the lift manufacturer of the dates when the erection of the lift may be commenced and is to be completed so that sufficient time is allowed for the manufacture and erection of the lift.

5.5 When submitting application for a building permit to the local Authority, the building plans shall include the details of lifts (number of lifts duly numbered, location, type, type of doors, passenger capacity and speed).

5.6 Positioning of Lifts

A thorough investigation should be made for assessing the most suitable position for lift(s) while planning the building. It should take into account future expansions, if any. Though each building has to be considered individually for purposes of location of lifts, factors influencing the locations of passenger and goods lifts are given in **5.6.2** to **5.6.4**.

5.6.1 *Arrangement of Lifts*

The lifts should be easily accessible from all entrances to the building. For maximum efficiency, they should be grouped near the centre of the building. It is preferable not to have all the lifts out in straight line and, if possible, not more than four lifts should be arranged in this manner. If more than 4 lifts have to be grouped together in a straight line, then destination control systems would require to adopt. Further, the corridor should be wide enough to allow sufficient space for waiting passengers as well as for through passengers.

In some cases, when there are more than three lifts, the alcove arrangement is recommended. With this arrangement, the lift alcove leads off the main corridor so that there is no interference by traffic to other groups or to other parts of the ground floor. This arrangement permits the narrowest possible corridors and saves space on the upper floors. Walking distance to the individual lift is reduced and passenger standing in the centre of the group can readily see all the lift doors and landing indicators. The ideal arrangement of the lifts depends upon the particular layout of the respective building and should be determined in every individual case. Some typical recommended arrangements are given in Fig. 2.

5.6.2 *Passenger Lifts*

5.6.2.1 *Low and medium class flats*

Where a lift is arranged to serve two, three or four flats per floor, the lift may be placed adjoining a staircase, with the lift entrances serving direct on to the landings. Where the lift is to serve a considerable number of flats having access to balconies or corridors, it may be conveniently placed in a well-ventilated tower adjoining the building.

5.6.2.2 *Office buildings, hotels and high class flats*

In general, the arrangement as recommended in **5.6.1** should be followed. However, in case that is not possible, it is desirable to have at least a battery of two lifts at two or more convenient points of a building. If this is not possible, it is advisable to have at least two lifts side by side at the main entrance and one lift each at different sections of the building for inter-communication. When two lifts are installed side by side, the machine room shall be suitably planned with sufficient space for housing the machine equipment. The positioning of lifts side by side gives the following advantages:

a) All machines and switch gear may be housed in one machine room;

b) Lifts can be inter-connected more conveniently from an installation point of view; and

c) Greater convenience in service owing to the landing openings and each floor being adjacent.

5.6.2.3 *Shops and departmental stores*

Lifts in shops and stores should be situated so as to secure convenient and easy access at each floor.

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5.6.2.4 For buildings with more than 12 floors, where passenger and service lifts are provided in one lobby, it is recommended to have group control for all the lifts.

5.6.3 *Goods Lifts*

The location of lifts in factories, warehouses and similar buildings should be planned to suit the progressive movement of goods throughout the buildings, having regard to the nature of position of the loading platforms, railway sidings, etc. The placing of a lift in a fume or dust laden atmosphere or where it may be exposed to extreme temperatures, should be avoided, wherever possible. Where it is impossible to avoid installing a lift in an adverse atmosphere, the electrical equipment should be of suitable design and construction to meet the conditions involved.

Normally goods lifts have lower speeds than passenger lifts for the same travel because traffic conditions are less demanding, and more time is required for loading and unloading. As loads for goods lifts increase in size and weight, so the operation of loading and unloading becomes more difficult. Therefore, it is usual to require greater accuracy of levelling as the capacity of the goods lift increases.

A large capacity goods lift operating at high speed is often a very uneconomical solution. The inherent high cost is enhanced due to the very small demand for such equipment, much of which is custom made. The high capital cost of the lift, building work and electrical supply equipment usually shows a much smaller return as an investment than more normal size of lifts.

5.6.4 *Hospital Bed Lifts*

Hospital bed lifts should be situated conveniently near the ward and operating at the entrances. There shall be sufficient space near the landing door for easy movement of stretcher/bed. It is convenient to place the passenger lifts in a hospital, near the staircases.

5.7 General Arrangement Drawings (GAD)

The general arrangement drawings should be prepared by the lift manufacturer. The lift manufacturer requires sufficient information for the preparation of working drawings and is usually obtained from architectôs drawings supplemented by any information obtained from the site and by collaboration with the other contractors.

General arrangement drawings showing the layout of lifts duly numbered, details of builders work, for example, holes in walls for guide fixing, holes in machine room floor for ropes and conduits, recesses for landing sills, supports for lift machine and loads imposed on the building should be submitted by the lift manufacturer to the architect/engineer for written approval.

5.8 Additional Requirements for Passenger, Goods and Service Lifts

5.8.1 *Refuge Spaces and Clearances in the Pit or Bottom Car Clearances*

When the car is at its lowest position, at least one clear area where a refuge space can be accommodated as per Table 12 shall be provided on the pit floor having a vertical clearance as specified.

When the car is at the lowest position the following conditions shall also be satisfied:

a) The free vertical distance between the bottom of the pit and the lowest parts of the car shall be at least 0.50 m. This distance may be reduced for any part of the apron or parts of the vertically sliding car door(s) to a minimum of 0.10 m within a horizontal distance of 0.15 m to the adjacent wall(s).

b) The free vertical distance between the highest parts fixed in the pit, for instance a tensioning device for compensation means being in its highest position, jack supports, pipes and other fittings and the lowest parts of the car, shall be at least 0.30 m.

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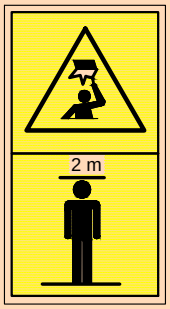
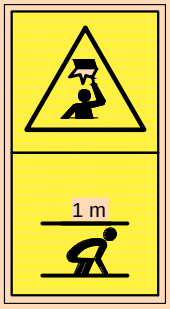
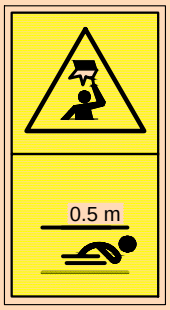
Table 12 Dimensional Requirements of Designated Area in the Pit

(*Clause* 5.8.1)

Sl No.	Type	Posture	Pictogram	Horizontal Dimensions of the Refuge Space mm Ĭ mm	Height of the Refuge Space mm
(1)	(2)	(3)	(4)	(5)	(6)
i)	1	Upright posture		400 I 500	2 000
ii)	2	Crouching		500 I 700	1 000
iii)	3	Laying		700 I 1 000	500

The following conditions shall also apply:

1) When the car is at its lowest position at least one clear area where a refuge space can be accommodated shall be provided on the pit floor.

2) If more than one person is necessary in the pit to carry out inspection and maintenance work, an additional refuge space shall be provided for each additional person.

3) In the case of more than one refuge space, they shall be of the same type and not interfering with each other.

4) A sign in the pit readable from the entrance(s) shall clearly indicate the allowed number of persons and the type of posture considered for the refuge spaces(s) accommodation.

NOTES

1 Dimensional requirements of designated area in the pit may vary depending upon manufacturer.

2 Designated manufacturer shall coordinate and upgrade the requirements on order specific.

3 Table 17 shall be referred for the recommended dimensions of pit depth.

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5.8.2 *Refuge Spaces on Car Roof and Clearances in Headroom or Car Top Clearances*

When the car is at its highest position, at least one clear area where a refuge space can be accommodated as per Table 13 shall be provided on the car roof having a vertical clearance as specified.

When the car is at its highest position, the clear distance between the lowest parts of the ceiling of the well (including beams and parts situated under the ceiling) and:

a) the highest pieces of equipment fixed on the roof, except for those covered in (b) and (c) below, shall be at least 0.50 m in any vertical or inclined direction within the projection of the car;

b) the highest part of the guide shoes or rollers, of the compensation means terminations and of the header or parts of vertically sliding doors, if any, shall be at least 0.10 m in any vertical direction within a horizontal distance of 0.40 m within the projection of the car; and

c) the highest part of the balustrade shall be at least:

1) 0.30 m within a horizontal distance of 0.40 m within the projection of the car and 0.10 m on the outside of the balustrade; and

2) 0.50 m in any inclined distance beyond 0.40 m within the projection of the car.

Table 13 Dimensional Requirements of Designated Area on Car Roof and Clearance on Head Room

(*Clause* 5.8.2)

Sl No.	Type	Posture	Pictogram	Horizontal Dimensions of the Refuge Space	Height of the Refuge Space
				mm Ĭ mm	mm
(1)	(2)	(3)	(4)	(5)	(6)
i)	1	Upright posture		400 Ĭ 500	2 000
ii)	2	Crouching		500 Ĭ 700	1 000

The following conditions shall also apply:

1) At least one clear area where a refuge space can be accommodated shall be provided on the car roof;

2) If more than one person is necessary in the car roof to carry out inspection and maintenance work, an additional designated area shall be provided for each additional person;

3) In the case of more than one refuge space, they shall be of the same type and not interfering with each other; and

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4) A sign on the car roof readable from the landings giving access to the car roof shall clearly indicate the allowed number of persons and the type of posture considered for the refuge space(s) accommodation.

NOTES

1 Dimensional requirements of designated area in the pit may vary depending upon manufacturer.

2 Designated manufacturer shall coordinate and upgrade the requirements on order specific.

3 Table 17 shall be referred for the recommended dimensions of pit depth.

5.9 Additional Requirements for Dumb Waiters

5.9.1 *Top Car Clearance*

The top car clearance shall be sufficient to avoid any protruding part fixed on the top of the car coming in direct contact with the ceiling or diverting sheave.

The clearance shall be calculated taking into account the following and shall not be less than the sum of the following four items:

a) bottom counterweight run-by;

b) stroke of the counterweight buffer used;

c) dimensions of the portion of the diverting sheave hanging underneath the ceiling in the lift well; and

d) 150 mm for compensating for gravity stopping distance and future repairs to the rope connections at counterweight and at the car or at the suspension points.

5.9.2 *Bottom Car Clearance*

The bottom car clearance shall be maintained in such a way that the counterweight shall not come in contact with the ceiling or any part hanging underneath the ceiling, when the car completely rests on fully compressed buffers, provided the buffers are spring type mounted on solid concrete or steel bed.

In case of wooden buffers the bottom car clearance shall be maintained in such a way that the total downward travel of the car from the service level of the immediate floor near the pit, shall not be more than the top counterweight clearance, when the wooden buffers are completely crushed.

5.9.3 *Top Counterweight Clearance*

The top clearance for the counterweight can be calculated taking into account the following and shall not be less than the sum of the following three items:

a) car run-by;

b) compression of the buffer spring or height of the wooden block used as buffer; and

c) 150 mm to compensate for gravity stopping distance for counterweight and any future repairs to rope connections at the counterweight at the car ends or at the suspension points.

5.9.4 *Run-by for Cars and Counterweights*

a) *Minimum bottom run-by* ð The bottom run-by for cars and counterweights shall not be less than 150 mm; and

b) *Maximum bottom run-by* ð In no case shall the maximum bottom run-by exceeds 300 mm.

5.10 Planning for Dimensions

5.10.1 *General*

The dimensions of lift well shall be chosen to accommodate the doors inside the well which is the normal practice. In special cases, the door may be accommodated in a recess in the front wall, for which prior consultation shall be made with the lift manufacturer.

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5.10.2 *Plan Dimensions*

All plan dimensions of lift well given hereunder, are the minimum clear plumb sizes. The architect/engineer, in conjunction with the builder, shall ensure that adequate tolerances are included in the building design so that the specified minimum clear plumb dimensions are obtained in the finished work.

NOTE ð The words 'clear plumb dimensions' should be noted particularly in case of high rise buildings.

Rough opening in concrete or brick walls to accommodate landing doors depend on design of architrave. It is advisable to provide sufficient allowances in rough opening width to allow for alignment errors of opening at various landings. When more than one lift is located in a common well, a minimum allowance of 150 mm for separator beams shall be made in the widths.

Where the governor operated counterweight safety is required under conditions stipulated in good practice [D-5A(1)], the tabular values under 5.10.3.1 should be revised in consultation with the lift manufacturer.

For outline dimensions of lifts having more than one car entrance, lift manufacturers shall be consulted.

5.10.3 *Outline Dimensions*

5.10.3.1 The outline dimensions of lift shaft, machine-room and machine room less lifts, pit depth, overhead height and raw door opening size for lifts to which this Subsection applies are specified in Table 14 to Table 32 as indicated below:

a)	Machine room lifts:		
	1)	Recommended dimensions of passenger lifts and service lifts	Table 14
	2)	Recommended dimensions of stretcher/hospital bed lifts	Table 15
	3)	Recommended dimensions of goods lifts with machine room	Table 16
	4)	Recommended dimensions of machine room height, overhead, pit depth for passenger, goods, stretcher/hospital lifts with machine room	Table 17
	5)	Recommended dimensions of automobile lifts with machine room ð Through type car	Table 18
	6)	Recommended dimensions of dumbwaiter lifts	Table 19
	7)	Entrance type for horizontal and vertical sliding doors	Table 20
	8)	Recommended dimension of goods lifts with machine room ð Series A : Vertical sliding door (entrance Type 4 and 5)	Table 21
	9)	Recommended dimension of goods lifts with machine room ð Series A : Vertical sliding door (entrance Type 6)	Table 22
	10)	Recommended dimension of goods lifts with machine room ð Series B : Horizontal sliding doors (entrance Type 3)	Table 23
	11)	Recommended dimension of goods lifts with machine room ð Series B : Vertical sliding doors (entrance, Type 4 and 5)	Table 24
	12)	Recommended dimension of goods lifts with machine room ð Series B : Vertical sliding doors (entrance Type 6)	Table 25
	13)	Recommended dimension of automobile lifts with machine room ð Trough type car ð Series B : Vertical sliding Door (entrance Type 4)	Table 26
b)	Machine room-less lifts:		
	1)	Recommended dimensions of passenger lifts MRL	Table 27
	2)	Recommended dimensions of stretcher/hospital lifts MRL	Table 28
	3)	Pit depth for passenger/stretcher/hospital lifts MRL	Table 29
	4)	Overhead height for passenger and stretcher/hospital lifts MRL	Table 30
	5)	Recommended dimensions of goods lifts MRL	Table 31
	6)	Recommended dimensions of automobile lifts MRL	Table 32

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Typical car and landing dimensions for horizontal sliding doors and vertical sliding doors for Series A and Series B are as shown in Fig. 8 and Fig. 9 respectively.

5.10.3.2 *Minimum floor to floor height*

Minimum floor to floor height for landings on same side for horizontally sliding door is f + 750 mm and for vertically bi-parting doors is 1.5 f + 250 mm, where f is clear entrance height in mm.

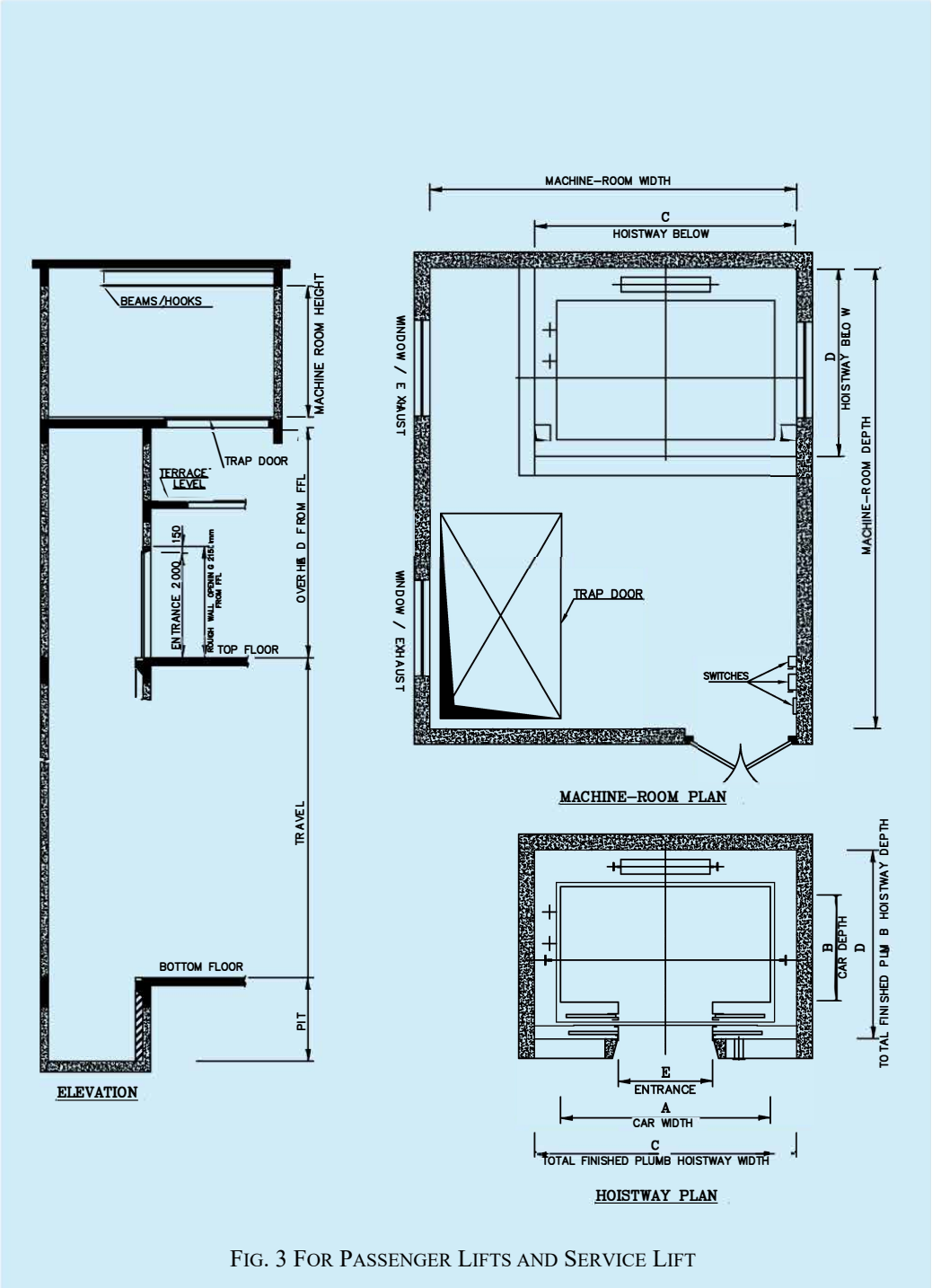

FIG. 3 FOR PASSENGER LIFTS AND SERVICE LIFT

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Table 14 Recommended Dimensions of Passenger Lifts and Service Lifts

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	No. of Passengers	Rated Load	Car Size		COPD Door	Passenger and Service Lifts with Machine Room: Shaft Sizes													
						Rated speed < 1 m/s		1.0 m/s Ò Rated Speed Ò2.5 m/s		3.0 m/s Ò Rated Speed Ò3.5 m/s		4.0 m/s Ò Rated Speed Ò5.0 m/s		Rated Speed = 6.0 m/s		7.0 m/s Ò Rated Speed Ò8.0 m/s		9.0 m/s ÒRated Speed Ò10.0 m/s	
						Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size	
		kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
i)	4	272	1 100	700	800	1 900	1 300	1 900	1 300	ï	ï	ï	ï	ï	ï	ï	ï	ï	ï
ii)	6	408	1 100	1 000	800	1 900	1 700	1 900	1 700	ï	ï	ï	ï	ï	ï	ï	ï	ï	ï
iii)	8	544	1 400	1 100	800	1 900	1 750	1 900	1 900	ï	ï	ï	ï	ï	ï	ï	ï	ï	ï
iv)	10	680	1 300	1 350	800	1 900	2 150	1 900	2 150	ï	ï	ï	ï	ï	ï	ï	ï	ï	ï
v)	13	884	2 000	1 100	900	2 600	1 900	2 600	1 900	2 800	2 200	ï	ï	ï	ï	ï	ï	ï	ï
vi)	14	952	1 600	1 400	900	2200	2100	2200	2100	2 400	2 400	ï	ï	ï	ï	ï	ï	ï	ï
vii)	15	1020	1450	1 650	1000	2 600	2 000	2 600	2 000	2 250	2 650	2 600	2 150	2 600	2 250	2 600	2 300	2 600	2450
viii)	16	1 088	1 600	1 600	1 000	2 450	1 900	2 600	2 100	2 400	2 600	2 600	2 350	2 600	2 450	2 600	2 500	2 600	2650
ix)	18	1 224	2 000	1 400	1 000	ï	ï	2 600	2 350	2 800	2 400	2 600	2 350	2 600	2 350	2 700	2 300	2 700	2450
x)	20	1 360	2 000	1 500	1 000	ï	ï	2 600	2 350	2 800	2 500	2 600	2 350	2 600	2 350	2 700	2 400	2 700	2550
xi)	22	1 496	2 100	1 600	1 100	ï	ï	2 700	2 300	2 900	2 600	2 700	2 350	2 700	2 450	2 800	2 500	2 800	2550

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Table 14 (*Concluded*)

Sl No.	No. of Passengers	Rated Load	Car Size		COPD Door	Passenger and Service Lifts with Machine Room: Shaft Sizes													
						Rated speed < 1 m/s		1.0 m/s Ò Rated Speed Ò2.5 m/s		3.0 m/s Ò Rated Speed Ò3.5 m/s		4.0 m/s Ò Rated Speed Ò5.0 m/s		Rated Speed = 6.0 m/s		7.0 m/s Ò Rated Speed Ò8.0 m/s		9.0 m/s Ò Rated Speed Ò10.0 m/s	
						Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size	
		kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
xii)	24	1 632	1 800	2 000	1 100	ï	ï	2 600	2 600	2 600	3 000	3 000	2 350	3 000	2 450	3 050	2 550	3 050	2550
xiii)	26	1 768	2 350	1 600	1 200	ï	ï	2 600	2 700	3 150	2 600	2 600	2 350	2 600	2 450	2 650	2 550	2 650	2550
xiv)	29	1 972	2 350	1 700	1 200	ï	ï	ï	ï	3 150	2 700	3 000	2 500	3 000	2 550	3 050	2 600	3 050	2700

NOTES

1 All dimensions given above for lifts having centre opening power operated doors (COPD) with counterweight at rear, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed between the manufacturer and the purchaser is permitted. However, variation in:

a) Car inside dimensions shall be within the minimum and maximum area limits specified in accordance with Table 37;

b) Entrance width on higher side is permitted; and

c) Entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

2 The minimum size of the lift car and all other requirements relating to accessibility, in all public buildings shall be in accordance with good practice [D-5A(3)].

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Table 15 Recommended Dimensions of Stretcher/Hospital Lifts

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl. No	No. of Passengers	Rated Load	Rounded off Rated Load	Car Size		2P TSP D Door	Hospital Bed / Stretcher Lifts with Machine Room: Shaft Sizes													
							Rated Speed Ò1 m/s		0.6 m/s Ò Rated Speed Ò2.5 m/s		3.0 m/s Ò Rated Speed Ò3.5 m/s		4.0 m/s Ò Rated Speed Ò5.0 m/s		Rated Speed = 6.0 m/s		7.0 m/s Ò Rated Speed Ò 8.0 m/s		9.0 m/s Ò Rated Speed Ò10.0 m/s	
							Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size	
		kg	kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
i)	15	1 020		1 000	2 400	800	1 800	3 000	1 800	3 000	2 100	3 400								
ii)	20	1 360		1 300	2 400	1 200			2 300	3 000	2 650	3 400	2 350	3 000	2 350	3 000	2 500	3 000	2 500	3 000
iii)	26	1 768	1 800	1 400	2 550	1 200			2 650	3 050	2 650	3 550	2 500	3 050	2 500	3 050	2 600	3 150	2 650	3 150
iv)	29	1 972	1 500	1500	2 700	1 400			2 650	3 200	3 100	3 700	2 600	3 200	2 600	3 200	2 700	3 200	2 700	3 200
v)	36	2 448	2 500	1 800	2 700	1 400			2 800	3 150	2 900	3 200	2 900	3 200	2 900	3 200	3 000	3 200	3 000	3 200

NOTES

1 All dimensions given above for lifts having two panel telescopic doors (2P TSPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser is permitted. However, variation in:

a) Car inside dimensions shall be within the maximum area limits specified in accordance with Table 37;

b) Entrance width on higher side is permitted; and

c) Entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

2 Car depth of 2 100 mm may be considered in residential/commercial buildings, where use of only ambulance stretcher is envisaged. The hoist-way depth maybe reduced accordingly.

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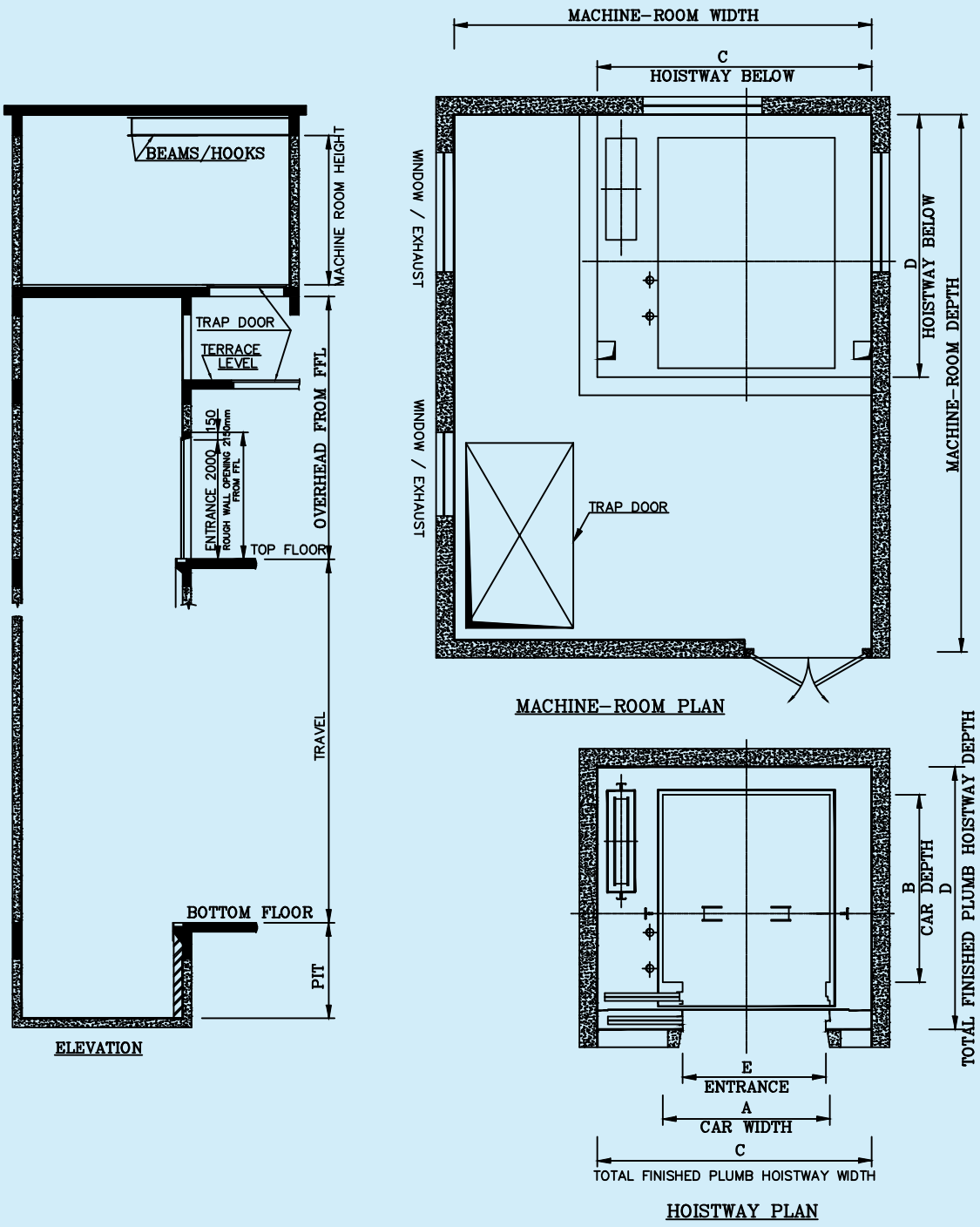

FIG. 4 (TABLE 15) FOR STRETCHER/HOSPITAL LIFTS

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Table 16 Recommended Dimensions of Goods Lifts with Machine Room

(*Clause* 5.10.3.1)

All dimensions are in millimetres.

Sl No.	Rated Load	Car Size		COPD Door	0.6 m/s Ò Rated Speed ÒÒ2.5 m/s		3.0 m/s Ò Rated Speed Ò3.5 m/s		4.0 m/s Ò Rated Speed Ò 5.0 m/s		Rated Speed = 6.0 m/s		7.0 m/s Ò Rated Speed Ò 8.0 m/s		9.0 m/s ÒRated Speed Ò10.0 m/s	
					Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size	
	kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
i)	1 000	1 400	1 800	2P-tel-1 200	2 550	2 200	ï	ï	ï	ï	ï	ï	ï	ï	ï	ï
ii)	1 500	1 700	2 000	4P-1 500	2 750	2 550	ï	ï	ï	ï	ï	ï	ï	ï	ï	ï
iii)	2 000	1 700	2 500	4P-1 500	2 800	3 050	2 800	3 050	2 900	3 050	3 000	3 050	3 000	3 050	3 000	3 050
iv)	2 500	2 000	2 500	4P-1 800	3 100	3000	3 000	3 050	3 100	3 050	3 200	3 050	3 200	3 050	3 200	3 050
v)	3 000	2 000	3 000	4P-1 800	3 100	3 550	3 000	3 550	3 100	3 550	3 200	3 550	3 200	3 550	3 200	3 550
vi)	4 000	2 500	3 000	4P-2 100/ 6P-2 100	3 700	4 000	3 700	3 650	ï	ï	ï	ï	ï	ï	ï	ï
vii)	5 000	2 500	3 600	4P-2 100/ 6P-2 100	3 850	4 250	3 850	4 250	ï	ï	ï	ï	ï	ï	ï	ï

NOTES

1 All dimensions given above for lifts having centre opening power operated doors (COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, the minimum rated load for the goods lift shall be based on a load of not less than 3.45 kN/m^2 of the net inside car area.

2 Car inside dimensions shall be within the maximum area limits specified in accordance with Table 32.

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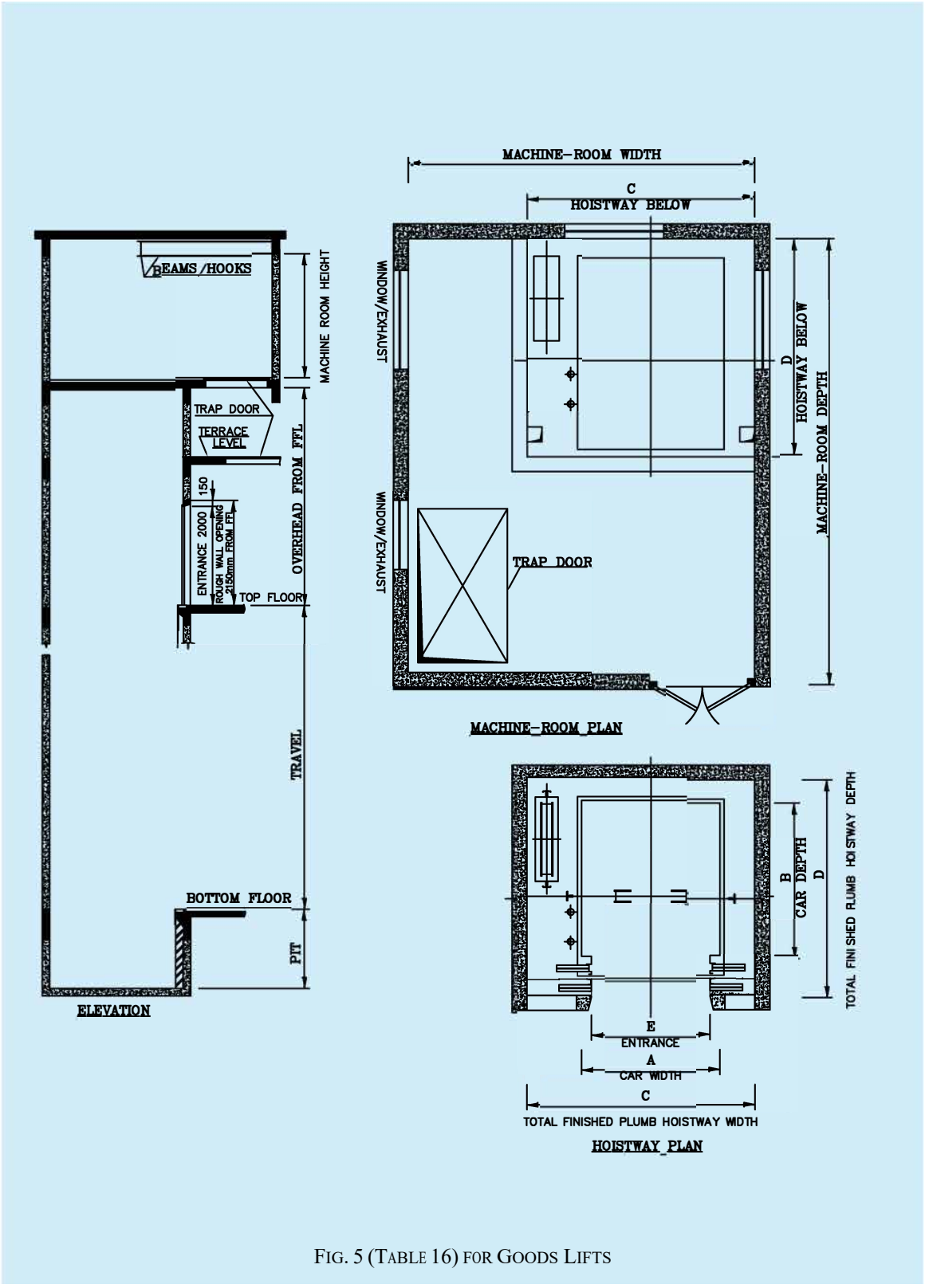

FIG. 5 (TABLE 16) FOR GOODS LIFTS

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Table 17 Recommended Dimensions of Machine Room Height, Overhead, Pit Depth for Passenger, Goods, and Stretcher/Hospital Lifts with Machine Room

(*Clauses* 5.8.1, 5.8.2 *and* 5.10.3.1)

All dimensions are in millimetres.

For Speed up to 3.5 m/s

Sl No.	No. of Passengers	Rated Load kg	Dimensions of Pit Depth, Overhead Height (HR) and Machine Room Height(MR)																			
			0.7 m/s			1.0 m/s			1.6 m/s			2 m/s			2.5 m/s			3 m/s			3.5 m/s		
			Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
i)	4	272	1 350	CH + 1 900	2 500	1 500	CH + 1 950	2 500	1 600	CH + 2 400	2 500	2 200	CH + 2 800	2 500	ï	ï	ï	ï	ï	ï	ï	ï	ï
ii)	6	408	1 350	CH + 1 900	2 500	1500	CH +1950	2500	1 600	CH + 2 400	2 500	2 200	CH + 2 800	2 500	ï	ï	ï	ï	ï	ï	ï	ï	ï
iii)	8	544	1 350	CH + 1 900	2 500	1500	CH +1950	2500	1 600	CH + 2 400	2 500	2 200	CH + 2 800	2 500	ï	ï	ï	ï	ï	ï	ï	ï	ï
iv)	10	680	1 350	CH + 1 900	2 500	1500	CH + 1950	2500	1 600	CH +2 400	2 500	2 200	CH + 2 800	2 500	2 250	CH + 2 800	2 500	ï	ï	ï	ï	ï	ï
v)	13	884	1 350	CH + 1 900	2 500	1500	CH +1950	2500	1 600	CH +2 400	2 500	2 200	CH + 2 800	2 500	2 500	CH + 3 000	2 500	3 200	CH + 3 250	3 500	4 500	CH + 3 550	3 500
vi)	14	952	1 350	CH + 1 900	2 500	1500	CH +1950	2500	1 800	CH + 2 400	2 500	2 200	CH + 2 800	2 500	2 500	CH + 3 000	2 500	3 200	CH + 3 250	3 500	4 500	CH + 3 550	3 500
vii)	16	1 088/ 1 000	1500	CH+ 1 900	2 500	1500	CH +1950	2500	1 800	CH + 2 400	2 500	2 200	CH + 2 800	2 500	2 500	CH + 3 000	2 500	3 200	CH + 3 250	3 500	4 500	CH + 3 550	3 500
viii)	18	1 224	ï	ï	ï	1 500	CH + 1950	2500	1 800	CH + 2 400	2 500	2 200	CH + 2 800	2 500	2 500	CH + 3 000	2 500	3 200	CH + 3 250	3 500	4 500	CH + 3 550	3 500
ix)	20	1 360	ï	ï	ï	1 500	CH + 1 950	2500	1 800	CH + 2 400	2 500	2 200	CH +2 800	2 500	2 500	CH + 3 000	3 000	3 200	CH+ 3 250	3 500	4 500	CH+ 3 550	3 500
x)	22	1 496/ 1 500	ï	ï	ï	1 500	CH + 1 950	2500	1 800	CH + 2 400	3 000	2 200	CH + 2 800	3 000	2 500	CH + 3 000	3 000	3 200	CH+ 3 250	3 500	4 500	CH+ 3 550	3 500
xi)	24	1 632	ï	ï	ï	1500	CH + 1950	2500	1 800	CH + 2 400	3 000	2 200	CH + 2 800	3 000	2 500	CH + 3 000	3 000	3 200	CH+ 3 250	3 500	4 500	CH+ 3 550	3 500
xii)	26	1 768	ï	ï	ï	1 500	CH + 1 950	3000	1 800	CH + 2 400	3 000	2 200	CH + 2 800	3 000	2 500	CH + 3 000	3 000	3 200	CH+ 3 450	3 500	4 500	CH+ 3 550	3 500
xiii)	29	1 972/ 2 000	ï	ï	ï	1 600	CH + 1 950	3000	1 800	CH + 2 400	3 000	2 200	CH + 2 800	3 000	2 500	CH + 3 000	3 000	3 200	CH+ 3 450	3 500	4 600	CH+ 3 550	3 500
xiv)	ï	2 500	ï	ï	ï	1 800	CH + 1 950	4000	1 800	CH + 2 400	4 000	2 200	CH + 2 800	4 000	2 500	CH + 3 000	4 000	3 200	CH+ 3 450	4 000	4 600	CH+ 3 550	4 000
xv)	ï	3 000	ï	ï	ï	1 800	CH + 1 950	4000	1 800	CH + 2 400	4 000	2 200	CH + 2 800	4 000	2 500	CH + 3 000	4 000	3 200	CH+ 3 450	4 300	4 600	CH+ 3 600	4 300
xvi)	ï	4 000	ï	ï	ï	1 800	CH + 2200	4300	1 800	CH + 2 400	4 300	2 200	CH + 2 800	4 300	2 500	CH + 3 000	4 300	3 200	CH+ 3 450	4 300	4 600	CH+ 3 600	4 300
xvii)	ï	5 000	ï	ï	ï	1 800	CH + 2200	4500	1 800	CH + 2 400	4 500	2 200	CH + 2 800	4 500	2 500	CH + 3 000	5 000	3 200	CH+ 3 450	5 000	4 600	CH+ 3 600	5 000

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Table 17 (*Concluded*)

Sl No.	No. of Passengers	Rated Load	Passenger, Goods, Stretcher/Hospital Lifts with Machine Room: Dimensions of Pit Depth, Overhead Height (HR) and Machine Room Height(MR)																			
			4 m/s			5 m/s			6 m/s			7 m/s			8 m/s			9 m/s			10 m/s		
		kg	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
i)	14	952	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
ii)	16	1 088/ 1 000	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
iii)	18	1 224	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
iv)	20	1 360	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
v)	22	1 496/ 1 500	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
vi)	26	1 768	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 300	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
vii)	29	1 972/ 2 000	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 300	5 500	CH + 3 800	4 300	5 900	CH + 5 000	5 000	6 500	CH + 5 800	5 000	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
viii)	ï	2 500	4 600	CH + 3 450	4 300	4 700	CH + 3 450	5 000	5 500	CH + 3 800	5000	5 900	CH + 5 500	5 000	6 500	CH + 6 300	5 000	7 100	CH + 7 000	5 000	7 500	CH + 7 500	5 000
ix)	ï	3 000	4 600	CH + 3 600	4 300	4 700	CH + 3 600	5 000	5 500	CH + 4 000	5 000	5 900	CH + 5 500	5 000	6 500	CH + 6 300	5 000	7 100	CH + 7 000	5 000	7 500	CH + 7 500	5 000

CH ï Car clear inside height measured from car finished floor level to false ceiling.

NOTES

1 Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in the table above. These dimensions may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

2 In case of goods lifts minimum pit depth required is 1 600 mm.

3 In case of lift speeds 3.5 m/s and 4 m/s with rear counterweight the pit depth requirement could be less by about 500 mm to 1 000 mm.

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Table 18 Recommended Dimensions of Automobile Lifts with Machine Room-Through Type Car

(Rated Speed = 0.6 m/s or 1.0 m/s)

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	Rated Load	Car Size		COPD Door	Shaft Size		Car Height	Overhead Height	Pit Depth	Machine Room Height
	Kg	Width	Depth	Width	Width	Depth	CH	HR	PH	MR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	2 500	2 500	5 000	4P - 2 400	4 000	5 780	2 200	5 200	1 800	4 000
ii)	3 000	2 700	5 400	4P - 2 400	4 000	5 880				
iii)	4 000	3 000	5 800	6P - 3 000	4 300	6 700			2 000	4 500
iv)	5 000	3 000	6 000	6P - 3 000	4 300	6 900				

NOTES

1 All dimensions given above for lifts having centre opening power operated doors (COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, the minimum rated load for the automobile lift shall be based on a load of not less than 1.45 kN/m^2 of the net inside car area.

2 Dimensions of machine room height, pit depth and overhead may differ in practice as per individual manufacturerõs design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(6)].

3 The lift car width should be selected such that in case of emergency while the automobile is in the car-lift the driver should be able to open the automobile door and come out of the automobile.

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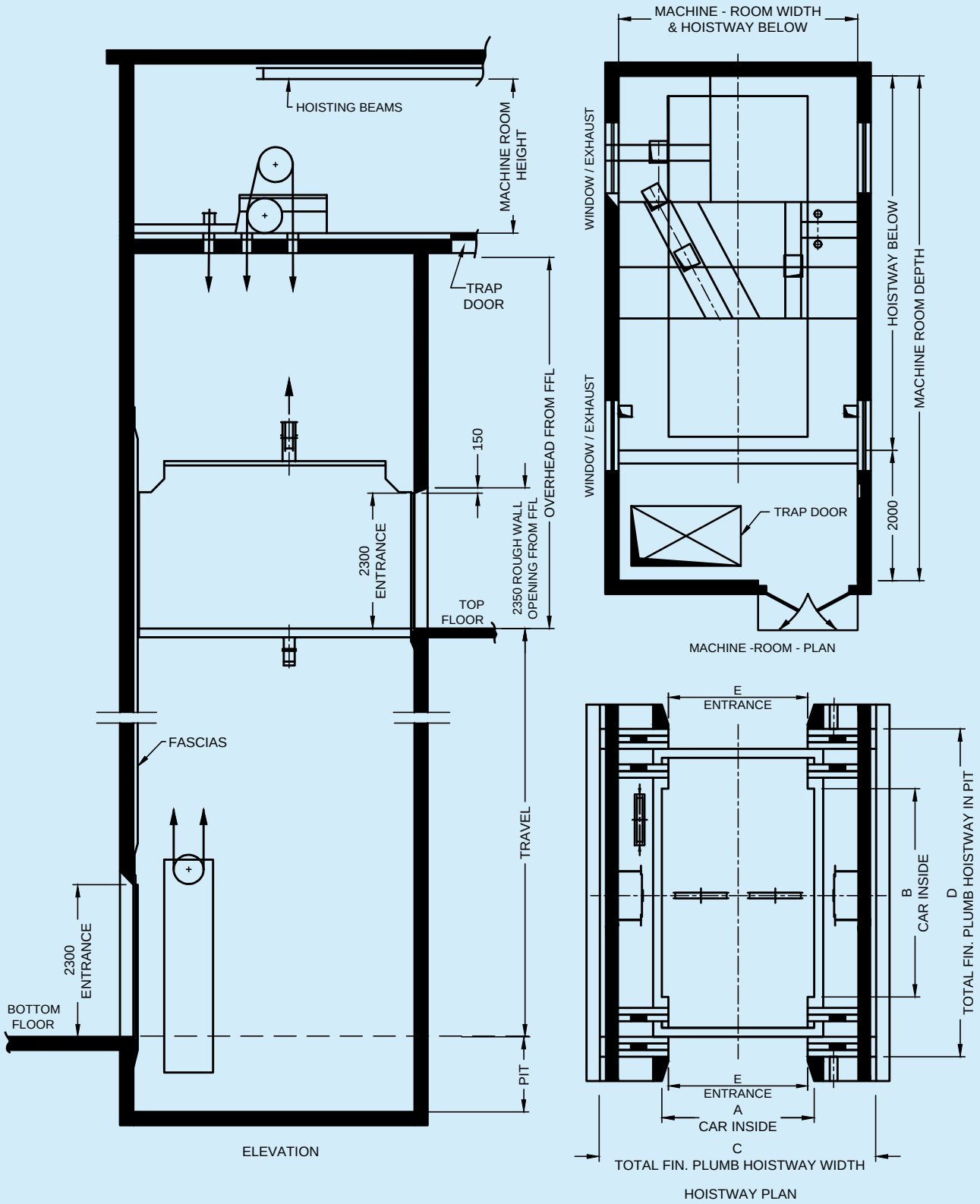

All dimensions in mm.

FIG. 6 (TABLE 18) FOR RECOMMENDED DIMENSIONS OF AUTOMOBILE LIFTS

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Table 19 Recommended Dimensions of Dumbwaiter Lifts

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	Load	Car Inside			Lift Well		Entrance	Machine Room Extension
	kg	*A*	*B*	*H*	*C*	*D*	*E*	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	100	700	700	800	1 200	900	700	D + 1 000
ii)	150	800	800	900	1 300	1 000	800	D + 1 000
iii)	200	900	900	1 000	1 400	1 100	900	D + 1 000
iv)	250	1 000	1 000	1 200	1 500	1 200	1 000	D + 1 000

NOTES

1 Entrance width óEô is based on assumption of provision of vertical bi-parting doors (no car door is normally provided).

2 D + 1000, where óDô is shaft depth.

3 Head room ï 3 000 (with M/C Room) *Max* speed 0.34 m/s.

4 Head room MRL ï 4 050 to 4 450 (*Max* speed 0.34 m/s).

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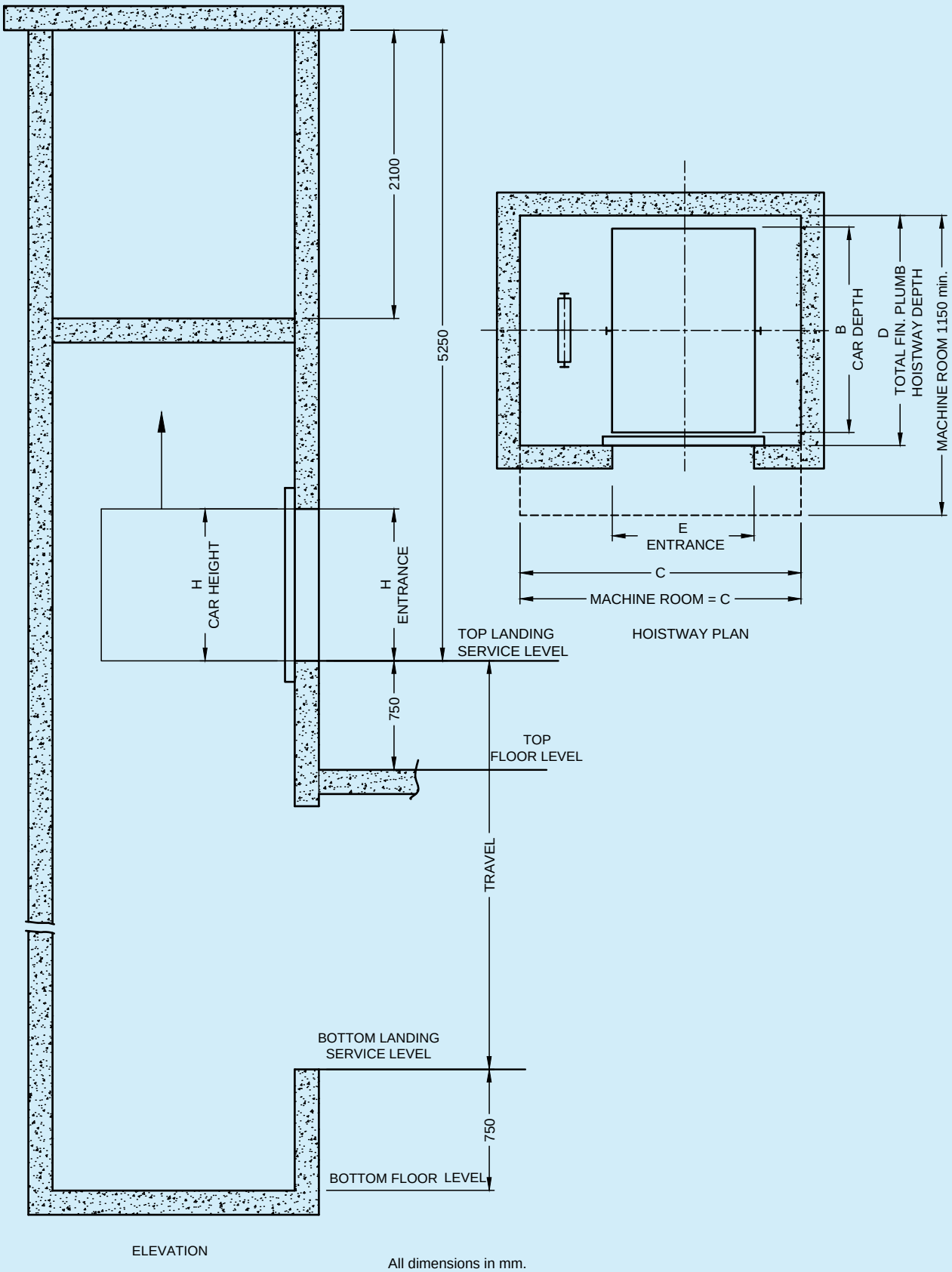

FIG. 7 (TABLE 19) FOR DUMBWAITER LIFTS

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Table 20 Entrance Type: Horizontal and Vertical Sliding Doors

(*Clause* 5.10.3.1, *Table* 21, *Table* 22, *Table* 24, *Table* 25 *and* *Table* 26)

Sl No.	Type	Horizontal Sliding Doors		Vertical Sliding Doors	
		Landing Door	Car Door	Landing Door	Car Door
(1)	(2)	(3)	(4)	(5)	(6)
i)	Type 1	Telescopic door (side opening)	Telescopic door (side opening)	ï	ï
ii)	Type 2	Centre opening door	Centre opening door	ï	ï
iii)	Type 3	Centre telescopic door	Centre telescopic door	ï	ï
iv)	Type 4	ï	ï	Bi-parting (central opening)	Telescopic upwards
v)	Type 5	ï	ï	Bi-parting pass type (central opening, overlapping)	Telescopic upwards
vi)	Type 6	ï	ï	Telescopic upwards	Telescopic upwards

Two types of loading (load per unit area) are addressed:

Series A ð Passenger and goods (freight) lifts with loading conforming to Table 6 and Table 7 of accepted standard [D-5A(1)].

Series B ð Goods (freight) and automobiles lifts which have lesser loading as compared to that for Series A.

The lift well and machine room dimensions of electric lift for Series A and Series B are as shown in Fig. 10, and lift well and machine room dimensions of hydraulic lift for Series A and Series B are as shown in Fig. 11.

Automobile lifts with machine room for through type car Series B with vertical sliding door is shown in Fig. 12.

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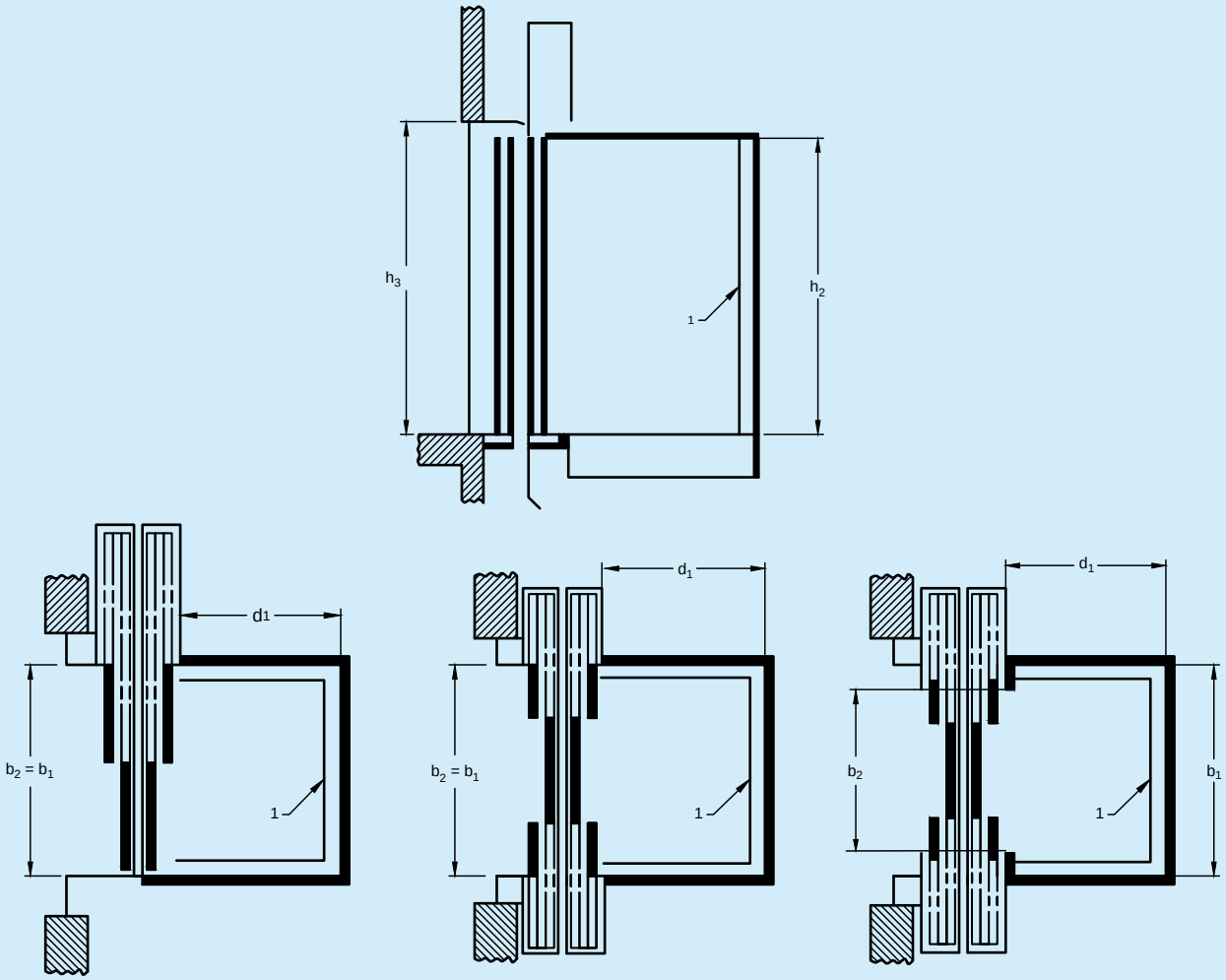

Key

1 Protective elements
b_1 Car width
b_2 Entrance width
d_1 Car depth
h_3 Entrance height
h_4 Car height

Entrance	:	Type 1	Type 2	Type 3
Landing door	:	Telescopic door (side opening)	Centre opening door	Centre telescopic door
Car door	:	Telescopic door (side opening)	Centre opening door	Centre telescopic door

FIG. 8 CAR AND LANDING DIMENSIONS FOR HORIZONTAL SLIDING DOORS FOR SERIES A AND SERIES B

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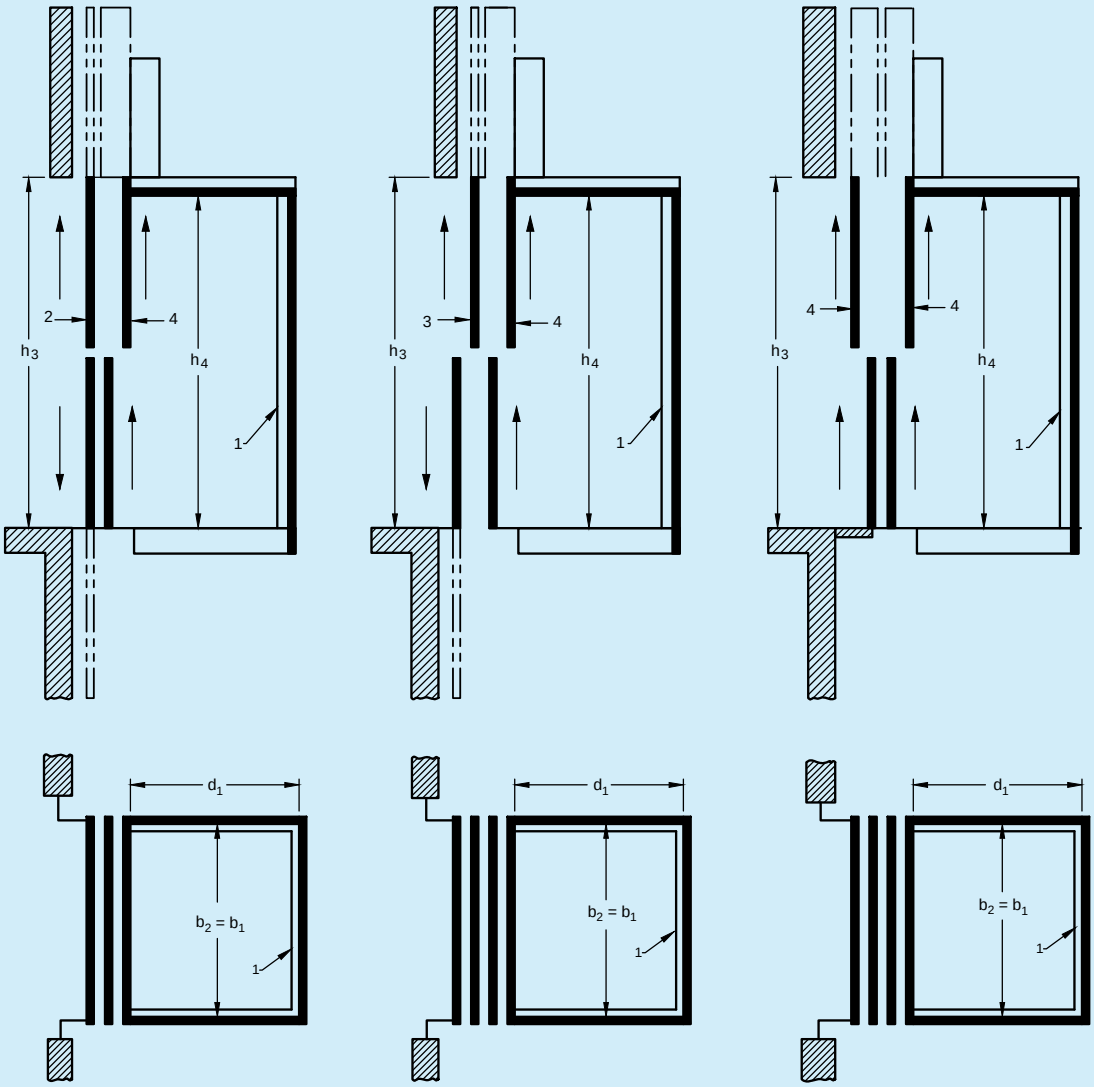

Key

1 Protective elements
2 Bi-parting (central opening)
3 Bi-parting , pass type (central opening, overlapping)
4 Telescopic upwards

b_1 Car width
b_2 Entrance width
d_1 Car depth
h_3 Entrance height
h_4 Car height

Entrance	:	Type 4	Type 5	Type 6
Landing door	:	Bi-parting (centre opening)	Bi-parting , pass type (centre opening, overlapping)	Telescopic upwards
Car door	:	Telescopic upwards	Telescopic upwards	Telescopic upwards

FIG. 9 CAR AND LANDING DIMENSIONS FOR VERTICAL SLIDING DOORS FOR SERIES A AND SERIES B

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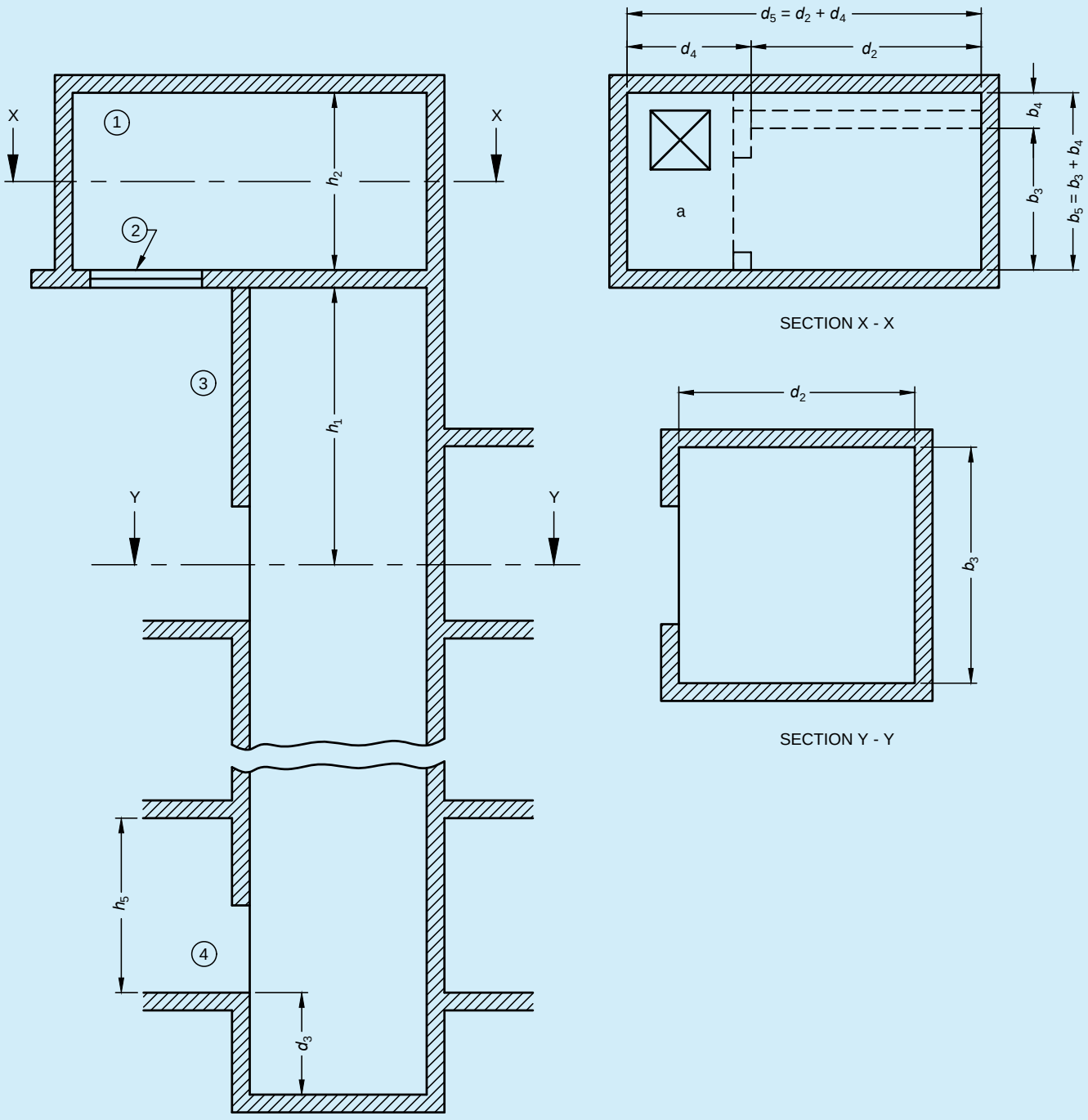

KEY :

1 - MACHINE ROOM
2 - TRAP DOOR
3 - HIGHEST LEVEL SERVE
4 - LOWEST LEVEL SERVED
5 - TELESCOPIC UPWARDS
6 - BI-PARTING (CENTER OPENING)
b_3 - WELL WIDTH
b_4 - MACHINE ROOM EXTENSION WIDTH
b_5 - MACHINE ROOM WIDTH
d_2 - WELL DEPTH
d_3 - PIT DEPTH
d_4 - MACHINE ROOM EXTENSION DEPTH
d_5 - MACHINE ROOM DEPTH
h_1 - OVERHEAD HEIGHT
h_2 - MACHINE ROOM HEIGHT

IT IS NECESSARY TO HAVE AN ACCESS DOOR TO THE MACHINE ROOM ALTHOUGH THIS IS NOT INDICATED ON THE SKETCH

FIG. 10 LIFT WELL AND MACHINE ROOM DIMENSIONS: ELECTRIC LIFTS FOR SERIES A AND SERIES B

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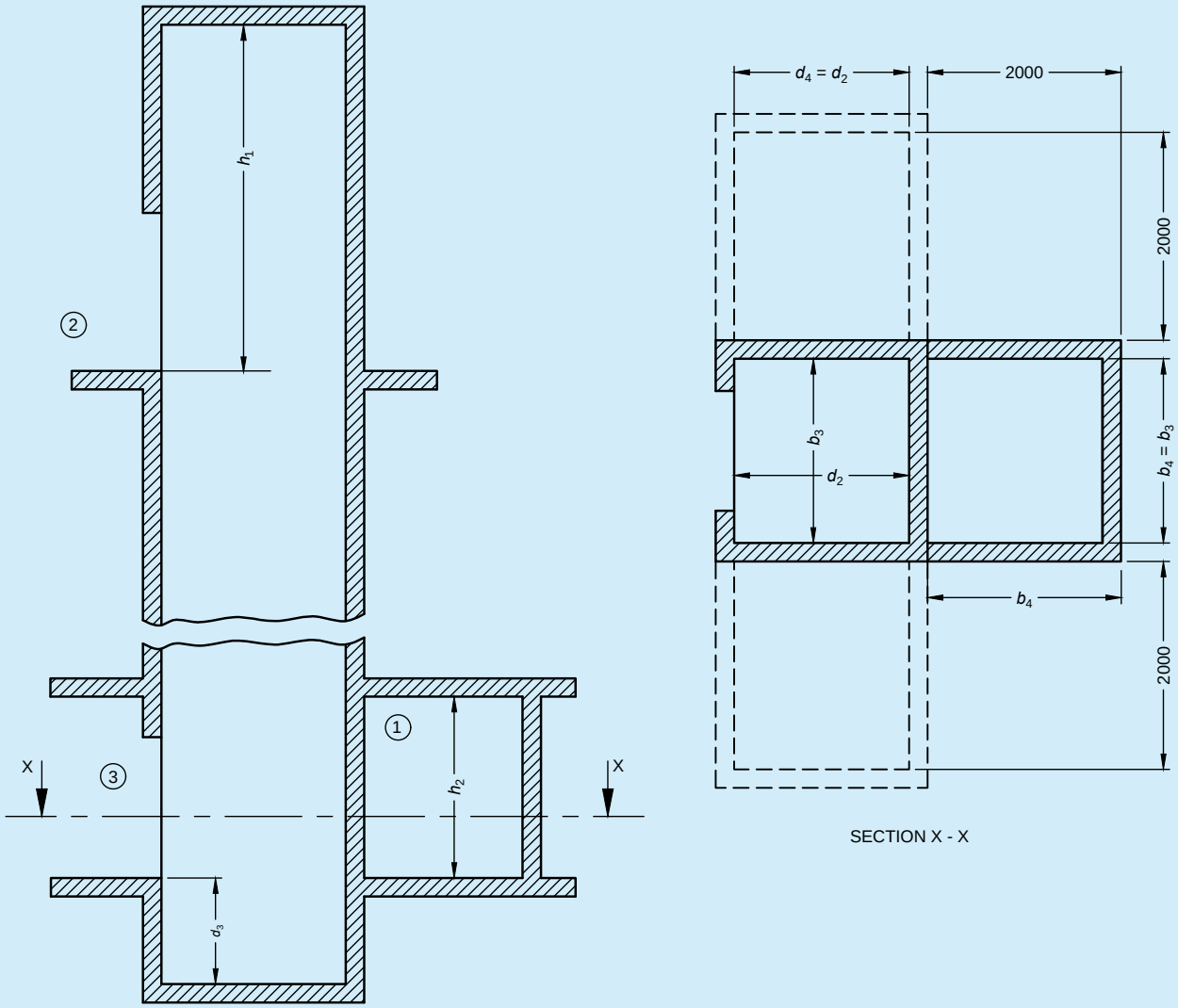

SECTION X - X

1 - MACHINE ROOM
2 - HIGHEST LEVEL SERVED
3 - LOWEST LEVEL SERVED
b_3 - WELL WIDTH
b_4 - MACHINE ROOM WIDTH
d_2 - WELL DEPTH
d_3 - PIT DEPTH
d_4 - MACHINE ROOM DEPTH
h_1 - HEADROOM HEIGHT
h_2 - MACHINE ROOM HEIGHT

IT IS NECESSARY TO HAVE AN ACCESS DOOR TO THE MACHINE ROOM ALTHOUGH THIS IS NOT INDICATED ON THE SKETCH

FIG. 11 LIFT WELL AND MACHINE ROOM DIMENSIONS: HYDRAULIC LIFTS FOR SERIES A AND SERIES B

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Table 21 Recommended Dimensions of Goods Lifts with Machine Room Series A Cars ð Vertical Sliding Door (Entrance Type 4 and 5)

(*Clause* 5.10.3.1)

All dimensions are in millimetres.

Series A Car with Vertical Sliding Door															
Sl No.	**Rated Load**	**Rated Speed**	**Car Size**		**Door**	**Shaft Size**		**Car Height**	**Entrance Height**	**Overhead Height**	**Pit Depth**	**Machine Room Size**		**Machine Room Height**	**Min Floor to Floor Height**
	kg	m/s	Width (b_1)	Depth (d_1)	Width (b_2)	Width (b_3)	Depth (d_2)	CH (h_4)	EH (h_3)	HR (h_1)	PH (d_3)	Width (b_5)	Depth (d_5)	MR (h_2)	MM (h_5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
i)	1 000	0.5 to 1.0	1 400	1 800	1 400	2 350	2 300	2 200	2 000	4 800	1 600	(b_3 + 1 000)	(d_2 + 2 500)	2 500	(h_3+f)
ii)	1 500		1 700	2 000	1 700	2 650	2 500	2 200	2 000	4 800	1 600			2 500	
iii)	1 600		1 700	2 100	1 700	2 650	2 600	2 200	2 000	4 800	1 600			2 500	
iv)	2 000		1 700	2 500	1 700	2 800	3 000	2 200	2 000	4 800	1 600			2 500	
v)	2 500		2 000	2 500	2 000	3 050	3 000	2 200	2 000	4 800	1 600			2 500	
vi)	3 000	0.5	2 000	3 000	2 000	3 100	3 600	2 200	2 000	4 800	1 800			3 000	
vii)	3 500		2 500	2 550	2 500	3 700	3 100	2 200	2 000	4 800	1 800			3 000	
viii)	4 000		2 500	3 000	2 500	3 700	3 600	2 200	2 000	4 800	1 800			3 000	
ix)	5 000		2 500	3 600	2 500	3 700	4 100	2 200	2 000	4 800	1 800			3 000	

NOTES

1 For width and depth of machine room and minimum floor to floor height requirement refer below:

a) Machine room width is (b_3 +b_4), where b_3 is width of shaft size and b_4 as 1000 mm to be considered;

b) Machine room depth is (d_2 +d_4), where d_2 is depth of shaft size and d_4 as 2500mm to be considered; and

c) Minimum floor to floor height (h_5) for landings for vertical sliding door is (h_3 + f), where óh_3ô is clear entrance height and dimension ófô depends upon the type of door. Refer Table 20 for vertical sliding door types.

2 In case counterweight safety is applicable check for dimensions with lift manufacturer.

3 Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in the table above. These dimensions may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

4 All dimensions given above for machine room lifts are recommended dimensions for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchasers are permitted. However, the minimum rated load for the goods lift shall be based on Class of loading for the net inside car area. Refer 8.3.1.1 for class of loading.

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Table 22 Recommended Dimensions of Goods Lifts with Machine Room ð Series A cars ð Vertical Sliding Door (Entrance Type 6)

(*Clause* 5.10.3.1)

All dimensions are in mm.

Series A Car with Vertical Sliding Door

Sl No.	Rated Load	Rated Speed	Car Size		Door	Shaft Size		Car Height	Entrance Height	Overhead Height	Pit Depth	Machine Room Size		Machine Room Height	Min Floor to Floor Height
	kg	m/s	Width (b_1)	Depth (d_1)	Width (b_2)	Width (b_3)	Depth (d_2)	CH (h_4)	EH (h_3)	HR (h_1)	PH (d_3)	Width (b_5)	Depth (d_5)	MR (h_2)	MM (h_5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	1 000	0.5 to 1.0	1 400	1 800	1 400	2 400	2 300	2 200	2 000	4 800	1 600	(b_3 + 1 000)	(d_2 + 2 500)	2 500	(h_3+ f)
ii)	1 500		1 700	2 000	1 700	2 700	2 500	2 200	2 000	4 800	1 600			2 500	
iii)	1 600		1 700	2 100	1 700	2 700	2 600	2 200	2 000	4 800	1 600			2 500	
iv)	2 000		1 700	2 500	1 700	2 850	3 000	2 200	2 000	4 800	1 600			2 500	
v)	2 500		2 000	2 500	2 000	3 100	3 000	2 200	2 000	4 800	1 600			2 500	
vi)	3 000	0.5	2 000	3 000	2 000	3 150	3 600	2 200	2 000	4 800	1 800			3 000	
vii)	3 500		2 500	2 550	2 500	3 750	3 100	2 200	2 000	4 800	1 800			3 000	
viii)	4 000		2 500	3 000	2 500	3 750	3 600	2 200	2 000	4 800	1 800			3 000	
ix)	5 000		2 500	3 600	2 500	3 750	4 100	2 200	2 000	4 800	1 800			3 000	

NOTES

1 For width and depth of Machine size dimensions and minimum floor to floor height requirement refer below:

a) Machine room Width is (b_3 +b_4), where b_3 is width of shaft size and b_4 as 1000 mm to be considered;

b) Machine room Depth is (d_2 +d_4), where d_2 is depth of shaft size and d_4 as 2500mm to be considered; and

c) Minimum floor to floor height (h_5) for landings for vertical sliding door is (h_3 + *f*), where óh_3ô is clear entrance height and dimension ó*f*ô depends upon the type of door. Refer Table 20 for vertical sliding door types.

2 In case counterweight safety is applicable check for dimensions with lift manufacturer.

3 Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in the table above. These dimensions may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

4 All dimensions given above for machine room lifts are recommended dimensions for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchasers are permitted. However, the minimum rated load for the goods lift shall be based on Class of loading for the net inside car area. Refer **8.3.1.1** for Class of loading.

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Table 23 Recommended Dimensions of Goods Lifts with Machine Room Series B Horizontal Sliding Doors (Entrance, Type 3)

(*Clause* 5.10.3.1)

All dimensions are in millimetres.

Series B Car with Horizontal Sliding Door															
Sl No.	**Rated Load**	**Rated Speed**	**Car Size**		**Door**	**Shaft Size**		**Car Height**	**Entrance Height**	**Overhead Height**	**Pit Depth**	**Machine Room Size**		**Machine Room Height**	**Min Floor to Floor height**
	kg	m/s	Width	Depth	Width	Width	Depth	CH	EH	HR	PH	Width	Depth	MR	MM
			(b_1)	(d_1)	(b_2)	(b_3)	(d_2)	(h_4)	(h_3)	(h_1)	(d_3)	(b_5)	(d_5)	(h_2)	(h_5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
i)	2 000	0.5 to 1.0	1 800	3 100	1 250	2 700	3 750	2 500	2 100	4 800	1 800	b_3 + 1 200	d_2 + 2 000	3 000	(h_3 + 750)
ii)	2 500		2 100	3 300	1 500	3 000	3 950	2 500	2 100	4 800	1 800	b_3 + 1 200	d_2 + 2 000	3 000	
iii)	3 500	0.25 to 0.5	2 400	3 600	1 750	3 300	4 250	2 500	2 100	5 000	2 000	b_3 + 1 200	d_2 + 2 000	3 000	
iv)	5 000		3 000	3 600	2 200	4 000	4 250	2 500	2 100	5 000	2 000	b_3 + 1 200	d_2 + 2 000	3 000	

NOTES

1 Minimum floor to floor height (h_5) for landings on same side for horizontal sliding door is (h_3 + 750), where óh_3ô is clear entrance height.

2 In case counterweight safety is applicable check for dimensions with lift manufacturer.

3 Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in the table above. These dimensions may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

4 All dimensions given above for machine room lifts are recommended dimensions for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchasers are permitted. However, the minimum rated load for the goods lift shall be based on class of loading for the net inside car area. Refer 8.3.1.1 for Class of loading.

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Table 24 Recommended Dimensions of Goods Lifts with Machine Room Series B Vertical Sliding Doors (Entrance, Type 4 and Type 5)

(*Clause* 5.10.3.1)

All dimensions are in millimetres.

Series B Car with Vertical Sliding Door															
Sl No.	**Rated Load**	**Rated Speed**	**Car Size**		**Door**	**Shaft Size**		**Car Height**	**Entrance Height**	**Overhead Height**	**Pit Depth**	**Machine Room Size**		**Machine Room Height**	**Min Floor to Floor Height**
	kg	m/s	Width	Depth	Width	Width	Depth	CH	EH	HR	PH	Width	Depth	MR	MM
			(b_1)	(d_1)	(b_2)	(b_3)	(d_2)	(h_4)	(h_3)	(h_1)	(d_3)	(b_5)	(d_5)	(h_2)	(h_5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
i)	2 000	0.5 to 1.0	1 800	3 100	1 800	2 700	3 550	2 500	2 500	5 300	1 800	b_3 + 1 200	d_2 + 2 000	3 000	(h_3 + f)
ii)	2 500		2 100	3 300	2 100	3 000	3 850	2 500	2 500	5 300	1 800	b_3 + 1 200	d_2 + 2 000	3 000	
iii)	3 500	0.25 to 0.5	2 400	3 600	2 400	3 300	4 050	2 500	2 500	5 300	2 000	b_3 + 1 200	d_2 + 2 000	3 000	
iv)	5 000		3 000	3 600	3 000	4 000	4 050	2 500	2 500	5 300	2 000	b_3 + 1 200	d_2 + 2 000	3 000	

NOTES

1 For minimum floor to floor height requirement refer below:

Minimum floor to floor height (h_5) for vertical sliding door is (h_3 + f), where ‘h_3’ is clear entrance height and dimension ‘f’ depends upon the type of door. Refer Table 20 for vertical sliding door types.

2 In case counterweight safety is applicable check for dimensions with lift manufacturer.

3 Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in the table above. These dimensions may differ in practice as per individual manufacturer’s design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

4 All dimensions given above for machine room lifts are recommended dimensions for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchasers are permitted. However, the minimum rated load for the goods lift shall be based on Class of loading for the net inside car area. Refer 8.3.1.1 for Class of loading.

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Table 25 Recommended Dimensions of Goods Lifts with Machine Room Series B Vertical Sliding Doors (Entrance, Type 6)

(*Clause* 5.10.3.1)

All dimensions are in millimetres.

Series B Car with Vertical Sliding Door																	
Sl No.	**Rated Load**	**Rated Speed**	**Car Size**		**Car Area**	**Loading**	**Door**	**Shaft Size**		**Car Height**	**Entrance Height**	**Overhead Height**	**Pit Depth**	**Machine Room Size**	**Machine Room Height**	**Min Floor to Floor height**	
	kg	m/s	Width	Depth	m^2	kN/m^2	Width	Width	Depth	CH	EH	HR	PH	Width	Depth	MR	MM
			(b_1)	(d_1)			(b_2)	(b_3)	(d_2)	(h_4)	(h_3)	(h_1)	(d_3)	(b_5)	(d_5)	(h_2)	(h_5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
i)	2 000	0.5 to 1.0	1 800	3 100	5.580	3.515	1 800	2 750	3 550	2 500	2 500	5 300	1 800	b_3 + 1 200	d_2 + 2 000	3 000	(h_3 + f)
ii)	2 500		2 100	3 300	6.930	3.538	2 100	3 050	3 850	2 500	2 500	5 300	1 800	b_3 + 1 200	d_2 + 2 000	3 000	
iii)	3 500	0.25 to 0.5	2 400	3 600	8.640	3.973	2 400	3 350	4 050	2 500	2 500	5 300	2 000	b_3 + 1 200	d_2 + 2 000	3 000	
iv)	5 000		3 000	3 600	10.800	4.540	3 000	4 050	4 100	2 500	2 500	5 300	2 000	b_3 + 1 200	d_2 + 2 000	3 000	

NOTES

1 Minimum floor to floor height (h_5) for vertical sliding door is (h_3 + f), where óh_3ô is clear entrance height and for dimension ófô depends upon the type of door. Refer Table 20 for vertical sliding door types.

2 In case counterweight safety is applicable check for dimensions with lift manufacturer.

3 Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in the table above. These dimensions may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

4 All dimensions given above for machine room lifts are recommended dimensions for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchasers are permitted. However, the minimum rated load for the goods lift shall be based on cass of loading for the net inside car area. Refer **8.3.1.1** for class of loading.

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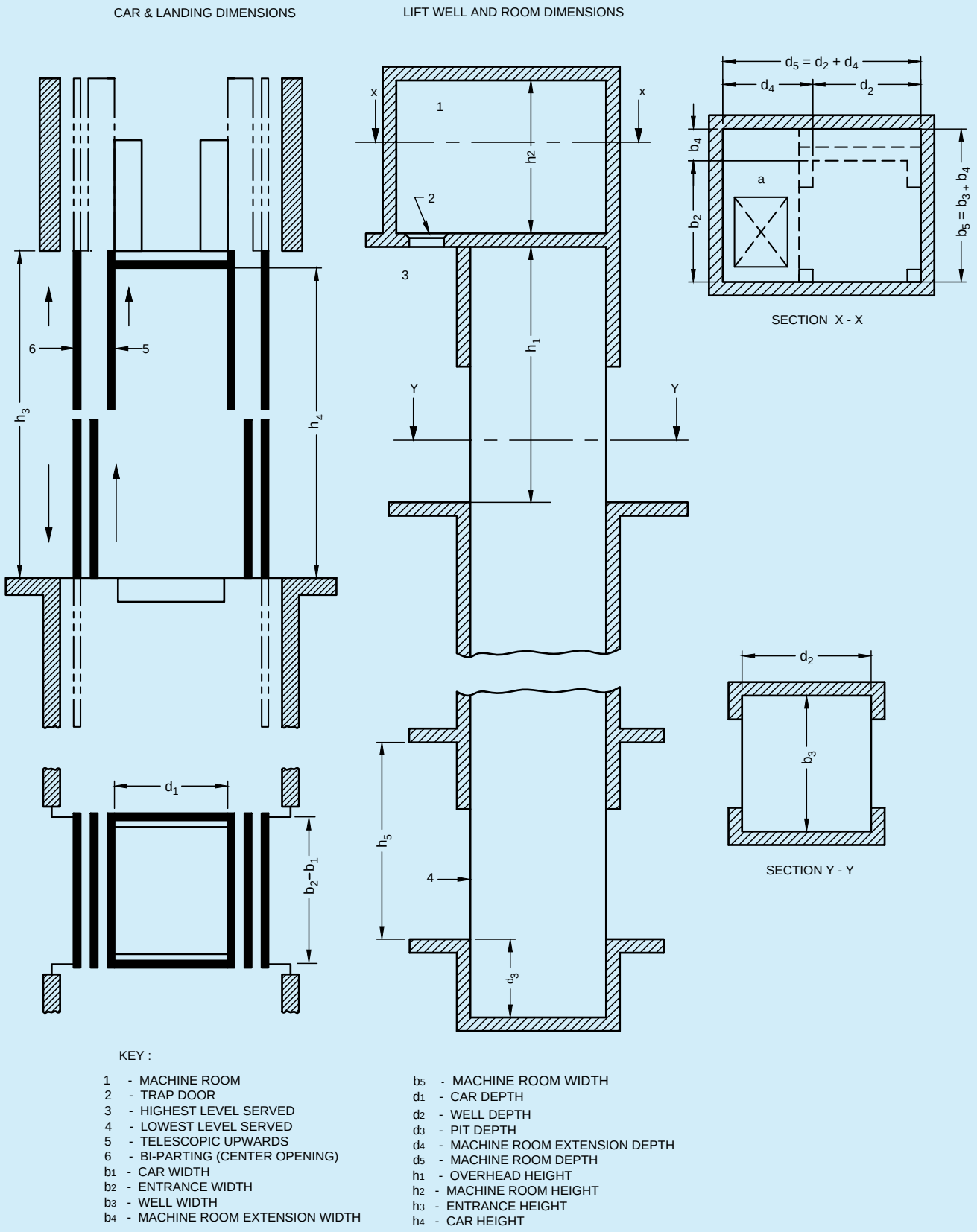

KEY :

1 - MACHINE ROOM
2 - TRAP DOOR
3 - HIGHEST LEVEL SERVED
4 - LOWEST LEVEL SERVED
5 - TELESCOPIC UPWARDS
6 - BI-PARTING (CENTER OPENING)
b_1 - CAR WIDTH
b_2 - ENTRANCE WIDTH
b_3 - WELL WIDTH
b_4 - MACHINE ROOM EXTENSION WIDTH
b_5 - MACHINE ROOM WIDTH
d_1 - CAR DEPTH
d_2 - WELL DEPTH
d_3 - PIT DEPTH
d_4 - MACHINE ROOM EXTENSION DEPTH
d_5 - MACHINE ROOM DEPTH
h_1 - OVERHEAD HEIGHT
h_2 - MACHINE ROOM HEIGHT
h_3 - ENTRANCE HEIGHT
h_4 - CAR HEIGHT

IT IS NECESSARY TO HAVE AN ACCESS DOOR TO THE MACHINE ROOM ALTHOUGH THIS IS NOT INDICATED ON THE SKETCH

FIG. 12 (TABLE 26) AUTOMOBILE LIFTS WITH MACHINE ROOM -THROUGH TYPE CAR SERIES B VERTICAL SLIDING DOOR

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Table 26 Recommended Dimensions of Automobile Lifts with Machine Room ð Through Type Car Series B Vertical Sliding Door (Entrance, Type 4)

(*Clause* 5.10.3.1)

All dimensions are in millimetres.

Sl No.	Rated Load	Rated Speed	Car Size		Door Size	Shaft Size		Car Height	Entrance Height	Overhead Height	Pit Depth	Machine Room Size		Machine Room Height	Below Lintel Height	Min Floor to Floor Height
	kg	m/s	Width (b_1)	Depth (d_1)	Width (b_2)	Width (b_3)	Depth (d_2)	CH (h_4)	EH (h_3)	HR (h_1)	PH (d_3)	Width (b_5)	Depth (d_5)	MR (h_2)		MM (h_5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
i)	2 500	0.5 and 1.0	2 500	5 300	2 500	3 600	5 910	2200	2 000	5 000	1 600	(b_3 + 1 000)	(d_2 + 2 500)	2 500	2 075	(h_3 + *f*)
ii)	3 000	0.5	2 700	5 400	2 700	3 900	6 010	2200	2 000	5 000	1 800			3 000	2 075	
iii)	4 000		3 000	5 800	3 000	4 200	6 410	2200	2 000	5 000	1 800			3 000	2 075	
iv)	5 000		3 000	6 000	3 000	4 200	6 610	2200	2 000	5 000	1 800			3 000	2 075	

NOTE ð For width and depth of Machine size dimensions requirement refer below,

1 For width and depth of machine size dimensions requirement refer below:

a) Machine room Width is (b_3 +b_4), where b_3 is width of shaft size and b_4 as 1 000 mm to be considered;

b) Machine room Depth is (d_2 +d_4), where d_2 is depth of shaft size and d_4 as 2 500 mm to be considered; and

c) Minimum floor to floor height (h_5) for vertical sliding door is (h_3 + f), where óh_3ô is clear entrance height and Dimension ófô depends upon types of door. Refer Table 20 for vertical sliding door types.

2 Car height normal range is 2 200 mm to 2 700 mm.

3 Overhead height for all values of car height CH shown above.

4 In case counterweight safety is applicable check for dimensions with lift manufacturer.

5 All dimensions given above for machine room lifts used for auto mobiles are recommended dimensions for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchasers are permitted. However, the minimum rated load for the automobile lift shall be based on a load of not less than 1.45 kN/m^2 of the net inside car area.

6 Dimensions of pit depth and overhead may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

7 The lift car width should be selected such that in case of emergency while the automobile is in the lift car the driver should be able to open the automobile door and come out of the automobile.

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Table 27 Recommended Dimensions of Passenger Lifts MRL COPD

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	No. of Passengers	Rated Load	Car Size		2 P COPD Door	1.0 m/s ÒRated Speed Ò 2.0 m/s		Rated Speed = 2.5 m/s		Rated Speed = 3.0 m/s	
						Shaft Size		Shaft Size		Shaft Size	
		kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	4	272	800	950	700	1 600	1 300	ï	ï	ï	ï
ii)	6	408	1 000	1 100	800	2 000	1 550	ï	ï	ï	ï
iii)	8	544	1 300	1 100	800	2 150	1 550	ï	ï	ï	ï
iv)	10	680	1 300	1 350	800	2 250	1 800	2 300	2 150	ï	ï
v)	13	884	1 500	1 450	900	2 250	1 900	2 550	2 150	2 550	2 250
vi)	15	1 020	1 500	1 600	1 000	2 550	2 050	2 650	2 150	2 650	2 250
vii)	16	1 088	1 500	1 650	1 000	2 550	2 050	2 650	2 200	2 650	2 300
viii)	20	1 360	1 700	1 800	1 000	2 550	2 350	2 850	2 350	2 850	2 350
ix)	22	1 496	1 800	1 900	1 000	2 700	2 400	2 800	2 450	2 750	2 450
x)	24	1 632	1 500	2 400	1 000	2 500	2 900	2 750	2 850	2 750	2 850
xi)	26	1 768	1 900	2 000	1 000	2 850	2 700	2 850	2 700	2 850	2 700
xii)	29	1 972	1 900	2 200	1 200	2 900	2 750	3 100	2 200	ï	ï

NOTES

1 All dimensions given above for lifts having centre opening power operated doors (COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, variation in:

a) car inside dimensions shall be within the maximum area limits specified in accordance with Table 37;

b) entrance width on higher side is permitted; and

c) entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

2 The minimum size of the lift car and all other requirements relating to accessibility, in all public buildings shall be in accordance with good practice [D-5A(3)] .

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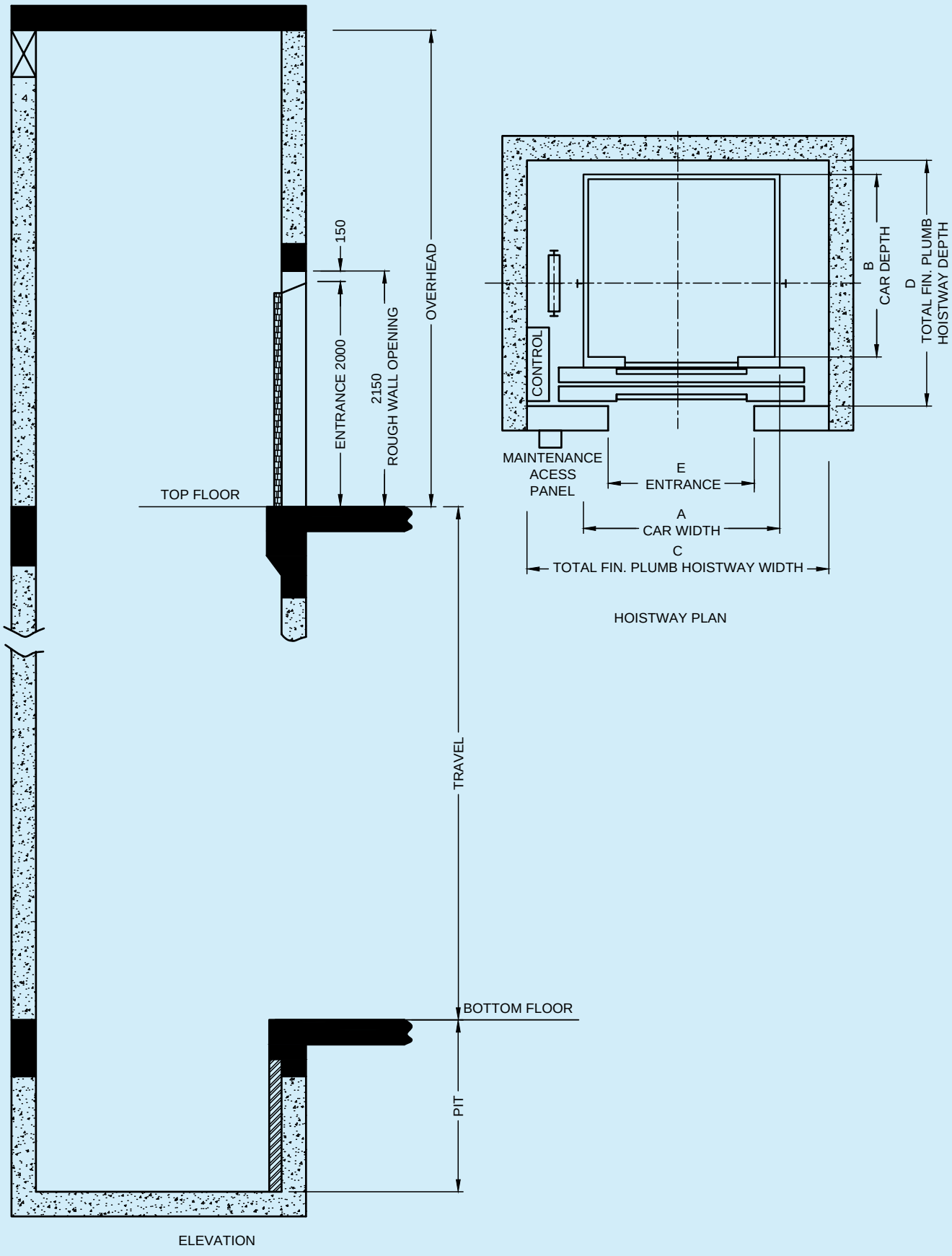

FIG. 13 (TABLE 27) FOR MRL LIFTS COPD

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Table 28 Recommended Dimensions of Stretcher/Hospital lifts MRL (2P Telescopic Door/4P COPD, Speed 1.0 m/s to 2.0 m/s)

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	Rated Load		Car Size		Door Size	Shaft Size	
	Persons	kg	Width	Depth		Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	15	1 020	1 000	2 400	1 000	2 150	2 900
ii)	20	1 360	1 300	2 400	1 000	2 350	2 950
iii)	24	1 632	1 500	2 400	1 000	2 400	2 950
iv)	26	1 768	1 600	2 400	1 000	2 550	3 000
v)	29	2 000	1 500	2 700	1 000	2 450	3 250

NOTES

1 All dimensions given above for lifts having 2 panel telescopic or 4 panel centre opening power operated doors (4P COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, variation in:

a) car inside dimensions shall be within the maximum area limits specified in accordance with Table 37;

b) entrance width on higher side is permitted; and

c) entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

2 Car depth of 2 100 mm may be considered in residential/commercial buildings where use of only ambulance stretcher is envisaged. The hoist-way depth maybe reduced accordingly.

Table 29 Pit Depth for Passenger/Stretcher/Hospital Lifts MRL

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	No. of Passengers	Pit Depth for Speed					
		1 m/s	1.6 m/s	1.8 m/s	2 m/s	2.5 m/s	3 m/s
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	4	1 600	1 800	2 000	2 200	ï	ï
ii)	6	1 600	1 800	2 000	2 200	ï	ï
iii)	8	1 600	1 800	2 000	2 200	ï	ï
iv)	10	1 600	1 800	2 000	2 200	ï	ï
v)	13	1 700	1 800	2 000	2 200	2 500	3 100
vi)	15	1 700	1 800	2 000	2 200	2 500	3 100
vii)	16	1 700	1 800	2 000	2 200	2 500	3 100
viii)	20	1 800	1 800	2 000	2 200	2 500	3 100
ix)	22	1 800	1 800	2 000	2 200	2 500	3 100
x)	24	1 800	1 800	2 000	2 200	2 500	3 100
xi)	26	1 800	1 800	2 000	2 200	2 500	3 100
xii)	29	1 800	1 800	2 000	2 200	2 500	ï

NOTE ð Recommended dimensions for pit depth for different lift speeds are given in the table. These dimensions may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the pit depth shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(6)].

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Table 30 Overhead Height for Passenger and Stretcher/Hospital Lifts MRL

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	No. of Passengers	Overhead Height for Speed				
		1 m/s	1.5 m/s Ò Rated Speed Ò 1.75 m/s	2 m/s	2.5 m/s	3 m/s
(1)	(2)	(3)	(4)		(5)	(6)
i)	4	CH + 1 900	CH + 2 400	ï	ï	ï
ii)	6	CH + 1 900	CH + 2 400	ï	ï	ï
iii)	8	CH + 1 900	CH + 2 400	CH + 2 600	ï	ï
iv)	10	CH + 1 900	CH + 2 400	CH + 2 600	CH + 3 200	ï
v)	13	CH + 1 900	CH + 2 400	CH + 2 600	CH + 3 500	CH + 3 700
vi)	15	CH + 1 900	CH + 2 400	CH + 2 600	CH + 3 600	CH + 3 800
vii)	16	CH + 1 900	CH + 2 400	CH + 2 600	CH + 3 700	CH + 3 900
viii)	20	CH + 2 300	CH + 2 600	CH + 2 700	CH + 3 800	CH + 4 000
ix)	22	CH + 2 300	CH + 2 600	CH + 2 700	CH + 3 800	CH + 4 000
x)	24	CH + 2 500	CH + 2 600	CH + 3 200	CH + 4 100	CH + 4 300
xi)	26	CH + 2 600	CH + 2 600	CH + 3 250	CH + 4 250	CH + 4 450
xii)	29	CH + 2 600	CH + 2 600	ï	ï	ï

NOTE ð Recommended dimensions for overhead height for different lift speeds are given in the table, where CH is the clear car height from car finished floor to car roof. These dimensions may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(6)].

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Table 31 Recommended Dimensions of Goods Lifts MRL (Speed 1.0 m/s)

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	Rated Load	Car Size		Door Size	Telescopic Door		4P COPD		2P COPD		Overhead Height	Pit Depth
					Shaft Size		Shaft Size		Shaft Size			
	kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth	HR	PH
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	500	1 100	1 200	900	ï	ï	ï	ï	2150	1650	CH + 1900	1 600
ii)	1 000	1 400	1 800	1 100	ï	ï	ï	ï	2 600	2 200	CH + 1900	1 600
iii)	1 500	1 700	2 000	1 500	ï	ï	2 650	2 550	ï	ï	CH + 2400	1 800
iv)	1 600	1 400	2 400	1 300	2 700	3 000	3 200	3 050	ï	ï	CH + 2700	1 800
v)	2 000	1 700	2 500	1 500	2 550	3 300	2 600	3 300	ï	ï	CH + 2700	1 800
vi)	2 500	2 000	2 500	1 800	3 150	3 050	3 200	3 050	ï	ï	CH + 2700	1 800
vii)	3 000	2 000	2 700	1 800	ï	ï	3 350	3 300	ï	ï	CH + 3000	1 800
viii)	4 000	2 100	3 400	1 800	ï	ï	3 400	4 000	ï	ï	CH + 3100	2 100
ix)	5 000	2 500	3 500	2 200	ï	ï	3 800	4 100	ï	ï	CH + 3200	2 200

NOTES

1 CH is the clear car height from car finished floor level to car roof (goods lifts will normally not have any false ceiling).

2 Normal range for CH is 2 100 mm to 2400 mm.

3 Door height is less than or equal to the car height CH.

4 In case counterweight safety is applicable check for dimensions with lift manufacturer.

5 All dimensions given above for lifts having telescopic or centre opening power operated doors (COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, the minimum rated load for the goods lift shall be based on a load of not less than 3.45 kN/m^2 of the net inside car area.

6 Recommended dimensions for overhead height and pit depth for different lift speeds are given in the table. These dimensions may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the overhead height and pit depth shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

7 Car inside dimension shall be with in maximum area limit specified in accordance with Table 38.

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Table 32 Recommended Dimensions of Automobile Lifts MRL COPD (Speed 0.5 m/s to 1.0 m/s)

(*Clause* 5.10.3.1 *and Table* 16)

All dimensions in millimetres.

Sl No.	Rated Load	Car Size		6P COPD Door Size: Opposite Entrances	Shaft Size		Overhead Height	Pit Depth
	Kg	Width	Depth	Width	Width	Depth	HR	PH
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	2 500	2 500	5 000	4P-2 500	3 800	5 480	5 000	2 500
ii)	3 000	2 500	5 500	2 200	3 800	6 450	5 000	2 500
iii)	4 000	3 000	6 000	2 700	4 300	6 950	5 000	2 500

NOTES

1 Car height normal range is 2 100 mm to 2700 mm.

2 Overhead height shown is required for all values of car height CH shown above.

3 In case counterweight safety is applicable check for dimensions with lift manufacturer.

4 All dimensions given above for machine room less lifts with 6 panel centre opening power doors (6P COPD) used for automobiles are recommended dimensions for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, the minimum rated load for the automobile lift shall be based on a load of not less than 1.45 kN/m^2 of the net inside car area.

5 Dimensions of pit depth and overhead height may differ in practice as per individual manufacturerôs design depending upon load, speed and drive. However, the pit depth and overhead height shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [D-5A(1)].

6 The lift car width should be selected such that, in case of emergency while the automobile is in the lift car the driver should be able to open the automobile door and come out of the automobile.

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6 CIVIL AND ELECTRICAL REQUIREMENTS FOR LIFTS

6.1 Civil Requirements

Lift well enclosures, lift pits, machine rooms and machine supports besides conforming to the essential requirements given below should form part of the building construction and comply with the lift manufacturerôs drawings.

6.1.1 *Requirements of Lift Well Enclosure*

The requirements of lift well enclosures are as given hereunder:

a) *Totally enclosed well* ð Lift wells shall be totally enclosed by imperforate walls, floor and ceiling, constructed for protection against all weather and of dust free surface material or should be painted to minimize dust circulation on to moving apparatus and from being pumped by the car movement into machine room or on to landings and shall be rendered minimum 120 min fire-resistant.

The lift well may have openings for landing doors, inspection and emergency doors, vent openings for escape of gases and smoke in case of fire, ventilation openings, openings in the machine room floor for connecting lift components such as ropes, cables, etc.

b) *Partially enclosed well* ð In case of partially enclosed lift wells used for applications, for example, observation lifts in connection with galleries or atriums, tower buildings, etc, the well does not need to be totally enclosed, provided the height of the enclosure at places normally accessible to persons is sufficient to prevent such persons:

1) being endangered by moving parts of the lift; and

2) interfering with the safe operation of the lift by reaching lift equipment within the well either directly or with handheld objects.

The height of the enclosure shall be minimum 3.5 m at the landing door side. The height of enclosure at other sides shall be 2.5 m minimum when the horizontal distance between the moving parts of the lift and enclosure is 0.5 m minimum. The height of enclosure at other sides may be reduced to 1.1 m progressively if the horizontal distance between the moving parts of the lift and enclosure increases to 2 m. The enclosure shall be located within 150 mm of the edge of the floor. The enclosure shall be imperforate and made of non-combustible material.

c) *General requirements related to the lift well* ð The well shall be exclusively used for lifts. It shall not contain ducts, cables, or devices, etc, other than those for the lift. Permanently installed adequate lighting shall be provided comprising sufficient number of lamps fixed throughout the lift well such that the illumination level 1 m above the car roof within its vertical projection at any position of the car in the well and 1 m above pit floor everywhere shall be at least 50 lux and at least 20 lux at remaining locations, even when all the doors are closed (so that a person can stand, work and/or move between the working areas).

NOTE ð Additional lamps may be fixed on the car top as a part of the well lighting system to achieve this.

Well lighting switches (or equivalent) shall be located both in the pit and in machine room or in controller (in case of machine room less application) so that the complete well lighting can be operated from either location that is, it shall be an arrangement of 2-way switch in machine room/controller (in case of MRL) and pit for controlling well lighting. Well lighting switch shall be in the machine room close to the main switch and pit lighting switch in lift well close to and easily accessible from lowest landing door. Each point of well lighting shall consist of bulkhead with bulb, 3-pin socket and switches to control supply.

Should a lift entrance open out into an area exposed to the weather, the entrance should be protected by a suitable canopy and the ground level sloped up to the lift entrance to prevent rain or drainage water entering the lift well through the clearances around the landing doors. Any push buttons exposed should be of weatherproof type.

The natural or artificial lighting of the landings in the vicinity of landing doors shall be at least 50 lux at floor level, such that a user can see ahead when they are opening the landing door to enter the lift, even

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if the car light has failed. The approach of the landing door on each floor shall be kept lit during the whole time the lift is available for use at night, and during the day time, if so required, due to insufficient natural light.

When the distance between consecutive landing door sills exceeds 11 000 mm, intermediate emergency landing(s) with lift landing door(s) shall be provided such that the distance between any two consecutive landings is not more than 11 000 mm. Rescue to these landings is permissible in case of automatic rescue device operation.

No counterweight shall be allowed to travel in any lift well, or part of any lift well other than that to which it belongs.

In the case of a lift well which is common to more than one lift and where the lift car or the counterweight of one lift is working in juxtaposition to the lift car or counterweight of another lift, such lift cars or counterweights shall be guarded carefully and adequately in order to protect persons working in the lift well or on the lift cars from accidental contact with such cars or counterweights in any part of their travel.

d) *Construction of the lift well* ð The side walls of the lift well may be made of reinforced cement concrete at least 150 mm thick; or brick or similar fire resisting materials provided tie beams are made available for lift guide rail fixings at such heights as specified by the lift manufacturer, to provide satisfactory anchoring arrangement for fixing guide rails and other equipment to the lift well.

The inner surface of the lift well and its enclosure facing any lift-car entrance shall, so far as practicable, be kept smooth and flush devoid of projections or recesses. Where any projection or top of the recesses cannot be rendered flush, they shall be levelled on the underside to an angle not less than 60ę from the horizontal, by means of metal plates, cement rendering or other fire resisting material.

Where a lift car levelling device is operative with the lift car door open, such interior surfaces shall always form a smooth and flush surface below each landing level for a depth of at least the depth of the car-levelling zone plus the distance through which the lift car may travel of its own momentum when the power is cut-off.

The horizontal distance between the sill of the car and sill of the landing doors shall not exceed 35 mm. The distance between the lift well enclosure on the sides facing any lift-car entrance and the sill edge of the car shall not be more than 35 mm in the landing zone below the landing gate. If such distance is more than 35 mm in the lift well enclosure, the same shall be finished with suitable and smooth plaster work or fascia plates so as to make the surface thereof devoid of all projections and recesses. In case the enclosure wall on the sides facing the lift-car entrance is more than 130 mm from the sill edge of the lift-car platform, the lift-car door of such lift shall be provided with means to prevent it from being opened except when the lift-car is at the landing served by such car entrance.

Sufficient space shall be provided between the guides for the car and the side walls of the lift well enclosure to allow safe and easy access to the parts of the safety gears for their maintenance and repairs.

All landing openings shall be protected by gates or doors which shall extend to the full height and full width of the landing openings. These openings shall not be less than 2 000 mm in clear height and 700 mm clear in width (*see* **5.10.3.1**) when the gates or doors are fully opened. There shall not be any common wall between lift well and water tank.

e) *Strength of the walls of the well* ð The structure of the well shall be able to support at least the loads which may be applied by the machine, by the guide rails at the moment of safety gear operation, by eccentric load in the car, by the action of buffers, by the application of anti-rebound devices, by loading and unloading the car, etc.

The walls of the well shall withstand a force of 1 000 N, being evenly distributed over an area of 0.09 m^2 in round or square section and applied at right angles to the wall at any point on either face,

1) without permanent deformation greater than 1 mm; and

2) without elastic deformation greater than 15 mm.

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Glass panels, plane or formed shall be made of laminated glass. Such panels and their fixings shall withstand horizontal static force of 1 000 N applied on an area of 0.09 m^2 at any point, from either side, without permanent deformation.

f) *Partition walls between lifts in a common lift well* ð In case of common lift well for multiple lifts, the partition wall(s) of the common lift well may be either be of RCC or brick or steel or glass which may be provided with openings for escape of air displaced due to movement of lift in the adjacent well. For high speed lifts the partition between the lifts maybe of suitable wire grill/expanded metal of following specifications:

1) It shall be made of at least 2.2 mm thick steel wire or expanded metal;

2) A ball of 25 mm diameter shall not pass through the wire grill; and

3) It shall be so fixed as not to deflect more than 15 mm when subjected to a force of 450 N applied horizontally at any point from either side.

6.1.2 *Requirements of the Pit*

Pit shall be soundly constructed and maintained in a dry (waterproofed) and clean condition. Where necessary, provision shall be made for permanent drainage. The floor of the pit shall be able to support beneath each guide rail, force due to mass of guide rails plus the reaction due to safety gear operation. The floor of the pit shall be able to support beneath the car buffer supports, force in Newton, equal to 4 times the static load being imposed by the mass of fully loaded car:

$$4.g\ (P + Q)$$

where

g = acceleration due to gravity;

P = mass of empty car and components supported by the car that is, part of travelling cable, compensating rope/chain, if any, etc, in kg; and

Q = rated load, in kg.

The floor of the pit shall be able to support beneath the counterweight buffer support, a force in Newton, equal to 4 times the static load being imposed by the mass of the counterweight:

$$4.g\ (P + q.Q)$$

where

g = acceleration due to gravity;

P = mass of empty car and components supported by the car, that is, part of travelling cable, compensating rope/chain, if any, etc, in kg;

q = live load balancing factor (normally, $q = 0.5$); and

Q = rated load, in kg;

The floor of the pit shall be able to support upward thrust of the tied down rope compensation device, if provided. If accessible spaces do exist below the well, the base of the pit shall be designed for an imposed load of at least 5 000 N/m^2 and the counterweight shall be equipped with safety gear. In addition, it is recommended to provide double slab for the lift pit.

NOTES

1 Lift wells should preferably not be situated above a space accessible to persons.

2 Enclosing projected area of the lift well under the pit in accessible spaces will not nullify the above provisions.

There shall not be any common wall/slab between lift pit and any water reservoir.

The pit shall be accessible by an access door. A permanent ladder inside the well may be provided close to the

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last landing *in-lieu* of access door, if the pit depth does not exceed 2.5 m.

NOTE ð In case of structural limitations for providing pit access door at pit floor level, alternative arrangement to access pit may be provided which shall allow access to pit with complete safety.

A physical means of protection shall be provided to prevent accidental contact with the counterweight.

The pit shall be equipped with a stop switch which is easily accessible from the lowest landing and the pit floor. If more than one switch is required, they shall be wired in series.

6.1.3 *Requirements Associated with Machine Room and Pulley Room*

It must be noted that generally lifts have machine rooms immediately over the lift well and this should be arranged, whenever possible, without restricting the overhead distance required for normal safety precautions. In case where machine room provision on top is a limitation, either machine room less lift or basement drive or side drive lift can be considered. The spaces and tolerances shall be in accordance with the following:

a) *Requirements associated with machine room and pulley room* (*where lift machinery is placed in the machine room*)

1) The lift machine, controller and all other apparatus and equipment of a lift installation, except such apparatus and equipment having functional location in the lift well or other positions, shall be placed in the machine room which shall be adequately lit and rendered fire-resistant and weather-proof.

If parts of different lifts are present in one machine room and/or pulley room each lift shall be identified with a number, letter or colour consistently used for all parts (machine, controller, over speed governor, switches, etc). If the machine room contains several lifts, it is necessary to have one switch per car to control the supply to the circuit for lighting and socket outlets of the car. This switch shall be located close to the corresponding main power switch.

2) Machine room should be considered as plant space, and conditions provided to permit reliable operation of electrical switchgear and rotating machinery and be conducive to good maintenance. The machine room shall be either air conditioned or adequately ventilated so as to maintain the ambient temperature therein between + 5 ÁC and + 40 ÁC. The machine room shall be such that the motors and equipment as well as electric cables, etc are protected as far as possible from dust and humidity. Machine room should also be protected from all weather and if ventilation louvers are provided, they should be designed and located to prevent entry of rainwater in the machine room. Preferably, metal or wooden louvers should be provided.

The well, machinery spaces and pulley rooms shall not be used to provide ventilation of rooms other than those belonging to the lift.

3) Rescue instructions with required tools and tackles, if any, shall be made available in the machine room.

4) Machine room floor shall be provided with a trap door, if necessary. The size of the trap door shall be as per manufacturerôs recommendation. Since the purpose of the trap door is to lift or lower the machinery, controller, etc between machine room and the top landing, it may be necessary to provide trap door of same size in the terrace slab which coincides with trap door in machine room, depending on the design of the building.

The trap door when closed shall be able to support 2 000 N on an area of 0.20 m Ĭ 0.20 m at any position. The trap door shall not open downwards. Hinges, if any, shall be of a type which cannot be unhooked. Trap doors shall be locked. When the trap door is in the open position, precautions shall be taken to prevent the fall of persons (for example, by a guardrail) and prevent the trapdoor from closing such as to cause a crushing hazard (for example, by counterbalance).

5) Lighting shall be provided to give at least 200 lux around the controller and machine. At least one plug socket point with button shall be provided in the machine room for every lift. The switch for the machine room light shall be fixed near the entrance of the machine room. The machine room walls, ceiling and floor should be finished in dust-resisting materials, tiles, etc or painted as a

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minimum to stop dust circulation, which otherwise could damage rotating machinery and cause failure of switchgear.

6) The machine room shall be so designed as to allow free and easy access to all parts of the equipment and the width of the clear space around the machine from any two sides shall in no case be less than 600 mm. Provision shall be made to allow the removal and replacement of various units. The entrance of the machine room shall be minimum 1 000 mm wide and 2 000 mm high to allow removal and replacement of machinery therein. The floor of the machine room shall be designed and constructed to carry safely at any point the heaviest part of the equipment and withstand the loads and forces to which they are intended to be subjected to. If the floor does not extend to the enclosing wall, the open sides shall be adequately guarded by suitable means for example, rails, guards, etc.

7) The height of the machine room shall be sufficient to allow any portion of the equipment to be accessible and removable for repairs and replacement. Distance between the machine lifting point and the machine room hook shall be at least 1 000 mm and there shall be a clear vertical distance of at least 300 mm above the rotating parts of the machine. Machine room height shall not be less than 2 100 mm clear from the floor of the access area and working area in any case. This clear height for movement is taken to the underside of the lowest striking point and measured from the floor of the access area.

8) The machine room shall be locked and shall be accessible to only those who are concerned with the operation and maintenance of the machinery or equipment. Machine room doors shall not open towards the inside of machine room. They shall be provided with a key-operated lock, capable of being reclosed and relocked without a key and be openable from inside the machine room without a key, even when locked. Approach way to machine room from top landing level shall be direct, easy and safe to walk by way of stairs. If stairs are not possible, sufficiently wide and deep permanent structural steps may be used. These structural steps shall be provided with adequate hand holds and shall not be too steep. Minimum width of the steps shall be 1 000 mm.

9) A danger notice board shall be displayed permanently on the outside of the machine room door, trap door and near the machinery. Refer **8.1(e)** for the warning signs.

10) There shall not be any common wall/slab between machine room and any water reservoir.

11) The machine room shall not be used as a storeroom or for any purpose other than housing the machinery/components connected with the lift installation. The machine room shall not act as a passage to any other room or utility.

The lift well, machine and pulley rooms may, however contain:

i) Equipment for air conditioning or heating of these spaces, excluding steam heating and high-pressure water heating. However, any control and adjustment devices of the heating apparatus shall be located outside the lift well, machine room and pulley room; and

ii) Fire detectors and/or suppression system, with a high operating temperature (for example, above 80 ÁC), appropriate for the electrical equipment and suitably protected against accidental impact.

For requirements of sprinkler, when sprinkler systems are used, refer **9.24.4** of good practice [D-5A(7)].

NOTE ð Such smoke, fire detection and sprinkler systems are the responsibility of the building management.

12) Machine room floor shall be designed to carry an imposed (live) load of not less than 10 kN/m^2 over the whole area and any load which may be imposed thereon by the equipment used in the machine room or by any reaction from any such equipment both during periods of normal operation, maintenance and repair.

13) One or more beams or hooks with the indication of the safe working load, as appropriate, shall be provided in the machinery spaces. Position of the beams or hooks shall be according to the layout

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provided by lift manufacturer. Hoisting beams or hooks shall be tested for safe working load (SWL) before indicating the lifting capacity on it.

14) The total load on overhead beams used for supporting machinery shall be assumed as equal to all equipment resting on the beams plus twice the maximum load suspended from the beams.

15) The factor of safety for all overhead beams and supports based on ultimate strength of the material and load in accordance with (14) shall not be less than the following:

i) For steel : 5

ii) For reinforced concrete : 7

The deflection of the overhead beams under the maximum static load calculated in accordance with above shall not exceed 1/1 500 of the span.

16) The place in which the overhead pulleys, over speed governors and similar machinery are fixed shall be easily accessible for maintenance and repair purposes. It shall be lit adequately and safe working procedure shall be established for maintenance and repair works.

17) It is recommended that emergency exit is provided in case of large machine rooms having four or more lifts.

18) Where the machine room occupies a prominent position on roof of a building, provision should be made for lightning protection in accordance Part D ôBuilding Services, Section 2 Electrical and Allied Installationsôof this NBCS and applicable standards.

b) *Requirements associated with machine spaces* (*where machinery is placed in the well*)

1) Access to the interior of the machinery and pulley spaces shall be capable of being properly lit by a permanent electric light fixture(s) with intensity of at least 200 lux at floor level, easy to use, and completely safe in all circumstances without necessitating entry into private premises.

2) Machinery spaces inside the well shall be designed and constructed to withstand the loads and forces they are subjected to.

3) In the case of partially enclosed wells located at the exterior of the building, the machinery shall be suitably protected against environmental influences.

4) Provision should be given to access the machine for maintenance purpose either from car top or otherwise.

5) The clear height for movement shall not be less than 2 000 mm.

6) The machinery spaces shall be suitably ventilated. The electric equipment of the machinery shall be protected as far as it is reasonably practicable from dust, harmful fumes and humidity.

7) The working area and machinery spaces shall be provided with permanently installed electric lighting with at least 200 lux at floor level.

8) One or more beams or hooks with the indication of the safe working load, as appropriate, shall be provided in the machinery spaces. Position of the beams or hooks shall be according to the layout provided by lift manufacturer. Hoisting beams or hooks shall be tested for safe working load (SWL) before indicating the lifting capacity on it.

9) The total load on overhead beams used for supporting machinery shall be assumed as equal to all equipment resting on the beams plus twice the maximum load suspended from the beams.

10) The factor of safety for all overhead beams and supports based on ultimate strength of the material and load in accordance with (9) shall be not less than the following:

i) For steel : 5

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ii) For reinforced concrete : 7

The deflection of the overhead beams under the maximum static load calculated in accordance with above shall not exceed 1/1 500 of the span.

c) *Requirements associated with machine spaces* (*where machinery is placed outside of the well*)

1) Machinery spaces outside of the well shall be constructed to withstand the loads and forces to which they are subjected;

2) The total load on beams used for supporting machinery shall be assumed as equal to all equipment resting on the beams plus twice the maximum load suspended from the beams;

3) The factor of safety for all beams and supports based on ultimate strength of the material and load in accordance with (2) above shall be not less than the following:

i) For steel : 5

ii) For reinforced concrete : 7

The deflection of the overhead beams under the maximum static load calculated in accordance with above shall not exceed 1/1 500 of the span.

4) Access to the interior of the machinery and pulley spaces shall be:

i) capable of being properly lit by a permanent electric light fixture(s) with intensity of at least 200 lux at floor level; and

ii) easy to use and completely safe in all circumstances without necessitating entry into private premises.

The clear height for movement shall not be less than 2 000 mm.

5) The machinery shall be located inside a cabinet consisting of imperforate walls, floor, roof and lockable door(s).

6) The machinery cabinet shall be suitably ventilated. It shall be such that the machinery is protected as far as it is reasonably practicable from dust, harmful fumes and humidity.

7) The inside of the machinery cabinet shall be provided with permanently installed electric lighting with at least 200 lux at floor level. The switch placed inside shall be close to the door(s), at an appropriate height, to control lighting of the cabinet.

d) *Dimensional tolerances*

1) *Lift well dimensions* ð Plan dimensions of lift wells given by the lift manufacturer, represent the minimum clear plumb sizes. The purchaserôs representative, in conjunction with the builder, should ensure that adequate tolerances are included in the building design so that the specified minimum plumb dimensions are obtained in the finished work. Dimensions in excess of these minimum plumb dimensions for lift well and openings (but not less) can be accommodated by the lift manufacturer up to certain maximum values beyond which changes in design may be necessary involving additional expense or work by the builder. The purchaserôs representative should take these factors into account when specifying the lift well structural dimensions on the basis of the constructional tolerance appropriate to the building technique.

2) *Landing door openings* ð It is very important that finished landing openings should be accurate to design size and plumb one above the other for the full travel of the lift. In constructing the structural openings in concrete walls to lift wells it is not possible to achieve a degree of accuracy vertically which will allow doors and frames to be inserted in the opening without some form of masking or packing to overcome inaccuracies. Provisions should therefore be made in design by increasing the nominal height from design finished floor level and width of openings to each jamb and head. In addition, the alignment of the outer face of the front wall of the lift well is of importance when architrave of fixed dimensions are called for and in this case the alignment of the outer face from

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floor to floor should not vary to a greater extent than can be accommodate by the subsequent front wall finish, the architrave being set accurately plumb.

3) *Structural limits for lift wells at any level* ð If the net plumb well (dimensions A and B in Fig. 14) and the nominal structural entrance openings (dimensions C and D in Fig. 14) are defined by plumb lines, the actual wall should not encroach on these dimensions.

Dimension K (inside face of wall of Fig. 14) should fall within the following limits:

i) For wells up to 30 m : 0 mm to 25 mm

ii) For wells up to 60 m : 0 mm to 35 mm

iii) For wells up to 100 m : 0 mm to 50 mm

iv) For wells taller than 100 m : 0 mm to 50 mm for any 100 m portion of the well.

When architraves are to be supplied by the lift manufacturer dimension L (side of structural opening of Fig. 14) should fall within the limits of 0 mm and 25 mm and dimension M (outer face of the front wall of Fig. 14) should not vary to a greater extent than can be accommodated by the subsequent front wall finish, the architrave being set accurately plumb. When the entrance linings are supplied by the builder, corresponding provision should be made for the finished openings to be accurately plumb one above the other for the full travel of the lift end to design size.

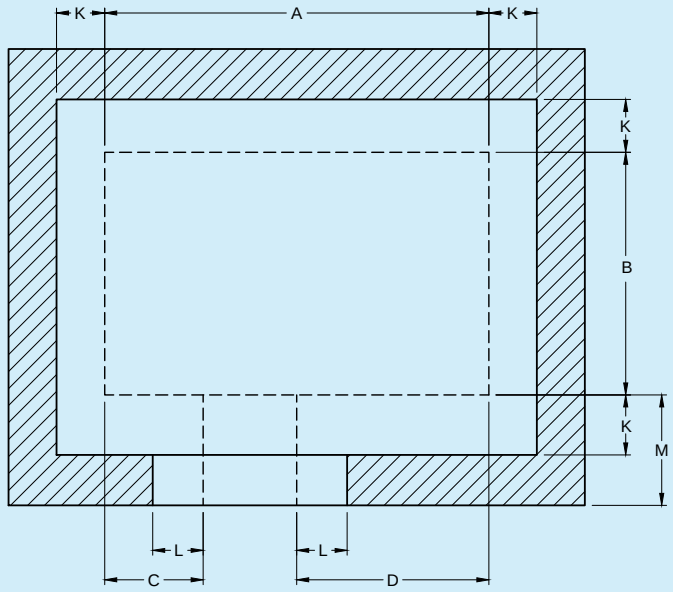

FIG. 14 LIFT WELL TOLERANCE

6.2 Electrical Installation Requirements

The lift manufacturer should specify, on a schedule, particulars of full load current, starting current, maximum permissible voltage drop, size of switches and other details to suit requirements. The main power cable and lighting cable shall be separate and routed through respective lift shaft for every lift. Every electric supply line other than the earthed or earthed neutral conductor of any system or the earthed external conductor of a concentric cable, shall be protected by a suitable switchgear by its owner. It is important that the switchgear at the intake and in the machine room which are provided by the electrical contractor of owner are of correct size. No form of ðNO VOLTô trip relay should be included anywhere in the power supply of the lift.

6.2.1 *Main Switchgear*

For each lift, a main switchgear capable of breaking the supply to the lift on all the live conductors shall be provided. This switchgear shall be capable of interrupting the highest current involved in normal conditions of use of the lift.

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This switchgear shall not cut the circuits feeding the following:

a) Car lighting and ventilation;

b) Socket outlet on the car roof;

c) Lighting of machinery spaces;

d) Socket outlet in the machinery and pulley spaces and in the pit;

e) Lighting of the lift well including pit;

f) Alarm device; and

g) Automatic rescue device.

The switchgear shall be located:

1) in the machine room, where it exists;

2) where no machine room exists, in the distribution box (DB) on top floor near the controller or meter room; or

3) at the emergency and test panel, when control panel is mounted in the well.

The following points shall be taken into consideration while fixing location of distribution box:

i) It shall be installed in common areas where there is no hindrance to reaching and operating, especially during emergency conditions; and

ii) Suggested height above floor level shall be such that it is beyond the reach of children. But the replacement/reset of protective devices shall be in an accessible position without the aid of any tackle, for example, at an average height between 1.8 m and 2.1 m.

If the emergency panel is separate from test panel, the switchgear shall be at emergency panel. If the main switch is not easily accessible from the controller cabinet, then the cabinet shall be provided with an isolating switch.

The main switchgear shall have stable open and closed positions and shall be capable of being locked-off in the open position with the use of a padlock or equivalent, to ensure no inadvertent operation takes place.

For a single lift, this switchgear should be fixed adjacent to the machine room entrance in the machine room or in distribution box (DB) near controller (in case of MRL). In a machine room common to more than one lift, each main switch should be conveniently situated with respect to the lift it controls. Main switch for each lift shall be conspicuously marked.

The supply to the car light should be from a separate circuit and controlled by a switchgear in the machine room or in distribution box (DB) near controller (in case of MRL). For multiple lifts with a common machine room a separate supply and switch gear should be provided for each car. The car lighting and well lighting supply should be independent of the power supply mains. Switch gear for car light and well light of each lift shall be separate and conspicuously marked.

Any capacitors to correct the power factor shall be connected before the main switch of the power circuit.

6.2.2 *Supply Cables Wiring and Apparatus*

The main power supply cables providing the electricity supply to a lift installation shall be flame retardant, low smoke, low halogen with cross-linked polyethylene (FRLSH XLPE) insulated armoured cables. The cables shall be terminated in the main switchgear panels/distribution box using cable glands such that the armour of the cables is positively connected to the metal body of switchgear panels/distribution box. For each lift, one 415 V $^{+ 6 \text{ percent}}_{- 10 \text{ percent}}$, 3-phase, 4-wire, 50 Hz and one single phase 230 V $^{+ 6 \text{ percent}}_{- 10 \text{ percent}}$, 3-wire, 50 Hz supply shall be independently provided. Other than this, power circuit at 230 V $^{+ 6 \text{ percent}}_{- 10 \text{ percent}}$ for power and lighting sockets in the lift machine room and the lift shaft shall be provided. This is to facilitate maintenance and other related works with lighting and socket outlets while the lift is switched off.

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The cables for lift shall be run in respective lift wells. Cables which are not part of lift installation shall not run in the lift well.

Fixed electrical wiring for circuit voltage up to 250 V located in lift wells shall be one of the following:

a) PVC wires encased in rigid conduit (or trunking) made either of metal or plastic;

b) PVC insulated PVC sheathed cables; and

c) PVC wires in flexible metallic or plastic conduits not exceeding 1 500 mm in length for limit switches, interlocks, push buttons and similar devices.

Control cables on lift cars shall run in rigid/flexible metallic/plastic conduit or trunking. Short runs of flexible conduits may be used, where they are securely fastened in place and not exposed to oil and grease. Short runs of flexible cord may be used as flexible connections between fixed wirings on the car and the switch on car door, provided that the chord is securely fastened in position and so located as not to be subjected to mechanical damage.

Wiring in machine room shall be run in rigid metallic trunking. The trunking in machine room floor shall be flush with the finished floor to avoid trip hazard. The following additional requirements may also be taken care of:

1) Dedicated power supply feeder shall be given for all lifts, which shall be separate from other building services. This feeder shall be distinctly identified and shall have controlled access such that it cannot be switched off by unauthorized person

2) The lift sub-circuit from the meter room should be separate from other building services. Each lift should be capable of being isolated from the mains supply. This means of isolation shall be with lock-out and tag-out facility. The electric supply cables shall run in a route safe from fire, subsequently within the respective lift shafts to the machine room.

3) For banks of interconnected lifts, a separate sub-circuit is required for the common supervisory system, in order that any car may be shut down without isolating the supervisory control of the remainder lifts.

4) When the alarm system is connected to a transformer or trickle charger, the supply should be taken from the machine room lighting.

5) All electrical supply lines and apparatus in connection with the lift installation shall be so constructed and shall be so installed, protected, worked and maintained that there may be no danger to persons therefrom.

6) All metal casings or metallic coverings containing or protecting any electric supply lines of apparatus shall be efficiently earthed.

7) No bare conductor shall be used in any lift car as it may cause danger to persons.

8) All cables and other wiring in connection with the lift installation shall be of suitable grade for the voltage at which these are intended to be worked and if metallic covering is used it shall be efficiently earthed.

9) Suitable caution notice shall be affixed near every equipment or apparatus in which voltage used exceeds 250 V.

10) A single trailing cable for lighting control and signal circuit shall be permitted, if all the conductors of this trailing cable are insulated for maximum voltage running through any one conductor of this cable.

11) *Emergency signal or intercom* ð The lift car shall be provided either with an emergency signal that is operative from the lift car and audible outside the lift well or with intercom.

12) When an alarm bell is to be provided, each car is fitted with an alarm push button which is wired to a terminal box in the lift well at the ground floor by the lift manufacturer. This alarm bell, to be supplied by the lift manufacturer (with indicator for more than one lift) should be fixed in an agreed position and wired to the lift well. The supply may be from a battery (or transformer) fixed in the machine room or, when available, from the building fire alarm supply.

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13) An intercom system or similar device, powered by the emergency supply, shall be installed for communication between inside the car, someone outside the lift (security/reception/BMS room) and the place from which the emergency operation is carried out, if the lift travel exceeds 15 m or if direct acoustic communication in- between these locations is not possible. When an intercom is to be provided in the lift car the lift manufacturer should fit it in the car and provide wiring from the car to a terminal box adjacent to the lift well. Alternatively, a hands-free unit may be provided. The type of intercom should be stated in the enquiry.

6.2.3 *Earthing*

Earthing provides safety of human beings, livestock and apparatus against earth faults. Any system is characterized by the type of distribution system, which include types of systems of live conductors and types of system earthing.

The subject of earthing covers the problems associated with connection of exposed conductive part of installations to the main earthing terminal of that installation and to achieve automatic disconnection of supply before the fault voltage creates a shock hazard. The terms earth and earthing have been used interchangeably, to denote a low impedance return path of the fault current. The earth is mainly used for fixing the voltage of system neutrals and is not used as a part of return circuit.

6.2.3.1 *System earthing*

Earthing of system is designed, primarily, to preserve the security of the system by ensuring that the potential on each conductor is restricted to value consistent with the level of applied insulation. It is equally important that earthing should ensure efficient and fast operation of protective gears, in the case of earth faults. Commonly used system earthing are TN, TT and IT.

6.2.3.2 *TN system*

A system having one or more points of the source of energy directly earthed, the exposed conductive-parts (and extraneous conductive parts) of the installation are connected by means of protective conductors to the earthed point(s) of the source, that is, there is a metallic path for earth fault currents to flow from the installation to the earthed point(s) of the source. TN systems are further sub-divided into TN-S, TN-C-S and TN-C systems.

a) *TN-S system* ð A system with separate neutral and protective conductor throughout the system (*see* Fig. 15).

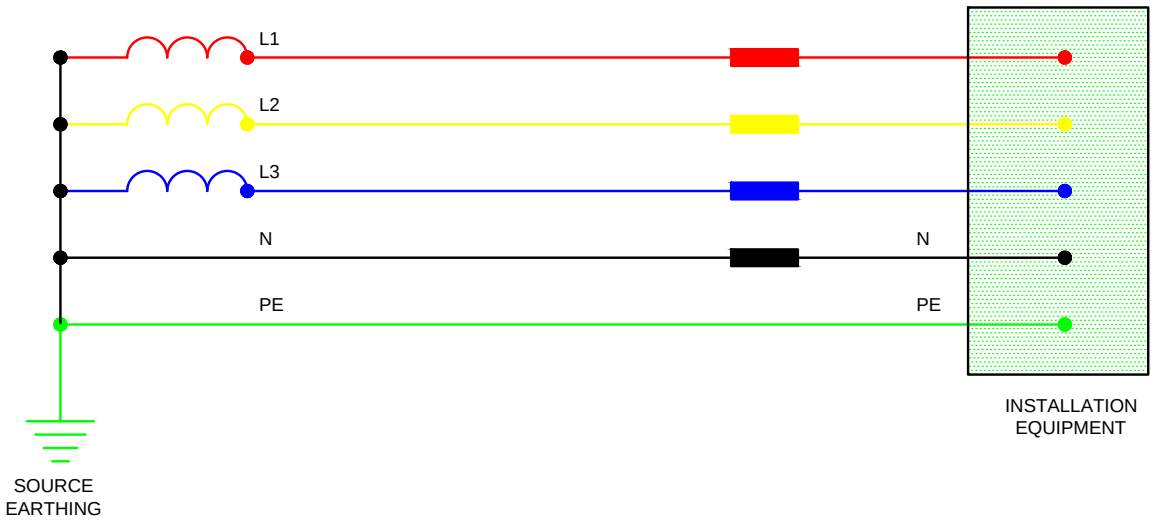

FIG. 15 TN-S SYSTEM WITH SEPARATE NEUTRAL AND EARTH CONDUCTOR FROM THE SOURCE

b) *TN-C-S system* ð A system in which neutral and protective conductors are combined in a single conductor in part of the system. The PEN conductor referred to as a combined neutral and earth (CNE or PEN) conductor, is earthed at the source and at multiple points. Multiple earthing of the PEN conductor ensures that if the conductor becomes open circuit due to any reason, exposed-conductor parts

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remain connected to earth. Under such conditions, the supply voltage between the installation line and neutral conductor is substantially reduced (*see* Fig. 16).

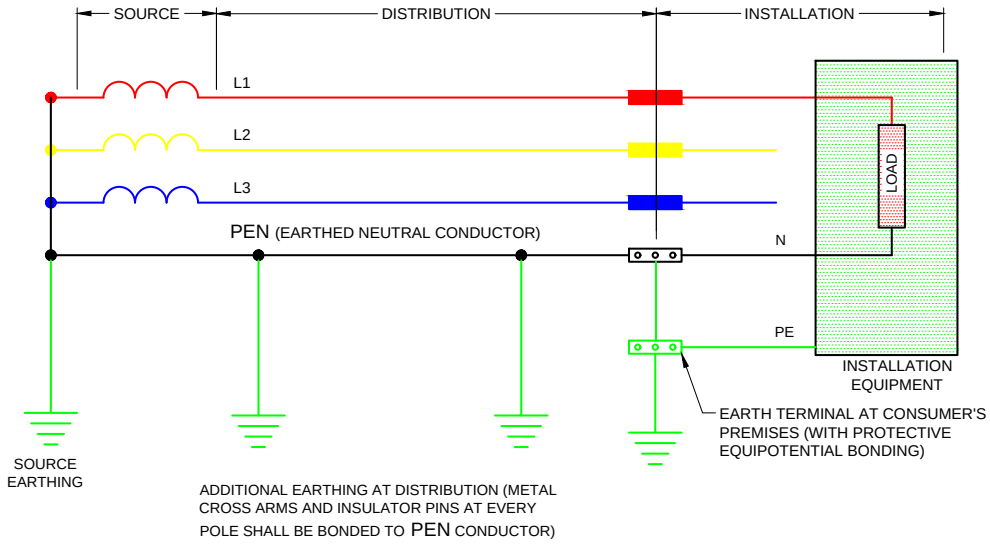

FIG. 16 TN-C-S SYSTEM WITH PROTECTIVE MULTIPLE EARTHING (PME) USED IN PUBLIC DISTRIBUTION

c) *TN-C system* ð A system in which neutral and protective conductors are combined in a single conductor throughout the system. TN-C is not permitted inside consumer premises (*see* Fig. 17).

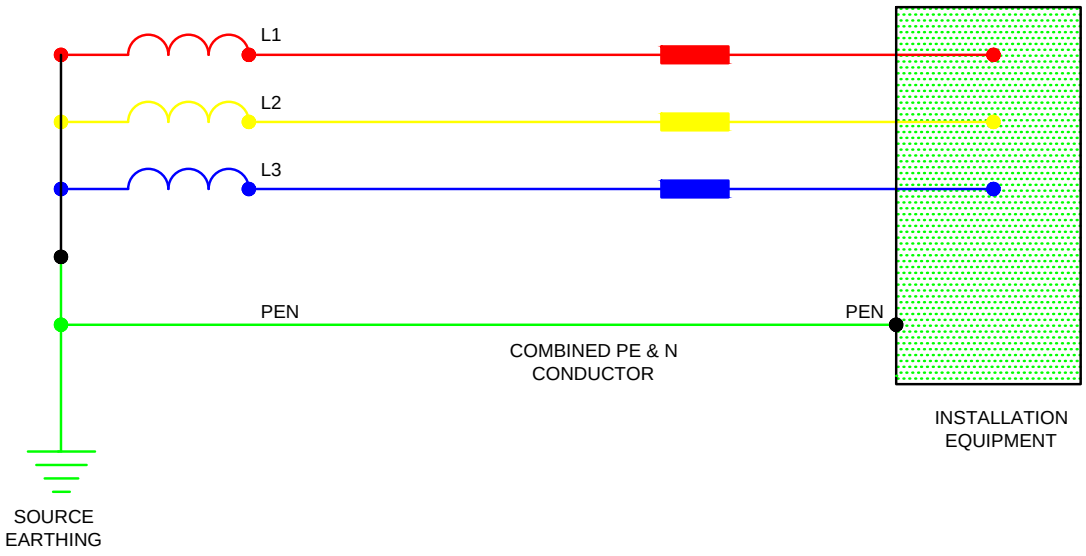

FIG. 17 TN-C SYSTEM (NEUTRAL AND PROTECTIVE FUNCTION COMBINED IN A SINGLE CONDUCTOR THROUGHOUT SYSTEM)

6.2.3.3 *TT system*

In this system one or more points of the source of energy are directly earthed and the exposed and extraneous conductive parts of the installation are connected to a local earth electrode, electrically independent of the source earth. Every consumer installation shall be protected with an RCD for earth fault protection at the origin of installation (*see* Fig. 18).

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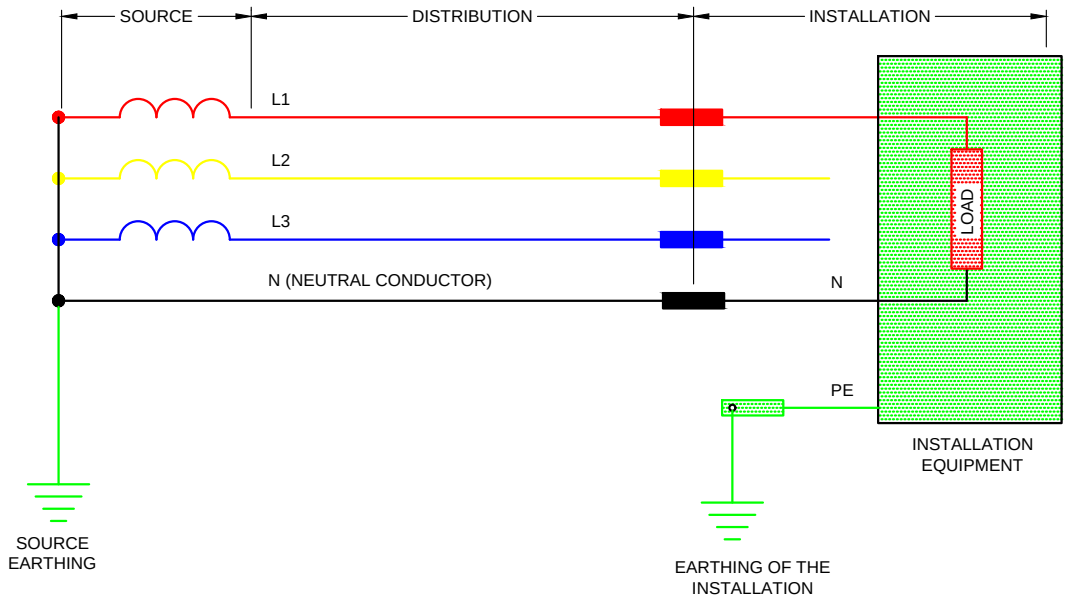

FIG. 18 TT SYSTEM

6.2.3.4 *IT system*

The live parts have no direct connection/isolated from earth or one point is connected to earth through an impedance. The exposed-conductive-parts of the electrical installation are earthed independently or collectively. The IT systems are generally used for special applications such as operation theatre in hospitals. It is not intended for use in lifts (*see* Fig. 19).

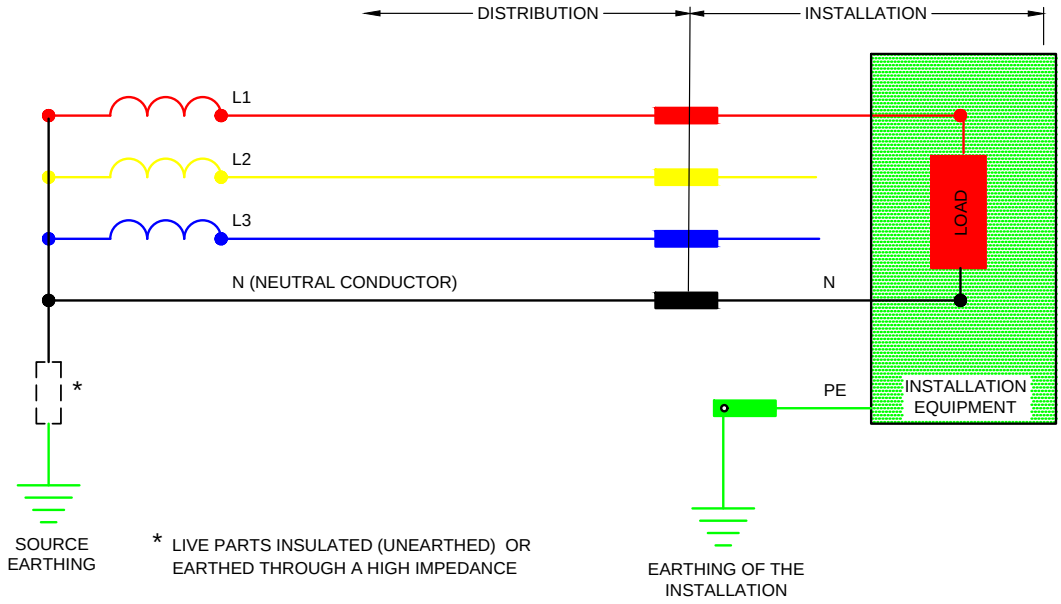

FIG. 19 IT SYSTEM

6.2.3.5 *Basic purpose of earth fault protection*

The occurrence of an earth fault in an installation creates two possible hazards:

a) Voltages appear between exposed conductive parts and extraneous conductive parts and if these parts are simultaneously accessible, these voltages constitute a shock hazard. This condition is known as indirect contact.

b) The fault current that flows in the phase and protective conductors of the circuit feeding the faulty equipment may be of such a magnitude as to cause an excessive temperature rise in those conductors, thereby creating a fire hazard.

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The protective measure known as protective equipotential bonding and automatic disconnection of the supply is intended to provide a high degree of protection against both hazards. The choice of protective device for disconnection is influenced by the type of system of which the installation is a part, because either:

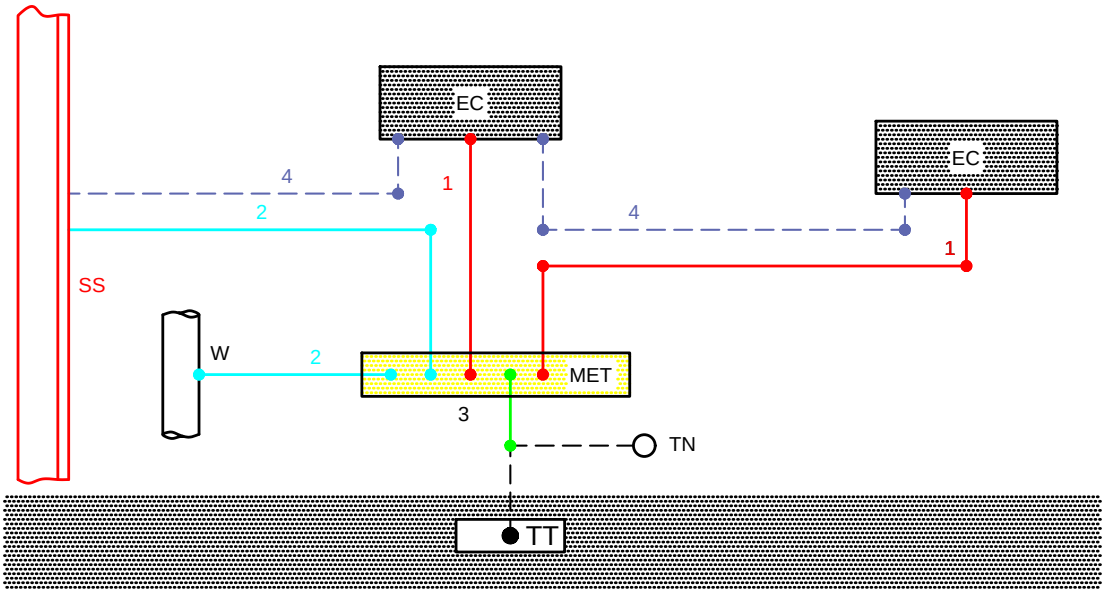
1) the earth fault loop impedance shall be low enough to allow adequate earth fault current flow to cause an overcurrent protective device (for example, a fuse or circuit breaker) in the faulty circuit to operate in a sufficiently short time; or

2) where it is not possible to achieve a low enough earth fault loop impedance, disconnection may be initiated by fitting a residual current device (RCD).

6.2.3.6 *Protective equipotential bonding*

Protective equipotential bonding is through connecting extraneous conductive parts in a building to the main earthing terminal of the installation by protective bonding conductors. Where such conductive parts originate outside the building, they shall be bonded near their entry point within the building.

Typical illustration of earthing and protective conductors is shown in Fig. 20.



Key

EC	Exposed conductive part (part board body)
MET	Main earthing terminal
SS	Structural steel (extraneous conductive part)
W	Metallic water pipe (extraneous conductive part)
TT	Earth electrode in a TT or IT system
TN	Other means of earthing in a TN system, for example, connection to earthed point of the point of the power system
1	Circuit protective conductor
2	Main protective bonding conductor
3	Earthing conductor
4	Supplementary protective bonding conductors (additional bonding, if required)
1,2,3,4	Protective conductors

FIG. 20 ILLUSTRATION OF EARTHING AND PROTECTIVE CONDUCTORS

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In each building the earthing conductor, the main earthing terminal and the following conductive parts shall be connected to the protective equipotential bonding (*see* Fig. 21):

a) metallic pipes supplying services into the building, for example, gas, water;

b) structural extraneous conductive parts, if accessible in normal use, metallic central heating and air-conditioning systems; and

c) metallic reinforcements of constructional reinforced concrete, if reasonably practicable.

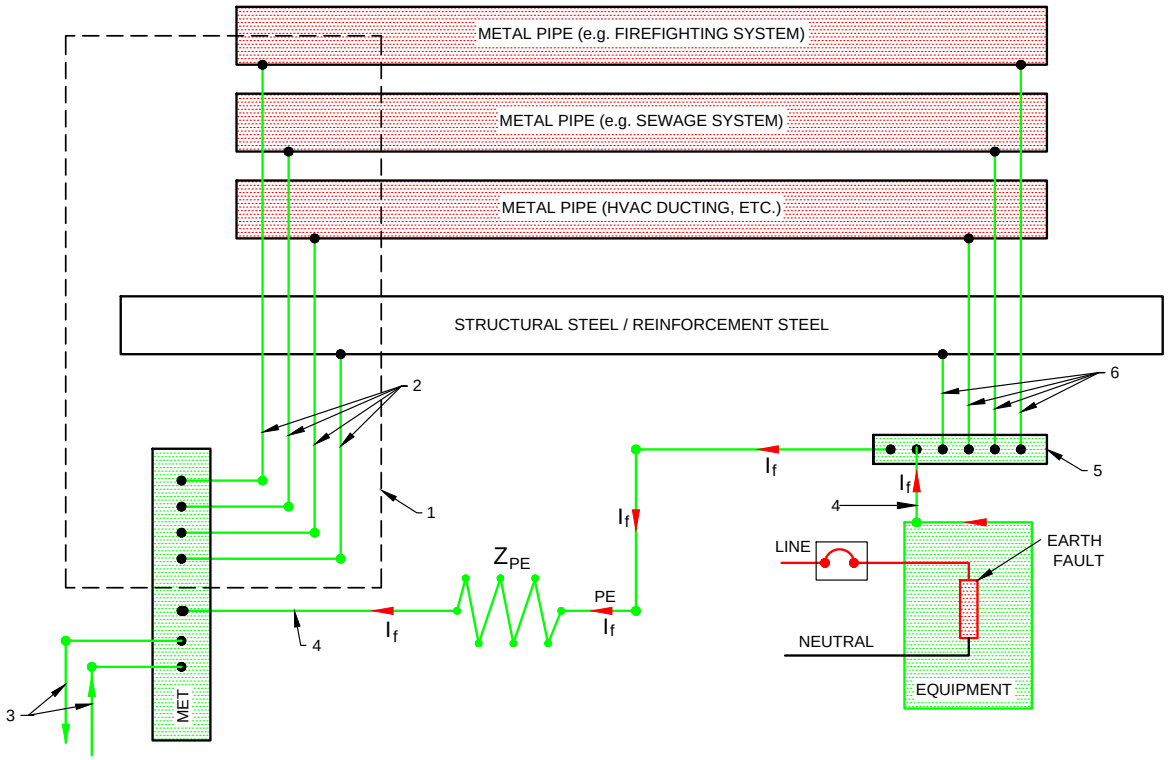

FIG. 21 ILLUSTRATION OF MAIN AND ADDITIONAL PROTECTIVE EQUIPOTENTIAL BONDING

The connection of various conductors in an earthing arrangement shall be proper. The connection shall be by exothermic welding, pressure connectors, clamps or other suitable mechanical connectors. Mechanical connectors shall be installed in accordance with the manufacturerôs instructions. Where a clamp is used, it shall not damage the electrode or the earthing conductor.

Two separate copper protective earthing conductors shall be provided from main earthing terminal (MET) to lift controller. Refer to Table 33 for cross sectional area of protective conductor.

Table 33 Cross Sectional Area of Protective Conductor

(*Clause* 6.2.3.6)

Sl No.	Cross-sectional Area of Line Conductor, S	Minimum Cross-Sectional Area of the Corresponding Protective Conductor
	mm^2 Cu	mm^2 Cu
(1)	(2)	(3)
i)	*S* Ò16	S
ii)	16 < *S* Ò35	16
iii)	*S* > 35	0.5 *S*

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Earthing system above 230 V should be designed as a protective multiple earthing (PME) system with separate protective conductor (TN-S). Protective multiple earthing system shall be implemented to reduce the earth fault loop impedance and to ensure reliable disconnection of supply during an earth fault by the over current protective device (OCPD), for example MCB/MCCB. In PME system, neutral of the supply transformer and the non-current carrying metal parts in the system are interconnected by the common earth grid, in addition to the separate protective conductor.

Hence, it is recommended to have TN-S system with PME (as shown in Fig. 22), where the neutral of the source and exposed conductive parts in the installation are solidly connected to the MET and an earthing grid. In this interconnected system, earth fault current is returned to the neutral, through the interconnected system consisting of the PE conductor and earth grid. Protective earth (PE) conductor shall run in parallel and proximity to line conductors.

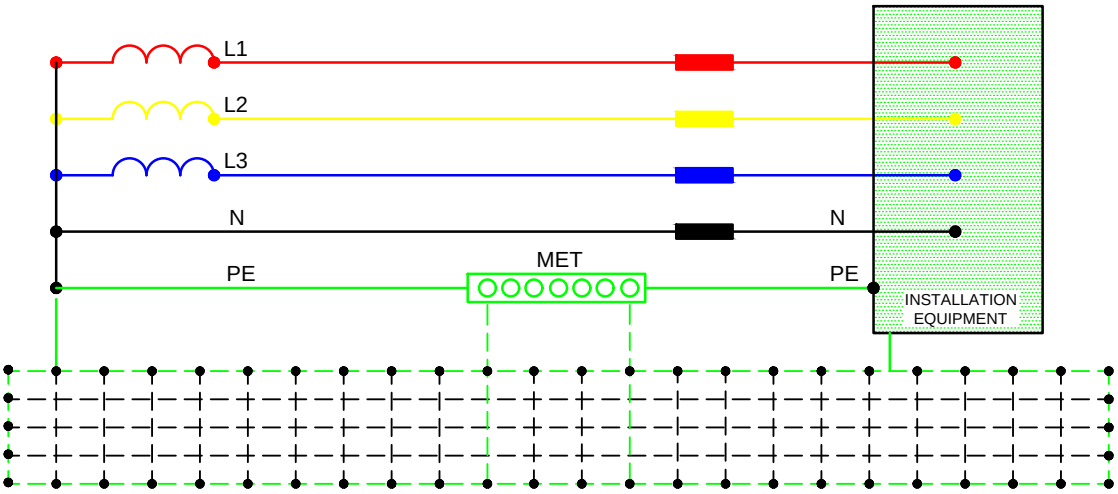

FIG. 22 SYSTEM WITH SEPARATE EARTH CONDUCTOR (TN-S) WITH PROTECTIVE MULTIPLE EARTHING (PME), RECOMMENDED FOR INDUSTRIAL AND COMMERCIAL USE

The continuity resistance of the earth return path through the earth grid shall be less than one ohm.

6.2.3.7 *Automatic disconnection of power supply in case of a fault*

Automatic disconnection of supply is a protective measure in which:

a) basic protection is provided by basic insulation of live parts or by barriers or enclosures; and

b) fault protection is provided by protective equipotential bonding and automatic disconnection in case of a fault in accordance with **4.2.11.3** to **4.2.11.6** of the good practice given in [D-5A(8)].

A protective device shall automatically interrupt the supply to the line conductor of a circuit or equipment in the event of a fault of negligible impedance between the line conductor and an exposed-conductive-part or a protective conductor in the circuit or equipment within the disconnection time specified in **4.3.11.2.2**, **4.3.11.2.3** and **4.3.11.2.4** of the good practice given in [D-5A(8)].

If automatic disconnection cannot be achieved in the time required, supplementary protective equipotential bonding shall be provided as specified in **4.2.15.2** of the good practice given in [D-5A(8)].

In general, every circuit is provided with a means of overcurrent protection. If the earth fault loop impedance is low enough to cause these devices to operate within the specified times (that is, sufficient current can flow to earth under fault conditions), such devices may be relied upon to give the requisite automatic disconnection of supply. If the earth fault loop impedance does not permit the overcurrent protective devices to give automatic disconnection of the supply under earth fault conditions, the first option is to reduce that impedance. It may be permissible for this to be achieved by the use of protective multiple earthing or by additional earth electrodes.

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An alternate approach is to be adopted for the complete safety of the operating personnel and equipment from the hazards that may result from earth faults. This is to use residual current devices with appropriate settings to clear the faults within the permissible time, based on the probable contact potential. This method is equally applicable where earth loop impedances cannot be improved.

6.2.3.8 *Residual current device* (*RCD*)

RCD's can be used for fault protection and additional protection. RCD is used for automatic disconnection of supply during earth fault, in case of failure of this protection by OCPD/MCB. The good practice given in [D-5A(8)] recommends that in locations where fault protection is achieved by 500 mA RCD, earth fault loop impedance test is not required.

RCD of I_{qpn} Ò30 mA shall be used as an additional protection against electric shock in locations where the chance of shock is high.

In addition to giving protection against earth fault or shock protection, RCDôs may also give fire risk protection, the degree of protection being related to the sensitivity of the device and magnitude of leakage current. The good practice given in [D-5A(8)] recommends use of 300 mA RCD for protection against fire in building due to leakage current.

Residual current device (RCD), when provided, right type and sensitivity shall be selected.

The RCD shall,

a) have maximum rating of I_{qpn} 500 mA as tripping current suitable for frequency converters with a 3-phase supply against earth faults; and

b) be sensitive for sinusoidal currents up to 1 000 Hz, and insensitive for currents more than 1 000 Hz.

NOTE ð National Electrical Code of India 2023 recommends Type B RCD for applications which may create smooth DC residual current, for example, three-phase variable frequency drive.

6.2.3.9 *Reinforced protective earthing conductors for currents exceeding 10 mA in the protective earthing conductor*

For lifts with ACVF of higher KVA ratings if the current in the protective earthing conductor exceeds 10 mA the following applies:

a) where the ACVF has only one protective earthing terminal, the protective earthing conductor shall have a cross-sectional area of at least 10 mm^2 Cu or 16 mm^2 Al, through its total run; or

NOTE ð Refer **5.4.3.4** of the good practice given in [D-5A(8)].

b) where the ACVF has a separate terminal for a second protective earthing conductor, a second protective earthing conductor of at least the same cross-sectional area as required for fault protection shall be run from a point where the protective earthing conductor has a cross-sectional area not less than 10 mm^2 Cu or 16 mm^2 Al.

6.2.3.10 *Additional protection*

Additional protection by means of a residual current device (RCD) with a rated residual operating current not exceeding 30 mA shall be provided for:

a) socket outlets;

b) control circuits for landing controls and indicators and the safety chain with voltage higher than 50 V AC; and

c) circuits on the lift car with voltage higher than 50 V AC.

This requirement is to protect persons from direct shock risk. It is different to automatic disconnection of supply offered by residual current device (RCD) > 30 mA as they are intended to protect persons from indirect shock risk to persons in contact with earthed part. Due to the inherent leakages from electronic devices such as power supplies and VFD's, an RCD of 30 mA as a fault protective measure could create unwanted tripping due to

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excessive PE conductor current. Refer **5.3.2.2.1.3** of the good practice given in [D-5A(8)]. Therefore, 3-phase power supply for the lift should never be protected with a 30 mA residual current device (RCD). The 30 mA RCD trips easily when the lift starts to drive and prevents the lift to run. If the construction-time power supply is for some reason protected with a 30 mA residual current device (RCD), suitably sized isolation transformer needs to be provided by the electrical contractor.

6.2.3.11 *Earth fault loop impedance*

The impedance of the earth fault current loop (phase to earth loop) starts and ends at the point of earth fault. Table 34 gives the recommended values. The earth fault loop comprises the following, starting at the point of fault:

a) the circuit protective conductor;

b) the consumerôs earthing terminal and earthing conductor, and for terre-neutre (TN) systems, the metallic return path;

c) for terra-terra (TT) and isolated-terra (IT) systems, the earth return path;

d) the path through the earth neutral point of the transformer;

e) the transformer winding; and

f) the line conductor from the transformer to the point of fault.

Table 34 Recommended Maximum Earth Fault Loop Impedance Values (Zs) for MCBs

(*Clause* 6.2.3.11)

Sl No.	MCB Rating	Zs		
	Amp	Type B MCB	Type C MCB	Type D MCB
(1)	(2)	(3)	(4)	(5)
i)	6	5.11	2.56	1.28
ii)	10	3.07	1.53	0.77
iii)	16	1.92	0.96	0.48
iv)	20	1.53	0.77	0.38
v)	25	1.23	0.61	0.31
vi)	32	0.96	0.48	0.24
vii)	40	0.77	0.38	0.19
viii)	50	0.61	0.31	0.15
ix)	63	0.49	0.24	0.12
x)	80	0.38	0.19	0.10
xi)	100	0.31	0.15	0.08
xii)	125	0.25	0.12	0.06

6.2.3.12 *Verification of effectiveness of automatic disconnection*

The effectiveness of the measures for protection against indirect contact by automatic disconnection of supply shall be verified according to **6.2.3.6** and **6.2.3.7** of the good practice given in [D-5A(8)].

Ensuring effectiveness of automatic disconnection of earth fault is essential in every lift. For this, earth fault loop impedance must be measured and compared with the characteristics of OCPD/MCB or test the disconnection

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time of RCD which is installed as an earth fault protective measure. This test shall be carried out before the lift is released for public usage.

NOTES

1 In TN systems, fault protection (protection against indirect contact) shall be offered by:

a) Overcurrent protective device (MCB/MCCB); and

b) Residual current protective devices (RCDs).

2 In TT systems, RCDs shall be used for fault protection.

3 Where an RCD is used for fault protection:

a) The circuit shall also be protected by an overcurrent protective device that is, standalone RCD shall not be used;

b) The disconnection time shall be according to Table 35; and

c) Fault protection is provided in this case also if the fault impedance is not negligible.

Table 35 Minimum Disconnection Time

(*Clause* 6.2.3.12)

Sl No.	**Voltage** V	**Disconnection Time** s			
		TN System		TT System	
		a.c.	d.c.	a.c.	d.c.
(1)	(2)	(3)	(4)	(5)	(6)
i)	50 < U_o Ò120	0.8	*See* Note	0.3	*See* Note
ii)	120 < U_o Ò230	0.4	5	0.2	0.4
iii)	230 < U_o Ò400	0.2	0.4	0.07	0.2
iv)	U_o > 400	0.1	0.1	0.04	0.1

NOTE ð Disconnection may be required for reasons other than protection against electric shock.

The terminal for the earthing of the frame of the motor, the winding machine, the frame of the control panel and similar electric appliances which normally carry the main current shall be at least equivalent to a 10 mm diameter bolt, stud or screw.

The terminal for the earthing of the metallic cases and covers of door interlocks, door contacts, call and control buttons, stop buttons, car switches, limit switches, junction boxes and similar electrical fittings which normally carry only the control current shall be at least equivalent to 5 mm brass screw (such terminal being one specially provided for this purpose) and the earth conductor size shall be at least equivalent to 0.5 mm^2 copper.

The earth conductor shall be secured to earthing terminal in accordance with the recommendations made in good practice [D-5A(9)] and also in conformity with the latest provisions of *Electricity Act*, 2003 and the CEA Regulations framed thereunder from time to time.

The exposed metal parts of electrical apparatus installed on a lift car shall be sufficiently bonded and earthed.

Where screwed conduit screws into electric fittings carrying control current making the case and cover electrically continuous with the conduit, the earthing of the conduit may be considered to earth the fitting. Where flexible conduit is used for leading into a fitting, the fitting and such length of flexible conduit shall be effectively earthed.

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7 FIRE PROTECTION REQUIREMENTS FOR LIFTS AND EVACUATION LIFTS

7.1 Fire Protection Requirements of Lifts in High Rise Buildings

7.1.1 *Buildings of Height* 15 m *and Above*

Following requirements over and above those specified in **6** and **8** are applicable to all lifts provided in buildings having height more than 15 m:

a) All materials of construction in load bearing elements, stairways and corridors and facades shall be non-combustible.

b) The interior finishing materials shall be of very low flame spread.

c) Walls of the lift well enclosure for a lift or group of lifts shall have a fire rating of 2 h. The lift well shall have a vent at the top, of area not less than 0.2 m^2 per lift.

d) *Landing doors* ð Lift landing doors shall be imperforate. Collapsible doors shall not be permitted. Lift landing doors shall have a minimum fire resistance rating of 1 h for integrity in accordance with accepted standard [D-5A(10)].

e) *Lift car door* ð Lift car doors shall be imperforate. Collapsible car doors shall not be permitted.

f) Telephone or other communication facilities shall be provided in the lift car and the lift main lobby. Communication system for lifts shall also be connected to the fire control room of the building, if provided. For lifts used by persons with disabilities, the facilities shall be provided in accordance with good practice [D-5A(3)].

g) Photo luminescent safety signs shall be posted and maintained on every floor at or near the lift indicating that in case of fire, occupants shall use the stairs unless instructed otherwise. The sign shall have the plan of the respective floor showing location of the stairways. The plan shall indicate the direction to and the level of refuge floors. All signs posted and maintained on every floor of buildings open to and used by the public shall comply with the requirements of accessible signage given in good practice [D- 5A(3)].

h) All lifts (firemanôs lifts/non firemanôs lifts) shall be provided with Phase I operation as per **7.1.1(j)** (grounding operation).

j) The grounding operation may be initiated by individual switches for lifts or a common switch for a group of lifts or by a signal from smoke detector/fire alarm system/BMS room of the building where available.

k) *Firemanôs lift* ï The firemanôs lift is provided in a building for the purpose of aiding firemen in evacuating trapped persons in the building and to take the equipment for fighting fire to upper levels with minimum delay. Some lifts out of all the lifts shall be identified as firemanôs lifts.

The number of required firemanôs lifts and their locations in a building will vary depending on the size, design, complexity of the building. Some considerations are as follows:

1) There shall be at least one firemanôs lift per building;

2) If there are multiple wings in the building, there shall be at least one firemanôs lift per wing;

3) If there are multiple banks of lifts in the building, there shall be at least one firemanôs lift per bank of lifts;

4) If the building height is up to 600 m and it is zoned height-wise and it does not have firemanôs lift serving every floor of the building, then there shall be at least one firemanôs lift per zone which shall serve the main level/fire access level and shall serve all the landings in the respective zones; and

5) If the building height is more than 600 m and it does not have any single lift serving all the floors, that is, it has all lifts serving only respective zones, the firemanôs lift shall be provided in each zone separately, serving all landings in respective zones, with a transfer landing for transferring from one zone to another.

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Considering all above the firemanôs lift(s) shall be identified on the building plan by the concerned firefighting authority. This shall be respected.

To be effective in firemen operation the firemanôs lift(s) shall be identified on the building plan and duly displayed in fire command centre. The firemanôs lift shall fulfil the following requirements:

i) The firemanôs lift may be used by the occupants in normal times;

ii) The firemanôs lift shall be provided with a firemanôs switch. The switch shall be a two position (ON/OFF) switch fixed at the evacuation floor (normally main entrance floor) to activate firemanôs mode. The switch shall be housed in a box with glass cover along with suitable label and fixed adjacent to the lift at the entrance level. When the switch is turned on, all landing operating panels shall become inoperative, and the lift shall operate only from car operating panel or priority control device. When the switch is off, the lift will return to normal working;

iii) The firemanôs lift shall be provided with an audio and visual signal in the car;

iv) The firemanôs lift shall have a floor area of minimum 1.43 m^2. It shall have load capacity of not less than 544 kg (8 persons lift);

v) The firemanôs lift shall be provided with power operated (automatic) doors of minimum 0.8 m width;

vi) The speed of the firemanôs lift shall be 1.0 m/s or more such that it can reach the top floor from main floor/fireman access level within 1 min. In case the building is zoned, the firemanôs lift shall operate from the lowest served landing to the topmost served landing in 1 min;

vii) Reliable back up source of power supply shall be provided for all firemanôs lifts through automatically operated change-over switch. In case of failure of normal electric supply, it shall automatically changeover over to alternate supply. The route of wiring shall be safe from fire;

viii) The normal power feeders and backup power feeders shall be provided with 2 h fire resistance rated enclosures until they reach the machine room/controller;

ix) Suitable arrangements such as providing slope in the floor of lift lobby shall be made at all the landings to prevent water used during firefighting from entering the lift shafts;

x) For requirements of sprinkler refer **9.24.4** of accepted standard [D-5A(7)];

xi) The words óFIREMAN LIFTô shall be conspicuously displayed in fluorescent paint/colour on the lift landings at each floor level;

xii) *Operational requirements of firemanôs lift* ð The lift shall be provided with the following operational controls, Phase I and Phase II:

A) *Phase* I: *Return to evacuation floor* ð Shall start when the firemanôs switch at the evacuation floor is turned to the óONô position or the signal from smoke detector/fire alarm system (if provided by the building management system) is on. All lifts controlled by this switch/signal shall cancel all existing car calls and separate from landing calls and no landing or car calls shall be registered. The audio and visual signal shall be turned on. All heat and smoke-sensitive door reopening devices shall be rendered inoperative.

If the lift is travelling towards the evacuation floor, it shall continue driving to that floor.

If the lift is travelling away from the evacuation floor, it shall reverse its direction at the nearest possible floor without opening its doors and return non-stop to the evacuation floor.

If the lift is standing at a floor other than the evacuation floor, it shall close the doors and start travelling non-stop to the evacuation floor.

When at the evacuation floor the lift shall park with doors open.

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The continuous audio signal is turned off after this return drive. The visual signal shall remain activated until the lift is restored to normal operation.

NOTE – If the building is designed for alternative evacuation floor, in case of fire at main floor the lifts shall park at the alternative evacuation floor with doors open.

B) *Phase* II*: Operation of the lift* – The Phase II is started after Phase I, if the firemanôs switch is óONô.

If the lifts are grounded by the signal from smoke detector/fire alarm system, for Phase II to begin it shall be necessary to turn the firemanôs switch óONô.

The lift does not respond to landing calls but registers car calls. All heat and smoke sensitive door reopening devices are rendered inoperative.

When the car call button is pressed the doors start closing. If the button is released before the doors are fully closed, they re-open. The car call is registered only when the doors are fully closed.

After registering a car call the lift starts driving to the call. If more than one car call is registered, only the nearest call is answered, and the remaining calls will be cancelled at the first stop.

At the floor the doors are opened by pushing the door open button. If the button is released before the doors are fully open, they re-close.

The lift returns to normal service when it stands at the evacuation floor with doors open and the switch is turned óOFFô thereafter.

The operation of firemanôs lift shall be by means of a full set of push buttons in the car. Other operating systems shall be rendered inoperative.

7.1.2 *Buildings of Height* 60 *m and Above*

The following requirements over and above those specified in **7.1.1** are applicable to the lifts and lift enclosures provided in buildings having height more than 60 m:

a) *Firemanôs lifts* — Following additional requirements apply to all firemanôs lifts in the building:

1) The firemanôs lift shall have loading capacity of not less than 1 000 kg and floor area not less than 2.35 m^2;

2) Electrical equipment within the firemanôs lift well and on the car, located within 1.0 m of any wall containing a landing door, shall be protected from dripping and splashing water or provided with enclosures classified to at least IPX3 according to good practice [D-5A(11)];

3) The electrical switchgear placed less than 1 m above lift pit floor shall be protected to IP67 according to good practice [D-5A(11)]. The socket outlet and lowest lamp shall also be located at least 0.5 m above the highest permissible water level in the pit;

4) Suitable means shall be provided in the lift pit to ensure that water will not rise above the level of the fully compressed car buffer;

5) Means shall be provided to prevent the water level in the pit from reaching equipment which could create a malfunction of the firemanôs lift; and

6) Alternative source of power supply shall be provided for all firemanôs lifts through automatically operated changeover switch. In case of failure of normal electric supply, it shall automatically change over to alternative supply. The route of wiring shall be safe from fire.

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b) There shall be fire command centre (FCC) and/or building management system (BMS) room in the building. CCTV cameras shall be fixed in the lift lobbies and the display screen(s) shall be placed in the FCC or BMS room.

7.2 Evacuation Lifts

Buildings, particularly super high rise (height more than 200 m) buildings, may be designed for a systematic evacuation of persons in case of emergencies that are relevant to a specific building. There are many reasons why a building may need to be evacuated, for example, a fire, explosion, chemical or biological attack, flooding, storm damage, earthquake, etc. Not all of these are relevant to every building hence those which are not relevant can be disregarded. Designers of buildings shall determine if a particular hazard is sufficiently great as to require addressing. This clause deals primarily with fire situation although similar logic can be used in case of other situations as well.

It defines intended use of the lift(s) by persons in order to assist the evacuation, either partial or complete, of a building in case of a fire emergency in the ógolden periodô that is, after detection of the fire and before arrival of the fire brigade at the affected building; so long as use of the lift(s) is safe, thereby preventing possible human casualties, especially in case of complex high-rise buildings.

The lifts may be planned only supplementary to, not as a replacement of, exits. In fact, using lifts instead of stairs may well increase evacuation times in many building designs, especially low and medium rise buildings. However, lifts may be allowed to play a positive role in assisting and improving efficiency of the building evacuation strategy especially for persons with disabilities. The building designers should decide, if they want to use lifts for evacuation purpose. The evacuation lift may be used by the occupants in normal times. It may be noted that in general a firemanôs lift may be suitable as an evacuation lift. Three evacuation operation methods are possible for lifts to be used for evacuation of persons. One or a combination thereof may be selected based on the building type and fire evacuation strategy planned for that building. These are:

a) Automatic evacuation operation;

b) Remote assisted evacuation operation; and

c) Manually assisted evacuation operation.

To ensure that the lift(s) is available in the event of an evacuation, following principles shall be considered:

1) The evacuation strategy and process has been defined consistent with the operation of the evacuation lift(s) as described here;

2) Building requirements mentioned in this document are followed; and

3) Until the evacuation of persons is complete, the evacuation strategy and process ensure that the evacuation lift(s) is dedicated to their evacuation.

The number and size of lifts required, or the size of door opening shall be determined on a case-by-case basis by the building designer for calculating the number of lifts required, and the fire evacuation plan for the building, in collaboration with lift specialists and fire officials.

In case of an emergency, the usual way for the occupants of a building to escape to an exit floor by taking to the building stairs shall continue to be available.

7.2.1 *Pre-requisites to Using Lifts for Evacuation in Case of Fire*

7.2.1.1 *Building interface and requirements for implementing an evacuation*

Evacuation operation is designed with the assumption that the following building provisions are in place:

a) The building shall be constructed and shall not sustained structural damage, for example, from fire, explosion, flood, lightning strike, earthquake, storm, etc;

b) The automatic sprinkler system required is installed except that sprinklers in lift machine rooms and in hoist ways are prohibited;

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c) The building shall be provided with a means to protect the lift(s) from the effects of fire and smoke at every landing, a safe area directly outside the lift door, and a fire-resistant structure;

d) The lift lobby at each floor shall be enclosed and separated from the remainder of the floor by a smoke barrier. The lift lobby door shall be 2 h fire rated and shall close automatically upon initiation of building fire alarm. The lift lobby shall be large enough to accommodate at least 25 percent of the floor population at 0.28 m^2 per person;

e) The lift lobbies and staircase shall be pressurized, if required;

f) The lift lobbies shall be provided with CCTV cameras with the monitor located in FCC/BMS room;

g) Fire/smoke/temperature detectors shall be provided in the building in a thoughtful manner in all areas of the building including lift shaft, machine room, lift lobbies, etc;

h) Activation of any of those detectors which signifies unsafe operating environment for the evacuation lift(s) shall initiate Phase I operation of the firemanôs/non firemanôs lift; and suspend the evacuation operation;

j) The fire alarm system may have a provision to automatically send public announcement messages to the residents of the floor with active alarm and to the residents of two upper and two lower contiguous floors;

k) Power supplies shall be secure and reliable; the provision of a secondary supply is essential. The cable providing power to the lift(s) shall be fire protected to the same fire protection level as given to the lift well structure;

m) The secondary power supply shall be sufficient to run the evacuation lift at the rated load and rated speed for a minimum period equal to the planned evacuation time consistent with the evacuation strategy;

n) The car lighting shall be also supplied by secondary power supply;

p) The normal power feeders and backup power feeders shall be provided with 2 h fire resistance rated enclosures until they reach the machine room/controller;

q) The source of the secondary supply, the level of independence between the primary and secondary supplies;

r) The source of the secondary power supply and automatic switch gear shall be located in a fire protected area;

s) The building shall be designed to minimize the risk of flooding into the lift or lift well. To this end sprinkler discharge, burst pipes, fire hose, etc should not be located to discharge towards the lift and any water close to the lift should be directed away from it by sloping floors, etc;

t) Water sensor shall be provided in the pit to shut down the lift in case the operation becomes unsafe due to accumulation of water in the pit;

u) Interior exit stairwell doors if locked, shall automatically unlock permitting exit and re-entry upon setting of alarm;

v) The lift shall be maintained, and the evacuation operation shall be tested at suitable regular intervals;

w) The building shall have a fire safety and evacuation plan including procedures for evacuation using stairs and lifts, the role of wardens, a routine training and drills for occupants;

y) Training shall include the message that lifts shall not be used for evacuation in buildings not having lifts provided with special occupant evacuation operation;

z) The machine room and lift lobbies shall be maintained with minimal fire load;

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aa) Responsibility for safe evacuation shall rest with and shall be in the control of a trained person(s) located at the building premises; and

bb) Those with a disability shall be evacuated with the help of specially trained persons or with their personal assistant.

7.2.1.2 *Detecting fire, smoke and temperature*

Methods of fire detection are well established. If the lifts are to operate a safe evacuation service, good monitoring of the fire in relation to lift equipment is essential.

To ensure the safety of users and lift equipment; the lift machine room, lift well (including lift pit and overhead areas) and landing areas shall be provided with means to detect and monitor for the presence of smoke and heat. Temperature in any safe area provided for persons to wait (lobby, refuge, etc) and the lift well, machine room, etc, should be continuously monitored to determine if it is safe and remains safe for persons and equipment. When an unsafe temperature or presence of smoke is detected, the information should be sent to the BMS or FCC. The BMS or FCC should determine what is to be done next and send appropriate signals to the lift, for example remove lift from service at the respective floor *x* with doors parked open or closed as required. The equipment used for this sensing and monitoring of heat and smoke should be specified by those responsible for the design of the building fire and smoke detection system and not the lift manufacturer.

7.2.1.3 *Location of an event in relation to lifts*

In detecting an event like fire it will be important to know its location in relation to any lift intended for evacuation use. Experts in fire detection systems and lift experts should be consulted to determine the best solution for the design in question. The more the level of sophistication of detection system employed, the more precise will be the level of information available to make decisions and more meaningful these decisions will be. The building designer shall determine the degree of sophistication required taking into account the importance of the building, type of occupancy, etc.

7.2.1.4 *Emergency power provisions*

Secondary (emergency) power shall be provided that has sufficient capacity to run all the evacuation lifts at full speed for the required evacuation time. The route of the wiring shall be safe from fire.

7.2.2 *Operational Decisions for Evacuation*

7.2.2.1 *Types of evacuation*

The evacuation strategy developed should lead to an obvious evacuation type. Lifts will not be able to evacuate all floors at once, so to some degree a systematic evacuation will be governed by the capacity of lifts and the number of persons to be evacuated. Lift engineers can calculate the number of persons that can be moved for a given set of circumstances but the first thing to determine is the number of persons to be evacuated within the required evacuation time. Fire engineers and other experts shall determine these figures. It shall also be determined what proportion of wheel chair and others with impaired mobility may be there and if there is likely to be a floor or building area with a particular concentration of them.

In many instances some sort of phased evacuation will be desirable while at other times a full evacuation may be essential. Phased evacuation involves the evacuation of certain areas first, usually those floors areas at greatest risk followed by other key areas. Also, there could be horizontal evacuation, partly or fully, for example, in case of hospitals.

7.2.2.2 *Evacuation process*

There are 3 types of lift operation methods to hasten the building evacuation process.

a) *Automatic evacuation operation* – The evacuation operation is completely automatic;

b) *Remote assisted evacuation operation* – The evacuation operation is controlled remotely by the "remote evacuation assistant"; and

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c) *Manually assisted evacuation operation* – The evacuation operation is controlled by an assistant in the car "manual evacuation assistant".

The type of evacuation operation(s) to be deployed in a building shall depend on the specific building fire evacuation strategy. The evacuation service shall be operational between the floors as decided by the building designer. The logic of operation shall be mutually agreed between the building designer, the lift designer and the fire expert.

7.2.2.2.1 *Evacuation service* (*Phase* 1)

7.2.2.2.1.1 *Initiation of evacuation service*

Evacuation service shall be initiated by a two-position switch having START-STOP functions provided at the emergency exit lobby (EEL) for the manually assisted evacuation operation and/or a switch at the remote-control panel located in FCC/BMS room for the remote assisted evacuation and/or another switch at the remote-control panel for the automatic evacuation operation**.**

This switch shall enable either starting (START) or stopping (STOP) the evacuation process. When this switch is turned to START position, the lift system shall be ready to evacuate all floors served by that group of lifts.

7.2.2.2.1.2 On activation of the evacuation service, the lift shall behave as described below:

a) All registered car and landing calls shall be cancelled and no new calls shall be registered;

b) In the car the door re-open button, the door close button, and the door protective device shall remain operative; and

c) The lift, occupied or unoccupied, shall proceed to the EEL as follows; except in case of automatic evacuation operation wherein the lift if unoccupied, shall proceed to the affected floor directly as per the pre-determined priority logic for serving the affected floors; and park there with doors closed till a landing call from the affected floor is initiated:

1) A car stationary at a landing in no call condition, shall close the doors if open and travel nonstop to the active EEL;

2) Visual indication in car operating panel shall display "Evacuation Service";

3) A car travelling away from the active EEL shall make a normal stop at the nearest landing without opening the doors, make an audible message such as "Evacuation Service" and return to the active EEL;

4) A car travelling towards the active EEL shall continue its travel nonstop to EEL;

5) If the lift has already started stopping at a level, it shall continue to make a normal stop and without opening the doors, with message displayed "evacuation service", proceed to the active EEL;

6) On reaching at the active EEL, the evacuation lift car shall open its door and shall provide an audio-visual indication "Exit Lift". The audible signal shall have a sound level of between 35 dBA and 55 dBA adjustable to suit the site conditions with a typical recommended level of 50 dBA;

7) If the door is not closed at the active EEL after 20 s, the protective device shall be made inactive, the doors shall attempt to close, and an audible signal shall sound in the car until the doors are closed;

8) To start the Evacuation Service:

i) in case of automatic evacuation operation, any landing call at the affected floor(s) shall initiate the travel of the lift to that floor as per priority logic decided;

ii) in case of remote assisted evacuation operation, the person-in-charge at the remote-control panel shall initiate the travel of the lift to the affected floor; and

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iii) in case of manually-assisted evacuation operation, pressing the car call button at car operating panel (COP) shall initiate the travel of the lift to the affected floor.

7.2.2.2.2 *Evacuation service* (*Phase* 2)

After the evacuation service (Phase 1) is completed and any type of evacuation operation signal is active, the lift shall operate in Phase 2 as follows:

7.2.2.2.2.1 *Automatic evacuation operation*

In automatic evacuation operation the lift shall operate as per the detail below:

a) When automatic evacuation signal is active and when no higher priority signal is active, the lift shall operate in automatic evacuation operation and shall serve registered landing calls;

b) The priority of answering the landing calls shall be based on the distance from the active EEL, with the furthest landing call getting highest priority;

c) On arrival at a landing other than the active EEL, the car shall open the doors and give a voice announcement as ôEvacuation Service. Enter the Carô

d) Once the doors are closed, the car shall proceed towards the active EEL. If the car is empty, it may respond the next landing call without visiting the active EEL.

e) The car if not full, may serve other landing calls on the way to the active EEL. If the car makes stops on the way to the active EEL, it shall provide audio-visual indication ôDo Not Exitô. The audible signal shall have a sound level of between 35 dBA and 55 dBA adjustable to suit the site conditions with a typical recommended level of 50 dBA.

f) Actuation of the landing call booking device shall not prevent a loaded car from closing its doors and leaving the floor.

g) On arriving at the active EEL, the evacuation lift car shall open its door and shall provide an audio-visual indication ôExit Liftô. The audible signal shall have a sound level of between 35 dBA and 55 dBA adjustable to suit the site conditions with a typical recommended level of 50 dBA.

7.2.2.2.2.1.1 *Deactivation of automatic evacuation operation:*

Automatic evacuation operation shall cease when:

a) the automatic evacuation signal is deactivated; or

b) the remote assisted evacuation signal is activated; or

c) the manually assisted evacuation signal is activated; or

d) the suspend service signal is activated; or

e) The lift receives Phase 1 signal of the fireman's control.

In these cases, the car shall return to the active EEL.

7.2.2.2.2.2 *Remote assisted evacuation service:*

Remote assisted evacuation is the evacuation under the control of an authorized person ôremote evacuation assistantô, who controls the lift from remote evacuation control panel located in BMS/FCC room in the same building.

NOTE ð Remote assisted evacuation operation shall be subjected to cybersecurity. Cybersecurity of industrial control systems are specified in the IEC 62443 series of standards and in the accepted standard [D-5A(12)].

In the remote assisted evacuation operation, control from outside the lift car that is, from a remote location, is permitted provided there are communication means between the remote-control location and the lift car. The use

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of remote assisted evacuation and the communication means shall be selected based on building evacuation strategy.

Activation of the remote assisted evacuation operation shall override the automatic evacuation signal, if any.

7.2.2.2.2.2.1 *Remote assisted evacuation operation*

After the completion of Phase 1 of evacuation service, if the remote assisted evacuation signal is active and no higher priority signal is active, the lift shall operate as per details below:

a) Information sharing between the lift and the remote evacuation control panel shall be opened by the lift control;

b) After communication sync is established, the remote evacuation control panel is activated to operate in remote control mode;

c) The alarm button and door open button in the car operating panel shall remain operative; and other controls of the lift shall be operable solely from the remote evacuation control panel;

d) The remote evacuation control panel shall have displays indicating the registered landing calls, car position and direction of travel, and car door status;

e) A call registered through remote evacuation control panel shall cause the lift doors to close and the car to travel to the required landing;

f) If the door closing is prevented by a door protective device, a separate door close command from remote evacuation control panel shall bypass the protective device and the doors shall attempt to close;

g) At any time, it shall be possible to register a new call from the remote evacuation control panel. The previous call shall be cancelled. The car shall travel in the shortest time to the newly registered landing;

h) On arrival at a landing, the lift shall open the doors and shall provide an audio-visual indication ôEvacuation Service. Enter the Carô. The audible signal shall have a sound level of between 35 dBA and 55 dBA adjustable to suit the site conditions with a typical recommended level of 50 dBA; and

j) On arriving at the active EEL, the evacuation lift car shall open its door and shall provide an audio-visual indication ôExit Liftô. The audible signal shall have a sound level of between 35 dBA and 55 dBA adjustable to suit the site conditions with a typical recommended level of 50 dBA.

7.2.2.2.2.2.2 *Deactivation of remote assisted evacuation*

Remote assisted evacuation operation shall cease when:

a) The remote assisted evacuation signal is deactivated; or

b) The remote evacuation control panel becomes inactive; or

c) The connection between the remote evacuation control panel and the lift is interrupted for more than 30 s; or

d) The audible or video communication system is interrupted for more than 30 s; or

e) The manually assisted evacuation signal is activated; or

f) The suspend service signal is activated; or

g) The lift receives Phase 1 signal of the fireman's control.

In these cases, the car shall return to the active EEL.

7.2.2.2.2.3 *Manually assisted evacuation operation*

Manually assisted evacuation operation shall override the automatic evacuation operation or remote assisted evacuation operation.

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Manually assisted evacuation is the evacuation under the control of an authorized trained person(s), who controls the lift from car operating panel and assists occupants to evacuate the building.

After the completion of Phase 1 of evacuation service, if the manually assisted evacuation operation signal is active, the lift shall operate as per details below:

a) Registered landing calls shall be indicated in the car operating panel by blinking car call acceptance light of the given landings;

b) Where multiple lifts in a group are in evacuation operation, all registered landing calls shall be indicated in each lift. If one of the lifts serves the landing call, the landing call shall be cancelled from the other lift(s) as well;

c) The active EEL location shall be indicated in the car;

d) All heat and smoke sensitive door protection devices shall be made inactive;

e) Constant pressure on any car call button or on the door close button shall cause the car door to close. Closing shall start only after 1 s to 2 s delay. If the button is released before the car door is fully closed, the doors shall automatically reopen;

f) Car call shall be registered when the car door is fully closed, and the car shall start to travel to the destination landing;

g) If car doors are closed by the door-close button and car call is not registered within 15 s, the car shall travel to the active EEL and open its doors;

h) At any time, it shall be possible to register a new call from within the car. The previous car call shall be cancelled, and the car shall travel to the newly registered landing; and

j) On arrival at any destination, the car shall automatically open its selected door and remain at the landing until the car door is closed by the attendant and a new car call is registered or until timeout expires.

7.2.2.2.2.3.1 *Deactivation of manually assisted evacuation operation*

Manually assisted evacuation operation shall stop when the car is at the EEL; and when the manually assisted evacuation operation signal is no longer active or when the suspend service signal is active or when the lift receives Phase 1 signal of the fireman's control.

7.2.2.3 The following decision for evacuation may be taken based on below:

a) *If evacuation is required* (*building management*)

This is a decision to be made by other experts and those responsible for building management. In large buildings evacuation may take some time and it shall not be assumed that continued use of a particular lift or lifts is guaranteed. Serious thought shall be given to how information will be displayed to those managing the building especially where the BMS system is capable of providing a large amount of information. It should be possible to see at a glance if lifts are operating correctly and what services they are running. There shall always be provision made to allow the building management or authorities to override any automatic evacuation signal that is generated by a smart BMS. Irrespective of the systems employed the evacuation decision cannot be made by a lift system and therefore other experts in this field shall determine what risks will constitute the need for evacuation and the type of evacuation (partial or full).

b) *If lifts are to be used for the evacuation*

If for some reason a significant number of lifts are not available for use then it may be prudent to remove all lifts from automatic evacuation service rather than have too few. If too few lifts are in service, delays will result that could be dangerous or cause panic. In such circumstances it is probably desirable to run a limited service for the evacuation of those who have difficulty negotiating stairs. Any such service

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needs to be managed by lift attendants who will drive the lift, manage possible crowding and assist those who need it. The decision to operate some form of service when not all lifts are available shall be taken by those managing the building evacuation.

7.2.2.5 *Building evacuation information*

When evacuation is required, updated information shall be provided through the building systems informing persons concerned including those in waiting areas which lifts to use during the particular emergency. This information shall be in both audible and visual format. Any safe areas/waiting areas should also have an emergency communication system.

7.2.3 *Specifications of Automatic Evacuation Lift*

7.2.3.1 *Determining the number and size of lifts*

To calculate the number and size of lifts required for an adequate evacuation service, the handling capacity of a given lift or group of lifts shall be determined considering possibility that a lift or lifts may not be available for some reason such as planned maintenance, repairs, etc. This analysis can be done by the lift designer. Also, due consideration shall be given to the requirement of accommodating a wheel chair in the lift car.

7.2.3.2 *Protection of lift equipment*

Lift shafts and machine rooms or machinery spaces located outside the shaft should be fully enclosed. The temperature in the enclosures should be monitored and maintained to acceptable levels for the equipment, as determined by the lift supplier in consultation with the building management. Protection from water may be considered, if required as per overall evacuation strategy.

7.2.3.3 *Removal or suspension of lifts from evacuation service*

Where a lift receives a command from a BMS or manual signal to stop or suspend service to a floor or area of the building, any stop shall be a controlled stop at a safe area. A controlled stop means allowing the lift to slow down and stop at a floor in the normal manner. Where a lift or lifts are instructed to suspend service the lift(s) shall inform the FCC and any BMS once it is no longer available for service.

7.2.3.4 *Remote lift car surveillance*

At times of emergency, it is vital to be able to see that lifts do not contain trapped passengers who may be incapacitated. A means to display the entire floor area of the car shall be provided with information to the occupants that the lift car is under surveillance. At least one viewing terminal shall be located in the FCC and clearly marked ôLift Car Surveillanceô with the lift designation identified.

7.2.3.5 *Communication system requirements*

As a minimum a 3-way communication system shall be available for passenger use to permit direct communication between the lift car and safe area and FCC. Operation of the communication device in the lift car shall be simply by means of a single button, operation of which shall connect the system to the FCC. Further operation of the device in the lift car shall be hands free.

7.2.3.6 *Initiation of evacuation service*

Evacuation service can be initiated by a device such as a button or lever, key, etc located near the lift shaft at the evacuation landing, or from a signal sent by a BMS or hazard detection system. Where a button or other manual activated device is used it shall be protected against unauthorized use. Its purpose shall be clearly marked with a symbol and/or the words ôLIFT EVACUATION SERVICEô.

The evacuation service shall be operational between the floors as decided by the building designer. The logic of operation shall be mutually agreed to between the building designer and the lift designer. However, any lift will be automatically removed or suspended from evacuation service if, where provided, it is turned to firemen operation.

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7.2.3.7 *Cancellation of evacuation service*

On cancellation of a signal from the device that initiated the service and receipt of a signal from an evacuation service cancellation switch, all lifts which are not at the main landing shall complete any allocated task and return to the main landing.

On arrival at the main landing the doors shall open and then the lift evacuation for that particular lift shall be cancelled. Any lift already at the main landing shall on opening its doors cancel its evacuation service.

7.2.4 *Information to be Provided to the Building Owner/Operator*

Detailed instructions shall be provided to the building owner/operator by the building designer in the form of a manual. The manual shall explain the evacuation strategies to be used, how any detection system operates, how they shall be maintained and how the lift will operate on evacuation service. It should also provide advice on periodic checks the owner/operator can make to ensure the system is working correctly and explain the importance of a suitable testing and maintenance system being in place. Training being very important aspect of this new concept, the manual shall include such details of training as who should be covered by training, how the training should be carried out, what should be the frequency, etc.

8 MINIMUM TECHNICAL AND SAFETY REQUIREMENTS

8.1 General Requirements

The following general requirements shall be adhered to:

a) Passenger and goods lifts shall comply with the safety requirements and/or protective measures as given below. In addition the passenger and goods lifts shall be designed according to good practices [D-5A(2)];

b) All labels, notices, markings and operating instructions shall be permanently affixed, indelible, legible and readily understandable (if necessary aided by signs or symbols). *See also* good practice [D-5A(3)]. They shall be of durable material, placed in a visible position, and written in the accepted language(s);

c) The minimum factor of safety for any part of the lift shall not be less than five. Higher factor of safety for various parts shall be applicable in accordance with good practice [D-5A(13)];

d) All passenger, goods, stretcher, automobile, dumbwaiter lifts shall have conformity with *Lifts Acts and Rules* in force, *The Electricity Act*, 2003, CEA Regulations and all relevant and applicable Indian Standards, applicable fire regulations, fire prevention act and rules in force;

e) *Notices* — The following notices shall be placed at respective places:

   1) A notice (*see* Fig. 23) bearing the following (typical) minimum inscription shall be fixed to the outside of doors or trap-doors (excluding landing doors and doors of emergency and test panels) giving access to machine and pulley rooms. Use of notice boards as per relevant standards is recommended, that is danger board shall be as per accepted standard [D-5A(14)]. Use of non-standard notice boards should be avoided; and

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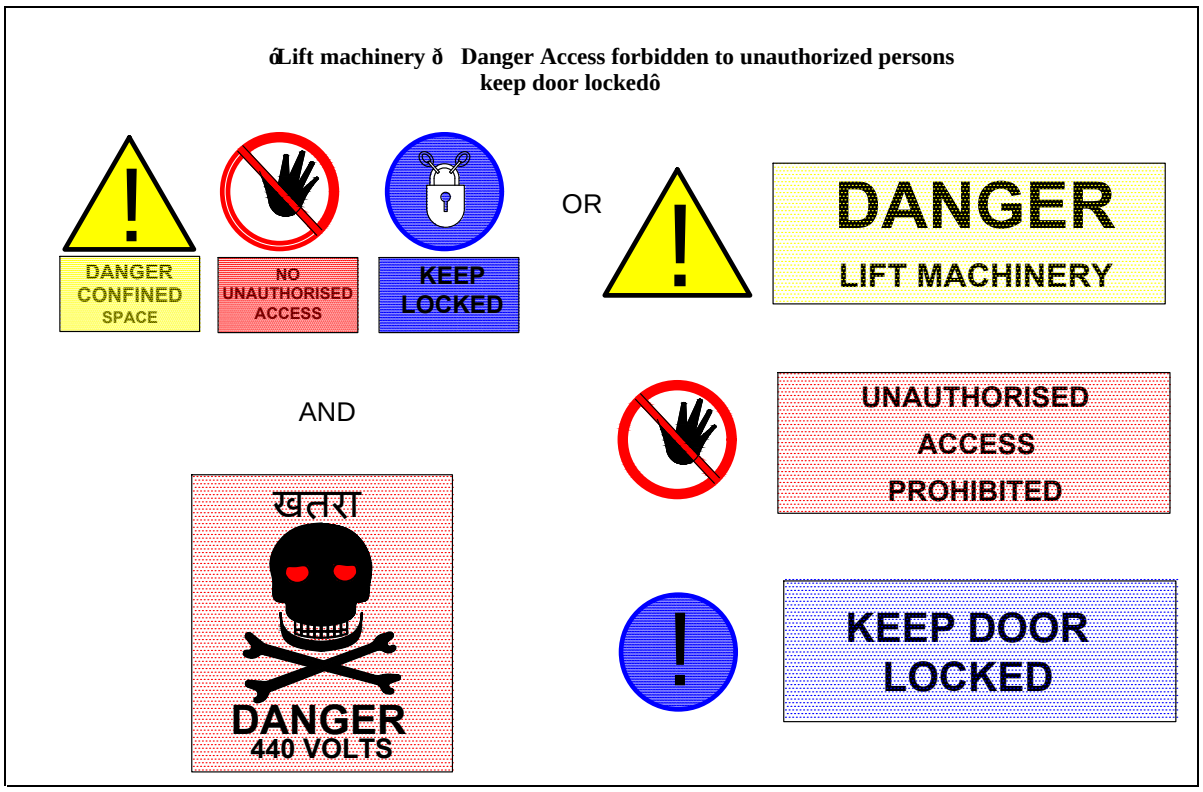

FIG. 23 TYPICAL INSCRIPTIONS ON DOORS

2) In the case of trap-doors, a permanently visible notice (*see* Fig. 24) shall indicate necessary warning to those using the trap-door.

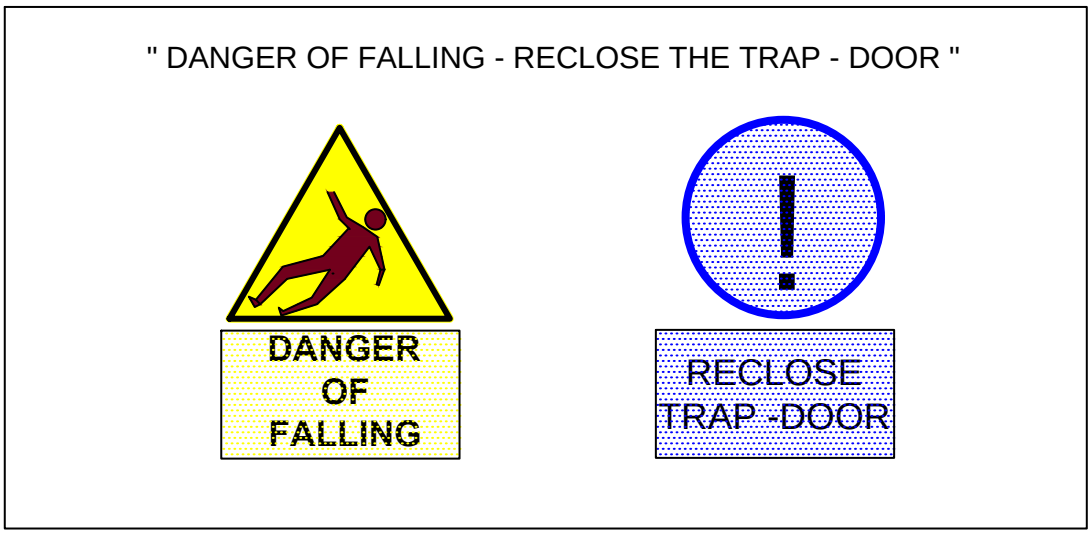

FIG. 24 TYPICAL NOTICE ON TRAP DOORS

3) Outside of the well, near the access doors and emergency doors, if any, there shall be a notice as shown in Fig. 25.

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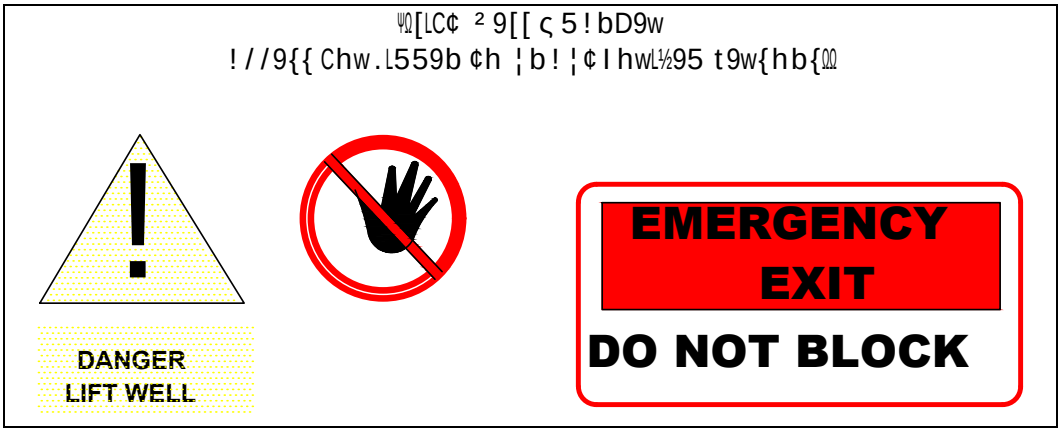

FIG. 25 TYPICAL NOTICE ON ACCESS DOORS AND EMERGENCY DOORS

4) A notice board with following instructions as applicable, and/or other applicable instructions shall be placed in conspicuous position in the lift car:

   i) Maximum capacity of lift _____ kg/_____ persons;

   ii) Close the car and landing door/gate properly, on entering, or while leaving the lift car;

   iii) Do not open the lift-car gate when the lift-car is moving. The gate should only be opened after the lift-car has stopped opposite a landing gate;

   iv) In case of danger, press the alarm button, but do not try to open the car door. Wait inside, until the lift car is brought opposite a landing, and do not attempt to leave the lift car until the landing door is opened fully; and

   v) Children under 12 years of age shall not use the lift, unless accompanied by an adult.

5) The Table 36 is a typical list of Do's and Don'ts that should be displayed in the lift car, and in case of lifts open to public use, in an accessible format complying requirements of accessible information board/signage, given in good practice [D-5A(3)]:

Table 36 List of Do's and Don'ts

[*Clause* 8.1(e)(5)]

Do's	Don'ts
a) Press call button lightly	a) Do not overload the lift beyond maximum capacity of the lift
b) Know your destination. Push lift call for direction you want to go	b) Do not press call button again and again
c) Stand aside for exiting passenger	c) Do not force-open the doors, it is dangerous
d) Pay attention to floor indicator	d) Do not stand in between the doors
e) Push and hold the door open button, if door needs to be held open	e) Do not fiddle with the equipment
f) Wait for the next car, if the lift is full	f) Do not step in until lift has stopped at landing and doors are fully open
g) Take the stairs, if there is a fire	g) Do not crowd in the middle of car
h) In case of emergency call customer service cell for rescue operation	h) Do not lean against car panels
j) Children of 12 years or below and pets shall always be accompanied by an adult inside the lift	j) Do not panic in case of power failure
	k) Do not attempt to jump out, if the lift has stopped out of floor level
	m) Do not try force open the doors when the lift is in motion

NOTE – No other notices should be fixed in the lift car.

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8.2 Power and Control Systems

8.2.1 *Features Associated with Power Systems*

The features associated with power systems are listed below.

8.2.1.1 *Industrial switchgear*

Switchgear for controlling lift power systems is characterized by its high duty cycle and its high rupturing capacity. Switchgear shall be robust enough and shall be so designed as to withstand the high duty cycle and high rupturing capacity introduced during the operation of the lifts.

8.2.1.2 *Levelling accuracy*

The levelling tolerances in accordance with good practice [D-5A(6)] are those which can be reasonably expected between no load and full load in either direction. With the VVVF drives good levelling accuracy can be expected.

8.2.1.3 *Corrective levelling*

This should only be used, when it is impossible otherwise to achieve the required levelling tolerances or on long travel lifts to maintain the required levelling tolerances during loading and unloading.

8.2.1.4 *Levelling with variable voltage*

A variable voltage system is one using continuous regulation which minimizes speed differences due to load variation. Therefore, the actual levelling speed is of less importance than the general refinement of its regulation control. In fact, no levelling speed as such may be identifiable.

8.2.1.5 *Overload tests*

A lift is designed to operate and transport the contract load, at the required duty cycle, and should not by intention or habitually be used to carry overloads. During test as a safeguard to cover variable supply and temperature conditions, a lift is checked for the car to complete one round trip with contract load plus 10 percent at nominal supply voltage and nominal ambient temperature. There is also a static test with contract load plus 25 percent to check that the brake will sustain the car. It is unnecessary to specify an additional overload test or capacity and in fact it is detrimental to the normal running efficiency and safety of the lift to do so.

8.2.1.6 *Occasional extra load*

It is not good practice to request that a lift should be designed to carry an occasional extra load. It is tantamount to specifying an excessive overload test which is detrimental to the normal running efficiency and safety of the lift.

8.2.2 *Description of Operation Systems*

The following description relates to the associated operating systems.

8.2.2.1 *Methods of control systems*

The methods of control systems are as follows [*see* **8.2.2.2(a)**]:

a) Attendant and dual control; and

b) Automatic push button operation.

8.2.2.2 *Types of control systems*

The features of control systems shall be as described below:

a) *Automatic push button operation* — Automatic control is a method of operation by which a momentary pressure on a push button sets the car in motion and causes it to stop automatically at any required lift landing. This is the simplest control system and it is sometimes referred to as push button control. A

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car answers a landing or car call, whichever is actuated first by momentary pressure provided the lift is not in use. Momentary pressure of a car push button will send the car to the designated floor. The car always responds to a car push button in preference to a landing push button. With this type of control, a red landing signal light or direction arrow indicates that the car is in use that is the lift is travelling. This type of control is recommended for single passenger lifts serving up to 4 floors and goods lifts.

For special purposes, the following two systems may be considered:

1) Dispatch from landings as an additional feature for a goods lift with manually operated doors. The call is registered by pressing the car push button and when the doors are closed the car will travel to the designated floor.

2) Automatic with attendant control as an additional feature on goods lifts with a key operated switch in the car to transfer the control from normal automatic to attendant operation. There is also a visual call indicator with buzzer in the car to indicate to the attendant the landing floors at which push buttons have been pressed when the car is under attendant control.

b) *Collective control* — Collective control is a generic term for those methods of automatic operation by which calls made by pressing push buttons in the car and at lift landings are registered and answered by the car stopping in floor sequence at each lift landing for which calls have been registered irrespective of the order in which the calls have been made, and until all calls have had attention. Collective control of any form is usually not suitable for goods lifts except where loading is not expected to fill the car and additional loads can be taken at other stops.

c) *Single push button collective control* — Single push button collective control has a single push button at each landing. It is not recommended, as the direction in which it is desired to travel cannot be registered by the intending passenger.

d) *Down collective control* — Down collective is a control system where landing calls are registered from a single push button, irrespective of the car being in motion or the landing door being open and calls are stored until answered. Any number of car calls can be registered and the car will stop in sequence in the down direction at each of the designated floors. The car will travel in the up direction to the highest call registered stopping only in response to car calls. It will then travel downwards answering calls in floor sequence. If only one call has been registered the car travels to the floor of call.

This system is suitable where there is traffic between the ground and upper floors only and no inter floor traffic. Two or three car banks have interconnected control. With this type of control the following signals are included:

1) A landing signal light indicates that the call has been registered and will be answered.

2) Illuminated car position indicator above car entrance.

e) *Directional collective control for one car* — Directional collective control for one car is a control system having 'UP' and 'DOWN' push buttons at intermediate landings whereby the call is registered for the intended direction of travel. Calls from the car or landing push buttons are registered and stored until answered. The car will answer calls in floor sequence in one direction of travel. Calls for the opposite direction of travel are answered when the direction of travel is reversed.

This system is suitable for single lifts serving four or more floors with inter floor traffic, such as small office blocks, hotels and blocks of flats. With this type of control the following signals are included:

1) A landing signal light for each landing push button indicates that the call has been registered and will be answered.

2) Illuminated car position indicator above the entrance in the car.

3) Arrow shaped signal lights in the back of the car or on the landing to indicate to the entering person in which direction the car is going to depart.

f) *Directional collective control for two or three cars* — Directional collective control for two or three cars is a system covering a control in which the two or three cars in a bank are interconnected. One push button unit with 'UP' and 'DOWN' push buttons or floor buttons (in case of car control from floor) are

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required at each landing and the call system is common to all lifts. If for architectural balance, in the case of a three car bank, extra push button units are required, these should be specified. Each landing call is automatically allocated to the best placed car. The control is designed so that cars are effectively spaced and thus give even service. When a car reaches the highest floor to which there is a call its direction of travel is automatically reversed when it next starts. One or more cars will return to the parking floor. Automatically bypassing of landing calls when a car is fully loaded is an essential feature for three-car banks. It is also necessary for two-car banks in offices. Other cars will continue to provide service to all floors. When three-car banks serve 7 or 8 floors and over, some form of automatic supervisory control [*see* **8.2.2.2(g)**] is generally necessary in the interest of efficiency. With this type of control the following signals are included:

1) A landing signal light for each landing push button to indicate that the call has been registered and will be answered.

2) Illuminated car position indicator above the entrance in the car.

3) Arrow shaped signal lights in conjunction with an audible single stroke gong or an indication on the landing call push button station above each landing entrance to indicate to the waiting person(s) which car is going to stop and in which direction it will continue its course.

g) *Group supervisory control* — A bank or group of intensive traffic passenger lifts requires a supervisory system to coordinate the operation of individual lifts which are all on collective control and are interconnected. The very nature of intensive service calls for a sophisticated automatic supervisory control system so as to match the speed capacity of these lifts. The supervisory system regulates the dispatching of individual cars and provides service to all floors as different traffic conditions arise minimizing such unproductive factors as idle cars, uneven service and excessive waiting time. The system will respond automatically to traffic conditions such as óUPô and óDOWNô peaks, balanced or light traffic and provides for other specialized features. If desired, a master station can be provided in the lift lobby which gives by indicators, visual information regarding the pattern under which the system is operating. Where the system is based on a definite programme, control means are provided for altering the type of traffic programme. There are other facilities, such as the removal of any lift from service.

h) *Destination control system* — In case of a bank of lifts having more than 6 lifts or as decided by user, destination control system (DCS) may be provided. The passengers enter their destination floors on the destination operating panels (DOPs) provided on the lift landings. The lift controller allocates a lift to every call registered which is displayed on the DOP. The passenger is expected to board the assigned lift and travel to his destination floor. He need not register his destination floor in the lift car operating panel (COP) again. In fact, COP in the lift car may not be provided with floor buttons in case of DCS control system. The principle behind the DCS is to group passenger with same destinations together thus reducing the number of stops of the lift reducing round trip time and boosting traffic.

j) *Number of DCS terminals* — Number of terminals at every floor shall be established based on the 5 min peak traffic, however it shall not be less than 2 on every floor.

It is recommended that the DCS input terminals barring one for people having special needs is not located in the position of the conventional hall buttons. It is recommended that the DCS input terminals are positioned outside the lift lobby or at the entrance to the lift lobby or integrated with the turnstiles.

The advantages of DCS system over conventional collective control are:

1) enhanced passenger handling capacity;

2) less transit time, few intermediate stops; and

3) passengers do not have to struggle through crowd to book the calls.

In addition to the DOPs the lift landings shall be provided with lift identifier. Indicators shall be provided on the car jambs indicating the car stops.

Hybrid destination control (HDCS) combines features of the DCS and conventional control system. The main floor is provided with DOPs, lift identifiers and the lift car is provided with the conventional COP as well. Thus, while availing benefit of traffic boosting HDCS provides convenience of call booking from inside the lift car as well.

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8.2.2.3 *Features of operation systems*

The features associated with the operating systems are as follows:

a) *Car preference* – Sometimes it is necessary to give a special personal service or a house service. When this service is required and for whatever purpose, it should be specified as "car preference"; is activated by a key operated switch in the car. The operation is then from the car only and the doors remain open until a car call is registered for a floor destination. All landing calls are bypassed and car position indicators on the landing for this lift are not illuminated. The removal of the key when the special operation is completed, restores the control to normal service.

b) *Landing call automatic bypass* – For collective operation, automatic bypassing of landing calls can be provided. This device will bypass landing calls when a car is fully loaded but the calls are not cancelled.

c) *Basement service* – For lifts with collective control when service is required below the main parking floor, which is usually the ground floor, to a basement and/or a sub-basement, the lift manufacturer should be informed of the type of service required, as special technical considerations are then usually necessary.

d) *Hospital service* – Lifts for carrying beds and stretchers require a car preference switch so that an attendant can have complete control of the car when required. This requirement should be specified as "car preference" and it will function as described in 8.2.2.1. Otherwise such lifts can have the same control systems as for normal passenger lifts, the choice depending on the number of floors served, the service required and the number of lifts.

e) *Manually operated doors* (*without closers*) – A "door open" alarm should be provided to draw attention to a car or landing door which has been left open.

f) *Automatically power closed doors* – For passenger operation when the car arrives at a landing the doors will automatically open and then close after lapse of a time interval. This time interval can be overruled by the pressure of a push button in the car to give instant door closing. An "open door" push button is provided in the car to reverse closing motion of the doors or hold them open.

g) *Controlled power closed doors* – When there are conditions that particularly affect the safety of passengers or damage to vehicles or trucks, the closing of the doors should only be made by the continuous pressure of push buttons in the car or on landings. A "door open" alarm should be provided to draw attention to a car or landing door which has been left open. This means of operation is required for some forms of goods lifts.

h) *Safe operation of doors* – The safety of passengers passing through lift entrances is fully covered by the provision of good practice [D-5A(13)]. No modification of these provisions should be specified.

j) *Directorial service* – There are many forms of giving special service for individuals, but they should always be avoided. They range from key operated switches at preferred landings to the complete segregation of one out of a bank of lifts. It is obvious that any preferential treatment of this nature can seriously jeopardize the efficiency of the service as a whole. When a bank of say three lifts is installed to meet the anticipated traffic requirements and then, when the building is occupied, one lift is detached permanently for directors' service, the traffic handling can be reduced by a half rather than a third. When preferential service is imperative, then the car preference feature should be available [*see* 8.2.2.3(a)].

k) *Indication of car arrival* – All lift cars are illuminated when available (in service). It is recommended that this illumination be used to signal the arrival of a car at a landing in preference to special signals such as "LIFT HERE" signs since signal lamps can fail when the lift is still operating satisfactorily.

The following is the practice adopted for vision panels in doors:

1) For lifts with manually operated car and landing doors, vision panels are provided in all doors.

2) For lifts with power operated car doors and manually operated landing doors, vision panels are provided in the landing doors only.

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m) *Service switches* ð When switches are provided to take cars out of service, that is because the remaining cars in the group can cater for the required passenger traffic, it is essential that such switches should not stop the firemanôs control from being operative in the event of the lift being designated as a firemanôs lift. Service switches should not be confused with maintenance switches which are only used when it is dangerous to attempt to operate the lift because maintenance work is actually in progress. A control station fitted on top of the car is regarded as a maintenance switch.

n) *Fire switch* — When required by the fire authority a fire switch has to be provided, the function of which is to enable the fire authority to take over the complete control of one or more lifts in an installation.

p) *Push buttons and signals* ð It is most important that the purpose of every push button and signal should be clearly understood by all passengers.

q) In public places where visually impaired are expected to use the lifts it is recommended to provide Braille/tactile buttons.

8.3 Capacity and Loading

The minimum rated load of a passenger lift car corresponding to the net inside car area shall bear the relationship given in Fig. 26; the net inside car area being evaluated as shown in Fig. 27. The net inside car areas for various passenger capacities with corresponding minimum rated loads have been given in Table 37 and for goods lifts in Table 38.

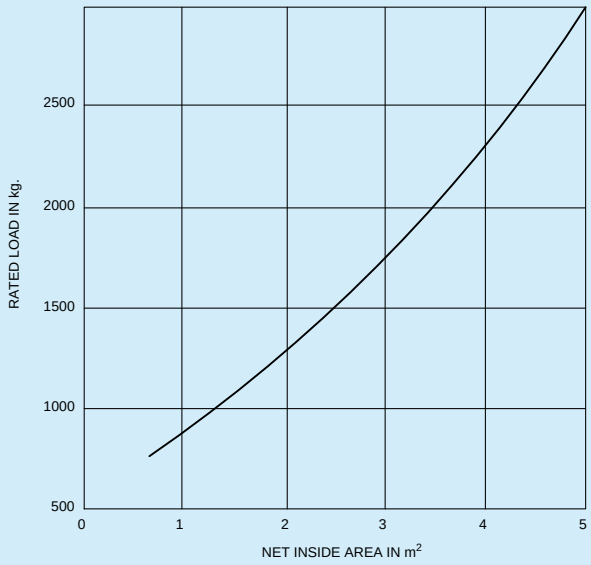

FIG. 26 MINIMUM RATED LOADS FOR PASSENGER LIFT CAR

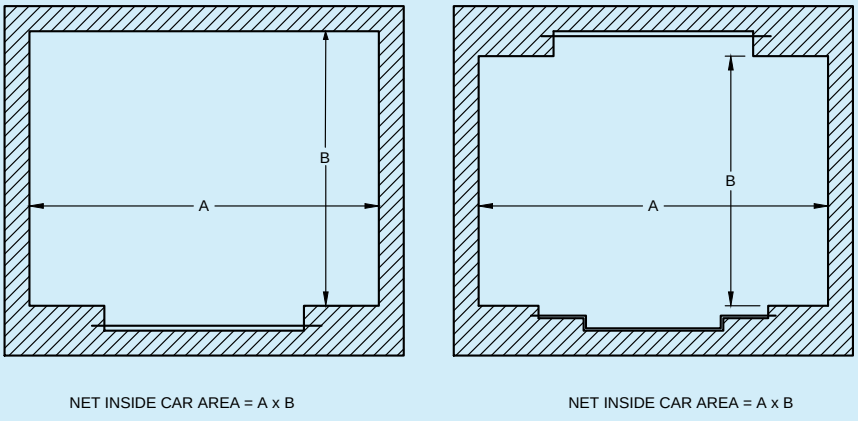

FIG. 27 NET INSIDE CAR AREA FOR PASSENGER LIFTS

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NOTES

1 The graph shown in Fig. 26 is based on the following formula:

$$W = 35.05\ A^2 + 325.66\ A$$

where

W = rated load, in kg; and

A = net inside areas, in m^2.

2 For rated loads exceeding those covered by the graph, value may be evaluated from the formula given above.

3 To avoid the possibility of serious overloading of bed lifts, they shall be treated as passenger lifts.

4 The minimum rated load for goods lifts shall be based on a load of not less than 3.45 kN/m^2 of the net inside car area.

5 The minimum rated load for automobile lifts shall be based on a load of not less than 1.45 kN/m^2 of the net inside car area.

6 When the load in a goods lift consists of pallets or similar single piece loads loaded by means of a power truck, it is necessary during loading and unloading to take into account the total load on the car platform the capacity of the brake and the resistance to slipping of the ropes on the sheave of a traction machine. Similarly, guide rails, guide fixing, car frame and platform shall be designed to withstand the horizontal thrust imposed by power trucks, motor vehicles and the like.

7 For motor vehicle and other special purpose lifts for transportation of light weight and heavy volume loads, the lift car inside dimensions mutually agreed to between the manufacturer and the purchaser will be permitted with the provision of a device to prevent the lift from starting from a landing in case of overloading.

8 A load plate giving the rated load of the lift shall be filled in each lift car in a conspicuous position. For passenger lifts, the rated load shall be given in number of person and kg. For goods lifts, the rated load shall be given in kg or other convenient units and in persons. For the purpose of this clause, a person shall be regarded as weighing 68 kg.

Table 37 Minimum and Maximum Net Car Areas for Various Rated Loads ð Passenger Lifts

(*Table* 14, *Table* 15, *Table* 27, *Table* 28 *and Clause* 8.3)

Sl No.	No. of Passengers	Rated Load W	Minimum Available Net Inside Area	Maximum Available Net Inside Area A
		kg	m^2	m^2
(1)	(2)	(3)	(4)	(5)
i)	4	272	0.68	0.77
ii)	5	340	0.85	0.95
iii)	6	408	1.00	1.12
iv)	7	476	1.16	1.28
v)	8	544	1.31 (1)	1.45
vi)	9	612	1.46	1.60
vii)	10	680	1.61	1.76
viii)	11	748	1.77	1.91
ix)	12	816	1.92	2.05
x)	13	884	2.06	2.20
xi)	14	952	2.23	2.34
xii)	15	1 020	2.35	2.47
xiii)	16	1 088	2.48	2.61
xiv)	17	1 156	2.62	2.74
xv)	18	1 224	2.75	2.87
xvi)	19	1 292	2.88	3.00

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Table 37 (*Concluded*)

Sl No.	No. of Passengers	Rated Load W	Minimum Available Net Inside Area	Maximum Available Net Inside Area A
		kg	m^2	m^2
(1)	(2)	(3)	(4)	(5)
xvii)	20	1 360	3.01	3.13
xviii)	21	1 428	3.14	3.25
xix)	22	1 496	3.26	3.37
xx)	23	1 564	3.38	3.49
xxi)	24	1 632	3.50	3.61
xxii)	25	1 700	3.62	3.73
xxiii)	26	1 768	3.74	3.84
xxiv)	27	1 836	3.85	3.95
xxv)	28	1 904	3.96	4.07
xxvi)	29	1 972	4.08	4.18
xxvii)	30	2 040	4.17	4.29
xxviii)	31	2 108	4.25	4.39
xxix)	32	2 176	4.34	4.50
xxx)	33	2 244	4.44	4.61
xxxi)	34	2 312	4.53	4.71
xxxii)	35	2 380	4.62	4.81
xxxiii)	36	2 448	4.72	4.92

NOTES

1 The maximum available car area is calculated as per formula:

$W = 35.05A2 + 325.66A$,

where

W = the rated load, in kg; and

A = the maximum area, in m^2.

2 Beyond 36 passengers add 0.109 m^2 in maximum available area for each extra passenger.

3 Beyond 36 passengers add 0.104 m^2 in minimum available area for each extra passenger.

4 Hospital lifts shall be treated as passenger lifts and shall be designed according to above table.

5 Minimum net car inside area for fireman lift shall be 1.43 m^2.

For planning the quantity of lifts (passenger/service/hospital bed/ stretcher lifts) and deciding their main specification in any project, reference shall be made to 4. For ǿenhanced personal spaceô in the lift car without impacting the rated load and the car area as specified; while planning for the lifts, passenger occupancy may be considered less than the 80 percent specified in 4, thereby providing larger area per person in the lift car. The suggested number of passengers may be displayed in the lobby and in the car alongside the statutory rating plate required as per **5.4.2.3.2** of good practice [D-5A(1)], by the user.

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Table 38 Maximum Net Car Areas for Various Rated Loads — Goods Lifts

(*Table* 31, *Clauses* 8.3 *and* 8.3.1)

Sl No.	Rated Load	Maximum Available Net Inside Area A
	kg	m^2
(1)	(2)	(3)
i)	250	0.71
ii)	500	1.34
iii)	750	1.91
iv)	1 000	2.43
v)	1 250	2.92
vi)	1 500	3.38
vii)	1 750	3.81
viii)	2 000	4.22
ix)	2 250	4.62
x)	2 500	5.00

NOTES

1 The maximum available area in above table is calculated as per formula:

$$W = 35.05A2 + 325.66A$$

where

W = the rated load, in kg

A = the maximum available area, in m^2.

2 Beyond 2 500 kg, add 0.16 m^2 for each extra 100 kg.

3 Refer to Notes under Fig. 27.

8.3.1 For goods lifts, the available area of the car may be greater than the value determined from Table 38, but shall not exceed the value in m^2 determined by dividing the rated load in kg by (3.45 kN).

For motor vehicle lifts, the available area of the car may be greater than the value determined from Table 38, but shall not exceed the value in m^2 determined by dividing the rated load in kg by (1.45 kN).

8.3.1.1 *Class of loading*

a) *General loading*

This applies where the load is distributed, the weight of any single piece of freight or of any single loaded hand truck is not more than 25 percent of the rated load of the lift, and the load is handled on and off the car platform manually or by means of hand trucks.

For this class of loading, the rated load of the lift shall be not less than the load (including any truck) to be carried, and shall in no case shall be based on less than 3.45 kN/m^2 of inside net platform area.

b) *Motor vehicle loading*

This applies where the lift is used solely to carry passenger automobiles up to the rated capacity of the lift.

For this class of loading, the rated load of the lift shall be not less than the load to be carried, and in no case shall be based on less than 1.45 kN/m^2 of inside net platform area.

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c) *Concentrated load with/without powered/manual industrial truck*

This applies where the weight of the concentrated load including a powered industrial or hand truck if used, is more than 25 percent of the rated load; during loading and unloading the maximum weight on the car platform may exceed the rated load up to a maximum of 150 percent of rated load; and where the load to be carried does not exceed the rated load.

For this class of loading, the car platform and car frame shall be designed for 150 percent of rated load. The driving-machine motor, safety gear, brake and traction relation shall be designed to sustain and level the full 150 percent of rated load. The guide rails, guide fixings, car frame and platform shall be designed to withstand the horizontal thrust imposed by power trucks, motor vehicles and the like.

The rated load of the lift shall be not less than the load (including any truck) to be carried and shall in no case be based on less than 3.45 kN/m^2 of inside net platform area.

d) *Other loading with heavy concentrations*

This applies where the weight of the concentrated load including a powered industrial or hand truck, if used, is more than 25 percent of the rated load; where the static load during loading and unloading does not exceed the rated load; and where the load to be carried does not exceed the rated load.

For this class of loading; the guide rails, guide fixings, car frame and platform shall be designed suitable for the forces due to the heavy concentrated load and its location in the car. The rated load of the lift shall be not less than the load (including any truck) to be carried, and shall in no case be based on less than 3.45 kN/m^2 of inside net platform area.

8.4 Other Technical and Safety Requirements

8.4.1 All lifts shall be provided with one or more car door(s) and landing doors, passenger lifts shall be provided with power operated doors which are imperforate.

8.4.2 Power operated car doors on automatically operated lifts shall be so designed that their closing and opening is not likely to injure a person. The power operated car door shall be provided with a sensitive device which shall automatically initiate reopening of the door in the event of a passenger being struck or is about to be struck by the door, while crossing the entrance during closing movement. The effect of the device may be neutralized:

a) During the last 58 mm of travel of door panel in case of side opening doors;

b) When panels are within 58 mm of each other in case of centre opening doors; and

c) During emergency fire operation.

The force needed to prevent the door from closing shall not exceed 150 N and this measurement shall not be made in the first third of the travel of the door. In order to achieve this, it is desirable that all power operated doors have a full length (covering at least 1 600 mm of car door height from bottom) infrared or equivalent light curtain safety to retract the door in the event of coming across any obstacle during closing of the door.

8.4.3 Single speed and two speed drives which are poor in levelling accuracy and energy consumption shall not be used for new lifts in view of availability of latest technology energy efficient variable voltage variable frequency (VVVF) drive systems with improved levelling accuracy.

When a lift moves up or down in negative load conditions, that is empty car/less than 50 percent load in UP direction or more than 50 percent load/full load in DOWN direction and during lift system deceleration, the lift motor generates energy which is lost in the form of heat in set of resistors in traditional non-generative drives. The additional heating could also result in additional cooling costs to the building owner depending on the size, duty and number of lifts in a building.

The regenerative drive converts the energy generated by the motor and feeds it back to the building internal electrical grid thereby eliminating the need of using braking resistors. This energy can be utilized to feed other loads or users connected to the same network. The amount of energy savings due to regeneration depends on various system parameters and configurations such as car load, speed, length of run, traffic pattern and system efficiency. The efficiency of the regenerative drive in both motoring and generating modes should not be less than 0.8. Regenerative drives lower overall building operating costs, delivering significant annual savings to

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building owners and tenants year-after-year during the life of the lift. These drives help to reduce peak power demand and energy consumption. As a result, both the fixed costs based on peak power demand (kVA) and variable costs based on energy consumption (kWh) decrease. Depending on different parameters (traffic, load, speed, etc) energy saving can be up to 40 percent. It reduces the cost of the air conditioning system and eliminates excess heat in the building that would have been otherwise wasted.

If a stand-alone generator or uninterrupted power supply (UPS) is used to feed power supply to the lift system, the energy fed back to the stand-alone generator or UPS during negative load conditions or deceleration cannot be consumed. It is therefore imperative to connect sufficient load to the generator (other than lift load), which can consume the regenerated energy. If UPS is used, it shall be capable of handling the recuperated energy. If such measures are not implemented, it will lead to frequent breakdowns of the lift or failure of regenerative drive. Building owners should consult lift manufacturers to understand the amount of regenerated energy and implement suitable measures.

8.4.4 For passenger lifts with car call button control in car, an additional car operating panel with call buttons shall be provided for ease of access to call buttons when the car is wider than 1 600 mm and/or the rated capacity of the lift is 16 passengers and more. This additional car operating panel shall be suitably located in the lift car. The faceplate of an operating panel is recommended to be in contrast to its surrounding background.

8.4.5 Battery operated automatic rescue device (ARD) shall be provided on all lifts in accordance with [D-5A(1)] to take lifts to the nearest possible landing in case of power failure, which includes power failure of one or more phases. In case of lifts equipped with backup generator with automatic mains failure (AMF) panel, the provision of ARD is optional. For all lifts with ARD, an audio and visual indicator shall be provided inside the lift car to alert the persons trapped inside that they are being rescued. Capacity of batteries shall be such that minimum three rescue operations can be performed with full charged battery, without recharging. Emergency light and at least one fan inside the lift car shall be operational till the end of rescue operation. Levelling accuracy of $\pm$ 40 mm or better shall be achieved in the ARD Operation. The ARD should operate only when all safety circuits are operational. The safety circuits shall be checked and verified continuously during the rescue operation.

8.4.6 Minimum one stretcher lift shall be provided in each building having height more than 24 m so as to take care of medical as well as other emergencies. This lift shall have minimum car entrance width of 800 mm and car depth of 2 100 mm.

8.4.7 Every passenger lift shall be provided with an overload device in accordance with [D-5A(1)].

8.5 Painting at Works and on Site

Lift equipment will normally receive a protective coat of paint at works before dispatch to site. Further painting of lift equipment may be necessary and is normally in the form of a finishing coat and can take place on site. Alternatively, the further painting of the equipment may be carried out at works as a finishing coat with normal touching up after site erection as may be necessary. Any additional painting, due to site conditions during erection and/or final operating conditions in the premises, is subject to negotiation between the lift manufacturer and the purchaser. Decorative finishes are a subject for separate negotiation.

8.6 Emergency Manual Rescue

The emergency manual rescue operation with brake release should only be carried out in an emergency and by authorized persons who have received necessary instructions, because it is dangerous for any other persons to attempt to do so.

Before attempting to move the car, it is imperative that any person in the car be warned of the intention to move the car and that they shall not attempt to leave the car until they are advised that it is safe to do so. Any failure to carry out this precaution may render the person concerned guilty of negligence should an accident occur.

Before attempting to hand wind the lift machine, it is vital that the supply is switched off at the main switch. It is usually necessary to have two persons in the machine room: one to operate the brake release and the other to carry out the hand winding. The exceptions are small lift machines where the hand winding can be easily controlled by one man and larger machines which need two men to operate the hand winding alone with an additional man to control the brake release. In case of gearless machines especially, the brake shall be released and applied at very

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short intervals (of the order of 0.5 s to 1 s) so as to avoid the lift car attaining dangerously high speed due to the lift car and create unbalance in the absence of the gear box with large reduction ratio.

If the car is stuck in the lift well and cannot be moved when an attempt is made to move it in a downward direction, then no attempt at hand winding should be made because the car safety gear may have set. Any further procedure should be carried out under the instruction of a qualified lift mechanic. Provided the car is free to be moved in the downward direction, then it should be hand wound to the nearest floor. There is a preference to move the car in down direction. However, this may not always be practical owing to the distance involved and the time taken to complete the movement. In addition, the amount of out of balance load on the counterweight side, due to the size of car and the small number of persons inside it, may make it necessary to wind the car upwards.

In the case of high speed lifts the direction of hand winding will usually be governed by the effort required to move the car because of the absence of a large gear reduction ratio. It is essential that all detail operations be carried out according to the manufacturerôs instructions for the lift concerned and these should be clearly stated and permanently displayed in the form of a notice in the machine room.

8.7 Flood Sensors

Water flood sensors shall be installed in the lift pit to monitor ingress of water levels. A warning hooter/alarm shall be provided to alert of any potential ingress of water in lift pit area. Two water level sensors to be installed in the pit to provide two input signals to the control system; one input is for warning and the other input is for shutdown of lift. When the first switch is activated, an alarm/hooter is to be generated, so that maintenance personnel can understand the situation of water ingress in the pit and eliminate the danger in advance by removing the water safely. In case action is not taken with first switch alarm and when the second switch is activated due to the rise in water level position which is going to affect the operation of the lift (for example, the potential submerged tension device switch), the lift shall stop at the nearest landing level and an alarm needs to be triggered again (*see* Fig. 28).

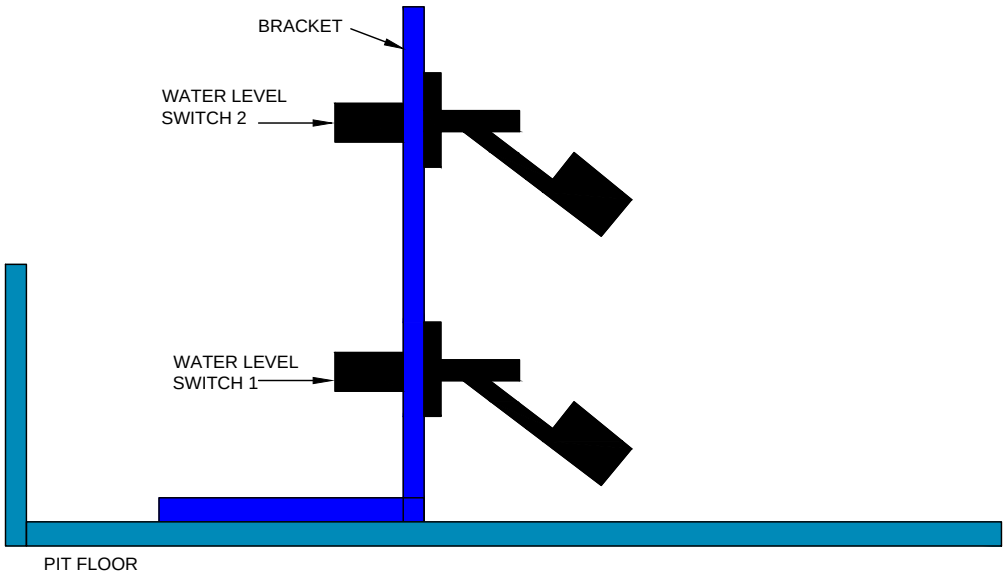

FIG. 28 FLOOD SENSORS (TYPICAL REPRESENTATION OF ARRANGEMENT)

The water level Switch 1 is recommended to be installed 50 mm to 100 mm above the pit floor to detect the low-level water accumulation. The water level Switch 2 is recommended to be installed at 200 mm to 300 mm above the pit so as to ensure that the water level detection switch lies below the liftôs any electrical switch such as buffer and safety switches which monitor the safe operation of the lift.

The pit water ingress signal from water level detection switch may be used to connect to a water pump to remove water from pit.

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9 SPECIAL TECHNICAL REQUIREMENTS

The objective of this clause is to define some special type of lifts that are used currently in buildings such as lifts without conventional machine rooms (MRL lifts), lifts used in private apartments (home lifts), hydraulic type of lifts and lifts required for differently abled persons, etc.

Additional requirement for lifts to be installed in hazardous (as classified) locations shall be considered. The electrical equipment or systems shall comply to Part D ôBuilding Services, Section 2 Electrical and Allied Installationsô. Also, equipment shall need valid statutory approvals as applicable.

9.1 Lifts without Conventional Machine Rooms (MRL Lifts)

9.1.1 MRL lifts are a special type of lifts where hoisting machine is placed inside the lift shaft and control system may be inside and/or adjacent or at close proximity to top landing door, eliminating the need for conventional machine room.

9.1.2 The MRL lifts shall be in conformance with good practice [D-5A(15)] apart from other relevant provisions of this Section.

9.1.3 MRL lifts may be provided with emergency door on the top portion of the hoist-way which is equipped with electromechanical lock wired in series with lift safety chain and of size 700 mm Ĭ 700 mm minimum, so as to access the machinery space in case of emergency or safety device being activated on or above the top landing.

9.2 Lifts Used in Private Apartments/Houses/Villas (Home Lifts)

9.2.1 The home lift is designed especially for private home having up to 5 stops (maximum rise 12 m), where the usage of the lift is restricted primarily to the residents of the private home. Unlike conventional lifts which allow virtually unlimited access to members of the general public, in case of home lifts non-residents shall have limited access.

9.2.2 The rated capacity of the home lift shall be minimum 208 kg (3 persons) and maximum 272 kg (4 persons) and lift car speed shall not exceed 0.2 m/s.

9.2.3 The home lifts shall conform to good practice [D-5A(1)] and [D-5A(16)] apart from other relevant provisions of this Section.

9.2.4 Electric MRL type home lifts, shall in addition conform to the technical requirements specified in good practice [D-5A(1)].

9.2.5 Hydraulic type home lifts shall in addition conform to the technical requirements specified in good practice [D-5A(1)].

9.3 Hydraulic Lifts

9.3.1 The hydraulic lift is a special type of lift where the lift car is directly or indirectly driven by action of one or more hydraulic jacks.

9.3.2 The hydraulic lifts shall conform to good practice [D-5A(1)] apart from other relevant provisions of this Section.

9.3.3 These lifts should preferably be hole-less type of lifts.

9.4 Lifts Accessible for Persons with Disabilities

9.4.1 All lifts open to public shall adhere to the accessibility provisions in terms of size of the car, door width, control panel, flooring, finishes, handrails, communication systems and information, given in good practice [D- 5A(3)].

9.4.2 Lifts for differently abled persons shall conform to good practice [D-5A(17)] apart from other provisions of this Section.

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9.5 Seismic Resistance in Lifts

When seismic protection of the passengers and equipment is a consideration, the safety requirements and protective measures given in good practice [D-5A(18)] may be adopted, the specified requirements being applicable when the units are subject to seismic conditions where the specified design acceleration (a_d) $\geq$1 m/s^2.

NOTE ð The design acceleration is a function of ground acceleration, soil behaviour, importance factor, etc. Thus, the value of (a_d) applicable to the building and to be considered for lift design/installation shall be provided by the building architect or structural designer to the lift manufacturer.

9.6 Automobile Lifts

Where required, lifts suitable for moving passenger vehicles such as light motor vehicles (LMV), small utility vehicles (SUV), etc, may be provided. The minimum requirements to be considered while providing such lifts are as given in **9.6.1** to **9.6.8**.

9.6.1 The minimum and maximum car area requirements for passenger lifts as defined in **6.1** of good practice [D-5A(1)] may not be applicable for automobile lifts. For this class of loading, the rated load shall be based on not less than 1.45 kN/m^2 of inside net platform area.

9.6.2 Strengthening stiffeners may be added to car panels to have sufficient strength to avoid permanent or temporary deflection of car panels beyond limits in case the vehicle touches the lift car panels while moving in or out. Under no circumstance, it should result into unsafe condition.

9.6.3 The hall button for calling the lift may be provided in the approach way at such a location that the button is accessible to the vehicle driver in the driving position without having to get off the vehicle. Optional light ray detection system or card reader system may be provided for automatic detection of vehicles and calling the lift to the floor.

9.6.4 Minimum entrance width of such lifts may be 2 400 mm and entrance height of 2 300 mm. The minimum car inside dimensions may be 2 500 mm wide and 5 300 mm deep and typically with entrance doors on both sides of the lift. This will enable the car to be driven inside and can be taken out in the same direction, without any need to reverse the same. Minimum load carrying capacity shall not be less than 2 500 kg.

9.6.5 Barricades may be provided outside the lift entrance door(s), so as to limit the size of the vehicle and preventing oversized vehicles from entering the lifts and possibly damaging the equipment.

9.6.6 There shall be sufficient place on both sides of the vehicle, once the vehicle is inside the lift. The lift car width should be selected such that in case of emergency while the automobile is in the lift car the driver should be able to open the automobile door and come out of the automobile.

9.6.7 The car operating panel, where the car call can be given, may be provided at such a location that is accessible by the vehicle driver in the driving position without having to get off the vehicle. The time duration for which the door remains open upon arrival at landing floor or upon stopping at landing floor shall be sufficient enough so as to enable smooth movement of the vehicles in and out of the lift car. Lift car entrance door(s), shall be equipped with light curtain device in accordance with **19.1.4** of good practice [D-5A(6)].

9.6.8 Overload warning device shall be installed in accordance with **6.2** of good practice [D-5A(1)].

9.7 Air Conditioning System for Lift Cabin (Car)

Where the lift car is equipped with air conditioning system, following additional requirements are recommended:

a) The whole equipment, its container, condenser, etc, should be typically made of corrosion resistant material, with average designed life span of 10 years.

b) The air conditioning system should work on single phase electric power supply of maximum 230 V a.c. and should be well within the current carrying capacity of trailing cable cores provided for the air conditioning system. The power supply for the air conditioning system shall be provided from RCCB of suitable rating. This RCCB shall be located in the lift machine room with proper identification and lock out tag out facility.

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c) The air conditioning system should be provided with suitable air filters which should ensure clean air inside lift car. The filters should be easily accessible and serviceable from top of the lift car in a safe and easy manner.

d) The lift air conditioning should typically include functions such as:

   1) Cooling, with adjustable temperature setting provided on the unit itself or through remote control unit, which may be maintained in the lift car.

   2) Heating, with adjustable temperature setting provided on the unit itself or through remote control unit, which may be maintained in the lift car.

   3) Ventilation, with adjustable air flow having less than 52 dBA noise level in the car.

   4) De-humidification, with effective condensation water management system.

e) The lift air conditioning should be equipped with effective condensation monitoring and condensed water recycling system so as to avoid water spillover or leakage on top of the lift car and other lift components, as detailed below:

   1) Condensation water monitoring and dealing with it is a very important feature any lift air conditioner shall have. Condensation water leakage or spillover on the lift car top may cause damage to the lift and may lead to electrocution or even fire.

   2) When the condensation water level in the reservoir reaches high level and remains at that or above that level for three minutes, the compressor should stop working and the air conditioner should go into ventilation mode. In the ventilation mode the air conditioner fan still works, water pump still runs, the water is pumped to the condenser for condensation water to be vaporized. When the water goes below 80 percent, the compressor may restart and the air conditioner may go into cooling mode.

   3) When the condensation water level reaches 100 percent, and remains at that level for 1 min, to avoid the water spill over and damage to lift components, the air conditioner should power off by itself. All components of air conditioner should stop working. This air conditioning unit shut down should not be automatically resettable and should require manual intervention. Also, it should be possible for this condensation water to be drained out by opening the drain plug provided. This facility of draining off excess condensation water shall be safely accessible either from lift car or lift pit.

f) It shall be possible to manually switch ‘ON’ and ‘OFF’ the lift air conditioning unit either by key switch provided in the lift car or by remote control.

9.8 Lift Interface with Building Management System (BMS)

Where required, a means to interface, monitor and control be provided by lift manufacturer, which should become the part of building management system. The following information and controls, but not limited to those, may be provided either through potential free contacts or building automation (BA) interface device suitable for providing necessary lift information over other accepted communication protocols. With potential free contacts only lift monitoring is possible. It shall not be possible to control the lift.

a) *Monitoring signals*:

   1) Floor position of the lift for each lif.

   2) Direction of travel for each lift.

   3) Load condition of each lift specially indicating overload status.

   4) Lift door status of each lift, whether open or closed.

   5) Lift modes such as attendant, automatic, independent operation, emergency fire service, seismic mode, emergency medical service and inspection mode for each lift.

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b) *Control signals*:

1) Bring the lift down to lobby floor in case of emergency or VIP movement.

2) Park and shutdown lifts based on building and traffic requirements, so as to save power.

3) Force the lift into emergency fire service, seismic mode or emergency medical service, etc through command from BA system based on respective sensorôs such as smoke detectors, seismic sensor, etc input to BMS.

c) *Reports* — Software tools may be developed to report out performance of each lift such as average response time, number starts per hour, average lift uptime, round trip time, etc with the flexibility to provide additional reports based on building requirements.

The above-mentioned requirement for potential free contacts, other standard protocols, etc, may be optional, if the full-fledged lift management system software is provided by lift manufacturer for monitoring and control of lifts in the building. This software may be custom built providing above mentioned requirements. The wiring between lift machine room to building management systems shall be planned and carried out by the builder along with other wiring in the building.

9.9 Closed Circuit Camera Inside Lifts for Monitoring (CCTV)

Where required, closed circuit camera is provided either by lift manufacturer or by third party supplier, inside the lift car for security purposes. Suitable warning mentioning ó*you are under CCTV surveillance*ô shall be posted inside the lift car. These cameras may be located at ceiling level and at any location which cannot be easily accessed, noticed or tampered with.

The cable used for connecting in car camera to monitoring system, provided by supplier, shall be of trailing grade. Ordinary co-axial or twisted pair wires shall not be lashed or tied along with trailing cables. Trailing cables are specialized cables used in lift applications. Wireless CCTV may also be considered alternatively.

If the camera signal is disconnected, either because of fault or intentionally, the lift monitoring system should get an alert indicating the same. Responsibility of monitoring, recording, organizing and maintaining CCTV shall be duly decided in advance.

9.10 Emergency Medical Service (EMS) for Hospitals

Optional emergency medical car operation may be provided especially for hospitals and operation theatre lifts and the lift behaviour in this mode is as described below. Activation of the emergency medical hall switch activates the in-car buzzer and illuminates a lamp in the car and hall. This forces the car to cancel car calls, reassigns hall calls, and return non-stop to the defined medical landing. Upon arrival, the door opens and the buzzer is deactivated.

The door remains open until the switch is turned off or the doors have been open for at least 60 s. If the medical switch is toggled, this operation remains in effect for additional 60 s. The second phase of EMS operation can only be activated when the doors are open at the medical landing. Once the car is on emergency medical operation fire service operation cannot be initiated, even though the fire service lamp and buzzer are activated.

If the car is performing fire service operations, emergency medical operations cannot be initiated, even though the medical lamp and buzzer are activated. The car automatically enters the emergency medical car operation after the doors are open at the medical return landing. If the emergency medical car switch is not activated within 60 s, the medical operation is cancelled.

To move the car, the emergency medical car switch needs to be activated. Prior to activation, the door cannot be closed and car calls cannot be registered. An active car switch allows car calls to be registered, which automatically closes the door and moves the car to the target landing. At the target landing the door opens and remains open until another car call is registered. The door close button has no effect on this operation.

If the car medical switch is deactivated away from the medical return landing with the doors open, the car remains at the landing not allowing car calls to be registered or the door to be closed. The car shall be returned to the medical landing and the emergency medical car switch deactivated to remove the car from emergency medical car operation.

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9.11 Destination Control System (DCS)

The destination control system (DCS) uses passenger destination information to improve traffic flow and travel time in busy mid- and high-rise buildings. Instead of using standard hall call buttons, passenger enters specific floor number he wants to travel to, before entering the lift. The system groups passengers traveling to nearby floors to the same car.

9.11.1 Conventional destination control system requires keypads or touch screens at all floors to book the calls. This conventional DCS may be additionally provided the car operating panel (COP) in the lift car to improve passenger comfort. Alternatively, the COP in the lift car may be hidden. Traditional hall lanterns are no longer needed.

9.11.2 Hybrid destination control system requires keypads or touch screens only at the main floor allowing up-peak boosting of traffic. Traditional hall button stations and hall lanterns need to be provided at all other floors. A full COP is required in the lift. With both conventional and hybrid DCS provided with touch screens and/or keypads, hot button(s) may be provided to facilitate call booking to common floors as fast as possible.

9.11.3 *Identification of Lifts*

To avoid confusion between identification of lifts and floor nomenclature, particularly when braille is considered, it is recommended that the lift identification should be alphabetic and floor nomenclature to be numeric.

9.11.4 *DCS Car Loading for Simulation*

While 80 percent is considered as the average loading for traffic analysis with conventional controls, the car loading for simulation with DCS shall not exceed 80 percent

9.11.5 It is advisable that DCS input keypads at main floor to be placed at the entrance of lift lobby and not at conventional location (between two lifts) to avoid multiple calls by same person. When DCS keypads are integrated with turnstiles, additional DCS keypad to be provided in the lobby to re-register the call in case a person fails to enter lift.

9.11.6 Conventional control system allows maximum of 8 lifts in group operation, having not more than 4 lifts in row, however DCS provides an advantage of increasing number of lifts in group operation, which can be extended to 10 lifts in a group to 16 lifts in a group. The designer should note that arrangement for lifts shall be limited to 5 lifts in row.

9.12 Special Environments

Standard equipment is suitable for use inside normal residential, commercial and industrial buildings but when unusual environments are likely to be encountered, the advice of the lift manufacturer should be sought at the earliest possible stage to enable the most economic satisfactory solution to be found. Special mechanical protection and or electrical enclosures may be necessary as well as compliance with statutory or other regulations and with the purchaserôs particular requirements, which should be fully considered at the time of enquiry.

Examples of situations which necessitate special consideration are:

a) Exposure to weather, for example, car parks;

b) Low temperatures, for example, cold stores;

c) High temperatures, for example, boiler plant;

d) Hosing-down, for example, for hygiene or decontamination;

e) Corrosive atmosphere, for example, chemical works;

f) Dusty atmospheres, for example, gas plants;

g) Explosive and inflammable atmosphere, for example, gas plants, and petroleum and polyester industries; and

h) Nuclear/heavy water plants.

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10 PERFORMANCE REQUIREMENTS FOR LIFTS AND EVACUATION LIFTS

10.1 It is necessary to have uniformity in the definition, measurement, processing and expression of vibration and noise signals that comprise lift ride quality. The aim of such uniformity is to benefit users by reducing variability in the results of lift ride quality measurements caused by differences in the methods of acquiring and quantifying the signals. Experience indicates that evaluation of vibration in terms of peak-to-peak levels is of particular relevance to passenger comfort. It is considered necessary to provide a dual form of expression, quantifying both the maximum peak-to-peak and A95 peak-to-peak vibration levels.

10.2 Measurement of Lift Ride Quality

Ride quality of all lifts shall be measured in accordance with accepted standard [D-5A(19)]. The selection and calibration of measuring and test equipment shall also be in accordance with this standard.

Measurements shall be made during normal building conditions, after the lift has been running under normal daily operation for at least one hour. Vibration measurements shall be made at the geometric centre of the car.

11 SPECIAL TECHNICAL REQUIREMENTS FOR SUPER TALL BUILDINGS

The provisions given hereunder describes the different physical phenomena that occur in super high-rise buildings (> 200 m high) and influence vertical transportation solutions.

Although there are no major differences regarding suspension and guidance systems between high-rise and low-rise lifts, there are other aspects to be considered such as system technology and passenger comfort levels. Control system artificial intelligence levels, safety requirements, load-bearing component ratings, rope weight, energy consumption, and thus cost increase exponentially with the height of the building.

11.1 Air Pressure Effect

In high rise buildings, air pressure is different on ground level and on top of the building. Practically, pressure change on the ear becomes uncomfortable for some persons when lift is landing faster than 10 m/s. The thresholds are lower for small children, elderly persons and passengers having flu. Therefore, practically, as a standard solution lifts are offered up to 10 m/s maximum speed.

11.2 Piston Effect

If high speed lifts, especially those having rated speed $\geq$ 4 m/s, are housed in single shaft, the displaced air due to movement of the lift car tries to escape through the gaps between the lift car walls and the shaft walls in turbulent flow. This phenomenon known as piston effect causes the ride quality in the lift to deteriorate. Noise level in the lift car may increase along with vibrations which will be felt by the passengers. The air being displaced past the car generates whining and whistling noises inside the car. Buffeting when passing doors may be audible and passenger may feel uncomfortable. Both lift car doors and landing doors may whistle at high speeds.

Therefore, high speed lifts should be preferably housed in common shaft with ventilation holes in the common wall(s), if any. These holes allow the air displaced due to the movement of the lift car to escape in the adjoining hoist-way. Thus, the velocity of the escaping air, which depends on the ratio of the lift car area to lift shaft area, reduces to mitigate the piston effect ensuring good ride comfort for the passengers. The size of the vent and the pitch at which the vents need to be provided depend on lift car size in relation to lift shaft size, as well as the speed of the lift and the ride comfort expected.

It is recommended to eliminate common wall between the shafts for lifts with speed $\geq$ 4 m/s. Shaft should be provided with divider beams at every bracket level for the support of the guide rails. Metallic wire mesh shall be provided for separation of shafts.

If a lift with speed $\geq$ 4 m/s is housed in an enclosed shaft which is standalone, it is recommended to increase the shaft size by 25 percent to 30 percent.

NOTE ð The percentage increase in shaft is given as a range to have flexibility for builders and lift manufacturers to accommodate the lift and reduce the piston effect.

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In addition, high speed lifts especially those having rated speed more than 6 m/s may have cars with aerodynamically designed exteriors. This special construction of the car however increases the requirements of the overhead and pit for which lift manufacturer should be consulted. To reduce hammering sounds caused by the passage of the lift past the landing doors, shaft in front of the lift car door may be clad with facia plates equal to full shaft width between the landing door sill of the upper floor and door header of the lower floor door to create an even, flush surface. Lift cars also need to be specially constructed to absorb noise and thus reduce transmission of noise in the car.

11.3 Stack Effect

Stack effect is defined as the vertical, natural air movement throughout a high-rise building caused by the difference in temperatures between the inside air and the outside air. Positive stack effect is characterized by a strong draft from the ground floor to the roof. Positive stack effect is more significant in cold climates because of the greater difference in temperature between the inside and the outside of the building. The colder the weather and the taller the building, the greater will be the stack effect. Negative stack effect can also occur in the reverse direction in hot climates but is not as significant because the difference in temperature is not as great.

The magnitude of stack effect is a function of:

a) building height;

b) air tightness of exterior walls;

c) air leakage between floors; and

d) difference in temperature between inside air and outside air.

The stack effect has following effects:

1) *Differential pressure on the lift landing doors* — The stack effect generates differential pressure on the landing doors. In case of buildings with airtight separation of each storey the differential pressure on a particular landing door from inside and outside of the lift shaft is small, however, the pressure on the door of the first landing and that on the last landing may vary a lot.

   In case of buildings with no air partitions the converse is true. The differential pressure on a particular landing is significant and is the maximum at the topmost and bottom most landings which are farthest from the neutral pressure level. At the neutral pressure level, which occurs somewhere in the mid section of the building height, the differential pressure on the landing door from inside and outside of the lift shaft is nil. The differential pressure on the landing door may cause difficulty in the operation of the door; and

2) *Smoke movement* — The stack effect influences the smoke movement. In case of positive stack effect, the air moves out from core of the building towards the exterior of the building above the neutral pressure level and it moves in from the exterior of the building to the core of the building below the neutral pressure level. In case of negative stack effect, reverse phenomenon occurs. This air movement naturally affects the smoke movement in case of fire and must be considered.

   Since stairwells, lift shafts and lifts tend to contribute to the stack effect it is essential that all lift lobbies are well sealed, and lifts parked with door closed to minimize stack effect. Especially in case of fire the stack effect needs to be controlled to prevent the spread of smoke in the building. On the other hand, the stack effect may be beneficially used to quickly drive smoke out of the building in case of fire.

11.4 Building Sway

The wind induced sway of the building may cause the lift suspension means and/or compensation ropes and lift car travelling cables to sway. Buildings have natural frequencies of oscillations. Similarly, lift ropes also have natural frequencies of oscillations which depend on the position of the car in the hoist-way amongst other parameters. When natural frequencies of the ropes and the building match, a large amount of energy is transferred to the ropes, and they start swaying violently. This results into reduced ride comfort for the passengers in the lift and increases possibility of ropes getting stuck to snag points in the shaft and damaging shaft equipment. In general, the rope and travelling cable resonance phenomenon should be considered in the lift design for over 200 m tall buildings and slender buildings over 150 m tall, for example, TV towers. It is a fact that the resonance

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cannot be completely avoided in high rise buildings, hence the need for the solutions to cope with the phenomenon. If resonance is not considered in the lift design, it could increase the lift down (out-of-service) time and decrease lift ride comfort.

The main purpose of the sway management is to improve lift safety and service time by reducing rope sway by optimizing tension of compensation ropes, providing shaft protection equipment to prevent ropes from entangling and damaging the lift equipment. A sway detector may be used to control the lift operations. The output signals from the sway detector are used to reduce the speed of the lifts or park them at a safe floor.

In order that the sway analysis is done, the building designer should be in touch with the lift designer since early design stage of the building and share information on the building natural frequencies, maximum amplitude of building displacement with probability of occurrence, etc. The lift designer would then be able to calculate the rope/cable sway and decide on the preventive measures to be taken in the lift design.

11.5 Ride Comfort

A robust car guide system with meticulously aligned guide rails is essential for reducing vibrations to an acceptable comfort level. Guide rails shall be rated for heavy-duty usage. Irregularity in the guidance system causes an unpleasant and uncomfortable transverse vibration within the car at high speeds. High-quality roller guide system is required for smooth ride. In addition, the lift guide system shall be able to withstand the effects of the building settling and the response of the buildingôs structure to thermal and climatic changes.

11.6 Jump Lifts

In super high-rise buildings, there may be a need to start lift erection before the machine room is finished to compress total time required to complete the building. The self-climbing lift technique may be used to build the lift as the building construction progresses. Jump lift uses a temporary machine room that is moved upward as construction progresses. Typically, when the building construction reaches the seventh floor, the jump lift may start operating and start serving lower floors. Exterior hoists can be removed sooner, enabling the facade to be enclosed. This means that lower floors are ready for finishing much earlier and the entire building can be completed sooner. Since all transportation takes place in a dry, windproof shaft, construction can continue safely and unhindered, even in bad weather. The change-over to final lift is very quickly done.

11.7 How to Handle High-Density Population in Buildings

Due to continued exponential growth in urbanization, thickly populated buildings are becoming common in all metro and Tier-I cities. It has become quite essential to improve the efficiency of vertical transportation systems within the available shafts in the buildings, significantly beyond the conventional single deck system (*see* Fig. 29).

The following two different types of systems are possible solutions:

a) 2 cabins running independently in one single shaft; or

b) 2 cabins mounted one above the other.

These systems are compliant with the latest good practices as per [D-5A(1)] and [D-5A(20)].

11.7.1 The benefits of these systems are as follows:

a) optimal use of shaft with 2 lift cabins arranged one above the other;

b) connection of two main landing levels with the highest efficiency;

c) handling of high traffic volume and short travel times between two main landing levels; and

d) simultaneous filling of both lift cars.

In combination with other lift systems, double deck is generally used as a shuttle lift. It is particularly suitable for passenger transport from main entrance levels to defined terminal landings, for example outdoor viewing platforms or transfer landings, so-called sky lobbies.

Two independent cars in a single shaft solution, is used where both up-peak and inter-floor traffic is heavy.

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The advantages come into their own when each of the landings in the access area or terminal landings are interconnected via escalators to split up the flows of passengers. In this case, both lift cars can be loaded and unloaded simultaneously.

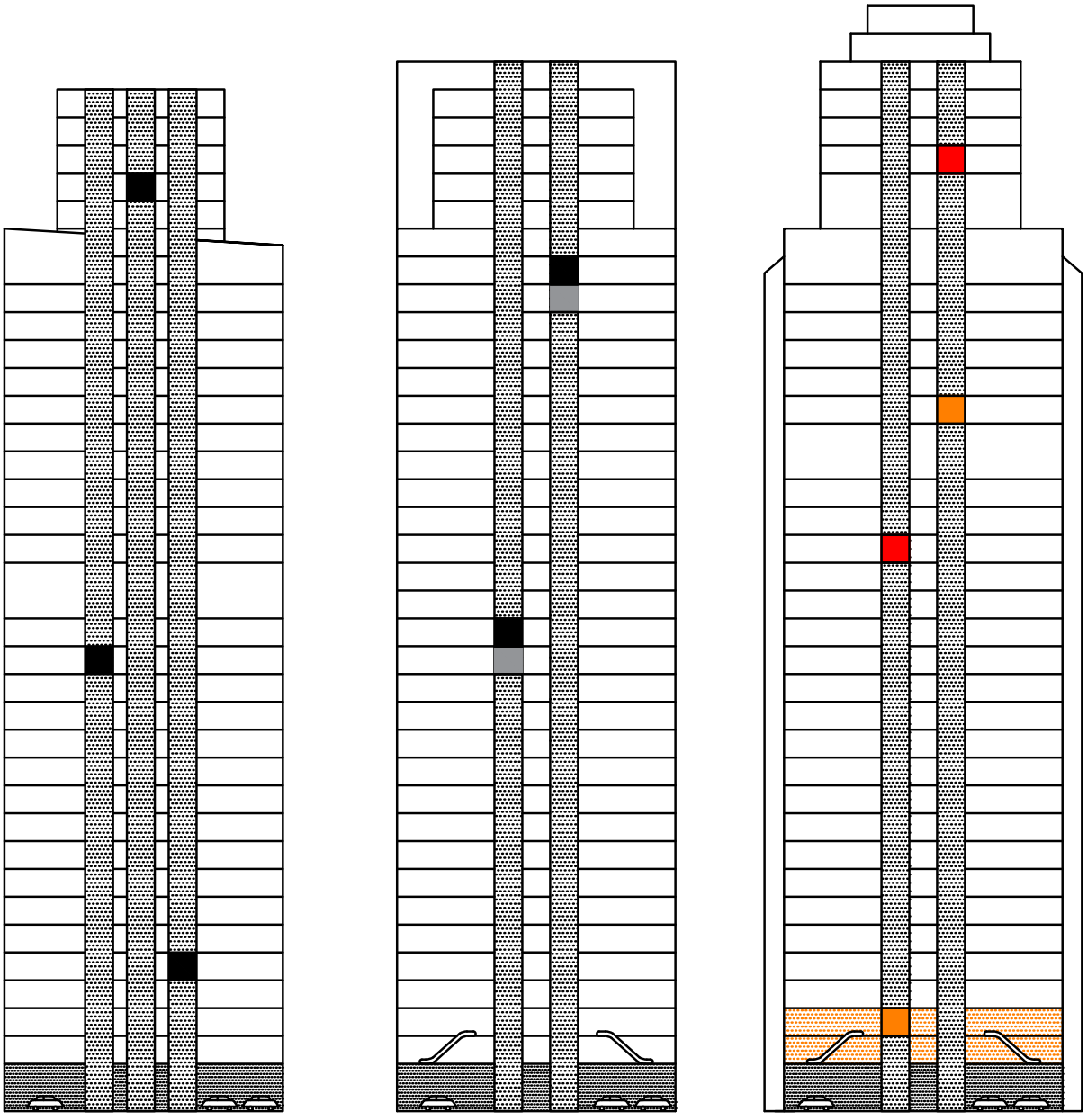

FIG. 29 DIFFERENT TYPES OF VERTICAL TRANSPORTATION SYSTEMS

11.7.1.1 The benefits for new installation projects include:

a) significantly more handling capacity with fewer lift shafts compared to conventional lifts;

b) 2 independent cars and 2 cars one above the other in one shaft reduce the building core by approximately 50 percent;

c) reduction in construction cost in both labour and material for the developer and contractor; and

d) increase in the rentable floor space and the rental income for the owner.

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11.7.1.2 The benefits for modernization projects include:

a) increased handling capacity with two lift cabins in one shaft;

b) reduction in waiting time by around 30 percent to 40 percent over the conventional single deck system; and

c) replace single-deck lifts that can no longer handle the building capacity and passenger comfort demands.

Whether used in new buildings or as part of a modernization project, these 2 car systems in one shaft can transport up to 40 percent to 50 percent more passengers.

11.7.2 An overview of the system with 2 separate cabins moving independently inside the shaft is given below:

a) The lift group must be planned as a multiple car system. The cars must operate independently and use the same shaft. The lift cars are arranged one above the other and run independently;

b) Both cars use the same guide rails. The cars can move towards each other and are also able to move away from each other;

c) Each of the 2 lifts has its own drive system and counterweight. Each counterweight runs on its own guide rails. Both lifts have their own safety equipment where required. Both cars use the same landing doors;

d) The suspension of the cars is dependent on the lift speed and travel height. It can be 1 : 1 or 2 : 1;

e) Measures for rope compensation can be designed with compensation chains or belts to reach the required traction. For speeds above 2.5 m/s tensioned compensation rope systems should be used;

f) The call assignments will be undertaken by destination control system. The destination call will be set onto an input station (terminal) in the lobby in front of the lifts or in its proximity. Therefore, pushbuttons for call assignment in the car are not required for passenger use. Hidden COP is provided for fireman or special operation. The cars can serve floors with adequate distance directly above each other;

g) The minimum required safety distance depends on contract speed of the lifts. An independent working safety controller guarantees the prevention of a collision in any operating condition;

h) Depending on the type of suspension and shaft dimensions, the drives are distributed in one, two or three machine room levels; and

j) This system is designed for safety integrity level (SIL) 3 as defined in PESSRAL.

NOTE ð Programmable electronic systems in safety related applications for lifts (PESSRAL) is included in the accepted standard [D-5A(21)].

11.7.3 An overview of the system with 2 cabins joined and mounted one upon the other is given below:

a) The lift group must be planned as a single car system with 2 entrances (upper and lower). The cars are joined to operate simultaneously and use the same shaft.

b) Both cars use the same guide rails, counter-weight rails, landing doors, machine, drive, controller system, rope system and safety equipment.

c) The suspension of the cars is dependent on the lift speed and travel height. It can be 1 : 1 or 2 : 1. The suspension of both cars is same.

d) Measures for rope compensation can be designed with compensation chains or belts to reach the required traction. For speeds above 2.5 m/s tensioned compensation rope system should be used.

e) The call assignments will be undertaken by destination control system (DCS). The destination call will be set onto an input station (terminal) in the lobby in front of the lifts or in its proximity. Therefore, pushbuttons for call assignment in the car are not required for passenger use. Hidden COP is provided for fireman or special operation. Depending on the speed, the drives are distributed in one or two machine room levels.

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11.8 Firemanôs Lift

Minimum one number of single deck lift (15 persons, 1 000 kg capacity) serving all floors of the building is to be provided meeting all the requirements as per concerned fire authority such as 1 h fire rated landing doors, minimum speed criteria of travel time less than 60 s for travel from the main lobby to the topmost landing (*see* Fig. 30).

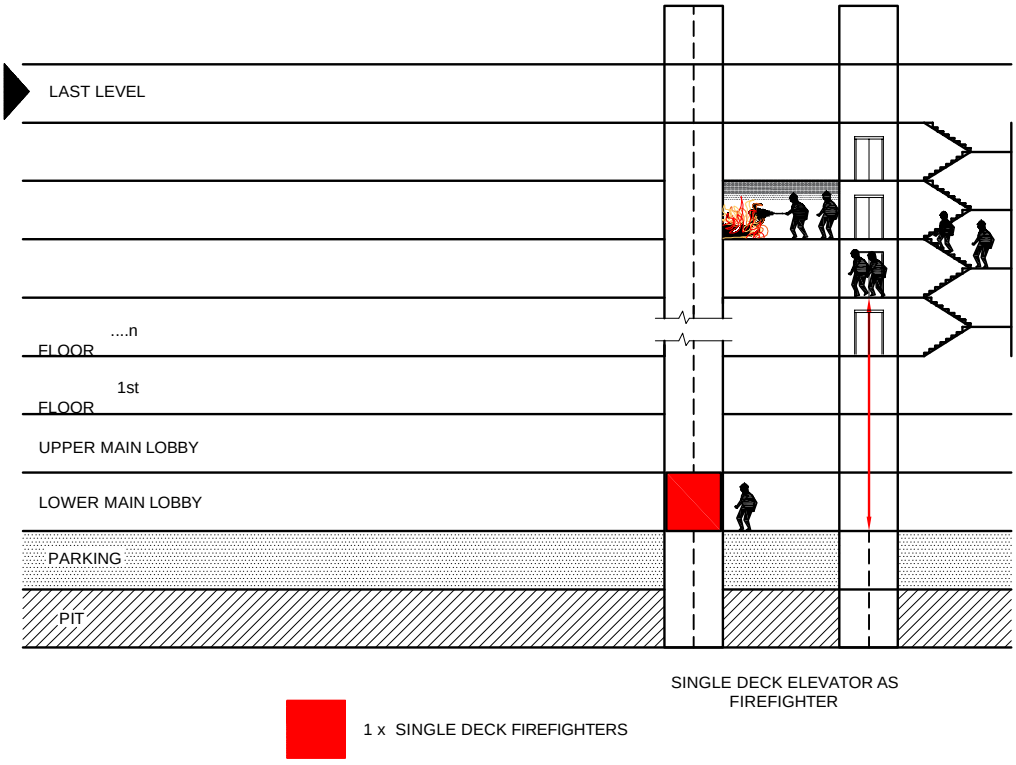
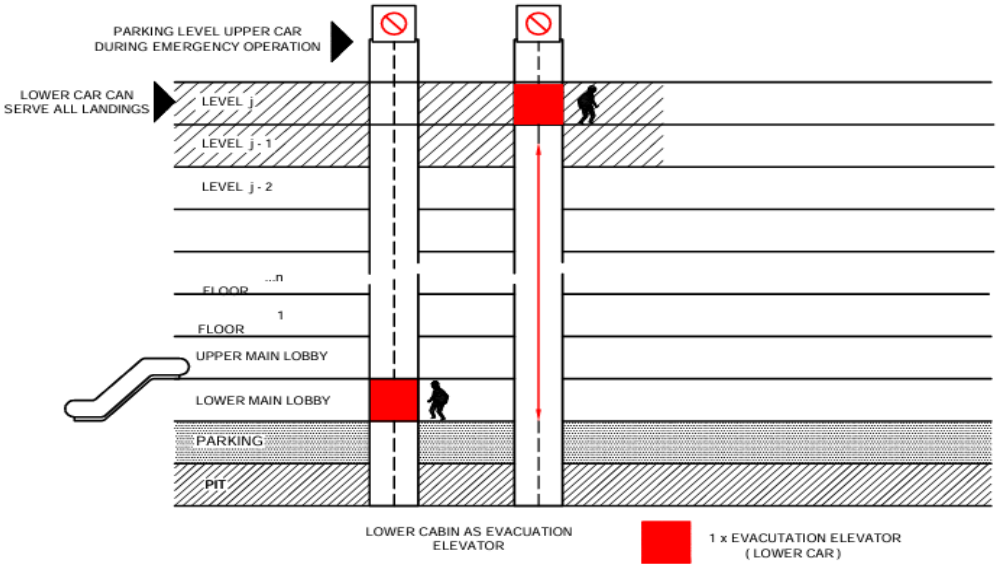


FIG. 30 FIREMANôS STRATEGY

11.8.1 *Passenger Evacuation Strategy for* 2 *Cabins Running Independently Inside a Single Shaft*

a) Case (I) ð (*see* Fig. 31)



NOTE ð OEM to be consulted for suitable depth of the pit.

FIG. 31 GIVE WAY IN LIFT OVERHEAD ROOM FOR UPPER CAR AND OPERATION ONLY WITH LOWER CAR

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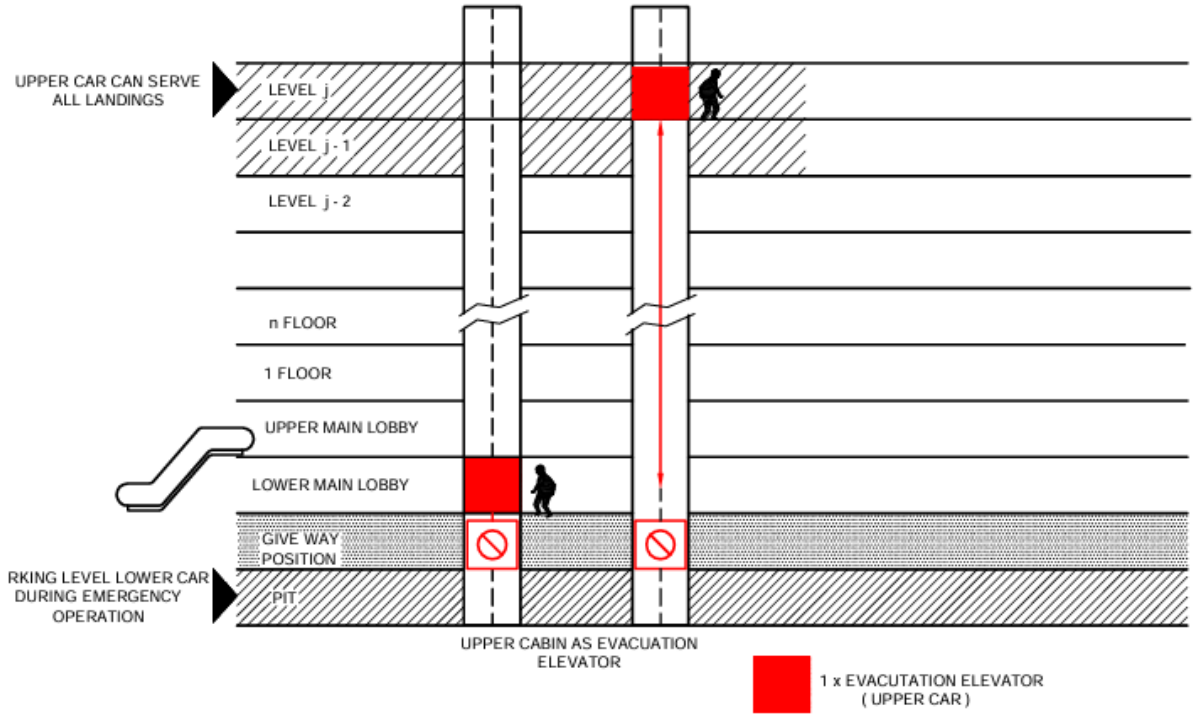
b) Case (II) ð (*see* Fig. 32)



NOTE ð OEM to be consulted for suitable depth of the pit.

FIG. 32 GIVE WAY IN LIFT PIT FOR LOWER CAR AND OPERATION ONLY WITH UPPER CAR

c) Case (III) ð Without any giveaway, either in pit/overhead, but with 2 firefighter access levels, one on the ground floor (lower main landing), and one on the first floor (upper main landing) so that either of the lifts can be utilized as an evacuation lift.

11.8.2 *Passenger Evacuation Strategy for* 2 *Cabins Mounted One Above the Other and Running Together Inside a Single Shaft*

It can be achieved with 2 firefighter access levels, one on the ground floor (lower main landing), and one on the first floor (upper main landing) so that either of the cabins can be utilized as an evacuation lift.

12 LIFT ENQUIRY OR INVITATION TO TENDER

12.1 General

A period of two to four weeks is normally sufficient for return of tenders. This should be extended, if large numbers of lifts or special requirements are involved.

The enquiry documents should be kept to the essential minimum, and should be strictly confined to material relevant to the lifts works and to the particular project concerned.

When enquiring for and ordering lifts, the particulars given below should be furnished:

a) Type of lift (passenger, goods, service or dumb waiter);

b) Number of lifts required;

c) Capacity/load of lift (s): number of persons (in kg);

d) Rated speed (m/s);

e) Travel (in m) and building height;

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f) Floors served (no. of regular openings, emergency openings, blocked openings);

g) Method of control (simplex or group control);

h) Position of machine room (if machine room-less, machine below, hydraulic);

j) Machine room height;

k) Clear overhead/clear top clearance;

m) Pit depth;

n) Sizes of hoist-way (width Ĭ depth), in mm;

p) Position of counterweight;

q) Car size (width Ĭ depth), in mm;

r) Construction, design and finish of car bodywork;

s) Car entrances:

   1) Number of entrances;

   2) Size (width Ĭ height); in mm

   3) Type of door (centre opening, telescopic, 4 panel, vertical bi-parting); and

   4) Whether through opening.

t) Car light;

u) Call indicator;

v) Position indicator in car;

w) Lift landing entrances:

   1) Number of entrances;

   2) Size (width Ĭ height); in mm

   3) Type of door or gates or shutters (for goods lifts) (centre opening, telescopic, 4 panel, vertical bi-parting); and

   4) whether through opening.

y) electric supply:

   1) Power in volts a.c.;

   2) Phase; and

   3) Cycles (wire system).

z) whether neutral wire available for control circuit;

aa) temporary guarding of hoist-way and car cabin;

bb) lighting volts a.c./d.c.;

cc) are premises subject to *Lifts Act and Rules*;

dd) disable friendly requirements [such as voice announcement of floor levels, accessible control panel (good contrast with the background wall, braille, raised letter and font), railing on three sides, two way accessible communication system];

ee) earthquake protection requirements; and

ff) additional items.

12.2 Additional Items

The enquiry should state any additional items required beyond those specified in good practice, such as interface requirements, dismantling of existing lifts, firemanôs control, seismic design consideration, sway/deflection requirements, gravity distortion, etc.

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12.3 Finishes

Finishes should be specified at the enquiry stage or provisional sums should be included for them. Finishes to be considered may include interior car finish, false ceiling design, false ceiling lighting, flooring material and weight, blower, ventilation details, car wall cladding details (weight to be considered), multimedia display details (like screen type, size, location, etc), door cladding details, transom details (flushed with the wall, material type, etc). *See also* good practice [D-5A(3)].

12.4 Inclusions and Exclusions

A number of peripheral items are associated with lifts installation, of which some should always be provided by the builder and some are best included by the manufacturer. The requirements vary to some extent with the type of installation.

It is important that the limits of responsibility are clearly understood, and the enquiry documents should be specific in this respect.

The lifts manufacturer should include such items mentioned in **12.1**.

The lifts manufacturer should exclude the supply and fixing of the items or as per the contract conditions as follows:

a) Builderôs work such as forming lift well, pit and machine room, and building wall inserts;

b) Machine room floor including any reinforcement necessary for load bearing;

c) Hoisting hook/lifting beam fixing, where necessary;

d) Any necessary tanking, lining or reinforcement of the pit;

e) Diving beams for multiple wells and inter well pit screen (or as per the contract);

f) Trap door;

g) Intermediate beams for bracket fixing;

h) Door cladding (or as per the contract);

j) Cutting away and making good;

k) Working lights/permanent electricity supplies; and

m) Site painting of steel work other than lift material (if any).

For more detailed discussion of the requirements for site preparation and work by other trades, reference should be made to good practice [D-5A(6)] and to other relevant clauses of this Subsection.

Facilities for the use of the main contractorôs crane should be provided to assist in installing heavy equipment in addition to other unloading facilities on site in the course of erection.

The main contractor should be instructed to include these facilities in his own quantities.

Where the lift manufacturer agrees to use mobile platforms in place of lift well scaffolding, the general contractor should provide 400/440 V 3-phase and 200/220 V single-phase supply in the lift shaft to operate such equipment, the supply to terminate at the position in the lift well required by the lift manufacturer.

These mobile platforms are limited in use for erection personnel and the transportation of light equipment only, but use of crane will also be necessary to assist in the installation of the heavy machinery and also in the initial installation of the mobile platform equipment.

12.5 Site Programme

The enquiry should indicate as accurately as possible the contract programme as it affects the manufacturer, in particular the target date for completion, construction schedule, site preparedness, the availability of crane for hoisting, coordination details (with other contractors like BMS interfacing, CCTV interfacing, etc).

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13 ACCEPTANCE OF TENDER AND SUBSEQUENT PROCEDURE

13.1 General

The procedure indicated below particularly relates to the most usual case, where the lift manufacturer is the sub-contractor.

13.2 Order

The building owner places an order with the selected contractor for supply and installation of lifts. If alternative schemes have been offered, the order should clearly indicate which has been accepted.

13.3 Programme

The contractor shall submit a detailed programme after acceptance of the order showing his intended method, stages of the works, together with the period of time that has been estimated for each and every stage of progress.

The programme shall cover each lift separately, including dates, such as:

a) date of order of equipment and materials;

b) date of commencement and completion of every stage of the works in line with the building construction programme;

c) date of expected completion of builder's work requirements;

d) date of delivery of equipment and materials to site; and

e) date of requirement of temporary and permanent electricity supply and date of completion, commissioning and testing.

The period between order and delivery of material falls into two stages: first the finalizing of details and secondly the actual production of the equipment which depends on the first stage. Within the first stage, other dates may need to be considered, such as:

1) all relevant building information available;

2) submission of lift manufacturer's drawings;

3) approval of drawings; and

4) final selection of finishes.

13.4 Drawings to be Submitted after Placing of Order

The lift manufacturer shall prepare layout drawings based on the civil/structure drawings, order requirements and submit to building owner within mutually agreed time frame. The same shall be briefed to building owner.

The drawings shall indicate clearly the position and sizes of all holes and cuttings, the loads on beams and structures, and all other requirements in relation to ôLift Installationô namely:

a) lift machine room and associated equipment, including sub-floor where appropriate;

b) all structural openings, such as landing entrances (including structural dimensions), ventilation openings, etc;

c) all bases, plinths, channels, holes, grouting-in of fixings, etc;

d) lifting beams or other facilities for supporting lifting tackle in the machine room and lift well, permanent means of access to the lift pit;

e) hoisting facilities and access required for delivery of equipment to the machine room, etc;

f) details of structural steelwork for lift machinery in the lift machine room;

g) details of shaft dividing steelwork for supporting guard brackets, etc and inter-well screens/wall for multiple wells; and

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h) method of fixing guide rails.

13.5 Approval of Drawings

The building owner should go through the drawings submitted by lift manufacturer and ensure that it is prepared in line with civil/structural drawing and order requirements provided.

If any addition/alteration is noted in the drawing, the same shall be updated in the drawing by the lift manufacturer and resubmitted to the building owner for approval. The drawing shall be approved by building owner, once it has been clearly understood.

13.6 Selection of Finishes

Where the contract provides for the purchaser's choice of decorative finishes, colours, etc, the decisions should be communicated by the purchaser's representative as early as possible, preferably not later than the time of approval of drawings.

13.7 Electricity Power Supply for Lifts

Operation of the machine requires electrical power supply from a comparatively early stage of installation for the most efficient working, and shall be provided accordingly. Whilst temporary supply may be sufficient for erection purposes, the quality of power should be ensured by provider. Final testing and setting up can only be carried out with the permanent power supply. For this reason, the timely provision of the permanent supplies is important.

14 CO-ORDINATION OF SITE WORK

14.1 Preparatory Work on Site

In accordance with the general arrangement drawing for the lift, the representative of the lift company would brief the building owner or his nominated representative about the preparatory work that is required to be carried out before commencement of the lift installation.

The building owner will ensure that the preparatory work is done in accordance with the general arrangement of lift and also the state lift rules are followed for the construction of the lift shaft as well as machine room. Once the preparatory work is completed, the building owner or his nominated representative, will ask the lift company to cross check and see that everything is in order. The lift installation will start after receiving all necessary statutory approvals applicable as per the state laws.

The representative of lift manufacturer shall check the lift shaft and bring the shortfalls, if any, to the notice of the building owner till the preparatory work is completed in compliance with the requirement of lift supplier. The following works shall be completed by the building owner before commencement of lift erection.

14.1.1 *Machine Spaces/Head Room*

a) Adequate ventilation for machine room with rain protected windows or louvers with exhaust fans or air-conditioning system so that the ambient temperature of the machine spaces is maintained between + 5 ÁC and + 40 ÁC (taking into account the heat dissipated by the equipment, ambient temperature, humidity, direct sunlight, air quality and air tightness of buildings due to energy saving requirements);

b) Suitable access door preferably with louvers to machine spaces with RCC steps or mild steel staircase with hand railing (not applicable for MRL);

c) Machine spaces access door shall be of ms, in two panels, hinged type construction, opening outward and clear entrance not less than 1 000 mm wide Ĭ 2 000 mm high with proper locking arrangement. Caution notices of 440V and restricted entry shall be marked on the entrance (not applicable for MRL). A trap door with steel enclosure shall be provided for each machine spaces as per GAD (not applicable for MRL).

d) Hoisting beams/load hooks of required lifting capacity in machine room for machine room lift, one directly above the lift shaft and other directly on top of the trap door as specified in the lift general

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arrangement drawing. The same shall be provided in the slab in the overhead area for machine room less lifts, as specified by the lift manufacturer in their general arrangement drawing. The safe working load (SWL) shall be specified after certification and tagged on the hook/beam in the machine room/ head room;

e) Machine room slab shall be cast after the slab marking for rope pocket holes is done by manufacturers team. Reinforced concrete machine room slab of 230 mm thickness designed to sustain more than 1 000 kg/sqm uniformly distributed load all over its surface in addition to specific load shown in GAD (not applicable for MRL);

f) Machine spaces walls, floor and ceiling to be treated and painted to minimize accumulation of dust (not applicable for MRL);

g) RCC pedestal for fixing the machine bed frame (not applicable for MRL); and

h) Fire extinguisher shall be provided by building contractor to prevent fire accidents.

14.1.2 *Hoistway*

a) Hoistway dimensions mentioned in the GAD shall have minimum clear plumb dimensions in mm and hence actual wall shall not encroach on these dimensions;

b) Hoistway shall be without any projections and recess from headroom to the pit floor;

c) If any projections or recesses are there, then those shall be flushed and levelled on underside to an angle not less than 60Áfrom the horizontal by means of metal plates or cement;

d) Anything not related to lift equipment like service pipes, ventilation ducts, plumbing and mechanical systems, electrical conduits shall not be allowed to run in lift well and machine room;

e) Front wall at the ground floor and top floor shall not be constructed until all lift equipment is set in position;

f) The thickness of lift walls shall be minimum 230 mm in brick or 150 mm in RCC. The walls shall be constructed in consultation with structural engineers or consultant to verify suitability based on lift load/reactions;

g) In case of brick walls, it would be recommended to have concrete solid block at locations where guide rail brackets are to be installed and in the overhead area in case of MRL Lifts. Similarly, in case of structural shaft suitable ISMC/ISMB shall be provided by the builder to fix guide rail brackets at all bracket fixing levels. The lift manufacturer shall provide a drawing indicating the locations of brackets in the lift shaft;

h) Similarly, for fixing the landing entrances, the builder shall provide RCC lintels/RCC beams for fixing landing door header and sill. In case of structural shaft suitable metallic channels shall be provided in the entrance area at lintel and floor level;

j) The shaft in masonry shall be fully plastered and given two coats of white wash or paint;

k) All the structural shafts shall be completely covered and finished in accordance to the local codes before the start of installation;

m) Suitable cut-outs near the entrance area as indicated in the lift general arrangement drawing shall be provided for fixing human interface system like landing operating panel, floor indicator, hall gong and lantern, emergency alarm, fireman switch and other devices like ôTHIS CAR NEXTô, group indicators, etc;

n) Scaffolding (bamboo/steel) shall be erected as required by the lift manufacturer with necessary safety measures;

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p) Adequate barricading shall be provided on all the lift entrance openings to avoid mishap;

q) Smoke window with louvers shall be provided below overhead slab in the hoistway as per GAD; and

r) Adequate measures shall be taken to prevent water from seeping into the hoistway at all times.

14.1.3 *Pit*

a) Lift well pit floor and side wall of the lift shaft may be plastered and water proofed. Pit shall be free from any water leakage/seepage and debris. Building owner shall ensure the construction of the pit depth in accordance with the speed of the lift as specified by the manufacturer in the general arrangement drawing;

b) Pit floor shall be strong enough to bear the load reactions as per GAD; and

c) Pedestals shall be provided for fixing car and counterweight buffers to bear the reactions as mentioned in GAD.

14.1.4 *Lighting and Power for Installation*

a) Lift shaft shall be provided with permanently installed electric lighting giving at least 50 lux, 1.0 m above the pit floor and above the pit platform (when provided) everywhere a person may stand, work and/or move between the working areas and at least 20 lux in all other areas, excluding shadows created by car or components, even when doors are closed;

b) The lighting to be protected against mechanical damage;

c) The lighting outside each landing to be provided with 50 lux illumination;

d) Adequate power supply (single phase/3 phase) as required by the lift manufacturer, shall be provided for running winch machine and lift machine for scaffold-less installation; and

e) Double earthing shall be provided in the machine room/control panel as required by the manufacturer.

14.2 Delivery of Material

The delivery of the material shall be made based on mutual agreement of the lift manufacturer and the building contractor. It is strongly recommended that the material should be delivered at site only when a suitable dry, lockable and weather-proof storage area is provided by the building contractor; the building shall be ready for installation as per GAD.

The scope of unloading and stacking materials shall be as per mutually agreed terms between the lift manufacturer and the building contractor. While unloading and shifting of materials due care shall be taken by both the parties to ensure safe unloading and shifting of materials.

Suitable equipment like hydra, fork lift, crane and trolleys shall be used for unloading and shifting of lift materials. Building contractor shall ensure safe passage for vehicles carrying materials, up to the storage area.

14.3 Storage

In order to enable efficient material distribution, it is important that the material shall be unloaded from the delivery truck within a distance of 50 m of the storage/unit location and have proper access from unloading area to storage area. The building contractor shall provide the storage area near the installation site, that is within 20 m distance from the installation site. The minimum storage space per lift shall be 35 m^2 and shall be increased adequately in consultation with the lift company for bigger capacity high speed lifts and tall buildings.

The storage room should be dry, well lit, weather protected and should have locking arrangement and provision of a 16 A power point is recommended. The storage area provided by the building owner should have PCC flooring. The storage room shall be kept ready before arrival of material at site and shall remain in possession of installation engineer till the erection of lift is completed and handed over to the owner.

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The material shall be stacked in sequential manner, in accordance with the planned activities. The storage area should be provided at a suitable location near the vicinity of the lift shaft preferably above the ground floor level and should remain in possession of the lift supplier till the installation and commissioning work is completed. It is strongly recommended that the location of the store is not changed to avoid material damages.

14.4 Site Meetings

For the successful progress of the work, full cooperation among all agencies is essential. In large sites, regular meetings of such agencies are beneficial for coordination of work efficiently. Programme for the constructional work in that part of the building containing the lift should be made in consultation among all parties concerned.

14.5 Service of Other Trades

The lift erector will require the services of architect, civil, and electrical contractors, and other agencies as the work proceeds, and it is essential that the lift erector should give due notice to the building contractor of the demands to be made on other trades, so that they may plan accordingly. Mutually agreed, periodic meeting to review work progress with agencies concerned would ensure better coordination and efficiency.

14.6 Scaffolding, Fencing, Wherever Provided

Scaffolds and stationary work platforms shall be erected in accordance with adequate safety under the supervision of a competent person. When used, wooden or synthetic planks shall be scaffold-grade or approved by a qualified person for scaffold and stationary work platform use, and the same shall be capable of withstanding 4 times the working load.

The assembly and disassembly of scaffolds and stationary work platforms shall be done using a safety harness, rope grabber and lifeline as required. All temporary lighting shall be so installed so as not to make any contact with the metal frames of the scaffold. Also, the metallic scaffolding shall be double earthed. Prior to start of any lift installation work, all lift landing shall be barricaded adequately, preferably to full height, with display of warning notices informing presence of persons at work. When scaffold less method of installation is used, certified man-riding rope hoist machine shall be used with double fall protection system.

14.7 System Building Sites

If the building programme allows insufficient time for lift erection in conventional fashion after the well is completely built special procedures are needed. This applies particularly to industrial and multi-storeyed buildings. The building contractor should provide a suitable portable cover to the completed portion of the lift well in order to protect the lift erectors working below against the weather and falling objects.

When the top of the well has been reached it is normal to cap it immediately with a precast load bearing floor slab on to which is lowered the pre-assembled machine room equipment. It then remains for the building contractor to complete and weatherproof the machine room as swiftly as possible. On all such projects the close cooperation between the building contractor and the lift manufacturer is essential.

14.8 Connecting to Power Supply

The lift manufacturer should give prior intimation to the building contractor of the date the power supply to the lift is required, so that suitable arrangements for connection should be made.

15 INSPECTION AND ACCEPTANCE PROCEDURE FOR LIFTS

15.1 Reference

This suggested procedure for inspection of lifts is based on good practice [D-5A(2)], [D-5A(15)] and [D-5A(21)] for the traction lift.

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15.2 Purpose

To ensure safe operation of new lifts on their completion and before being placed in service, they need to be subjected to acceptance inspection and tests in the field to determine that installation shall conform to the requirements of applicable standards. An inspection and test shall also be carried out on an existing installation after a major alteration.

15.3 General Requirements

These requirements shall be as follows:

a) *Personal safety*:

1) Use of relevant personal protective equipment is mandatory by the inspector and his support staff at the time of inspection; and

2) Work should be stopped and correction(s) arrangement, if unsafe conditions are noticed at the installation.

b) *Safety precautions during inspection*:

1) Inspectors should have a proper working knowledge of the lifts;

2) They should always ensure that the car is in his control while working on car roof and pit;

3) They should at all times be alert of moving objects, and when on top of lift car for moving counter weight, hoist-way projection such as beams, adjacent moving cars, cams and other equipment attached thereto or mounted in the hoist-way;

4) The overhead clearance should always be noted as number of fatal accidents occurs due to cars running into limited overhead spaces while inspections are made from top of the lift cars;

5) Inspector should never enter in lift pits containing water;

6) When working in the lift pit the inspector should always note the position of car; and

7) Clear distance shall be kept from descending counterweight in the hoist-way of the lift being inspected and those in adjoining hoist-way.

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15.4 Description of Installation

The following provides a template of typical description of installation:

Site name with details	Vendor
Length of travel (mm)	Job No:
Number of floors served	Purchaserôs identification number
Total: *	Power supply
Front: *	Permanent
Rear: *	Temporary
Car door: Glass/ SS Landing door: Glass / SS	Voltage *
Rated load	Phase *
Rated speed m/s *	Frequency *
Lift Type : Passenger/Goods Machine room/Machine room less/hydraulic	Wire (3 or 4) *
Location of machine room (for MR/ hydraulic lifts)	MCCB rating *
Give a tick mark in the appropriate box	RCD rating *
Above well	Are the above entries acceptable
Below well	Yes No
At side	
Roping Ratio: _____	

15.5 Visual and Functional Checks

A typical checklist of visual and functional checks involved in the installation of lifts is given in Annex A.

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16 MAINTENANCE OF LIFTS

16.1 Maintenance of the lift essentially covers all necessary operations to ensure safe and intended functioning of the installation and its components after completion of the installation and throughout its life cycle. To this effect, regular maintenance of the installation shall be carried out to ensure the safety of the installation, the ability to be maintained without causing injury or damage to health.

16.2 Information to the Owner of the Installation

16.2.1 The need for the owner to keep the installation in a safe operating condition. To fulfil this, owner shall use a maintenance organization with trained manpower, adequate infrastructure, lift spares and complying with the state requirements.

16.2.2 The need for the owner to take care of any state/local regulations and other requirements, where relevant, and their implications on maintenance.

16.2.3 The need for planned maintenance to be carried out by a maintenance organization, at the latest when the installation is put into service or if the installation is to remain unused for a long period of time, before being put into service first time thereafter.

16.2.4 The importance for the owner of the installation to have the same maintenance organization in the case of several installations having common well/spaces and/or machine room/spaces.

16.2.5 The need for the owner of a passenger/goods-passenger lift to keep the two-way means of communication efficient and linked to a 24 h rescue service for the whole of the time that the installation can be used.

16.2.6 The need for the owner to remove the passenger/goods-passenger lift from service when the two-way means of communication is out of order.

16.2.7 The need for the owner to put the installation out of service in case of dangerous situations.

16.2.8 The need for the owner of the installation to inform the maintenance organization, immediately about any perceived abnormal operation of the installation or abnormal change in its direct environment,

a) immediately after putting the installation out of service in the case of a dangerous situation;

b) after any rescue intervention by their authorized and instructed person(s);

c) before any modification related to the installation and/or its environment;

d) before any authorized third-party inspection or works other than maintenance works are carried out on the installation;

e) before taking the installation out of service for a prolonged period; and

f) before putting the installation back into service after a prolonged period of non-operating time.

NOTE ð The owner of the installation should obtain from the company carrying out the relevant modification, the maintenance instructions for the maintenance organization.

16.2.9 The owner needs to inform the access ways to areas reserved to maintenance persons, the need for the owner of the installation to inform the maintenance organization, about:

a) the access ways to be used and fire evacuating procedures from the building;

b) the place where the keys of the reserved areas can be found;

c) if necessary, the persons who shall accompany the maintenance persons to the installation; and

d) if necessary, personal protective equipment to be used in the access ways and, possibly, where such equipment can be found.

The information shall be made available also on site to the maintenance organization.

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16.2.10 The need for the owner of the installation to ensure that the name and the telephone number of the maintenance organization are always available to the user of the installation, permanently affixed and clearly visible.

16.2.11 The need for the owner of the installation to ensure that the keys of machine and pulley room doors (trap doors) and of inspection and emergency doors (trap doors) are permanently available in the building and are used only by persons authorized to gain access.

16.2.12 The need for the owner of the installation to provide, in all circumstances, safe access to the building and to the installation for the maintenance organization involved in the rescue of persons.

16.3 Information to the Owner of the Installation Regarding Self-Monitoring

In addition to those examinations and tests which the owner of the installation entrusts to the maintenance organization, there is a need for the owner to carry out periodically, in their own interests, the following:

a) A full ascent and descent travel to assess any changes in the quality of the ride or damage to the equipment. Typical items to be checked to ensure that they are in place, undamaged and functioning correctly are:

   1) landing doors and bottom door tracks;

   2) stopping accuracy;

   3) indicators that are not located in a reserved area;

   4) landing push controls;

   5) car push controls;

   6) door open controls;

   7) two-way means of communication in the car which provides permanent contact with a rescue service;

   9) normal car lighting;

   10) door reversal device; and

   11) safety signs/pictograms.

b) For goods only and service lifts the checks to be carried out are the same, when relevant.

16.4 Information to the Owner regarding Lift Rescue Operations

The information to the owner shall be inclusive of that given in **16.4.1** to **16.4.5**.

16.4.1 The need for person(s) authorized by the owner of the installation to rescue trapped passengers to be trained by the maintenance organization.

16.4.2 The need to ensure that the training is appropriate to the specific installation and updated.

16.4.3 The need to ensure his authorized person(s) rescue people only through landing doors.

16.4.4 The need to ensure that the maintenance organization is called when the owner's authorized person(s) is not able to move the car using the manual and/or electric emergency devices.

16.4.5 The need to inform their authorized person(s) about any condition for which only the maintenance organization shall carry out a rescue operation.

The information required for maintenance of lifts, to be known to the owner of the installation is included, as above detailed maintenance guide for lifts is included in accepted standard [D-5A(22)].

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ANNEX A

(*Clause* 15.5)

TYPICAL CHECKLIST OF VISUAL AND FUNCTIONAL CHECKS INVOLVED IN THE INSTALLATION OF LIFTS

A-1 MACHINE ROOM

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
i)	There shall be easy access from the top landing to the machine room	Accessible/Not accessible	
ii)	Steps along with handrail for the access to machine room to be provided	Provided/Not provided	
iii)	Machine room access door of M.S, in two panels, hinged type construction, opening outward and clear entrance not less than 1000 mm wide Ĭ 2000 mm high	Provided/Not provided	
iv)	Caution notice of 440 V and restricted entry marked on the entrance	Displayed/Not displayed	
v)	Locking arrangement provided and machine room shall be kept locked	Provided/Not provided	
vi)	The machine room used for the purpose of lift machinery only	Yes/No	
vii)	Machine room walls, floor and ceiling treated and painted to minimize accumulation of dust	Yes/No	
viii)	Machine room shall be maintained clean, without any seepage of water from roof, walls or any other opening	Yes/No	
ix)	The height of the machine room shall not be less than 2 100 mm at working areas	Yes/No	
x)	Machinery spaces and pulley rooms provided with permanently installed electric lighting with an intensity of at least 200 lux at floor level everywhere a person needs to work and 50 lux at floor level to move between working areas	Provided/Not provided	
xi)	Adequate ventilation for machine room with rain protected windows or louvers with exhaust fans or air-conditioning system so that the ambient temperature of the machine room is maintained between + 5 ºC and + 40 ºC	Yes/No	
xii)	Are the rope openings below the machine closed adequately as required	Yes/No	
xiii)	The hoisting beams or hooks are certified as per the safe working load required and marked	Provided/Not provided	

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Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
xiv)	Trap door with metal cover to be provided to lift the machine to/or from the machine room and to be located vertically below the hook provided in the machine room ceiling	Provided/Not provided	
xv)	Rescue chart pasted in the machine room with proper identification	Yes/No	

A-2 POWER SUPPLY

Sl No.	Requirement		Result	Remarks
(1)	(2)		(3)	(4)
i)	Incoming power supply to be 415 V Ñ 10 percent or as specified in the contract agreement		R-Y : _____ Y-B : _____ R-B : _____ Ok/Not Ok	
ii)	Neutral ð Earth voltage	Idle condition within (0 to 3) V	Value: _____ Ok/Not Ok	
iii)	Neutral ð Earth voltage	Running condition within (0 to 3) V	Value: _____ Ok/Not Ok	
iv)	Separate supply with MCB	Three phase supply	Provided/Not provided	
		Single phase supply (for car lighting and hoistway lighting)	Provided/Not provided	
v)	Check whether the power cables are connected with lugs for termination		Connected/Not connected	
vi)	The correct capacity main switch (with lock out tag out provision) with protective device, provided as per the requirement, separately for lift power, light for machine room and hoistway. Three pin sockets with switch provided		Provided/Not provided	
vii)	Double grounding conductor of correct size is provided on the main switch. Earthing of lift motor, control panel, overspeed governor switch, etc provided		Provided/Not provided	
viii)	Hoistway lighting provided at least 50 lux,1 m above the pit floor and above the pit platform (when provided), everywhere a person can stand, work and/or move between the working areas and at least 20 lux in all other areas, excluding shadows created by car or components, even when doors are closed		Provided/Not provided	

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Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
ix)	Residual current protective device (RCD) with rated residual operating current not exceeding 30 mA (not applicable to main drive) provided	Provided/Not provided	

A-3 MACHINE AND BRAKE ASSEMBLY (FOR TRACTION LIFTS)

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
Make:	*Sl No.*:	*Rating*: _____	
i)	The motor is smooth in operation without overheating	Satisfactory/Unsatisfactory	
ii)	The gear box (if provided) is smooth and without any oil leakage except little oozing	Satisfactory/Unsatisfactory	
iii)	The condition of machine grooves is such that the ropes/CSB do not slip when the traction sheave stops normally	Satisfactory/Unsatisfactory	
iv)	Is the machine fixation as per the installation manual	Yes/No	
v)	Are the electrical connections of the machine routed and well tightened	Yes/No	
vi)	Are the machine isolation pads installed correctly (if applicable)	Yes/No	
vii)	Ropes/elastomeric coated steel belts fixed by suspension means in the machine room are fixed as required and locked with nuts and split pins.	Yes/No	
viii)	Clear vertical distance of at least 300 mm is available above rotating equipment	Yes/No	
ix)	The lift provided with braking system which operates automatically in the event of loss of: a) the main power supply b) the supply to the control circuits	Provided/Not provided	
x)	The machine, governor, etc, identified with the correct contract number	Yes/No	
xi)	The manual brake release device is available and easily accessible	Yes/No	
xii)	Guards provided for moving parts such as machine sheave, etc to protect against pinching hazard	Provided/Not provided	

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A-4 CONTROLLER

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
Type:	*Sl No.*:	*Wiring drawing No*:	
i)	The controller fixed as per the GAD (general arrangement drawing)	Yes/No	
ii)	The controller identified with the correct contract number	Yes/No	
iii)	The controller should have an easy access to open and close with lock	Yes/No	
iv)	The required warning stickers pasted	Provided/Not provided	
v)	All extra cables neatly arranged	Yes/No	
vi)	Are the battery terminals covered	Yes/No	
vii)	The field and controller wiring properly routed	Yes/No	
viii)	The control panel wiring is neatly grouped and the insulation of wires is not more than one Mega Ohm with 500 volt megger	Yes/No	
ix)	Logbook maintained in up-to-date condition	Maintained/Not maintained	

A-5 OVER SPEED GOVERNOR

Sl No.	Requirement	Result	Remarks
Make:	*Model*: *Sl No*:	*Tripping speed*:	
i)	Is the correct over speed governor provided and installed as per layout	Yes/No	
ii)	The sticker/painted indication represents the down direction of rotation which will facilitate the safety gear actuation	Yes/No	
iii)	Check whether the OSG is calibrated and sealed	Yes/No	
iv)	The governor is aligned, and the rope passes through the holes without any obstruction	Yes/No	
v)	The governor rope runs free is not in contact with any object in the hoist way	Yes/No	
vi)	The governor tripping mechanism is free and clean	Yes/No	
vii)	The electrical switch is provided and operates in both the directions	Yes/No	
viii)	All fixation bolts are provided and adequately tightened	Yes/No	

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A-6 GENERAL INSPECTION ON CAR ROOF

Sl No.	Requirement	Result	Remarks
Instructions before entering to the car top: a) *Allow the lift to move in down direction from the top terminal landing with no load* b) *Stop the lift from the controller by changing to maintenance mode, such that easy access to enter the car top from the top terminal landing* c) *Switch on the shaft lighting* d) *Use the door open key to open the top terminal landing door* e) *Switch on the car top stop switch from the landing to enable the 'STOP' mode* f) *Switch on the light on car top* g) *Switch to maintenance mode from the car top before entering the car top* h) *Put Stop switch to Run position and press UP/DN and common button to move the car UP or down in maintenance speed*			
i)	Car top guard rail on car roof to be provided of 0.70 m where the distance between car and hoistway wall is > 0.30 m and < = 0.50 m; is 1.10 m where the distance exceeds 0.50 m and not required if the distance is < 0.30 m	Provided/Not provided	
ii)	The car roof has been provided with toe board of 100 mm and non-slip working area	Provided/Not provided	
iii)	Car roof has sufficient strength to resist a minimum force of 2 000 N at any position on an area of 0.30 m Ĭ 0.30 m without permanent deformation	Yes/No	
iv)	Lighting with proper protection is provided on the car roof of at least of 50 lux intensity, 1.0 m above the car roof	Provided/Not provided	
v)	Emergency light on car top with minimum intensity of 20 lux for 1 h operation and alarm initiation device provided	Provided/Not provided	
vi)	Wires and trunking are properly routed and does not hinder with any maintenance related equipment	Yes/No	
vii)	The car fan/blower is properly fixed with isolation	Yes/No	
viii)	Three pin plug sockets with switch is available and is in working condition	Yes/No	
ix)	The emergency stop switch is positioned not more than 0.75 m from the landing	Yes/No	
x)	Check whether the top car clearance meets the requirement Value required: _____	Value measured: _____ Ok/Not Ok	
xi)	Overhead dimension in W Ĭ H Ĭ D Value required: _____	Value measured: _____ Ok/Not ok	
xii)	If overhead height is less, then the indication to be provided with zebra painting in the overhead	Provided/Not provided	

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Sl No.	Requirement	Result	Remarks
xiii)	Floor levelling switches are fixed as per requirement	Yes/No	
xiv)	Rope/CSB hitches on car roof are fixed as required and locked with nuts and split pins	Yes/No	
xv)	Car sheave; if available; is adequately guarded from accidental contact	Yes/No	
xvi)	The junction box is fixed securely and all wires are adequately protected	Yes/No	
xvii)	The car shoe liners/rollers are fixed as per requirement and adjusted properly	Yes/No	
xviii)	Oil tank are provided and fixed with proper oil levels	Yes/No	
xix)	Engagement of the car door coupler with the landing door at every landing	Ok/Not ok	
xx)	Engagement of shaft limit switches	Ok/Not ok	
xxi)	The governor rope and linkage is correctly connected to the car	Yes/No	
xxii)	The guide rail clips are fixed as per requirements and in the correct directions	Yes/No	
xxiii)	The safety gear assembly and connecting rod should be free from external disturbances	Yes/No	
xxiv)	The safety switches have been verified for correct operation during travel	Yes/No	
xxv)	The safety gear linkages is checked for operation and actuation of switches	Yes/No	
xxvi)	Clearance between the car door coupler and the landing sill to be as per the manufacturer design at every landing	Ok/Not ok	
xxvii)	Clearance between the landing rollers with the car sill to be as per the manufacturer design at every landing	Ok/Not ok	

A-7 PIT INSPECTION

Sl No.	Requirement	Result	Remarks
Instructions before entering to the pit: a) *Allow a person on the car top and ask him to move the lift to the topmost landing* b) *Open the bottom terminal landing door with door open key* c) *Switch on the pit stop switch from outside the pit* d) *Enter into the pit using ladder or from access door*			
i)	It should be clean and dry	Yes/No	

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Sl No.	Requirement	Result	Remarks
ii)	Pit access door to be provided, if pit depth exceeds 2 500 mm. Either an access door or a ladder inside the well to be provided, where pit depth does not exceed 2 500 mm	Pit depth = mm Pit access door/ Ladder provided/ Not provided	
iii)	Oil trays are available at the bottom of each guide rail	Provided/Not Provided	
iv)	Pit stop switches to be provided, accessible from the lowest landing. When pit depth > = 1.6 m, two pit switches, one accessible from lowest landing and other from pit floor to be provided	Provided/Not Provided	
v)	Pit stop switches to be verified with the electrical circuit such that lift should not move further after the activation of pit stop switches	Ok/Not OK	
vi)	Inspection control station is permanently installed in the pit. If more than one inspection control station is switched to ôinspectionô, it shall not be possible to move the car from any of them, unless the same push buttons on the inspection control are operated simultaneously	Provided/Not Provided Ok/Not Ok	
vii)	Counterweight screen should be provided and fixed, except where rope compensation sheave is provided	Provided/Not Provided	
viii)	Buffers provided for bottom limit of travel of car and counterweight are correctly fixed and not in bent condition. PU buffers not to be in degenerated condition	Ok/Not Ok	
ix)	The governor tension pulley is fixed at the correct height from the pit floor as per the manufacturer recommendation	Ok/Not Ok	
x)	The electrical switch for the tension pulley is verified, if provided	Ok/Not Ok	
xi)	Check whether the bottom car clearance meets the requirement Value required: _____	Value measured: _____ Ok/Not Ok	
xii)	Pit lighting to be provided of at least 50 lux,1 m above the pit floor and above the pit platform (when provided), everywhere a person can stand or work	Ok/Not ok	
xiii)	Refuge space to be provided in the pit and signage readable from entrance, indicating allowed number of persons and type of posture to be provided	Provided/Not provided	
xiv)	Is the travelling cable below car secured and correctly fixed and the excess cable is not secured below car	Ok/Not ok	

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Sl No.	Requirement	Result	Remarks
xv)	The travelling cable is adjusted and clear of the pit floor with the car at the lowest position	Ok/Not ok	
xvi)	The bottom guide shoes or rollers are fixed as per requirement and adjusted for smooth travel	Ok/Not ok	
xvii)	The car safety gear is properly adjusted as per the installation manual	Ok/Not ok	
xviii)	The compensation chain fixing arrangement is fixed as per requirement	Ok/Not ok	

A-8 EARTHING

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
i)	Separate earth bar to be provided in the machine room	Provided/Not provided	
ii)	Earthing to be done for all controllers and the machine	Yes/No	
iii)	Earthing to be done for the shaft equipment and car top components	Yes/No	
iv)	Earthing from controller to car top components to be linked through the travelling cable	Yes/No	
v)	Routing of the earth from the controller to the main earth bar	Ok/Not ok	
vi)	Connection of the lift earth bar to main earth bar	Ok/Not ok	

A-9 INSPECTION FROM THE LIFT CAR

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
Instructions: a) *No one should be present in the pit as well as on the car top* b) *Make sure the lift is normal mode* c) *Enter the lift car from any of the landing*			
i)	Car inside width Value required: _____	Value at site: _____ Ok/Not Ok	
ii)	Car inside depth Value required: _____	Value at site: _____ Ok/Not Ok	

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Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
iii)	Height below false ceiling Value required: _____	Value at site: _____ Ok/Not Ok	
iv)	Door opening width Value required: _____	Value at site: _____ Ok/Not Ok	
v)	Door opening height Value required: _____	Value at site: _____ Ok/Not Ok	
vi)	Car capacity to be displayed inside the lift car	Yes/No	
vii)	Safety warning plate to be displayed (*see* Note)	Yes/No	
viii)	Functioning of car display	Functioning/ Not functioning	
ix)	The stopping accuracy of the car shall be $\pm$ 10 mm. If during loading and unloading levelling accuracy of $\pm$ 20 mm is exceeded, shall be corrected to $\pm$10 mm	Ok/Not Ok	
x)	DO button and DC button functional check: For power operated door: 1) Press the DO button at level - Door should open 2) Press the DO button during running - Door should not open 3) While closing press the DO button at level - Door should open 4) DC button at level when the door is in open condition - Door should close	Functioning/ Not functioning	
xi)	*For manual operated door:* 1) Lift should not move if any of the door car/landing in open condition 2) If door is opened during run, lift should stop and should not move further	Functioning/ Not functioning	
xii)	Car alarm functions even though there is no power supply to the lift	Functioning/ Not functioning	
xiii)	Functioning of intercom (*see* Note)	Functioning/ Not functioning	
xiv)	Functioning of car call buttons and landing call buttons (*see* Note)	Ok/Not ok	

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Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
xv)	Provision of fan/blower and its operations	Provided/ Not provided	
xvi)	Provision and working of permanently installed cabin lights that are continuously illuminated except when the car is parked with doors closed. Illumination shall be 100 lux	Provided/ Not provided	
xvii)	Emergency light provided shall come on automatically upon failure of the normal car lighting supply. Shall be capable of illumination intensity of at least 20 Lux for 1 h	Provided/ Not provided	
xviii)	Provided with ventilation apertures on the upper and lower parts of the car with imperforate car doors	Provided/ Not provided	
xix)	Doors are verified for smooth opening and closing at each level	Ok/Not Ok	
xx)	Riding comfort ð No appreciable jerk shall be noticed at the time of travelling, stopping/starting in the car	Ok/Not OK	
xxi)	Car door protective device shall automatically initiate re-opening of the power operated car door(s) in the event of person crossing the entrance during the closing movement	Ok/Not OK	
xxii)	Lift should not move for any safety failure	Ok/Not Ok	
xxiii)	Provision of grab bars inside the lift car (*see* Note)	Provided / Not provided	
xxiv)	Provision of buffer rail (applicable only for service lifts) at the rear panel of the lift car	Provided / Not provided	

NOTE ð Lifts open to public use shall also be inspected for requirements as per good practice [D-5A(3)], including those relating to lift closing time, finishes of interior surfaces, etc.

A-10 INSPECTION FROM THE FLOOR LANDINGS

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
i)	Provision and functioning of landing door de-locking at every landing	Functioning/Not functioning	
ii)	Condition of landing door at every floor	Ok/Not ok	
iii)	Functioning of landing display at every floor	Functioning/Not functioning	
iv)	Functioning of landing call button	Functioning/Not functioning	
v)	Functioning of duplex/group operation at every landing (if applicable)	Functioning/Not functioning	

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A-11 RESCUE OPERATIONS

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
i)	Is the automatic rescue device (ARD) installed and operating as per the instructions	Yes/No	
ii)	An audio-visual indicator is provided inside the lift car to alert the passenger(s) trapped inside the car that the lift is on emergency power or there is a mains power failure and they are being rescued	Yes/No	
iii)	Is the stopping accuracy of $\pm$ 40 mm achieved during the automatic rescue operation	Yes/No	
iv)	ARD operate in case of failure of any one phase, or any two phases or all the three phases. It also operates during phase reversals (in non-VF type lifts where phase failure relays are installed)	Yes/No	
v)	Emergency light is at least operational till the end of the ARD operation)	Yes/No	

A-12 FIRE OPERATION

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
i)	Phase I a) When the fireman switch is activated, all the landing calls to be inoperative and the car shall report to the evacuation floor and the lift doors to be in opened condition b) If the lift is moving away from the evacuation floor, then it shall reverse its direction at the nearest floor landing without opening its door, and return back to the evacuation floor and remains there itself with the doors open	Functioning/ Not functioning	
ii)	Phase II (if applicable) a) It will be started once after the completion of Phase I along with the fireman switch in ON position b) In Phase II, lift should not respond to landing call and when the car call button is pressed, the door should start closing. If the button is released before the full close of doors, then the doors should open automatically c) After the full close of door, the lift should move on to the floor of registered car call d) The doors should only open if the open button is pressed after reaching the level. If the open button is released before the full open, then the doors should reclose automatically	Functioning/ Not functioning	

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A-13 INSPECTION FOR HYDRAULIC LIFTS

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
Instructions before inspecting hydraulic lift: a) *Do not open or tighten the parts of a pressurized system* b) *Make sure that the energy source has been locked and tagged before starting the work* c) *Ensure that there is no pressure* d) *The car must be at the lowest position* e) *The piston must be at the bottom* f) *The shut-off valve must be closed* g) *Press the emergency lowering valve to release all system pressure*			
a)	Check that the oil level in the tank covers the motor-pump system (minimum 20 mm over the motor) when the cylinder is in upper end position and the oil level is 70/80 mm under the tank edge, when the cylinder is in lower extra travel position	Found Ok/Not ok	
b)	Check visually the connection pipe sealing, the joints of the flexible hoses and rigid pipes	Found Ok/Not ok	
c)	Check the rapture valve intervention by loading the car with rated load uniformly distributed and over-speeding the descending car	Found Ok/Not ok	
d)	Is the oil temperature, same as room temperature after the rapture valve intervention	Ok/Not ok	
e)	Check protection against accidental operation of emergency lowering valve	Ok/Not ok	
f)	When the main shut off valve is closed, activating the hand pump, the pressure on the manometer has to increase up to the adjusting valve	Ok/Not ok	
g)	Check the provision of motor thermistor	Provided/Not provided	
h)	Any abnormal noise during normal drive, both in UP and DN direction travel	Ok/Not ok	
j)	Check the working of electrical anti-creep system	Ok/Not ok	
k)	Emergency lowering with battery backup provided and working	Provided/Not provided	
m)	At least one electrically retractable pawl is provided, designed in its extended position to stop the downward moving car against fixed supports	Provided/Not provided	
n)	Check visually, the integrity of the hydraulic system after applying 200 percent full load pressure applied between the non-return valve and the jack for 5 min (observe for any leakage/drop in pressure)	Ok/Not ok	

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A-14 SAFETY DEVICES

Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
Instructions: a) *The lift is in idle condition and the following safety devices get activated, then it should not move further* b) *If the lift is in running condition and the following safety devices get activated, then the lift shall stop and should not move further*			
i)	OSG ð Over speed governor	Functioning/ Not functioning	
ii)	Car door contact	Functioning/ Not functioning	
iii)	Landing door contact	Functioning/ Not functioning	
iv)	Car top stop switches	Functioning/ Not functioning	
v)	Pit stop switches	Functioning/ Not functioning	
vi)	Functioning of screen sensors and door safety edge: 1) Door should reopen, if we cut the screen 2) Door should reopen, if it hit any object	Functioning/ Not functioning	
vii)	Check whether the car and counterweight buffers installed as per the requirement	Yes/No	
viii)	Functioning of limit switches so as lift should not travel beyond the limit	Functioning/ Not functioning	
ix)	Brake on its own shall be capable of stopping the machine when the car is travelling downward at rated speed and with the rated load plus 25 percent	Ok/Not Ok	
x)	Ascending car overspeed Protection provided to detect overspeed of the ascending car and cause the car to stop or at least reduce its speed	Functioning/Not functioning	
xi)	Provision to prevent or stop unintended car movement away from landing with landing door not in the locked position and the car door not in the closed position. Stopping distance shall not exceed 1.20 m from the landing where the unintended car movement has been detected	Functioning/ Not functioning	
xii)	Safety gear test: 1) Lift car safety gear to be tested in down direction with 100 percent rated load in the lift car (during maintenance it shall be tested only in inspection speed), with test tripping arrangement 2) If provided, counterweight safety gear to be tested in up direction of lift car with no load with test tripping arrangement	Stopping distance: ——— Ok/Not ok	

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Sl No.	Requirement	Result	Remarks
(1)	(2)	(3)	(4)
	3) Lift stopping distance depends upon the tripping speed of the governor and shall be within the range as per the Indian Standard		

A-15 STOPPING ACCURACY AND RUNNING CLEARANCE TEST

Instructions:

a) *The stopping accuracy shall be within ±10 mm of the finished floor level*

b) *The running clearance between the lift car threshold and landing door sill should be 35 mm*

No. of floors: _____

Floors (Landing)	Stopping Accuracy		Running Clearance		
	UP	DN	LH	Centre	RH
1st					
2nd					
3rd					
4th					
5th					
6th					
é					
é					
Result Ok/Not ok					

A-16 LOAD TEST

Sl No.	Load in Percent	Direction of Travel	Voltage	Current
			V	A
(1)	(2)	(3)	(4)	(5)
Instructions: a) *With balanced load, the current value in both the up and down directions to be same* b) *Check the current only after the lift reaches its rated speed*				
i)	No load	UP		
		DN		
ii)	Balance load	UP		
		DN		
iii)	Full load	UP		
		DN		

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LIST OF STANDARDS

The following list records those standards which are acceptable as ógood practiceôand ówaccepted standardsôin the fulfilment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used as a guide in conformance with the requirements of the referred clauses in this NBCS.

	IS No.	*Title*
(1)	IS 17900 (Part 1) : 2022	Lifts for the transport of persons and goods: Part 1 Safety rules
(2)	IS 17900 (Part 2) : 2022	Lifts for the transport of persons and goods: Part 2 Design rules calculations examinations and tests of lift components
(3)	IS 4963 : 2025	Accessibility in built environment for older adults and persons with disabilities ð Requirements (*second revision*)
(4)	IS 12615 : 2018	Line operated three phase a.c. motors (IE Code) ówfficiency classes and performance specification (*third revision*)
(5)	IS 1950 : 1962	Code of practice for sound insulation of non-industrial buildings
(6)	IS 14665 (Part 2/Sec 1 and Sec 2) : 2000	Electric traction lifts: Part 2 Code of practice for installation, operation and maintenance, Section 1 Passenger and goods lifts, Section 2 Service lifts
(7)	IS 15105 : 2021	Design and installation of fixed automatic sprinkler fire extinguishing systems ð Code of practice (*first revision*)
(8)	IS 732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
(9)	IS 3043 : 2018	Code of practice for earthing (*second revision*)
(10)	IS 17518 (Part 2) : 2021/ ISO 3008-2 : 2017	Fire-resistance tests: Part 2 Lift landing door assemblies
(11)	IS/IEC 60529 : 2001	Degrees of protection provided by enclosures (IP Code)
(12)	IS 17805 (Part 20) : 2024 ISO 8102-20 : 2022	Electrical requirements for lifts escalators and moving walks: Part 20: Cyber security
(13)	IS 14665 (Part 3/Sec 1 and Sec 2) : 2000	Electric traction lifts: Part 3 Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts
(14)	IS 2551 : 1982	Danger notice plates (*first revision*)
(15)	IS 15785 : 2007	Installation and maintenance of lifts without conventional machine rooms ð Code of practice
(16)	IS 15259 : 2002	Installation and maintenance of home lifts ð Code of practice
(17)	IS 15330 : 2020	Requirements of lifts for persons with disabilities (*first revision*)
(18)	IS 17900-7-7	Lifts for the transport of persons and goods: Part 7 Lifts for special applications, Section 7 Lifts under seismic conditions (*under prepration*)
(19)	IS 17615 (Part 1) : 2021/ ISO 18738-1 : 2012	Measurement of ride quality : Part 1 Lifts elevators

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	IS No.	*Title*
(20)	IS 17106 (Part 1) : 2019/ ISO 22201-1 : 2017	Lifts (elevators), escalators and moving walks — Programmable electronic systems in safety-related applications: Part 1 Lifts (elevators) (PESSRAL)
(21)	IS 17900 (Part 5) : 2026	Lifts for the transport of persons and goods: Part 5 Guide for inspection of lifts
(22)	IS 17900 (Part 6) : 2022	Lifts for the transport of persons and goods: Part 6 Guide for maintenance of lifts

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 5 INSTALLATION OF LIFTS, ESCALATORS, MOVING WALKS AND POWER-DRIVEN PARKING SYSTEMS

5B ESCALATORS AND MOVING WALKS

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part D/Subsection 5B) covers the requirements for planning and design, installation, operation, maintenance, and inspection of escalators and moving walks to ensure safe movement of people with satisfactory performance.

This Section was first published in 1970 and was subsequently revised in 1983, 2005 and 2016 as a part of National Building Code of India. This Section covers the requirements for installation of lifts and escalators in buildings. This Section should be read with Part F 'Fire and Life Safety' of this NBCS from fire safety requirements point of view. The major changes in the first revision of 1983 were addition of outline dimensions of different types of lifts and detailed requirements of escalators in buildings. Emphasis was laid on coordination between the engineer/architect and the lift manufacturer to arrive at the number and position of lifts for attaining optimum efficiency in serving the building with safety.

The significant changes with respect to lifts incorporated in the 2005 revision, included the addition of new clauses/recommendations on the building management system; addition of new clauses on fireman's lift, infrared light curtain, safety and Braille button for blind people and updation of provisions as per the revised standards on lifts on which this Section was based.

In the 2016 revision, the erstwhile Section 5 on lifts and escalators was divided into two Subsections namely:

a) 5A Installation of lifts; and

b) 5B Installation of escalators and moving walks.

This Subsection 5B addresses exclusively the provisions related to the installation of escalators and moving walks, which have been increasingly provided in buildings. It covers comprehensive provisions on all aspects, including requirements for planning and design, installation, operation, maintenance, and inspection of escalators to ensure the safe movement of people with satisfactory performance. This Subsection also covers the provisions on moving walks.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

As a result of technical developments in the subject of escalators and moving walks, the experience gained since implementation of 2016 version of this NBCS and feedback received as well as the revision of related Indian Standards on the subject, a need was felt to revise this Subsection. The significant modifications made in this revision of the subsection include amongst others, the following key changes:

a) The terminology has been updated addressing maintenance aspects and electrical safety system.

b) The requirements of power supply including protection devices have been elaborated, in **6.5.3**.

c) Fire protection requirements for the installations have been elaborated, in **7**.

d) Technical requirements for outdoor escalators/moving walks and semi- outdoor escalators/moving walks have been included in **9.2** and **9.3**.

e) Inspection check list has been revised, under **14.6.2**.

f) Annex A on typical escalator site checklist/inspection list has been considerably revised.

g) Annex B on typical check list for functional tests on safety switches and devices has been revised.

The information contained in this Subsection is largely based on the following Indian Standards/Special Publications:

IS 732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
IS 3043 : 2018	Code of practice for earthing (*second revision*)

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IS 4591	Escalators and moving walks:
(Part 1/Sec 1) : 2020	Safety requirements (*first revision*)
(Part 1/Sec 2) : 2020	Guide for planning and selection (*first revision*)
(Part 1/Sec 3) : 2020	Inspection and test (*first revision*)
(Part 2) : 2022	Guide for maintenance
CEA : 2023	Central Electricity Authority Regulation: 2023
SP 30 : 2023	National Electrical Code of India 2023

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

Assistance has also been derived from the following publications in the revision of this Subsection:

IBC 2024 International Building Code, International Code Council, Washington, USA

CIBSE Guide D : Transportation Systems in Buildings, 2025, The Chartered Institution of Building Services Engineers, London, U.K.

EN 115-1 : 2017 Safety of escalators and moving walks — Part 1: Construction and installation

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **'accepted standard'** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practices [D-5B(1)] refers to the Indian Standard(s) referred to in serial number (1) of the list of standards given at the end of this Part/Subsection, that is, SP 30 : 2023 'National Electrical Code of India 2023', IS 732 : 2019 'Code of practice for electrical wiring installation (*fourth revision*)', IS 3043 : 2018 'Code of practice for earthing (*second revision*)'.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 5 INSTALLATION OF LIFTS, ESCALATORS, MOVING WALKS AND POWER-DRIVEN PARKING SYSTEMS

5B ESCALATORS AND MOVING WALKS

1 SCOPE

1.1 This NBCS (Part D/Subsection 5B) covers the essential requirements for planning, installation, operation, maintenance, and inspection of escalators and moving walks to ensure safe movement of people with satisfactory performance.

1.2 This Subsection gives information that should be exchanged among the architect/engineer, the consulting engineer and escalator/moving walk manufacturer from the stage of planning to installation including maintenance.

2 TERMINOLOGY

For this Subsection, the following terms and definitions apply.

2.1 General Terms Relating to Escalators and Moving Walks

2.1.1 *Angle of Inclination* — Maximum angle to the horizontal in which the steps, the pallets, or the belt move.

2.1.2 *Operational or Service Brake* — Brake that usually acts on motor shaft and used to stop an escalators/moving walk under all normal conditions or under certain fault conditions.

2.1.3 *Balustrade* — Part of the escalator/moving walk which ensures the user's safety by providing stability, protecting from moving parts and supporting the handrail.

2.1.4 *Balustrade Decking* — Transverse member of the balustrade which meets the handrail guidance profile, and which forms the top cover of the balustrade.

2.1.5 *Brake Load* — Load on the step/pallet/belt for which the brake system is designed to stop the escalator/moving walk.

2.1.6 *Comb* — Pronged section at each landing that meshes with the grooves of the steps/pallets.

2.1.7 *Comb Lighting* — Small flush light panels located in the skirt panels on both sides of the escalators/ moving walk unit at both upper and lower landing and immediately adjacent to the comb teeth to illuminate the comb and step tread and assist passengers boarding and alighting the escalators/moving walk.

2.1.8 *Comb Plate* — Platform at each landing to which the combs are attached.

2.1.9 *Comb Plate Switch* — Switch in safety circuit that opens when excessive force is detected in vertical and/or horizontal direction on the comb or comb plate of escalators/moving walk.

2.1.10 *Comb Teeth* — Series of teeth which ride the grooves of the escalators/moving walk step tread as the step passes underneath and are designed to allow them to break-off if a wedging action should occur at their point of contact with step tread.

2.1.11 *Auxiliary or Emergency or Safety Brake* — Mechanically operated brake which operates automatically to stop a fully loaded escalator if the drive chain breaks. It is typically situated on one side of the main drive shaft.

2.1.12 *Emergency Stop Switch* — Separate stop button usually located in adjacent walls, columns or within the balustrade providing the facility to stop the escalator/moving walk, in the event of emergency.

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2.1.13 *Inspection Door* — Means of access to equipment areas and other spaces pertaining to an escalators/moving walk installation such as machinery spaces, etc, and with access usually restricted to authorized persons.

2.1.14 *Electrical Safety Devices* — Part of a safety circuit consisting of safety switches and/or fail-safe circuits.

2.1.15 *Escalator* — Power-driven, inclined, continuous moving stairway used for raising or lowering persons in which the user carrying surface (for example, steps) remains horizontal.

NOTE — Escalators are machines even when they are out of operation and shall not be considered or used as fixed staircases.

2.1.16 *Exterior Panel* — Part of the exterior side of the enclosure of an escalator or moving walk.

2.1.17 *Handrail* — Power-driven moving rail for persons to grip while using the escalator or moving walk.

2.1.18 *Interior Panel* — Panel located between the skirting or lower inner decking and the handrail guidance profile or balustrade decking.

2.1.19 *Lower Inner Decking* — Profile that connects the skirting with the interior panel when they do not meet at a common point.

2.1.20 *Lower Outer Decking* — Profile that connects the exterior panels with the interior panel.

2.1.21 *Machinery* — Escalator or moving walk machine(s) mechanisms and associated equipment.

2.1.22 *Machinery Spaces* — Space(s) inside or outside of the truss where the machinery as a whole or in parts is placed.

2.1.23 *Maximum Capacity* — Maximum flow of persons that can be achieved under operational conditions.

2.1.24 *Moving Walk* — Power-driven installation for the conveyance of persons in which the user carrying surface remains parallel to its direction of motion and is uninterrupted (for example, pallets, belt).

NOTE — Moving walks are machines even when they are out of operation and shall not be considered or used as a fixed access.

2.1.25 *Newel* — End of the balustrade.

2.1.26 *Nominal Speed* — Speed in the direction of the moving steps, pallets, or the belt, when operating the equipment under no load condition (that is, without persons), stated by the manufacturer as that for which the escalator or moving walk has been designed.

NOTE — Rated speed is the speed the escalator/moving walk moves under rated load conditions.

2.1.27 *Pit* — Recess in the floor to receive that portion of the lower landing and the lower end of the incline section which occurs below the floor line when there is no floor under the escalator such as in a basement.

2.1.28 *Rated Load* — Load which the equipment is designed to move.

2.1.29 *Rise* — Vertical distance between the upper and lower finished floor levels.

2.1.30 *Safety Circuit* — Part of the electric safety system consisting of electrical safety devices.

2.1.31 *Skirting* — Vertical part of the balustrade interfacing with the steps, pallets, or belt.

2.1.32 *Skirt Deflector* — Device to minimize the risk of trapping between the step and the skirting.

2.1.33 *Electrical Safety System* — Safety related part of the electrical control system as an arrangement of safety circuits and monitoring devices.

2.1.34 *Maintenance* — All the necessary operations to ensure the safe and intended functioning of the installation and its components after the completion of the installation, throughout its life cycle. *See* **15.1** for details.

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2.1.35 *Maintenance Organization* — Company or part of company where competent maintenance person(s) carry out maintenance operation on behalf of the owner of the installation.

2.1.36 *Competent Maintenance Person* — Designated person, suitably trained, qualified by knowledge and practical experience, provided with necessary instructions, and supported within their maintenance organization to enable the required maintenance operations to be safely carried out.

2.1.37 *Manufacturer* — Entity who takes responsibility for the design, manufacture and placing on the market the machinery of escalators or moving walks.

2.1.38 *Installer* — Entity who takes responsibility for the design, manufacture, installation and placing on the market of escalator/moving walk.

2.1.39 *Installation* — Completely installed escalator or moving walk.

2.1.40 *Owner of the Installation* — Person who has the power of disposal of the installation and/or takes the responsibility for its operation and use.

2.2 Terms Related to Performance Requirements of Escalators and Moving Walks

2.2.1 *Acceleration* — Rate of change of velocity. It is expressed in m/s^2.

2.2.2 *Ride Quality* — Sound levels and vibration of the steps/pallet, relevant to passenger perception, associated with escalator or moving walk operation.

2.2.3 *Sound Pressure Level* (L_p) — Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure to the square of the reference sound pressure.

NOTE — The reference sound pressure level is 20 µPa (2×10^{-5} Pa).

2.2.4 *Velocity* — Rate of change of displacement. Velocity is reported as speed and direction of travel. It is given in metre per second (m/s).

2.2.5 *Vibration* — Variation with time of the magnitude of acceleration. It is expressed in metre per second square (m/s^2).

3 GENERAL

3.1 Conformity with Act and Rules

3.1.1 The installation of escalators and moving walks has been governed in states by different Acts and Rules, as applicable, which are intended to ensure safe installation and operation of the same.

3.1.2 The installation shall be generally carried out in conformity with relevant Act and Rules wherever they are in force.

3.1.3 It is the responsibility of the owner of the premises where the escalators and moving walks will be installed, to obtain necessary permission from the Authority before and after the erection of escalators and moving walks and for their subsequent operation.

3.1.4 A license for public use is a safety provision issued by state authorities under applicable Act and Rules, wherever they are in force.

3.2 Conformity with *Indian Electricity Act* and Rules

All electrical work in connection with installation of escalators and moving walk shall be carried out in accordance with the provisions of *Electricity Act,* 2003 Central Electrical Authority (Measures relating to Safety and Electric Supply) Regulations, 2023 and accepted standards [D-5B(1)] as amended up to date along with the rules and regulations framed thereunder and shall also comply with the other provisions of Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS.

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3.3 Conformity with Indian Standards

All materials, fittings, appliances, etc, used in electrical installation shall conform to Indian Standard specifications, wherever these exist. In case of materials for which Indian Standard specifications do not exist, the materials shall be approved by the competent authority. The installation shall be according to best practices as in the accepted standards [D-5B(1)].

3.4 Conformity with Fire Regulations

The installation shall be carried out in conformity with the state fire acts/local fire regulations, wherever they are in force *See also* Part F 'Fire and Life Safety' of this NBCS for guidance purpose.

3.5 Safety Design Considerations and Selection of Escalator and Moving Walks

The design consideration for type and selection of escalator and moving walk shall be based on following criteria:

a) *Location* — To ensure reliability, it is important to have design specifications to suit environmental conditions;

b) *Physical Requirements* — Physical factors like the vertical and horizontal distance to be spanned shall be considered. The ability of the building infrastructure to support the heavy components is also a critical physical concern;

c) *Type of Segment and Traffic Patterns* — The design consideration depends on segment type. Some typical segments are transit systems like metro, airport, shopping malls, hotels, etc. Traffic patterns shall also be anticipated in escalator and moving walk design. The carrying capacity of an escalator system shall match the expected peak traffic demand;

d) *Safety Considerations* — Escalators and moving walks shall not be subjected to abuse, misuse, and negligence. There are a few potential hazards, both from escalators and moving walks themselves and those hazards that users may bring with them, which include loose clothing, type of footwear (especially soft footwear), carried goods and trolleys. The severity of these hazards may increase when used by vulnerable groups of people, such as the old, very young and those with impaired mobility. Proper design risk assessment and control are all critical to ensure reliability and, above all safety; and

e) *Aesthetic Preferences* — To be suitably decided between the parties concerned.

3.6 Maintenance

The considerations relating to maintenance shall be as follows:

a) The escalator or moving walk installation should receive regular cleaning, lubrication, adjustment, and adequate servicing by authorized competent persons at such intervals as the type of equipment and frequency of service demand. It is desirable and normal for the escalator or moving walk supplier to be entrusted with the servicing during the guarantee period of new equipment;

b) In order that the escalator or moving walk installation is always maintained in a safe condition, a proper maintenance schedule shall be drawn up in consultation with the manufacturer and rigidly followed. Provision of a logbook to record all items relating to general servicing and inspection is recommended. Any accident arising out of operation or maintenance shall be duly reported to the Authority in accordance with the rules laid down;

c) Escalators and moving walks are required by statutory regulations to be examined at regular intervals as specified by Acts and Rules, by a competent person. The company entrusted with maintenance contract shall have valid license to maintain the escalators and moving walks. The persons assigned for maintenance work shall be appropriately qualified and experienced as required by statutory Acts and Rules;

d) Companies and organizations responsible for the safe use of escalator and moving walks should ensure that their employees are adequately instructed and informed about the safe use of the escalator or moving walk and the hazards arising from their unsafe use and are familiar with emergency procedures; and

e) Proper barricading shall be done to ensure that the open pits of escalator shall be reached/accessed by only the maintenance team. The maintenance service provider shall be responsible for placing of the

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barricades and signages before start of the maintenance work.

3.7 Energy Efficiency and Sustainability

The following technologies shall be encouraged for reducing power consumption by using energy efficient equipment and behavioural changes:

a) As an option, escalators/moving walk should not run when there are no passengers to move. In this stop mode, only the control system and the passenger detection system are kept running. Another option is to reduce the speed to match the passenger demand, thus reducing energy consumption using variable voltage variable frequency (VVVF) drives, which provide very smooth, almost imperceptible speed transitions;

b) Energy saving LED lamps for lighting in place of conventional lamps;

c) Improvement in total power factor of the motor drive of an escalator or moving walk at the isolator connecting equipment to the building's electrical supply circuit; and

d) Adoption of materials and practices that are environmentally friendly and sustainable shall be promoted.

4 DESIGN GUIDELINES FOR ESCALATORS AND MOVING WALKS

4.1 Escalators are desirable where the movement of people, in large numbers at a controlled rate in the minimum of space, is involved, for example, railway stations, shopping centres/malls, airports, etc. These encourage people to circulate freely and conveniently. Inclined moving walks are preferable where trolley movement is expected between levels, like department stores, airport, etc.

Typically, horizontal moving walks are used where medium to long distance travel is involved such as airports/metro stations/exhibition halls.

4.2 As the escalators and moving walks operate at a constant speed, serve only two levels, and have a known maximum capacity, the traffic study is rather easy, provided the population to be handled in a given time is known. It is easy to predict the rate at which the population can be handled.

Depending on the location of project and the expected tenancy, architect/owner shall provide the expected footfall in weekdays/weekends/special occasions (holidays, sale, etc) to the designer to consider the peak footfall while providing escalators.

Figure 1 shows the brief idea about the steps to be followed for arriving at appropriate escalator and moving walk solution for an application.

Based on Fig. 1, type, and location of building, expected population, and the serving floor details are required to work on the preliminary traffic analysis for escalators and moving walks.

For selection, installation and location of escalators and moving walks, the design of escalators and moving walks fall into four distinct duty categories, as shown in Table 1.

When deciding the duty category, following points shall be considered:

a) The duration and magnitude of peak demands that the equipment might be subjected to; and

b) The number of passengers using the escalators or moving walks per day.

NOTE — Select an escalator or moving walk appropriate for intended duty. If in doubt specify a more robust escalator or moving walk, as applicable.

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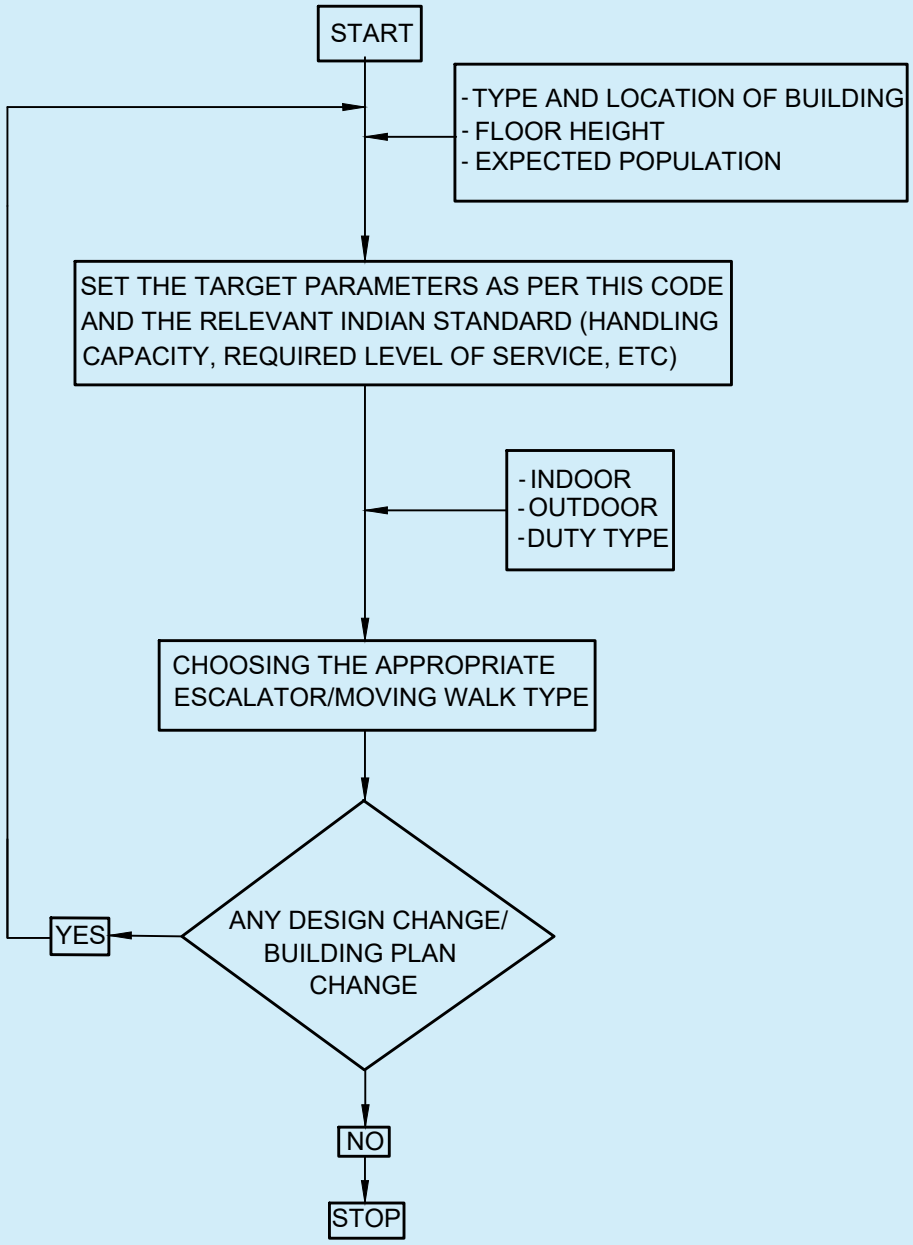

FIG. 1 TYPICAL FLOWCHART ON PRELIMINARY DESIGN

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Table 1 Escalator Duty Categories

(*Clause* 4.2)

Sl No.	Duty Category	Typical Usage (Passengers/Day)	Typical Locations
(1)	(2)	(3)	(4)
i)	Light	Up to 3 000	Shops, museums, libraries, leisure facilities and multiplexes
ii)	Medium	Up to 10 000	Department stores, shopping centres, domestic airports and railway stations
iii)	Heavy	Up to 20 000	Major railway and metro stations, major international airports and critical locations such as underground railway systems
iv)	Intensive	Over 20 000	Same as heavy category, but at a higher usage

4.3 The most common rated speed of escalators is 0.5 m/s although speeds of 0.65 m/s and 0.75 m/s are available. Most escalators run at one speed only, although some escalators running in energy saving mode can switch to the higher speed on traffic detection.

Step widths of 600 mm, 800 mm and 1 000 mm for escalators are available, the latter allowing two columns of passengers to be carried.

Angle of inclination of an escalator from the horizontal shall not exceed 30°, but for rises not exceeding 6 m and rated speed not exceeding 0.5 m/s the angle of inclination is permitted to be increased up to 35°.

The rated speed of the escalator shall not exceed:

a) 0.5 m/s for an escalator with an angle of inclination of more than 30° but within 35°; and

b) 0.75 m/s for an angle of inclination up to 30°.

For normal peak periods, the recommended handling capacities for design purposes should be taken as 3 200 to 6 400 persons per hour depending upon the width of the escalator.

The number of persons that may be theoretically carried by the escalator in 1 h can be calculated as follows:

1) The density factor (k) considers the step occupancy levels according to step width. For determination of theoretical capacity, it is assumed that one step with an average depth of 0.4 m can carry 1 person for a step width of 0.6 m, 1.5 persons for a step width of 0.8 m and 2 persons for a step width of 1.0 m;

2) The theoretical capacity then is: $3\,600 \times (\text{rated speed in m/s} \times k)/0.4$

where

k = 1, 1.5, or 2 for 0.6, 0.8 and 1.0 m step widths respectively.

c) Some values calculated as per the above are given in Table 2:

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Table 2 Theoretical Escalator Handling Capacity

(*Clause* 4.3)

Sl No.	Step/Pallet Width m	Nominal Speed m/s		
		0.5	0.65	0.75
		Persons/hour	Persons/hour	Persons/hour
(1)	(2)	(3)	(4)	(5)
i)	0.6	4 500	5 850	6 750
ii)	0.8	6 750	8 775	10 125
iii)	1.0	9 000	11 700	13 500

4.4 The handling capacity (C_e) of a standard escalator with a step depth of 400 mm is: $C_e = 150\ V\ k$

where

V = speed along the incline in m/s; and

k = average density of people (persons per escalator step).

The density factor (k) considers the step occupancy levels. From experience, practical values of k that have been found satisfactory are:

a) For 600 mm steps:

k = 0.5 (one person per two steps of 600 mm);

b) For 800 mm steps:

k = 0.75 (one and half persons per two steps of 800 mm); and

c) For 1000 mm steps:

k = 1.0 (one person per step of 1 000 mm).

Table 3 gives guidance to practical escalator handling capacities based on the densities assumed above in person per hour and horizontal speeds in meters per second.

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Table 3 Practical Escalator Handling Capacity

(*Clause* 4.4)

Sl No.	Step/Pallet Width m	Nominal Speed m/s		
		0.5 Persons/hour	0.65 Persons/hour	0.75 Persons/hour
(1)	(2)	(3)	(4)	(5)
i)	0.6	2 250 [3 600*]	2 925 [4 400*]	3 375 [4 900*]
ii)	0.8	3 375 [4 800*]	4 388 [5 900*]	5 063 [6 600*]
iii)	1.0	4 500 [6 000*]	5 850 [7 500*]	6 750 [8 200*]

*IS 4591 values are shown in parentheses, which assumes passenger densities averaging k = 0.75, 1.00, 1.25 respectively and suggests maximum values.

4.5 Moving walks can be horizontal or inclined. Horizontal moving walks are typically used for medium/long range travel in airports, exhibition centres and railway stations. Inclined moving walks are typically used for short range travel in shopping centres, stores and railway stations.

Inclinations range from 6° to 12°, although the safest maximum inclination is generally considered to be 10°. The typical running speeds for horizontal moving walks are 0.5 m/s, 0.65 m/s and 0.75 m/s. For moving walks with an inclination greater than 6°, the nominal speed shall be limited to 0.5 m/s. The speed is measured in the direction of movement of the pallets.

Nominal widths for moving walks up to an inclination of 6° are 800 mm, 1 000 mm and 1 400 mm and above 6° are 800 mm and 1 000 mm. A width of 1 400 mm allows two columns of passengers and the possibility for some passengers to walk along the moving walk.

The use of suitably designed shopping trolleys and baggage carts on moving walks is permitted. Shopping trolleys or baggage carts which are chosen for use on a moving walk shall be specified between the baggage cart manufacturer and the moving walk manufacturer. If non-specified shopping trolleys or baggage carts are available in the moving walk area, there is a serious risk of misuse. It is necessary to prevent access to the moving walk entrance. The width of the shopping trolley or baggage cart and its contents shall be at least 400 mm less than the nominal pallet/belt width. Passengers shall be able to leave the moving walk, even if shopping trolleys or baggage carts are on the moving walk.

Table 4 provides the theoretical values of handling capacity in person per hour of a moving walk.

4.6 Table 5 gives guidance to practical moving walk handling capacities in person per hour assuming a density of 2.0 persons/m^2.

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Table 4 Theoretical Moving Walk Handling Capacity

(*Clause* 4.5)

Sl No.	Pallet Width m	Horizontal Moving Walk (0° Inclination)			Inclined Moving Walk For (Nominal Speed 0.5 m/s		
		Nominal Speed (m/s)			Inclination		
		0.5	0.65	0.75	6°	10°	12°
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	0.8	3 000	3 700	4 400	3 000	3 700	3 000
ii)	1.0	3 800	4 600	5 400	3 700	3 700	—
iii)	1.4	5 100	6 400	7 700	5 100	—	—

Table 5 Practical Moving Walk (Horizontal and Inclined) Handling Capacity

(*Clause* 4.6)

Sl No.	Step/Pallet Width m	Nominal Speed m/s		
		0.5 Persons/hour	0.65 Persons/hour	0.75 Persons/hour
(1)	(2)	(3)	(4)	(5)
i)	0.8	2 880 [4 800*]	3 648 [5 900*]	4 320 [6 600*]
ii)	1.0	3 600 [6 000*]	4 560 [7 300*]	5 400 [8 200*]
iii)	1.4	5 000 [--------*]	6 350 [-------*]	7 560 [-------*]

*IS 4591 values are shown in parentheses.

NOTES

1 Use of shopping trolleys and baggage carts will reduce the capacity by approx. 80 percent.

2 For moving walks with a pallet width in excess of 1.0 m the capacity is not increased as users need to hold the handrail, the additional width is to principally enable the use of shopping trolleys and baggage carts.

5 ARRANGEMENT AND PLANNING DIMENSIONS

5.1 Escalators are typically used for short range of movement between adjacent floors. They are usually situated in an obvious circulation path making it easy for pedestrians to board them. Escalators and moving walks should only be accessed from adjacent corridors/walkways, landing and lobby areas, where people do not obstruct other pedestrian circulation routes. Space should be available to accommodate queuing at the boarding point.

It is especially important that the boarding and alighting areas adjacent to an escalator or moving walk are not part of another circulation route, to provide a safe area for passengers to board and alight at landings. The area of this space is defined as a distance between the handrails plus 160 mm, multiplied by a depth of 2.0 m to 2.5 m, depending on the configuration of escalator or moving walk.

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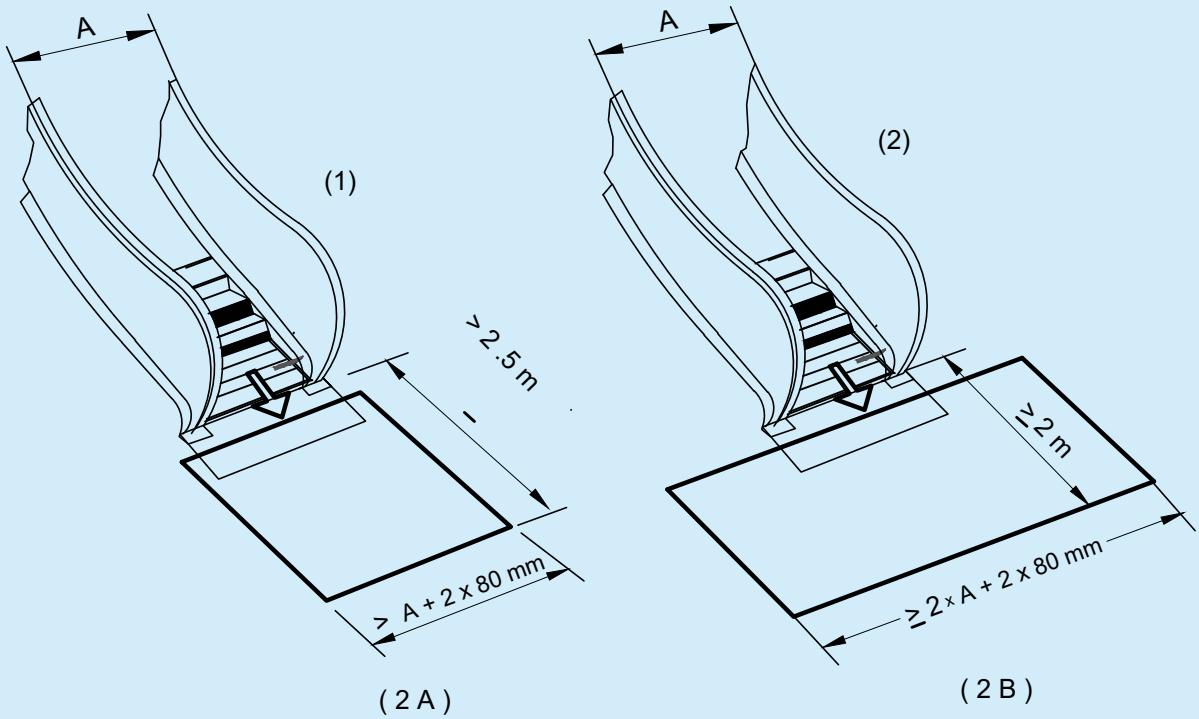
Figure 2 illustrates the above clause with option 1 being a 2.5 m landing depth and option 2 being 2.0 m landing depth. Where successive units are installed, each successive escalator or moving walk should have its own individual unrestricted area. For succeeding escalators and moving walks the depth of an unrestricted area shall be determined in each individual case depending on, for example, type of use (persons only or persons with transport devices, number of intermediate exits, relative orientation, and theoretical capacity).



Key

A = Distance between outer edge of handrail

Option 1 >> unrestricted area >= 2.5 m from end of balustrade and width >= A+(2*80) mm

Option 2 >> unrestricted area >= 2.0 m from end of balustrade and width >= (2*A) +(2*80) mm

FIG. 2 UNRESTRICTED FREE SPACE

Where the exit of the escalator or moving walk is blocked by structural measures (for example shutters, fire protection gates, removable barriers), an additional STOP button for emergency situations shall be provided:

a) within reach from inside the escalator/moving walk at 2.00 m to 3.00 m before the steps/pallets reach the comb intersection line; and

b) Between 200 mm below and 400 mm above the handrail, measured from the top of the handrail to the middle of the actuator of STOP button.

NOTE — STOP button shall be with protection to prevent nuisance activation for example shroud guard. STOP switch with cover is not permitted.

Figure 3 illustrates the position of additional STOP button.

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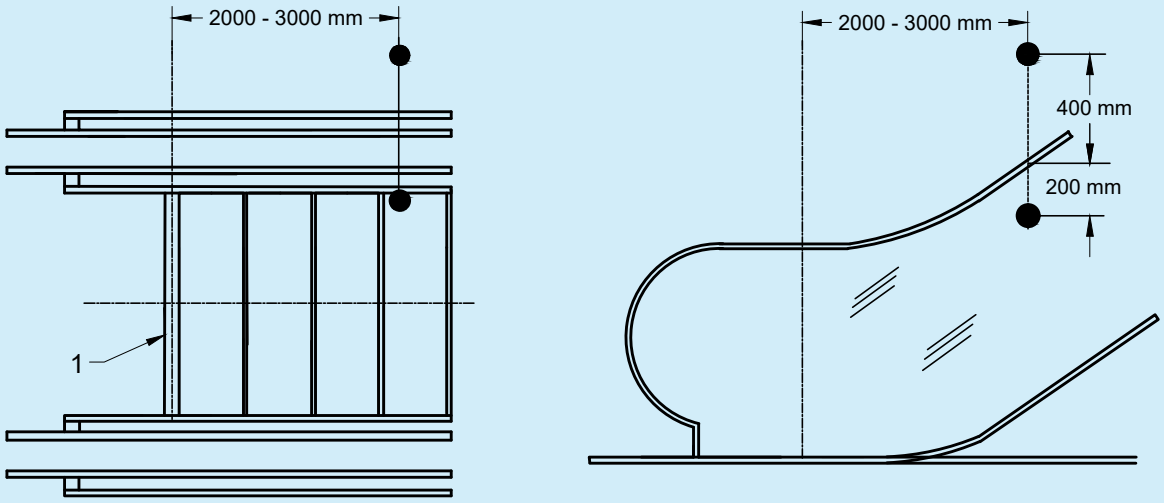

FIG. 3 LOCATION AND DISTANCE OF ADDITIONAL STOP BUTTON

The position of the shutters, fire protection gates, removable barriers, etc shall be protected with a contact in the safety circuit. As soon as the doors close, the escalator or moving walk should stop.

Escalators occupy more space than stairs to accommodate their inclination. There are few standard escalator arrangements as shown in Fig. 4. Type (a) and type (b) provide efficient circulation by providing the shortest transition path and time from one escalator and the next. Type (b) requires larger structural opening than type (a) and type (c) and present users with a higher risk of falling into the void. Type (c) is typical of a store as it allows the store to lengthen the circulation route past goods for sale. This configuration also takes up free space.

Some moving walks are adopted to receive and lock on shopping/baggage trolleys. In these cases, the unrestricted area at the landing should be increased to at least 5 m and number of flat/horizontal steps at the boarding and alighting points increased. The most significant effect is the increased footprint required for the equipment. Shopping/baggage trolleys are not permitted on escalator.

To encourage pedestrian confidence and to assist efficient and safe boarding/ alighting of escalators, the start and end of escalator should present a few horizontal/flat steps. At least two flat steps are provided for escalators speeds up to 0.5 m/s; at least three flat steps for speeds above 0.5 m/s and up to 0.65 m/s for escalator having rise more than 6 m; and at least four flat steps for speeds above 0.65 m/s. In locations where it is anticipated that escalators may be used by persons with impaired mobility or heavy passenger traffic, additional flat steps should be considered.

5.2 Ensuring Accessibility for All Users

5.2.1 The accessibility requirements shall be complied with.

5.2.2 The location of escalators and moving walks should be considered in relation to the position of adjacent fire protected lift shafts and lobbies, staircases, and their associated areas of rescue assistance, as at the time of an emergency these become non-functional. A surface of the escalator and moving walks should contrast visually with the approach and there should be audible signals or pre-recorded messages that indicate the start and finish of the escalator to help visually impaired people.

For important reasons of safety, special warning notices and tactile warning indicators shall be provided at the top and bottom of escalators. Escalators shall not be considered as the accessible route. Persons with locomotor disability cannot use them. Hence a lift should also be installed as an alternative accessible route.

For moving walks, the maximum inclination should be up to 6° for use by people with disabilities. People with disability may find it difficult to use moving walks. Hence, alternative like an accessible battery cart, may be provided to them in appropriate cases. Moving walks shall be free of projecting objects and obstacles up to a height of 2 100 mm. A minimum level of illumination of 100 lux shall be provided on moving walks.

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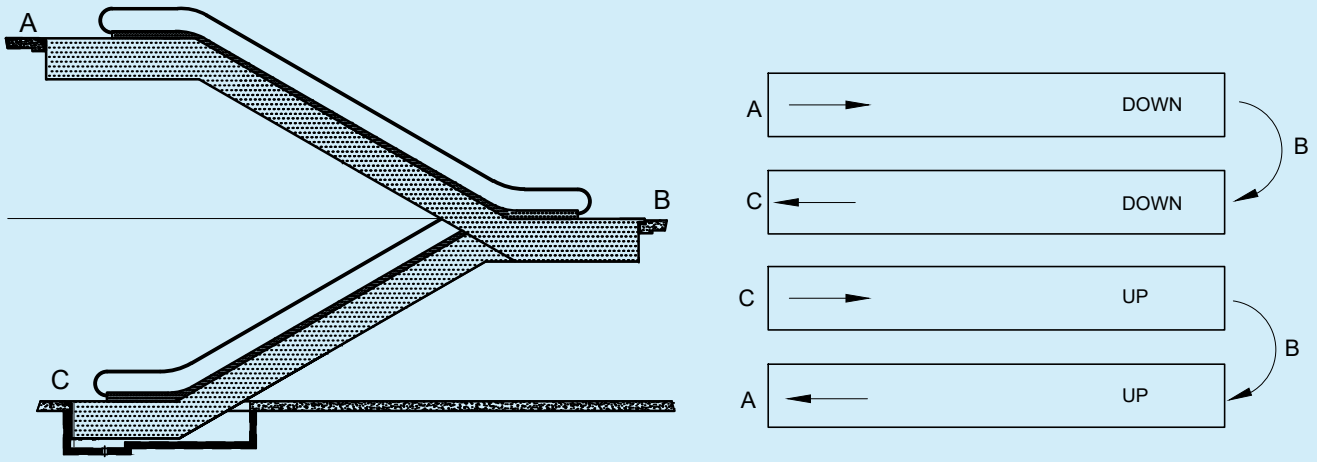
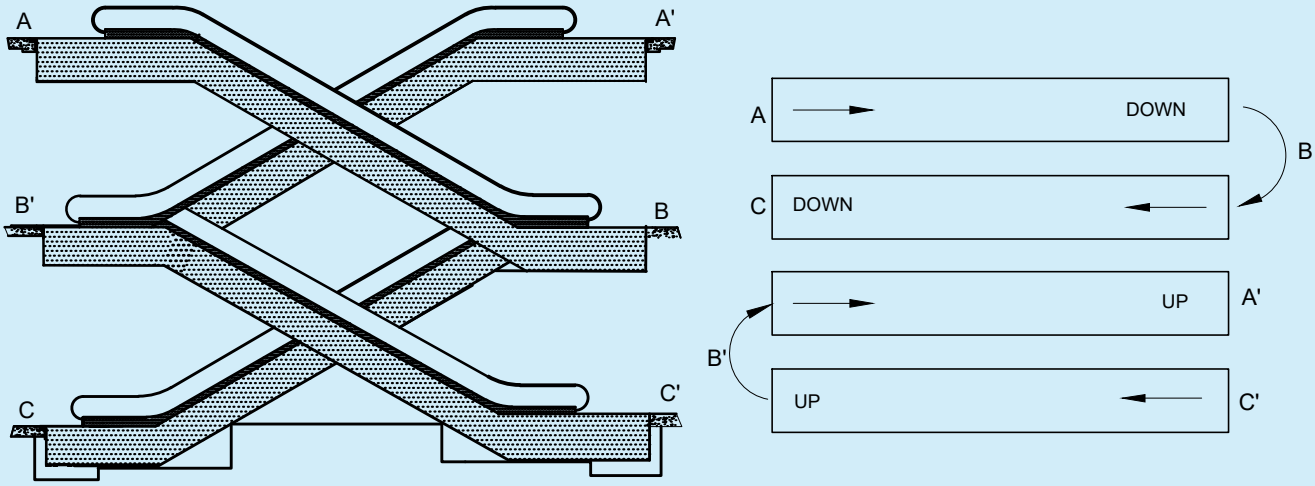
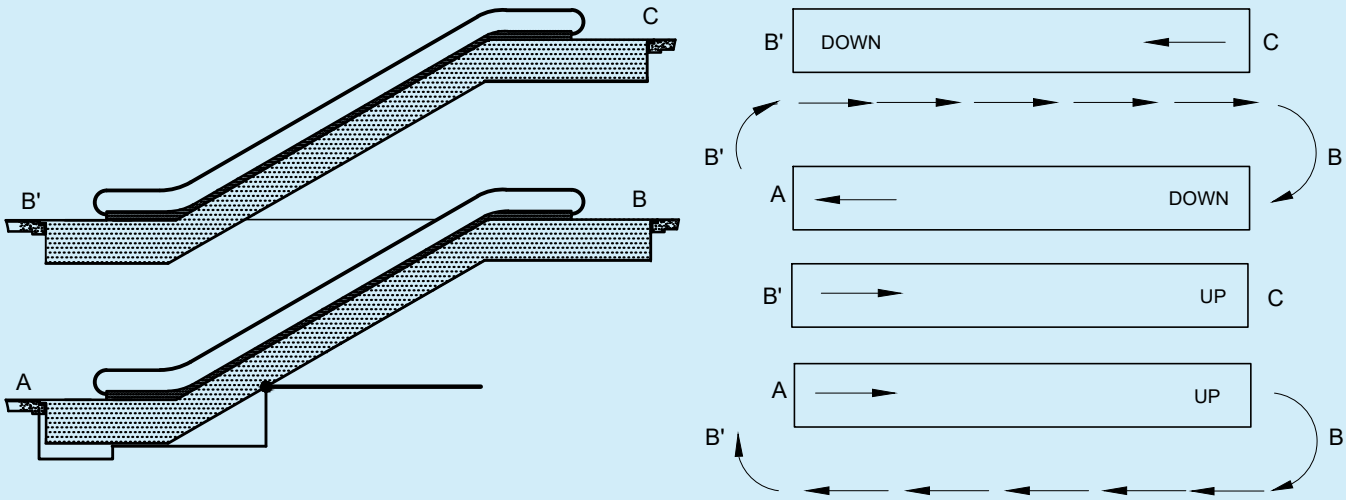


4 A PARALLEL



4 B CRISS CROSS



4 C WALK AROUND

FIG. 4 ESCALATOR CONFIGURATION

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6 SPACE REQUIREMENT

6.1 Free Space for Users

6.1.1 The clear height above the steps of the escalator or pallets or belt of the moving walk at all points shall not be less than 2.30 m (*see* X4 in Fig. 5 and Fig. 7). The clear height shall extend to the end of the newel.

NOTE — The clear height of 2.30 m should also be applied to the unrestricted area.

6.1.2 To prevent collision, a minimum free area around the escalator or moving walk is defined as per Fig. 5. The height X12, measured from the steps of the escalator or the pallets or the belt of the moving walk shall be at least 2.10 m (*see* X12 in Fig. 5). The distance between the outer edge of the handrail and walls or other obstacles (*see* Y10 in Fig. 5) shall under no circumstances be less than 80 mm horizontally and 25 mm vertically below the lower edge of the handrail (*see* Y12 in Fig. 8). The area is permitted to be smaller, if by appropriate measures, the risk of injury is minimized.

6.1.3 For escalators arranged adjacent to one another either parallel or criss-cross, the distance between the handrails shall be not less than 160 mm (*see* Y11 in Fig. 5).

6.1.4 Where building obstacles may cause injuries, appropriate preventive measures shall be taken.

At floor intersections and on criss-cross escalators or moving walks, a vertical deflector of not less than 0.30 m in height, not presenting any sharp cutting edges, shall be placed above the handrail level and extend at least 25 mm below the lower edge of the handrail, for example, as an imperforate triangle (*see* X5 in Fig. 7 and Fig. 9).

It is not necessary to comply with these requirements when the distance Y9 between the outer edge of the handrail and any obstacle is equal to or greater than 400 mm (*see* Fig. 5).

6.1.5 In the case of successive escalators and moving walks with intermediate landing without exits, they shall be electrically interlocked to run in same direction and shall have the same transportation capacity. They shall also be electrical interlocked to stop the escalator carrying passengers into the intermediate landing without exits if the escalator carrying passengers away from the landing stops.

6.1.6 Where it is possible for people to come into contact with the outer edge of a handrail at a landing and may be drawn into a hazardous situation, such as toppling over a balustrade, appropriate preventive measures shall be taken (for example, *see* Fig. 6).

Some examples are:

a) Prevention of entry into the space by the placement of permanent barriers.

b) Increasing the height of the building structure of the fixed balustrade in the hazard area by at least 100 mm above the handrail level and positioned between 80 mm and 120 mm from the outer edge of the handrail.

The placement of permanent barriers shall be towards the newel end in the area where the handrail becomes flat after the curved portion of the newel. The permanent barriers shall be designed to prevent injury to travelling passengers.

6.1.7 The surrounding space of the escalator or moving walk shall be illuminated, especially in the vicinity of the combs.

NOTE — Information should be exchanged between the manufacturer and the customer.

6.1.8 It is permissible to arrange the lighting in the surrounding space and/or at the installation itself. The intensity of illumination at the landings including the combs shall be related to the intensity of illumination of the general lighting in the area. The intensity of illumination shall be not less than 50 lux at the comb intersection line measured at floor level.

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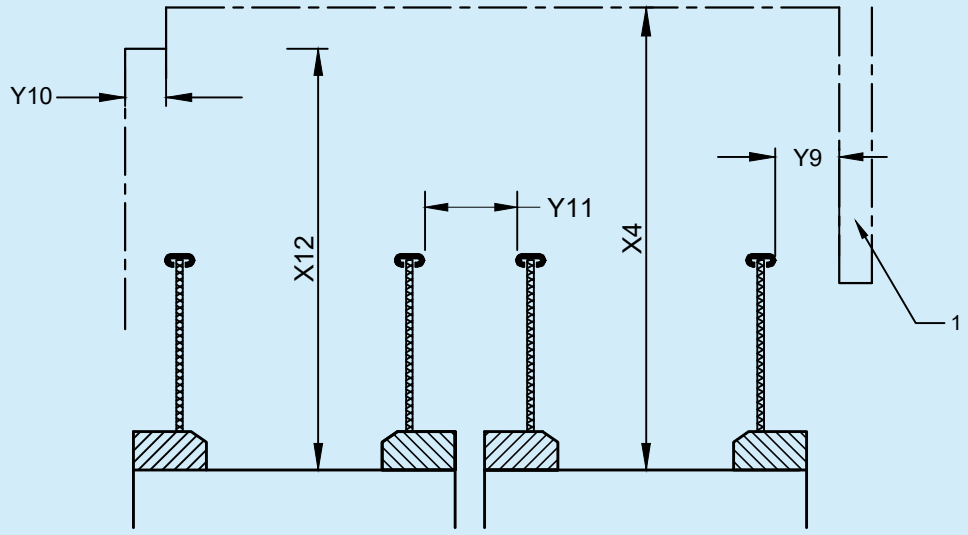
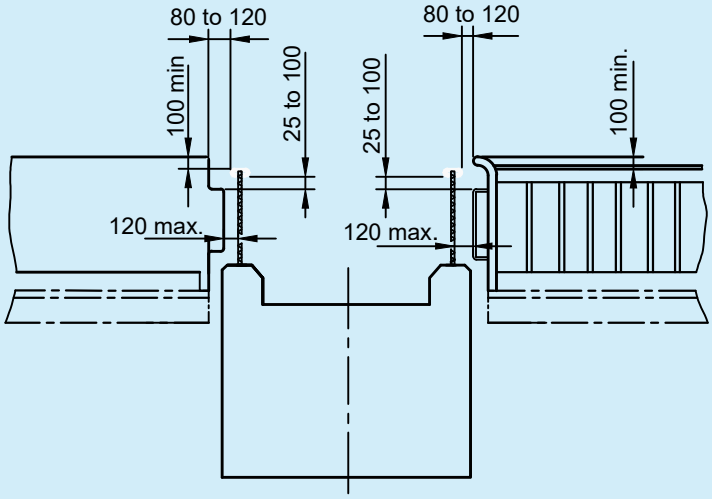


FIG. 5 CLEARANCES BETWEEN BUILDING STRUCTURE AND ESCALATOR / MOVING WALK



All dimensions in millimetres

FIG. 6 EXAMPLE OF BARRIERS AT LANDINGS

Key

1 Obstacle (for example, Column)

Sl No.	*Principal Dimensions*	*Ref to Clause*	*Principal Dimensions*	*Ref to Clause*
	Clause		*Clause*	
(1)	(2)	(3)	(4)	(5)
i)	Y9 ≥ 400 mm [Sl No. (xxii) of Annex A]	6.1.4	X4 ≥ 2 300 mm [Sl No. (xix) of Annex A]	6.1.1
ii)	Y10 ≥ 80 mm [Sl No. (xx) of Annex A]	6.1.2	X12 ≥ 2 100 mm [Sl No. (xxii) of Annex A]	6.1.2
iii)	Y11 ≥ 160 mm [Sl No. (xxi) of Annex A]	6.1.3	–	–

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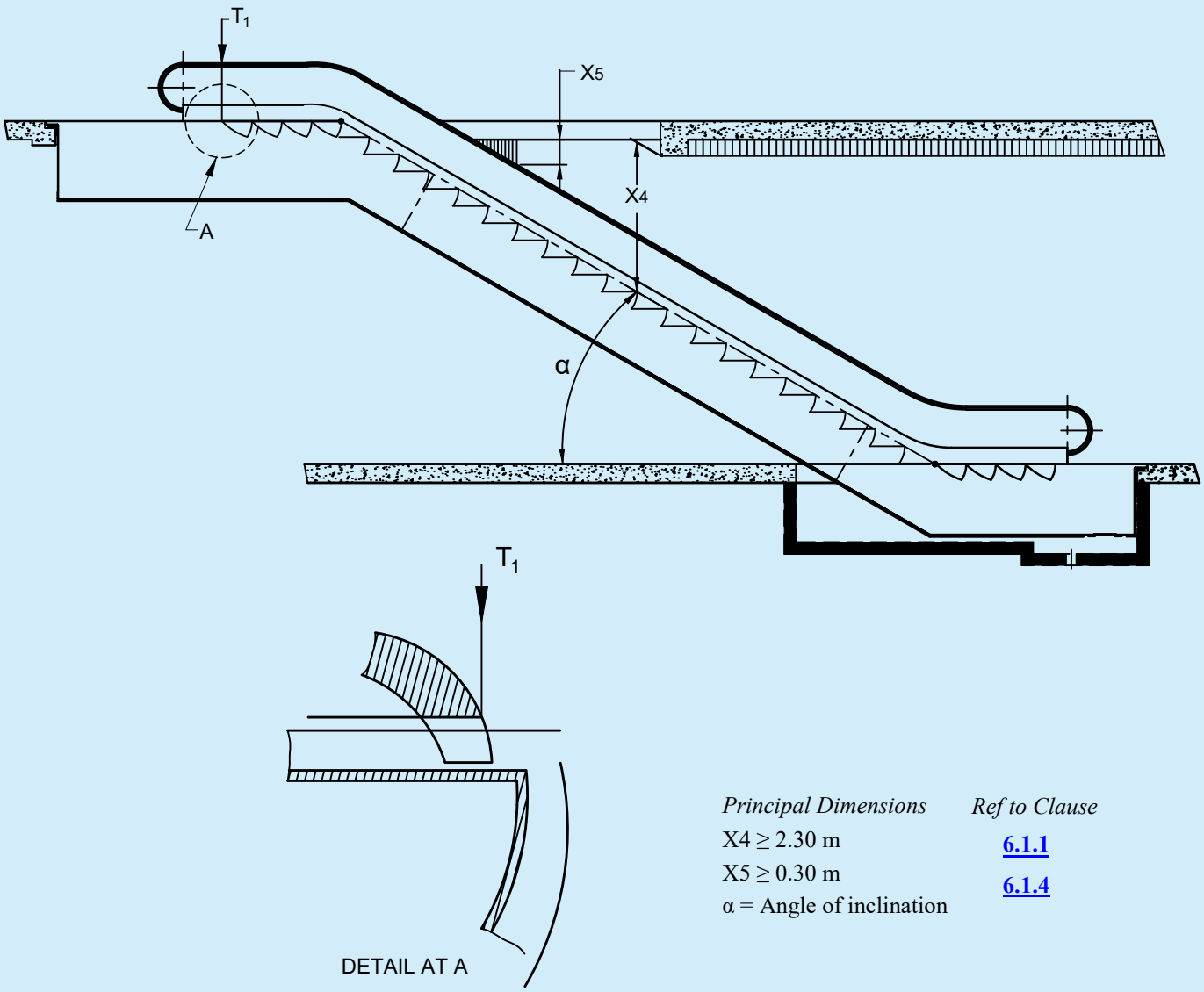
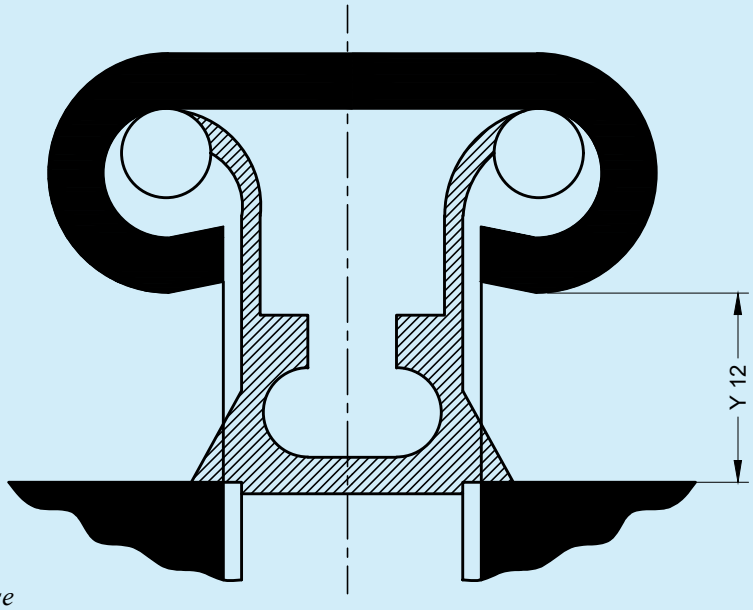


Principal Dimensions	*Ref to Clause*
X4 ≥ 2.30 m	6.1.1
X5 ≥ 0.30 m	6.1.4
α = Angle of inclination	

FIG.7 ESCALATOR (ELEVATION), PRINCIPAL DIMENSIONS



Principal Dimensions	*Ref to Clause*
Y12 ≥ 25 mm	6.1.2

FIG.8 HANDRAIL (SECTIONAL VIEW)

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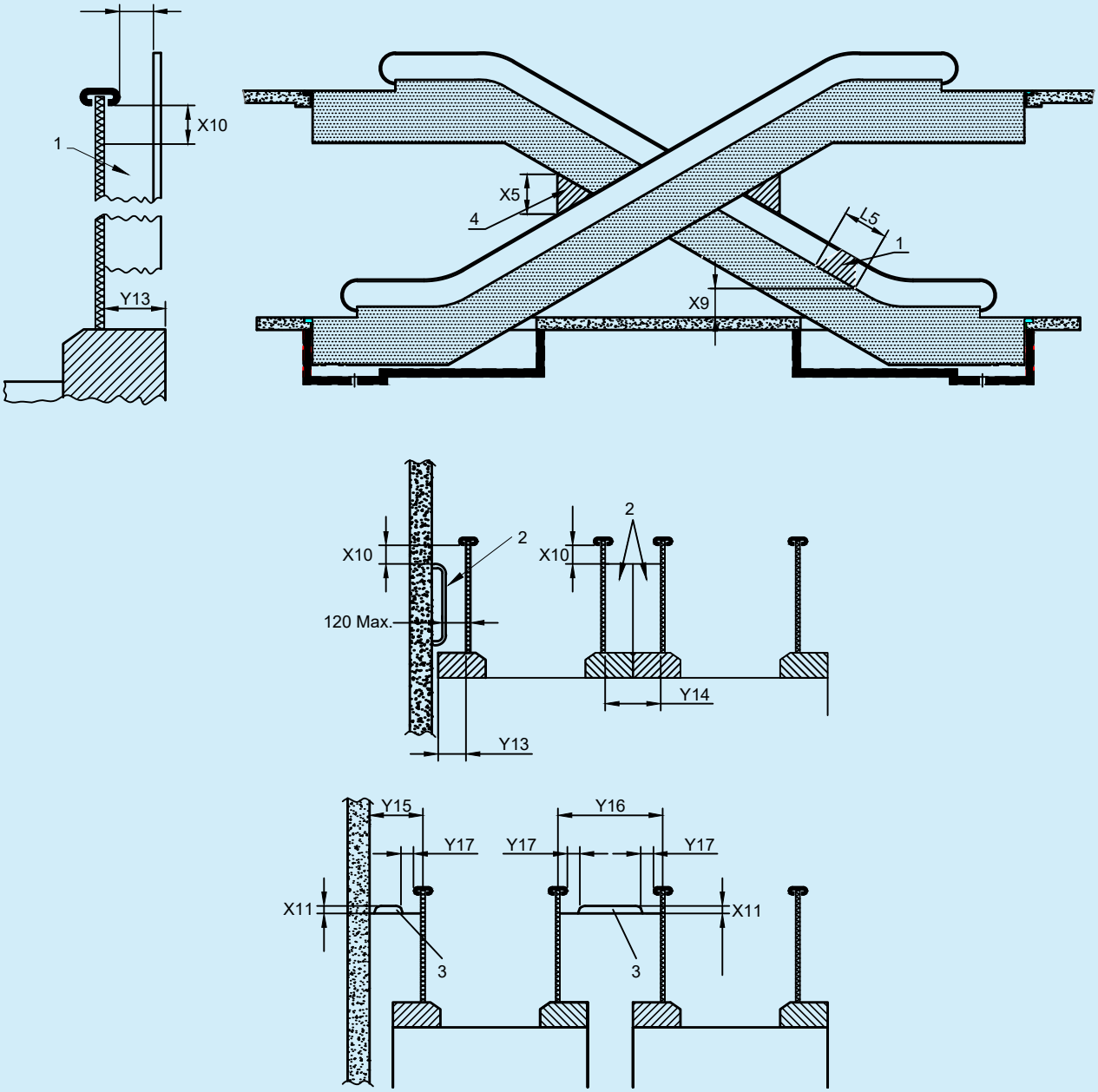

Key

1) Anti-climbing device (*see* 6.3)
2) Access restriction device (*see* 6.3)
3) Anti-slide device (*see* 6.3)
4) Vertical deflector (*see* 6.1.4)

Principal Dimensions	*Ref to Clause*
Y13, Y14, Y15, Y16	6.3
Y17 ≥ 100 mm	6.3
X5 ≥ 0.30 m	6.1.4
X9 = (1 000 ± 50) mm	6.3
X10 = 25 mm to150 mm	6.3
X11 ≥ 20 mm	6.3
L5 ≥ 1 000 mm	6.3

FIG. 9 ANTI-MISUSE DEVICES

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6.2 Machinery Spaces Outside the Truss

The following shall be ensured:

a) A safe access for persons to machinery spaces shall be provided;

b) Machinery spaces shall be lockable and only accessible to authorized persons;

c) Machinery spaces shall be provided with permanently installed electric lighting on the following basis;

   1) Minimum of 200 lux at floor level in working areas;

   2) Minimum of 50 lux at floor level in access routes leading to these working areas.

d) Emergency lighting shall be installed to allow the safe evacuation of all personnel working in any machinery space.
   NOTE — Emergency lighting is not intended for continuation of maintenance or other activities.

e) The dimensions of machinery spaces shall be sufficient to permit easy and safe working on equipment, especially the electrical equipment. These shall be provided at least at a clear height of 2.00 m at working areas, and a clear horizontal area in front of the control panels and the cabinets. This area is defined as follows:

1)	Depth, measured from the external surface of the enclosures	At least 0.70 m;
2)	Width, the greater of the following values	0.50 m or the full width of the cabinet or panel.

   A clear horizontal area of at least 0.50 m × 0.60 m for maintenance and inspection of moving parts at points where this is necessary.

f) The clear height for movement shall not be less than 1.80 m. The access ways to the clear spaces shall have a width of at least 0.50 m. This value may be reduced to 0.40 m where there are no moving parts. This full height for movement is taken to the underside of the structural roof beams and measured from both:

   1) the floor of the access area; and

   2) the floor of the working area.

g) In machinery spaces the clear height shall under no circumstances be less than 2.0 m;

h) 3 pin plug with socket for the maintenance propose; and

j) Machinery spaces shall not accommodate equipment not related to the escalator or moving walk.

6.3 Balustrade

Balustrades shall be installed on each side of the escalator or moving walk. The dimensions of the balustrade shall be as follows:

In the inclined section the vertical height X1 from step nose or pallet surface or belt surface to top of the handrail shall not be less than 0.90 m and not exceed 1.10 m (*see* Fig. 10).

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The balustrades shall have no parts on which a person will normally stand.

Appropriate measures shall be taken to discourage people from climbing on the outsides of the balustrade if there is a danger of people falling from them.

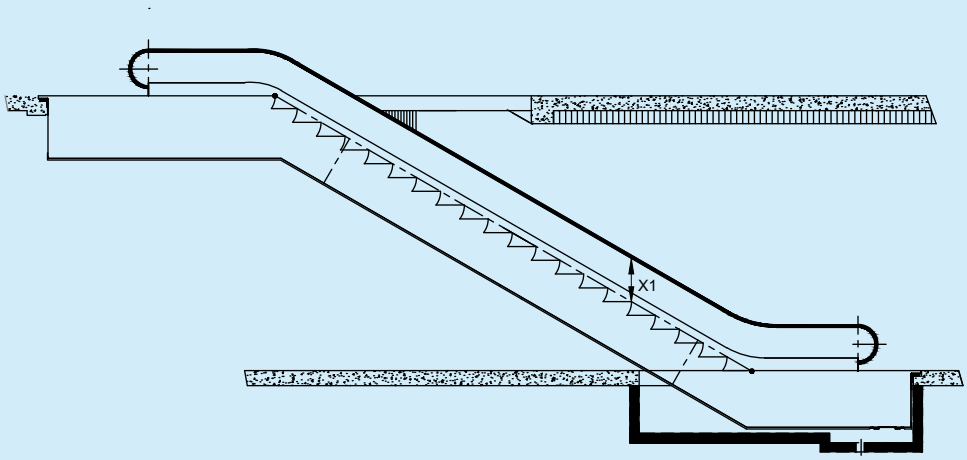
To ensure this, on escalators and moving walks, devices (*see* 1 in Fig. 9) shall be provided on the lower outer decking at a point 1 000 mm ± 50 mm above the floor level (*see* X9 in Fig. 9) where the bottom of the device intersects with the balustrade decking and shall extend to a length L5 of at least 1 000 mm parallel with the balustrade decking where no stepping is possible. The device shall extend to at least a height in line with the top of the handrail not conflicting with the requirements of Y10 and Y12 (*see* Fig. 5 and Fig. 8).

Where escalators or moving walks are located adjacent to walls, devices (*see* 2 in Fig. 9) to restrict access to the balustrade decking shall be provided at the top and bottom ends of these walls when the lower outer decking width Y13 exceeds 125 mm. On adjacent parallel arrangements, this protection shall be provided when the combined balustrade decking width Y14 exceeds 125 mm. The device shall extend to the height X10 (*see* Fig. 9).

All exposed fastener heads for the devices should be of the vandal resistant type.

Where handrail level balustrade decking are provided between escalators/inclined moving walks and adjacent walls, anti-slide devices (*see* 3 in Fig. 9) shall be provided on the balustrade decking when the distance Y15 between the structure of the building (wall) and the centreline of the handrail is greater than 300 mm. These devices shall consist of objects fastened to the balustrade decking, no closer than 100 mm to the handrail (*see* Y17) and spaced no greater than 1 800 mm apart. The height X11 shall be not less than 20 mm. The devices shall have no sharp corners or edges (*see* Fig. 9).

The above mentioned also applies to adjacent escalators/inclined moving walks when the distance Y16 between the centrelines of the handrails is greater than 400 mm.



Principal Dimensions 0.9 m ≤ X1 ≤ 1.10 m

FIG. 10 ESCALATOR (ELEVATION) , PRINCIPAL DIMENSIONS

Exposure of one or both sides of escalators over a void, and the changes made to the balustrade/handrail design on escalators, can increase risks to users. The placement and type of escalator may introduce hazards, particularly when exposed over a void, leading to risks of falling at two areas:

a) *Escalator and Moving Walk Landings* — There is a risk for people to come into contact with the outer edge of a handrail and be drawn into the void; and

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b) *Escalator and Moving Walk Balustrades* — There is a risk for people to trip or accidentally overbalance and topple into the void.

A risk assessment should be conducted to identify hazards, potential misuse, affected individuals, and necessary preventive measures. Some examples of misuse are - sitting, standing, sliding on the handrail, holding onto the handrail from outside the balustrade, being lifted onto the handrail, walking up, and sliding down the decking.

Balustrades should balance fall risk and passenger support. Balustrade with 1 100 mm height offer firm grip and better fall protection than 900 mm. To mitigate falling risks, following risk mitigation measures shall be considered:

1) Avoiding voids to remove the hazard;
2) Using 1 100 mm high balustrades if voids are present; and
3) For escalators exposed over a void, falling risks increase, and additional protection beyond the handrail and balustrade may be needed. Where escalators are not bounded totally by adjacent walls or partitions and are therefore exposed over a void on one or both sides, persons are at risk of falling a substantial height. The building architects/developers might need to make provision of additional protection beyond the handrail and balustrade. Glass enclosures, shields, or additional guard rails shall be installed as shown in Fig. 11 if high balustrades alone are insufficient.

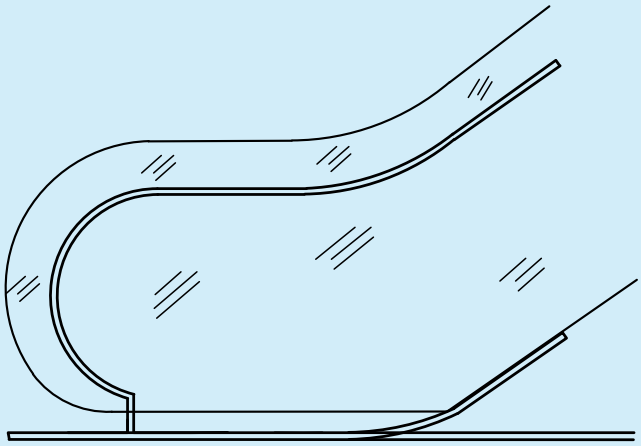

FIG. 11 TYPICAL ARRANGEMENT OF ESCALATOR LANDING WITH GLASS BALUSTRADE

NOTE — Based on the risk assessment carried out, fixing of external guarding, if required, shall be undertaken with professional consultation to ensure that the integrity of the escalator truss or balustrade is not compromised.

6.4 Installation

The following needs to be planned and carried out on site to ensure easy installation of escalators and moving walks.

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6.4.1 *Installation Timing*

To prevent damage to the escalator during the construction phase, the timing of installation and assembly should be as close as possible to the opening date. It should, however, proceed completion of the floor to dispense with the need to take further measures to protect floor coverings. Ensure that the provisional floors along the transport route in the building may comfortably cope with the load weight.

6.4.2 *Transport to the Assembly Site*

A suitable unloading area shall be available in front of the building. The access routes to the building shall be level and negotiable by heavy duty rollers. Along the entire transport route to the assembly site, the free height shall not be less than the minimum specified in the manufacturer plan (also goes for pipes and other attachments fitted by others to the ceiling structure).

6.4.3 *Access Openings, Transport Route and Load Capacity*

Normally, escalators are moved in through openings at the side of the building at ground level. Optionally, suitable roof openings should be provided, to bring the escalators by crane. It is important that the route to the assembly location within the building is free of obstacles and level, and the ceiling can support a load. Otherwise, the appropriate weight distribution shall be catered to.

6.4.4 *Special Delivery*

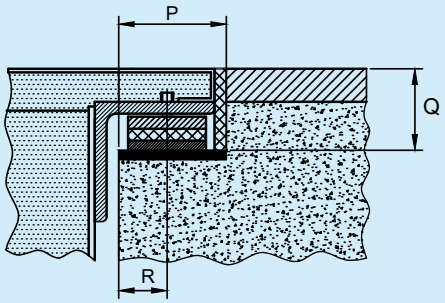
Some escalators are so long that they should be installed in sections. In this case, the escalator may have to be manufactured in split form and assembled on site.

6.4.5 *Ceiling Openings*

Manufacturer should notify the location and size of the required ceiling openings on the installation drawing. Builder shall supervise the precise implementation of these openings.

6.4.6 *Top and Bottom Supports*

While designing the support recess, the support loads shall be considered. They are shown on the installation drawing given by the manufacturer. At those locations where the supports of escalator (or moving walk) will be placed, the support shall be able to bear the weight of the escalator including traffic load. When preparing the supporting structures, the measurements indicated on manufacturer's installation plans shall be precisely adhered to (*see* Fig. 12).



NOTE - P, Q, R ARE BASED ON MANUFACTURER'S DRAWING

FIG. 12 TOP AND BOTTOM SUPPORTS

6.4.7 *Intermediate Supports*

Intermediate supports are needed on escalators with a considerable travel height (recommended above 5 000 mm) and on long moving walks. If the intermediate support is required, the manufacturer shall provide the location and load on intermediate support to the customer irrespective of the segment for which the escalator is provided, to include the additional space required in the construction plan (*see* Fig. 13).

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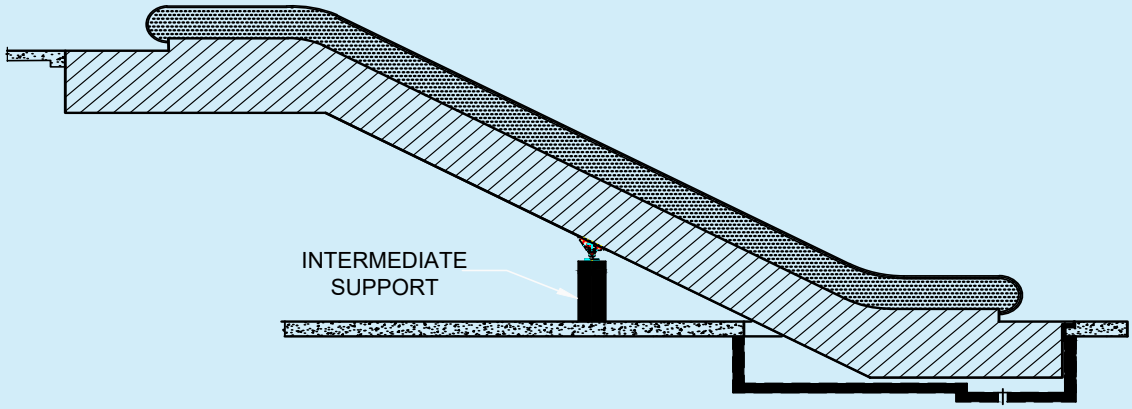

FIG. 13 INTERMEDIATE SUPPORTS

6.4.8 *Hoisting Arrangement*

It shall be ensured that pick-up points for hoisting and supporting the escalator shall be fitted securely during assembly. These should be located exactly above the centre of the supporting points. For systems with several supporting structures, plan for additional pick-up points above the intermediate supports. All pick-up points shall be capable of taking a load strain (*see* Fig. 14).

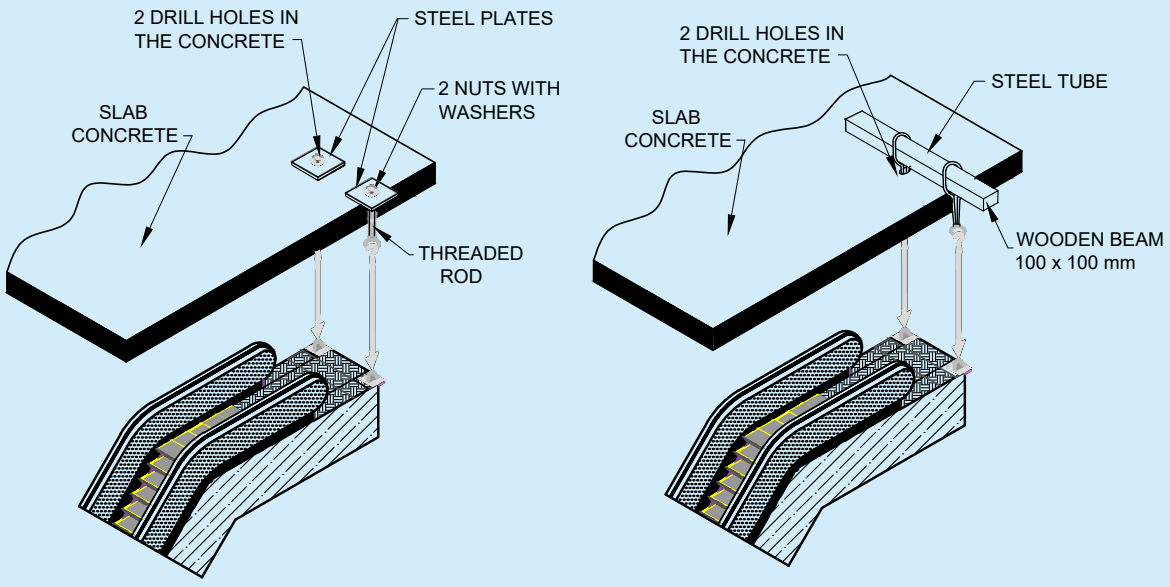

FIG. 14 PICK-UP POINTS

6.4.8.1 *Installation with a frame*

If no assembly holes can be provided, the escalators and moving walks should be lifted to their final location by means of special sturdy girder construction. In this case, ceiling load strain shall bear the capacity as per the manufacturer's instruction.

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6.4.8.2 *Installation with lifting gear*

Holes with a 100 mm diameter are to be made through the ceiling, according to manufacturer instructions. These are used by installation team for fixing the lifting gear. In this way escalator or moving walk is simply lifted upwards from floor to floor. The load strain of every pick-up point shall be maintained as per the manufacturer instruction.

6.4.8.3 *Installation with crane assembly*

Where a suitable roof opening is available, or the site is located outdoor, lift the escalator or moving walk by crane and place it on the supports provided. The builder is responsible for ensuring for all local authority approvals.

6.4.8.4 Permanent hoisting hooks shall be provided by the builder in the top slab for hoisting the escalator as per the load requirement.

6.4.9 *Sprinkler Piping*

An optional safety feature is the installation of a sprinkler piping within the escalator or moving walk (*see* Fig. 15 for typical sprinkler piping arrangement).

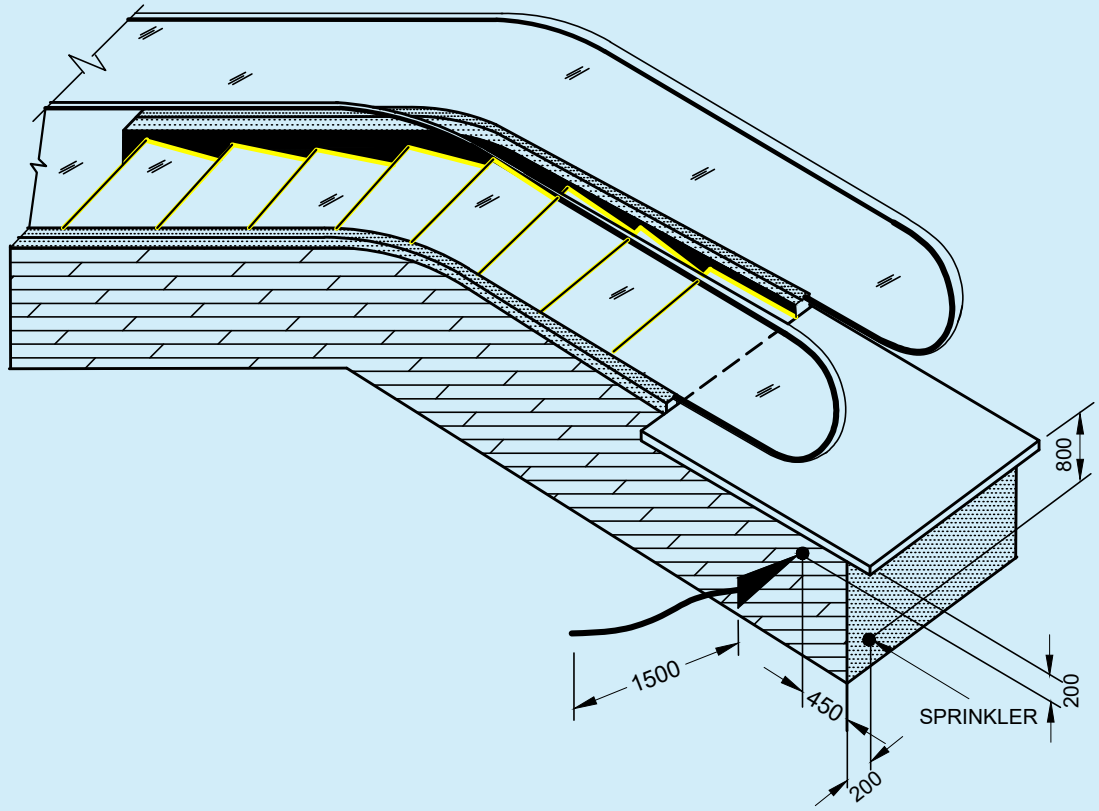

FIG.15 TYPICAL SPRINKLER PIPING ARRANGEMENT

6.4.10 *Oil Separator*

A type-proofed oil separator is essential for escalators and moving walks which are exposed to the weather. At the construction site, a recess shall be provided for the oil separator in the escalator pit.

6.4.11 *Railings*

In the threshold areas of the escalators, railings should be installed by the builder. The distance to the escalator handrail from railing shall be at least 80 mm. For adjacent escalators, the distance between the edges of the handrails shall be at least 160 mm (*see* Y11 in Fig. 5).

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6.5 Electrical Requirement

6.5.1 The electrical installations shall be in accordance with Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS and good practice [D-5B (2)].

6.5.2 *Power Supply*

6.5.2.1 The main power supply cables providing the electricity supply from main electrical panel of the building to escalator/moving walk equipment shall be PVC or XLPE insulated, flame retardant type, armoured cables. The cables shall be terminated in the main switchgear panels/distribution box using cable glands such that the armour of the cables shall be positively connected to the metal body of switchgear panels/distribution box. For each escalator/moving walk, one 415 $V^{+6\ percent}_{-10\ percent}$, 3-phase, 4-wire, 50 Hz supply and one 230 $V^{+6\ percent}_{-10\ percent}$, 1-phase, 3-wire, 50 Hz supply shall be provided outside the escalator/moving walk in the vicinity of the machine or in the return stations, or in the vicinity of the control devices. Main switchgear shall be capable of breaking the supply to the motor, to the brake releasing device and to the control circuit in the live conductors.

The electric lighting and the socket outlets shall be independent of the power supply to the machine being fed either by a separate cable or a branch cable which is connected before the main switch of the escalator or moving walk. It shall be possible to break the supply of all phases by means of a separate switch. This switch shall not cut the supply to the socket outlets or to the lighting circuits while the escalator/moving walk is switched off for inspection and maintenance. Size of the three-phase and single-phase cables shall be as specified by the manufacturer.
When separate supplies are provided for auxiliary equipment, such as, heating, balustrade lighting and comb lighting, it shall be possible to switch them off independently. The corresponding switches shall be located close to the main switch and be marked unambiguously.

6.5.2.2 The escalator/moving walk sub-circuit from the meter room should be separate from other building services. Each equipment should be capable of being isolated from the mains supply. This means of isolation shall be with lock out and tag out facility. The electric supply cables shall run in a route safe from fire.

6.5.2.3 All electrical supply lines and apparatus in connection with the escalator/moving walk installation shall be so constructed and shall be so installed, protected, worked, and maintained that there may be no danger to persons therefrom.

6.5.3 *Protection*

It is important that earthing should ensure efficient and fast operation of protective device, in the case of earth faults. Escalators or moving walks may be provided with or without variable voltage and variable frequency (V3F) drives. Due to its principle of operation, the V3F drive produces leakage current greater than 3.5 mA. Therefore, the cross-section of earthing conductor should be at least the cross-section of the active conductors and at least 10 mm². As an alternative, two ground conductors with the same cross-section as the active conductors (if < 10 mm²) may be used in parallel.

Suitable overcurrent protection device (MCB/MCCB) and residual current device (RCD) shall be provided outside the escalator/moving walk in the vicinity of the machine or in the return stations or in the vicinity of the control devices.

Protective measure of protective equipotential bonding and automatic disconnection of supply is intended to provide protection against shock and/or fire hazard. The choice of protective device, depends on the earthing network that is TN-S, TN-C-S, TT.

Residual current device (RCD) shall be required in case of fault protection against indirect contact or in case of TT network. When RCD is used, circuit shall also be protected by overcurrent protective device that is standalone RCD shall not be used.

6.5.3.1 *MCB and RCD in 3-phase circuit:*

a) Irrespective of whether the escalator or moving walk is with or without V3F, MCB of characteristics 'D' shall be used.

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b) *RCD with V3F* — Special type of residual-current circuit breaker appropriate for this application should be used having following characteristics:

1) Suitable for use with a frequency converter;
2) Universal-current-sensitive (Characteristic *B*);
3) Short-time delayed tripping (Type *S*);
4) Tripping current at nominal frequency: 300 mA; and
5) Tolerant against leakage currents of up to 2 000 mA at higher frequencies.

c) *RCD without V3F* — RCD with below specifications shall be used:

1) Type *A* or *AC* — details to be provided by manufacturer;
2) Non-delayed; and
3) Tripping current: 100 mA

Alternatively, residual current circuit breaker with overcurrent protection (RCBOP) which meets above specifications may be provided.

NOTE — RCD/RCBO is mandatory in case of TT network.

6.5.3.2 *Over current protective device in the 1-phase circuit*

For the lighting circuit, miniature circuit breaker (MCB) of characteristics 'C' shall be provided. In addition, RCD of the following specification shall be provided:

a) Pulse-current-sensitive (Characteristic *A*);
b) Non-delayed;
c) Tripping current: 30 mA; and
d) Rated current: 16 A.

Alternatively, RCBO which meets above specifications may be provided.

7 FIRE PROTECTION

Fire protection and building requirement differ with the application/use of building. For specific requirements for fire protection, Part F 'Fire and Life Safety' of this NBCS should be referred. It is recommended that escalators and moving walks are made of non-combustible material that do not create additional hazard in case of fire.

To limit the danger caused by overheating, ventilation for the rooms/spaces that contain the motors and gears shall be provided. These areas may contain fire alarm systems, extinguishing systems, and sprinkler heads if the equipment is adequately protected from incidental damage and do not create additional dangers for maintenance personnel to operate. In case sprinklers are used, their integration and fixation into the escalator and moving walk shall be done by taking into consideration the special needs of the machine.

Accumulation of materials (such as grease, oil, dust, paper) represent a fire hazard. Therefore, it should be possible to clean the underside enclosure. If such cleaning is not possible, other precautions (such as installation of sprinkler system) shall be provided to avoid the fire hazard. Outer and inner decking, truss, pallets/steps, track system shall be according to Class 3 of accepted standards [D-5B(3)]. In case of fire, upon receiving the signal, the escalator operation should stop immediately. It is recommended that as far as possible, escalators and moving walks are not used in case of emergency situations.

Escalator wellways may be equipped with a fire shutter(s), operated by an activation of temperature and smoke detectors, and shuts off the wellway of a floor and prevent the spread of fire up through the building.

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8 MINIMUM TECHNICAL AND SAFETY REQUIREMENTS

8.1 General

The safety requirements of escalators and moving walks shall comply with good practice in accordance with this Subsection. Certain escalators and moving walks are subject to special operational and environmental conditions.

8.2 Supporting Structures (Truss) and Enclosure

The truss shall be designed to safely sustain steps and running gear in its guides. All mechanically moving parts of the escalator or moving walk shall be completely enclosed within imperforate panels or walls. Exceptions are the accessible steps, the accessible pallets, the accessible belt, and that part of the handrail available for the user. Apertures for ventilation are permitted. However, it shall not be possible to pass a straight rigid rod 10 mm in diameter through the enclosure and to touch any moving part through a ventilation aperture.

Angle of inclination of an escalator from the horizontal shall not exceed 30˚, but for rises not exceeding 6 m and nominal speed not exceeding 0.5 m/s the angle of inclination is permitted to be increased to 35°.

Rise m	*Speed* m/s	*Angle of Inclination*	
		Standard	Option
≤ 6	≤ 0.5	30°	35°
≤ 6	> 0.5	30°	-
> 6	≤ 0.5	30°	-
> 6	> 0.5	30°	-

The angle of inclination of moving walks shall not exceed 12°.

8.3 Step, Pallet, or Belt

For escalators and moving walks, the nominal width shall not be less than 0.58 m and not exceed 1.10 m. For moving walks with an angle of inclination up to 6°, widths up to 1.65 m are permitted.

8.3.1 *Step Treads and Pallets*

The step depth in the direction of travel shall not be less than 0.38 m. The step height shall not exceed 0.24 m. The surface of the step treads shall have grooves in the direction of the movement, with which the teeth of the combs mesh. They shall be sensibly horizontal in the usable area of the escalator. The step risers shall be cleated, and the surface of the cleat shall be smooth. The ends of the step tread shall mesh with the cleating of the next step riser.

The width of the grooves shall be at least 5 mm and shall not exceed 7 mm. The depth of the grooves shall not be less than 10 mm. The web width shall be at least 2.5 mm but not exceed 5 mm.

8.3.2 *Belts*

The belts shall have grooves in the direction of travel with which the teeth of the comb mesh. The width of the grooves shall be at least 4.5 mm and shall not exceed 7 mm. The depth of grooves shall not be less than 5 mm. The web width shall be at least 4.5 mm but not exceed 8 mm. Splicing of tread way belt shall be such as to provide continuous unbroken tread way surface.

8.4 Driving Machine and Brake

8.4.1 A driving machine shall not drive more than one escalator or moving walk.

8.4.2 The speed of an unloaded escalator shall not deviate by more than ± 5 percent from nominal speed at nominal frequency and nominal voltage.

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8.4.3 The driving machine shall be connected to main drive shaft, preferably by non-friction driving elements such as by gear wheels, shaft, coupling, multiplex chain, two or more single chains. Where friction elements are used such as trapezoidal belts (flat belts are not permitted) an auxiliary brake shall be used.

8.4.4 *Braking System*

Escalators and moving walks shall have an operational braking system by means of which they can be brought to rest with a uniform deceleration and maintained stationary; there shall be no intentional delay in the application of the braking system. If the control system starts a braking sequence immediately to bring the escalator/moving walk to a stop, this is not considered as an intentional delay. A device shall be provided to monitor the lifting of the braking system after starting the escalator/moving walk.

Operational braking shall be affected by an electro-mechanical brake or by other means. Where no electro-mechanical operational brake is used, an auxiliary brake shall be provided.

8.4.4.1 *Auxiliary brake*

Escalators and inclined moving walks shall be equipped with auxiliary brake(s) if:

a) the connection between the operational brake and the driving sprockets of the steps/pallets or the drum of the belt is not accomplished by shafts, gear wheels, multiplex chains, or more than one single chain; or

b) the operational brake is not an electro-mechanical brake; or

c) the rise exceeds 6 m; or

d) escalators or moving walks are part of a public transport/service system.

8.5 Steps and Pallets Drive

The steps of escalators shall be driven by at least two chains of which at least one shall be located on each side of the step. The pallets of moving walks may be permitted to be driven by only one chain if the parallel movement of the pallets in the usable area is ensured by other mechanical measures.

8.6 Belt Drive

The belt shall be driven by drums and be tensioned continuously and automatically. Springs working in tension are not permitted for the tensioning device. When weights are used for tensioning, they shall be safely retained should their suspension break.

8.7 Balustrade

Balustrades shall be installed to comply with the requirements of **6.3**.

If glass is used for the interior panel, it shall be toughened glass. In case of splinter free one layer safety (tempered) glass, the minimum thickness shall be 6 mm. When multi-layer glass balustrades are used, they shall be laminated toughened glass, the thickness of at least one layer shall also be not less than 6 mm.

8.8 Skirting

The skirting shall be vertical, plain, and sufficiently rigid. Where the skirting of escalators or moving walks is placed beside the steps and pallets or the belt the horizontal clearance shall not exceed 4 mm at either side, or 7 mm for the sum of clearances measured at both sides at two directly opposite points.

Where the skirting of moving walks finishes above the pallets or the belt, the clearance shall not exceed 4 mm measured vertically from the tread surface. Motion of the pallets or the belt in lateral direction shall not cause a gap between the sides of the pallets or the belt and the vertical projection of the skirting.

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8.8.1 *Requirements for Skirt Deflectors*

The skirt deflectors shall be designed with rounded edges. Fastening heads and joint connections shall not extend into the path of travel. They shall consist of a rigid and a flexible part (for example, brushes and rubber profiles) and shall be mandatorily provided in the escalators.

8.9 Handrails

Each balustrade shall be provided with a handrail moving on the top of each balustrade, in the same direction and at the same speed, within tolerance of $^{+2}_{0}$ percent, as the steps, pallets or belt. Each moving handrail shall extend at normal handrail height not less than 300 mm beyond the line of point of comb plate teeth at the upper and lower landings. Hand or finger guards shall be provided at the points where handrails enter the balustrade.

The width of handrail shall be between 70 mm and 100 mm. The handrail shall be a minimum of 80 mm horizontally and 25 mm vertically away from adjacent surfaces (*see* Fig. 6). The handrail shall be guided and tensioned in such a way that it does not leave its guides during normal use.

8.10 Landing

The landing area (that is, comb plate and floor plate) of escalator shall have a surface that provides a secure foot hold (combs are exempted from this) for a minimum distance of 0.85 m measured from the root of the comb teeth.

8.10.1 *Configuration of Steps, Pallets, and Belts*

8.10.1.1 At the upper and lower landing, the steps of the escalator shall be guided in such a way that the front edges of the steps leaving the comb and the rear edges of the steps entering the comb are moving horizontally for a length of at least 0.80 m measured from point T1 (*see* Fig. 7 and detail A).

8.10.1.2 At the upper landings of moving walks with an inclination of more than 6°, the pallets or belt shall move for a length of at least 0.40 m at a maximum angle of 6° before entering or after leaving the comb.

8.11 Comb Plates

There shall be a comb plate at the entrance and at the exit of every escalator. The comb plate teeth shall be meshed with and set into the tread surface so that the points of the teeth are always below the upper surface of the treads. The comb plates shall be adjustable. Combs shall be easily replaceable.

8.12 Speed Governor

8.12.1 Where speed control devices are used for this purpose, they shall have switched off the escalator before the speed exceeds 1.2 times the nominal speed. This requirement may not be applied if the design prevents the excessive speed.

8.12.2 Escalators and inclined ($\alpha \geq 6°$) moving walks shall be equipped in such a way that they stop automatically by the time the steps and pallets or the belt change from the pre-set direction of travel.

8.12.3 For operation and safety devices, electrical work, precautions and tests, reference may be made to accepted standards [D-5B(3)].

8.13 Inspection Control

Escalators or moving walks shall be equipped with inspection controls to permit operation during maintenance or repair or inspection by means of portable and manually operated control devices. At least one portable control device shall be provided for each escalator or moving walk.

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8.14 Information for Use

8.14.1 *General*

All escalators and moving walks are required to be provided with documentation that shall include an instruction handbook relating to use, maintenance, inspection, periodic checks and rescue operations. Information for use shall cover, separately or in combination, transport, assembly and installation, commissioning, use (setting, teaching/programming, operation, cleaning, fault finding and maintenance) of the escalator and moving walk, and, if necessary, de-commissioning, dismantling and disposal.

8.14.2 *Signals and Warning Devices*

8.14.2.1 *Plates, inscriptions, and notices for use*

a) *General* — All signs, inscriptions and notices for use shall be of durable material, placed in a conspicuous position and written in clearly legible characters in English as well as in local language.

b) *Safety signs near the entrances of escalators or moving walks* — The following mandatory action signs and prohibition signs for the user shall be fixed in the vicinity of the entrances:

   1) Small children shall be held firmly (*see* Fig. 16);
   2) Pets shall be carried (*see* Fig. 17);
   3) Use the handrail (*see* Fig. 18);
   4) Push chairs not permitted (*see* Fig. 19); and
   5) Soft footwear prohibited (*see* Fig. 20).

When required by local conditions, prohibition signs, for example, ‘Transportation of bulky and heavy loads not permitted’ and mandatory action signs like ‘Use permitted only with footwear’, shall be necessitated.

The minimum diameter of the signs shall be 80 mm.

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"SMALL CHILDREN SHALL BE HELD FIRMLY"
FIG.16 MANDATORY ACTION SIGN

"PETS SHALL BE CARRIED"
FIG.17 MANDATORY ACTION SIGN

"USE THE HANDRAIL"
FIG.18 MANDATORY ACTION SIGN

"PUSH CHAIRS NOT PERMITTED"
FIG.19 PROHIBITION SIGN

"SOFT FOOTWEAR PROHIBITED"
FIG. 20 PROHIBITION SIGN

"WHEELCHAIR USERS NOT PERMITTED"
FIG. 21

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Stop devices shall be colored red either on the device itself or in its immediate vicinity and be marked with the inscription 'STOP'.

During maintenance, repair, inspection or similar work, the access to the escalator or moving walk shall be barred to unauthorized persons by devices which shall bear the notice 'NO ACCESS' or the 'NO ENTRY' indicator and be available in immediate area.

NOTE — The safety sign (*see* Fig. 21) shall be affixed prominently near the entrances of escalators or moving walks which are inclined above 6°.

c) *Instructions for hand winding devices* — If a hand winding device is provided, operating instructions for use shall be available in the vicinity. The direction of travel of the escalator or moving walk shall be indicated clearly.

d) *Notices on the access doors to machinery spaces outside the truss, driving and return stations* — On access doors to machinery spaces outside the truss, and driving and return stations, a notice shall be fixed with the inscription reading, 'MACHINERY SPACE — DANGER' and 'ACCESS PROHIBITED TO UNAUTHORIZED PERSONS'.

9 SPECIAL TECHNICAL REQUIREMENTS

If escalators or moving walks are intended to be operated under special conditions, such as directly exposed to the weather or explosive atmosphere, or in exceptional cases serve as emergency exits, appropriate design criteria, components, material and instructions for use should be used that satisfy the particular conditions.

9.1 Escalators or Moving Walks for Public Transport

For escalators and inclined moving walks for public transport which:

a) are part of a public transport system including entrance and exit points; or

b) are suitable for intensive use, regularly operating for approximately 140 h/week with a load reaching 100 percent of the brake load for a total duration of at least 0.5 h during any time interval of 3 h.

It is recommended to install auxiliary brakes also for rises less than 6 m. Auxiliary brakes shall be mandatory for public transport. The load conditions and additional safety features should be agreed to between the manufacturer and the owner reflecting the traffic levels which exist.

9.2 Semi Outdoor Escalator/Moving Walk

Semi-outdoor escalators and moving walks are installed outside the building while they have roofs above them to protect them from rain and snow. Wherever possible, the escalator/moving walks should be placed above the road level, with a ramp, to prevent water on the road directly entering the escalator/moving walk. These escalator/moving walk shall have:

a) Aluminium die-cast step;

b) Outdoor type handrail;

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c) Three-layered protective truss painting;

d) Float switch at lower machine room;

e) Cooling fan in control panel box;

f) Control box of IP54 protection rating;

g) Inverter with enclosure of IP54 protection rating;

h) Safety switch IP65 protection rating;

j) Comb heating (temperature below 4 °C) (if applicable);

k) Step/pallet band heating (temperature below 0 °C) (If Applicable);

m) Lubrication: Lifetime lubricated and sealed step chain roller bearings; and

n) Water drainage system.

9.3 Outdoor Escalator/Moving Walk

Fully outdoor escalators and moving walks are installed outside the building without any roof or overhead covers. Wherever possible, the escalator/moving walk should be placed above the road level, with a ramp, to prevent water on the road directly entering the escalator or moving walk. These escalator/moving walk shall have:

a) Aluminium die-cast step;

b) Extrude aluminium floor plate panel;

c) Outdoor type handrail;

d) Hot-Dip galvanized truss (minimum thickness of 85 microns);

e) Zinc plated track and handrail guide;

f) Galvanized steel drive chain cover;

g) Float switch at lower machine room;

h) Control panel box cooling system:

   1) with inbuilt cooling fan; or

   2) with external cooling fan.

j) Control box of IP54 protection rating;

k) Inverter with enclosure of IP54 protection rating;

m) Safety switches of IP65 protection rating;

n) Stainless steel material grade 304 or higher for skirting, outer decking, handrail decking, balustrade (if not glass balustrade);

p) Class E insulation of electromagnet;

q) Class F insulation of motor;

r) Comb heating (temperature below 4 °C) (if applicable);

s) Step/Pallet band heating (temperature below 0 °C) (if applicable);

t) Lubrication-Life time lubricated and sealed step chain roller bearing;

u) Water drainage system;

w) Provision of galvanized drip pans below the step chain throughout the length of chain with catch tray at return station;

x) Automatic lubrication system with lubrication reservoir of adequate capacity;

y) Provision of hose/pipe to drain water from oil/water separator;

z) Provision for prevention of flooding of return station; and

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aa) Stainless steel fasteners, wherever provided.

9.4 Measures to Prevent Access of Shopping Trolleys and Baggage Carts

9.4.1 *General*

If there is a reasonably foreseeable risk that shopping trolleys and/or baggage carts may be taken onto escalators or moving walks, adequate measures shall be taken to eliminate risks and access shall be prevented, if the following conditions are given:

a) *For escalators* — Where shopping trolleys or baggage carts are available in the area around; and where shopping trolleys or baggage carts are in an area not close to the escalator, but it is reasonably foreseeable that they are taken onto the escalator.

b) *For moving walks* — Where shopping trolleys or baggage carts are not intended to be used on a moving walk.

9.4.2 *Barriers*

If barriers are used, the following requirements shall be fulfilled:

a) Barrier shall be installed at the entrance only. An installation at the exit is not permitted in the unrestricted area;

b) Design of the barrier shall not create another risk;

c) Free entrance width between ends of the newels and barriers and between barriers itself, shall be at least 500 mm and less than the width of the type of shopping trolley or baggage cart to be used;

d) Height of the barrier shall be between 900 mm and 1 100 mm;

e) Barrier and its fixation should withstand the following load: At a height of 200 mm a horizontal force of 3 000 N applies. This force results from an impact of a chassis of a shopping trolley/baggage cart loaded with 160 kg moving with a speed of 1.00 m/s;

f) Barrier shall be fixed preferably at the building structures. It is also permitted to fix it at the floor plate. In that case, when the defined forces apply, there shall be no permanent deformation and increased/additional gaps; and

g) If the escalator/moving walk is dedicated to operating in both directions, the presence of the removable barrier shall be electrically monitored preventing wrong positioning of the barrier resulting in operation towards the barrier, except when under maintenance condition.

9.4.3 *Fixed Devices*

Where fixed devices such as guiding barriers and/or traffic columns are necessary in the unrestricted area, their design shall not create another risk. The following requirements shall be complied with:

a) Guiding barriers or traffic columns shall have a minimum horizontal distance (radius) of 500 mm to any point of the handrail and shall be positioned outside of the centre line of the handrail;

b) Minimum horizontal distance (radius) to any point of the handrail may be reduced to 300 mm, provided that the guiding barriers or traffic columns are positioned outside of the centre lines of the handrails and an additional barrier is installed between the guiding barriers or traffic columns and the vertical centre line of the balustrade newel;

c) The additional barrier shall have a lateral distance between 80 mm and 120 mm of the handrail outer edge and shall close at least the area between the actual lowest point of the handrail entry into the newel and the balustrade decking profile and shall have filled inlets with gaps less than 25 mm;

d) Minimum horizontal distance (radius) to any point of the handrail may be reduced to 180 mm, provided that the guiding barrier or traffic column is positioned outside of the outer edge of the handrail and an additional barrier is installed between the guiding barrier or traffic column and the vertical centre line of the balustrade newel;

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e) The additional barrier shall have a lateral distance between 80 mm and 120 mm of the handrail outer edge and shall close at least the area between the actual lowest point of the handrail entry into the newel and the balustrade decking profile and shall have filled inlets with gaps less than 25 mm; and

f) Minimum horizontal distance (radius) to any point of the handrail may be reduced to 100 mm, provided that the guiding barrier or traffic column is of a round shape and is positioned outside of the outer edge of the handrail and an additional barrier is installed between the guiding barrier or traffic column and the vertical centre line of the balustrade newel.

In addition, the following specific requirements shall apply:

1) Devices and its fixation shall withstand a horizontal force of 1 kN/m applied to the top of the device;

2) Barrier shall be fixed preferably at the building structures. It is also permitted to fix it at the floor plate. In that case, when the defined forces apply, there shall be no permanent deformation and increased/additional gaps;

3) Height of traffic columns shall be at least the height of the handrail level;

4) Height of guiding barriers shall be at least the height of the balustrade decking;

5) If fixed devices are placed inside the unrestricted area, the size of the unrestricted area shall remain the same and in this case be extended in the length; and

6) Guiding barriers and traffic columns are not considered as structural measures that block the exit.

NOTE — For fixed devices in the immediate environment of the unrestricted area these requirements also apply.

9.5 Escalators and Moving Walks Subject to Seismic Conditions

9.5.1 *Structural Requirements*

The requirements given below are applicable:

a) *General* — Escalators and moving walks, if specified to meet specified seismic conditions, shall comply with the relevant safety requirements and/or protective measures as listed below;

b) *Pit/support* — Pit and support conditions are to be secured in that way that the escalator and moving walk under seismic condition is not subjected to constraint. One support should be executed as fixed support and the other supports are to be executed as movable support in horizontal direction. The supporting conditions need to be simply statically determinate;

c) Escalator and moving walk shall be retained on the supports in vertical direction by adequate measures so that the unit shall not jump off the supports under seismic conditions;

d) *Arrangement* — The length and the movability of the escalator and moving walk should be chosen in accordance with the building movement between two storeys of the building. The minimum allowable compensation length of the movable support of the escalator and moving walk has to be chosen same as the maximum allowed storey drift of the building; and

e) *Mechanical safety devices for escalators and moving walks* — If the design of the escalator and moving walk does not allow the safe situation in the pit or support an additional safety device need to be applied so that the escalator and moving walk should not fall off the support.

9.5.2 *Design Requirements*

It is assumed that negotiations have been made for each contract between the customer and the supplier/installer about the peak ground acceleration to be considered. The building designer or owner shall provide the design acceleration which shall be documented in the information. Client and supplier/contractor should agree on one common acceleration value. The acceleration value needs to be communicated between all participants of the contract. The following to be considered in addition to the above:

a) The design of the truss for the escalators and moving walks shall be sufficiently executed for the ambient seismic condition. The structural design shall provide a dissipation capacity to withstand a design-relevant earthquake of the region where it is located;

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b) *Drive and control unit* — Machinery [including control cabinet(s) and drive system, machine, main switch(es), and means for emergency operations], free-wheeling switch shall be designed and anchored to prevent overturning and displacement due to the forces imposed on them including forces generated by the design acceleration; and

c) *Electrical installation and other equipment* — In case the building where the escalator and moving walk will be installed is equipped with a seismic detector/sensor, the electrical system of the unit shall provide an interface for the connection and shall stop the escalator and moving walk in case of seismic activity.

9.6 Escalator/Moving Walk Interface with Building Management System (BMS)

Where required, a means to interface, monitor and control be provided by the escalator/moving walk manufacturer, which should become the part of building management system. Following information and controls, but not limited to these, may be provided either through potential free contacts or building automation interface device suitable for providing necessary escalator/moving walk information over accepted communication protocols:

a) *Monitoring signals:*

1) Power status;

2) Running up/down (Escalator);

3) Running forward/backward (Moving walk);

4) Under maintenance;

5) Under fault; and

6) Emergency 'STOP' pressed.

b) *Remote operation* — Escalator or moving walk shall not be started or stopped from remote monitoring station using remote signal, unless the escalator/moving walk operation is visible/monitored from the remote station.

10 PERFORMANCE REQUIREMENTS FOR ESCALATORS AND MOVING WALKS

10.1 It is necessary to have uniformity in the definition, measurement, processing and expression of vibration and noise signals that comprise escalator and moving walk ride quality. The aim of such uniformity is to benefit escalator and moving walk users by reducing variability in the results of ride quality measurements caused by differences in the methods of acquiring and quantifying the signals. Experience indicates that passenger perception and sound pressure levels measured while travelling on an escalator or moving walk may be influenced by the presence of extraneous noise and vibration sources and by acoustic characteristics of the environment in which the unit is installed and operated. Additionally, the proximity of the escalator or moving walk to strong reflecting surfaces such as walls, ceilings or diagonally opposite units may also influence the sound pressure level measured. These influences may cause a sound pressure level measurement to significantly overestimate the sound level emitted exclusively by the unit. To address this issue, this Subsection defines the methodology for measuring vibration and sound pressure level that corresponds to passenger perception and additionally defines the methods that should be used, if further understanding of the result is required to quantify vibration and noise emitted by the unit as compared to the background or environmental contributions.

10.2 Measurement of Escalator and Moving Walk Ride Quality

Escalator and moving walk should be measured in both running directions except where the unit is designed to operate in one direction only. The measurements should be carried out under following conditions where, escalator and moving walk shall:

a) be assembled completely, adjusted and operating in accordance to the requirement;

b) have reached normal operating temperature;

c) be measured in unloaded condition;

d) be measured after starting sequence has been completed. If the unit operates at different speeds, all the speeds shall be measured;

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e) have finished star/delta changeover, if used, before starting the measurement;

f) have vibration measurements made by aligning the axis of transducer to the axis of entire escalator or moving walk; and

g) have the noise measured at measuring distance to the floor/surface of steps and pallets of 1.55 m ± 0.075 m.

NOTE — Accepted standard [D-5B(4)] shall be referred for Ride Quality measurements.

11 ESCALATOR AND MOVING WALK ENQUIRY OR INVITATION TO TENDER

11.1 A period of two to four weeks is normally sufficient for return of tenders. This should be extended if large numbers of escalators/moving walks or special requirements are involved. The enquiry documents should be kept to the essential minimum and should be strictly confined to material relevant to the escalators/moving walk works and to the project concerned.

When enquiring for and ordering the escalators/moving walks, the particulars given below should be furnished:

a) Type(s) of escalator/moving walk;

b) Number of escalators/moving walks;

c) Location of escalators/moving walks (indoor or outdoor);

d) Capacity/usage type (persons per hour/heavy duty, medium duty, light duty);

e) Angle of inclination, in degree;

f) Rise (travel), in mm;

g) Nominal speed, in m/s;

h) Step width, in mm;

j) Number of flat steps (2 or 3 or 4);

k) Balustrade details;

m) Construction, design, finishes details;

n) Escalator/moving walk lighting details;

p) Electric supply — power volts a.c./d.c.; phase; cycles; wire system;

q) Proposed date for commencement on site;

r) Additional items, if required;

s) Details of maintenance, schedule and circuit diagram where so specified;

t) Details of voice announcements, visual contrast, tactile indicators and warning signage; and

u) Number of horizontal steps/pallets.

11.2 Additional Items

The enquiry should state any additional items required beyond those specified in accepted standards [D-5B(3)], such as interface requirements, seismic design, etc.

11.3 Finishes

Finishes should be specified at the enquiry stage or provisional sums should be included for them. Finishes to be considered may include step lighting, handrail colour, handrail lighting, balustrade material, step colour, truss cladding details (weight to be considered).

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11.4 Inclusions and Exclusions

Several peripheral items are associated with escalators/moving walk installation, of which some should always be provided by the builder, and some are best included by the manufacturer. The requirements vary to some extent with the type of installation.

It is important that the limits of responsibility are clearly understood, and the enquiry documents should be specific in this respect.

The escalators/moving walk manufacturer should include items (as applicable), such as:

a) tracks;
b) drive unit;
c) controller;
d) broken chain detection switch;
e) stop switches at both ends;
f) balustrade;
g) handrail;
h) steps/step drive assembly;
j) saree/skirt guard;
k) step demarcation lights;
m) missing steps;
n) comb plate;
p) flat steps;
q) comb plate switches/skirt switches;
r) floor plate (anti-slip material);
s) truss;
t) guarantee of equipment; and
u) scaffolding for installation.

The escalators/moving walk manufacturer should exclude the supply and fixing of the items (as applicable) or as per the contract conditions as follows:

1) Hoisting hook/beam fixing;
2) Truss cladding;
3) Temporary guarding;
4) Cutting and making goods;
5) Working lights/permanent electricity supplies; and
6) Site painting of steel work.

For more detailed discussion of the requirements for site preparation and work by other trades, reference should be made to relevant provisions of this NBCS and other good practices.

Facilities for the use of the main contractor's crane should be provided to assist in installing heavy equipment in addition to other unloading facilities on site in the course of erection. The main contractor should be instructed to include these facilities in his own bill of quantities.

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11.5 Site Programme

The enquiry should indicate as accurately as possible the contract programme as it affects the manufacturer, in particular the target date for completion, construction schedule, site preparedness, the availability of crane for hoisting, co-ordination details (with other contractors like BMS interfacing, CCTV interfacing, etc).

12 ACCEPTANCE OF TENDER AND SUBSEQUENT PROCEDURE

12.1 Order

The owner places an order with the selected contractor for supply and installation of escalator/moving walk.

12.2 The general arrangement drawings supplied by owner with the tender documents,

a) are provided for the supplier’s guidance and information when tendering;

b) should the arrangement and dimensions shown be inadequate to properly install the equipment as specified then necessary amendments shall be issued by client; and

c) any amendments issued after the commencement of contract shall be subject to the agreement and approval.

12.3 Layout Drawing

The contractor shall furnish proposed layout giving particulars such as dimensions, steel work requirements and loading imposed on structure. Such drawings shall include following details:

a) Position and sizes of all holes and cuttings;

b) Loads on beams and structure;

c) Escalator/moving walk pits and associated equipment;

d) Requirement of end supports, intermediate support(s) with location and load;

e) Hoisting facilities and access requirement for delivery of equipment;

f) Builder's work; and

g) Power and ventilation requirement.

12.4 Approval of Layout Drawing

The contractor shall commence actual production of equipment after approval of drawings submitted by contractor. Where the contract provides for the purchaser’s choice of decorative finishes, colours, etc, the decisions should be communicated as early as possible, and preferably not later than the time of approval of drawings.

12.5 Programme of Works

The contractor shall submit a detailed programme showing intended method and stages together with period estimated for each stage. The programme shall include following:

a) date of commencement and completion of every stage of the works in line with the building construction programme;

b) date of expected completion of builder's work requirements;

c) date of delivery of equipment and materials to site;

d) date of requirement of temporary and permanent electricity supply; and

e) date of completion, commissioning and testing.

The contractor shall ensure the work in accordance with the criticality of adherence of installation dimensions and supports as indicated in layout.

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12.6 Electricity Supply to Escalators/Moving Walk

Operation of the machine under power is required from a comparatively early stage of installation for most efficient working, and power supply shall be furnished accordingly. Whilst temporary power supply may be sufficient for erection purposes, final testing and setting up should only be carried out with the permanent power supply connected. For this reason, the timely provision of the permanent power supply is important.

13 COORDINATION OF SITE WORK

13.1 Preparatory Work on Site

13.1.1 It is expected for the escalator/moving walk supplier to make periodic visits to the site to check progress on the construction and discuss relevant matters with the owner. The contractor should assure himself that all building work has been completed in accordance with his requirements. Immediately before the time for erection to commence, the contractor should check that site conditions are fit to permit erection to proceed.

13.1.2 Building works to be completed before the erection work, includes the following:

a) Providing adequate access to the well-way to allow for setting the equipment in place;

b) If the project is not ready for placement at the time of delivery, providing dry storage area located close to well-way;

c) Providing protection of all floor openings adjacent to and in the general area of escalator/moving walk;

d) Providing safety compliant stairwell access to floors;

e) Providing clear unobstructed workspace adjacent to well-way;

f) Providing safety compliant overhead and floor opening protection;

g) Providing barricades to prevent the entrance of unauthorized personnel to construction area;

h) Drying and cleaning of pit and floor openings with proper dimensions;

j) Providing properly located supports of adequate strength for the truss at the landings including intermediate supports, if required;

k) Providing suitable floor fill and patching of flooring including floor covering, adjacent to the landing plates of the escalator/moving walk; all floor finishing to be completed after installation of the landing plates; and

m) Providing flooring with little slope in direction outwards of the escalator to prevent ingress of water, etc, into the escalator.

13.2 Delivery of Material

The contractor should advise the owner when equipment is ready for dispatch, so that the owner is able to make arrangements on site to receive and unload as near as possible to the well-way.

13.3 Storage

Adequate provision should be made by the owner for storage, protection and preservation against loss, deterioration of or damage to all material on the site. Attention is drawn to the adverse effect of damp conditions on electrical equipment.

13.4 Site Meetings

The contractor shall coordinate his proposed programme of work with that of the building contractor and all other contractors and sub-contractors to adhere to the latest overall construction programme and to achieve efficient and safe working on site. In large sites, regular meetings of all parties are beneficial for successful progress of work.

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13.5 Service of Other Trades

The contractor may require the services of other trades as the work proceeds, and it is essential that the contractor should give due notice to the building contractor of the demands to be made on other trades, so that he may plan accordingly.

13.6 Connecting to Power Supply

The contractor should give prior notice to the owner of the date the power supply is required, so that suitable arrangements for connection can be made. During erection, necessary electrical power shall be provided for illumination, operation of required tools and hoist and for starting, testing and adjustment.

14 INSPECTION AND ACCEPTANCE PROCEDURES

14.1 General

Escalators and moving walks shall be inspected, before their first use; after major modifications; and at regular intervals. Such inspections and tests should be made by a competent person.

14.2 Constructional Inspection and Acceptance Inspection and Test

14.2.1 The constructional inspection and acceptance inspection and test shall be carried out at the jobsite on completion of the escalator or moving walk. During inspection and tests, precautions shall be taken so that escalators or moving walks are not set in motion without the knowledge and consent of the person(s) performing such work.

For the constructional inspection and acceptance inspection and test, the data specified in **14.4** should form part of a pre-completed test sheet. Furthermore, layout drawings, description of the equipment and wiring diagrams (current flow chart with legend or explanations, and a terminal connection chart) which permit a check of compliance with the safety requirements, shall be provided.

The constructional inspection comprises the examination of the completed installation for conformity with the required data and about proper workmanship as specified hereunder.

14.2.2 The acceptance inspection and test comprises,

a) overall visual inspection;

b) functional test;

c) test of electric safety devices regarding their effective operation; and

d) test of the brake(s) of the escalator or moving walk under no load, for compliance with the prescribed stopping distances.

Measurement of the insulation resistance of the different circuits between conductors and earth shall also be done. For this measurement, the electronic components shall be disconnected. This includes a test of the electric continuity of the connection between the earth terminal(s) in the driving station and the different parts of the escalator or moving walk, liable to be live accidentally.

14.3 Inspection and Test after Major Modifications

A major modification is a change of the location, a change of the speed, of the electric safety devices, of the braking system, of the drive, of the control, of the step band, of the truss and of the balustrades. Wherever applicable, the principles set forth for the constructional inspection and acceptance inspection and test should apply to the new environmental conditions, modified components and other components which are affected.

The replacement of parts with parts of same design is not considered to be a major modification.

14.4 Specific Data, Test Reports and Certificates

The following documentation should be held by the manufacturer:

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a) stress analysis of the truss or equivalent certificate by a stress analyst;

b) proof by design calculation of sufficient breakage resistance of the parts directly driving the steps, pallets or the belt, for example step chains, racks;

c) calculation of the stopping distances for loaded moving walks together with adjustment data;

d) proof testing of steps or pallets;

e) proof of the breaking strength of the step chain/pallet chain/belt;

f) proof of sliding coefficients for skirting;

g) proof of anti-slip properties of tread surfaces (steps, pallets, floor and comb plates without combs);

h) proof of stopping distances and deceleration values;

j) proof of electromagnetic compatibility; and

k) test certificate for handrail breaking strength (for public service escalators and public service passenger moving walks).

14.5 Escalator Site Checks and Inspection List

Suitable site checklist/inspection list may be used. A typical list is given at Annex A.

14.6 Escalator Commissioning and Acceptance Tests

14.6.1 *Escalator Details*

Typical details to be provided are given below:

a) Name of station :

b) Location :

c) Escalator No. and job No. :

d) Drawing No. :

e) Rise :

f) Type of balustrade : SS/Glass - Tick (√)

g) Manufacturer's Sl No. :

14.6.2 *General Inspection*

A typical general inspection list is given below:

Sl No.	*Item*	*Method/Requirement*	*Result*
(1)	(2)	(3)	(4)
i)	All unwanted material have been removed	Visual check	
ii)	Escalator (including steps, handrails, floor plate, cladding, etc) has been cleaned	Visual check	

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Sl No.	*Item*	*Method/Requirement*	*Result*
(1)	(2)	(3)	(4)
iii)	Proper barricading of the area has been done prior to testing	Visual check	
iv)	Emergency signage to be fixed at the emergency stop; safety labels placed at top/bottom newel end	Visual check	
v)	Check provision of 'Danger Sign' plate on the escalator control panel	Visual check	
vi)	Wedge guard/deflector fixed for obstacles such as walls, pillars, floor intersection or criss-cross arrangement of escalators/moving walks	Visual check	
vii)	Clear height of 2.3 m above steps throughout the length of escalator	Measurement check	
viii)	Access restriction guard fixed between parallel escalators	Visual check	
ix)	Permanent barriers at entry and exit with gaps according to code requirement	Measurement check	
x)	Connection of hose/pipe to oil/water separator	Visual check	
xi)	Power cables and earthing provided at drive station	Visual check	

14.6.3 *Electrical Test*

A typical check list of electrical tests is given below:

Sl No.	*Item*	*Test Procedure*	*Recommended Result*	*Instrument / Sl No.*	*Measured Value*	*Result*
(1)	(2)	(3)	(4)	(5)	(5)	(7)
i)	Insulation resistance test	Shall be tested between lines connected together and earth at 500 V d.c.	> 0.5 MΩ (Mega Ohm)			

NOTES

1 Protective earthing of escalator shall be as per clauses 4.2.11.3.1.1 of good practice [D-5B(5)].

2 Verification of the effectiveness of the measures for fault protection by automatic disconnection of supply shall be according to 6.2.3.6 and 6.2.3.7 of good practice [D-5B(5)].

3 Where the current exceeds 10 mA under normal operating conditions, a reinforced protective conductor shall be used according to 5.4.3.7 of good practice [D-5B(5)].

14.6.4 *Functional Tests on Safety Switches and Devices*

A typical check list is given in Annex B

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15 OPERATION AND MAINTENANCE

15.1 General

The installation shall be maintained in good working order in accordance with the installer's instructions. To this effect, regular maintenance of the installation shall be carried out to ensure the safety of installation. The safety of an installation shall consider the ability to be maintained without causing injury or damage to health.

Regular maintenance of the installation shall be carried out to ensure the reliability of the installation. The access and the associated environment shall be maintained in good working order in accordance with the installer's instructions.

The instructions for maintenance of an installation shall be provided by the manufacturer, when placed on the market, after risk assessment.

In order that the aim of the maintenance instructions should be achieved, they shall be formulated so that they should be clearly and easily understood by competent maintenance person. The competent maintenance person within the maintenance organization shall be continuously updated.

The installer/manufacturer shall provide maintenance instructions intended for the owner of the installation (*see* 15.3.2) including the information intended for the maintenance organization (*see* 15.3.3).

NOTE — The owner of the installation should be informed that the qualification of the maintenance organization is in conformity with the regulation applicable in the location in which the installation operates.

Maintenance aspects include:

a) Lubrication, cleaning, etc;

b) Checks;

c) Passenger rescue operations;

d) The operations of setting and adjustment; and

e) Repair or changing of components which may occur due to wear and tear, and do not affect the characteristics of the installation.

However, cleaning of the external parts of the escalator or moving walk shall not be considered as maintenance.

The following shall not be considered as maintenance operations:

1) changing of major component, such as the machine, even if the characteristics of the new component are the same as the original;

2) replacement of installation;

3) modernization of the installation including changing of any characteristics of the installation (such as load, speed, etc); and

4) rescue operation carried out by fire brigade.

15.2 Elements to be considered for Maintenance Instructions

When preparing the content of the maintenance instructions (*see* 4.3 and 5) the following elements shall be considered:

a) Specifications and the intended use of the installation (type of installation, performance, etc);

b) Environment in which the installation and its components are installed (weather conditions, vandalism, etc);

c) Any restriction of use;

d) Result of risk assessment (*see* 5) for every working area and for every task undertaken;

e) Specific maintenance instructions provided by the manufacturer of safety components; and

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f) In case of components other than safety components, where maintenance is necessary, the maintenance instructions provided by the manufacturer of these components.

15.3 Information to be Included in the Maintenance Instructions

15.3.1 *General*

The maintenance instructions shall contain information relating to the tasks of both the owner and the maintenance organization, respectively.

15.3.2 *Information to the Owner of the Installation*

The information relating to the tasks of the owner of the installation shall include the following:

a) Need for the owner to keep the installation in a safe operating condition. To fulfil this, the owner shall use a maintenance organization complying with the requirements of this Subsection;

NOTE — It is recommended to inform the owner of the installation about the need to use a maintenance organization with adequate and proper insurance cover provided by an insurance company.

b) Need for the owner to take care of applicable regulation(s) and other requirements, where relevant, and their implications on maintenance;

c) Need for planned maintenance to be carried out by a maintenance organization, at the latest when the installation is put into service or if the installation is to remain unused for a long period of time before first being put into service;

d) Importance for the owner of the installation to have the same maintenance organization in the case of several installations having common well/spaces and/or machine room;

e) Need for the owner to put the installation out of service in case of dangerous situations;

f) Need for the owner of the installation to inform the maintenance organization:

1) Immediately about any perceived abnormal operation of the installation or abnormal change in its direct environment;

2) Immediately after putting the installation out of service in the case of a dangerous situation;

3) After any rescue intervention by their authorized and instructed person(s);

4) Before any modification related to the installation and/or its environment or use;

NOTE — The owner of the installation should obtain from the company carrying out the relevant modification the maintenance instructions for the maintenance organization.

5) Before any authorized third-party inspection or works other than maintenance works are carried out on the installation;

6) Before taking the installation out of service for a prolonged period; and

7) Before putting the installation back into service after a prolonged period of non-operating time.

g) Need for the owner of the installation to take into consideration the consequences of the risk assessment carried out by the maintenance organization;

h) Need for the owner of the installation to make sure that the risk assessment for maintenance is carried out:

1) If the maintenance organization is replaced;

2) If the use of the building and/or the installation changes;

3) After a major modification of the installation or of the building; and

4) If it is the case, after an accident involving the installation.

j) Need for the building owner to ensure, through a risk assessment, that:

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1) their premises are safe and free from risk to health as far as is practicable. This includes access to the premises and installation equipment, and articles or substances used according to the regulation for the use of work equipment at the workplace;

2) the persons using the premises are informed about any remaining risks; and

3) any action to be done as a consequence of risk assessment carried out.

Regarding the access ways to areas reserved for maintenance persons, the need for the owner of the installation to inform the maintenance organization, about,

i) the access ways to be used and fire evacuating procedures from the building;

ii) the place where the keys of the reserved areas shall be found;

iii) if necessary, the persons who shall accompany the maintenance persons to the installation; and

iv) if necessary, personal protective equipment to be used in the access ways, and, possibly, where this equipment shall be found.

The information shall be made available also on site to the maintenance organization.

k) Need for the owner of the installation to ensure that the name and the telephone number of the maintenance organization are always available to the user of the installation, permanently affixed and clearly visible;

m) Need for the owner of the installation to ensure that the keys of machine room doors (trap doors) and of inspection and emergency doors (trap doors), if any, are permanently available in the building and are used only by persons authorized to gain access;

n) Need for the owner of the installation to provide, in all circumstances, safe access to the building and to the installation for the maintenance organization involved in the rescue of persons;

p) Need for the owner of the installation to keep the access to working areas and working rooms safe and free for the maintenance persons and to inform the maintenance organization about any hazard or change in the workplace and/or the access ways (lighting, obstructions, ground conditions, etc);

q) In addition to those examinations and tests (for escalators/moving walk) which the owner of the installation entrusts to the maintenance organization, the need for the owner to carry out periodically, in their own interests, include the following:

1) A full travel in both directions, when they exist, to assess any changes in the quality of the ride or damage to the equipment.

2) Typical items to be checked to ensure that they are in place, undamaged and functioning correctly are:

i) all lighting and indicators;

ii) emergency stopping device;

iii) handrails;

iv) skirting/deflector devices;

v) combs;

vi) safety signs/pictograms;

vii) approximation of speed between handrail and steps/pallets;

viii) steps/pallets;

ix) balustrade and panels;

x) head guard and decking; and

xi) safe and unobstructed access to entry and exit areas.

15.3.3 *Information for the Maintenance Organization*

The information relating to the tasks of the maintenance organization shall include the following:

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a) Need to carry out the work of maintenance in conformity with the maintenance instructions and based on systematic maintenance checks. After these checks, the maintenance organization shall decide in conformity with the maintenance instructions what is required to be done. A list of typical examples of maintenance checks to maintain the installation is shown in Annex C;

NOTE — Due to the fact that the components may be different in design and operation, it is therefore not possible to give specific guidelines in this Subsection.

b) Need to update the original maintenance instructions, if the installation changes its intended use and/or the environmental conditions existing on the completion of the installation;

NOTE — The maintenance organization should be provided by the owner of the installation with the relevant maintenance instructions where modifications are carried out on the installation.

c) Need for the maintenance organization to ensure that a risk assessment for any working area and for any maintenance operation has been carried out considering the installer's maintenance instructions and all information supplied by the owner of the installation;

d) Need for the maintenance organization to inform the owner of the installation about any work to be carried out as a consequence of a risk assessment especially for the access and/or the environment related to the building/installation;

e) Need to carry out a maintenance plan so that preventive maintenance is suitable for the installation and maintenance time is as short as reasonably practicable, without reducing the safety of persons, in order to minimize the non-operational time of the installation;

f) Need to adapt the plan for maintenance to take account of any predictable failures, for example, those due to misuse, mishandling, deterioration, etc;

g) Need to carry out maintenance operations by competent maintenance persons and provided with the necessary tools and equipment;

h) Need to maintain the competency of maintenance persons;

j) Need to carry out the maintenance periodically. In determining the frequency of maintenance interventions, the following non-exhaustive list should be considered:

1) Operating time and any non-operating periods of time;

2) Age and condition of the installation;

3) Location and type of building in which the installation is installed, as well as the needs of the users; and

4) Local environment where the installation is situated, as well as external environmental elements, for example, weather conditions (rain, heat, cold, etc) or vandalism.

k) Need to provide a 24 h, all year-round call-out service for rescue of persons;

m) Need to keep records of the result of each intervention due to a failure of the installation. These records shall include the type of failures to detect any repetition. They shall be available to the owner of the installation on request;

n) Need to put out of service the installation, if the maintenance organization is aware of a dangerous situation, detected during the maintenance, which cannot be eliminated immediately, and to inform the owner of the installation of the need to keep it out of service until repaired;

p) Need to be organized to provide the necessary spare parts for any repair;

q) Possible need for attendance of a competent maintenance person(s), given reasonable notice, for any inspection carried out by an authorized third party or for building maintenance works to be carried out in the areas reserved for the maintenance organization;

r) Need to inform in due time, the owner of the installation about necessary progressive upgrading of the installation; and

s) Need to organize rescue operations, even with sub-contractor(s), and to make provision for circumstances such as fire, panic, etc.

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15.4 Maintenance Contract

It is recommended that the maintenance is carried out by original equipment manufacturer (OEM). Any maintenance contract should include the following at a minimum, to ensure that escalators/moving walk is always maintained/operated in the safe working condition:

a) All batteries used for emergency operations;

b) All safety switches/devices;

c) Handrail system components including handrails;

d) Operational and auxiliary brake; and

e) Combs.

15.5 Risk Assessment

15.5.1 *General*

Before an installation is placed on the market, it is necessary that the installer/manufacturer carries out a risk assessment. Every risk shall be limited as much as reasonably possible by means of safety measures and suitable instructions. The instructions can never replace a safety measure which can be provided to reduce the risk.

It is necessary to determine the different intervention procedures of the maintenance operations and to determine the appropriate safety measures for each of these procedures.
The use of diagnostic systems may support fault finding, improve the maintainability of the installation and reduce the exposure of maintenance persons to hazards.

Safety in maintenance operations of the installation is ensured by adopting safety measures and providing instructions. Safety measures on the installation and in the building shall be provided by the installer and by the owner of the installation, respectively.

For any working area, it is necessary to identify the list of the specific hazards related to health and safety and to carry out a risk assessment for any maintenance operation, including access to the working area.

For this purpose, the following should be considered:

a) Presence of one or more maintenance persons in a working area;

b) Foreseeable actions of persons other than maintenance persons (for example, person switching on or off power circuits and dependent circuits or lighting circuits or trying to use the installation during maintenance operations, etc); and

c) Possible states of the installation (normal or abnormal due to a foreseeable failure of its component parts, external disturbances, disturbance of its power supply, etc).

Annex D gives a list of examples of elements to be considered in any risk assessment for maintenance operations. However, several methods are available for the systematic assessment of risk.

15.5.2 *Information for the Maintenance Organization*

For safe maintenance and to provide relevant instructions, it is first necessary to identify the maintenance operations.

Maintenance operations are:

a) those operations considered necessary for a correct and safe functioning of the installation and its components after the completion of the installation; and

b) those operations considered necessary during the ‘life’ of some components, determining, as far as possible, the time or condition after which the functioning or the integrity of the component is no longer ensured even if correctly maintained.

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In carrying out specific maintenance operations, if it is necessary to neutralize some safety functions (for example, an electric safety device), the hazard identification shall be considered for such a situation.

It is necessary to inform and warn the maintenance persons about: (a) residual risks, that is, those for which risk reduction by design and safeguarding techniques are not there or not completely effective; and (b) risks that arise from the necessary removal of certain guards to carry out specific maintenance operations. The maintenance instructions and warnings shall prescribe the procedures and operating modes intended to overcome these risks and, if it is necessary, to specify personal protective equipment, instruments, tools and provisions to be used.

15.6 Markings, Signs, Pictograms and Written Warnings

If the risk assessment of the maintenance organization indicates that additional specific warnings are required for the purpose of maintenance, these shall be affixed directly on the installation/component or, in the close vicinity, when this is not possible. Markings, signs, pictograms, and written warnings shall be readily understandable and unambiguous. Readily understandable signs and pictograms shall be used in preference to written warnings.

Signs or written warnings carrying only the words 'DANGER' shall not be used. Information affixed directly on the installation/component shall be permanent and legible.

Any markings, signs, pictograms, and written warnings affixed on the installation shall be renewed if they become illegible.

15.7 Format of the Maintenance Instruction Handbook

The maintenance instruction handbook for any installation shall contain at the front at least the following:

a) Type of installation, with its serial number, to which the instructions apply;

b) Title of the handbook;

c) Date of issue;

d) Name and address of the installer/manufacturer; and

e) Name of the publisher, when different from the installer/manufacturer.

In the handbook:

1) all units used shall be SI units;

2) all pages shall be numbered; and

3) all references to other documents shall be in full.

Warnings shall state the hazard, the related risks, and the appropriate safety measure.

Type and size of print shall ensure the best possible legibility. Safety warnings and/or precautions shall be emphasised using colours or symbols and/or large print.

Documents giving instructions for maintenance shall be produced in durable form (that is, they shall be able to survive frequent handling) or triplicate copies shall be provided.

15.8 Maintenance Record and Annual Inspection

Maintenance organization is required to maintain a logbook at the equipment to record of maintenance and repair work carried out on the equipment. In addition, the layout diagram and latest wiring diagram is required to be maintained at the equipment by maintenance organization. Maintenance organization is required to carry out annual inspection of the installation and certify that escalator is in safe for operation. Owner of the installation is responsible for ensuring that any deficiencies found during the annual inspection are rectified before the equipment is put back in service.

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ANNEX A

(*Clause* 14.5)

CHECK LIST FOR INSPECTION OF ESCALATOR/MOVING WALK AT SITE

Sl No.	Reference No.	Item	OK	Not OK	NA
(1)	(2)	(3)	(4)	(5)	(6)
	1	Escalator/Moving Walk - External			
i)	1.1	General fire protection			
ii)	1.2	Geometry			
iii)	1.3	Handrails			
iv)	1.4	Entrance and exit ends			
v)	1.5	Lighting			
vi)	1.6	Caution signs			
vii)	1.7	Comb-plate			
viii)	1.8	Deck barricade			
ix)	1.9	Steps/Pallets and upthrust device			
x)	1.10	Operating devices			
xi)	1.11	Skirt obstruction devices			
xii)	1.12	Handrail-speed monitoring devices			
xiii)	1.13	Speed			
xiv)	1.14	Balustrades			
xv)	1.15	Ceiling intersection guards			
xvi)	1.16	Step/pallet/skirt clearance panels and performance index			
xvii)	1.17	Outdoor protection			
	2	Escalator/Moving Walk - Internal			
xviii)	2.1	Machinery space access, lighting, receptacle and condition			
xix)	2.2	Stop switch			
xx)	2.3	Controller and wiring			
xxi)	2.4	Drive machine and brake			
xxii)	2.5	Speed governor			
xxiii)	2.6	Broken drive chain and disconnected motor device			
xxiv)	2.7	Reversal stop switch			
xxv)	2.8	Broken step/pallet chain switch			
xxvi)	2.9	Step/pallet upthrust device			
xxvii)	2.10	Missing step/pallet device			
xxviii)	2.11	Step/pallet level device			
xxix)	2.12	Step/pallet, step/pallet chains and trusses			
xxx)	2.13	Handrails			
xxxi)	2.14	Name plate			
xxxii)	2.15	Response to smoke detector			
xxxiii)	2.16	Log card			
xxxiv)	2.17	Pit cleanliness			
xxxv)	2.18	Inspection box			

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ANNEX B

(*Clause* 14.6.4)

TYPICAL CHECK LIST FOR FUNCTIONAL TESTS ON SAFETY SWITCHES AND DEVICES

Sl No.	Check Point	Method	Value Required	Measured Value	Result
(1)	(2)	(3)	(4)	(5)	(6)
i)	Emergency stop switch	Push the button	OK/NOT OK	Top:	
			OK/NOT OK	Intermediate level:	
			OK/NOT OK	Bottom:	
ii)	Direction key switch (Start switch)		OK/NOT OK	Top:	
			OK/NOT OK	Bottom:	
iii)	Traffic bollard		OK/NOT OK		
iv)	Traffic light working	Check for correct movement indication. (Up/Down) visual check	OK/NOT OK	Top:	
			OK/NOT OK	Bottom:	
v)	Provision of comb light	Visual check	OK/NOT OK		
vi)	Sprinkler:				
	a) Connected to main system		Yes/No/NA		
	b) Number of sprinkler heads provided		Yes/No/NA		

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ANNEX C

[(*Clause* 15.3.3(a)]

TYPICAL EXAMPLES OF MAINTENANCE CHECKS TO MAINTAIN THE INSTALLATION

C-1 ESCALATORS AND MOVING WALKS

Sl No.	Component	Checks
(1)	(2)	(3)
i)	Controller	Check cabinet is clean, dry and free from dust
ii)	Gear box	Check gear and associated parts
		Check lubrication
iii)	Drive motor	Check bearings for wear
		Check lubrication
iv)	Brake	Check braking system
		Check parts for wear
v)	Auxiliary brake	Check braking system
		Check parts for wear
vi)	Intermediate gear box	Check gear and associated parts
		Check lubrication
vii)	Main drive chain	Check for tension and wear
		Check lubrication
viii)	Step/Pallet chain	Check for tension and wear
		Check lubrication
ix)	Step/pallet	Check step/pallet and step/pallet wheels for integrity
x)	Conveyor belt	Check for condition and tension
xi)	Drive belt	Check for condition and tension
xii)	Clearances	Check step to step and step to skirting clearances
xiii)	Combs	Check condition
		Check meshing with steps, pallets or belt
xiv)	Comb plate	Check clearances and operation
xv)	Handrails	Check for free running and condition
		Check tension
		Check synchronization between step/pallet band and the handrail
xvi)	Track system	Check for condition and wear
		Check fixings
xvii)	Safety devices	Check operation
xviii)	Deflector devices	Check condition
xix)	Lighting	Check operation
xx)	Display	Check operation
xxi)	Signs/pictograms	Check condition
xxii)	Balustrade	Check condition of panels
		Check fixings of interior claddings

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ANNEX D

(*Clause* 15.5.1)

EXAMPLES OF ELEMENTS TO BE TAKEN INTO ACCOUNT THE RISK ASSESSMENT FOR MAINTENANCE OPERATIONS

D-1 ESCALATORS/MOVING WALKS

Elements	Machinery Spaces	On Step/Pallet Band	Inside Step/Pallet Band	Upper and Lower Landing	Control Cabinet	Machine Room (External Drives)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Access and entry	R	R	R	R	R	R
Inadequate lighting (including access)	R	R	R	R	R	R
Falls/slips	R	R	R	R	R	R
Falling on machine	NR	R	NR	R	NR	NR
Falling over balustrade	NR	R	NR	R	NR	NR
Contact with moving machinery	R	R	R	R	R	R
Indirect contact with machinery	R	R	R	R	R	R
Crushing and shearing (step to step or comb/step to skirting)	R	R	R	NR	NR	NR
Gaps in balustrade	NR	R	NR	NR	NR	NR
Intersection between floors and/or escalators	NR	R	NR	NR	NR	NR
Persons on the step band	NR	R	NR	R	NR	NR
Safety switches and emergency stopping device(s)	R	R	R	R	R	R
Inspection control	R	R	R	R	R	R
Intersection between fixed and moving parts	NR	R	NR	NR	NR	NR
Unintentional start/stop	R	R	R	R	R	R
Machine moving (other than on power)	R	R	R	R	R	R
More than one maintenance person working	R	R	R	R	R	R
Manual operation	R	NR	R	R	R	R
Falling objects	R	R	R	R	NR	R
Unexpected water/dirt	R	R	R	R	R	R
Contamination by oil and grease	R	R	R	R	NR	R
Dangerous substances	R	R	R	R	R	R
Fire	R	NR	R	NR	R	R
Missing step/pallet	R	R	R	R	NR	NR

'R' = Relevant and 'NR' = Not relevant

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used for conformance with the requirements of the referred clauses in this NBCS.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

	IS No.	*Title*
(1)	SP 30 : 2023	National Electrical Code of India 2023
	IS 732 : 2019	Code of practice for electrical wiring installation (*fourth revision*)
	IS 3043 : 2018	Code of practice for earthing (*second revision*)
(2)	IS 12777 : 1989	Method for classification of flame spread of products
(3)	IS 4591	Escalators and moving walks:
	Part 1/Sec 1 : 2020	Safety requirements *(first revision)*
	Part 1/Sec 2 : 2020	Guide for planning and selection *(first revision)*
	Part 1 / Sec 3 : 2020	Inspection and test *(first revision)*
	Part 2 : 2022	Guide for maintenance
(4)	IS 17615 (Part 2) : 2021/ ISO 18738-2 : 2012	Measurement of ride quality: Part 2 Escalators and moving walks
(5)	IS 732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 5 INSTALLATION OF LIFTS, ESCALATORS, MOVING WALKS AND POWER-DRIVEN PARKING SYSTEMS

5C POWER-DRIVEN PARKING SYSTEMS

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part D/Subsection 5C) covers the requirements for planning and design, installation and operation, of car parking systems to ensure efficient operation of system with satisfactory performance.

This Section was first published in 1970 and was subsequently revised in 1983, 2005 and 2016 as a part of National Building Code of India. This Section covers the requirements for installation of lifts and escalators in buildings. This Section should be read with Part F 'Fire and Life Safety' of this NBCS from fire safety requirements point of view. The major changes in the first revision of 1983 were the addition of outline dimensions of different types of lifts and detailed requirements of escalators in buildings. Emphasis was laid on coordination between the engineer/architect and the lift manufacturer to arrive at the number and position of lifts for attaining optimum efficiency in serving the building with safety.

The significant changes with respect to lifts incorporated in the 2005 revision, included the addition of new clauses/recommendations on the building management system; the addition of new clauses on the fireman's lift, infrared light curtain, safety and braille button for blind people and updation of provisions as per the revised standards on lifts on which this Section was based.

In the 2016 revision, the erstwhile Section 5 on Lifts and Escalators was divided into two subsections namely:

5A Lifts

5B Escalators and moving walks

The growing demand for efficient and space-saving parking solutions for passenger cars in urban environments has led to the development of power-driven parking systems in the country that address the requirements of power-driven vehicle parking systems. These systems, which may be either automated or semi-automated, are crucial for optimizing land use in densely populated areas. Recognizing the importance of such systems, in this NBCS, a new subsection 5C 'Power-Driven Parking Systems' has been introduced to provide comprehensive guidelines for the planning, design, installation, operation, maintenance and inspection of parking systems assuming safe and efficient movement of vehicles.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

This new Subsection on power-driven parking systems reflects the evolving technological advancements and urban planning needs and its integration within the lifts and escalators related building services chapter underscores the significance of vertical transportation solutions in modern building infrastructure.

The following important provisions are addressed in this new Subsection:

a) *Automated parking systems* — Fully automated car parks allow drivers to leave their vehicles at designated entry points, from where the vehicles are transported and parked automatically. This system minimizes human intervention, reduces parking time and enhances space utilization;

b) *Car lifts and ramps* — In semi-automated systems, the movement of cars depends on the use of car lifts with/without ramps. It is essential to conduct a detailed analysis to determine the optimal number of car lifts required, ensuring that the average car retrieval/parking time does not exceed 3 min; and

c) *Design and safety* — Car lifts are to be designed to accommodate the largest vehicles intended for use, providing adequate space for door opening to facilitate passenger evacuation in case of emergencies. Additionally, designers need to account for potential queues and provide sufficient holding areas for vehicles.

This NBCS (Part D/Subsection 5C) deals with the requirements for planning, design, installation, operation, maintenance and inspection of parking systems so as to ensure safe movement of cars within and out of the building spaces and with satisfactory performance.

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Assistance has also been derived from the following publications in the preparation of this Subsection:

IBC 2024	International Building Code, International Code Council, Washington, USA
DIN EN 14010 : 2009-12	Safety of machinery — Equipment for power-driven parking of motor vehicles — Safety and EMC requirements for design, manufacturing, erection and commissioning stages

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **'accepted standard'** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Sec shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [D-5C(1)] refers to the Indian Standard given at serial number (1) of the List of Standards given at the end of this Part 5/ Subsection 5C, that is, SP 30 : 2023 'National Electrical Code of India 2023'.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 5 INSTALLATION OF LIFTS, ESCALATORS, MOVING WALKS AND POWER-DRIVEN PARKING SYSTEMS

5C POWER-DRIVEN PARKING SYSTEMS

1 SCOPE

1.1 This NBCS (Part D/Subsection 5C) covers the requirements for planning, design, installation, operation, maintenance and inspection of permanently installed power-driven vehicle parking systems in buildings so as to ensure safe parking and movement of cars with satisfactory performance. These systems which may be automated or semi-automated are crucial for optimizing land use in densely populated areas.

1.2 This Subsection gives information that should be exchanged among the architect/engineer, the consulting engineer and the car parking solution providers/installers from the stage of planning of installation including up to the functioning and maintenance stage.

2 TERMINOLOGY

For the purpose of this Subsection, the following definitions shall apply.

2.1 General

2.1.1 *Grid* — One or more (sideways) working areas load handling devices standing vertically one above the other.

2.1.2 *Operating Panel* — Stationary or mobile device giving command for parking space request. Signal transmission for mobile controls can be based on different technologies (radio, infrared, RFID, bluetooth, etc).

2.1.3 *Parking Unit* — A parking unit refers to one or several load carriers connected together mechanically and moving as a single entity.

2.1.4 *Parking Equipment Attendant* — A person tasked with operating, cleaning and/or supervising power-driven parking equipment.

2.1.5 *Public Use* — Those parking systems designed and intended for access and use by the general public, as opposed to private or restricted use.

2.1.6 *Series* — One or more load-handling attachments placed horizontally and one behind the other as a multi-row arrangement.

2.1.7 *Transfer Area* — An area within a semi-automatic/fully automatic parking facility into which cars are parked in and/or from which they are removed. Normally only the driver should be allowed to enter in this area.

2.1.8 *Working Area* — Power-operated parking system for motor vehicles and cars, in which the transfer area is the same as the working area. A main vertical and horizontal sliding door (recommended for safety) is located in front of each transfer area which stores and makes the car available again in sequential operation. During the operation of the parking system, access of any personnel is prevented in this working area.

2.2 Terms Relating to Parking Systems

2.2.1 *Automatic Parking System* — A parking system that consists of parking equipment along with its linked ancillary equipment, such as main doors, working area doors and emergency doors all of which operate in an automatic/preprogrammed manner.

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2.2.2 *Electromechanical Parking Systems* — A parking system that employs mechanical components such as gears, pulleys, ropes and chains to move vehicles horizontally or vertically into parking positions, often using automated platforms or carriages.

2.2.3 *Hydraulic Parking Systems* — A parking system that utilizes fluid-driven mechanisms, including hydraulic cylinders, to lift and lower vehicles into designated parking spaces, typically allowing for multiple vehicles to be stacked vertically in a compact space.

2.2.4 *Locking Device* — A mechanism that prevents the platform from leaving a defined position within the parking system.

2.2.5 *Puzzle Parking System* — A type of automated parking system in which vehicles are moved on platforms in vertical direction and horizontal direction (similar to a puzzle).

2.2.6 *Safety Switch* — A control switch with one or more break-contact elements connected via non-resilient members, ensuring full contact opening when the actuator is moved through the specified positive opening travel.

2.2.7 *Safety Gear* — A mechanical device designed to stop and hold the platform in case of over speeding with gravity within the parking system.

2.2.8 *Stack Parking System* — A type of parking system which moves the car in up and down position.

2.2.9 *Wheel Track Width* — The distance between the centre lines of the wheels on a single axle of a vehicle.

2.2.10 *Wheel Base* — The distance between the centres of the wheels on the front and rear axles of a vehicle.

2.3 Terms Relating to Semi-Automatic Parking Systems

2.3.1 *Area of Parking* — The area reserved for the car parking system where the system is supported at various load bearing points shall ensure firm support from flooring/ceiling.

2.3.2 *Drive Way* — The front open space in the parking system (minimum 6.0 m in length or the diagonal distance of car + 500 mm) where the car enters in 90° direction into the system.

2.3.3 *Horizontal Movements* — The lateral shifting of vehicles within a parking level, often using automated platforms or conveyors for efficient space utilization.

2.3.4 *Restricted Access* — Access restricted to authorized persons to use the parking facilities and are controlled through access code, magnetic card, key switch, etc.

2.3.5 *Vertical Movements* — The transporting of vehicles between different levels vertically, typically using car lifts or stacker systems to maximize vertical space.

3 GENERAL

3.1 Conformity with Act and Rules

3.1.1 The installation of parking systems, including stack parking, puzzle parking, tower parking and other automated parking systems, is governed by different acts and rules across states, intended to ensure the safe installation and operation of such systems.

3.1.2 The installation shall be carried out in conformity with relevant acts and rules wherever they are in force, ensuring compliance with all safety and operational guidelines.

3.1.3 A license for public use is a safety provision issued by state authorities under applicable acts and rules, wherever they are in force.

3.2 Conformity with the Electricity Act and Rules

3.2.1 All electrical work related to the installation of parking systems shall be carried out in accordance with the

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provisions of the *Electricity Act*, 2003 and *Central Electricity Authority* (CEA) Regulations as amended up to date, along with the Rules and Regulations framed thereunder. Additionally, the installation shall comply with the provisions of Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS.

3.3 Conformity with Indian Standards

3.3.1 All materials, fittings, appliances, etc used in the installation of parking systems shall conform to Indian Standard specifications wherever these exist. In cases where Indian Standard specifications do not exist, the materials shall be approved by the competent authority (*see* Part B 'Building Materials' of this NBCS). The installation shall adhere to best practices as outlined in relevant standards such as accepted standards [D-5C(1)], [D-5C(2)] and [D-5C(3)].

3.4 Conformity with Fire Regulations

3.4.1 The installation of parking systems shall be carried out in conformity with the applicable state fire acts/rules/local fire regulations, wherever they are in force. The installation shall be carried out in conformity with relevant acts and rules wherever they are in force, ensuring compliance with the same. *See also* Part F 'Fire and Life Safety' of this NBCS for guidance purpose.

3.5 Safety Design Considerations

The design consideration for type and selection of parking systems walk shall be based on following criteria:

a) *Location* — To ensure reliability and longevity, the design specifications of parking systems should suit the environmental conditions of the installation site. Factors such as exposure to weather elements, seismic activity, susceptibility to stagnant rain water/flood prone zone and temperature variations should be considered when selecting and designing a parking system;

b) *Physical Requirements* — The physical characteristics of the site, such as available space and the building's structural capacity, play a crucial role in selecting the appropriate parking system. The system should be designed to accommodate the vertical and horizontal dimensions of the space. The building infrastructure should also be evaluated to ensure it can support the weight and dynamic loads of the components of the parking system, apart from the various external loads, forces and effects (*see* Part C 'Structural Design, Section 1 Loads and Load Effects' of this NBCS);

c) *Type of Segment and Traffic Patterns* — The design and selection of parking systems depend on the type of segment where they will be installed, such as residential buildings, commercial complexes, transit hubs, or public parking facilities. The expected traffic patterns and peak demand should be carefully analysed to ensure that the parking system's capacity matches the anticipated usage, preventing congestion and delays;

d) *Safety Considerations* — Parking systems should be designed and installed with a focus on safety to prevent accidents and injuries. Safety features should include proper load limits, emergency stop functions, and clear signalling systems. Operators and users should adhere to the rules for safe operation, including compliance with all safety signals and instructions outlined in the operation and maintenance manual. Routine inspections should be conducted before operation to confirm the equipment's condition, and overloading should be strictly avoided to prevent mechanical failure and any local buckling damage; and

e) *Aesthetic Preferences* — The aesthetic integration of the parking system with the surrounding environment should be determined in consultation with all relevant stakeholders. This may involve choosing materials, finishes and designs that complement the architectural style of the building or site.

4 PARKING SYSTEMS (OVERVIEW AND SPECIFICATIONS)

4.1 General

Parking systems are essential in urban environments where space is limited and the demand for efficient vehicle storage is high. These systems optimize the use of vertical and horizontal space, ensuring that vehicles are securely and conveniently parked. The choice of a parking system should be based on factors such as the type of

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vehicles to be parked, the available space, the required capacity and specific site conditions, time taken in parking, maintainability and economy.

4.2 Stack Parking System

An optimized system in which vehicles are stacked vertically is known as stack parking system. Such systems are particularly useful in urban settings where land space is scarce. The stack parking system operates by lifting vehicles and placing them on platforms supported by vertical columns. They are ideal for residential and commercial buildings having limited space and are also suitable for above-ground installations where space constraints prevent extensive horizontal expansion. There are two types of stack parking systems, namely:

a) *Dependent stack parking system* — A vertical parking arrangement where two/three cars are parked one above the other. The lower car should be removed to access the upper car. This system is suitable for both indoor and outdoor installations and offers a cost-effective solution by utilizing a single driving level to create two parking levels (*see* Fig. 1A and Fig. 2A). The dimensions and configurations for two-level and three-level dependent stack parking systems are provided in Table 1.

Table 1 Dimension and Configuration of Dependent Stack Parking System

[*Clause* 4.2(a)]

Sl No.	Dependent System	Minimum Height mm				
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	2 Level parking system:					
	a) Upper level	1 600	1 600	1 600	1 600	1 600
	b) Lower level	1 600	1 700	1 800	1 900	2 000
	c) Combined system	3 400	3 500	3 600	3 700	3 800
ii)	3 Level parking system:					
	a) Upper level	1 600	1 700	1 800	1 900	2 000
	b) Middle level	1 600	1 700	1 800	1 900	2 000
	c) Lower level	1 600	1 700	1 800	1 900	2 000
	d) Combined system	5 300	5 600	5 900	6 200	6 500

b) *Independent stack parking system* — A parking system that allows two/three cars to be parked vertically above each other, with each parking level being independently accessible. This system maximizes space efficiency by providing multiple parking levels on a single driving level, making it an ideal solution for areas with limited space (*see* Fig. 1B and Fig. 2B). The dimensions and configurations for two-level and three-level independent stack parking systems are provided in Table 2.

Table 2 Dimension and Configuration of Independent Stack Parking System

[*Clause* 4.2(b)]

Sl No.	Independent System	Height mm		
(1)	(2)	(3)	(4)	(5)
i)	2 Level parking system:			
	a) Required pit	1 850	2 000	2 250
	b) Upper level	1 650	1 800	2 050
	c) Lower level	1 650	1 800	2 050
	d) Combined system	3 550	3 850	4 350

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Table 2 (*Concluded*)

Sl No.	Independent System	Height mm		
(1)	(2)	(3)	(4)	(5)
ii)	3 Level parking system:			
	a) Required pit	3 450	3 750	3 850
	a) Upper level	1 550	1 700	1 750
	b) Middle level	1 550	1 700	1 750
	c) Lower level	1 550	1 700	1 750
	d) Combined system	4 950	5 400	5 550

4.2.1 *Key Features and Components*

The following are the key features and components of stack parking systems:

a) *Vertical support* — Supported on two sides by vertical columns with a pair of slides that hold the platform and allow movement along the columns.

b) *Balancing chain* — A chain fixed at both ends that supports the platform during travel, having sufficient strength to withstand impact loads in case of a sudden fall. This also ensures that platform remains in horizontal position during entire operation.

c) *Locking mechanism* — Lockers positioned on both sides of the vertical columns engage during downward movement. Locking mechanism restricts free fall of platform ensuring safety during entire travel length (*see* Note).

d) *Hydraulic cylinder* — The system uses hydraulic cylinders designed to bear the load of the vehicle on the platform during vertical transportation.

e) *Hydraulic power pack* — A single hydraulic power pack can serve multiple systems, with individual controls for each system.

f) *Non-return valve* — Controls the flow of hydraulic oil in one direction with a self-locking arrangement to prevent accidental movement.

g) *Foundation support* — The system is anchored by RCC foundations (minimum M25 grade) capable of sustaining the pull-out loads exerted through foundation bolts ensuring anchoring depth of (125 mm to 150 mm) and concrete depth of 200 mm.

h) *Ceiling or side supports* — The upper end of the system is supported by either ceiling or side supports.

j) *Four-column support* — The car's weight is transferred to four supporting pillars, typically driven by mechanical traction machines using ropes or chains.

k) *Braking system* — The movement is controlled by brakes, though the system lacks a secondary stopping mechanism if the brakes fail.

m) *Limit switches and sensors* — Limit switches control movement, but over-reliance can lead to accidents. Sensors below the platform detect vehicles, though potential blind spots exist.

n) *Operational safety* — An emergency safety switch is mandatory for every operating panel. The system requires a 'hold to run' operation to ensure no objects are within the parking area before activation.

p) *Security features* — Each operating device should have a key lock to prevent unauthorized use. The system's components should have an IP rating of 67 for outdoor installations.

NOTE — Until the Indian Standard on the subject is formulated, specialist literature like EN 14010 : 2003 'Safety of machinery — Equipment for power-driven parking of motor vehicles. Safety and EMC requirements for design, manufacturing, erection and commissioning stages' may be referred to.

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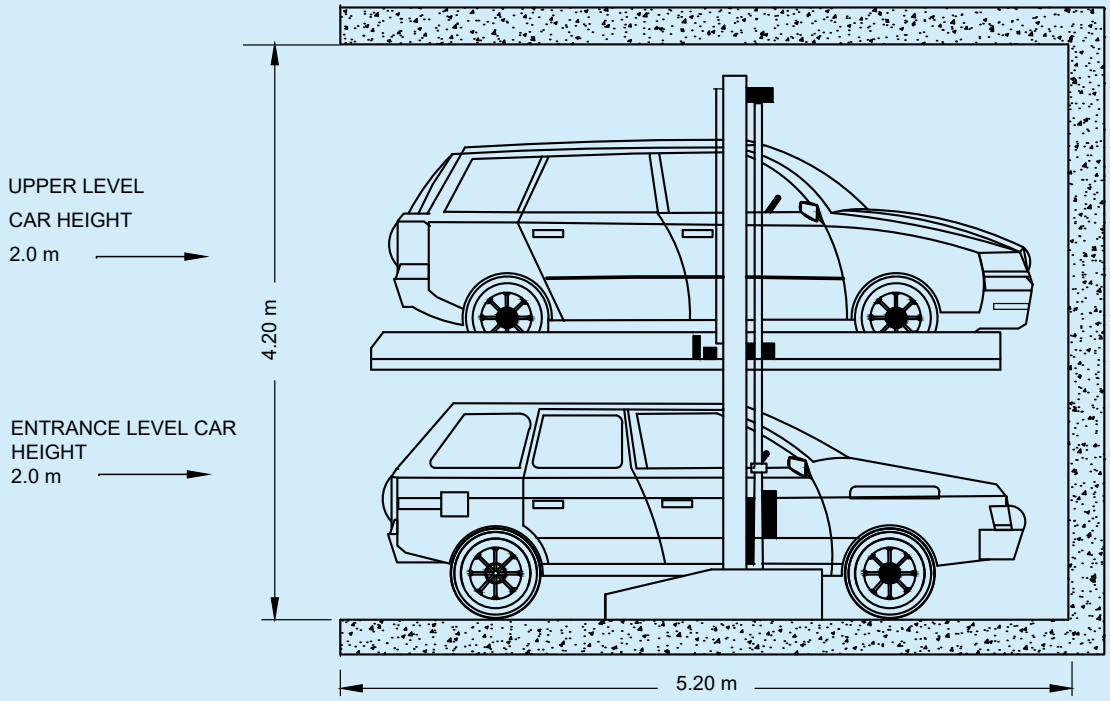
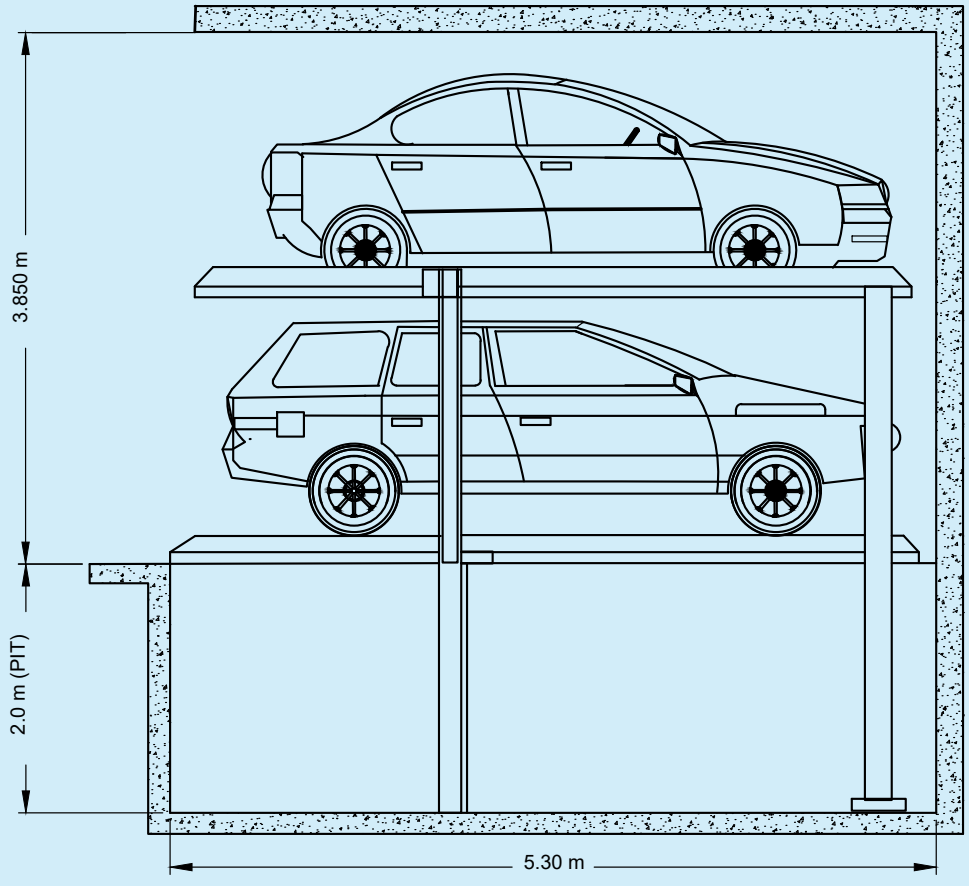


1 A DEPENDENT TWO LEVEL STACK PARKING SYSTEM (TYPICAL)



1 B INDEPENDENT TWO LEVEL STACK PARKING SYSTEM (TYPICAL)

FIG. 1 STACK PARKING SYSTEM TWO LEVELS

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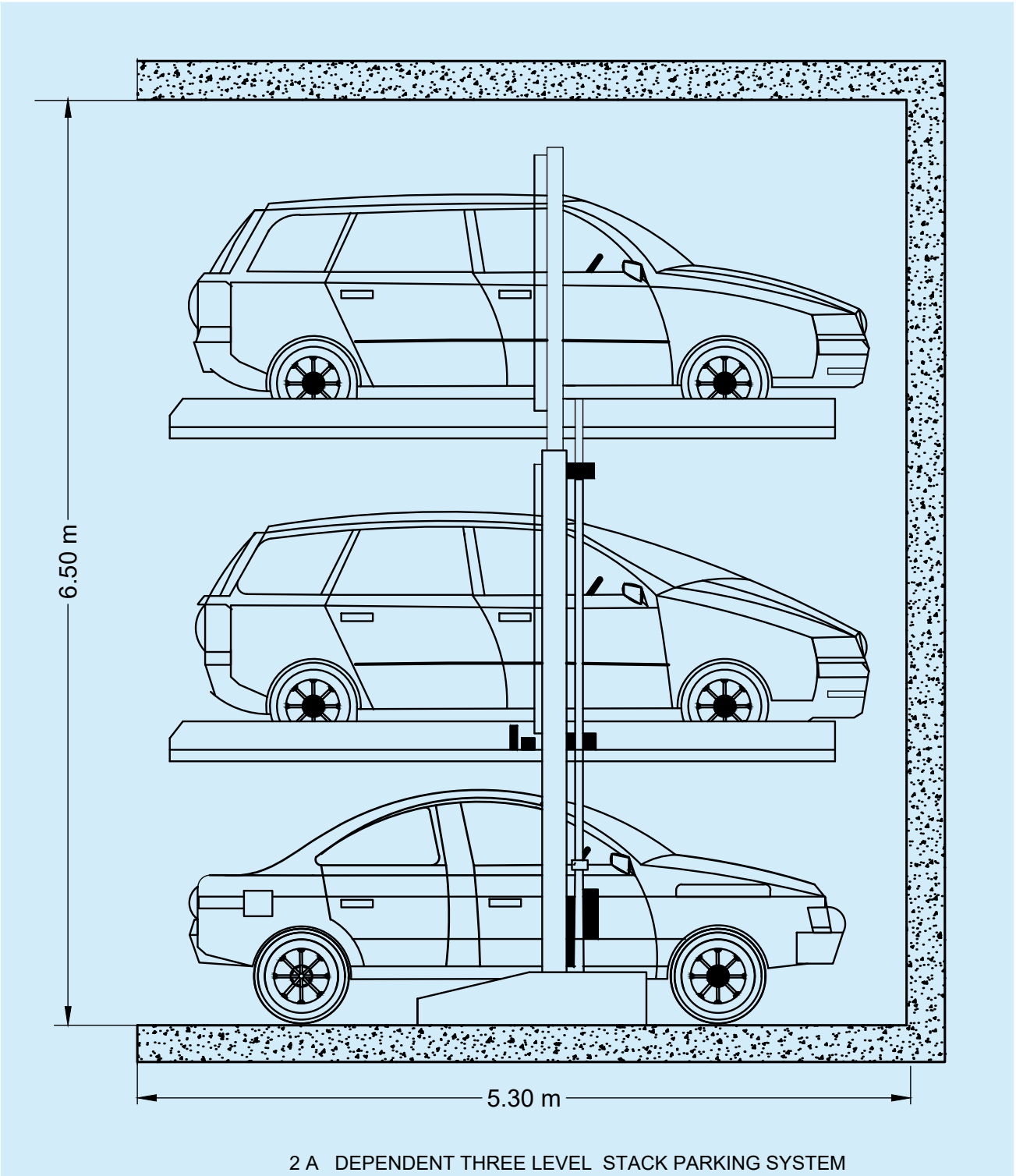

2 A DEPENDENT THREE LEVEL STACK PARKING SYSTEM

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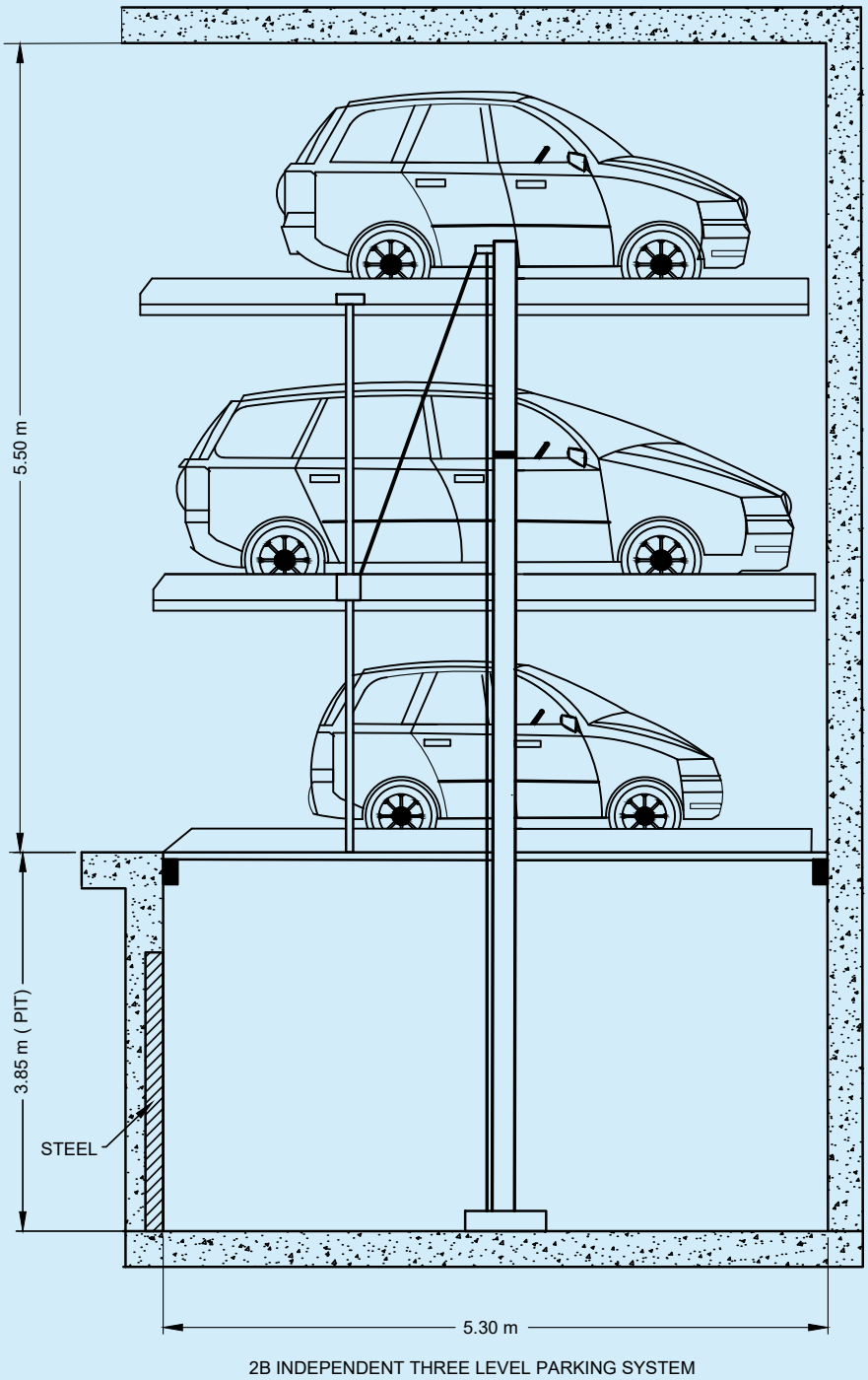

FIG. 2 STACK PARKING SYSTEM — THREE LEVELS

4.3 Puzzle Parking

Puzzle parking system is a type of semi-automatic parking system designed to maximize parking space efficiency by utilizing a combination of vertical and horizontal movements. The system mechanically arranges vehicles in a grid-like structure to optimize space utilization and minimize the need for manual parking. Figure 3 to Fig. 8 depicts various options of puzzle parking and the essential systems in them. The retrieval time for cars should be maintained within the time range specified in Table 3 to ensure efficient operation and user convenience.

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Table 3 Categorization of Retrieval Time

(*Clause* 4.3)

Sl No.	Performance Level	Retrieval Time s
(1)	(2)	(3)
i)	Excellent	≤ 90
ii)	Very good	90 to 100
iii)	Good	100 to 120
iv)	Acceptable	120 to 140
v)	Poor	> 140

NOTE — These are under ideal conditions. However, it may vary depending upon the arrangement of parking systems.

4.3.1 *Key Features and Components*

The features and components of the puzzle parking are described hereunder:

a) *Vertical movement*:

1) *Geared motor and machine* — The geared motor and machine for vertical movement shall be located at the side or rear of the system. Movement shall be facilitated using ropes or chains; and

2) *Hydraulic cylinders* — Vertical movement using hydraulic cylinders may be located either vertically or horizontally, depending on the system design.

b) *Horizontal movement* — Horizontal movement shall be controlled by a traction motor utilizing a chain sprocket mechanism.

c) *Safety precautions*:

1) *Entry to transfer rooms* — Access to transfer rooms should be controlled with sliding doors to ensure safety. Sensors may be used to halt the system in case of obstruction, but reliance solely on sensors may not fully prevent accidents; and

2) *Flood sensors* — Flood sensors shall be installed in the pit to monitor water levels. A warning hooter shall be provided to alert any potential malfunction in the sump pump system.

d) *Pit requirements:*

1) *Waterproofing* — The pit shall be waterproofed to prevent water ingress. A sump shall be provided for efficient water removal;

2) *Condition before installation* — The pit shall be handed over with a whitewash applied prior the installation of the puzzle parking system; and

3) Entire area to be properly ventilated, illuminated and in hygienic conditions.

e) *Maintenance and inspection* — Regular maintenance and inspection schedules shall be established to ensure all components are functioning correctly and system is in safe working condition.

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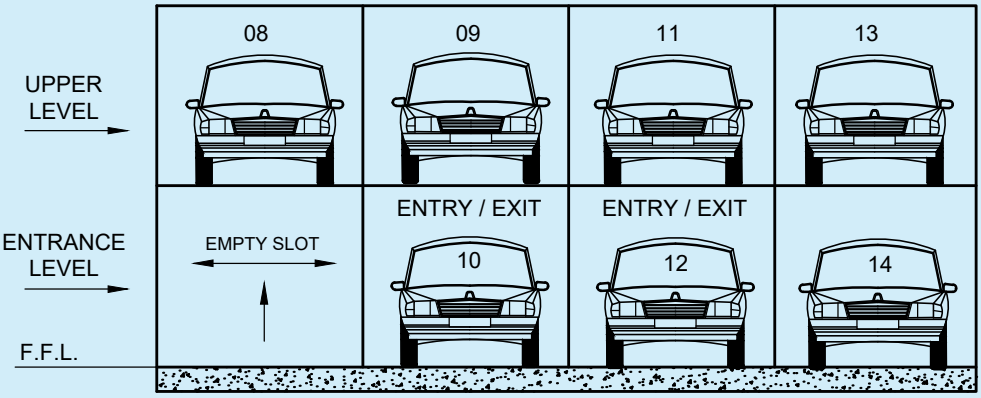
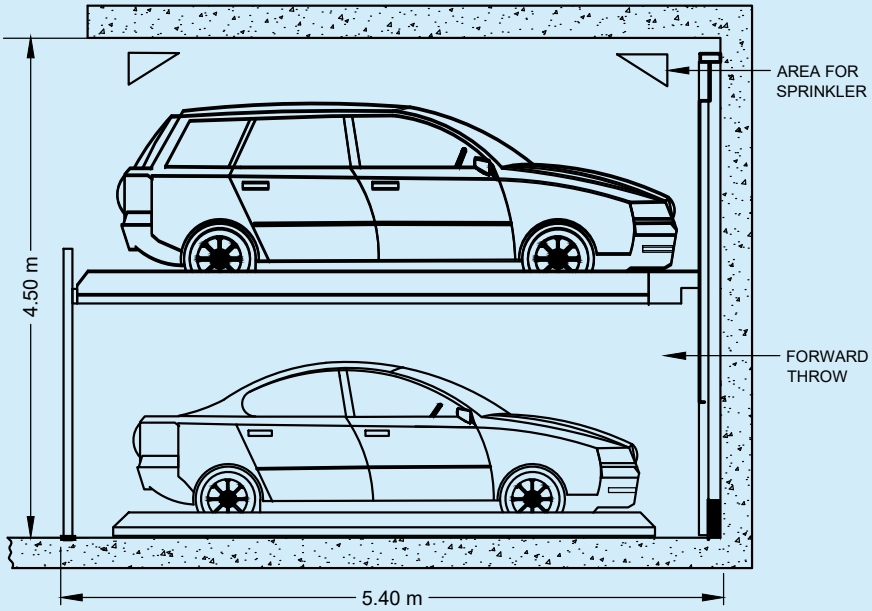
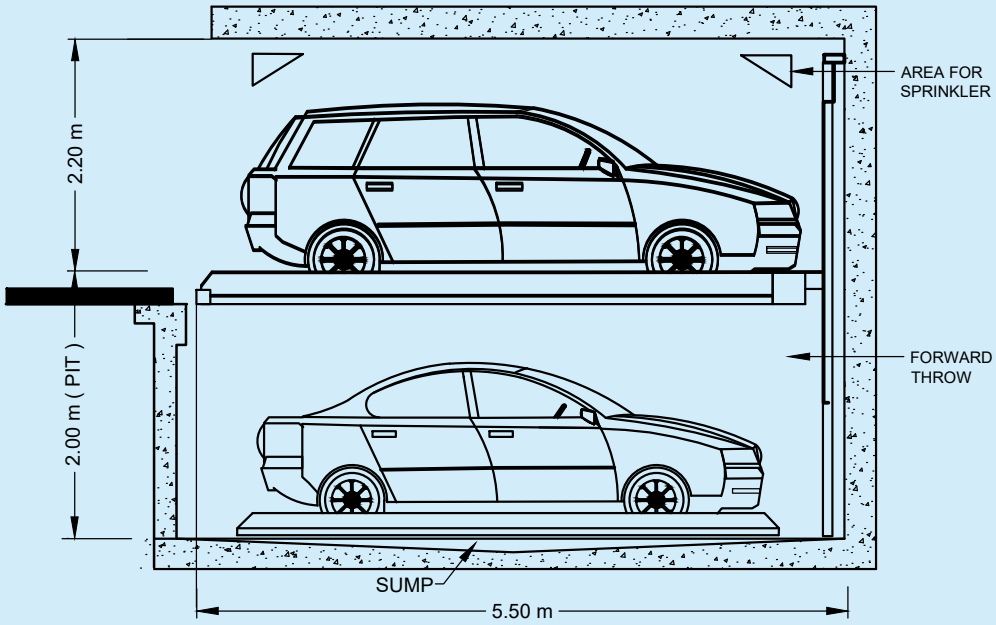


FIG. 3 SYSTEM SHOWING 2 LEVEL PARKING ABOVE GROUND



4A TWO LEVEL INDEPENDENT PUZZLE PARKING SYSTEM



4B TWO LEVEL INDEPENDENT PUZZLE PARKING SYSTEM WITH PIT

FIG.4 CROSS-SECTION SHOWING FREE SPACE FOR SERVICES LIKE FIRE SPRINKLERS

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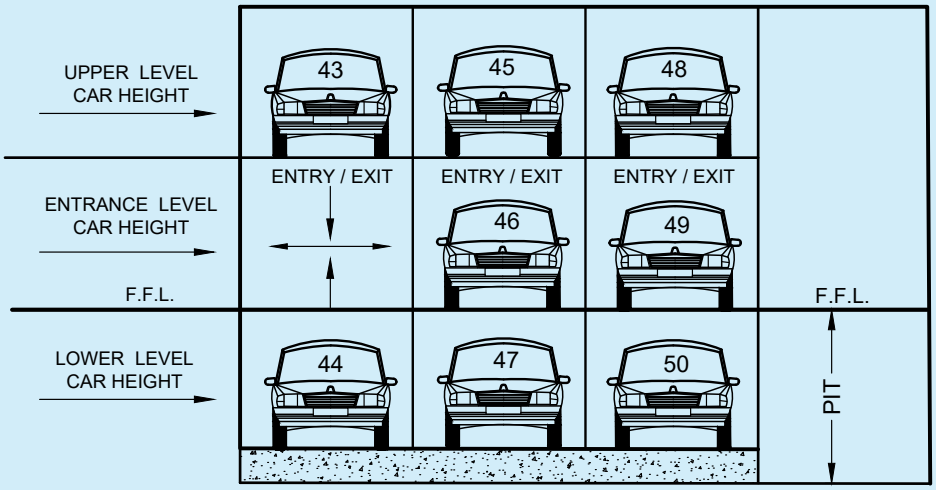

FIG. 5 SYSTEM SHOWING 3 LEVEL PUZZLE PARKING WITH PIT

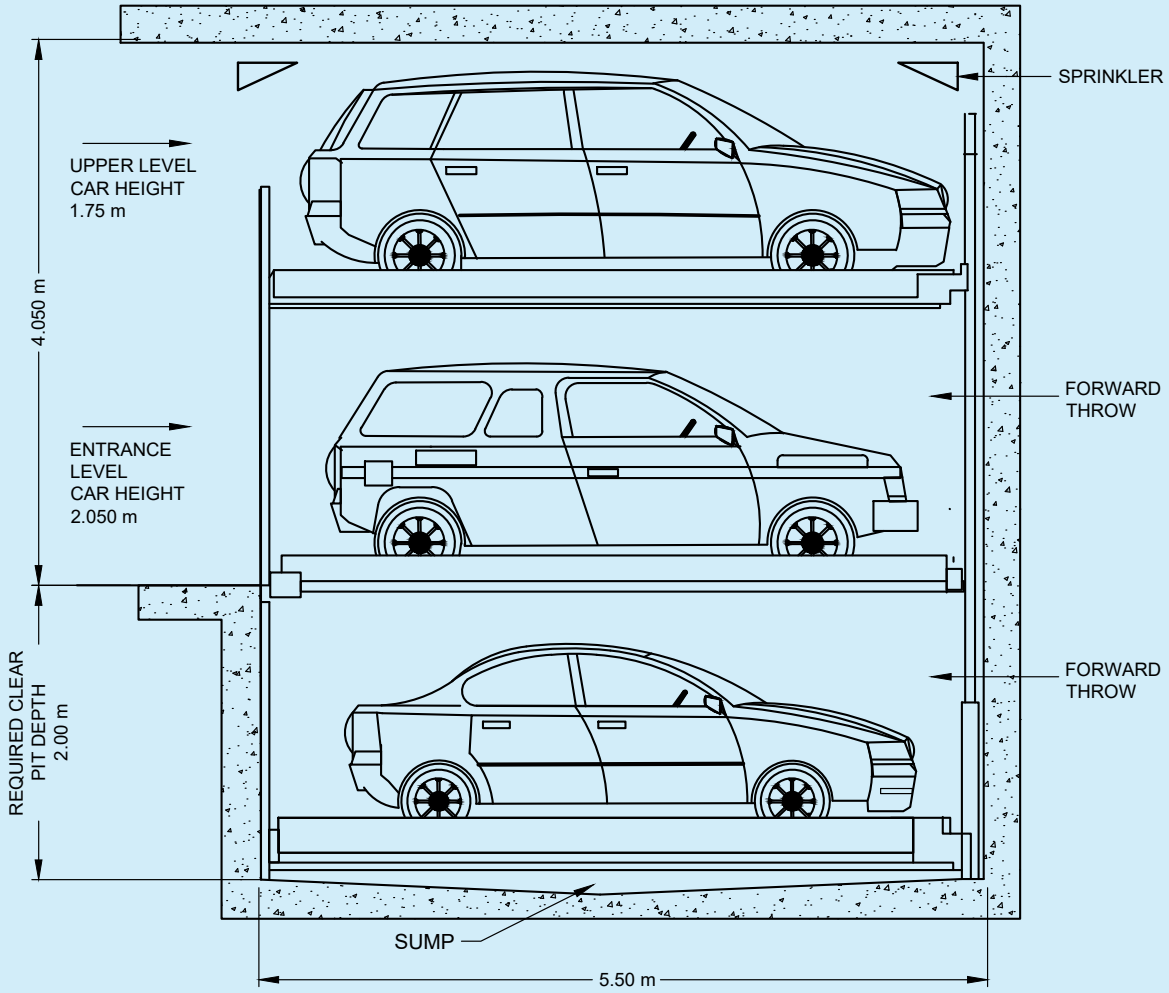

FIG. 6 CROSS-SECTION SHOWING FREE SPACE FOR SERVICES LIKE FIRE SPRINKLERS

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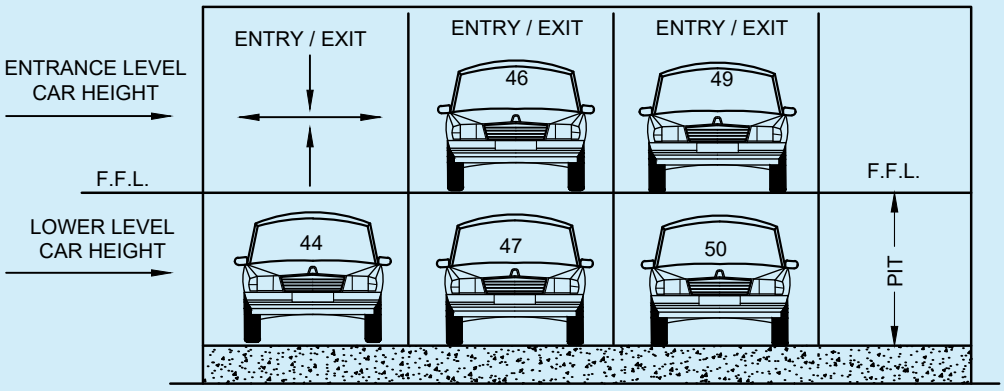

FIG. 7 ARRANGEMENT OF PUZZLE WITH PIT

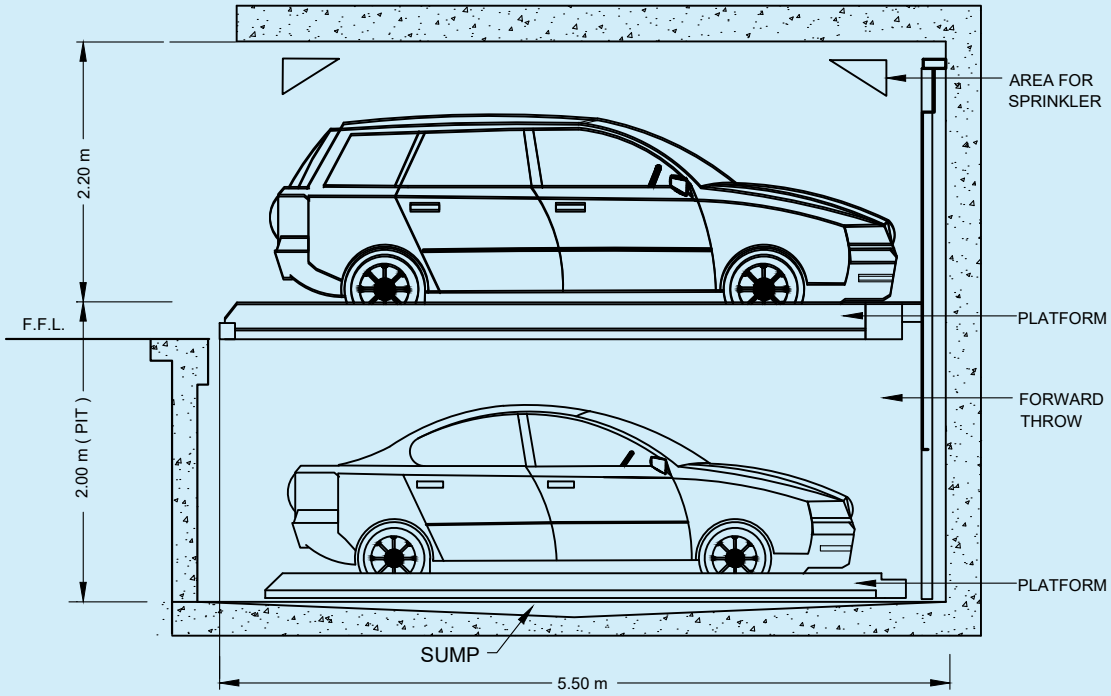

FIG. 8 CROSS-SECTION SHOWING FREE SPACE FOR SERVICES LIKE FIRE SPRINKLERS

4.4 Automatic Tower Parking System — Inside RCC Shaft and Free Standing Structure

Automatic tower parking system is a vertically oriented automated parking system designed to efficiently utilize space by stacking vehicles in a slender tower. The system combines mechanical and automation technologies to transport vehicles to the designated parking spots within the tower. Foundation shall be evaluated as per structural stability norms (*refer* Part C 'Structural Design, Section 2 Soils and Foundations' of this NBCS). Free standing tower, shall be enclosed within RCC framework for better stability.

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4.4.1 *Key Features and Components*

The following shall be applicable:

a) *System configuration* — The system features a central lift with various configurations including 1/1, 1/2, 1/3, 2/2, 2/3 and 3/3 arrangements, as illustrated in the system's design, *see* Fig. 9.

b) The lift facilitates the vertical transportation of vehicles to different levels within the tower.

c) *Entrance room* — Its location shall be positioned for convenient access to vehicles entering the parking tower thereby allowing smooth entry and exit of vehicles, facilitating the parking process.

d) *Car handling and turning* — Turntables or turning devices to rotate vehicles to ensure proper alignment for exit direction.

e) *Car hold area* — There shall be adequate space in front of the entrance room to accommodate vehicles during the parking and retrieval process.

f) *Car handling capacity* — The system should be able to handle approximately 25 cars to 30 cars per hour, with a full cycle of filling or evacuating the tower completed in about 3 h.

g) *Parking capacity* — The tower should have a capacity to accommodate up to 90 cars for optimum retrieval time.

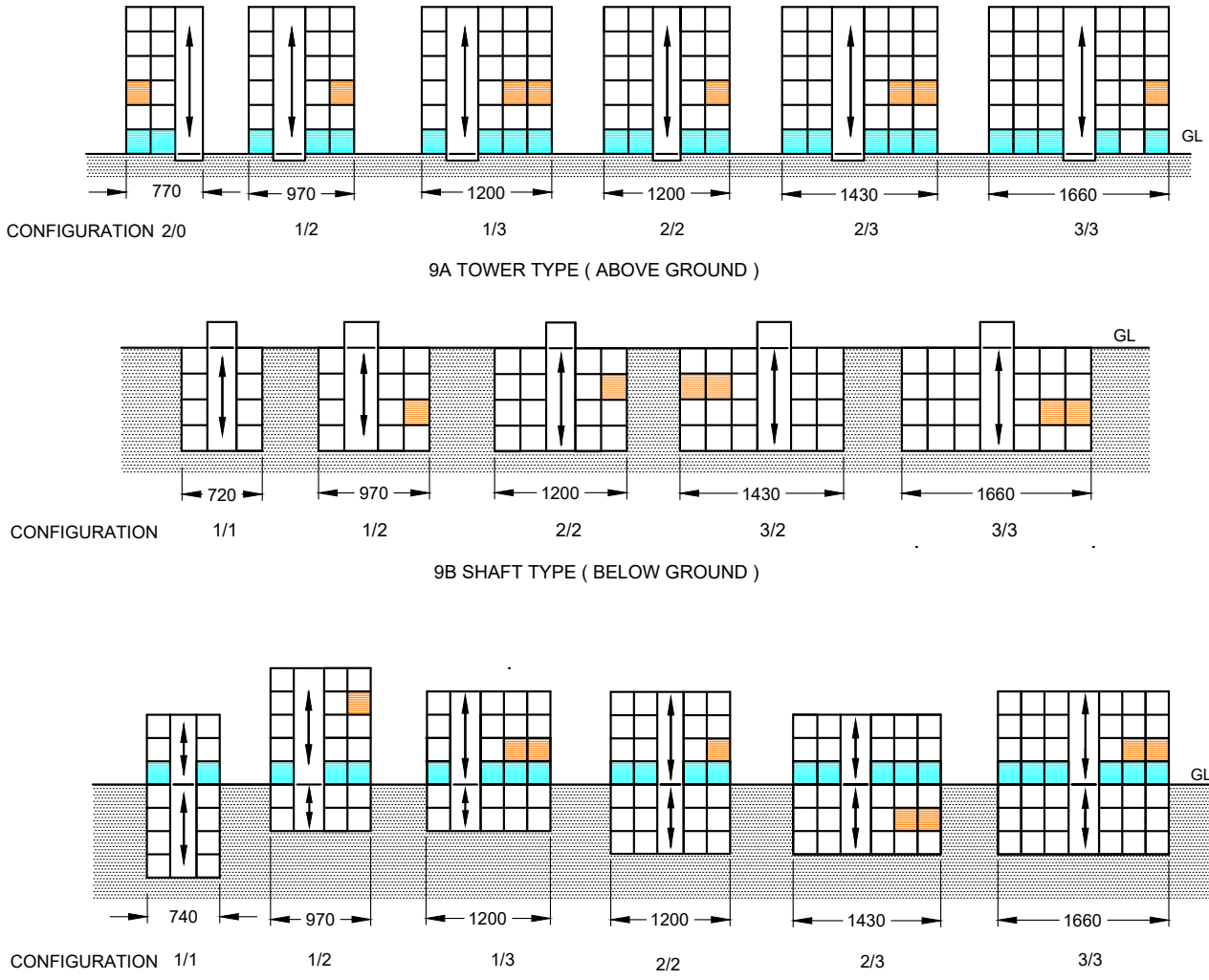

FIG. 9 VARIOUS ARRANGEMENTS DEPICTING THE SECTIONS/SLOTS FOR PARKING

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h) *Lift locking mechanism* — It should be ensured that the lift platform is securely locked before any vehicle transfer or retrieval operation is performed.

j) *Platform guide rails* — Closed-type guide rails shall be employed to provide stability and ensure safe vehicle movement within the tower.

k) *Platform locking mechanism* — Each platform guide rails should have built-in feature which includes an integrated locking mechanism to secure vehicles in place.

m) *Tower structure stability* — Proper anchoring of the tower structure should be ensured for stability and safety during operation.

n) *Illumination inside shaft* — Light points shall be installed every 6.0 m, controlled by 3-phase 16A switches to ensure adequate visibility inside the shaft.

p) *Sound and vibration control* — The vertical structure should be connected to the RCC with sound isolation pads to mitigate noise and vibration transmission.

q) *Shaft size* — The shaft dimensions shall be designed to accommodate large-size cars comfortably.

r) *Finish of the structure* — The structure should be finished with hot-dip galvanization and is fire-resistant for up to 120 min to ensure durability and safety.

s) *Entrance door* — Safety doors shall be able to withstand a force of 300 N applied perpendicular to the surface without permanent deformation or impairment of functionality. The force should be distributed evenly over an area of 500 mm^2.

4.5 Longitudinal Parking System

This is a parking system having lift at centre with front and back arrangement when there is more space available in length than in width. This system is thus considered and designed to maximize parking efficiency in narrow spaces, particularly in narrow broad strips between buildings, such as the area between the set-back lines and the building.

4.5.1 *Key Features and Components*

The following shall be applicable:

a) *Vehicle accommodation*:

1) *Car height and length* — The system shall be designed to accommodate various car heights and lengths, ensuring flexibility for different vehicle types; and

2) *Capacity* — The slim parking system shall be capable of parking up to 30 cars, depending on the specific design and available space.

b) *Design efficiency:*

1) *Floor plan* — The system shall be designed with a very small floor plan area and a slim construction, maximizing the use of narrow spaces; and

2) *Ramps and driveways* — No space-intensive ramps or driveways shall be required for this system, allowing for a more compact and efficient design.

c) *Configurations and arrangements*:

1) *Configurations* — The system shall offer configurations of 1/1 or 2/2, which are particularly suitable for the side margins of buildings;

2) *Above or below ground* — The system should allow for both above-ground and below-ground arrangements, depending on the site's requirements (*see* Fig. 10 and Fig. 11);

3) *Lengthwise transportation* — Vehicles shall be transported lengthwise with restricted levels to control the number of vehicles within the system; and

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4) *Capacity* — The longitudinal parking system shall have a capacity of around 30 cars, accommodating the needs of various building types.

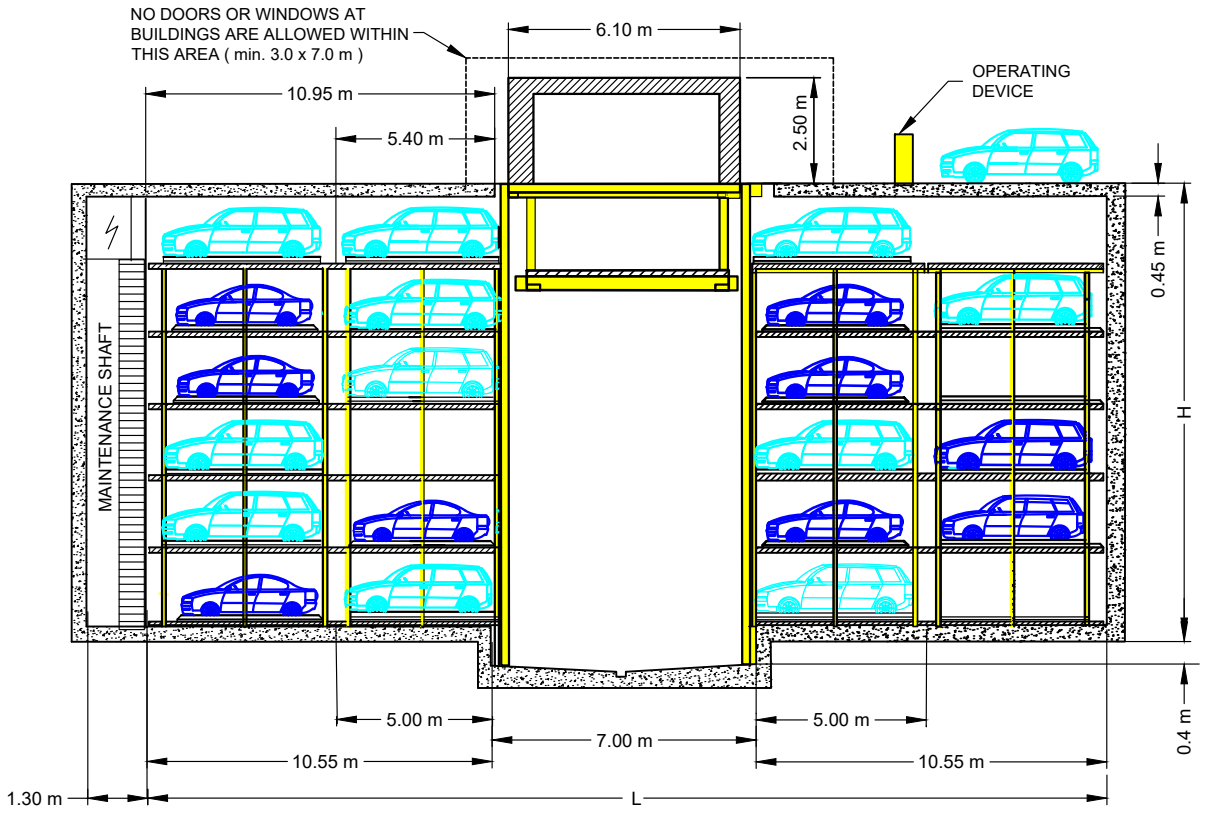

FIG. 10 ARRANGEMENT BELOW GROUND

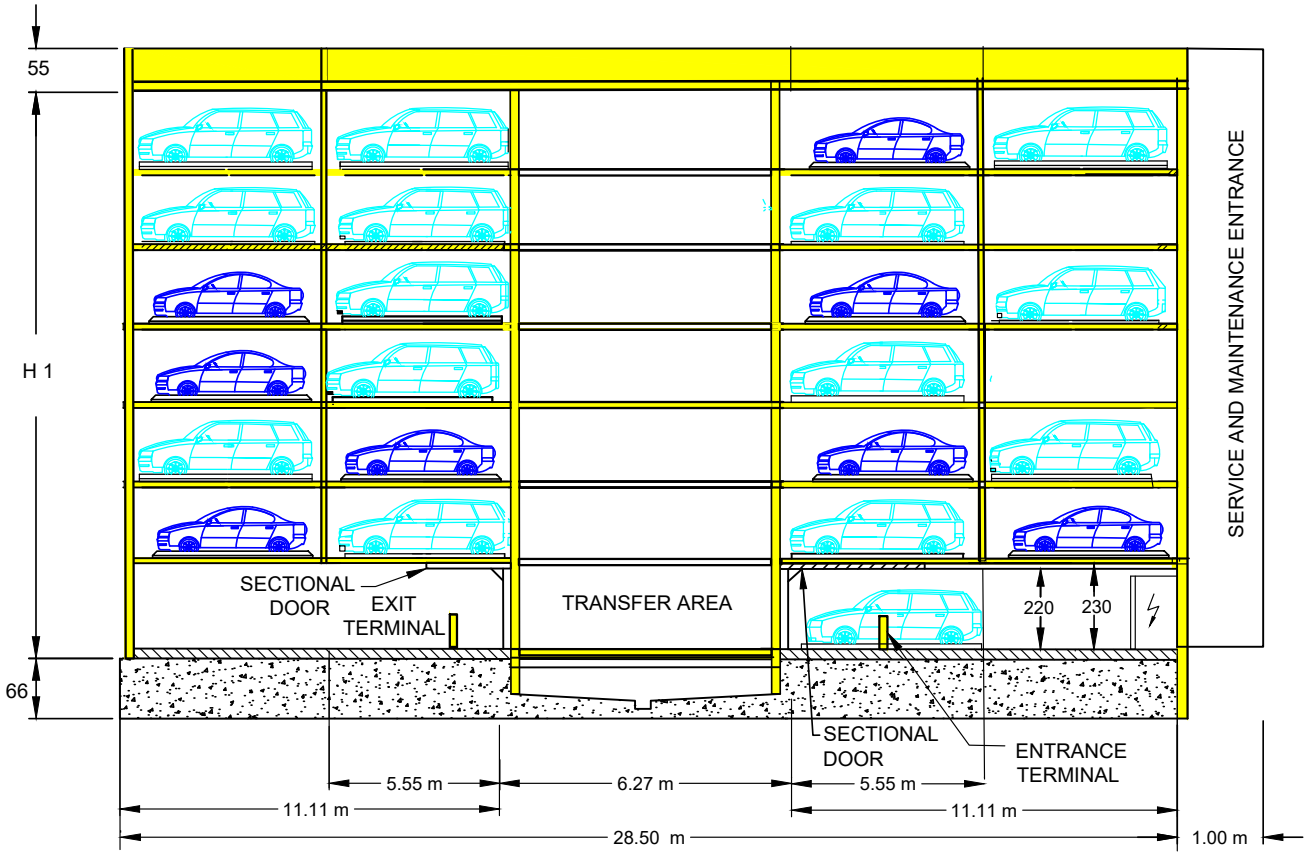

FIG. 11 ARRANGEMENT ABOVE GROUND

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4.6 Chess Parking System

The chess parking system, also referred to as the level parker, shall be employed in scenarios where vertical space is optimized for vehicle storage. This system features a vertical lift serving multiple levels, with vehicles being horizontally circulated in a loop and transported to an entrance room or transfer area. *See* Fig. 12 and Fig. 13 for details of typical arrangement of the vehicles and the operation sequence.

4.6.1 *Key Features and Components*

a) *Vertical lift* — The system shall be equipped with a vertical lift that serves various levels, enabling the vertical movement of vehicles within the parking structure;

b) *Horizontal circulation* — Vehicles shall be circulated horizontally in a loop, allowing them to be transported efficiently to the designated entrance room or transfer area;

c) *Synchronized movement* — All platforms within the loop shall move simultaneously in synchronization, ensuring the coordinated transportation of vehicles;

d) *Performance considerations:*

1) *Speed* — The chess parking system should be noted for its slower operational speed compared to other parking systems, as the synchronized movement of all platforms can reduce efficiency; and

2) *Power requirements* — The system shall require more power due to the simultaneous movement of all platforms in the loop.

e) *Design efficiency* — The following parameters to be considered for efficiency:

1) *Space utilization* — The system shall be designed to maximize vertical space utilization, making it suitable for locations with single entry and exit with efficient horizontal space utilization; and

2) *Loop configuration* — The loop configuration should be designed to ensure smooth and continuous movement of vehicles within the system.

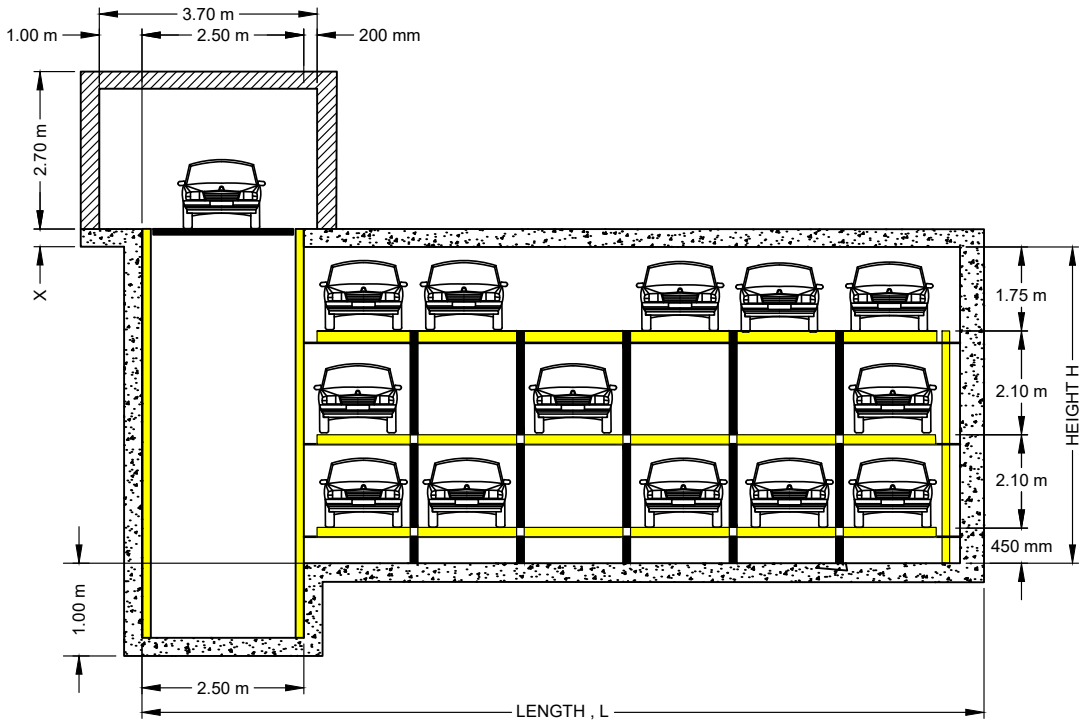

FIG. 12 CROSS SECTION SHOWING LIFT MOVEMENT AND PLATFORMS ARRANGEMENT

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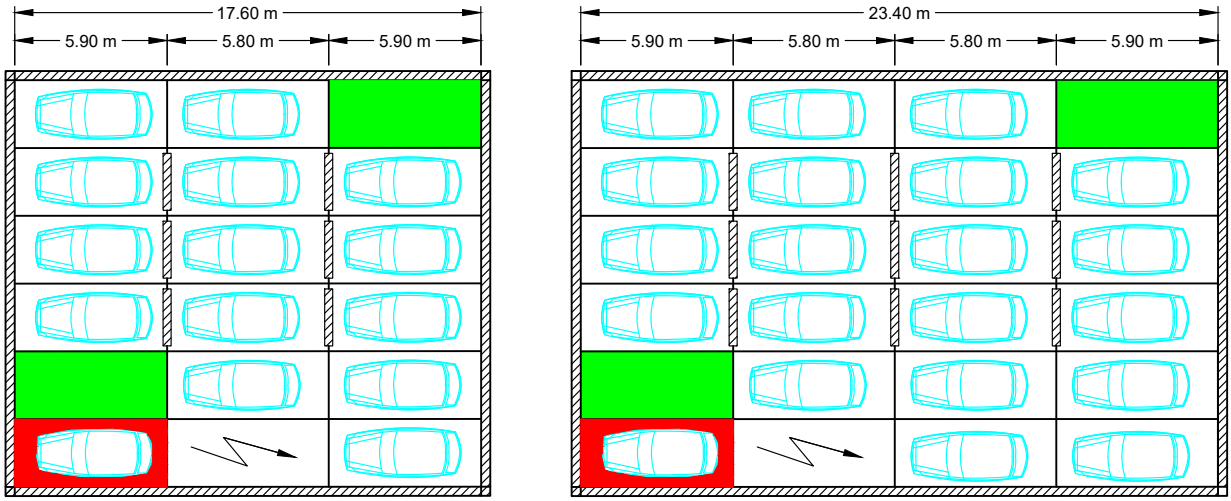

FIG. 13 ARRANGEMENT SHOWING MULTI-ROW ARRANGEMENT IN PLAN

4.7 Robotic Parking System

The robotic parking system is an advanced automated vehicle storage and retrieval system that shall utilize robotics technology to move vehicles efficiently within a parking facility. This system operates on the X, Y and Z axes, either with or without pallets, using steel or RCC structures. The system should ensure precise and swift car placement and retrieval, optimizing both space and time. Figure 14, Fig. 15 and Fig. 16 depict the typical arrangement in robotic parking system.

4.7.1 *With Pallets*

The following are the key features of this system:

a) *Parking arrangement* — Vehicles shall be parked on pallets, which shall remain engaged from the time of parking until retrieval. The system may be arranged above or below the ground, depending on the location of the entrance room;

b) *Structural requirements* — Steel structures used in this system shall be galvanized to ensure durability and protection against corrosion; and

c) *Installation flexibility* — This system shall be possible to install above ground, below ground, or with a combination of both, depending on site-specific requirements and design considerations.

4.7.2 *Without Pallets*

The following are the key features of this system:

a) *System movement* — The system shall operate on the X, Y and Z axes, with vehicles parked directly on RCC slabs or steel floor without the use of pallets. The system shall be faster in service as the car is transferred by a lift to the robot, utilizing a shuttle and dolly mechanism for movement;

b) *Noise reduction* — Parking vehicles on RCC slabs should help reduce noise levels compared to pallet-based systems, providing a quieter operational environment;

c) *Fire safety* — The use of RCC slabs between levels shall aid in controlling the spread of fire from one level to another, enhancing the overall fire safety of the system; and

d) *Installation flexibility* — This system shall be possible to install above ground, below ground or with a combination of both, depending on site-specific requirements and design considerations.

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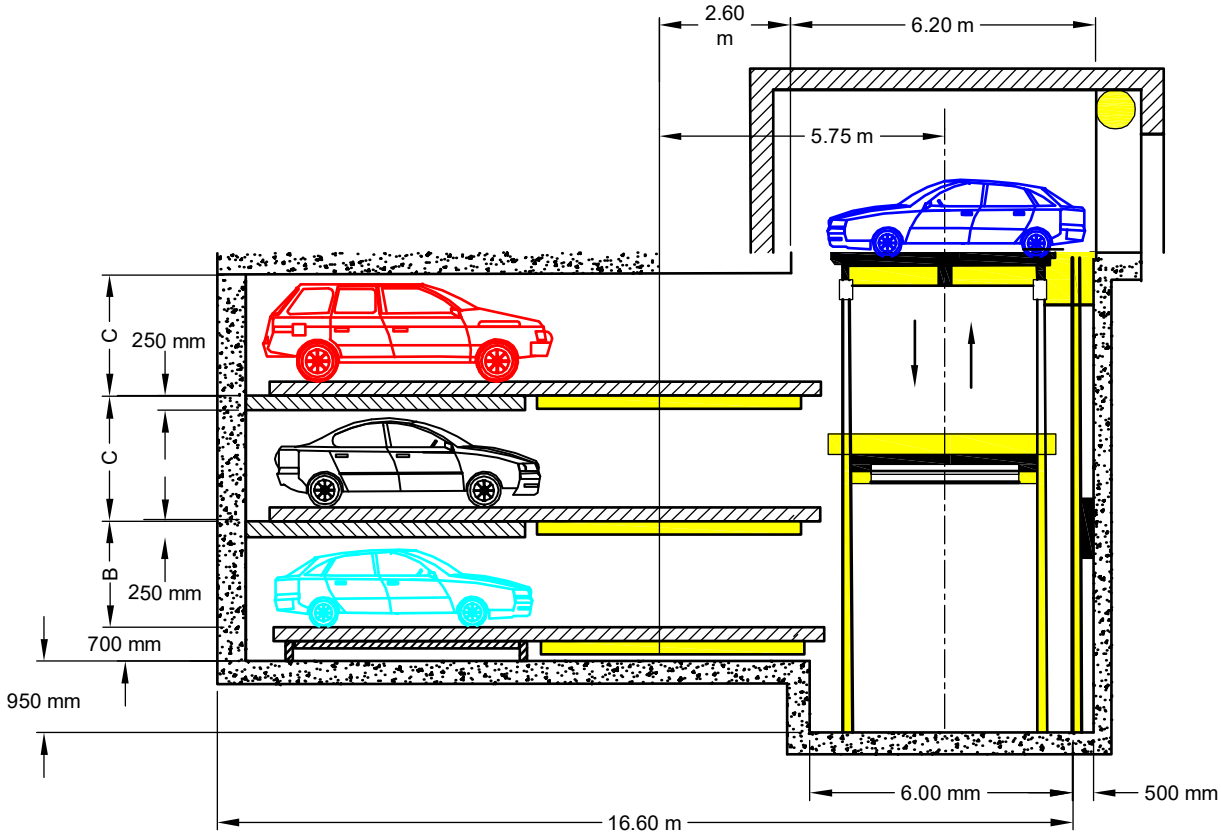
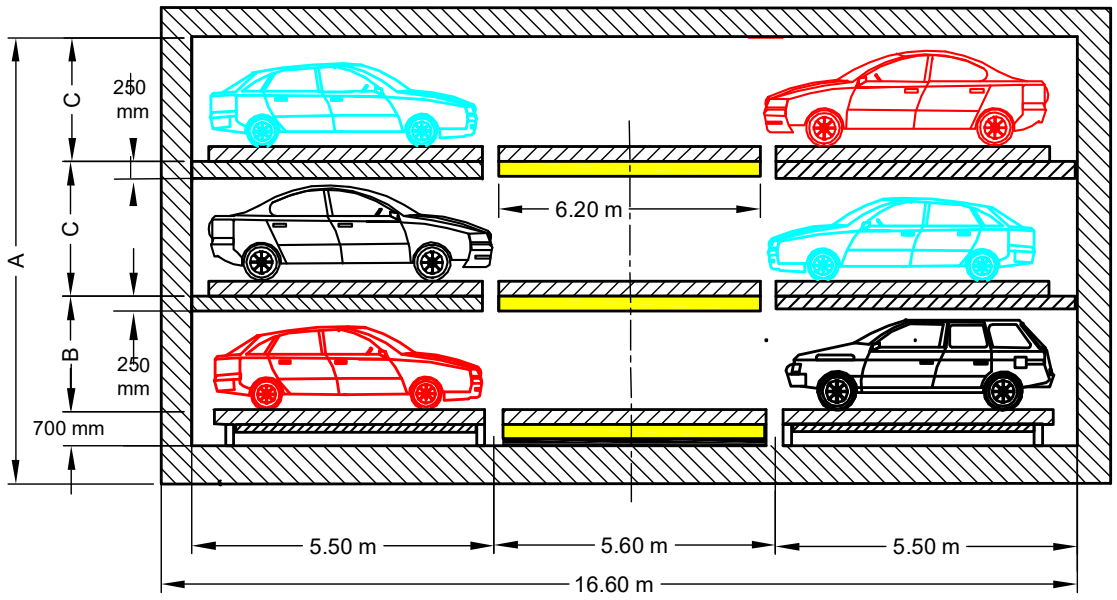


14 A WITH PALLETS



14 B WITHOUT PALLETS

FIG.14 ROBOTIC PARKING SYSTEM CROSS-SECTIONAL VIEW

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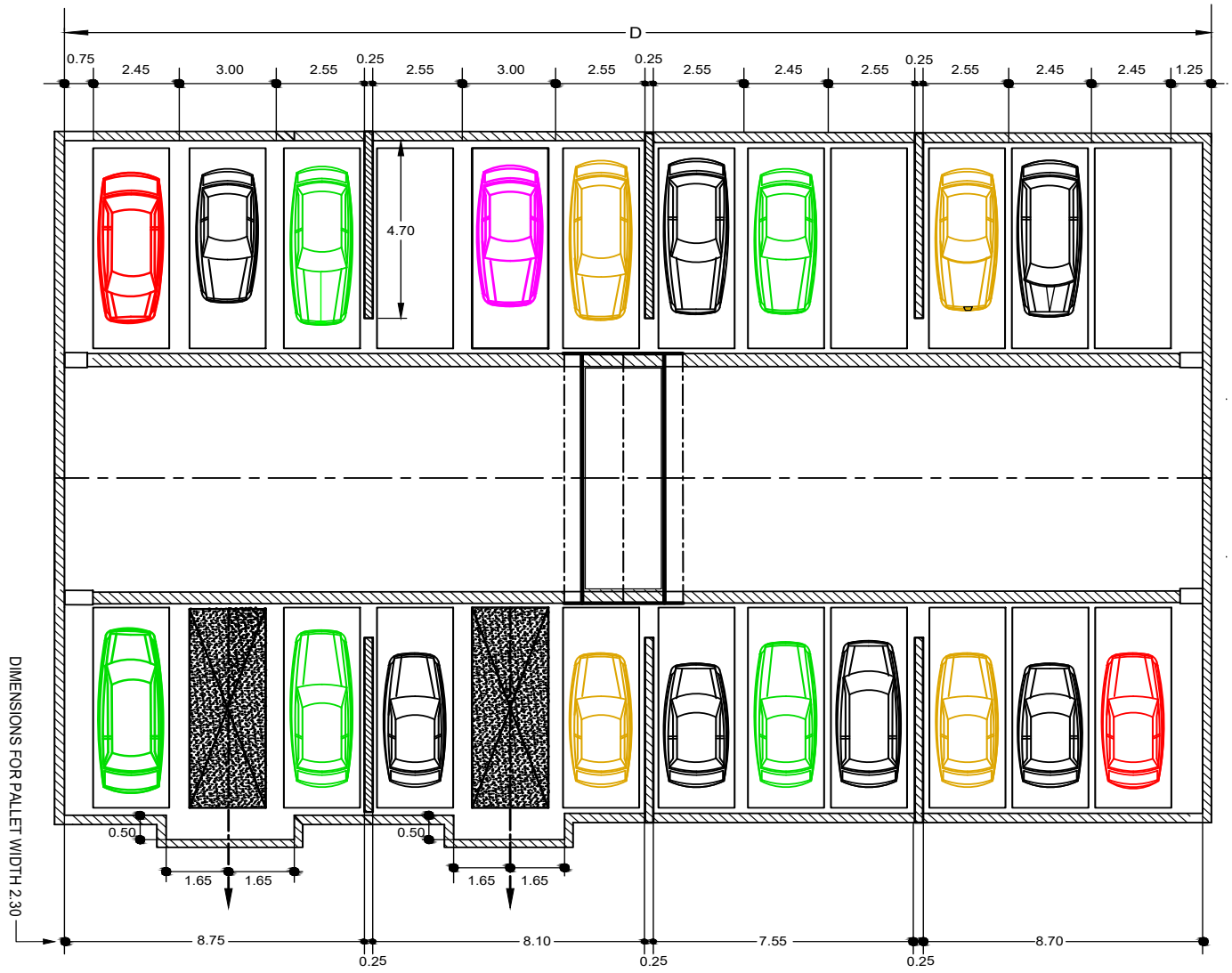

All dimensions in metres.

NOTE — For the control unit, space (at least length 2.40 m × width 1.60 m × height 2.20 m) must be available near the transfer area.

FIG. 15 ROBOTIC PARKING SYSTEM PLAN

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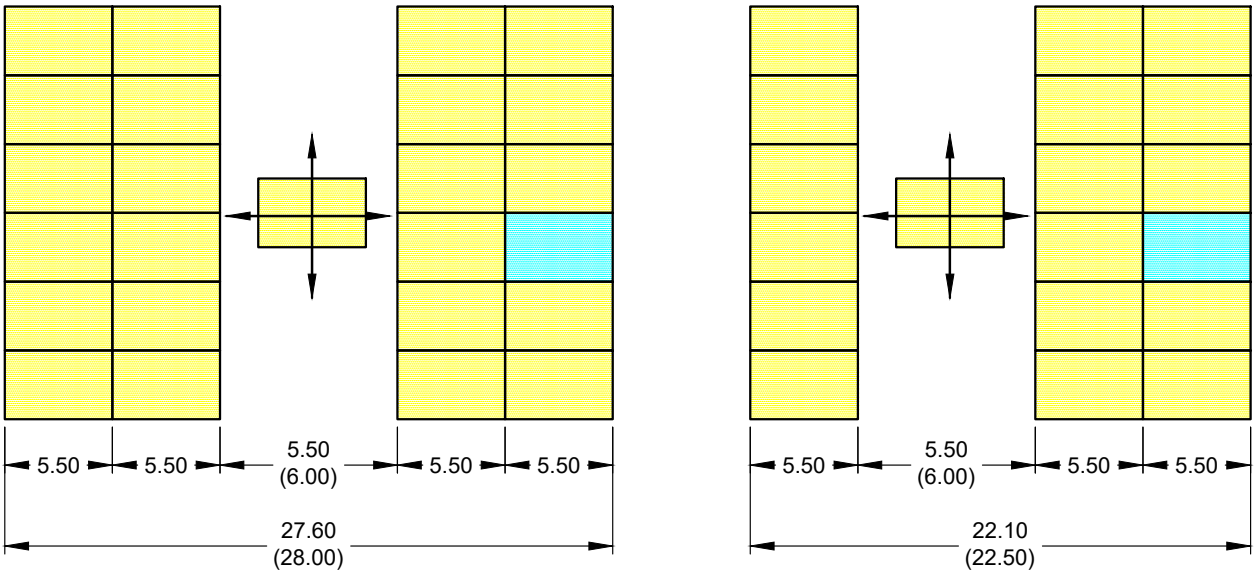
MULTI-ROW ARRANGEMENT



All dimensions in metres.

NOTE — The multi-row arrangement allows an optimum utilization of the available space and/or land area and saves construction costs, particularly with the shaft variant.

(DIMENSIONS IN BRACKETS ARE FOR STORAGE AND RETRIEVAL UNIT WITH TURNING DEVICE)

FIG. 16 POSSIBILITY OF MULTI-ROW ARRANGEMENT

4.8 Rotary Parking

The rotary parking system is a space-efficient vehicle storage solution designed for locations where ground space is limited, but vertical space can be utilized. This system operates by rotating vehicles (anticlockwise or clockwise) in a vertical loop, allowing multiple cars to be parked in a compact footprint.

4.8.1 *Key Features*

The following are important features of rotary parking:

a) *Anchoring and structure* — The rotary parking system shall be a free-standing type, securely anchored to the ground. This ensures stability and safe operation, even in areas with limited space or challenging terrain;

b) *Entry and exit* — The system shall provide entry and exit at the ground level for easy access by drivers. To ensure safety, the entry and exit points shall be protected by an entrance door or gate that automatically opens and closes as vehicles enter or exit the system;

c) *Rotational movement* — The parking platforms within the system shall rotate in both clockwise and anti-clockwise directions, allowing for flexible vehicle placement and retrieval. This bi-directional movement enhances the system's efficiency, enabling quicker access to parked vehicles; and

d) *Vehicle capacity and variations*:

1) *Capacity options* — The rotary parking system may be available in various configurations, typically accommodating up to 20 cars, among other possible variations. These options allow for customization based on the specific needs and space constraints of the installation site; and

2) *Vertical loop design* — Vehicles are rotated vertically in a loop, with each vehicle occupying a designated platform. The system shall be designed to minimize the time required for vehicle retrieval, ensuring that any vehicle within the system can be accessed quickly and efficiently.

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4.9 Sliding Platforms

These parking platforms are used to slide the car sideways or in longitudinal directions. Rails are placed directly on the flooring. Cars are parked on the platform and moved sideways.

5 PLANNING AND DESIGN GUIDELINES FOR PARKING SYSTEMS

5.1 Design Criteria for Power-Operated Parking Equipment

When designing or specifying power-operated parking systems, several critical design criteria shall be taken into consideration to ensure the safety, durability and efficiency of the equipment. These criteria are essential to accommodate various types of vehicles, ensuring smooth operation and long service life of the parking system.

5.2 Nominal Load Capacity

The nominal load capacity of the parking system should be designed to handle vehicles with a minimum weight of 2 000 kg and not more than 3 500 kg. This range is typical for most passenger vehicles and ensures that the system can safely accommodate both lighter and heavier cars within this spectrum.

5.3 Wheelset Load Distribution

The load on the wheelsets should be distributed evenly, with 50 percent of the nominal load allocated to the front and rear wheelsets. This balanced distribution is crucial for maintaining stability and preventing uneven stress on the parking platform.

5.4 Individual Wheel Loads

Each wheel should bear approximately 25 percent of the nominal load, ensuring that the weight is evenly distributed across all four wheels. This distribution minimizes the risk of overloading any single wheel, which could lead to mechanical failure or uneven wear on the system.

5.5 Wheelbase Specification

The design should account for a wheelbase of 2.90 m, measured from the centre of the front wheel to the centre of the rear wheel. This specification ensures compatibility with a wide range of vehicle sizes and provides adequate spacing for secure parking.

5.6 Track Gauge Requirements

The track gauge, or the distance between the wheels in width, should range from a minimum of 1.5 m to a maximum of 2.10 m. This range accommodates different vehicle widths while ensuring that the parking system can handle various car models without compromising stability.

5.7 Tyre Footprint Consideration

The tyre footprint, or the area of the tyre that comes into contact with the parking platform, should measure approximately 0.18 m by 0.18 m. This specification helps distribute the vehicle's weight evenly across the platform, reducing the risk of damage to the system.

5.8 Forces in Direction of Travel

The design should account for forces in the direction of travel equivalent to 1/7 of the nominal load in kilonewton (kN). This consideration is critical to ensure that the system can handle the dynamic forces exerted when vehicles move on or off the platform.

5.9 Transverse Forces

Forces transverse to the direction of travel should be considered as 1/20 of the nominal load in kilonewton (kN). While this does not exclude other design criteria, it ensures that the system can withstand lateral forces, such as those generated by turning or shifting vehicles.

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5.10 Load Considerations for Parking Equipment

When designing or specifying parking equipment, it is essential to consider the worst-case loads that may occur. These include loads from the stationary position of the vehicle on the platform as well as dynamic loads during transportation or when the vehicle is driving onto the platform. These considerations help ensure that the system is robust enough to handle peak stresses without failure.

5.11 Equipment Life Expectancy

The parking system should be designed for a minimum operational life of 20 years. This long-term durability requirement ensures that the system remains functional and reliable over an extended period.

5.12 Operation Cycle Requirements

The system should be capable of performing at least one parking-in and one parking-out operation per day, amounting to two cycles per platform or space. This cycle rate should be sustainable every day of the year, ensuring the system can meet the daily demands of a busy parking facility.

6 ARRANGEMENT AND PLANNING DIMENSIONS

6.1 Grid and Rows

When planning and designing parking systems, it is essential to define the maximum number of rows and grids to ensure optimal space utilization and system efficiency. The arrangement of grids and rows in a parking module impacts the capacity and operational effectiveness of the parking system (*see* Fig. 17).

6.1.1 Maximum Number of Rows

The parking system shall not exceed a maximum of four rows to maintain manageable distances for vehicle retrieval and to ensure safety and accessibility within the parking structure.

6.1.2 *Maximum Number of Grids*

The maximum number of grids shall be as given below:

a) *One-row system* — A module with a maximum of 15 grids should be utilized. However, it is advisable to limit it to no more than 10 grids to maintain ease of access and operational efficiency;

b) *Two-row system* — The module should contain no more than 10 grids to ensure that vehicles can be parked and retrieved with minimal obstruction;

c) *Three-row system* — The system should be designed with a maximum of 6 grids to allow for sufficient manoeuvring space within the parking structure; and

d) *Four-row system* — A limit of 4 grids per module should be adhered to for optimal operation and safety.

6.1.3 *Control Panel Requirements*

An additional control panel shall be installed after every maximum of 5 grids on either the left or right side of the parking system as shown in the Fig. 17. This requirement ensures that users can conveniently operate the system and enhances the safety and usability of the parking setup.

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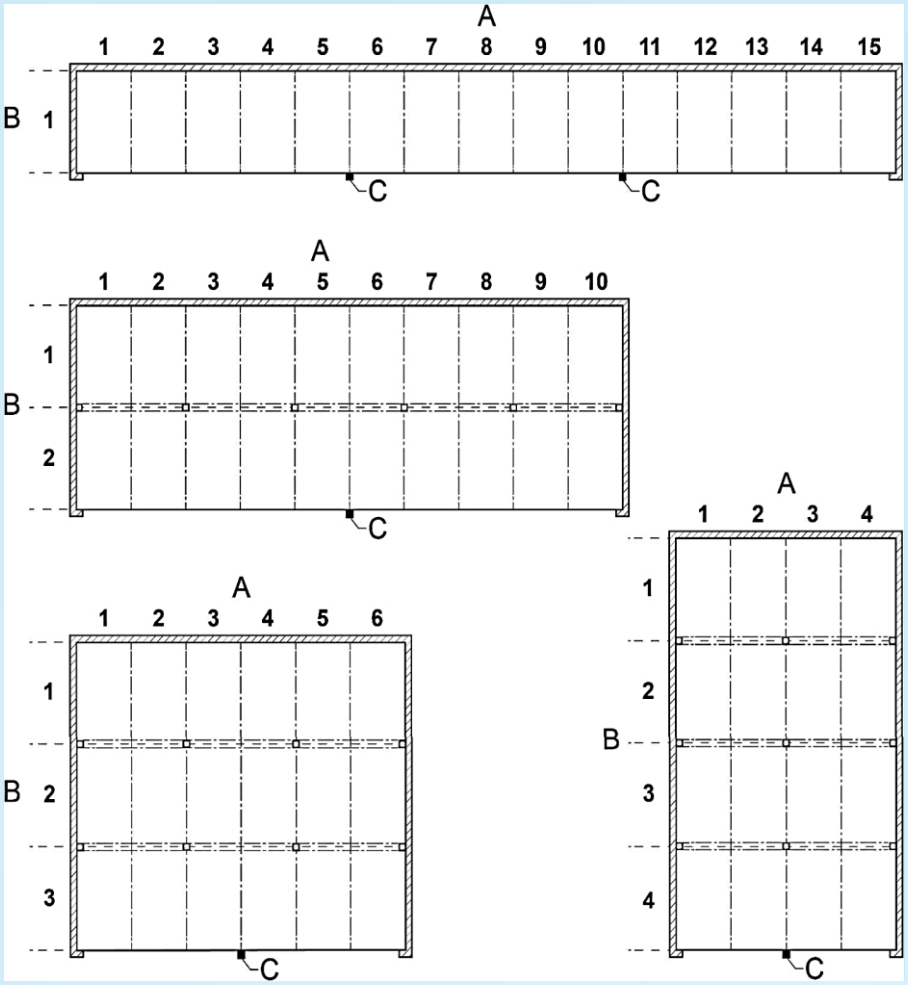

Key

Grid Horizontal parking spaces

Rows Back-to-back parking arrangement

C Indicates control panel

FIG. 17 GRID AND ROWS IN PARKING SYSTEM

6.2 Arrangement and Planning

The suggested guidance on the arrangement and planning of the parking requirements are given above; *see also* Fig. 17.

6.2.1 *Open Parking Spaces*

Open-to-sky parking areas may be permitted in side margins or in the surrounding open spaces of a building.

6.2.2 *Closed Parking Spaces*

Parking areas within the building line, in basements or on lower ground or podium levels inside the building.

6.2.3 *Automatic Parking Spaces*

Unmanned areas where vehicles are transported from the entrance room by means of mechanical systems such as conveyors, lifts, etc and transported back to the exit room. The parking area may be clearly demarcated with a

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reflective paint and driveways shall be connected to all the parking areas.

6.2.4 *Car hold area*

The space between the entrance from the connecting road to the actual parking area shall be considered as the storage space or car hold area.

6.2.5 *Entrance and exit room*

This room should be properly ventilated and illuminated.

6.2.6 *Width of Parking Area*

The clear width of a parking space shall be not less than 2.7 m for small cars, such as sedans and hatchbacks. The clear width of a parking space shall be not less than 2.9 m for large cars, such as sport utility vehicles (SUVs). Typical layouts of parking spaces are illustrated in Fig. 20.

6.2.7 *Ramps and Driveways*

For curvatures and circular ramps or driveways, the inner radius shall be 5.0 m. Wider driveways with an inner radius of approximately 10.0 m should be considered for safety purposes (*see* Fig. 18).

6.2.8 *Pedestrian Walkway*

In large parking areas, a separate pedestrian walkway of 0.8 m next to driveways shall be considered, which should be raised above the main parking level or marked permanently and illuminated for visibility and safety.

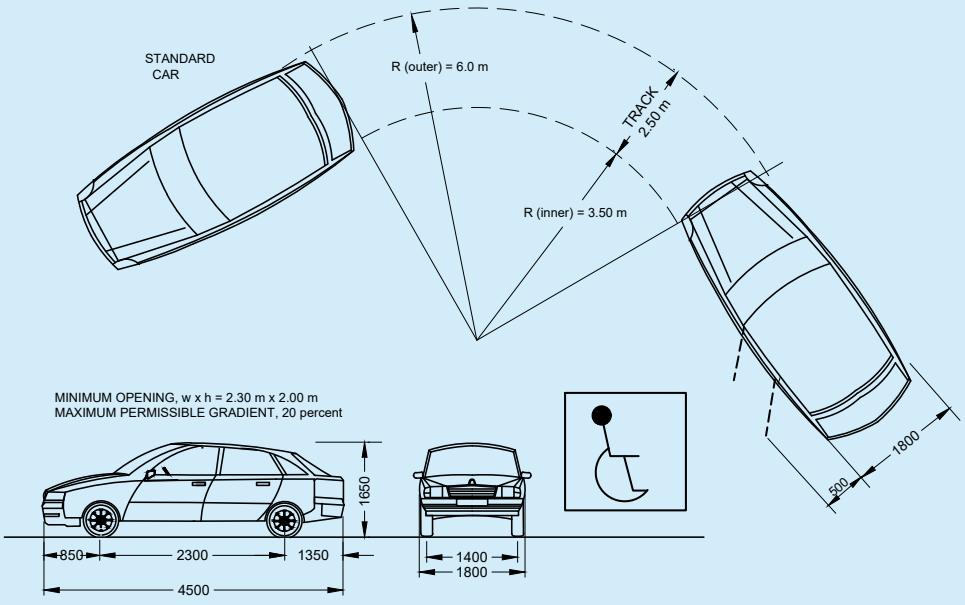

FIG. 18 PARKING SPACE DIMENSIONS

6.2.9 *Slope of the Ramps*

The inclination of ramps shall not exceed 15 percent or a 1 : 8 ratio. The recommended slope is 1 : 10. The width shall not be less than 2.75 m, and at least 3.5 m in circular or curved areas for single-lane traffic. The joint at the start and end of the ramp shall have a slope of 3 percent with proper curvature to ensure smooth travel and prevent vehicles from hitting the bottom or nose of the car. For public parking, a slope not exceeding 10 percent (1 : 10 ratio) should be considered. An extension of at least 3.0 m in front of the ramp shall be provided (*see* Fig. 19).

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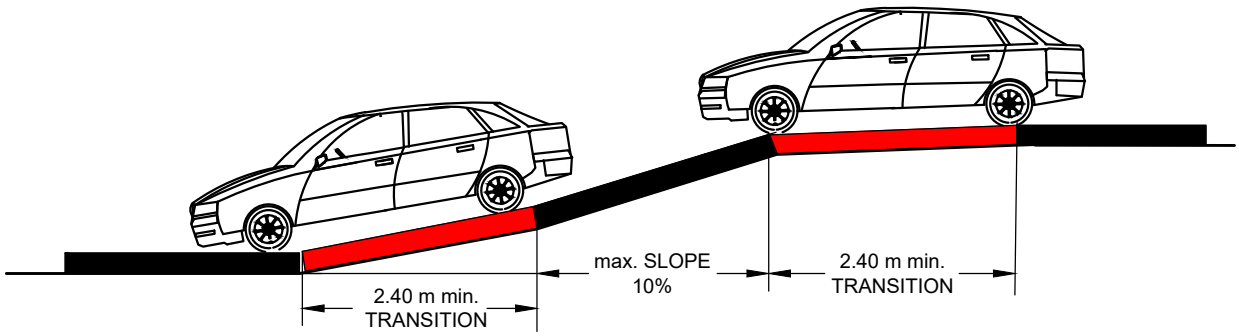


FIG. 19 TRANSITIONAL RAMP

6.2.10 *Size of Parking Space and Women Parking Space*

The length of car parks shall be 5.0 m, and parking arranged alongside driveways shall be at least 6.0 m wide. The entire parking space may be designed as a column-less structure for safety.

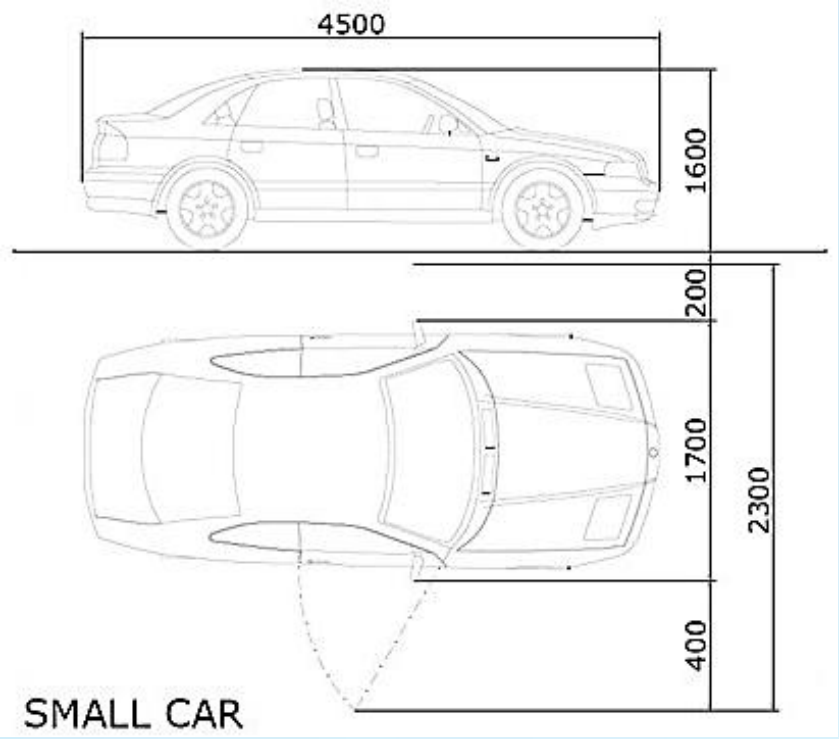
6.2.11 *Parking Space*

The minimum width for parking spaces shall be 2.3 m for small cars (*see* Fig. 20A) and 2.5 m for big cars (*see* Fig. 20B). For power-operated mechanized parking systems, at least 0.2 m of space on either side shall be added to the above basic widths. *See also* Fig. 20:

a) *Small cars* — 2 300 mm × 5 000 mm (clear space + additional space of 400 mm for mechanized clearance);

b) *Big cars* — 2 500 mm × 5 500 mm (clear space + additional space of 400 mm for mechanized clearance); and

c) *Clearance for door opening* — Minimum of 400 mm on the driver's side for normal parking and 1 000 mm for persons with disabilities.



20A FOR SMALL CAR

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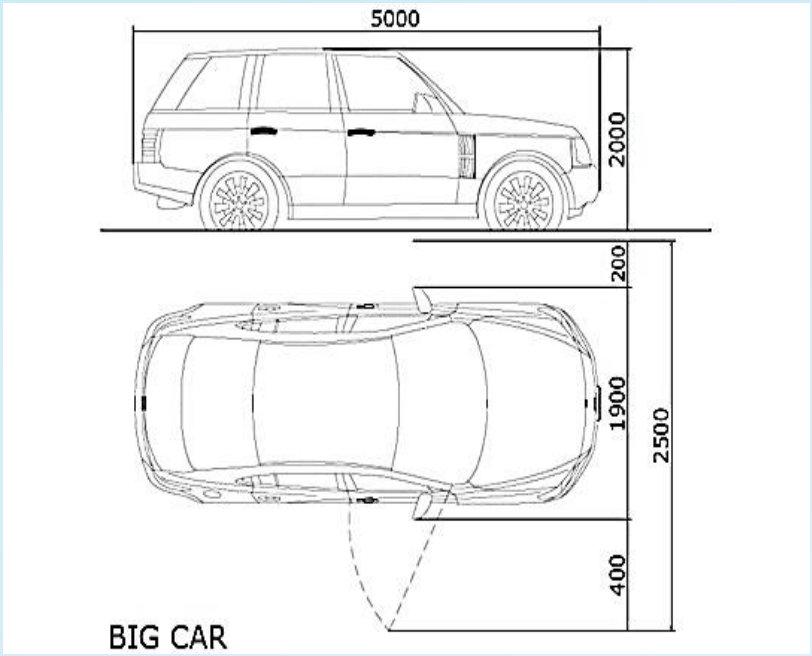

20B FOR BIG CAR

FIG. 20 PARKING SPACE DIMENSION

6.2.12 *Reserved Parking for Persons with Disabilities*

Parking spaces for the persons with disabilities shall be as per and shall be considered as conventional parking having size 3 900 mm in width with 5 400 mm in length. One to two percent of the parking spaces shall be reserved as per local norms and the type of project, located close to the barrier-free entrance and as close as possible to the ramp and passenger lifts. The area shall be highlighted with signages.

6.2.13 *Driveway Width for* 90 *Degree Entry*

The driveway width shall be at least 6.5 m in front of mechanized systems.

6.2.14 *Single Driveways/Passing Driveways*

Single driveways where parking is not connected shall be at least 2.75 m wide and for two-way traffic, the width shall be at least 5.0 m.

6.2.15 *Identification of Driveways*

Parking systems and driving aisles shall be clearly marked. The signage indicating entry/exit direction of driveways shall be permanently marked and illuminated. *See* Fig. 21 for guidance.

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FIG. 21 MARKINGS IN DRIVEWAYS AND PARKING SPACES

6.2.16 *Demarcation of Parking Space*

Parking spaces shall be marked with numbers on the floor to facilitate easy identification of parking spots.

6.2.17 *Reserved Parking for Women*

Ten percent of the parking spaces in large parking area shall be reserved for women drivers and should be located near access ramps/roads, preferably in areas free of columns or other obstructions.

6.2.18 *Clear Height for Pedestrian Passage*

A clear passage height of 2.2 m in pedestrian areas shall be maintained and clearly marked with signages on the floor.

6.2.19 *Escape Route*

Every medium-sized and large-sized parking spaces shall have at least two independent escape routes on each floor. The second escape route may lead through ramp. In parking areas above ground, one escape route is sufficient. External staircases shall be arranged.

6.2.20 *Stairway*

At least two staircase or exit to the open air shall be provided from each floor. Permanent and easily recognizable signage/indications of exits shall be provided. General electric lighting shall be provided to ensure an illuminance of at least 20 lux in escape routes and driving aisles. Solar-powered illumination should be considered for environmental sustainability.

6.2.21 *Emergency Lighting in Parking Area*

Emergency lighting, with a backup power source independent of the mains supply, shall switch on automatically in the event of a power failure. The lighting shall be designed for at least 1 h of operation with an illuminance of at least 20 lux or shall be provided with fluorescent markings that offer adequate illumination for at least 1 h, leading to exits in an easily recognizable manner.

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7 SAFETY REQUIREMENTS

7.1 Safety Doors

Parking systems employing pit type designs shall be protected by safety doors to ensure user safety and system integrity.

7.1.1 *Strength of Safety Doors*

The safety doors shall have mechanical strength in the closed position, capable of withstanding a force of 300 N applied at any point perpendicular to the door surface on either side, evenly distributed over an area of 500 mm^2. This force should not cause permanent deformation of the door or impair its normal function. The height of the safety doors shall be considered as 2.0 m unless restricted by a car height of less than 2.0 m. This requirement does not apply to emergency access doors for automatic systems. The size of the emergency access doors may be restricted to 0.65 m in width and 2.0 m in height. If the main door(s) is intended to be closed manually by the user, the control devices shall be located such that the door is visible from the operating position. Safety devices shall not be easily accessible to users. The safety device preventing the door from opening shall be designed as an interlock. The movement of the load-carrying means shall not be possible until the locking device(s) has/have engaged by at least 7 mm. The latch shall resist without permanent deformation or release of the latch when a force of 1 000 N is applied at the height of the latch in the direction of the door opening. The latch shall remain engaged and held permanently in position. Electromagnets, pneumatic and hydraulic devices shall not be used as retainers.

7.2 Operation of Parking Facilities

7.2.1 *General Operation*

The following lists the general operations in the semi-automatic parking facilities:

a) The user parks the motor vehicle in the transfer area;

b) The motor vehicle shall be automatically stored;

c) The motor vehicle shall be automatically made available for retrieval; and

d) The user retrieves the motor vehicle and drives out of the transfer area.

7.2.2 *Design of Transfer Area*

For permanent users, the design of the system shall allow the main door to be opened by signals from outside, such as remote control, magnetic card, induction loop, manually operated control devices, or mobile terminals. The particular door from which a ‘PARKING IN’ or ‘PARKING OUT’ call is registered shall open.

7.2.3 *Checking the Vehicle Dimensions*

The user shall ensure that the maximum vehicle dimensions and weights, as specified in the operating instructions, are not exceeded.

7.2.4 *Closing the Main Door*

The following illustrates the steps involved for:

a) *For manually operated doors* — The user shall exit the motor vehicle and leave the transfer area through the main door. The user shall check that no person remains in the transfer area before manually closing the main door; and

b) *For power-operated doors* — The user shall exit the motor vehicle and leave the transfer area through the main door. The user shall check that no person remains in the transfer area before closing the main door using the designated control device, such as a magnetic card or manually operated control device. Access during the closing process shall be monitored by a light barrier sensor.

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7.3 Safe Practices

7.3.1 *Monitoring by System Operator*

The user should not remain in the car for an extended period and shall exit the car within 45 s. The operator shall ensure adherence to this practice for safety.

7.3.2 *Automatic Malfunction Detection Devices*

Semi-automatic parking facilities shall be equipped with one or more automatic malfunction detection devices designed and installed to minimize the risk of unsafe operation. When any fault or hazardous condition is detected, an appropriate audible and/or visible warning shall be provided to the user or operator. The equipment shall be immediately stopped using the emergency safety button located on the operation panel. Restarting the equipment shall only be possible by maintenance personnel and under the control of all safety devices.

7.3.3 *Operating Modes*

The changeover from automatic mode to any other operating mode shall only be carried out by authorized or instructed persons. The changeover to safety-related operating modes shall comply with all safety requirements.

7.3.4 *Safety Monitoring and Testing*

The following aspects shall be adhered to:

a) *Type test* — Verification of the machine type to determine whether the parking system meets the requirements;

b) *Individual testing* — Testing each parking system in order to ensure compliance with safety requirements before putting it in operation and handing over to end user;

c) *Design test* — Checking whether the design of the parking system or its components meets the functional requirements;

d) *Visual inspection* — Determining the presence of required safety features on the machine, system, or component, and ensuring that provided documents meet the functional requirements;

e) *Measurements* — Ensuring that specified measurable parameters, such as geometric dimensions and safety distances, are met; and

f) *Operational test* — Verifying that the parking system operates as intended and that all safety devices function correctly during a normal cycle or part of a cycle without load.

7.4 Safety Devices

Parking systems shall be equipped with the following safety devices to ensure the safe and efficient operation of the equipment:

a) *Limit switches* — These shall be installed to detect and control the movement of the parking platforms in the upward direction, preventing them from exceeding their designated range of motion;

b) *Non-return valve* — This shall be integrated into the hydraulic system to prevent the unintended lowering of the platform in the event of a hydraulic failure, ensuring that vehicles remain securely positioned;

c) *Wheel stoppers* — Wheel stoppers shall be provided at the end of each parking bay or platform to prevent vehicles from rolling off the platform. These shall be of sufficient strength and size to securely hold the vehicle in place;

d) *Locker* — These shall be fitted in the vertical guide rail element of the parking system to stop the downward movement in case of brake failure;

e) *Electromagnetic locks* — These shall be used to securely lock the platforms or gates in place when the parking system is not in operation, preventing unauthorized movement or access;

f) *Car height sensor* — A car height sensor may be installed to detect the height of the vehicle and ensure it is compatible with the parking system's designated height restrictions, preventing potential collisions with the platform or ceiling;

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g) *Car in-out sensor* — These sensors shall detect the presence of a vehicle entering or exiting the parking bay, ensuring that the system operates when it is safe to do so; and

h) *Emergency stopper* — An emergency stop device should be provided at accessible locations within the parking area to immediately halt the operation of the system in the event of an emergency, preventing accidents or injuries.

7.5 Wiring Practices

Wiring practices for power-driven parking equipment, including the connections to the disconnection means from the power supply, shall adhere to the guidelines outlined in Part 1 of good practice [D-5C(1)] and [D-5C(2)]. The electrical equipment of the parking system shall comply with the good practice [D-5C(4)]. The earthing and bonding connections shall be as per the good practice [D-5C(3)] and lightning protection of the parking system shall comply with accepted standard [D-5C(5)].

7.5.1 Wiring methods both inside and outside of enclosures shall be clearly identified and marked to prevent incorrect connections that could result in hazardous conditions, such as unintended movement direction or disruption of safety devices.

7.5.2 Whenever possible, external wiring shall be positioned away from combustible materials and areas where it might be subject to mechanical damage. In situations where this cannot be avoided, the wiring shall be protected using appropriate means such as rigid conduits, flexible tubing, raceways or other suitable protective methods.

7.5.3 Electrical equipment shall be designed, marked, and arranged to minimize the risk of incorrect connections, which could lead to injury. Proper care shall be taken to ensure all connections are safe and correctly executed.

7.6 Essential Safety Guidelines for Operation of Parking Systems

Apart from the operational mechanisms, the following essential safety guidelines shall be observed for the successful and safe operation of various parking systems.

7.6.1 *Maintenance Doors*

Properly designed maintenance doors are critical to ensure safe access for inspection and repair without compromising system integrity. The following requirements shall apply:

a) In fully automatic systems, a separate maintenance door shall be provided in addition to the main door. This door shall be openable only from outside by authorized persons with a key and from inside without a key;

b) Maintenance doors shall not open inwards into the working area and shall be provided with appropriate electrical connection; and

c) When the maintenance door is opened, the parking equipment shall automatically stop by means of a safety switch or equivalent device. Restarting of the equipment shall only be possible when the service door is closed and shall be carried out by authorized personnel.

7.6.2 *Access and Inspection*

Safe and reliable access routes are essential for regular inspection, servicing and emergency interventions. Accordingly, the following provisions shall apply:

a) A separate staircase shall be externally installed, with access provided at every alternate level for inspection; and

b) Emergency doors for accessing the system shall be provided with electrical/electronic controls to switch off the system.

7.6.3 *Selector Switches*

Selector switches shall be located outside the working area with free access for changeover from mains supply to alternate power source.

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7.6.4 *Safety Guards*

Fixed enclosure guards or interlocking guards shall be provided to protect persons from hazards such as crushing, shearing, entanglement or entrapment.

7.6.5 *Walkways, Control Stands and Platforms*

Safe access routes shall be ensured during installation. Permanent access to control panels and parking areas shall be provided in accordance with applicable building safety norms.

7.6.6 *Illumination of Working and Transfer Areas*

Adequate lighting is vital to maintain visibility, safety and ease of operation in both working areas and transfer areas. The following requirements shall apply:

a) Working areas where maintenance, inspection, cleaning, and lubrication are to be carried out shall be properly illuminated, with a minimum of 100 lux; and

b) The transfer area shall be adequately illuminated between 40 lux and 60 lux. Lighting in the transfer area may automatically switch off after closing of the main door.

7.6.7 *Safety Railings*

Safety railings of minimum 1 m height shall be provided in stack and puzzle parking systems to prevent accidental access to open spaces around the system.

7.6.8 *Operating Instructions*

Clear operating instructions shall be displayed at suitable locations.

7.6.9 *Restricted Entry*

Unauthorized persons shall be prevented from entering the transfer and working areas during system operation.

8 VENTILATION AND FIRE SAFETY REQUIREMENTS FOR PARKING SYSTEMS

8.1 Mechanical Exhaust Air Systems

8.1.1 Mechanical exhaust air systems shall be required in closed medium-sized and large parking areas. The supply air openings shall be distributed to ensure sufficient ventilation throughout all parts of the parking areas. If the supply air openings are inadequate, a mechanical supply air system shall be provided.

8.1.2 The mechanical exhaust air systems shall be dimensioned to ensure that the half-hourly mean value of carbon monoxide (CO) concentration in the air, measured at a height of 1.5 m above the floor, does not exceed 100 ppm. This requirement shall be deemed satisfied if the exhaust air systems in parking areas with low ingress and egress traffic discharge at least 6 m^3 of exhaust air per hour per m^2 of usable parking area. In other garages, the system shall discharge at least 12 m^3 of exhaust air per hour per m^2 of usable parking area.

8.1.3 Mechanical exhaust air systems shall be equipped with at least two equally sized fans in each ventilation system, which together shall provide the required total volume flow during simultaneous operation. Each fan of a mechanical supply or exhaust air system shall be supplied from a separate circuit, to which no other electrical systems shall be connected. If the ventilation system is temporarily operated with only one fan, the fans shall be switched in such a way that in the event of failure of one fan, the other fan automatically switches on.

8.2 CO Monitoring and Warning Systems

8.2.1 Large enclosed parking areas with substantial incoming and outgoing traffic shall have CO measuring and warning systems. The CO warning systems shall be designed to prompt users to switch off their engines through acoustic signals and flashing signals if the CO content in the air exceeds 250 ppm. These CO warning systems shall be connected to a backup power source.

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8.3 Safety Notices

8.3.1 In enclosed medium-sized and large parking areas, the following notices shall be prominently and permanently displayed at the entrance and on each floor:

"EXHAUST FUMES ENDANGERS HEALTH.
AVOID PROLONGED STAY."

8.4 Fire Safety Provisions

8.4.1 Fire extinguishing systems, smoke and heat extraction systems, and fire alarm systems should be provided in accordance with the requirements specified in Part F 'Fire and Life Safety' of this NBCS.

8.4.2 Automatic parking areas with more than twenty parking spaces shall be equipped with sprinkler systems. For automatic parking areas with less than twenty parking spaces, power-operated lifting platforms that allow vehicles to be stacked, and parking spaces separated from tramlines by closures, non-automatic fire extinguishing systems shall be provided. The type of system shall be determined on a case-by-case basis in consultation with the fire protection authority, ensuring that all parking spaces within the parking areas can be reached with an extinguishing agent in every operating state.

8.4.3 Enclosed medium-sized and large parking areas shall be equipped with fire alarm systems if they are connected with structural installations or rooms for which fire alarm systems are required.

8.4.4 Fire extinguishing systems may also be required for enclosed medium-sized parking areas if necessary for deploying fire lines for flammable substances or electrical lines connected to the fire tank.

8.4.5 A sprinkler system shall be installed in all parking areas, regardless of size (small, medium or large) and shall be designed to cover all parked vehicles effectively. This requirement also applies to automatic parking areas with more than twenty parking spaces. The sprinkler system should preferably not be positioned at the immediate centre (S2 as depicted in Fig. 22) of the top area with respect to the parking system. Instead, it should have some eccentricity from the centre position (S1 and S3 as depicted in Fig. 22) to enhance effectiveness in the event of a fire, ensuring better coverage and rapid response.

8.5 Ventilation Requirements

8.5.1 Natural ventilation for parking system installed at ground or above natural ventilation shall be considered.

8.5.2 Natural ventilation for parking system installed below ground for low traffic, natural ventilation may also be sufficient.

8.5.3 *Ventilation Openings and Shafts* (*for Fully Automatic Systems*)

Permanent ventilation openings or ventilation shafts, with a total free cross-section of at least 0.15 m^2 per parking space, shall be provided up to a height of 2 m to ensure proper air circulation. These provisions shall comply with the requirements outlined in the local building code to maintain safety standards and mitigate fire risks.

8.6 Restrictions on Parking Locations

Motor vehicles shall not be parked in stairwells or generally accessible corridors, including ramps.

9 SPECIAL TECHNICAL REQUIREMENTS

This is considered for special applications of parking; for example, parking systems within the side margins of the existing buildings. These systems can be considered above or below the flooring within the side margins

9.1 Cantilever Systems

These systems are also installed within side margins, however due to its construction, the systems are not suitable for long life.

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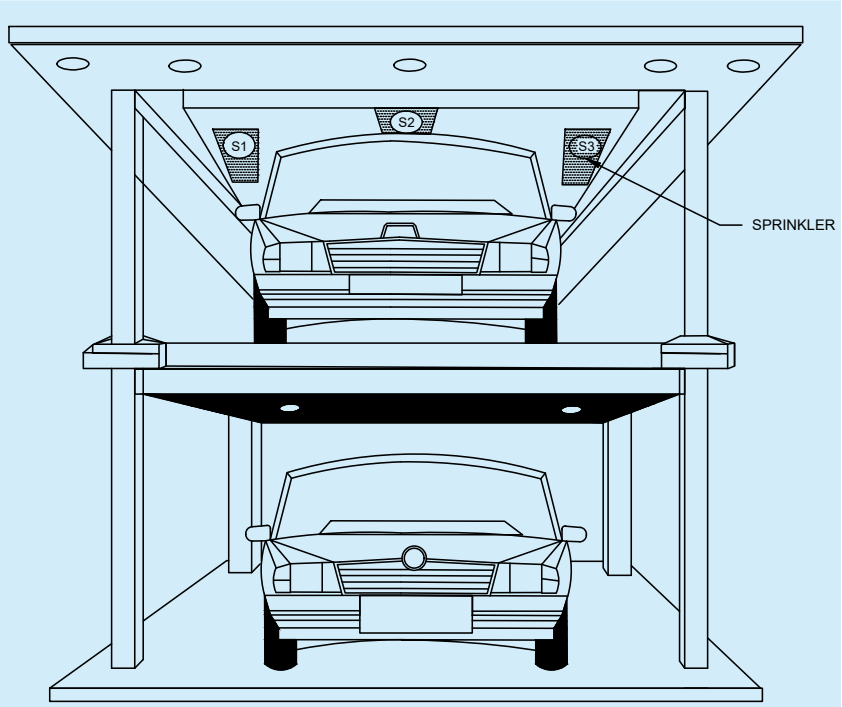

FIG. 22 PREFERRED SPRINKLER SYSTEM POSITIONING (AT S1 AND S3) IN THE UPPER LEVEL

9.2 Suspended Systems

These systems are hung from top connected through building beams and are not safe.

10 PERFORMANCE REQUIREMENTS FOR PARKING SYSTEMS

10.1 Design Considerations

When designing or specifying parking equipment, consideration shall be given to the worst-case loads that may arise from both the stationary position of a motor vehicle on the platform or load-carrying equipment, as well as during the vehicle's movement on the load-carrying equipment, where such movement may cause higher stresses.

10.2 Service Life Definition

The parking system shall be designed to meet the following minimum service life criteria:

a) Service life : 20 years

b) Cycle definition : 1 parking in and 1 parking out operation

c) Cycles per day : 2 cycles per platform or space

d) Operating days per year : 365 days

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used for conformance with the requirements of the referred clauses in this NBCS.

In the following list, the number appearing in the first column within parenthesis indicates the number of the reference in this Part/Section.

	IS No.	*Title*
(1)	SP 30 : 2023	National Electrical Code of India 2023
(2)	IS 732 : 2019	Code of practice for electrical wiring installations (*fourth revision*)
(3)	IS 3043 : 2018	Code of practice for earthing (*second revision*)
(4)	IS 16504 (Part 1) : 2019/ IEC 60204-1 : 2016	Safety of machinery — Electrical equipment of machines: Part 1 General requirements (*first revision*)
(5)	IS/IEC 62305-1 : 2010	Protection against lightning: Part 1 General principles
	IS/IEC 62305-4 : 2010	Protection against lightning: Part 4 Electrical and electronic systems within structures

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 6 INFORMATION AND COMMUNICATION ENABLED INSTALLATIONS

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part D/Section 6) covers the essential requirements for information and communication enabled installations, technology systems and cabling installations in a building. It also covers the basic design and integration requirements for telecommunication spaces within building/buildings along with their cabling infrastructure, their pathway components and passive connectivity hardware. It also includes general requirements relating to installation of different wireless and wireline communication equipment, cable terminations, power connections and general guidelines required for planning and providing information and communication technology (ICT) services in the building at the planning and execution stages. The provisions given herein are basic requirements applicable to all residential and other buildings. These can be used at the time of upgradation of existing buildings for properly accommodating telecom systems/services. Buildings meant for data centres and those for housing telecom exchanges/facilities for offering public services may have various other considerations. For such buildings, provisions of this Section are indicative and may be a subject of actual requirements.

Telecommunication plays a vital role in modern society similar to electricity, water, gas, and transport systems. It is difficult to imagine a life without telecommunication technologies. In a building, a broad variety of telecommunication systems are expected to be installed. Buildings have provision for installation of various utilities. However, unlike traditional utilities, telecommunication systems are constantly evolving at a rapid pace.

Telecommunications connectivity can be delivered through cable, wire, optical fibre, fixed wireless and mobile wireless technologies. Each of these technologies when considered for use inside buildings, especially when the buildings are either commercial or multi-dwelling units or complexes, places its own requirement in terms of building space, power supply, internal extensions to various work areas/dwelling units. For example, for wire line services, broadband cable television, etc. The entry to the buildings/complexes will be through underground cables and the distribution of services further into the complexes will be from the bottom of the building to the upper stories. On the contrary, any wireless technologies, where antennas are to be installed at terrace along with a system which can distribute the signals through cables or in building solutions, the flow of cables will be from top storeys of the building to the bottom. Keeping in view that there are multiple telecom service providers (TSPs), there is growing need for provision of seamless wireless services to the users at public buildings such as airport, malls, hospitals, railway stations by sharing infrastructure without any discrimination.

The telecom facilities can be chosen by the user from the gamut of technologies and associated features as options are available based on the requirement, cost, service and maintenance convenience, future upgradation requirements, user preference, quality of service/experience etc. While providing telecom enabling infrastructure in the building, the provisions are to be made for making the infrastructure supportive for multiple technologies/ products and the requirements of telecom service providers. Use of building management system (BMS), access control, surveillance, and creation of ‘Smart’ building will require significant telecom infrastructure to be created within the buildings which may be supported by M2M communication technologies. Individual/tenant users of the building may also have their own M2M/IoT systems with wireline or wireless (cellular, satcom, wifi, loRa, zigbee, and other wireless protocols) gateways. The telecom support infrastructure in the buildings/campuses needs to be responsive and accommodative of these requirements.

In order to facilitate installation/upgradation of telecom systems, proper planning and understanding of enabling provisions for telecom technologies and physical infrastructure are necessary. Modern telecommunication technologies such as distributed antenna system, in-building solutions (using technologies for example wifi 6/6E or higher versions, cellular 4G/5G and beyond) are also to be considered during the building planning stage itself and providing shared access to multiple telecom service providers as per demand by end users. The enabling infrastructure may include cable riser systems, conduits, cable trays, fibre management systems, passive and active infrastructure, distributed antenna system (DAS), etc. Appropriate space need to be earmarked for installation of equipment at the entry point of service and running the cables, etc, through shafts and horizontal conduits inside the walls, centre of the corridors and centre of the work space, etc. Thus, cabling pathways infrastructure should be designed to be of general nature but flexible enough to accommodate a variety of current and future telecom systems and emerging technologies.

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Choice of service to be provided inside the complexes/buildings will depend on the users. As already mentioned above, the delivery of service can be spread across technologies and across various service providers. Therefore, the arrangement for telecommunication infrastructure needs to be made in such a manner that the requirements and the challenges of at least near future (say 10 years) can be met without disturbing or retrofitting the building infrastructure. This Section has been formulated to cover these aspects.

In the formulation of this Section, due weightage has been given to international coordination among the standards and practices prevailing in different countries, in addition to relating it to the practices in this field in this country. This has been done by deriving assistance from the publications of ISO, IEC, ITU, TEC, TRAI Regulations and DOT Orders/Guidelines, etc.

Considering all the above, this Section was introduced in 2016 as a part of National Building Code of India to address the essential requirements for information and communication enabled installations and the related.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

In line with technological advancements and evolving connectivity requirements, significant modifications have been made to the section on ICT installations in buildings, in this version of NBCS. These updates aim to address current demands for faster data transfer rates, advanced wireless standards, and improved maintenance protocols to ensure robust and reliable ICT infrastructure. The significant changes incorporated in this revision include:

a) The table on balanced twisted-pair cabling channel performance is updated to reflect maximum data transfer rates, aligning with present-day bandwidth demands and ensuring future readiness;

b) A new provision on meshed bonded networks, which provide enhanced immunity to electromagnetic interference (EMI) and are recommended for environments with high-density ICT equipment, in **4.1.1**;

c) A new clause **A-6** is included on overview of in-building solutions (IBS), including distributed antenna systems (DAS), leaky feeder cables, and small cells, to enhance indoor wireless connectivity in areas with weak signals. It also includes key considerations such as coverage requirements, interference management, capacity planning, and aesthetic integration to ensure seamless indoor mobile connectivity;

d) A new informative Annex B on street furniture that highlights the use of streetlights, utility poles, bus stops, traffic signals, etc to support ICT infrastructure; and

e) A new Annex C on building related information and digital connectivity requirements has been introduced.

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **'accepted standard'** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practices [D-6(1)] refers to the Indian Standard(s) give at serial number (1) of the list of standards given at the end of this Part D/Section 6, that is, IS 9537 (Part 2) : 1981 'Specification for conduits for electrical installations: Part 2 Rigid steel conduits'

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART D BUILDING SERVICES

SECTION 6 INFORMATION AND COMMUNICATION ENABLED INSTALLATIONS

1 SCOPE

1.1 This NBCS (Part D/Section 6) covers the essential requirements for information and communication enabled installations, technology systems, cabling installations, and other passive and active equipment in a building. It also covers the basic design and integration requirements for telecommunication spaces within building/buildings along with their cabling infrastructure, their pathway components and passive connectivity hardware considering future requirements including flexibility requirement for installation of active infrastructure by the service providers.

1.2 It also includes general requirements relating to installation of different communication equipment, cable terminations, power connections and general guidelines required for planning and providing information and communication technology (ICT) services in the building at the planning and execution stages. The provisions given herein are basic requirements applicable to all residential and other buildings. These can also be used at the time of upgradation of existing buildings for properly accommodating telecom systems/services. Buildings meant for data centres and those for housing telecom exchanges/facilities for offering public services may have various other considerations. For such buildings, provisions of this Section are indicative and may be a subject of actual requirements. Introduction of street furniture as a crucial enabler of ICT infrastructure, leveraging existing structures like streetlights, utility poles, and bus stops to support small cells and air fibre for enhanced connectivity has been made.

NOTE — In this Section, 'Telecom' has been used interchangeably with 'ICT', as most of the time there may be only telecommunication hardware present. Apart from the provision of telecommunication systems, Information Technology (IT) system in the building may be either common for the building or separate for the individual users. In case the entire building is used by the same user, the IT system may be common and thus IT space for Building Management System (BMS), CCTV, etc, can be shared with telecom facilities. In case where individual IT systems owned by several users are provided, separate spaces may be earmarked inside telecom spaces for individual IT infrastructure. Sometimes, individual users may also use the common IT facilities. However, the cabling, wiring, etc, for IT systems should use the same pathways, which are used for telecommunication hardware.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

2.1 Access Point — A hardware device or a computer's software that acts as a communication hub or as an interconnection port for users of wireless devices to connect them to a wired or wireless local area network (LAN).

2.2 Antenna — An electrical device designed to transmit or receive radio waves or more generally, electromagnetic waves for the purpose of radio frequency communication such as Wi-Fi, radio, television, satellite communication, radar communication and mobile communication. This is also called an aerial.

2.3 Attenuation — A general term that refers to any reduction in the strength of an electrical/electromagnetic signal.

2.4 Backbone — A high-capacity facility (for example, pathway, cable or conductors) which acts as a major pathway within a network from which further smaller capacity facilities get distributed.

2.5 Backbone Cabling Media Distribution and Building Pathway — A part of a building premises telecom cable distribution system that provides connection between telecommunications spaces. It typically provides building connections between floors in multi-storeyed buildings as well as campus connections in multi-building environments.

2.6 Building Management System — It is a low voltage automation or remote control system installed for managing different building sub-systems like, heating, ventilation, lighting, air conditioning, fire protection, access control, etc.

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2.7 Bus Bar — It refers to thick strips of copper or aluminium, in electrical power distribution that conduct electricity within a switchboard, distribution board, substation, or other electrical apparatus.

2.8 Coaxial Cable — A type of wire that consists of a centre wire surrounded by insulation and then a grounded shield of braided wire. The shield minimizes electrical and radio frequency interference.

2.9 Consolidation Point (CP) — A location for interconnection between horizontal cables extending from building pathways and horizontal cables extending into furniture pathways.

2.10 Cross-Connect — A facility enabling the termination of cable elements and their interconnection or cross-connection.

2.11 Distributed Antenna System (DAS) — It is a system that uses network of physically or spatially separated antennas to extend radio coverage of any technology inside a building.

2.12 Direct to Home (DTH) — The direct reception of satellite programs using small dish antennae (personal dish) placed on a roof or window of a house.

2.13 Frequency — The measurement of the number of times that a repeated event occurs per unit of time.

2.14 Horizontal Cabling — It includes:

a) the cabling between and including the telecommunications outlet/connector and the horizontal cross-connect; and

b) the cabling between and including the building management system outlet or the first mechanical termination of the horizontal connection point and the horizontal cross-connect.

2.15 Horizontal Cabling Media Distribution and Building Pathway — It consists of the horizontal cabling in the building, the horizontal pathways supporting the horizontal cabling, and the telecommunications spaces that support the horizontal pathways. The use of the term horizontal in the name of the element does not require that the elements be placed or installed parallel to the ground or floor.

2.16 Horizontal Cross-Connect (HC) — A cross-connect of horizontal cabling to other cabling, for example, horizontal, backbone, and equipment.

2.17 In-Building Solution (IBS) — It is a telecom infrastructure solution designed to enhance indoor network coverage for mobile or fixed wireless or Wi-Fi network for seamless indoor connectivity. DAS can be a part of IBS.

2.18 Inside Plant (ISP) — Telecommunications infrastructure designed for installation, interior to the buildings.

2.19 Intermediate Cross-Connect (IC) — A cross-connect between first level and second level backbone cabling. First level backbone is a cable between a main cross-connect (MC) and intermediate cross-connect (IC) or horizontal cross-connect (HC). Second level backbone exists between an intermediate cross-connect (IC) and horizontal cross-connect (HC).

2.20 Internet of Things (IoT) — A network of all physical objects connected to internet primarily using M2M communication technologies.

2.21 Local Multipoint Distribution System (LMDS) — A broadband radio service designed to provide two-way transmission of voice, high-speed data and video (wireless cable TV) digitally through microwave.

2.22 Local Area Network (LAN) — A computer network covering a local area, like a home, office or small group of buildings.

2.23 Machine to Machine (M2M) Communication — It is a set of wired/wireless communication technologies which enable machine/device (for example sensor, meter, etc) to capture an event (for example temperature, motion, meter reading, etc) and relay through communication network to an application that translates the data from device to a meaningful information.

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2.24 Main Cross-Connect (MC) — A cross-connect for first level backbone cables, entrance cables, and equipment cables.

2.25 Main Distribution Frame (MDF) — A structure where all the copper wires, fibre or coaxial cables for a network terminates for patching/cross-connection on separate or composite frames.

2.26 Metropolitan Area Network (MAN) — A network designed to carry data over an area larger than a campus, such as an entire city and its outlying area.

2.27 Multichannel Multipoint Distribution System (MMDS) — A method of delivering multiple voice/data/television signals digitally by microwave transmission to subscriber households.

2.28 Multi-user Telecommunications Outlet Assembly (MUTOA) — A grouping in one location of several telecommunications outlet/connectors.

2.29 Optical Fibre — It refers to the medium and the technology associated with the transmission of signals/information as light pulses along a glass fibre.

2.30 Optical Distribution Frame (ODF) — Optical fibre distribution frame where ends of optical fibre terminates for further patching/cross-connection.

2.31 Outside Plant (OSP) — Telecommunications infrastructure designed for installation, exterior to the buildings.

2.32 Propagation Delay — In a communications system, it refers to the time lag between the departure of a signal from the source and the arrival of the signal at the destination.

2.33 Public Mobile Network — A network that is established and operated by a telecom service provider for the specific purpose of providing mobile telecommunications services to the public using technologies such as GSM, CDMA and LTE.

2.34 Radio Frequency — A frequency range from 20 kHz and above, used for transmitting/receiving text, data, audio, or video signals.

2.35 Server — Any computer on a network that contains data or applications shared by users of the network on their client terminals.

2.36 Splicing — The process of permanent joining of bare fibre end to another fibre by means of splicing tools.

2.37 Smart City/Building/Home — An innovative city/building/home that uses information and communication technologies, and other means to improve quality of life, efficiency of operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.

2.38 Telecommunication Spaces — The rooms and areas where telecommunications cabling systems are terminated, cross-connected and interconnected to installed telecommunications equipment. Various examples of these based on the function and areas, are equipment room (ER), telecommunications room (TR), entrance facilities (EF) and telecommunication enclosures (TE).

NOTE — The definitions of telecommunication spaces and workspace (*see* 2.46) are used for calculation of infrastructure requirements, facilities, etc. This does not inhibit the utilization of space for any other purpose. Depending upon the requirements, number of telecommunication spaces in a given building may vary for the same area.

2.39 Telecom Service Provider (TSP) — A service provider who is duly authorized by Government of India or its designated entity to operate telecom services.

For example, access service providers, telecom infrastructure providers (IP1s), internet service providers (ISP), virtual network operators (VNOs), satellite communication service providers, public data offices (PDO) and public data office aggregators (PDOA), or any other wireline, wireless, direct to home (DTH), cable service providers, IPTV service providers and any other service provider authorized by the government from time to time.

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2.40 Telecom Tower/Mast/Pole — A vertical structure for installation of antenna(e) that provide radio frequency air interface for telecommunications services. It can also be in the form of mast or multiple poles of varying height. Poles may be located at different points typically on the roof.

2.41 Telecommunication Media and Connecting Hardware — It consists of cables, equipment cords, patch cords, and connecting hardware components. All balanced twisted-pair, optical fibre, coaxial cabling and wireless systems are made up of such components. These cabling components and resulting cabling systems are used in outside plant (OSP) and premises cabling [also known as inside plant (ISP)] environments of the building telecommunication infrastructure.

2.42 Underground Cable Vault (UCV) — An underground cable vault (part of an underground duct system) used to facilitate placing, connecting, and maintaining telecommunications cables and associated equipment. It collectively refers to manholes, hand holes, and pull holes.

2.43 Very Small Aperture Terminal (VSAT) — It usually refers to satellite terminal used to transmit and receive signal from satellites with an antenna installed in user premises.

2.44 Wide Area Network (WAN) — It is a network that is capable of spanning a geographical area larger than a city.

2.45 Workstation — An electronic device that performs some information processing or display function and connects to the communications network. Typically, this may be a desktop computer with keyboard and display or laptop computer, but might also be a telephone, a printer, an access control terminal, or some data-gathering device.

2.46 Workspace — Any location and the space around where a workstation may be located. Typically, there can be several workspaces in a room.

3 GENERAL REQUIREMENTS FOR TELECOMMUNICATION SPACES AND CONNECTING HARDWARE

3.1 Telecommunication Spaces

3.1.1 *General Considerations*

The following shall be the considerations for telecommunication spaces:

a) *Accessibility* — Telecom spaces that are intended to serve multiple users should be located in common spaces that should be accessible through a common corridor or outside door. The space for each telecom service providers may be separated to the extent feasible by partitions for security reason and controlled access to their equipment. The telecommunication spaces should be accessible, but the access should be controlled against the unauthorized access (for example, with a lock and key arrangement or by an electronic access system).

b) *Acoustic noise levels* — Acoustic noise levels in telecom spaces should be kept to a minimum by not collocating noise-generating equipment (for example, photocopy equipment, high-speed printers, and mechanical equipment).

c) *Administration* — All pertinent documentation of deployment of telecom equipment and cables should be maintained by owner or agent when the installation is completed. All telecom spaces shall have appropriate signs to identify the space and should be included within the security plan of the building. There must be sufficient space between the equipment of different service providers for maintenance and better workmanship.

d) *Cable separation* — Telecom cables should be separated from possible sources of electromagnetic interference (EMI) and from possible radio frequency interference (RFI). For safety purposes, power cables should be separated from telecom cables.

e) *Ceilings* — The general requirements for ceilings in telecom spaces should include the following:

   1) Generally, the minimum ceiling height shall be 2.4 m above finished floor. However, consideration may be given for having a 3 m ceiling height.

   2) If suspended ceilings are provided, necessary rodent protection may be provided.

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3) The ceiling finish should minimize dust and be light coloured to enhance the room lighting.

f) *Conduits, trays, slots, sleeves and ducts* — Slot/sleeve systems should be located in places where pulling and termination of cables is easy to achieve. Bend radius requirements and service loop guidelines shall be considered. Sleeves and slots should not be left open after cable installation. All sleeves and slots shall be fire-stopped. (*See also* Part F 'Fire and Life Safety' of this NBCS for guidance purpose).

The size and number of conduits or sleeves used for backbone pathways depends on the usable floor space served by the backbone distribution system. However, sleeves in multiple of 100 mm are recommended to serve a TR, ER or EF. Multiple telecom spaces on the same floor shall be interconnected with a minimum of one 75 mm conduit or a pathway that provides equivalent capacity.

g) *Dust and static electricity* — Dust and static electricity should be avoided by:

1) Placing active printers outside of telecom spaces.

2) Treating floors, walls, and ceiling to minimize dust.

h) *Electrical power* — When active equipment of TSPs or the building equipment (for example, PABX) are installed in TR/ER, etc, the telecom spaces shall be equipped to provide adequate electrical power with redundancy and sub-meters to each of the service providers at TRs and ERs. The recommendations are as under:

1) A power generator set should be considered if longer power interruptions are expected for which the battery backup is not adequate. Further, as telecom services are required on 24 × 7 basis, uninterrupted electrical power for telecom services shall be provided from local or central uninterrupted power supply (UPS) with adequate battery backup. Further, UPS arrangement may be extended to equipment in TE/corridors also.

2) Separate socket outlets for equipment, tools, test instruments, etc.

3) Separate electrical distribution panels that serve telecom equipment/spaces from those that serve other purposes are recommended. These should be clearly identified with proper sign writing.

j) *Prevention from flooding* — Telecom spaces should be located above any threat of flooding. When locating telecom spaces where a threat of flooding is unavoidable, rack elevations may be designed so that active equipment and telecom components are placed above the threat level. Sometimes locating the ER/TR on a floor above ground floor may be safer. The locations that are below or adjacent to areas of potential water hazard (for example, restrooms, kitchens) should be avoided. Liquid carrying pipes (for example, water, waste, steam) should not be routed through, above, or in the walls encompassing the ICTs space. If due to unavoidable circumstances, liquid carrying pipes are passing through telecom spaces then these spaces may be preferably monitored for water seepage by deploying suitable water seepage detection system. Otherwise, regular watch may be kept to detect seepage.

When air conditioning ducts are installed in telecom spaces, water dripping/leaking from AC vent should be controlled and, if required, monitored by water leaking system. Instructions for prevention from liquid cleaning agents, air purifying liquids, pest repellents and sprays usage should be indicated by proper sign writing.

k) *Lighting* — Following are the important considerations for lighting of telecom spaces:

1) Locating light switches near the entrance(s) to the telecom space.

2) Coordinating the lighting layout with the planned equipment layout (especially overhead cable trays) to ensure that lighting is not obstructed.

3) Providing electrical power for the lighting and ICT equipment from different circuits.

4) Placing at least one light or set of lights on normal power and one light or set of lights on emergency/UPS power.

5) Using a light coloured finish on walls, floors, and cabinets to enhance room lighting.

6) Providing task lighting illumination at the point of cable termination.

7) Providing adequate lighting of spaces, which may be controlled by automated controllers such as building management system (BMS), if required, or ensured otherwise. Use of dimmers and

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occupancy sensors is not recommended.

m) *Location* — All telecom spaces shall be located in areas that are best suited (preferably centrally located to reduce the cable length) to serve the occupants of a floor or building. The following shall be observed when locating the spaces:

1) Telecom spaces in multi-floor buildings should be aligned vertically.

2) Telecom spaces should be located in areas that are dedicated to telecom use. Equipment that is not related to the support of telecom spaces (for example, piping, duct work, distribution of building power) shall not be located in or pass through a telecom space.

n) *Environmental control* — When active devices which are heat producing equipment are present, original equipment manufacturer (OEM) recommended temperature and humidity range should be maintained by adequate arrangement for heat dissipation. If environmental parameters are exceeded, an alarm should be activated. A positive pressure is required to be maintained with a minimum of one air change per hour in the telecom space. More stringent requirements may apply based on the equipment needs in the telecom space. It is recommended to have sufficient arrangements of air conditioners for cooling of telecommunication equipment housed or to be housed in telecom room and equipment room.

p) *Fire protection* — The telecom spaces shall be equipped with adequate fire detection, alarm and suppression systems. (*See also* Part F 'Fire and Life Safety' of this NBCS for guidance purpose). Fire retardant cables are recommended to be used inside the building to reduce incidences of fire.

q) *Bonding and grounding* — All equipment and cable shields shall be properly bonded to the telecom bonding and grounding infrastructure of the space (*see* **4.1** for details).

3.1.2 *Equipment Room* (*ER*)

3.1.2.1 An equipment room is an environmentally controlled centralized space for telecom equipment that usually house equipment of higher complexity than telecommunication rooms and also usually houses a main or intermediate cross-connect. Any or all of the functions of a telecommunications room may be provided in an equipment room. ERs differ from TRs in the way, that, ERs are generally considered to serve a building, campus, tenant, or SP, whereas TRs serve a floor area of a building. In some cases, an ER may also contain the EF or it may serve as TR. ERs may be connected to backbone pathways that run both within and between buildings. Although an ER usually serves an entire building, many building designs may use more than one ER in order to provide separate facilities for different types of equipment and services or redundant facilities and disaster recovery strategies.

The initial assessment for design and specifications for an ER shall be based on detailed information about the site, including:

a) User requirements;

b) Telecom pathway locations;

c) Service providers' requirements;

d) Environment/facility conditions; and

e) Building requirements.

The functional earth terminals of ICT equipment shall be connected either directly to the Primary Bonding Busber (PBB) or through an Secondary Bonding Busber (SBB) as per **4.1**. Where mesh bonding network is used, multiple connections (minimum four) from ICT to mesh-BN are recommended.

3.1.2.2 *Space allocation and layout*

The space allocation and layout may be determined by following methods:

a) *Determining size based on area served* — When the telecom designer does not know what specific equipment will be used in an ER, the designer can use the amount of floor space that the room will serve, to determine the minimum size of the ER. If the usable floor space is also unknown, the usable floor space may be estimated by deducting 20 percent from the total floor area.

Generally, an area of 9.3 m^2 may be considered for calculating the work areas. If work areas are smaller

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leading to possible increase in number of work areas in building, the size of the ER should be increased accordingly. The minimum reco mmended size for ER is 14 m^2. The general practice is to provide 0.07 m^2 of ER space for every 10 m^2 of usable floor space. For special use buildings, such as, hospitals and hotels, ER size requirements may vary.

b) *Telecom service provider space requirements* — If equipment or cable terminations that are owned or maintained by a TSP are to be located in the ER, then location and amount of space required shall be determined as per the space requirement of TSP.

c) *Telecom equipment locations* — As equipment for communication systems are located in the various equipment rooms throughout the building, these rooms shall be physically secure, aesthetically provisioned and conveniently located. The communication equipment may be located with due consideration of the modular provision of building design and criteria for expansion joints matching to electrical distribution and maximum fire safety distance requirements. The other considerations for telecom equipment location include the following aspects.

1) Types of cables, their uses, bending radius, turning radius, conduit radius, etc;

2) *Provision for future expansion* — In view of the evolving nature of the communication technologies, provision for future expansion should be ensured by way of stand-by arrangements. The distribution infrastructure should also be as flexible as possible. Small conduits will quickly fill up and may not accommodate some technologies, for example, low loss broadband or high capacity fibre optic cables. The most flexible distribution design involves cable trays for horizontal (floor level) distribution with large conduit sleeves for wall penetration, where necessary. Vertical trunk distribution should also be achieved with conduit sleeves; and

3) *Maintainability* — As it is difficult to remove or shift just a few cables from a crowded or convoluted conduit system for operational or maintenance requirements, steps should be taken to ensure easy access and maintainability of cable system right in the initial architectural design stage.

3.1.3 *Telecommunications Room* (*TR*)

3.1.3.1 A telecommunications room is the area within a building that houses the telecommunications cabling system and associated equipment. This includes the mechanical terminators and/or cross-connects for floor-serving distribution facility for horizontal cabling and backbone cabling system. There should be at least one TR or TE per floor. TR or TE can also house active equipment, like LAN switches, routers, OLT, DAS, cable TV or DTH systems etc, or passive equipment, like optical splitters, FDMS. Most of these equipment are available in wall mount units. The switches/routers can also be shared between telecom equipment and other low voltage in-building systems. This reduces the demand on floor space requirements for TR/TE. Sometimes, a TSP with the consent of the building owner may require to provide additional equipment, such as for mobile signal booster, at a later stage, in TR/TE. Therefore, it is recommended to have additional space in advance, especially in tall buildings of five storeys or higher, preferably on top floor.

The functional earth terminals of ICT equipment shall be connected either directly to the PBB or through an SBB as per **4.1**. Where mesh bonding network is used, multiple connections (minimum two) from ICT to mesh-BN are recommended.

3.1.3.2 Multiple rooms TEs are required if the cable length between the horizontal cabling (floor distribution) [HC (FD)] and the work area outlet location, including slack, exceeds 90 m (or more in case of optical fibre depending upon its type and application as indicated in **3.2.4.2**). If the usable floor space to be served exceeds 930 m^2, additional TRs should be considered. Following are the guidelines for TR size:

Sl No.	*Area Served*	*Dimension of TR*
(1)	(2)	(3)
i)	465 m^2 or less	3 m × 2.4 m
ii)	More than 465 m^2 and less than equal to 930 m^2	3 m × 3.4 m

NOTE — The size of 3 m × 2.4 m has been specified to allow a centre rack, cabinet, or enclosure configuration.

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In smaller buildings, less space is required to serve the telecom distribution needs of the occupants. The size guidelines for smaller buildings should be as below:

Sl No.	*Building Smaller Than*	*Served as*
(1)	(2)	(3)
i)	465 m^2	Shallow/Walk-in rooms (Walk-in rooms shall be at least 1.3 m × 1.3 m. Shallow rooms shall be at least 0.6 m deep by 2.6 m wide.)
ii)	93 m^2	Wall cabinets, self-contained cabinets, enclosed cabinets

NOTE — Installation of active equipment in shallow or walk-in rooms is not recommended because many types of equipment require environmental controls and a depth of at least 1 m.

3.1.4 *Entrance Facilities* (*EF*)

Building entrance facilities (EF) provide the point at which outdoor cabling of the telecom service provider interfaces with the intra-building/intra-campus backbone cabling. In cases, where the functions of the EF are combined with the functions of the ER in the same space, the room may house equipment that is owned and maintained by service providers. In these cases, requirements specified by the service providers shall be considered when designing the ER.

If a separate space is required for service providers, it should be in or adjacent to the EF and may require a mesh partition or locked cabinet. A space of at least 1.2 m × 1.83 m shall be considered for each service provider. An entrance facility necessarily be an enclosed space. However, having an enclosed area or access protected area is suggested at all occasions, considering safety requirements.

The duct from the cable vault (CV) of the telecom service provider generally consists of 100 mm conduits encased in reinforced concrete. The exact number of conduits will depend upon the size and use of the building. These conduits may be used for all communication systems serving the building including additional capacity and access cables and pathways capacity. To maintain the safety of the TSP cable, it may preferably enter the building above the ground and then feed the equipment room.

A separate 230 V, 16/6 A circuit with double outlets should be provided (for plugging in temporary test equipment or to power the tools) every 2.4 m along the EF and ER combined wall. All wall outlets are to be located approximately 300 mm above the finished floor levels with the breaker and clearly labelled. In addition, two dedicated 230 V, 16/6 A sockets should be provided for each (permanently installed) communication service rack. If the sockets of racks are fed from UPS power, appropriate levelling may be provided to distinguish between main power sockets and UPS power sockets.

3.1.5 *Telecommunication Enclosures* (*TE*)

A TE is simply a case or housing for telecom equipment, cable terminations, and cross-connect cabling for distribution of telecom services on a floor. The TE may also contain access points for wireless services. Although, TEs serve much in the same way as that of a TR, a minimum of one TE should be located on each floor, if no TR is considered on the floor. The TE door(s) may be hinged or removable. If the enclosure consists of metallic components, it shall be earthed to either PBB or SBB.

3.2 Telecom Media and Connecting Hardware

3.2.1 A cabling system consists of cables, equipment cords, patch cords, and connecting hardware components like cable patch panel, MDF and FDMS. All balanced twisted-pair, optical fibre, and coaxial cabling systems are made up of such components. There can be different topologies for cabling used in a building like star, tree, bus bar, ring, etc, or a combination of these to suit different technological requirements. Within a building, most of the wiring is between the work spaces and the equipment room. Wireless systems can also be part of the telecom media. However, connectivity to the network, which delivers telecom service, is generally provided using cables at the back end.

The selection of appropriate style of cabling is important and accordingly, some of the user requirements to be

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considered before selecting the specifications and style of cabling and connectors for a telecom enabled building may include the following:

a) Number of user work areas and telecom spaces used to serve the building occupants;

b) Types of services and technology used for delivery of services;

c) Number of telecom outlets/connectors desired at each user work area;

d) Number and styles of user equipment (for example, telephony, LAN, building automation);

e) Cabling system transmission performance expectations;

f) Backbone distances and horizontal cable lengths involved in the building or campus;

g) Future growth expectations (for example, 15 percent to 20 percent recommended minimum growth factor);

h) Environmental conditions including electromagnetic interference; and

j) Other types of low voltage systems and their network requirements.

3.2.2 The cables should have ferrule marking at the terminations as well as along the length of the cable at suitable interval. Similarly, copper pair/fibre pair should be identifiable at terminating end for easy identification and convenience during maintenance. For the purpose, a suitable chart should be available at locations, like inside cross-connect box. Further, all the documentation of pathways and cables should be properly maintained.

3.2.3 While designing the cabling system for large multi-tenant building, it should be kept in mind that the tenants may prefer subscribing to the services of multiple service providers. Thus, enough space should be available in ducts, pathways, etc, for laying additional conduits/trays, keeping in view the present and future demands. Capacity for pathways (that is, conduit, raceways, trays, baskets) may be planned so that initial installation achieves a fill of 40 percent and at final installation, fill of 60 percent, taking into account the expected future requirements.

3.2.4 Various cabling systems are described under **3.2.4.1** to **3.2.4.3**. For the purpose of reference, details about connecting hardware components and classification of cables by fire safety properties are given in Annex A.

3.2.4.1 *Copper twisted-pair*

The transmission performance of balanced twisted-pair cabling and telecom associated components are based on a number of factors within the cabling or component design. These performance levels use the terms category and class. Standards developed internationally utilize both class and category, depending on the specific cabling element, as described in Table 1.

Table 1 Balanced Twisted-Pair Cabling Channel Performance

(*Clause* 3.2.4.1)

Sl No.	ISO Category/Class	TIA Category	Frequency MHz	Maximum Data Transfer Rate
(1)	(2)	(3)	(4)	(5)
i)	Category 3/Class C	Category 3	16	10 Mbps
ii)	Category 5/Class D	Category 5e	100	1 Gbps
iii)	Category 6/Class E	Category 6	250	1 Gbps
iv)	Category 6A/Class EA	Category 6A	500	10 Gbps
v)	Category 7/Class F	NA	600	10 Gbps
vi)	Category 7A/Class FA	NA	1 000	10 Gbps
vii)	Category 8/Class G	Category 8	1 500 to 2 000	25/40Gbps

NOTE — For Category 8/Class G balanced twisted-pair cabling, the maximum permissible distance is restricted to 30 m.

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A large number of cable designs are used in the ICT industry, resulting in various names and acronyms for their identification. Specialist publication (*see* NOTE) may be referred which gives balanced twisted-pair cable designations using *x*/*y* designation, where *x* is the overall screen type and *y* is the individual pair screen type, which may be used. Details of various nomenclature based on this, using various categories of cables, are given in Annex A.

NOTE — The specialist publication referred here is ISO/IEC 11801 : 2002 'Information technology — Generic cabling for customer premises'.

3.2.4.2 *Optical fibre*

Optical fibre cables are used in backbone and horizontal cabling applications, when the service is delivered on fibre to the user or inter/intra building communication is to be carried on fibre. For example, of former is gigabit passive optical network (GPON), which require fibre to the home (FTTH) and the example of latter is LAN implementation using optical network. Transmission of information through optical fibre cables is not degraded by crosstalk, ambient noise, lightning, and most electromagnetic interference (EMI). It has better loss characteristics compared to copper pair. Thus, it permits high data rate communication to be carried out to a much larger distances than copper pair.

Optical fibres are classified as either single-mode or multi-mode. Single-mode optical fibres have a relatively small diameter featuring a core of 8 µm to 11 µm and a cladding diameter of approximately 125 µm. Multi-mode optical fibre has a larger core diameter (for example 50 µm or 62.5 µm) with the cladding of approximately 125 µm. Multi-mode fibre has higher loss compared to single-mode fibre. However, it is generally recommended for in building/intra campus use as it cost less than the single fibre. The latter has low loss characteristics and can carry higher speed to longer distances due to which it is mainly used in long haul applications. However, depending upon the size of the building/campus or availability of various types of cables, combination of both types of cables or only single-mode cable may need to be used. Use of single-mode fibre has the advantage that future upgradation requirements are taken care of right in the beginning.

Optical fibre cables are available in various capacities in terms of number of fibres like 6 fibre, 12 fibre, 24 fibre, 48 fibre, 96 fibre, etc. Each fibre has a different colour which helps in easier identification during installation and operations. The colour scheme is repeated for every group of 12 fibres for higher fibre count cables.

Selection of optical fibre cable size for different segments of cabling depends upon various factors.

The colour code chart for fibre optic cable is as under:

Sl No.	*Fibre/Tube No.*	*Color*
(1)	(2)	(3)
i)	1	Blue
ii)	2	Orange
iii)	3	Green
iv)	4	Brown
v)	5	Grey
vi)	6	White
vii)	7	Red
viii)	8	Black
ix)	9	Yellow
x)	10	Purple
xi)	11	Rose
xii)	12	Aqua

NOTE — The specifications of the certain types of optical fibre cables are available in Department of Telecommunications, Telecom Engineering Centre (TEC), Govt. of India, the details of which can be seen from TEC website, www.tec.gov.in

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When it is decided to use optical fibre cable, choice is to be made from among variety of standard cables. There are two broad categories of cables namely multi-mode optical fibre (OM) and single-mode optical fibre (OS). The former is suitable for much shorter distances compared to the later as, data rate supported by cable is a function of cable length used. OM cables are preferred cables for campus applications as they are economical for short distances. OM cables are further sub-categorized into OM1, OM2, OM3 and OM4, which are differentiated based on data speed and distance combinations. Once the data speed and distance to be covered is decided, choice of cable category becomes simpler. When used inside the buildings, attenuation of signals is caused due to cable fibres facing sharp bends. Multi-mode cables show larger attenuation than single-mode cables on bends inside the building. Thus, bend insensitive and fire retardant optical fibre cable as per relevant TEC specification are recommended for use in the buildings.

Considering that backbone cable carries the combined traffic of all work areas and the growth of data use with time, provision for future expansion should be provided. It is recommended that planning should be done for 10 Gbps to 1 Tbps or above speeds depending upon anticipated requirements of the users. Therefore, when using multi-mode cable, choice may need to be made typically from among OM3 and OM4 cables.

A chart showing typical length and data rate support characteristics of various cables is given below:

Sl No.	*Subsystem Backbone*	*Lengths Up to*	*Data Rates Up to*
(1)	(2)	(3)	(4)
i)	Campus backbones (OM1 fibre)	2 000 m	155 Mb/s
ii)	Campus backbones (OM2 fibre)	550 m	1 Gb/s
iii)	Building backbones (OM2 fibre)	300 m	1 Gb/s
iv)	Building backbones (OM3 fibre)	300 m	10 Gb/s
		100 m	100 Gb/s
v)	Campus/building backbones (OM4 fibre)	550 m	10 Gb/s
		150 m	100 Gb/s
vi)	Campus/building backbones (OS fibre)	10 000 m	100 Gb/s

Enhanced versions of OM3/OM4 cables can also be examined for use. Once the cable category is selected, care should be taken that active equipment which feeds the fibre is equipped with the corresponding interface, to take care of, for example requirement of different optical power source and optical wavelengths for different types of cables. Further, from each TR drop fibre or cable of 2 to 4 fibres are also recommended.

3.2.4.3 *Coaxial cable*

The predominant coaxial cables are Series-6, Series-11, and radio grade (RG) 59. These coaxial cables have a characteristic impedance of 75 Ω. While the termination procedures may be similar, special attention shall be paid to the manufacturer's specific instructions for termination and connectors. The cables/passive components used for DAS/IBS system should cover frequency range from 400 MHz to 4 000 MHz. Coaxial RF telecom cables of various sizes (for example, 12.70 mm, 22.23 mm, 31.75 mm) or as required for efficient RF signal transmission be deployed to ensure comprehensive mobile signal coverage within the building.

Coaxial cable is used for computer networks, CATV and video systems. Historically, coaxial cable was designated as RG cable. Coaxial cables used in broadband applications are available in the market with following constructional variations:

a) Centre conductor diameter;

b) Centre conductor being solid or stranded;

c) Dielectric composition;

d) Outer braid's percent of coverage; and

e) Impedance.

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3.2.5 *Wireless Systems*

Wireless connectivity is also provided inside the building for enabling access to public mobile network or for enabling internet/intranet connectivity with flexibility of user terminal movement. Various wireless systems are described below:

a) *Wireless LAN* (*WLAN*) *access point* (*AP*) — A wireless LAN (WLAN) access point (AP) is a network device located in areas of a building or campus and placed in relatively close proximity to where users interact with their wireless enabled network devices. APs allow wireless enabled devices (for example, computer, printer, mobile, tablets, laptop, IoT devices or any other device) to connect through Wi-Fi or related standards. Wireless networks here can even include the networks of low voltage automation system in the building as well as M2M/IoT smart buildings/smart homes/smart offices. There are various wireless standards for M2M/IoT device connectivity. AP network devices are typically mounted on walls or ceilings with structured cabling that provides a physical connection to a HC (FD), which provides further connectivity to private/public network through the facility installed in TR/TE.

b) *Wi-Fi access points* (*WAP*) *with centralized controller* — Access point shall support at least IEEE 802.11 ax/be or any higher versions/ more modern standards. There may be numbers of WAPs to cover area/building and in such situation user may prefer centralized controller. Centralized controller can be hardware or software based and depending upon number of WAPs may be provided at each ER/TR/TE. These access points can also be used for connecting the low voltage automation systems (building management system and other in-building system). The access points are connected to the network as described in (a).

NOTE — The secure access to Wi-Fi network and authorization of users is critical and the same will need to be ensured by owner.

c) *Distributed antenna systems* (*DAS*)*/In-building solutions* (*IBS*) — DAS/IBS are signal distribution systems for strengthening the public mobile wireless signal inside the buildings or installations. They require cable and passive antenna to be installed in corridors/rooms, normally along the centre line. The active equipment, wherever required can be installed in ER/TR/TE, on which cables to/from DAS/ IBS are connected.

d) *Wireless repeater* — It takes an existing signal from a wireless router or wireless access point and rebroadcast it with amplified signal. It is also called wireless range extender. This is used to mitigate low signal issues.

While planning and installing wireless devices, it is required to maintain enough spacing between them to avoid frequency overlap and interference by their own signal. The wireless coverage area radius is impacted by a number of factors including the following, and these factors like penetration losses, signal to noise ratio etc, are to be taken into account by using for which the site survey approach and planning. An appropriate planning tool should be considered for this purpose:

1) Building materials (concrete, sheetrock, wood, steel, etc);
2) Building configuration (closed, semi-closed or open space); and
3) Building furnishings (cabinets, partitions, furniture, etc).

Periodic monitoring is desirable for maintaining wireless coverage.

3.2.6 *Connecting Hardware*

The ends of cable terminating in work areas or on intermediate equipment like LAN switches, splitters, etc, need to be provided with connectors. There can be variety of equipment which may be connected to the cable ends. Hence, a careful planning should be done to identify types of connectors with flexibility to connect variety of equipment keeping in view also the fact that the cable ends are permanently wired on to connector panels in the work areas. Details of the typical connecting hardware are given in Annex A.

3.3 Backbone Cabling Media Distribution and Building Pathways

The backbone distribution system provides interconnection between telecom spaces, that is, telecommunication rooms, equipment rooms and entrance facilities. It consists of the backbone cables, intermediate and main cross-

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connects, mechanical terminations and patch cords or jumpers used for backbone-to-backbone cross- connection. This includes:

a) Vertical cable connections between floors (risers);

b) Cables between an equipment room and building cable entrance facilities; and

c) Cables between buildings (inter building).

The elements of the telecommunications cabling system structure are:

1) Horizontal cabling;

2) Backbone cabling;

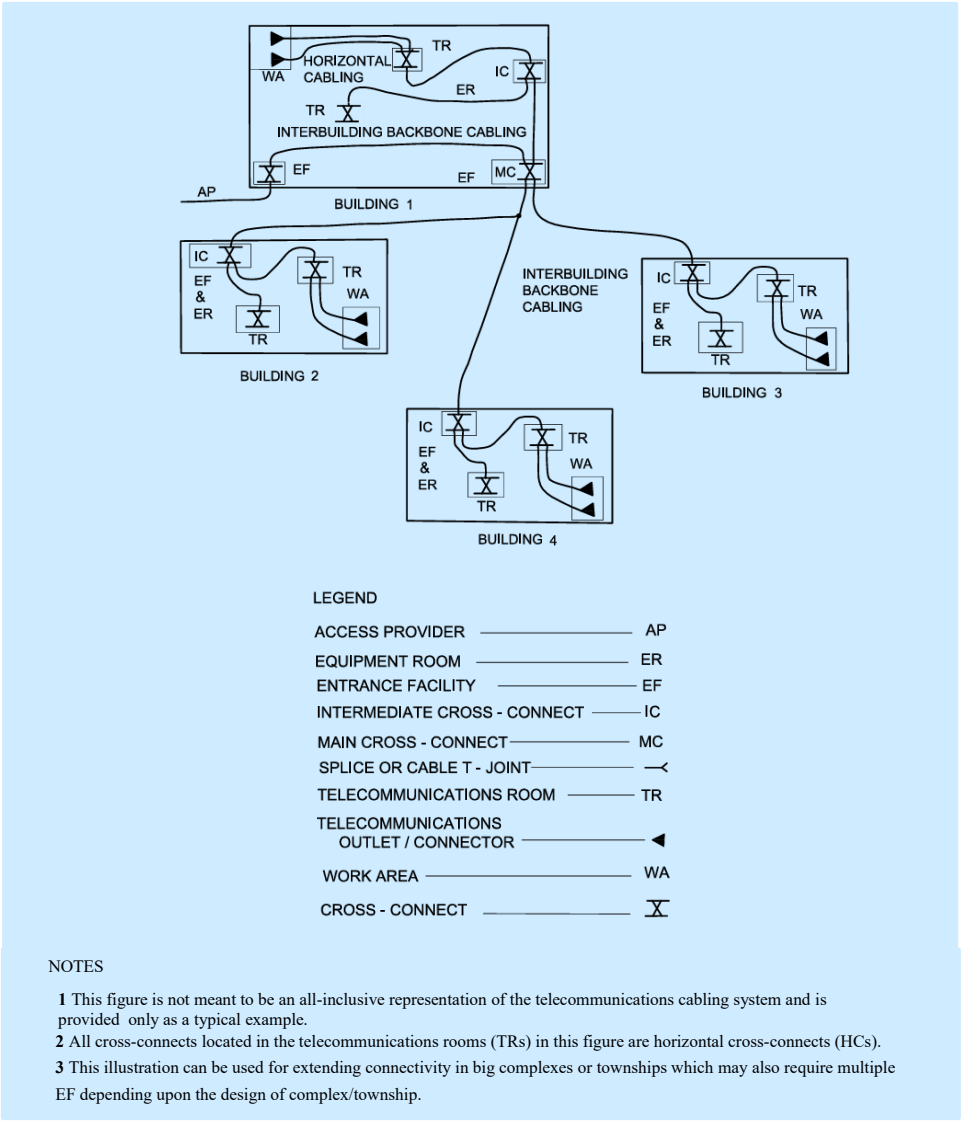
3) Work area;

4) Telecommunications rooms;

5) Equipment rooms; and

6) Entrance facilities.

Figure 1 illustrates a representative model for the various functional elements that comprise a building campus/complex telecommunications cabling system. It depicts the relationship between the elements and how they are configured to create a total system.



NOTES

1 This figure is not meant to be an all-inclusive representation of the telecommunications cabling system and is provided only as a typical example.

2 All cross-connects located in the telecommunications rooms (TRs) in this figure are horizontal cross-connects (HCs).

3 This illustration can be used for extending connectivity in big complexes or townships which may also require multiple EF depending upon the design of complex/township.

FIG. 1 TYPICAL TELECOMMUNICATIONS CABLING SYSTEM

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3.3.1 *Backbone Cabling and Topologies*

Cabling between the building cross-connect (main or intermediate) and the horizontal cabling (floor distribution) [HC (FD)] is designated as backbone cabling. In a multi-building complex, inter-building cabling, though terminating in the EF, is designated as inter-building backbone cabling. The cable(s) can be of any type, for example, copper pair, optical fibre or coaxial.

3.3.1.1 The two primary options for connectivity are:

a) Star topology, where the HC (FD) is connected directly to the main cross-connect (campus distributor) [MC (CD)] which is further connected to inter building backbone, where applicable; and

b) Hierarchical star topology, where some or all of the HCs (FDs) are connected to an intermediate cross-connect (building distributor) [IC (BD)], which in turn, is connected to the MC (CD).

3.3.1.2 The best design is the star design between the building MC and the HCs. However, in some extremely large buildings (for example, high-rises), a hierarchical star may be an option for consideration. The trade-offs between different cable sizes and labour cost is to be considered to determine a suitable cost effective solution. The direct connections between HCs are generally avoided. Although this kind of connectivity might be of value in providing a redundant path, a user should design a link from HC to HC only in specific applications. The best design is the star design between the building MC and the HCs.

3.3.1.3 A typical star configuration in a building with MC (CD) or HC (FD) is given Fig. 2.

3.3.1.4 An example of backbone hierarchical star topology with addition of IC (BD) is shown in Fig. 3.

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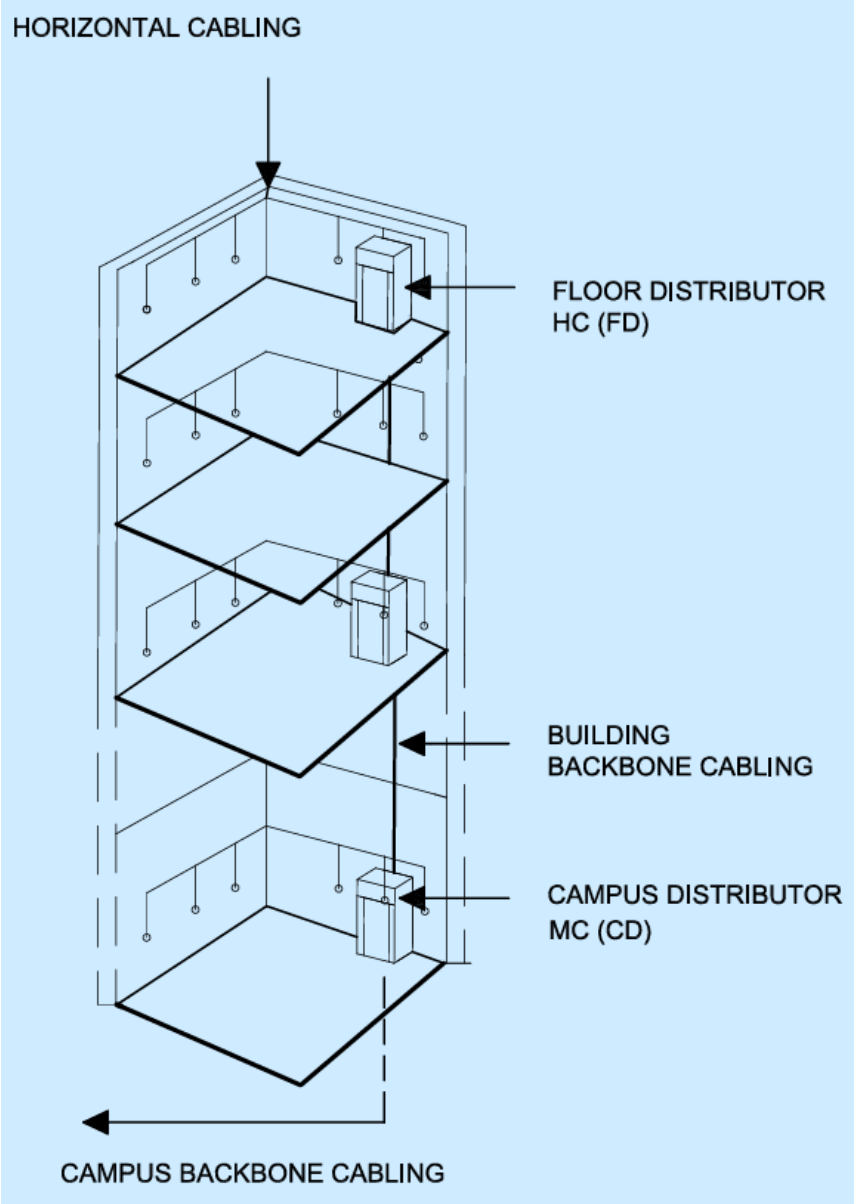

FIG. 2 TYPICAL CABLING STAR CONFIGURATION IN A BUILDING

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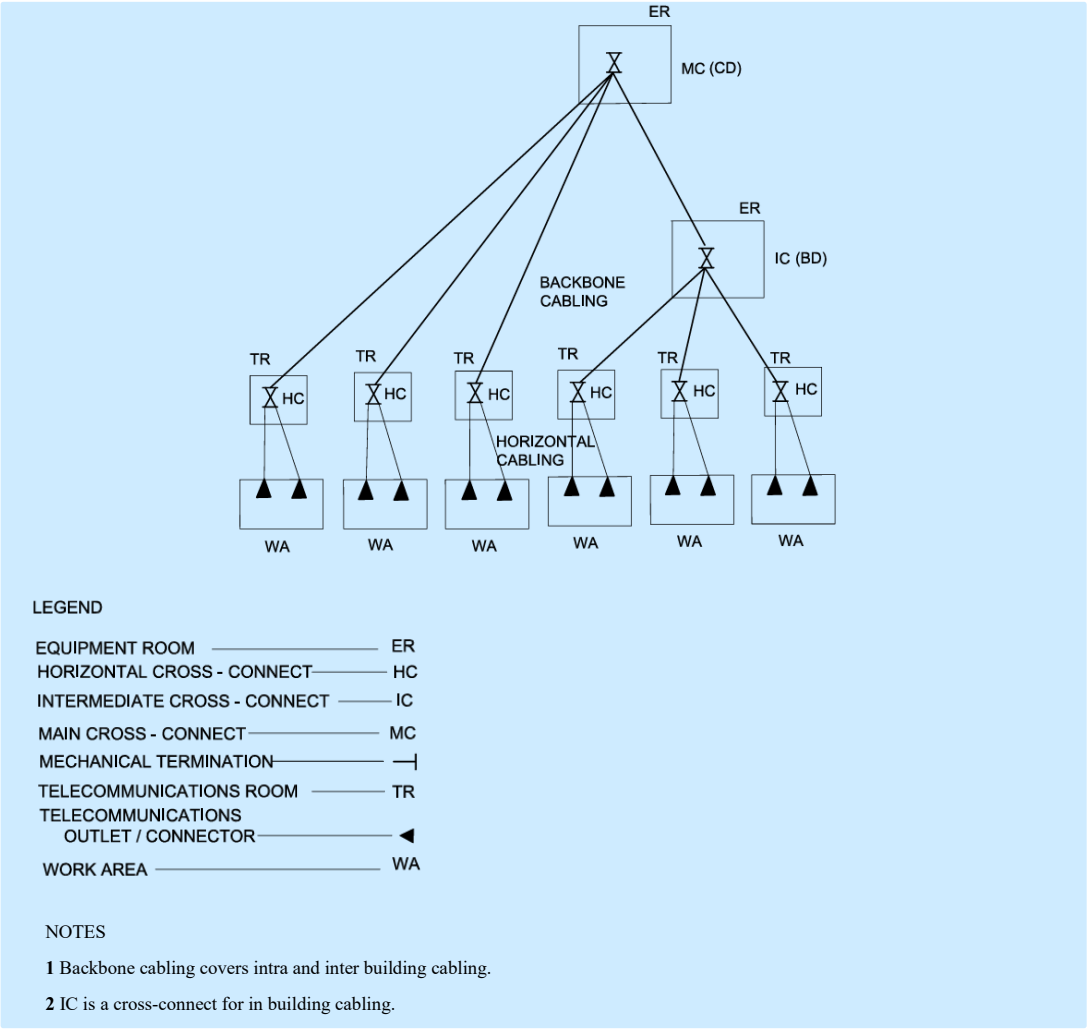

FIG. 3 EXAMPLE OF BACKBONE HIERARCHICAL STAR TOPOLOGY

3.3.2 *Inter-Building Pathways*

In a campus environment, inter-building pathways are required to connect separate buildings. For this, underground, buried, aerial and tunnel are the main pathway types used. As the complexes have varying conditions of land features and locations, size and use of building, choice if any or combination of the pathways need to be made based on local requirements. The cable running over the pathways generally terminates at the entrance facility of the building at both ends.

3.3.2.1 *Underground inter-building backbone pathways*

The pathway shall be fully covered and the cabling shall be installed within protective conduit or ducting for the entire external section of the cable route in all inter-building pathways. Provision should be made for existing as well as future demand. Underground pathways consist of conduit, ducts and troughs; possibly including manholes. The manhole can be planned normally, if:

a) The cable requires joint;

b) The distribution of copper/fibre pair is required midway; or

c) Numbers of bends in the path are more than two.

Each manhole should be dimensioned to accommodate spare cable of 2 m to 4 m length in each direction, which is generally kept in spare loop to take care of maintenance needs. All conduit and duct shall have a diameter of

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at least 100 mm. Bends are not recommended; however, if required, there should be not more than two 90° bends.

In a multi-building and multi-operator campus, an underground cable vault (UCV) may be considered close to entrance facility. Manholes/pull holes may also be provided for O&M activity in the outside plant pathway system for the pulling, placing, and splicing of cables. Size of UCV, manholes and pull holes should be decided based on the pathway capacity, number and types of cables, etc. All such points should be covered with properly marked iron covers of appropriate thickness and structural support below them keeping in view the load they are expected to bear due to pedestrian or vehicle movement.

In the planning for underground cabling, the following shall be considered:

a) Limitations dictated by the topology (this includes land development);

b) Grading of the underground pathway to permit proper drainage;

c) Need to vent gaseous vapours; and

d) Amount of vehicle traffic to determine the amount of cover over the pathway and whether or not concrete encasement is required.

3.3.2.2 *Direct buried inter-building backbone pathways*

In this case, the telecommunications cables are completely covered in earth. Direct burial of telecommunications cables is achieved by trenching, augering or boring (pipe-pushing). When selecting a route for the pathway, it is important to consider the landscaping, fencing, trees, paved areas and other possible services. Direct burial has the challenges of cable repair in case of faults and also in future upgradation.

3.3.2.3 *Aerial inter-building backbone pathways*

An aerial pathway consists of poles, cable-support strand and support system. Some considerations to make when using aerial backbone include the following:

a) Appearance of the building and surrounding areas;

b) Separation and clearances for electrical installations and roads;

c) Span length, building attachments, storm loading and mechanical protection; and

d) Initial number of cables and future growth potential.

3.3.2.4 *Tunnel inter-building backbone pathways*

Tunnels provide pathways for conduit, trays, wire-ways or support strand. Normally tunnels support other building services too. Hence, the location of telecom pathways within a tunnel should be planned to allow for accessibility as well as for separation from other services. In general, tunnelling inside the premises for telecom services alone may not be cost effective.

3.3.3 *Backbone Building Pathways*

Backbone building pathways can be built in various ways depending upon the building layout, locations of TR/TE, etc. While designing and implementing such pathways, certain requirements need to be met and precaution taken. Typical topologies and requirements/ precautions relating to these are described below:

a) *Vertically pathway topology* — Vertically aligned TRs with connecting sleeves or slots are the most common type of backbone pathway though it is not a necessary condition. Vertical alignment is desirable because the building planner can stack them with other mechanical spaces, and it makes distribution of telecom cables more efficient because of shorter conduits and cabling runs. If the TRs/TEs are not aligned vertically above one another, the conduits interconnecting them will have horizontal offsets. There shall be not more than two 90° bends in any such conduit run. Any bend shall have an inside radius 10 times the diameter of the conduit (typically 1 m). If these conditions cannot be met, then intermediate pull boxes shall be used wherever a non-standard transition is required. This pull box shall be at least 600 mm × 600 mm in the plane of the attached conduits, and 150 mm deep. All conduits other than simple sleeves between floors shall be fitted with a continuous 1.5 mm nylon pull rope, or a 0.6 mm steel fish wire or a 0.5 mm fibre composite fish wire.

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b) *Conduits, trays, slots, sleeves, and ducts* — All rigid metallic conduit pipes shall be of steel and shall be conforming to accepted standard [D-6(1)]. The wall thickness of the pipe shall be not less than 1.6 mm (16 SWG) for conduits up to 32 mm diameter and not less than 2 mm (14 SWG) for conduits above 32 mm diameter. These shall be solid drawn or reamed by welding and finished with galvanized or stove enamelled surface.

All non-metallic conduit pipes and accessories shall be of suitable material complying with the accepted standards [D-6(2)] for rigid conduits, and accepted standards [D-6(3)] for flexible conduits. Such pipes shall not be exposed.

The vertical backbone pathway consists of telecommunications rooms located on each floor, tied together by sleeves or slots. In this context, the term 'sleeve' refers to a circular opening in a wall, ceiling or floor to permit the passage of cables between adjacent spaces. A 'slot' is the same as a 'sleeve', except that the shape of the opening is usually rectangular. The cable sleeves or slots are positioned adjacent to a wall on which the backbone cables can be supported. The recommendation in respect of slots and sleeves are as under:

1) Slots with a minimum 25 mm high curb; and

2) Sleeves to extend a minimum of 25 mm above the floor level and a maximum of 77 mm above the floor level. Sleeves should be located at a minimum of 25 mm from the wall or between adjacent sleeves to provide room for bushings, but not so far from the wall that it becomes a tripping hazard or create too large a cable span from the sleeve to the backboard/tray.

c) *Riser systems* — For connectivity to TR/TE on upper floors from the building EF, conduit or raceway should preferably be provided vertically. Vertically mounted ladder rack shall be mounted on the wall between incoming and outgoing sleeves within the TR/TE. The ladder rack should be used to provide strain-relief for cables transiting TR/TE within the riser system. If the building plan is large enough to require a second communications TR/TE on one or more floors, then the riser pathway should preferably be duplicated from the EF up to second set of TR/TE.

d) *Vertical pathway size* — A minimum of three 100 mm diameter conduits, or equivalent raceway cross section, should be provided between the TR/TE on adjacent floors and between the EF and the first floor TR/TE.

e) *Access to the roof* — For installations like antenna, powering the roof top/tower top equipment, access shall be provided through suitable number of conduits. This connectivity from the roof should be seepage and rodent proof. A minimum of two 75 mm and one 20 mm conduit shall extend from the topmost TR/TE to the roof terminated in a weatherproof metal enclosure. Sometimes, it may not be feasible or desirable to have direct vertical access, thus requiring horizontal extension from the rooms before vertical extension, the user may keep this in view for taking action with respect to architectural considerations.

f) *Pathway finish details* — Conduit shall be free of burrs or sharp edges. Sheet metal sleeves, if used, shall have rolled edges. Conduits or sleeves shall protrude at least 25 mm from the surface they penetrate but not more than 75 mm. Conduits shall be fitted with a smooth bushing.

g) *Fire protection of shafts* — All penetrations shall be filled with fire resistant material. Fire compartment plan and integrity of compartment should be maintained by either blocking permanently or by recognized systems automatically responding to temperature increase.

h) *Open cable shafts* — Open cable shafts should be used when available and where large quantities of cables are required on a floor that is distant from the main ER. Backbone cable pathways shall not be located in elevator shafts.

j) *Enclosed metallic raceways or conduits* — Enclosed metallic raceways or conduits are also used as vertical and horizontal cable pathways. It should be bonded to form a common bonding network.

k) *Cable trays* — A cable tray can be used as a vertical cable pathway within shafts or as part of the pathway between vertically aligned TRs. A cable tray can be open or covered and provides a means for attaching vertical cable runs to the cable tray members. The cable tray can also accommodate ethernet LAN cables running from building management system and other low voltage automation system in the building.

3.3.4 *Ethernet in the First Mile* (*EFM*)

Ethernet in the first mile (EFM), also known as ethernet to the last mile, describes the access network from the

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access point to the subscriber's premise. The first mile is the critical connection from business and residential users to the public and the public network.

Ethernet is the dominant mode of digital connectivity to user computers and other devices. Local area network (LAN) connectivity is extended to the end user computers through ethernet cable and connector. Ethernet cables generally used are Cat 5e and Cat 6. However, higher categories of cables are available (Cat 7 and Cat 8), which supports data rates of 10 Gbps and 40 Gbps. In many implementations, backbone and horizontal cabling may be on optical fibre. Such implementations address the Cat 5e/Cat 6 cable length limitations as only the last drop from TR/TE to the work area will use Cat 5e/ Cat 6 cable.

However, in many large buildings, optical to ethernet converters/switches may be required to be installed beyond TR/TE also, which may be installed in safe places in corridors false ceiling, work area, etc, where provision for supply of power should also be made. This holds true for Cat 5e/Cat 6 backbone and/or horizontal cabling also. Cabling to work area may be through conduits inside the wall or conduits on open surfaces. In cases where multiple tenants want to set up their own LAN, they may set up their system and horizontal cabling. However, they should preferably use backbone cabling of the building to reach EF for further connectivity to a telecom service provider for internet/leased bandwidth, etc.

3.4 Horizontal Cabling Media Distribution and Building Pathways

A horizontal distribution system consists of the horizontal cabling, the horizontal pathways supporting the horizontal cabling, and the telecom spaces that support the horizontal pathways. As horizontal distribution systems, cabling, and pathways often change direction, elevation, or physical orientation to accommodate obstructions, barriers, and other building systems, the use of the term horizontal in the name of the element does not require that the elements be placed or installed parallel to the ground or floor.

3.4.1 *Horizontal Cabling Systems*

The horizontal cabling is the portion of the telecommunications cabling system that extends from the work area telecommunications outlet/connector to the horizontal cross-connect in the telecommunications room (TR). The horizontal cabling includes horizontal cables, telecommunications outlet/connectors in the work area, mechanical terminations, and patch cords or jumpers located in the telecommunications room, and may include multi-user telecommunications outlet assemblies and consolidation points.

3.4.1.1 The following media types can be considered as options for horizontal cabling:

a) Four-pair 100 Ω unshielded twisted-pair (UTP) or screened twisted-pair (ScTP) cables with a distance limit of 90 m taking care of 10 m patch cord/jumper cable required for work area.

b) In case of optical fibre, OM cable normally of grade lower than or equal to the backbone cable may be selected. Such limitation is not faced if OS or appropriate ITU-T standard single-mode cables as mentioned in **3.2.4.2** are used. Distance limits with respect to data rate to be supported on horizontal cabling system may be seen from table under **3.2.4.2**. Care should be taken that the equipment for corresponding fibre interface is selected.

While laying cables, maximum recommended length of cable by including provision for jumper cables/patch cords in TR and extension in work area should be kept in view.

3.4.2 The requirements for horizontal pathways, measures for avoiding electromagnetic interference in the design of cabling pathways are described in **3.4.2.1** and **3.4.2.2**.

3.4.2.1 *Horizontal pathways*

Horizontal pathways are used for distributing, supporting, and providing access to horizontal cabling and telecom associated connecting hardware between the telecom outlets/connectors and the HC, typically located in the ER, TR or TE. Horizontal cabling is contained within horizontal pathways. Generally, the horizontal pathways are one of two types:

a) Continuous pathways (for example, conduit, cable tray, cable matting) used for containment of telecom cabling.

b) Non-continuous pathways (for example, the space between cable supports such as J-hooks) through which cables are placed between physical supports or containment components.

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A pathway component should be designed to accommodate all standards compliant cabling and address the potential need for change and expansion during the life cycle of the cabling system and building. The emphasis should be first on the design of pathway systems and then on the cabling systems design. This approach helps to ensure a robust pathway system that supports the cabling installation over the facility's life cycle. As frequently accessing or changing the horizontal cabling leads to disruption to occupants, the choice and layout of horizontal cabling types are important to the design of the building structured cabling system. The following should be considered for the horizontal distribution system's design:

1) Allow for the accommodation of change over the facility's life cycle with the goal of reducing long-term maintenance and operational costs;

2) Utilize standardized cabling, components and systems; and

3) Include appropriate pathway and cabling components to accommodate ease of access and a variety of user specified technology applications.

The horizontal cabling system should be designed in order to support various telecom applications, including:

i) Voice services;

ii) Data services;

iii) Audio and video services; and

iv) Building signalling systems [for example, smart building ICT systems, building automation systems (BAS), and fire safety and security systems].

It is preferable to have provision for conduits, junction box, etc, during planning and construction stage for providing radio/wireless data equipment at the centre line of rooms and corridors to avoid unplanned provisions later on.

3.4.2.2 *Avoiding electromagnetic interference* (*EMI*)

Avoiding electromagnetic interference (EMI) is an important consideration in the design of cabling pathways. Providing physical separation from sources of EMI for these elements of the telecom infrastructure inherently provides separation of their contents (for example, cable and connecting hardware).

The telecom pathways should be located away from sources of EMI to the extent feasible, including:

a) Electrical power cabling and transformers;

b) RF sources;

c) Large motors and generators;

d) Induction heaters;

e) Arc welders;

f) X-ray equipment; and

g) Photocopy equipment.

3.4.2.3 *Topology*

Horizontal cabling should be installed in a physical star topology. Each telecom outlet/connector should be cabled directly to an HC (FD) in the appropriate telecom space. Exceptions to this practice are possible, when:

a) A consolidation point (CP) or multi-user telecommunications outlet assembly (MUTOA) is used to connect the open office cabling;

b) A transition point (TP) is required the connect to under-carpet cabling; or

c) Centralized optical fibre cabling is implemented from main cross-connect (campus distributor) [MC (CD)] to the work area(s).

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Some applications may utilize a bus, ring, or tree topology, which can be implemented within a physical star topology. However, in case of large number of work areas, ring or tree topology may require intermediate distribution points like MUTOA, etc. Typical horizontal and work area cabling using a star topology is shown in Fig. 4.

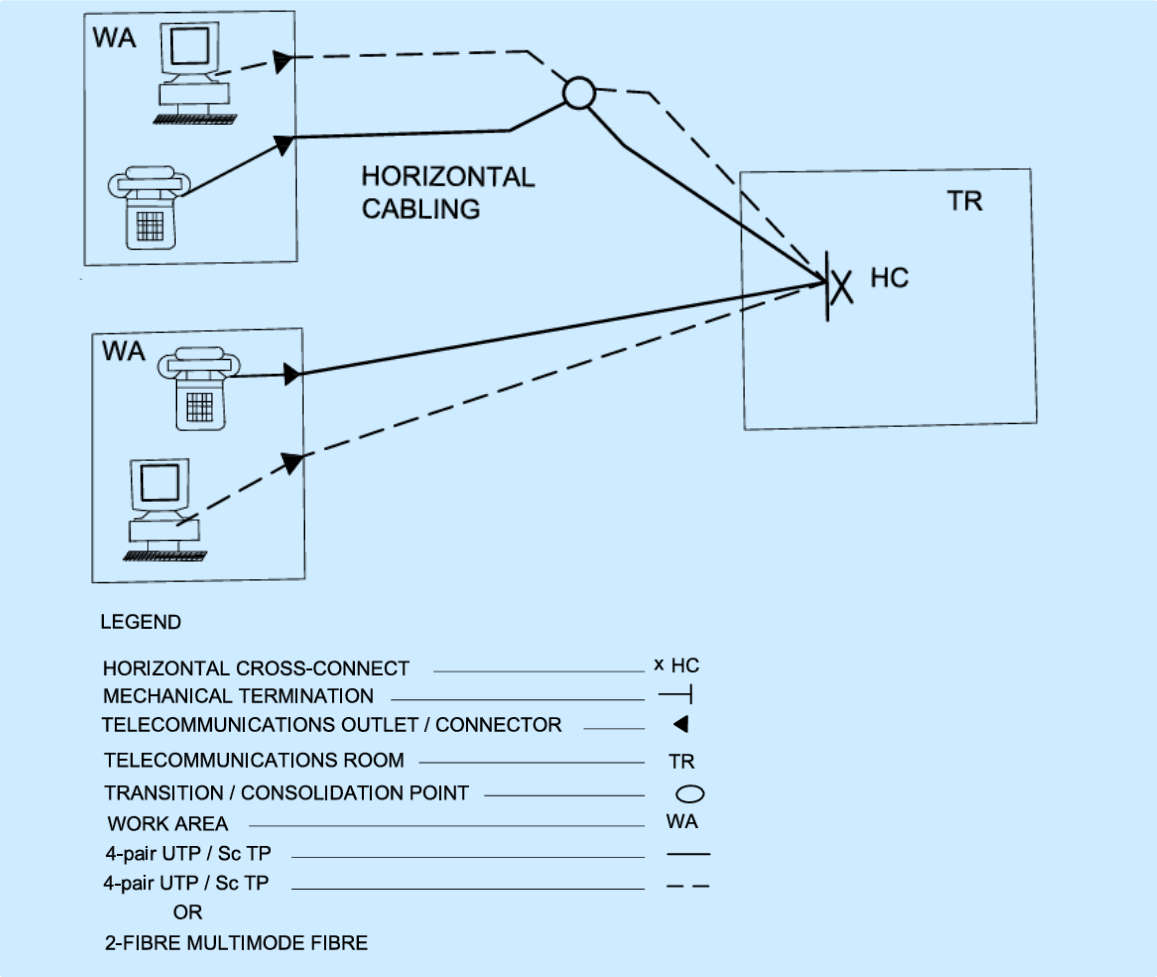

FIG. 4 TYPICAL HORIZONTAL AND WORK AREA CABLING USING A STAR TOPOLOGY

3.4.2.4 *Work areas and open office cabling*

3.4.2.4.1 The work area includes those spaces in a building where occupants normally work and interact with their ICT equipment. While work areas have traditionally been fixed, discrete locations, open office cabling design practices have introduced flexible layouts to support collaborative work by small teams. Such spaces are often rearranged to meet changing requirements of group work. Many other open office work situations also require frequent reconfiguration. An interconnection in the horizontal cabling allows open office spaces to be reconfigured frequently without disturbing horizontal system cabling runs. Work area equipment that may require access to the horizontal cabling includes:

a) Telephones;

b) Networking equipment;

c) Fax machines;

d) Computers;

e) Network peripherals; and

f) Any device plugged into a telecom outlet/connector that is located within the work area.

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3.4.2.4.2 The key elements of open office cabling are the MUTOA and CP. To accommodate equipment in the work area, following components are typically used as needed:

a) Telecom outlet/connector;

b) Work area equipment cords;

c) MUTOAs and CPs; and

d) WAPs.

Some of these components and requirements or recommendations relating to them are described below:

a) *Multi-user telecom outlet assembly* (*MUTOA*) — The MUTOA serves as a method of connecting more than one user (work area) to the horizontal cabling system. MUTOAs may be advantageous in open office spaces that are moved or reconfigured frequently. A MUTOA facilitates the termination of horizontal cabling system cables in a common location within a furniture cluster or similar open area. The use of MUTOAs allows the horizontal cabling to remain unchanged when the open office plan is changed. Work area equipment cords originating from the MUTOA should be routed through work area pathways (for example, furniture pathways). Each furniture cluster should have one MUTOA which may typically serve 12 work spaces. The work area equipment cords shall be connected directly to work area equipment without any additional connections. For copper cables, any combination of horizontal, work area cables and equipment cords may not exceed 100 m. The work area cables shall be connected directly to work station equipment without the use of any additional intermediate connections (*see* Fig. 5); and

b) *Consolidation Point* (*CP*) — The consolidation point (CP) is an interconnection point within the horizontal cabling system. Like the MUTOA, a CP may be used for balanced twisted-pair cabling or optical fibre cabling. The functional difference between the CP and the MUTOA in the open office environment is that the CP introduces an additional connection for each horizontal cabling run. A CP may be useful when reconfiguration is not so frequent as to require the flexibility of the MUTOA. The CP may be located in the suspended ceilings, access floors, modular office furniture or work area. Further CPs may serve a zone consisting of number of work areas even in different rooms.

   Some additional considerations and guidelines that apply specifically to the CP are as under:

   i) Cross-connections should not be used at a CP. Not more than one CP should be used within the same horizontal system cable run so as to avoid additional points of failure. Depending upon the size and number of the cables, there can be a single CP for all cables or separate CPs for different sets of cables;

   ii) For balanced twisted-pair cabling, the CP should be located at least 15 m from the HC (FD) in order to reduce the effect of near end cross talk (NEXT) and return loss from multiple connections in close proximity;

   iii) CPs shall be located in fully accessible and permanent locations. CPs shall not be located in an obstructed area; and

   iv) The CP should be sized and cabled so that it meets the telecom requirements of the zone it serves. If the floor space requirements change for an existing CP, then the CP should be reconfigured to accommodate the new requirements (*see* Fig. 6).

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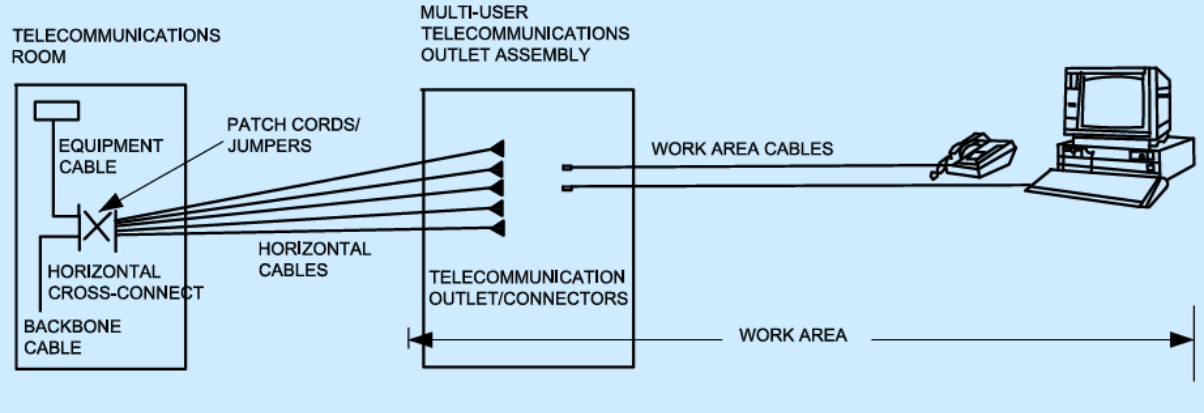

FIG. 5 APPLICATION OF MULTI-USER TELECOMMUNICATIONS OUTLET ASSEMBLY

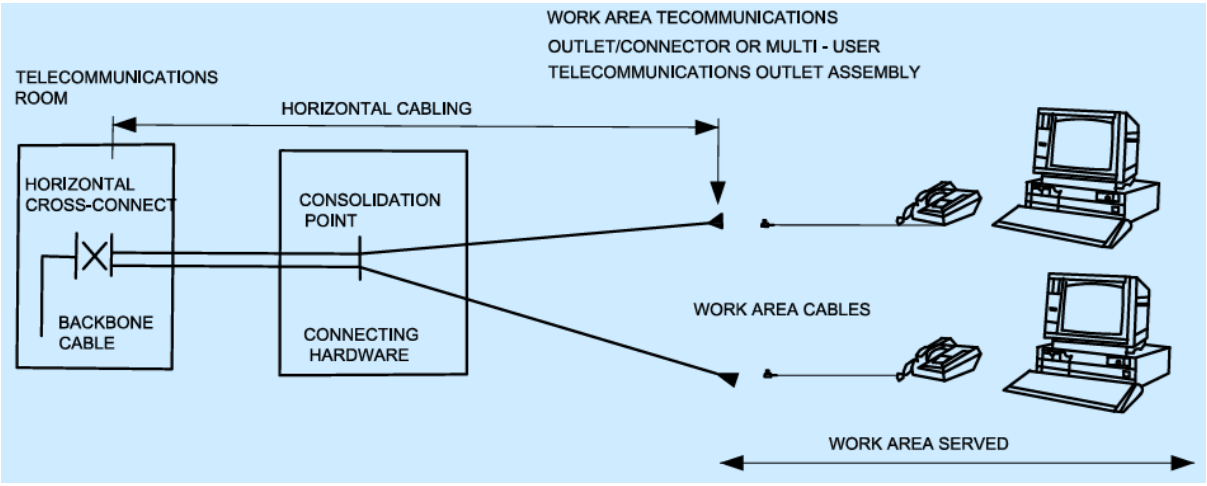

FIG. 6 APPLICATION OF CONSOLIDATION POINT

3.4.2.5 *Centralized optical fibre cabling* (*fibre to the desk*)

The HCs (FD), deployed throughout a building and located on each floor of a building, offers maximum flexibility to the user, especially in the deployment of distributed electronics or in multi-tenant buildings. In spite of the advantages of distributed cross-connections, some users may prefer data networks with centralized electronics which requires centralized cabling to provide connections from the work areas to the centralized cross-connect. Any of the following methods can be used for cabling:

a) Pull-through cabling from the centralized cross-connection;

b) Interconnection cabling in a floor-serving telecom space; and

c) Spliced cabling in a floor-serving telecom space.

However, flexibility for rearrangement of work areas and need for additional work areas in future by the user should be kept in view while adopting any of the above methods.

3.5 Building Information for Telecommunication Infrastructure Planning

For facilitation of proper design or upgradation of telecommunication infrastructure, it is important to have some basic information about the building and its users. For this purpose, a template containing a typical set of data points is provided in Annex C. Additional details may also be included as deemed necessary, so as to meet the objective of ensuring appropriate planning, design, and implementation of telecommunication infrastructure and services.

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4 SPECIFIC REQUIREMENTS FOR TELECOM INFRASTRUCTURE CABLING

4.1 Telecommunications Bonding and Grounding

The bonding and earthing infrastructure of a telecom installation is an essential part of an information technology systems (ICT) design. Earthing systems are an integral part of the signal or telecommunications cabling system that they support. In addition to helping protect personnel and equipment from hazardous voltages, a proper earthing system may reduce electromagnetic interference (EMI) to and from the telecommunications cabling system. Improper earthing can produce induced voltages and those voltages can disrupt other telecommunications circuits. Earthing and bonding shall meet the appropriate requirements and practices of applicable standards.

The overall purpose for the ICTs bonding infrastructure is to equalize potentials between metallic surfaces (exposed and extraneous conductive parts) predominantly in the event of lightning, a.c. electrical system faults, electromagnetic induction, or electrostatic discharge.

The primary bonding busbar (PBB) serves as the dedicated extension of the building's protective earthing system for the ICTs infrastructure from the main earthing terminal (MET). It serves as the central attachment point for the telecom bonding backbone (TBB). Secondary bonding busbar (SBB) is the earthing connection point for ICTs infrastructure systems (for example, cabling, pathways) and ICTs equipment in the area served by an ER or TR. The PBB and-SBB should be a pre-drilled copper bus bar with holes for use with standard-sized lugs. A TBB is a ICTs bonding conductor to connect equipment/TRs/TEs on multiple floors of a building with an ultimate connection to the PBB. Typical telecommunication earthing and bonding arrangement is shown in Fig. 7.

PBB is recommended for minimum dimensions of 6.35 mm thick, 101.6 mm wide and variable in length and the recommended minimum dimension for SBB is 6.35 mm thick and 50 mm wide. The TBB conductor sizing are as under:

Sl No.	*Maximum PBB-SBB length (l)* m	*TBB cross-sectional area* mm^2
(1)	(2)	(3)
i)	$l \leq 4$	16
ii)	$4 < l \leq 6$	25
iii)	$6 < l \leq 8$	35
iv)	$8 < l \leq 10$	35
v)	$10 < l \leq 13$	50
vi)	$13 < l \leq 16$	60
vii)	$16 < l \leq 20$	70
viii)	$20 < l \leq 26$	95
ix)	$26 < l \leq 32$	120
x)	$32 < l \leq 38$	150
xi)	$38 < l \leq 46$	150
xii)	$46 < l \leq 53$	185
xiii)	$53 < l \leq 76$	150
xiv)	$76 < l \leq 91$	300

NOTE — For lengths in excess of those shown above, the conductor cross-sectional area should be calculated as 3.3 mm^2 per meter. The figures given in parentheses are in AWG.

4.1.1 *Meshed Bonded Networks*

The mesh bonded networks provide enhanced immunity to EMI compared to that provided by the other bonding networks. This may be preferred for application, where high density of ICT equipment are installed, for example data centres, hospitals, airports. A merged MESH-BN and protective earthing network in buildings shall include the interconnections to the integrated lightning protection system, bonding measures of antenna installations (including satellite receiving equipment under private property) and cable networks, bonding measures of information technology cabling. The typical indicative diagram for meshed bonded network is given in Fig 8.

NOTE — For further information refer special publication, ISO/IEC 30129 : 2015 'Information technology — Telecommunications bonding networks for buildings and other structures'.

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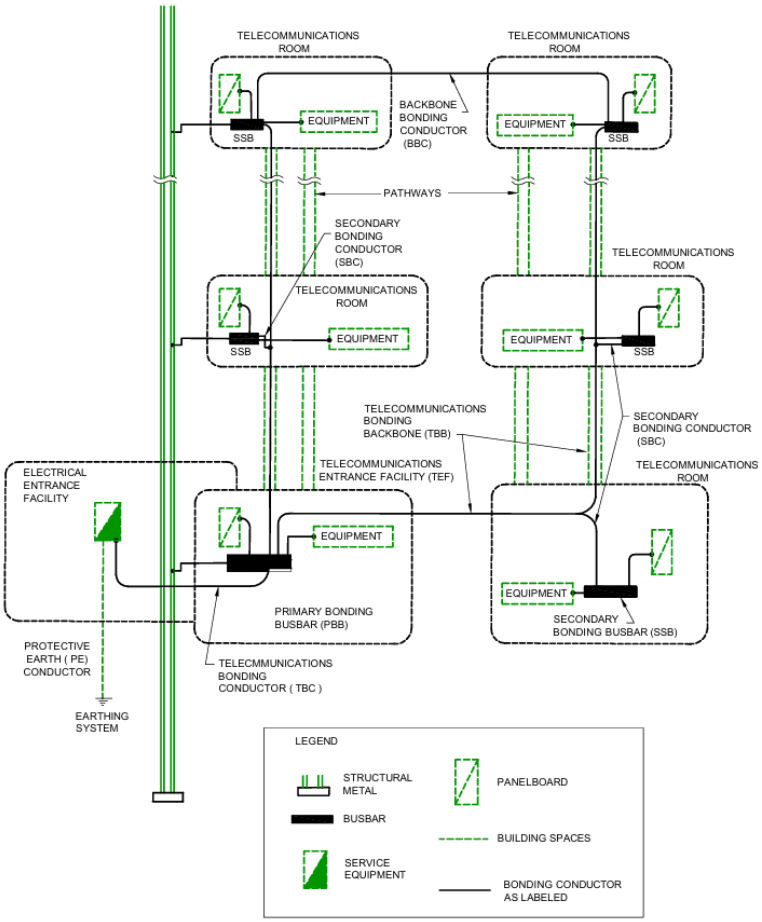

FIG. 7 TYPICAL TELECOMMUNICATION EARTHING AND BONDING ARRANGEMENT

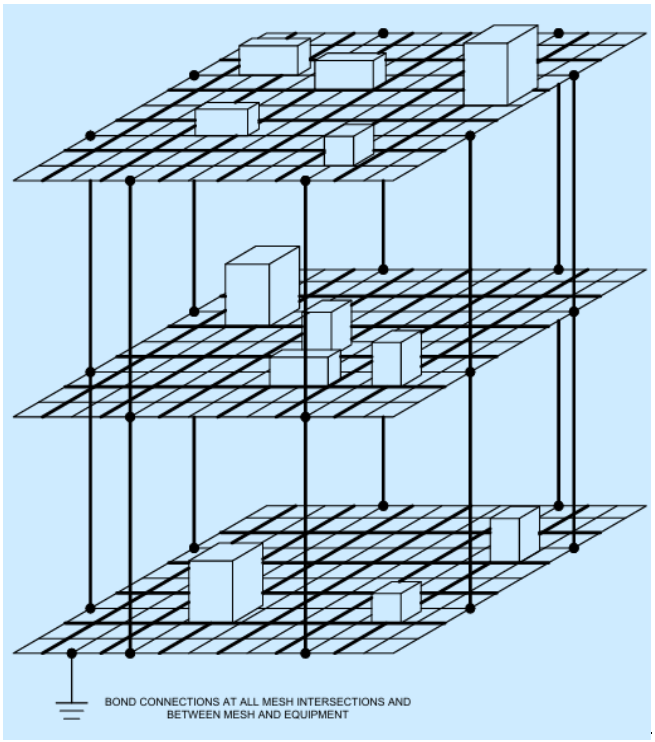

FIG. 8 MESH-BN WITH EQUIPMENT CABINETS, FRAMES, RACKS, CBN AND GLOBAL EARTHING BONDED TOGETHER

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4.2 Installation and Workplace Safety

4.2.1 *Cabling Installation Guidelines*

The installation of system components has a tremendous effect on the final performance level of the network; therefore, it is essential to ensure that the performance of the entire network is not diminished through improper installation. The cables can be easily damaged if they are improperly handled or installed. It is imperative that certain procedures be followed in the handling of these cables to avoid damage and/or limiting their usefulness.

Care shall be taken not to stretch or abrade cables during installation, that is, the pulling tension for cables shall not be exceeded. Cables that pass through the infrastructure of the building shall be suitably protected against damage. Through walls and floors, this shall involve an appropriate type of sleeve; through any form of metalwork or stiff plastic then a rubber grommet shall be used.

To ensure cable management and also strain relief, cables shall be properly dressed using velcro cable ties. However, cable's ties should never be over tightened. On vertical runs, the cables shall be dressed and tied from the bottom up, thus putting minimum strain on the cables. In order that the system may be easily re-routed, or damaged sections quickly replaced, free access to the cable should be ensured and where possible, it is important to leave draw cords in ducting, piping, etc, for future use.

4.2.1.1 *Improvement areas*

a) *Do not exceed the maximum tensile load* — On runs from 40 m to 100 m, use proper lubricants and make sure they are compatible with the cable jacket. On runs over 100 m, use proper lubricants and pull from the middle out to both ends. If possible, use an automated puller with tension control or at least a breakaway-pulling eye;

b) *Maintaining minimum bending radius* — Sharp bends in the cable may damage the insulating material, thus causing unacceptable losses in the transmission medium. Therefore, the internal radius of every bend in a cable shall be such as not to cause damage to the cable, nor impair the characteristics of the cable;

c) *Proper cable slack at outlet points and patch panels* — Install the system such that sufficient slack remains to enable re-termination of the outlets, a minimum of twice, and a limited scope for movement of the cabinets;

d) *Patch panels and cable management* — Where possible, patch panels shall be installed within the communications units from the top, continuing downwards;

e) *Electromagnetic compatibility* (*EMC*) — As a passive medium, structured cabling need not comply with the EMC regulations. However, telecom designers should be aware that cabling, when connected to transmission equipment, could radiate, receive and conduct electromagnetic disturbances and act accordingly. When crossing mains cables, this shall be done at right angles;

f) *Maintaining proper cable routes* — Cable shall not be routed over pipes, conduits, other cabling, ceiling tiles, etc, but shall rest directly on the supporting surface so as to minimize the potential for sharp bends, kinks, etc. Every cable used shall be supported in such a way that it is not exposed to undue mechanical strain so that there is no appreciable mechanical strain on the terminations; and

g) *Labelling* — The cable shall be clearly labelled at both ends, as outlined in the documentation and/or drawing. Each 8P8C connector (information outlet) shall be individually labelled. The label shall contain a unique identification, as outlined in the documentation and/or drawing, and shall be indelible and placed behind a transparent cover. At the patch panels, each socket shall be labelled according to its corresponding outlet identification.

4.2.2 *Workplace Safety*

Following measures shall be ensured for workplace safety:

a) To maintain workplace safety, personal protective equipment (PPE) like protective clothing, helmets and

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goggles should be used to protect the personnel from injury or infection from hazards such as physical, electrical, heat, chemical and biohazards;

b) Lighting in telecom spaces shall be provided in an adequate amount such that continuing work operations, routine observations, and the passage of employees can be carried out in a safe and healthful manner. Certain specific tasks in centres, such as splicing cable and the maintenance and repair of equipment frame line-ups, may require a higher level of illumination and adequate provisioning should be provided for the purpose; and

c) While working with optical fibre installation, the real issue of eye safety is getting fibre scraps into the eye. The broken ends of fibres and scraps of fibre created during the termination and splicing may also be dangerous. Therefore, protective eyewear such as safety glasses should be worn by personnel while carrying out splicing and termination operations. Further, fibre optic splicing and termination use various chemical cleaners and adhesives as part of the processes. Therefore, careful handling of fibre, cleaner and adhesive shall be ensured by the use of safety gloves and respiratory masks.

5 OTHER APPLICATIONS IN TELECOM INFRASTRUCTURE CABLING

5.1 Electronic Access Control (EAC)

EAC is important for overall personal safety and the protection of physical and intellectual property. EAC devices can include locks, integrated electronic devices controlling a single door or room, or a complex system of interconnected electronic devices controlling a zone, building, or campus. Access to private or secured spaces can be controlled in a great variety of methods. In addition, the user often has multiple levels of access required within a space. Personnel may have access to any given number of these. This access level may be required to change during the course of the day, week, or month. In contrast to a lock-and-key system, a modern computer-supported control system can meet these and many other user goals. This system employs programmable EAC. Time-of-day and day-of-the-week access levels can be applied to all personnel who have authorized entry. Additional precautions should be taken against weaknesses in the EAC system (for example, piggybacking, tailgating, unauthorized entry). A great number of possibilities exist from the passive card to biometrics and any combination in between. A user may issue smart cards.

A typical EAC cable consists of four individually shielded pairs that are used for the door strike, card reader, door contact, and request for exit. The four individual wire pairs may be supplied individually or in a group. Coloured foil shields or jacket colours may be used to designate the intended purpose of each of the wire pairs within the cables.

In a shared communication environment, the EAC data travels along with other building systems and data networks packets on the same physical network. This is often accomplished through an ethernet connection. It may also use building automation networks. Another media for shared communication relies on a private branch exchange and local analog telephone line (*See* Annex A for details).

5.2 Video Surveillance

Video surveillance is the extension of human vision to areas requiring surveillance. Some primary applications of this technology include investigation, prosecution, deterrence, observation and intrusion detection. In addition to traditional capture devices that operate within the visible band of the electromagnetic spectrum, other technologies provide unique viewing capabilities using IR, thermal and film cameras. (*See* Annex A for details.)

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ANNEX A

(*Clauses* 3.2.4, 3.2.4.1, 3.2.6, 5.1 *and* 5.2)

ADDITIONAL GUIDELINES FOR INFORMATION AND COMMUNICATION ENABLED INSTALLATIONS

A-1 GENERAL

This Annex contains information which supplements the text of this Section. The information can be used to make decisions while exercising options from among various types of hardware, cables, etc, and also for guidance.

A-2 CONNECTORS AND CONNECTING HARDWARE

Various types of connecting hardware may be as described below.

A-2.1 Balanced Copper Twisted-Pair Connectors:

a) *Insulation displacement contact (IDC) connectors* — The insulation displacement contact (IDC) is a gas-tight physical contact between two electrical conductors. The gas-tight contact is established by a cold weld with the elimination of the air gap between the conductor and the IDC and therefore the possibility of contact interface corrosion. Such contact creates a reliable, long-lasting connection with stable electrical properties. IDC connectors also eliminate conductor preparation (for example, insulation removal), reducing the termination time and the number of tools;

b) *Modular plug* — Modular plugs have IDC contacts designed for either stranded or solid conductors as well as connectors having universal contacts that accept both stranded and solid conductors. Materials used to build modular plugs are typically flame retardant polycarbonate (body) and phosphor bronze with gold plating over nickel in contact area (contacts); and

c) *Modular jack* — Modular jacks are available in various sizes and shapes (keyed and unkeyed). The number of positions indicates the connector's width, while the number of contacts installed into the available positions indicates the maximum number of conductors the connector can terminate.

A-2.2 Optical Fibre Connectors

The most common optical fibre interfaces include:

a) *LC connector* — It is a simplex connector that can be converted to a duplex using a clip. It is keyed, low-loss, pull-proof and wiggle-proof. It can be terminated in many different ways, including using anaerobic (quick cure) adhesive, cleave and crimp, and hot melt. This is often referred to as a small form factor (SFF) connector. The LC connector provides a pull-proof design and small size perfect for high-density applications. It is available in simplex or duplex versions. The LC connector is provided with a 1.25 mm ferrule. It also incorporates a unique latching mechanism providing stability in system rack mounts.

b) *Subscriber connector (SC)* — It is a simplex connector that can be converted to a duplex using a clip. It is keyed, low-loss, pull-proof, and wiggle-proof. It can be terminated in many different ways, including using anaerobic (quick cure) adhesive, cleave and crimp, and hot melt. The SC connector is a snap-in connector that latches with a simple push-pull motion, with a 2.5 mm ferrule and is widely used for its excellent performance. It is also available in a duplex configuration.

c) *Straight tip (ST) compatible* — It is a simplex connector. It is a keyed, low loss connector. It can be terminated many different ways, including using anaerobic (quick cure) adhesive, cleave and crimp and hot melt.

d) *Splices (Optical fibre connectors)* —These are used for adding optical fibre cable lengths. There are two primary splicing methods for optical fibres, fusion and mechanical. Both methods are field proven and have excellent long-term reliability when completed according to the manufacturer's instructions. Splices and stripped optical fibre cables are protected and secured by a splice enclosure. When a splice enclosure is used for splicing inside a building, it is generally secured to a rack or wall. In both cases, the splice enclosure contains the optical fibre splices in splice trays or organizers, typically in groups of 6, 12, 24, or more optical fibres per splice tray or organizer.

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A-2.3 Coaxial Connectors

Connectors are installed on the end of a coaxial cable to provide electrical and mechanical connection to a system component. Either male or female connectors can be attached to coaxial cable, but most installations use male connectors on cable ends.

There are many styles of coaxial cable connectors. Three popular styles are:

a) BNC-style connector;

b) F-style connector; and

c) N-style connector.

A-2.4 Connecting Hardware

Cables are terminated in outlets in work areas or intermediate equipment through connecting hardware. Basic connecting hardware styles are:

a) Telecom outlets/connectors, including multiuser outlets;

b) Patch panels;

c) Connecting (wiring) blocks;

d) Cable assemblies;

e) Optical distribution frames; and

f) Splices.

To facilitate their installation, servicing, administration and maintenance, connecting hardware of different styles of connectors may be considered to be grouped in one unit. However, depending upon the given situation, one or more type of connecting hardware (copper pair, coaxial or optical) may be installed on separate panels/frames.

A-3 CLASSIFICATION OF CABLES BY FIRE SAFETY PROPERTIES

A-3.1 Twisted Pair Cables

Different communication cable types and their markings on cable sheath are as given below:

Sl No.	*Marking*	*Cable Type*
(1)	(2)	(3)
i)	CMP	Communications plenum cable
ii)	CMR	Communications riser cable
iii)	CMG/CM	Communications general-purpose cable
iv)	CMX	Communications cable, limited use
v)	CMUC	Under carpet communications wire and cable

A-3.1.1 *Type CMP* (*Communications Plenum Cable*)

Type CMP communications plenum cables are suitable for use in ducts and plenums and they have adequate fire-resistant and low smoke-producing characteristics.

A-3.1.2 *Type CMR* (*Communications Riser Cable*)

Type CMR communications riser cables are suitable for use in a vertical run in a shaft when penetrating one or more floors as they have fire-resistant characteristics and thus be capable of preventing the carrying of fire from floor to floor.

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A-3.1.3 *Type CMG*/*CM* (*Communications General-Purpose Cable*)

Type CMG general-purpose communications cables are suitable for general-purpose communications use, with the exception of risers and plenums, and these cables are resistant to the spread of fire.

A-3.1.4 *Type CMX* (*Communications Cable, Limited Use*)

Type CMX limited-use communications cables are suitable for use in dwellings and raceways as being resistant to flame spread.

A-3.1.5 *Type CMUC* (*Under Carpet Communications Wire and Cable*)

Type CMUC under carpet communications wires and cables are suitable for under carpet use and they are resistant to flame spread.

A-3.2 Optical Fibre Cables

Different optical fibre cable types and their markings on cable are as given below:

Sl No.	*Marking*	*Cable Type/Suitability*
(1)	(2)	(3)
i)	*OFNP*	Non-conductive optical fibre plenum cable
ii)	*OFCP*	Conductive optical fibre plenum cable
iii)	*OFNR*	Non-conductive optical fibre riser cable
iv)	*OFCR*	Conductive optical fibre riser cable
v)	*OFNG*	Non-conductive optical fibre general-purpose cable
vi)	*OFCG*	Conductive optical fibre general-purpose cable
vii)	*OFN*	Non-conductive optical fibre general-purpose cable
viii)	*OFC*	Conductive optical fibre general-purpose cable

A-3.2.1 *Types OFNP and OFCP*

Types OFNP and OFCP non-conductive and conductive optical fibre plenum cables are suitable for use in ducts and plenums and they have adequate fire-resistant and low smoke-producing characteristics.

A-3.2.2 *Types OFNR and OFCR*

Types OFNR and OFCR non-conductive and conductive optical fibre riser cables are suitable for use in a vertical run in a shaft when penetrating one or more floors and have the fire-resistant characteristics capable of preventing the carrying of fire from floor to floor.

A-3.2.3 *Types OFNG and OFCG*

Types OFNG and OFCG non-conductive and conductive general-purpose optical fibre cables are suitable for general-purpose use, with the exception of risers and plenums, and these cables are resistant to the spread of fire.

A-3.2.4 *Types OFN and OFC*

Types OFN and OFC non-conductive and conductive optical fibre cables are suitable for general-purpose use, with the exception of risers and plenums and have resistance to the spread of fire.

A-4 BALANCED TWISTED-PAIR CABLE NOMENCLATURE

Details of nomenclatures of twisted pair cables using various combinations of overall screen type and individual

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pair screen type, as follows, are given in Table 2:

Sl No.	*Overall Screen Type* (*x*)	*Individual Pair Screen Type* (*y*)
(1)	(2)	(3)
i)	Overall screen absent (*U*)	Individual screens absent (*U*)
ii)	Overall foil screen (*F*)	Individual foil screens (*F*)
iii)	Overall braid screen (*S*)	
iv)	Dual overall screen (foil + braid) (*SF*)	

Table 2 Balanced Cable Nomenclature

(*Clause* A-4)

Sl No.	Global Abbreviations (*x*/*y*)	North American Abbreviation	Overall Braid Screen	Overall Foil Screen	Individual Foil Screen
(1)	(2)	(3)	(4)	(5)	(6)
i)	*U*/*U* TP	*U* TP	No	No	No
ii)	*U*/*F* TP	*S* TP	No	No	Yes
iii)	*F*/*U* TP	*F* TP, *S*cTP, PiMF	No	Yes	No
iv)	*F*/*F* TP	*S* TP, *SS* TP	No	Yes	Yes
v)	*S*/*U* TP	*S* TP	Yes	No	No
vi)	*S*/*F* TP	*S* TP, *SS* TP	Yes	No	Yes
vii)	*SF*/*U* TP	*S* TP, *SS* TP	Yes	Yes	No
viii)	*SF*/*F* TP	*S* TP, *SS* TP	Yes	Yes	Yes

NOTE — The abbreviations represent as follows:

1 F/F TP — Foil-screened foil-screened twisted-pair (Individually foil-screened twisted-pair in overall foil screen).

2 F/U TP — Foil-screened unscreened twisted-pair (Unscreened twisted-pair in overall foil screen).

3 S/F TP — Braid-screened foil-screened twisted-pair (Individually foil-screened twisted-pair in overall braid screen).

4 S/U TP — Braid-screened unscreened twisted-pair (Unscreened twisted-pair in overall braid screen).

5 Sc TP — Screened twisted-pair.

6 SF/F TP — Braid-screened-foil-screened foil-screened twisted-pair (Individually foil-screened twisted-pair in overall foil and braid screen).

7 SF/U TP — Braid-screened-foil-screened unscreened twisted-pair (Unscreened twisted-pair in overall foil and braid screen).

8 U/F TP — Unscreened foil-screened twisted-pair (Individually foil-screened twisted-pair).

9 U/U TP — Overall unshielded twisted-pair with unshielded twisted-pair.

A-5 ELECTRONIC ACCESS CONTROL (EAC) AND VIDEO SURVEILLANCE

A-5.1 Electronic Access Control (EAC)

An EAC system allows several levels of security. Once the number and type of people are determined, a user or access level for each person is established. Access levels are incorporated into the system integration and the areas of access are determined. Factors affecting the user level include security clearances, job title, rank, short-term employee and employee type. The access level is determined by the physical layout of building and is directly related to the doors and other portals it controls.

The basic components of an EAC system include:

a) A computer;

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b) One or more control panels; and

c) One or more peripheral devices connected to the control panels (for example, card reader, siren and sensor).

The host computer runs the EAC software, manages the system parameters, maintains the system database, and controls all communication with the control panels. The host computer receives all event and alarm transactions from the control panels. It then saves them into separate history files that may be used to run reports by specific criteria.

The control panels manage the activation of peripheral devices by turning the devices on or off and controlling access to certain areas through card readers and door-locking hardware.

Media for communications may include the following:

a) *Balanced twisted-pair* — Shielded twisted-pair, unshielded twisted-pair, and screened twisted-pair;

b) *Optical fibre* — Multi-mode and single-mode;

c) *Wireless* — Microwave, radio frequency (RF), and infrared (IR); and

d) Cellular networks connection.

A-5.2 Video Surveillance

A-5.2.1 In addition to traditional capture devices that operate within the visible band of the electromagnetic spectrum, other technologies that provide unique viewing capabilities are, as follows:

a) *IR cameras* — These refer to specially designed imagers capable of seeing into the low IR bandwidth. They are sometimes referred to as starlight cameras because of their night time viewing capabilities;

b) *Thermal cameras* — They capture heat or temperature values of a scene rather than light values, regardless of how bright or dark the scene appears to the human eye. Although the identification of colours and details are impossible with thermal cameras (because they only view temperature), these cameras are quite useful in viewing dark scenes for activities that have heat signatures; and

c) *Film cameras* — They have been on the market for many years. These self-sustaining units are equipped with traditional camera film, which permanently stores the scenes. The film requires replacement when exhausted.

A-5.2.2 Camera placement is based on security objectives identified through a need-assessment. Video surveillance applications include two typical types of camera mounts, as follows:

a) *Fixed* — It refers to a camera dedicated to single view that does not change unless the camera is physically moved; and

b) *Pan and tilt* — It refers to a camera with a pan and tilt that allows for a 180º or 360º view, which is controlled electronically from a remote viewing station.

From a practical standpoint, the trade-off between the two types is that a pan and tilt provides a more flexible area of coverage at a higher cost than a fixed camera. Pan and tilt technology allows for auto-panning where the camera moves in a predefined cycle. Camera mounting locations are typically dictated by the available physical infrastructure and are balanced against the required field of views. Connectivity of cameras to the main system in a building environment is generally through coaxial cables.

A-6 OVERVIEW OF IN-BUILDING SOLUTIONS (IBS)

A-6.1 General

The information in this annexure can be used to plan IBS to provide seamless mobile data and voice experience for indoor users including in areas like lifts, staircase and basements. IBS is a telecommunications infrastructure designed to enhance wireless network coverage. It is particularly useful in establishments such as offices, malls, hospitals, airports, sport arenas, multistorey residential complexes and other areas, where outdoor mobile signals may be weak due to distance and structural obstructions.

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A-6.2 Types of In-Building Solutions

The various types of IBS technologies, to enhance indoor connectivity, are as under:

A-6.2.1 *Distributed Antenna Systems* (*DAS*) — It consist of multiple antennas distributed throughout a building or a venue. These antennas connect to a radio frequency source(s) and distribute signals effectively overcoming signal degradation in indoor environments. Typical layout of a DAS is shown in the Fig. 9. Following are the main components of DAS:

a) *Distributed antennas* — Acts as radiating source for RF signals. These are distributed throughout the building based on radio network planning;

b) *Splitter* — A passive component that divides the RF signal power equally among multiple output ports;

c) *Coupler* — A passive device that extracts a small portion of the signal from the main feed while allowing most of it to continue;

d) *Radio unit* — The radio frequency or mobile signal source that connects the in-building system to the mobile network; and

e) *RF or fibre cable for signal distribution* — The RF is used in passive DAS to carry the radio signals up to the antennas while fibre cable is used to connect master and slave unit in case of active DAS.

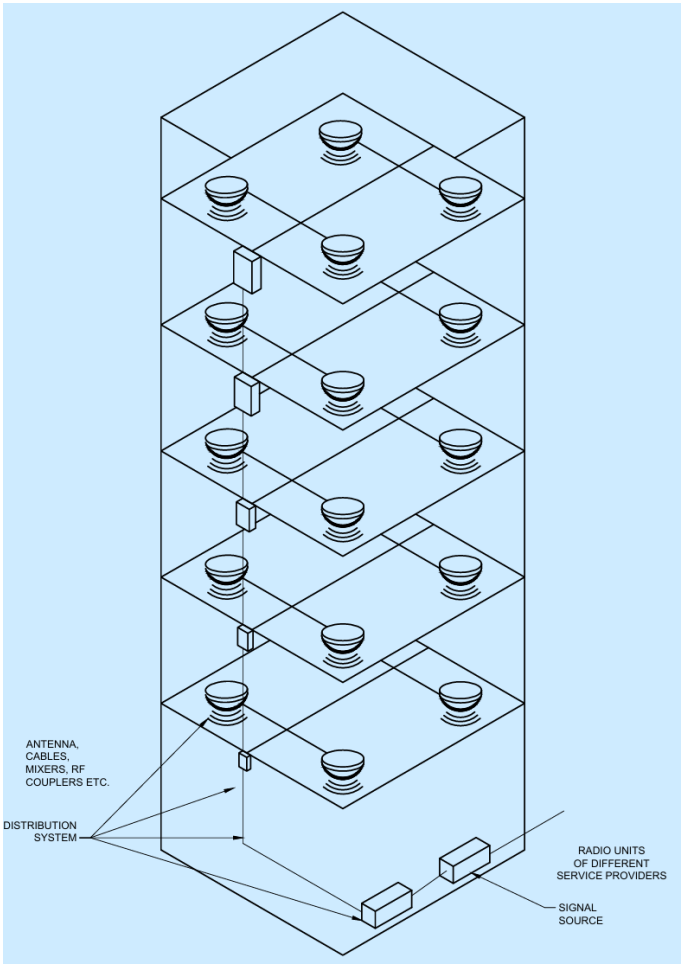

FIG. 9 TYPICAL COMPONENTS OF A DISTRIBUTED ANTENNA SYSTEM (DAS)

A DAS can support multi frequency bands to carry radio frequency signals of multiple service providers for different technologies (2G/3G/4G/5G, etc) using common DAS. This common DAS infrastructure provide considerable cost savings with improved building aesthetics while providing seamless mobile coverage including in basements, lifts and lobbies.

There are different types of distributed antenna systems suitable for different use cases. Overview of some

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important DASs are covered below:

1) *Passive distributed antenna system* (*DAS*) — In passive DAS, only passive components are used to distribute the RF signals. The size of the cable depends upon the frequency in use, coverage and capacity requirement. The distribution of combined mobile signal is done using passive components in the network like RF cable, couplers and splitters. The RF signal is coupled with the antennas installed across the floor(s) for radiating in different sections of the building as indicated in the Fig 10; and

2) *Active distributed antenna system* — This type of system is used where the coverage is required in a huge building and airport etc. where conventional passive cable system does not give adequate coverage due to high losses in the coaxial cables as shown in Fig 11.

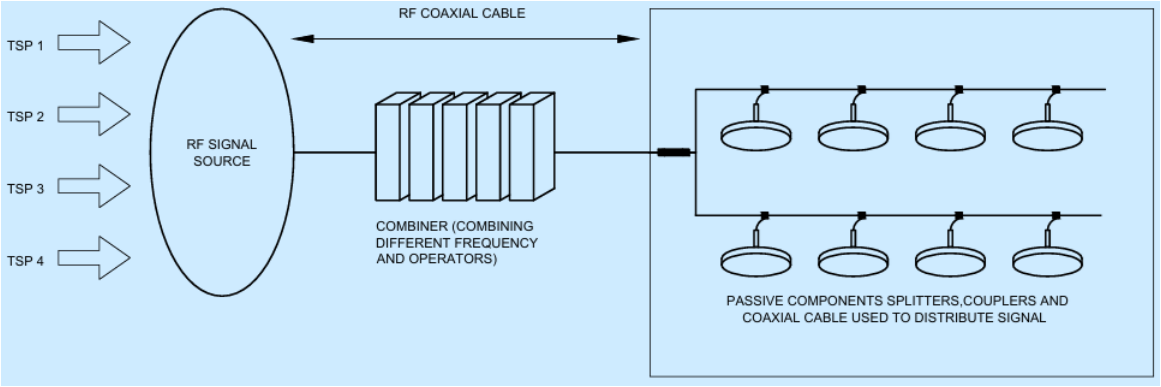

FIG. 10 KEY COMPONENTS OF TYPICAL PASSIVE DAS

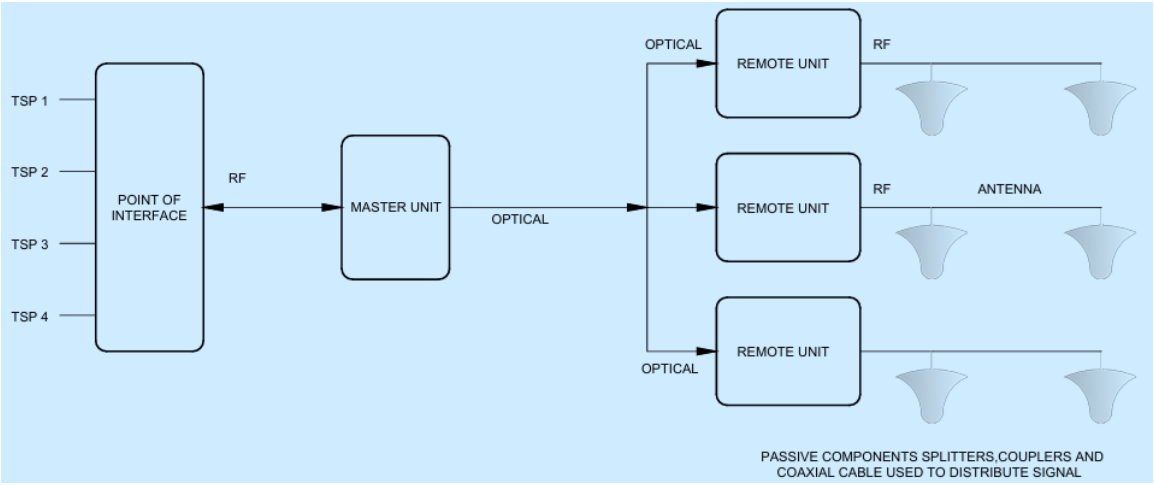

FIG. 11 KEY COMPONENTS OF TYPICAL ACTIVE DAS

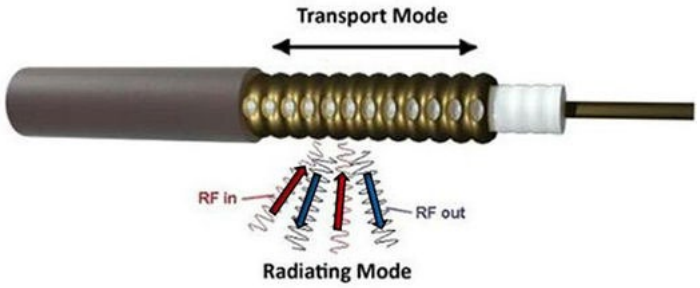

FIG. 12 TYPICAL LEAKY CABLE INSTALLATION IN A TUNNEL

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A-6.2.2 *Leaky Feeder Cable System* — In this system this is a special type of cable known as leaky feeder cable in which the slots are cut as window in the cable itself and when the RF signal is pumped in it which get radiated through these windows which acts as an antenna as indicated in Fig. 12. Such cables are generally used in the tunnels where installation of active components may be difficult.

A-6.2.3 *Small Cells, Including Femtocell and Pico Cells* — They are low-powered radio access nodes designed to cover small geographic areas, such as a single room or a specific area in a larger venue. They complement main cellular networks by providing targeted coverage and traffic capacity.

A-6.3 Key Considerations for Planning an In-Building Solution

a) *Coverage requirements* — Determining the appropriate coverage levels for an in-building solution depends on user density and the types of applications being used. High-density areas require a robust network capable of handling simultaneous connections from multiple users. The design should account for variations in density across different floors and zones to ensure uniform coverage. Additionally, the nature of services being provided whether voice, video, or data — Plays a crucial role in coverage planning;

b) *Interference management* — Effective interference management is essential to maintain signal quality within an indoor environment. Identifying potential interference sources, such as nearby wireless networks, electronic devices, and structural obstacles, helps in mitigating performance issues. To minimize interference, strategies such as frequency planning, power control, and spatial diversity should be implemented;

c) *Capacity planning* — Proper capacity planning ensures that an in-building solution can handle both current and future network demands. By analyzing user behaviours and application requirements, network designers can forecast growth in user numbers and data consumption patterns; and

d) *Aesthetics and integration* — Careful placement of antennas, cables, and other infrastructure components helps maintain the visual appeal of the space. Where possible, discreet installations such as ceiling-mounted antennas or concealed cabling are preferred. Engaging stakeholders including building owners, architects, and end-users during the IBS design phase ensures that the network aligns with both functional and aesthetic requirements.

NOTE — The relevant standards, prescribed by Telecom Engineering Centre (TEC), Department of Telecom, Ministry of Communications, may be referred at [https://www.tec.gov.in] for the implementation of in-building solutions.

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ANNEX B

(*Foreword*)

STREET FURNITURE FOR ICT INSTALLATIONS

B-1 Street furniture, such as streetlights, utility poles, bus stops, and traffic signals, is expected to play a significant role in enabling ICT infrastructure, especially as India deploys next-generation technologies targeting the mobile devices used by public. As ICT installations expand, these existing structures provide an efficient and cost-effective foundation for small cell and air fibre, supporting enhanced connectivity, quicker deployments, and seamless integration into urban landscapes. The Telecom Regulatory Authority of India (TRAI) and the PM Gati Shakti National Master Plan recognize the potential of street furniture in, integrating digital connectivity into public infrastructure. Additionally, the *Telecommunications* (*Right of Way*) *Rules*, 2024, defines small cells as having a coverage range of up to 2 km, reinforcing their role in improving network reach

Further, under the PM Gati Shakti National Master Plan, 26.5 million units of street furniture have been mapped digitally to simplify planning, accelerate approvals, and reduce site survey timelines. This creates a ready-to-use foundation for 5G and future ICT infrastructure, helping embed digital connectivity into public infrastructure efficiently.

The guidelines for earmarking and use of street furniture are expected to be put in place by Department of Telecommunication (DoT)/TRAI in due course.

Some of the important aspects of use of street furniture which require consideration for effective ICT deployments are given below.

B-1.1 Structural and Positional Aspects

The aspects include, but are not limited to:

a) Load-bearing requirements to support equipment such as small cells and associated hardware;

b) Telecom equipment designs blend with urban aesthetics to avoid visual clutter;

c) Proximity to existing power sources;

d) Protection of pedestrian and vehicle traffic;

e) Public safety; and

f) Structural stability and safety considering the weight and required height for installation of equipment as well as sharing among service providers.

B-1.2 Administrative Aspects

The following aspects are applicable:

a) Easy right of way (RoW) for installation and maintenance and upgrades of the equipment;

b) Possibility of development of a GIS-mapped inventory of street furniture assets, detailing specifications like load capacity, power availability, and contact information for streamlined maintenance and coordination; and

c) Adherence to municipal guidelines and permissions for ICT installations on public or private street furniture.

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ANNEX C

(*Clause* 3.5)

BUILDING RELATED INFORMATION AND DIGITAL CONNECTIVITY REQUIREMENTS

C-1 GENERAL INFORMATION

Sl No.	*Item*	*Description/ Response*
i)	Name of building/Project and address	
ii)	Property manager detail (name, contact etc)	
iii)	Type of building	
iv)	Number of floors (including parking floors)	
v)	Total built-up area (sq. meters)	
vi)	Total carpet area (*see* NOTE)	
vii)	Year of construction completion (it will same as occupancy certificate year)	
viii)	Building/Property layout	Attachment
ix)	Ownership type (owners/tenants/developer owned/shared space)	
x)	a) Occupancy classification: 1) Group A: Residential 2) Group B: Educational 3) Group C: Institutional b) Hospitals/Healthcare: 1) Group D: Assembly c) Public buildings: 1) Airports/Railway stations/Bus stands/Metro train stations/Taxi stands, etc d) Exhibition centers: 1) Group E: Business e) Commercial retail: f) Commercial office: 1) Group F: Mercantile 2) Group G: Industrial 3) Group H: Storage 4) Group I: Hazardous 5) Group J: Mixed-use buildings	
xi)	Projected date of completion	
NOTE — Digital connectivity coverage design will require all areas including open, lifts, corridors, underground parking floors, basement etc. Therefore, total area where mobile or Wi-Fi coverage is required will be important to capture.		

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C-2 OCCUPANT/USER DETAILS

Sl No.	*Item*	*Description/Response*
(1)	(2)	(3)
i)	Total number of units (flat, office etc)	
ii)	Estimated No. of occupants/ users	
iii)	Number of tenants/offices	
iv)	Occupant categories (residential, academic, business, public use etc)	

C-3 DIGITAL CONNECTIVITY REQUIREMENTS

Sl No.	*Item*	*Description/Response*
(1)	(2)	(3)
i)	Number of internet and mobile service providers present in the area	
ii)	Expected number of internet connections per unit	
iii)	Typical internet speed requirements	
iv)	Number of devices (for example, mobile, tablets, laptop etc) per unit	
v)	Preference for neutral FTTx infrastructure (Yes or No)	
vi)	Need for redundant paths/Backup connectivity (Yes or No)	
vii)	Use of smart devices/Home automation (Yes or No)	
viii)	Cybersecurity requirements (Yes or No)	
ix)	IoT integration requirements (if any) (Yes or No)	
x)	Fibre connectivity requirement (Yes or No)	
xi)	Requirement of secure Wifi (Yes or No)	

C-4 INFRASTRUCTURE SUPPORT (APPLICABLE IN CASE OF EXISTING BUILDINGS)

Sl No.	*Item*	*Description/Response*
(1)	(2)	(3)
i)	Centralized cable pathways availability	
ii)	Duct space and shaft accessibility and maintainability	
iii)	Existing server or telecommunication rooms	
iv)	Power backup with provision of uninterrupted power supply for ICT	

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	Equipment in telecom room
v)	Proposed upgrades (if any)
vi)	Provision of future expansion (telecom Room, cable pathways, IoT etc)
vii)	Provision of elevated structure for TI/Telecom room to address flood situations
viii)	Redundant entry paths/Ducts for extending backhaul telecom connectivity by the service providers to the property

Declaration

This information is collected for planning and designing telecommunication infrastructure. In case of unavailability of user-specific data, data from similar building typologies shall be used.

Signature of Property Manager/Owner: _____

Date: _____

NOTE — It may be noted that in many cases, buildings or complexes are of mixed-use nature. The template provided for collecting building information may be used only as a reference document specifically for telecommunication infrastructure and services planning. The classification used in this template applies only to this section and has no relation to the occupancy classification given in any other part of this NBCS.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used for conformance with the requirements of the referred clauses in this NBCS.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

	IS No.	*Title*
(1)	IS 9537	Specification for conduits for electrical installations:
	(Part 2) : 1981	Rigid steel conduits
(2)	IS 9537	Specification for conduits for electrical installations:
	(Part 3) : 1983	Rigid plain conduits for insulating materials
	IS 3419 : 1988	Specification for fittings for rigid non-metallic conduits (*second revision*)
(3)	IS 9537	Conduits for electrical installations — Specification
	(Part 5) : 2000	Pliable conduits of insulating materials

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART E PLUMBING SERVICES

(INCLUDING SOLID WASTE MANAGEMENT)

SECTION 1 WATER SUPPLY

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part E/Section 1) covers the requirements of water supply in buildings. The water supply provisions covered in this Section encompass the requirements of water supply, plumbing connected to public water supply, design of water supply systems, principles of conveyance and distribution of water within the premises, hot water supply system, inspection and maintenance of water supply systems. It also covers design of water supply systems in high altitudes and/or sub-zero temperature regions.

In the first version of the Code formulated in 1970, as part of the National Building Code of India, three separate sections of this Part on 'Plumbing Services' were brought out, namely, Section 1 'Water Supply', Section 2 'Drainage and Sanitation', and Section 3 'Gas Supply'. These sections were subsequently revised in 1983.

The major changes incorporated in the first revision in 1983 Section 1 Water Supply, were: Rationalization of definitions and addition of definitions for more terms; addition of universal pipe friction diagram and nomogram of Hazen and Willam's equation for discharge computation, deleting the discharge curves based on Chezy's formula; introduction of a detailed clause giving guidance on the design of water supply system for multi-storeyed buildings; modification to indicate that no separate storage need be provided for flushing and domestic purposes for health reasons and a single storage tank may be provided; modification/amplification of provisions relating to domestic hot water supply installations; introduction of a detailed clause covering recommendations to be considered while planning and designing water supply systems peculiar to high altitude and/or sub-zero temperature regions of the country; and addition of requirements relating to inspection, testing and maintenance applicable to hot water supply system.

As a result of experience gained in implementation of 1983 version of the Code and feedback received as well as revision of some of the standards based on which this Section was formulated, a need to revise this Section was felt then. The second revision of 2005 was therefore formulated to take care of these. In the revision, the erstwhile two sections were merged and a combined and comprehensive section, namely Section 1 Water supply, drainage and sanitation (including solid waste management), was brought out. Gas supply was brought out as Section 2. Following significant changes were incorporated in the second revision of Section 1 on water supply, drainage and sanitation, in respect to water supply: modification of provision of water supply requirement; addition of a new clause on water supply for other than residential purposes; addition of a new clause on quality of water, also including therein a sub-clause on waste water reclamation; modification of the provision regarding storage of water and introduction of guidelines for calculating storage capacity; modification, in the design of distribution system provisions for discharge computation, to include designed consumer pipes based on fixtures unit also taking into account probable simultaneous demand instead of earlier computation based on Reynold's Number; introduction of an alternative option of variable speed drive pumping system to hydro pneumatic system; addition of a new clause on backflow prevention; addition of provision for suitability of galvanized mild steel tanks on the basis of *p*H of the water; detailing of types of hot water heater; and restructuring of the section was done to make it more user friendly.

The second revision in 2005 also incorporated for the first time the provisions on solid waste management.

In the third revision in 2016, to address the various and distinct features related to the plumbing aspects and solid waste management comprehensively, this Part on 'Plumbing Services' was rearranged as follows:

Section 1 Water supply

Section 2 Drainage and sanitation

Section 3 Solid waste management

Section 4 Gas supply

The revision of Section 1 in 2016 incorporated several modifications; provisions on water supply requirements for buildings were related to the estimated occupancy in the chosen type of building; Table 1 on water requirements for buildings other than residences was updated concerning building types and included domestic and flushing requirements separately; water demand for landscaping purposes was included; requirements related

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to wastewater treatment and the usage of recycled wastewater were included; materials used for storage water tanks were updated; provisions regarding the quantity of water to be stored were revised; measures for protecting the water supply were included to prevent cross-connection between treated and raw water supplies, ensure backflow prevention, and secure identification of non-potable water supply pipes; the list of materials used for manufacturing pipes was updated; general requirements for the design of distribution systems were introduced; Table 2 on fixture units for different types of fixtures was updated; Table 3 on probable simultaneous demand was revised with demand values covering various intermediate and up to 10 000 fixture units, along with graphs for probable demand; maximum flow rate and flush volumes were specified; provisions concerning inadequate and excessive water pressure were introduced; guidance on water hammer effects was included; distribution system provisions for multi-storeyed buildings were updated with illustrations; provisions related to zoning of distribution systems were included; hot water supply systems were incorporated under the existing clause on hot water supply installations; detailed provisions for swimming pools were included; guidance on allowance for expansion of water pipes was provided; a new clause on colour coding for different types of water pipes was added; provisions were reviewed and updated to ensure accessibility for the elderly and persons with disabilities, duly giving cross-references to **13** of Part 3 'Development Control Rules and General Building Requirements'; certain terminologies were introduced and some were revised; and cross-references to Indian Standards were updated.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

In this revision of the Section 1, the following significant changes have been incorporated:

a) Population requirements for residential buildings have been updated, in **4.1**;

b) Population requirement is introduced for warehouses and industrial occupancies, to arrive at their water demand;

c) Suggestive breakup of water for general consumption is included, in **4.1.1.1**;

d) Table 1 'Water requirements for buildings other than residences' now provides the quantity for various categories of hotels;

e) Storage requirement for hydro-pneumatic/pressurized water supply system have been included, in **4.4.10**; and

f) Terminology has been updated by including drinking water fountain, design flood elevation, demand recirculation water system, vacuum breaker, etc.

This Section is largely based on the following Indian Standards:

IS 1172 : 1993	Code of basic requirements for water supply, drainage and sanitation (*fourth revision*)
IS 2065 : 1983	Code of practice for water supply in buildings (*second revision*)
IS 6295 : 1986	Code of practice for water supply and drainage in high altitudes and or sub-zero temperature regions (*first revision*)
IS 7558 : 1974	Code of practice for domestic hot water installations
IS 12183 (Part 1) : 1987	Code of practice for plumbing in multi-storeyed buildings: Part 1 Water supply

A reference to SP 35 : 1987 'Handbook on water supply and drainage' may be useful, from where also, assistance has been derived.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the formulation of this Section, reference has also been made to the following:

International Plumbing Code 2024, International Code Council, and

Uniform Plumbing Code 2024, International Association of Plumbing and Mechanical Officials

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As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **"accepted standard"** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Sec shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [E-1(1)] refers to the Indian Standard(s) given at serial number (1) of the list of standards given at the end of this Part E/Section 1, that is, IS 10446 : 1983 'Glossary of terms relating to water supply and sanitation'.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART E PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

SECTION 1 WATER SUPPLY

1 SCOPE

1.1 This Section covers the basic requirements of water supply for residential, business and other types of buildings, including traffic terminal stations. This Section also deals with general requirements of plumbing connected to public water supply and design of water supply systems along with general guidelines about expansion in piping systems, and swimming pools.

1.1.1 This Section does not take into consideration the requirements of water supply for industrial plants and processes, which have to be provided for separately. It also does not provide the requirements of water supply for other purposes, such as firefighting and street cleaning.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply in addition to the definitions given in accepted standard [E-1(1)].

2.1 Definitions Relating to Water Supply

2.1.1 *Access Panel* — A removable panel mounted in a frame, normally secured with screws and mounted in a wall or ceiling, to provide access to concealed valves or items which may require maintenance.

2.1.2 *Air Gap, Water Distribution* — Unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet conveying water to a tank or plumbing fixture and flood level rim of the receptacle.

2.1.3 *Air Valve* — A valve that releases air from a pipeline automatically without loss of water or introduce air into a line automatically if the internal pressure becomes less than that of the atmosphere.

2.1.4 *Aspirator* — A device supplied with water or other fluid under positive pressure that passes through an integral orifice causing a vacuum. Aspirator is also referred as suction apparatus.

2.1.5 *Authority Having Jurisdiction* — The authority which has been created by a statute and which for the purpose of administering this NBCS/Part may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.1.6 *Available Head* — The head of water available at the point of consideration due to mains' pressure or overhead tank or any other source of pressure.

2.1.7 *Anti-siphon* — A device or mechanism to prevent siphonage.

2.1.8 *Backflow*

a) the flow of water or other liquids, mixtures or substances into the distributing pipes of a system of supply of potable water from any source or sources other than its intended source; and

b) the flow of a liquid in a direction reverse of that intended.

2.1.9 *Backflow Prevention Device* — Any approved measure or fitting or combination of fittings specifically designed to prevent backflow or back siphonage in a water service.

2.1.10 *Back Pressure Back Flow* — Due to an increased pressure above the supply pressure, which may be due to pumps, other equipment, gravity or other source of pressure.

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2.1.11 *Back Siphonage* — The flowing back of used, contaminated, or polluted water from a plumbing fixture or vessel into a water supply due to a reduced pressure in such pipe (*see* **2.1.8**).

2.1.12 *Barrel* — This portion of a pipe in which the diameter and wall thickness remain uniform throughout.

2.1.13 *Base* — The lowest portion or lowest point of a stack of vertical pipe.

2.1.14 *Bath Room Group* — Group of fixtures consisting of water closet, lavatory, bath tub or shower and other fittings with a floor drain located together.

2.1.15 *Bedding* — The material on which the pipe is laid and which provides support for the pipe. Bedding can be concrete, granular material or the prepared trench bottom.

2.1.16 *Chair* — A bed of concrete or other suitable material on the trench floor to provide a support for the pipes at intervals.

2.1.17 *Channel* — The open waterway through which sewage, storm water or other liquid wastes flow at the invert of a manhole or an inspection chamber.

2.1.18 *Communication Pipe* — That part of a service pipe which vests in the water undertakes. It starts at the water main and terminate at a point which differs according to the circumstances of the case.

2.1.19 *Consumer* — Any person who uses or is supplied water or on whose application such water is supplied by the Authority.

2.1.20 *Consumer's Pipe* (*Service Pipe*) — The pipe taking up from the street main originating from the ferrule leading up to the water meter for supply of water to consumer. The portion of pipe used for service connection is not the property of the Authority (*see* Fig. 1).

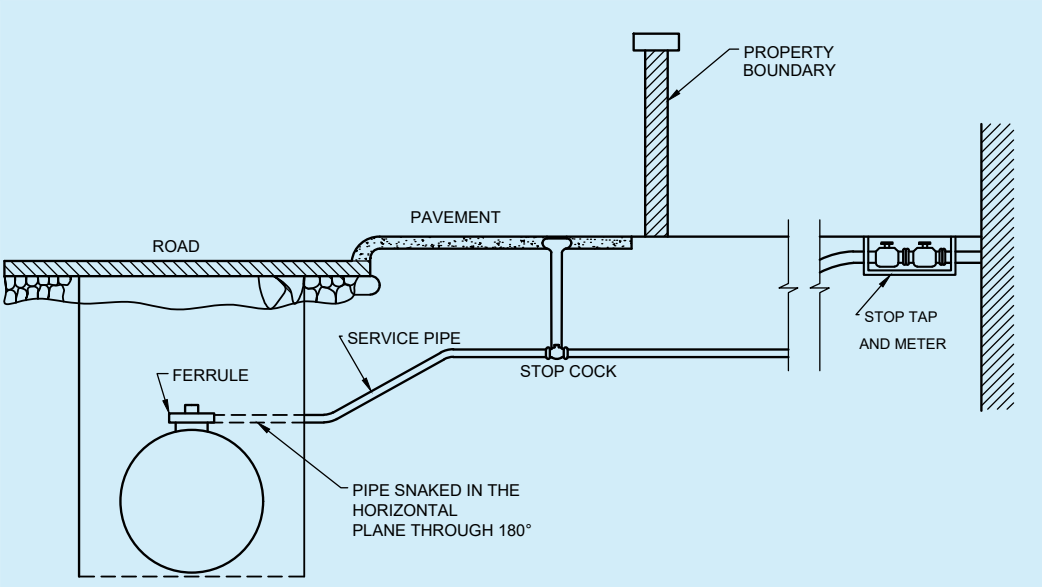

FIG. 1 CONSUMER'S PIPE CONNECTION

2.1.21 *Cover*

a) a removable plate for permitting access to a pipe, fitting, vessel or appliance; and

b) the vertical distance between the top of the barrel of a buried pipe or other construction and the surface of the ground.

2.1.22 *Cross-Connection* — Any physical connection or arrangement between the separate piping systems, one of which contains potable water and the other contains water of unknown or questionable safety, whereby water may

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flow from one system to the other, the direction of flow depending on the pressure differential between the two systems.

2.1.23 *Circulating Hot Water System* — A specifically designed hot water distribution system where one or more pumps are operated in the service hot water piping to circulate heated water from the water heating equipment to fixture supply and back to the water heating equipment

2.1.24 *Direct Tap* — A tap which is connected to a supply pipe and is subject to pressure from the water main.

2.1.25 *Demand Recirculation Water System* — A water distribution system within the built space where one or more pumps prime the service hot water piping with heated water upon a demand for hot water. Typically, this can be achieved by a timer or sensor.

2.1.26 *Design Flood Elevation* — The elevation of the 'design flood', including wave height, relative to the datum specified on the authorities legally designated flood hazard map. In areas designated as zone, the design flood elevation shall be the elevation of the highest existing grade of the building's perimeter plus the depth specified in the flood hazard map. In case the depth is not specified in the map the depth shall be taken as 610 mm.

2.1.27 *Drinking Water Fountain* — A plumbing fixture that is connected to the potable water distribution system and the drainage system. The fixture allows the user to obtain the potable water directly from a stream of flowing water without the use of any accessories.

2.1.28 *Down Take Tap* — A tap taken off from a storage tank situated at a higher elevation in the building.

2.1.29 *Effective Opening* — The minimum cross-sectional area at the point of water supply, measured or expressed in terms of,

a) the diameter of a circle; and

b) the diameter of a circle of equivalent cross-sectional area, if the opening is not circular.

2.1.30 *Feed Cistern* — A storage vessel used for supplying cold water to a hot water apparatus, cylinder or tanks.

2.1.31 *Fittings* — The appurtenances such as coupling, flange, branch, bend, tees, elbows, unions, waste (with or without plug), P or S trap (with or without vent), stop ferrule, bib tap, pillar tap, bath faucet, water meter, garden hydrant, valves and any other article used in connection with water supply, drainage and sanitation.

2.1.32 *Fixture Unit* — A quantity in terms of which the load producing effects on the plumbing system of different kinds of plumbing fixtures is expressed on some arbitrarily chosen scale.

2.1.33 *Float Operated Valve* — Ball valves or ball taps and equilibrium valves operated by means of a float.

2.1.34 *Flushing Cistern* — A cistern provided with a device for rapidly discharging the contained water and used in connection with a sanitary appliance for the purpose of cleaning the appliance and carrying away its contents into a drain.

NOTE — The nominal size of a cistern is the quantity of water discharged per flush.

2.1.35 *Flushometer Tank* — A tank integrated with an air accumulator vessel that is designed to discharge a predetermined quantity of water to fixtures for flushing purposes.

2.1.36 *Flow Pressure* — The pressure in the water supply pipe measured near the faucet or water outlet while the faucet or outlet is open or in use.

2.1.37 *Formation* — The finished level of the excavation at the bottom of a trench or heading prepared to receive the permanent work.

2.1.38 *Frost Line* — The line joining the points of greatest depths below ground level up to which the moisture in the soil freezes. Reference may be made to good practice [E-1(2)] for more details in this regard.

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2.1.39 *General Washing Place* — A washing place provided with necessary sanitary arrangement and common to more than one tenement.

2.1.40 *Geyser* — An apparatus for heating water with supply control on the inlet side and delivering it from an outlet.

2.1.41 *Gridded Water Distribution System* — A water distribution system where every water distribution pipe is interconnected to provide two or more path to each fixture supply line.

2.1.42 *Haunching* — Outward sloping concrete support to the sides of a pipe or channel above the concrete bedding.

2.1.43 *Heel Rest Bend or Duck-Foot Bend* — A bend, having a foot formed integrally in its base, used to receive a vertical pipe.

2.1.44 *High Altitudes* — Elevations higher than 1 500 m above mean sea level (MSL).

2.1.45 *Highway Authority* — The public body in which is vested, or which is the owner of, a highway repairable by the inhabitants collectively; otherwise the body or persons responsible for the upkeep of the highway.

2.1.46 *Horizontal Pipe* — Any pipe of fitting which makes an angle of more than 45° with the vertical.

2.1.47 *Hot Water Tank* — A vessel for storing hot water under pressure greater than atmospheric pressure.

2.1.48 *Hydro-pneumatic System* — The water supply pumping system which operates automatically in conjunction with pump(s), pressure vessel and pressure switch.

2.1.49 *Junction Pipe* — A pipe incorporating one or more branches.

2.1.50 *Lagging* — Thermal insulation or pipes.

2.1.51 *Licensed* (*or Registered*) *Plumber* — A person licensed (or registered) under the provisions of this NBCS.

2.1.52 *Offset* — A pipe fitting used to connect two pipes whose axes are parallel but not in line.

2.1.53 *Period of Supply* — The period of the day or night during which water supply is made available to the consumer.

2.1.54 *Pipe Work* — Any installation of piping with its fittings.

2.1.55 *Plumbing*

a) the pipes, fixtures and other apparatus inside a building for bringing in the water supply and removing the liquid and water borne wastes; and

b) the installation of the foregoing pipes, fixtures and other apparatus.

2.1.56 *Plumbing System* — The plumbing system shall include the water supply and distribution pipes; plumbing fittings and traps; soil, waste, vent pipes and anti-siphonage pipes; building drains and building sewers including their respective connections, devices and appurtenances within the property lines of the premises; and water-treating or water-using equipment.

2.1.57 *Potable Water* — Water which is satisfactory for drinking, culinary and domestic purposes and meets the requirements of the Authority.

2.1.58 *Premises* — Premises shall include passages, buildings and lands of any tenure, whether open or enclosed, whether built on or not, and whether public or private in respect of which a water rate or charge is payable to the Authority or for which an application is made for supply of water.

2.1.59 *Pressure Balancing Valve* — Mixing valve that senses incoming hot and cold water pressures and compensates for fluctuations.

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2.1.60 *Residual Head* — The head available at any particular point in the distribution system.

2.1.61 *Residual Pressure* — The pressure available at the fixture after allowance is made for pressure drop due to friction loss and head in the system during maximum demand periods.

2.1.62 *Saddle* — A purpose made fitting, so shaped as to fit over a hole cut in a sewer or drain used to form connections.

2.1.63 *Static Pressure* — The pressure exerted by a fluid that is not moving or flowing.

2.1.64 *Stop-Cock* — A cock fitted in a pipe line for controlling the flow of water.

2.1.65 *Stop Tap* — Stop tap includes stop-cock, stop valve or any other device for stopping the flow of water in a line or system of pipes at will.

2.1.66 *Storage Tank* — A container used for storage of water which is connected to the water main or tube-well by means of supply pipe.

2.1.67 *Studio Apartment* — An apartment unit consisting of a single room and a bathroom, the single room functioning as living room, bedroom and kitchen.

2.1.68 *Subsoil Water* — Water occurring naturally in the subsoil.

2.1.69 *Subsoil Water Drain*

a) a drain intended to collect and carry away subsoil water; and

b) a drain intended to disperse into the subsoil from a septic tank.

2.1.70 *Sub-zero Temperature Regions* — Regions where temperatures fall below 0 °C and freezing conditions occur.

2.1.71 *Supply Pipe* — The water pipe that is owned by the owner of the building and lies within the boundary of the property. It connects via the communication pipe to the water main.

2.1.72 *Supports* — Hangers and anchors or devices for supporting and securing pipe and fittings to walls, ceilings, floors or structural members.

2.1.73 *Surface Water* — Natural water from the ground surface, paved areas and roofs.

2.1.74 *Surface Water Drain* — A drain conveying surface water including storm water.

2.1.75 *Thermostatic/Pressure Balancing Valve* — Mixing valve that senses outlet temperature and incoming hot and cold water pressure and compensates for fluctuations for stabilization.

2.1.76 *Vertical Pipe* — Any pipe or fitting which is installed in a vertical position or which makes an angle or not more than 45º with the vertical.

2.1.77 *Vacuum Breaker* — Type of back flow preventer installed on openings subject to normal atmospheric pressure that prevents back flow by admitting atmospheric pressure through ports to the discharge side of device.

2.1.78 *Warning Pipe* — An overflow pipe so fixed that its outlet, whether inside or outside a building, is in a conspicuous position where the discharge of any water there from can be readily seen.

2.1.79 *Wash-Out Valve* — A device located at the bottom of the tank for the purpose of draining a tank for cleaning, maintenance, etc.

2.1.80 *Water Hammer Arrestor* — A device designed to provide protection against hydraulic shock in the building water supply system.

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2.1.81 *Water Main* (*Street Main*) — A pipe laid by the water undertakers for the purpose of giving a general supply of water as distinct from a supply to individual consumers and includes any apparatus used in connection with such a pipe.

2.1.82 *Water Outlet* — A water outlet, as used in connection with the water distributing system, is the discharge opening for the water: (a) to a fitting; (b) to atmospheric pressure (except into an open tank which is part of the water supply system); and (c) to any water-operated device or equipment requiring water to operate.

2.1.83 *Water Supply System* — Water supply system of a building or premises consists of the water service pipe, the water distribution pipes, and the necessary connecting pipes, fittings, control valves, and all appurtenances in or adjacent to the building or premises.

2.1.84 *Waterworks* — Waterworks for public water supply include a lake, river, spring, well, pump with or without motor and accessories, reservoir, cistern, tank, duct whether covered or open, sluice, water main, pipe, culvert, engine and any machinery, land, building or a thing used for storage, treatment and supply of water.

2.1.85 *Wholesome Water* — Water that is safe and suitable for drinking, cooking, and other domestic purposes and free from harmful microorganisms and chemical contaminants, meets regulatory quality standards, and has a pleasant taste.

2.2 Definitions Relating to Swimming Pool

2.2.1 *Appurtenance* — An accessory facility or feature at a swimming pool, such as a diving board, slide, wading pool, plunge pool, spray pool.

2.2.2 *Bather Load* — The maximum number of persons that may be allowed in the pool area at one time without creating undue health or safety hazards.

2.2.3 *Deep Area* — An area of a swimming pool in which the water depth exceeds five feet.

2.2.4 *Diving Pool* — A pool designed and intended for use exclusively for diving.

2.2.5 *Inlet* — An opening or fitting through which filtered water enters the pool.

2.2.6 *Main Drain* — The outlet or outlets for drain provided in the pool.

2.2.7 *Make-up Water* — The water added to a pool to replace that which is lost.

2.2.8 *Pool* — A swimming pool or other recreational water basin utilized in conjunction with or as an appurtenance to a swimming pool.

NOTE — The term does not refer to spas and therapy pools not designed or intended for swimming or to basins for individual use that are drained after each use.

2.2.9 *Pool Depth* — The vertical distance between the pool floor and the water level.

2.2.10 *Shallow Area* — An area in a swimming pool, in which the water depth does not exceed 1.5 m at any point.

2.2.11 *Skimmer* — A mechanical device connected to the recirculation piping which is used to skim the pool surface.

2.2.12 *Swimming Pool User Load* — The number of bathers using the pool in a 24 h period for which a certain per capita capacity is often considered.

NOTE — The capacity of a swimming pool in terms of its user load is dictated by the capacity of water treatment equipment.

2.2.13 *Transition Point* — A location in a shallow area of a swimming pool where an area, having a floor slope of no more than 300 mm vertical in 3.65 m horizontal, adjoins an area where the floor slope exceeds 1 in 12.

2.2.14 *Turnover Period* — The time required to recirculate a volume of water equivalent to the water volume of

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the pool through the filtration system.

2.2.15 *Wading Pool* — A pool having a maximum water depth not exceeding 76 cm.

2.2.16 *Water Level* — The level of the overflow lip of a perimeter overflow system or the mid-level of surge weirs, if present, or the mid-level of the skimmer operating range.

2.2.17 *Zero-Depth Edge* — That portion of the perimeter of a zero-depth pool where the pool floor intersects the pool water surface.

2.2.18 *Zero-Depth Pool* — A swimming pool where the pool floor intersects the water surface along a portion of its perimeter.

3 GENERAL

3.1 Basic Principles

The design of water supply takes the following into consideration:

a) number of occupants;

b) minimum water requirements for different purposes;

c) treatment of water based on the quality of water;

d) quantity of water stored; and

e) sizing of pipes.

The basic principles of water supply, drainage and sanitation are given below, and the design of water supply should in general be guided by the applicable principles.

3.1.1 *Potable Water*

All premises intended for human habitation, occupancy, or use shall be provided with supply of potable water. This water supply shall not be connected with unsafe water resources, nor shall it be subject to the hazards of backflow.

3.1.2 *Water Provision*

Plumbing fixtures, devices and appurtenances shall be provided with water in sufficient volume and at pressures adequate to enable them to function properly and without undue noise under normal conditions of use.

There should be at least a residual head of 0.018 N/mm^2 (0.18 bar) at the consumer's tap. There may be certain fixtures or appliances in the installation that may require a higher pressure, such as 0.05 N/mm^2 (0.5 bar) or even higher pressure [such as 0.1 N/mm^2 (1.0 bar) in case of flush valves], in which case the system shall be designed using pumps, tanks or both to achieve the required minimum pressure.

NOTE — The residual head shall be taken at the highest/farthest outlets in the building.

3.1.3 *Water Efficiency*

Plumbing system shall be designed, installed and adjusted to use the optimum quantity of water consistent with proper performance and cleaning.

3.1.4 *Safety Devices*

Plumbing system shall be designed and installed with safety devices to safeguard against dangers from contamination, explosion, overheating, etc.

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3.1.5 *Minimum Water Amenities*

It is recommended that each dwelling unit should have at least one water closet, one lavatory, one kitchen wash place or a sink, and one bathing place or shower to meet the basic requirements of sanitation and personal hygiene.

In case of a group housing, the requirements relating to toilet or sanitary room and kitchen as given in good practice [E-1(3)] shall also be complied with.

3.1.6 *Drainage System*

The drainage system shall be designed, installed and maintained to guard against fouling, deposit of solids and clogging and with adequate cleanouts so arranged that the pipes may be readily cleaned.

3.1.7 *Materials and Workmanship*

The plumbing system shall have durable material, free from defective workmanship and so designed and installed as to give satisfactory service for its reasonable expected life. The accessories of the plumbing system should be of such specifications as to meet the functional requirements of the installation, so as to also avoid any inconsistency leading to leakage and resultant seepage.

3.1.8 *Fixture Traps and Ventilating Pipes*

Each fixture directly connected to the drainage system shall be equipped with a liquid seal trap. Trap seals shall be maintained to prevent sewer gas, other potentially dangerous or noxious fumes, or vermin from entering the building. Further, the drainage system shall be designed to provide an adequate circulation of air in all pipes with no danger of siphonage, aspiration, or forcing of trap seals under conditions of ordinary use by providing ventilating pipes throughout the system.

3.1.9 *Foul Air Exhaust*

Each vent terminal shall extend to the outer air and be so installed as to minimize the possibilities of clogging and the return of foul air to the building, as it conveys potentially noxious or explosive gases to the outside atmosphere. All ventilating pipes shall be provided with a cowl.

3.1.10 *Testing*

The plumbing system shall be subjected to required tests to effectively disclose all leaks and defects in the work or the material.

3.1.11 *Exclusion from Plumbing System*

No substance that will clog or accentuate clogging of pipes, produce explosive mixtures, destroy the pipes or their joints, or interfere unduly with the sewage-disposal process shall be allowed to enter the drainage system.

3.1.12 *Light and Ventilation*

Wherever water closet or similar fixture is located in a room or compartment, it should be properly lighted and ventilated.

3.1.13 *Individual Sewage Disposal Systems*

If water closets or other plumbing fixtures are installed in buildings where connection to public sewer is not possible, suitable provision shall be made for acceptable treatment and disposal.

3.1.14 *Maintenance*

Plumbing systems shall be maintained in a safe and serviceable condition.

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3.1.15 *Approach for Use and Cleaning*

All plumbing fixtures shall be so installed with regard to spacing as to be approachable for their intended use and for cleaning. All doors, windows and any other device needing access within the toilet shall be so located that they have proper approach.

3.1.16 *Accessibility for Persons with Disabilities*

All doors, windows and fixtures, including WC, urinals, grab bars, washbasin, mirror and all other accessories for use by persons with disabilities shall be so installed/located that they have proper access with appropriate width, height, space, centrelines, and ease of operation {*see* good practice [E-1(3)]}.

3.1.17 *Structural Safety*

Plumbing system shall be installed with due regard to preservation of the structural members and prevention of damage to walls and other surfaces.

3.1.18 *Protection of Ground and Surface Water*

Sewage or other waste shall not be discharged into surface or sub-surface water without acceptable form of treatment.

3.2 Water Supply Connection

3.2.1 *Application for Obtaining Supply Connection*

Every consumer, requiring a new supply of water or any extension or alteration to the existing supply shall apply in writing in the prescribed form (*see* Annex A) to the Authority.

3.2.2 *Bulk Supply*

In the case of large housing colonies or campuses, or where new services are so situated that it will be necessary for the Authority to lay new mains or extend an existing main, full information about the proposed scheme shall be furnished to the Authority. Information shall also be given regarding their phased requirements of water supply with full justification. Such information shall include site plans, showing the layout of roads, footpaths, building and boundaries and indicating thereon the finished line and level of the roads or footpaths and water supply lines and appurtenances.

3.2.3 *Completion Certificate*

On completion of the plumbing work for the water supply system, the licensed/registered plumber shall give a completion certificate in the prescribed form (*see* Annex B) to the Authority for getting the water connection from the mains.

3.3 Licensing/Registration of Plumbers

3.3.1 *Execution of Work*

The work which is required to be carried out under the provisions of this Section, shall be executed only by a licensed/registered plumber under the control of the Authority and shall be responsible to carry out all lawful directions given by the Authority. No individual shall engage in the business of plumbing unless so licensed/registered under the provisions of this Section.

3.3.1.1 No individual, firm, partnership or corporation shall engage in the business of installing, repairing or altering plumbing unless the plumbing work performed in the course of such business is under the direct supervision of a licensed/registered plumber.

3.3.2 *Examination and Certification*

The Authority shall establish standards and procedure for the qualification, examination and licensing/registration

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of plumbers and shall issue licences to such persons who meet the qualifications thereof and successfully pass the examination.

3.3.3 For guidelines for registration of plumbers including the minimum standards for qualifications for the grant of licences/registration, reference may be made to good practice [E-1(4)]. The Authority may also utilize the services of the certified plumbers who are certified for the required skill level under the appropriate scheme of the Government.

4 WATER SUPPLY

4.1 Water Supply Requirements for Buildings

The total quantity of water per day is estimated based on the proposed occupancy and activities catered. Designer has to identify all the possible sources for augmenting the shortfall in water supply. The analysis of available water is done to decide the treatment for consumption and treatment process depends on the quality of water and the purpose for which it is used.

Projection of population for each building shall be made on the basis of its usage. Population for each type of building shall be estimated on the basis of information obtained from the users. Alternatively, population may be worked on the following basis, for different type of buildings:

a) *Residential buildings*

Sl No.	*Accommodation*	*Population Requirements*
(1)	(2)	(3)
i)	1 bedroom dwelling unit	3
ii)	2 bedroom dwelling unit	4
iii)	3 bedroom dwelling unit	5
iv)	4 bedroom dwelling unit and above	6

NOTES

1 The above figures consider a domestic household including support personnel, wherever applicable.

2 For plotted development, the population may be arrived at after due consideration of the expected number and type of domestic household units.

3 Dwelling unit under EWS category shall have population requirement of 4 and studio apartment shall have population requirement of 2.

b) *Other than residential buildings*

Sl No.	*Occupancy*	*Population Requirement*
(1)	(2)	(3)
i)	Offices	1 person per 10 m^2 of floor area (*see* Note 1)
ii)	Schools	Strength of school + teaching and non-teaching staff
iii)	Hostels	Number of beds + 4.5 × (warden's residence) + staff
iv)	Hotels	Number of beds + staff + requirement of restaurant seats
v)	Hospitals	Number of beds + staff + patient attendants (generally population density per bed in secondary care hospital is 5, tertiary care is 7 and quaternary care is 9)
vi)	Mercantile	1 person per 3 m^2 of street floor and sales basement areas + 1 person per 6 m^2 of upper sale floors (Total population may be segregated into 10 percent for fixed and 90 percent for floating/visitors)

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Sl No.	*Occupancy*	*Population Requirement*
(1)	(2)	(3)
vii)	Traffic terminal stations	Average number of users per day (Total annual passenger traffic/365) + Staff + Vendors
viii)	Ware house	1 person per 20 m^2 of floor area (*see* Note 1)
ix)	Industrial/Hazardous	1 person per 10 m^2 of floor area
x)	Storage	1 person per 30 m^2 of floor area
xi)	Assembly (*maximum should be as per Part F 'Fire and Life Safety' of this NBCS*).	
	a) Concentrated use without fixed seating	1 person per 0.65 m^2 of floor area
	b) Less concentrated use without fixed seating	1 person per 1.2 m^2 of floor area
	c) Fixed seating	1.2 × Number of fixed seats
	d) Dining area and restaurants with seating and tables	1 person per 1.8 m^2 of floor area

NOTES

1 Wherever there are multiple work shifts, the number of users within a 24 h period may be considered as per actuals.

2 Population of 5 percent to 15 percent, depending on the usage of building, shall be considered for visitors and floating population likely to use the building's facilities.

4.1.1 Water *Supply for Residences*

A minimum of 70 litre to 100 litre per head per day may be considered adequate for domestic and flushing needs of urban communities (which varies based on type of building occupancy). As a general rule the following rates per capita per day may be considered for domestic and non-domestic needs:

a) For urban communities: 135 LPCD

b) For urban communities using water efficient fixtures in buildings: 100 LPCD (*see* Note 1)

c) For rural communities, water demand of 70 LPCD may be considered including 15 LPCD as flushing water demand.

NOTES

1 For buildings using water efficient fixtures, reference may be made to accepted standard [E-1(5)].

2 Usage of high flow or high pressure fixtures is not recommended from the point of view of water conservation and sustainable development.

4.1.1.1 Out of the per capita demand as mentioned in **4.1.1** (a) and **4.1.1** (b), 30 litre per head per day shall be taken for flushing requirements and the remaining quantity for other domestic purposes. The following depicts the general breakdown of the water consumption in residential buildings:

Sl No.	*Description*	For Urban Communities (*Residential*)	For Urban Communities Using Water Efficient Fixtures (*Residential*)
(1)	(2)	(3)	(4)
i)	Drinking	5	5
ii)	Bathing (*Suggested cold and hot water is 60:40*)	35	25
iii)	Cooking	10	5
iv)	Washing utensils	20	15

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Sl No.	*Description*	For Urban Communities (*Residential*)	For Urban Communities Using Water Efficient Fixtures (*Residential*)
(1)	(2)	(3)	(4)
v)	Floor cleaning	10	5
vi)	Washing clothes	25	15
	Total	**105**	**70**

4.1.2 *Water Supply for Buildings Other than Residences*

Minimum requirements for water supply for buildings other than residences shall be in accordance with Table 1.

The water demand for the laboratory facilities will depend on actual requirements based on functional point of view.

Table 1 Water Requirements for Buildings Other than Residences
(*Clause* 4.1.2 *and* 4.1.3)

Sl No.	**Type of Building**	**Domestic per Day**	**Flushing per Day**	**Total Consumption per Day**
		litre	litre	litre
(1)	(2)	(3)	(4)	(5)
i)	Factories including canteen where bathrooms are required to be provided	30 per head	15 per head	45 per head
ii)	Factories including canteen where no bathrooms are required to be provided	20 per head	10 per head	30 per head
iii)	Hospital (excluding laundry and kitchen) (*see* Note 2):			
	a) Number of beds not exceeding 100	a) 230 per bed	a) 110 per bed	a) 340 per bed
	b) Number of beds exceeding 100	b) 300 per bed	b) 150 per bed	b) 450 per bed
	c) Outpatient department (OPD)	c) 10 per bed	c) 5 per bed	c) 15 per bed
	d) Hospital with secondary care			d) 800 per bed
	e) Super speciality hospital			e) 950 per bed
iv)	Nurses' homes and medical quarters	90 per head	45 per head	135 per head
v)	Hostels	90 per head	45 per head	135 per head
vi)	Hotel (up to 3 star) excluding laundry, kitchen, staff and water bodies without bathtub (*see* Note 7)	120 per head	60 per head	180 per head
vii)	Hotel (4 Star and above) excluding laundry, kitchen, staff and water bodies and excluding bathtub (*see* Note 7)	260 per head	60 per head	320 per head
viii)	Hotel with bathtub (*see* Note 7)	320 per head	60 per head	380 per head
ix)	Banquet area	30 per head	15 per head	45 per head
x)	Health club			
	a) with shower	25 per head	20 per head	45 per head
	b) without shower	15 per head	10 per head	25 per head

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Table 1 Water Requirements for Buildings Other than Residences
(*Clause* 4.1.2 *and* 4.1.3)

Sl No.	Type of Building	Domestic per Day litre	Flushing per Day litre	Total Consumption per Day litre
(1)	(2)	(3)	(4)	(5)
xi)	Indoor Sports Facility	10 per head	5 per head	15 per head
xii)	Offices (including canteen)	25 per head	20 per head	45 per head
xiii)	Restaurants and food court including water requirement for kitchen:			
	a) Restaurants	55 per seat	15 per seat	70 per seat
	b) Food court	25 per seat	10 per seat	35 per seat
xiv)	Clubhouse	25 per head	20 per head	45 per head
xv)	Cinemas, concert halls and theatres and multiplex	5 per seat	10 per seat	15 per seat
xvi)	Schools/Educational institutions:			
	a) Without boarding facilities	a) 25 per head	a) 20 per head	a) 45 per head
	b) With boarding facilities	b) 90 per head	b) 45 per head	b) 135 per head
xvii)	Shopping and retail (mall)			
	a) Staff	25 per head	20 per head	45 per head
	b) Visitors	5 per head	10 per head	15 per head
xviii)	Traffic terminal stations (*see* Notes 3 and 4)			
	a) Airports	40 per head	30 per head	70 per head
	b) Railway stations (Junctions) with bathing facility	40 per head	30 per head	70 per head
	c) Railway stations (Junctions) without bathing facility	30 per head	15 per head	45 per head
	d) Railway Stations (Intermediate) with bathing facility	25 per head	20 per head	45 per head
	e) Railway Stations (Intermediate) without bathing facility	15 per head	10 per head	25 per head
	f) Interstate bus terminals	25 per head	20 per head	45 per head
	g) Intrastate Bus Terminals/Metro Stations/ High speed rail stations	10 per head	5 per head	15 per head

NOTES

1 For calculating water demand for visitors, consumption of 15 litre per head per day may be taken.

2 The water demand includes requirements of patients, attendants, visitors and staff. Additional water demand for kitchen, laundry and clinical water shall be computed as per actual requirements.

3 The number of persons shall be determined by the average number of passengers handled by stations, with due consideration given to the staff and vendors who are using these facilities.

4 Consideration should be given to seasonal average peak requirements.

5 The hospitals may be categorized as Category A (25 to 50 beds), Category B (51 to 100 beds), Category C (101 to 300 beds), Category D (301 to 500 beds) and Category E (501 to 750 beds).

6 Total water demand can be reduced by 25 percent if the building is equipped with 100 percent 3-star rated fixtures and fittings as per good practice [E-1(5)].

7 Bathtub water volume may be considered additionally based on size

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4.1.3 *Water Supply Requirements of Traffic Terminal Stations*

The water supply requirements of traffic terminal stations (railway stations, bus stations, harbours, airports, etc) include provisions for waiting rooms and waiting halls. They do not, however, include requirements for retiring rooms. Requirements of water supply for traffic terminal stations shall be as per Table 1.

4.1.4 *Water Supply for Firefighting Purposes*

4.1.4.1 Provisions shall be made to meet the water supply requirements for firefighting in the city/area, depending on the population density and types of occupancy. *See also* Part F 'Fire and Life Safety' of this NBCS.

4.1.4.2 Provisions shall be made for water supply requirements for firefighting purposes within the building, depending upon the height and occupancy of the building. *See also* Part F 'Fire and Life Safety' of this NBCS.

4.1.4.3 Provisions shall be made regarding water supply in storage tanks, capacity of fire pumps, arrangements of wet riser-cum-down comer and wet riser installations for buildings, depending upon the occupancy use and other factors as applicable. *See also* Part F 'Fire and Life Safety' of this NBCS.

4.1.5 *Water Supply for Other Purposes*

4.1.5.1 Water supply in many buildings is also required for many other applications other than domestic use, which shall be identified in the initial stages of planning so as to provide the requisite water quantity, storage capacity and pressure as required for each application. In such instances information about the water use and the quality required may be obtained from the users. Some typical uses other than domestic use and firefighting purposes are air conditioning, swimming pools and water bodies, and gardening. Treated water from sewage treatment plant, with suitable tertiary treatment, should be used for flushing purpose (with dual piping system), gardening purpose, cooling tower make up, and/or for other non-potable usage.

4.1.5.2 The water demand for landscaping purposes is generally taken as 6 litre/m^2/day to 8 litre/m^2/day for lawns. For shrubs and trees the above value can be reduced considerably.

4.2 Water Sources and Quality

4.2.1 *Sources of Water*

The origin of all sources of water is rainfall. Water can be collected as it falls as rain before it reaches the ground; or as surface water when it flows over the ground or is pooled in lakes or ponds; or as ground water when it percolates into the ground and flows or collects as ground water; or from the sea.

Contamination of water supplies can occur in the source water as well as in the distribution system after water treatment has already occurred. There are many sources of water contamination, including naturally occurring chemicals and minerals (for example, arsenic, radon, uranium), local land use practices (fertilizers, pesticides, concentrated animal feeding operations), manufacturing processes, and sewer overflows or wastewater releases. The presence of contaminants in water can lead to adverse health effects, including gastrointestinal illness, reproductive problems, and neurological disorders.

4.2.2 The water supplied shall be free from pathogenic organisms, clear, free from undesirable taste and odour, neither corrosive nor scale forming and free from minerals which could produce undesirable physiological effects. The quality of water to be used for drinking shall be as per accepted standard [E-1(6)].

4.2.3 For purposes other than drinking, water if supplied separately, shall be absolutely safe from bacteriological contamination so as to ensure that there is no danger to the health of the users due to such contaminants.

For purposes other than drinking, where there is an overall risk of legionella growth, it is advisable that for cold water supplies, the temperature does not exceed 20 °C and a minimum temperature of 50 °C for hot water supplies be maintained at all points of network so as to ensure that it is absolutely safe from bacteriological contamination and there is no danger to the health of the users due to such contaminants.

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4.2.4 *Waste Water Reclamation*

Treated sewage or other waste water of the community may be utilized for non-domestic purposes such as water for flushing, landscape irrigation, cooling towers of HVAC system, in fountains and recreational lakes where swimming is not allowed, and for certain industrial purposes after its necessary treatment to suit the nature of the use. This supply system shall be allowed in residences only if proper provision is made to avoid any cross-connection of this treated waste water with domestic water supply system for which it is recommended to use dual piping system.

4.2.4.1 *Treatment of waste water and usage of recycled water*

Waste water is generated by residential and other establishments like institutional, business, mercantile and industrial. It includes household waste liquid from toilets, baths, showers, kitchens and sinks that is disposed of *via* sewers. Waste water treatment is the process of removing contaminants from wastewater, including household sewage and runoff (effluents). It includes physical, chemical, and biological processes to remove contaminants. Treatment of waste water and usage of recycled waste water may be done to make it usable for appropriate applications. The objective is to produce an environmentally safe fluid waste stream (or treated effluent) and a solid waste (or treated sludge) suitable for disposal or reuse.

Separation of household waste into grey water and black water (and draining of black water into sewerage system) is becoming more common with grey water being permitted to be used for watering plants or recycled for flushing toilets after proper treatment. Waste water collection and treatment is typically subject to statutory regulations. Treatment depends on the characteristics of influent and the treatment requirements that are needed for treating the same. Waste water treatment generally involves the following three stages:

a) *Primary treatment* — It consists of temporarily holding the wastewater for settlement of heavy solids at the bottom while oil, grease and lighter solids float to the surface;

b) *Secondary treatment* — It removes dissolved and suspended biological matter; and

c) *Tertiary treatment* — It is more intensive treatment done in order to allow rejection into a highly sensitive or fragile ecosystem. The tertiary treatment is generally followed by disinfection.

4.2.5 *Water Conservation, Water Balance and Use of Recycled Water*

Water conservation encompasses the policies, strategies and activities to manage fresh water as a sustainable resource, to protect the water environment and to meet current and future demand. Population, household size, and growth and affluence all affect the quantity of water used. Water balance studies should be carried out to study the availability of water from different sources and its usage for different purposes.

4.2.6 Whenever a building is used after long intervals, the water quality of the stored water shall be checked so as to ensure that the water is safe for use as per water quality requirements specified in this NBCS.

4.3 Estimate of Demand Load

4.3.1 Estimates of total water supply requirements for buildings shall be based on the occupant load consistent with the provisions of **4.1**.

4.3.2 In making assessment of water supply requirements of large complexes, the future occupant load shall be kept in view. The following methods may be used for estimating future requirements:

a) demographic method of population projection;

b) arithmetic progression method;

c) geometrical progression method;

d) method of varying increment or incremental increase;

e) logistic method;

f) graphical projection method; or

g) graphical comparison method.

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4.4 Storage of Water

4.4.1 In a building, provision is required to be made for storage of water for the following reasons:

a) to provide against interruptions of the supply caused by repairs to mains, etc;

b) to reduce the maximum rate of demand on the mains;

c) to tide over periods of intermittent supply; and

d) to maintain storage for the firefighting requirement of the building (taking into consideration the water for sprinklers and hydrants separately, apart from domestic water requirements).

4.4.2 The water may be stored in overhead tanks (OHT) and/or underground tanks (UGT).

4.4.3 *Materials Used*

Reservoirs and tanks for the storage of water shall be constructed of reinforced concrete, brick masonry, ferrocement, mild steel, stainless steel, or plastic or glass reinforced panels.

4.4.3.1 Tanks made of steel may be of welded, riveted or panel/pressed construction. The metal shall be galvanized or coated externally with a good quality anti-corrosive weather-resisting paint. Lead-based paint shall not be used in the tank. Lead-lined tanks shall not be used. Rectangular pressed steel tanks shall conform to good practice [E-1(7)].

4.4.4 Each tank shall be provided with the following:

a) *Manholes* — Adequate number of manholes for access and repair. The manholes shall be made of corrosion resistant material (for example, cast iron, reinforced cement concrete, steel fibre reinforced concrete, galvanized steel, high density polyethylene, fibre glass reinforced plastic or such other materials) acceptable to the Authority. Manholes shall be provided with locking arrangement to avoid misuse and tampering;

b) *Ladders* — Tanks higher than 900 mm deep shall be provided with corrosion resistant ladders according to the depth to enable a person to reach the bottom of the tank;

c) *Overflow pipe* — Each tank shall be provided with an overflow pipe terminating above the ground/terrace level to act as a 'Warning Pipe' to indicate overflow conditions. The size of the overflow pipe shall be adequate to accept the flow. Normally the overflow pipe size shall be one size higher than the inlet pipe. When the inlet pipe diameter is large, two or more overflow pipes of equivalent cross-section may be provided;

d) *Vent pipes* — Tanks larger than 5 000 litre capacity shall be provided with vent pipes to prevent development pressure in the tank which might result in 'NO FLOW' condition or inward collapse of the tank;

e) *Scour pipe* — Each tank shall be provided with a scour pipe with an accessible valve for emptying the tank

f) *Connection of overflow and scour pipe* — Under no circumstances tank overflow and scour pipe shall be connected to any drain, gully trap or manhole to prevent back flow and contamination of the water. All such connections shall be discharged over a grating with an air gap of 50 mm. All overflow and vent pipes shall be provided with a mosquito proof brass grating to prevent ingress of mosquito, vermin and other insects;

g) The top slab of the tank shall be suitably sloped away from its centre for proper drainage of the rainwater; and

h) Tanks on terraces and above ground shall be supported by appropriate structural members so as to transfer the load of the tank and the water directly on the structural members of the building.

4.4.5 Every storage tank shall be easily accessible and placed in such a position as to enable thorough inspection and cleaning to be carried out. If the storage capacity required is more than 5 000 litre, it is advantageous to arrange it in a series of tanks so interconnected that each tank can be isolated for cleaning and inspection without

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interfering with the supply of water. In large storage tanks, the outlet shall be at the end opposite the inlet to avoid stagnation of the water.

4.4.6 The outlet pipe shall be fixed 50 mm to 75 mm above the bottom of the tank and fitted with a strainer, preferably of brass.

4.4.7 In the case of underground storage tanks, the design of the tank shall be such as to provide for the draining of the tank when necessary and water shall not be allowed to collect around the tank. The tank shall be perfectly water-proof and shall be provided with a cement concrete cover, having a manhole opening, with a properly fitting hinged cast iron cover on a leak-proof cast iron frame.

The underground tanks should not be located in low lying areas or near any public or private sewer, septic tank, leaching pool or soakage pit to prevent any contamination. The overflow of the tank should be well above (preferably 600 mm) the external surface level and terminate as a warning pipe with a mosquito proof grating. Care shall be taken to prevent backflow of local surface water into the tank in case of local flooding. Otherwise the overflow shall be terminated in a safer manner as per the site conditions. For tanks with at least one side exposed to a basement, it is safer to discharge the overflow into the basement level.

The tank top slab shall also be designed to carry the load due to fire tender movement where anticipated as in the case of an extended basement.

There should be no common wall between the tanks storing safe water and tanks storing water from unsafe sources.

4.4.8 In case of overhead tanks, bottom of the tanks shall be placed clear off the terrace slab such that the elevation difference between the outlet pipe of the tank and the highest fixture at the top floor of the building is minimum 2 m, which shall also prevent leakage into the structural slab. In tall buildings, the top of the tank shall be provided with the safe ladder or staircase. The top slab shall be provided with railing or a parapet wall.

4.4.9 For jointing steel pipe to a storage tank, the end of the pipe shall be screwed, passed through a hole in the tank and secured by backnuts, both inside and outside. The pipe end shall be flush with the face of the inside backnut. For jointing copper pipe to steel or copper tank, a connector of non-ferrous material shall be used. The connector shall have a shoulder to bear on the outside of the tank and shall be secured by a backnut inside.

4.4.10 The quantity of water to be stored shall be calculated taking into account the following factors:

a) hours of supply at sufficiently high pressure to fill up the overhead storage tanks;

b) frequency of replenishment of overhead tanks, during the 24 h;

c) rate and regularity of supply; and

d) consequences of exhausting storage particularly in case of public buildings like hospitals.

In case of intermittent water supply, the following guidelines should be adopted for calculation of capacity:

1) when the supply is from main OHT, such as in case of plotted development, the capacity of individual OHT may be taken as half a day demand;

2) in case of all the other buildings (apartments, hotels, hospitals, and commercial), the capacity of UGT and OHT may be taken as one and a half days and half a day demand. Wherever raw water and treated water are stored in separate UGTs, the combined storage capacity shall be of one and a half day's demand; and

3) in case of sewage treatment plant, for treated water storage in respect of flushing, one-day flushing demand shall be stored in UGT or treated effluent storage tank, which is part of the plant, and half a day demand shall be stored in OHT.

NOTES

Minimum requirements for calculation of capacity of these storage tanks are as follows:

1 In case only OHT is provided, it may be taken as 33.33 to 50 percent of one day's requirement.

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2 In case of combined storage, that is UGT and OHT with gravity water supply system is provided, it may be taken as 150 percent of one day's requirement for UGT and 50 percent of one day's requirement for OHT.

3 In the case of hydro-pneumatic/pressurized water supply system from UGT, the storage of water in UGT to be considered as 200 percent of one day's requirement.

For additional requirement of water storage for firefighting purposes, reference may be made to Part F 'Fire and Life Safety' of this NBCS.

4.4.11 Where the water supply distribution system is catering for separate potable water and flushing water supply, and where reclaimed or recycled treated water is being used within the building, it shall be considered as dual water supply system. In such cases, storages for flushing/reclaimed/recycled water shall be separated proportionately. Adequate measures and precautions shall be taken for physical segregation for sanitary purposes and to avoid cross-contamination in the distribution system and to prevent back contamination of water supply sources (*see* **4.5**).

4.4.12 When only one communication pipe is provided for water supply to a building, it is not necessary to have separate storage for flushing and sanitary purposes for health reasons. In such cases when only one storage tank has been provided, tapping of water may be done at two different levels (the lower tapping for flushing) so that a part of the water will be exclusively available for flushing purposes.

4.5 Protection of Water Supply

4.5.1 *General*

The water supply system shall be designed, installed and maintained in such a manner so as to prevent contamination from non-potable liquids, solids or gases being introduced into the potable water supply system through cross-connections or any other connection to the system.

4.5.2 *Plumbing Fixtures*

The water supply lines and fittings for plumbing fixtures shall be installed so as to prevent back flow and shall provide required back flow protections in accordance with **4.11**.

The devices, appurtenance intended for special function such as sterilization, processing, distillation, etc, shall be provided with back flow protection devices.

The water supply for hospital fixtures shall be protected against backflow with a reduced pressure principle back flow assembly, an atmospheric or spill resistant vacuum breaker assembly, or an air gap. Vacuum breakers for bed pan washer hoses shall not be located less than 1 525 mm above floor. Vacuum breakers for hose connections in health care or laboratory areas shall not be less than 1 800 mm above floor.

4.5.3 *Cross-Connection Control*

Cross-connections shall be prohibited, except where approved back flow prevention assemblies/devices are installed to protect the potable water supply (*see* **4.11**).

Potable water outlets and combination stop and waste valves shall not be installed underground or below grade. Freeze proof yard hydrants that drain the riser into the ground are considered to be stop and waste valves.

Back flow prevention can be achieved by means of providing proper air gap, reduced pressure principle back flow prevention assemblies, back flow preventer with intermediate atmospheric vent, barometric loop, pressure vacuum breaker assemblies, atmospheric type vacuum breakers, double check back flow prevention assemblies, spill resistant pressure vacuum breaker, dual check back flow preventer, etc.

4.5.4 *Identification of Non-potable Water Systems*

Where non-potable water systems are installed, the piping conveying the non-potable water shall be identified either by colour marking, metal tags or tapes in accordance with the relevant standards and good engineering practices.

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4.6 Materials, Fittings and Appliances

4.6.1 *Standards for Materials, Fittings and Appliances*

All materials, water fittings and appliances shall conform to Part B 'Building Materials' of this NBCS.

4.6.2 *Materials for Pipes*

Pipes may be of any of the following materials:

a) Cast iron, vertically cast or centrifugally (spun) cast;

b) Steel (internally lined or coated with bitumen or a bituminous composition, and out-coated with cement concrete or mortar, where necessary);

c) Ductile iron, internally lined;

d) Reinforced concrete;

e) Prestressed concrete;

f) Galvanized mild steel tubes;

g) Copper;

h) Brass;

j) Wrought iron;

k) Stainless steel;

m) Polyethylene;

n) High density polyethylene (HDPE);

p) Unplasticized PVC;

q) Chlorinated PVC;

r) Polypropylene-random copolymer (PPR);

s) Composite pipes (PE-AL-PE) or any other combination;

t) Cross-linked polyethylene (PEX); or

u) Polybutylene pipe.

4.6.2.1 The material chosen shall be resistant to corrosion, both inside and outside or shall be suitably protected against corrosion.

4.6.2.2 Polyethylene and unplasticized PVC pipes shall not be installed near hot water pipes or near any other heat sources. For temperature limitations in the use of polyethylene and unplasticized PVC pipes to convey water, reference may be made to accepted standards [E-1(8)].

4.7 Design of Distribution Systems

4.7.1 *General*

For designing the distribution system, the following guidelines, in addition to those given in **4.7.2** to **4.7.6** shall be followed:

a) All plumbing systems in buildings shall conform to the general requirements given in **3.1**;

b) Peak factor for calculation in case of intermittent flows may generally be adopted in design as 2 to 3; and

c) The residual head at consumer's tap shall be as per **3.1.2**.

4.7.2 *Rate of Flow*

One of the important items that needs to be determined before the sizes of pipes and fittings for any part of the

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water piping system may be decided upon, is the rate of flow in the service pipe which in turn depends upon the number of hours for which the supply is available at sufficiently high pressure. If the number of hours for which the supply is available is less, there will be large number of fittings in use simultaneously and the rate of flow will be correspondingly large.

The data required for determining the size of the communication and service pipes are:

a) the maximum rate of discharge required;

b) the length of the pipe; and

c) the head loss by friction in pipes, fittings and meters.

4.7.3 *Discharge Computation*

4.7.3.1 *Design of consumer's pipes based on fixture units*

The design of the consumers' pipes or the supply pipe to the fixtures is based on:

a) the number and kind of fixtures installed;

b) the fixture unit flow rate; and

c) the probable simultaneous use of these fixtures.

The rates at which water is desirably drawn into different types of fixtures are known. These rates become whole numbers of small size when they are expressed in fixture unit.

The water supply fixture units (WSFU) for different sanitary appliances or groups of appliances are given in Table 2.

4.7.3.2 *Probable simultaneous demand*

The possibility that all water supply taps in any system in domestic and commercial use will draw water at the same time is extremely remote. Designing the water mains for the gross flow will result in bigger and uneconomical pipe mains and may not be necessary. A probability study made by Hunter suggests the relationship shown in Fig. 2 and Table 3. In the absence of similar studies in India, the curves based on Hunter's study may be followed. In making use of these curves, special allowances are made as follows:

a) demands for service sinks are ignored in calculating the total fixture demand;

b) demands of supply outlets such as hose connections and air conditioners through which water flows more or less continuously over a considerable length of time shall be added to the probable flow rather than the fixture demand; and

c) fixtures supplied with both hot and cold water exert reduced demands upon main hot water and cold water branches (not fixture branches).

Table 2 Water Supply Fixture Units (WSFU) for Different Fixtures with Minimum Pipe Sizes

(*Clause* 4.7.3.1)

Sl No.	Type of Fixture	Application		Minimum Pipe Size mm
		Private	Public	
(1)	(2)	(3)	(4)	(6)
i)	Bath tub	4	–	15
ii)	Ablution faucet/Bidet	1	1	15
iii)	Clothes washer	4	4 (*see* Note 7)	15

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Table 2 Water Supply Fixture Units (WSFU) for Different Fixtures with Minimum Pipe Sizes

(*Clause* 4.7.3.1)

Sl No.	Type of Fixture	Application		Minimum Pipe Size mm
		Private	Public	
(1)	(2)	(3)	(4)	(6)
iv)	Dishwasher	1.5	1.5	15
v)	Drinking fountain	–	0.5 (0.75)	15
vi)	Hose bib	2.5	2.5	15
vii)	Wash basin (with metered faucet)	1	1	15
viii)	Wash basin (with standard faucet)	1.5	1.5 (2)	15
ix)	Service sink	–	3	15
x)	Kitchen sink	2	4	15
xi)	Surgical sink	–	2	15
xii)	Scrub station in hospital (per outlet)	–	3	15
xiii)	Shower	2	3	15
xiv)	Bathroom group (flush tank)	5	6	20
xv)	Bathroom group (flush valve)	8	10	25/32
xvi)	Urinal (flush valve)	3	5 (6)	20
xvii)	Urinal (flush tank)	2	2 (3)	15
xviii)	Urinal (sensor operated)	2	2 (3)	15
xix)	Water closet (flush valve)	5	5(8)	25/32
xx)	Water closet (flush tank)	2	3 (5)	15
xxi)	Combination fixture (faucet)	3	–	15
xxii)	Laundry trays (faucet)	3	–	15

NOTES

1 The above table is based on Hunter's method.

2 Hunter's method of estimating load in plumbing systems is based on assigning a fixture unit (FU) weight to the plumbing fixtures and then converting these to equivalent litres per minute, based on the theory of probability of usage and based on the observation that all fixtures are not used simultaneously.

3 The fixture unit concept is a method of calculating maximum probable water demand within large buildings based on theory of probability. The method is based on assigning a fixture unit (FU) value to each type of fixture based on its rate of water consumption, on the length of time it is normally in use and on the average period between successive uses.

4 The values of probable demand will not change in respect of systems with flush valves and flush tanks for fixture units more than 1 000.

5 The fixtures or appliances which are not included in the above table may be sized referring to fixtures having similar flow rate and frequency of usage.

6 The minimum supply branch pipe sizes for individual fixtures are nominal sizes.

7 The clothes washer for public does not include large washer extractors, and in such cases the pipe sizing shall be determined as per manufacturer's recommendations.

8 For more information on bathroom groups, reference may be made to specialist literature.

9 The fixture units listed in the above table represent the load for cold water service. The separate cold and hot water fixture unit value for fixtures having both hot and cold water connections may each be taken as three quarter of the listed total value of fixture.

10 A shower head over a bath tub does not increase the fixture unit value.

11 The values given in parantheses pertain to such public use buildings where an enhanced requirement is expected to be encountered as compared to the normal maximum use in public use buildings.

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Table 3 Probable Simultaneous Demand

(*Clause* 4.7.3.2)

Sl No.	Demand in Fixture Units	Demand with Flush Tanks litre/min	Demand with Flush Valves litre/min
(1)	(2)	(3)	(4)
i)	1	0	–
ii)	2	3.8	–
iii)	3	11.4	–
iv)	4	15.1	–
v)	5	22.7	–
vi)	6	25.5	–
vii)	8	28.1	–
viii)	10	30.3	102.20
ix)	20	53.0	132.48
x)	30	75.7	155.19
xi)	40	94.6	177.90
xii)	50	109.8	196.82
xiii)	60	121.1	208.18
xiv)	70	132.5	223.32
xv)	80	143.8	234.67
xvi)	90	155.2	246.03
xvii)	100	166.5	257.38
xviii)	140	200.6	295.23
xix)	180	230.9	329.30
xx)	200	246.0	348.22
xxi)	250	283.9	382.29
xxii)	300	321.7	416.35
xxiii)	400	397.4	476.91
xxiv)	500	473.1	537.47
xxv)	750	643.5	673.73
xxvi)	1 000	787.3	787.28
xxvii)	1 250	908.4	908.40
xxviii)	1 500	1 010.6	1 010.60
xxix)	1 750	1 112.8	1 112.79
xxx)	2 000	1 215.0	1 214.99
xxxi)	2 500	1 419.4	1 419.38
xxxii)	3 000	1 635.1	1 635.12
xxxiii)	3 500	1 811.1	1 811.12
xxxiv)	4 000	1 987.1	1 987.13
xxxv)	4 500	2 115.8	2 115.82
xxxvi)	5 000	2 244.5	2 244.51
xxxvii)	5 500	2 312.6	2 312.64
xxxviii)	6 000	2 380.8	2 380.77
xxxix)	6 500	2 411.0	2 411.05
xl)	7 000	2 479.2	2 479.18
xli)	7 500	2 547.3	2 547.31
xlii)	8 000	2 615.4	2 615.44

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Table 3 (*Concluded*)

Sl No.	Demand in Fixture Units	Demand with Flush Tanks litre/min	Demand with Flush Valves litre/min
(1)	(2)	(3)	(4)
xliii)	8 500	2 683.6	2 683.57
xliv)	9 000	2 751.7	2 751.70
xlv)	9 500	2 831.2	2 831.18
xlvi)	1 000 0	2 910.7	2 910.67

NOTE — For any water line other than flushing line, refer flush tank column to arrive at flow.

4.7.3.3 The maximum flow rate and flush volumes shall be as below:

Sl No.	*Plumbing Fixtures/Fittings*	*Baseline* (*Max*) *Flow Rate*	*Max. Flow Rate for* 1 *or* 2- *or* 3- *Star Water Efficient Fixture/Fitting* [accepted standards [E-1(5)]]
(1)	(2)	(3)	(4)
i)	Water closets	6 litre/flush	6.0/4.8/4.0 litre/full flush and 3.0/2.8/2.0 litre/reduced flush
ii)	Urinals	3.8 litre/flush	3.0/2.0/1.0 litre/flush
iii)	Lavatory, metered faucet (Public)	1 litre/use	1.0/0.8/0.6 litre/use
iv)	Lavatory, faucet (Private)	8 litre/min	8.0/6.0/3.0 litre/min
v)	Sink, faucet	8 litre/min	8.0/6.0/4.5 litre/min
vi)	Bidet, hand-held spray	8 litre/min	6.0/5.0/4.0 litre/min
vii)	Shower head	10 litre/min	10.0/8.0/6.8 litre/min

NOTE — The maximum flow rates of plumbing fixtures and fittings provided are at the pressure of 0.42 N/mm^2. Water closets with dual flush cisterns and urinals with reduced flush volumes are recommended. Users/designers are encouraged to use low-flow fixtures.

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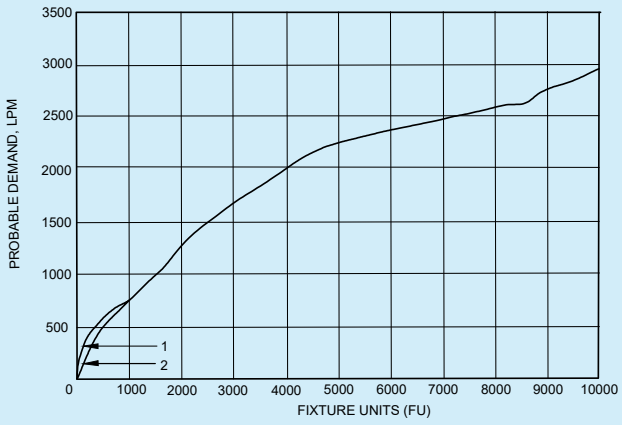
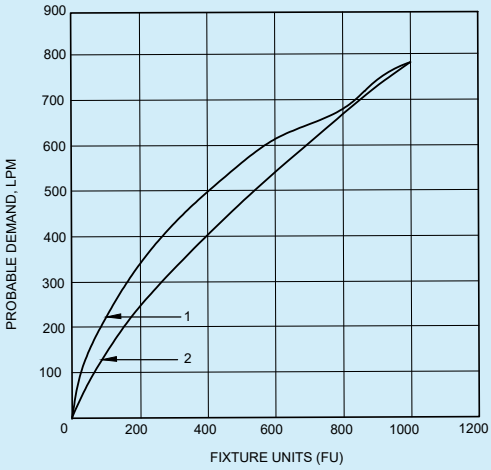


2A GRAPH FOR PROBABLE DEMAND UP TO 10 000 FU



CURVE 1 - SYSTEM WITH FLUSH VALVES
CURVE 2 - SYSTEM WITH FLUSH TANKS

2B GRAPH FOR PROBABLE DEMAND UP TO 1000 FU

FIG. 2 GRAPH FOR PROBABLE DEMAND

4.7.4 *Pipe Size Computation*

Commercially available standard sizes of pipes are only to be used against the sizes arrived at by actual design. Therefore, several empirical formulae are used, even though they give less accurate results. The Hazen and William's formula and the charts based on the same may be used without any risk of inaccuracy in view of the fact that the pipes normally to be used for water supply are of smaller sizes. Nomogram of Hazen and William's equation has been provided in Annex C.

4.7.5 *Adequate and Excessive Water Pressure*

The requirements shall be as follows:

a) *Adequate water pressure* — A minimum water pressure in accordance with **3.1.2** shall be ensured in the distribution system. The maximum pressure shall be maintained at 0.42 N/mm^2. Also, while designing, the maximum/minimum pressure required for operation of special fixtures and fittings is to be maintained as per the technical data sheet; and

b) *Excessive water pressure* — Whenever pressure exceeds 0.42 N/mm^2, and the distribution system may not be able to withstand the same, pressure reducing valves shall be installed for reduction of pressure.

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4.7.6 *Water Hammer Effects*

Water hammer is a pressure wave phenomenon created by a relatively sudden changes in the water velocity or its direction. It is also observed when valves are shut off. Water hammer arrestors may be used to absorb high pressures resulting from sudden closure of valves/taps.

4.8 Distribution Systems in Multi-Storeyed Buildings

4.8.1 There are following four basic methods of distribution of water to a multi-storeyed building:

a) direct supply system from mains – public or private;

b) gravity distribution system;

c) pressurized distribution system (Hydro-pneumatic pumping system); and

d) combined distribution system.

4.8.2 *Direct Supply System from Mains — Public or Private*

This system is adopted when adequate pressure is available in the mains to supply water at adequate pressure at the topmost floor. With limited pressure available in most city mains, water from direct supply is normally not available above two or three floors. However, in gated communities or large campuses, this system can be adopted for taller buildings by incorporating design parameters such as elevated centralized water tank(s) or central hydro-pneumatic pumping system(s). For details of this system, reference may be made to good practice [E-1(9)] may be referred.

4.8.3 *Gravity Distribution System*

This is the most common water distribution system. The system comprises pumping water to one or more overhead water tanks. Water transferred to overhead tank(s) is distributed by gravity to various parts of the building by the system of piping network.

4.8.4 *Pressurized Distribution System* (*Hydro-pneumatic Pumping System*)

4.8.4.1 Pressurized distribution system is a direct pumping system incorporating a recharge diaphragm vessel.

4.8.4.2 The system may incorporate multiple pumps with suction and discharge manifolds and a control panel to facilitate automatic operation. Total discharge capacity required may be shared by a number of pumps, where the pumps operate in duty, assist and standby configuration.

4.8.4.3 The system shall also incorporate automatic sequencing of pumps to ensure even wear and tear also a low level cut-off, to prevent dry run of the pumps. The system shall be provided with continuous power supply with provision of emergency power backup.

4.8.4.4 Modern hydro-pneumatic systems are available with variable frequency drive, where the pump is efficiently used to deliver water at rates of flow as required by the system, by varying its speed with the assistance of an electronic device, thereby meeting the demand flow through variation in speed of the motor. With this arrangement, the same pump can deliver water at required pressure and flow as required at different times of the day. The system consumes energy in proportion to the work done and helps in controlling the water surge in the distribution line.

4.8.4.5 Hydro-pneumatic system generally eliminates the need of an overhead tank. As a good engineering practice and to take care of emergencies, an overhead of smaller capacity should be provided which feeds by gravity to the system (*see* Fig. 3).

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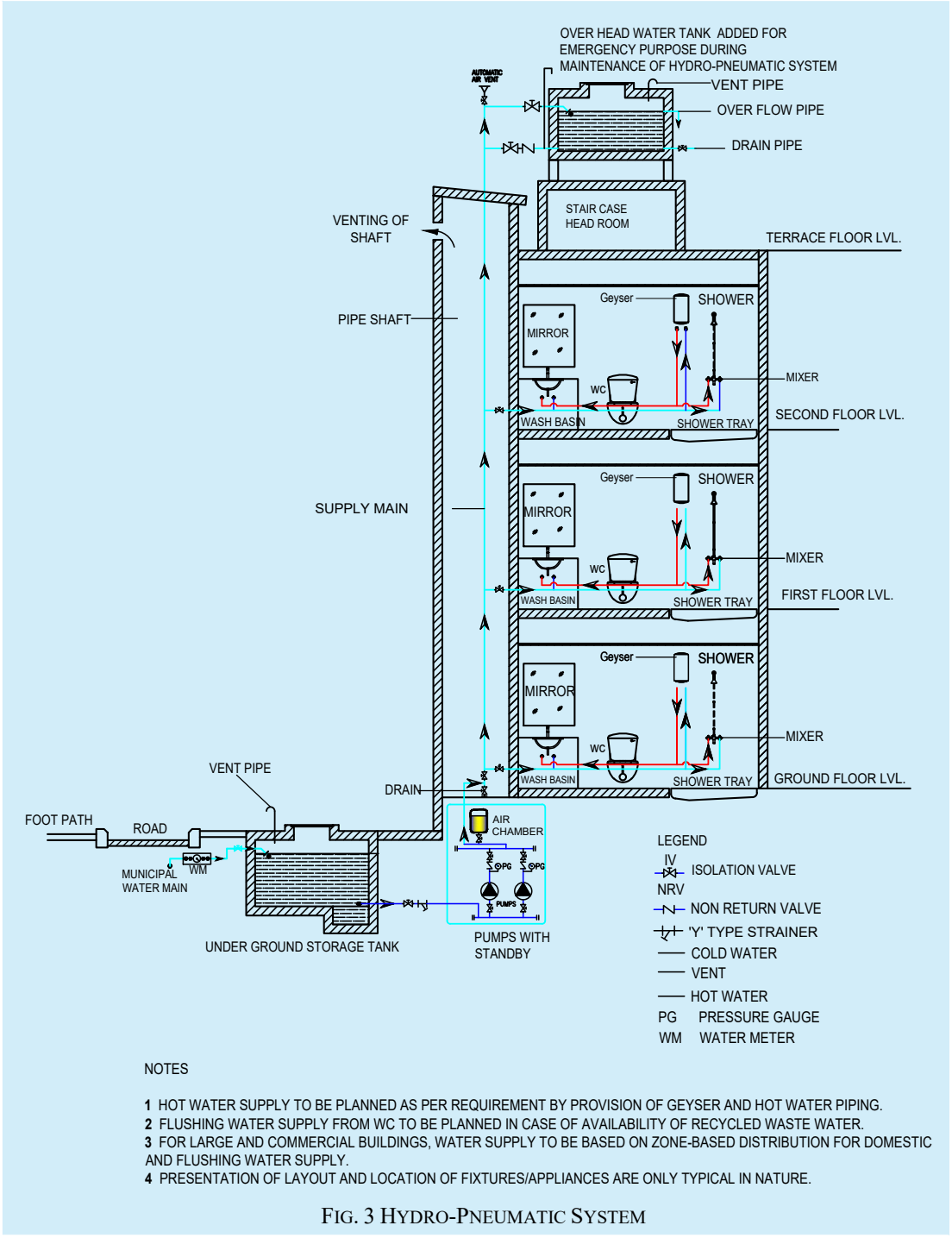

FIG. 3 HYDRO-PNEUMATIC SYSTEM

4.8.5 *Combined Distribution System*

4.8.5.1 In this system, a combination of gravity and pressurized distribution is adopted. A few upper floors are provided with a pressure booster pumping system to achieve the desired residual pressure, while the lower floors are fed by gravity supply.

4.8.5.2 Water collected in the overhead tank is distributed to the various parts of the building. To achieve required residual pressure for top 2 to 4 floors for proper functioning of the fixtures, a pressure booster pumping system is installed on the dedicated outlet from overhead tank with its own distribution piping serving the top 2 floors to 4 floors. For lower floors, water is distributed by gravity system.

4.8.5.3 Water distribution is accomplished by providing down take pipes in the shaft from the terrace ring mains (*see* Fig. 4).

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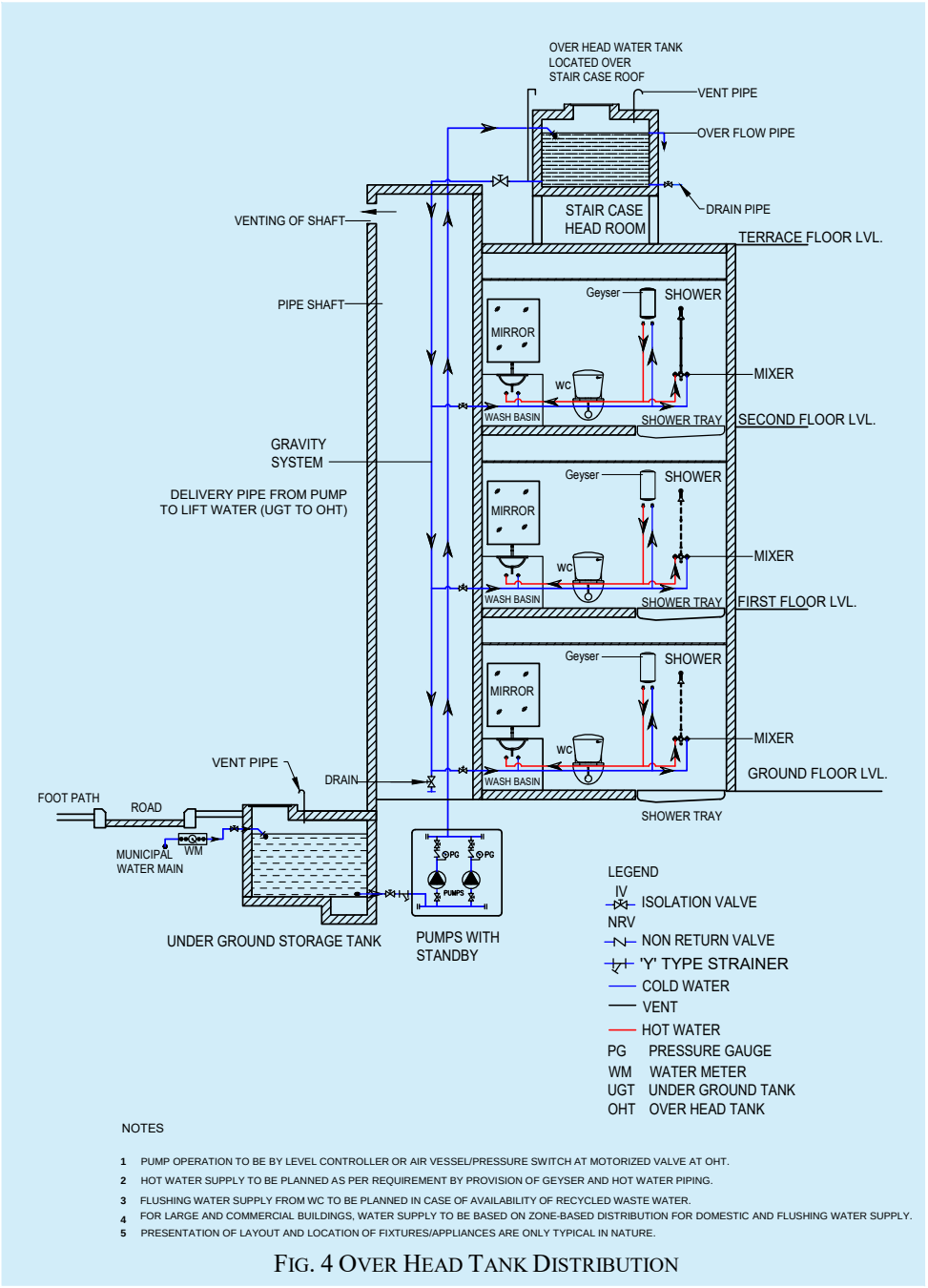

FIG. 4 OVER HEAD TANK DISTRIBUTION

4.8.6 *Zoning of Distribution Systems*

The zoning of water distribution network may be adopted for 7 floors to 9 floors, while conforming to the adequate pressure requirements and excessive pressure limitations in the hydraulic design (*see* **4.7.5**). *See* Fig. 5 and Fig. 6 for zoning of gravity distribution system and pressurized distribution system (hydro-pneumatic pumping system), respectively.

The recommended maximum permissible velocity is 2.4 m/s for water distribution. In case of hot water distribution through copper pipes, the velocity is restricted to 1.5 m/s due to concern of erosion of the piping material.

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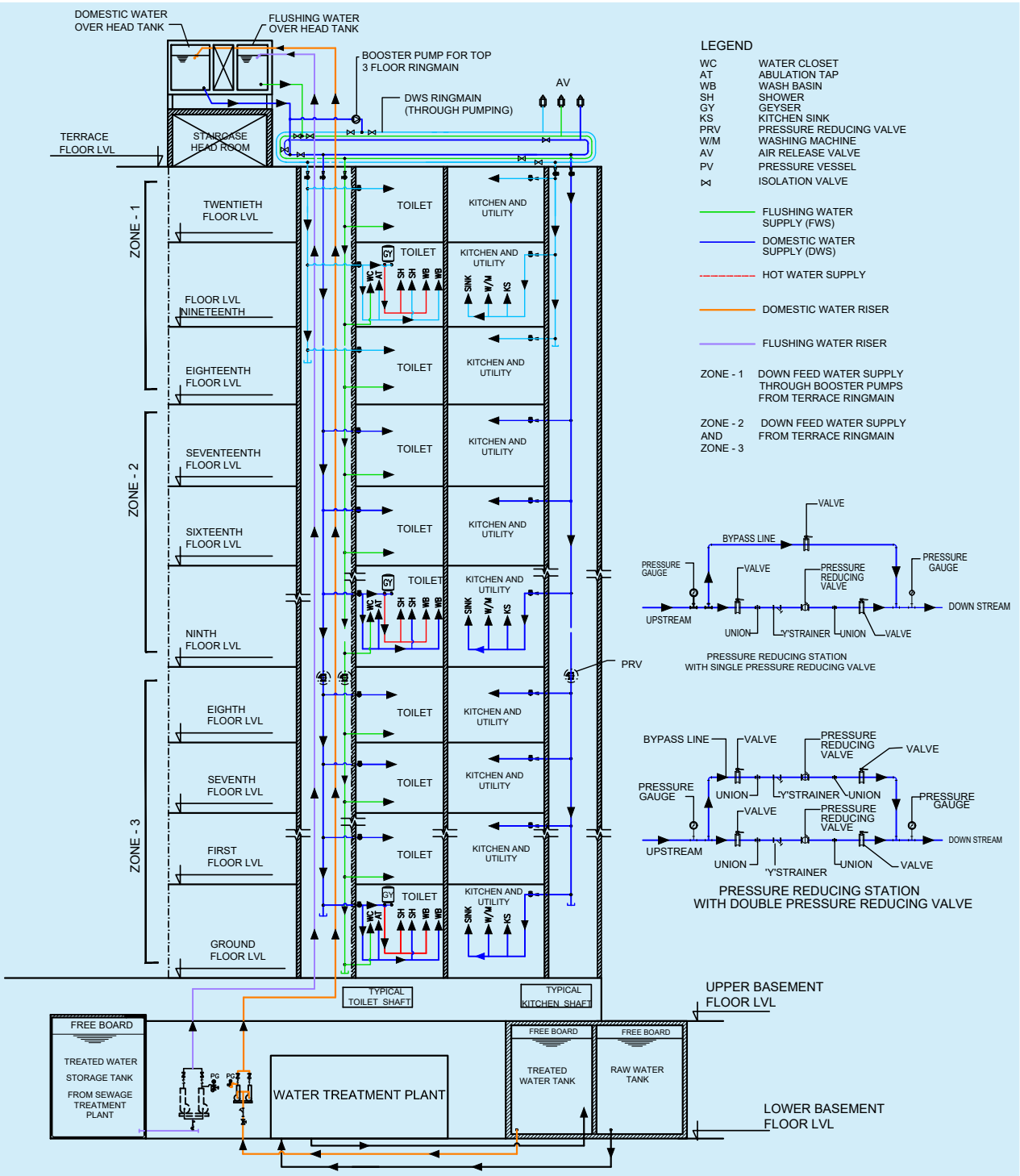

NOTES

1 APPURTENANCE, SUCH AS PRV SHOULD BE PLANNED IN MAIN PIPING NETWORK OR BRANCH PIPING, AS REQUIRED, TO RESTRAIN PRESSURE TO UPPER LIMITS.

2 REQUIREMENTS FOR STORAGE AND USAGE OF FIRE WATER SHOULD BE AS PER PART F 'FIRE AND LIFE SAFETY' OF THIS NBCS.

FIG. 5 SCHEMATIC DIAGRAM SHOWING THE DISTRIBUTION SYSTEM IN RESPECT OF GRAVITY SYSTEM FOR A MULTI-STOREYED BUILDING

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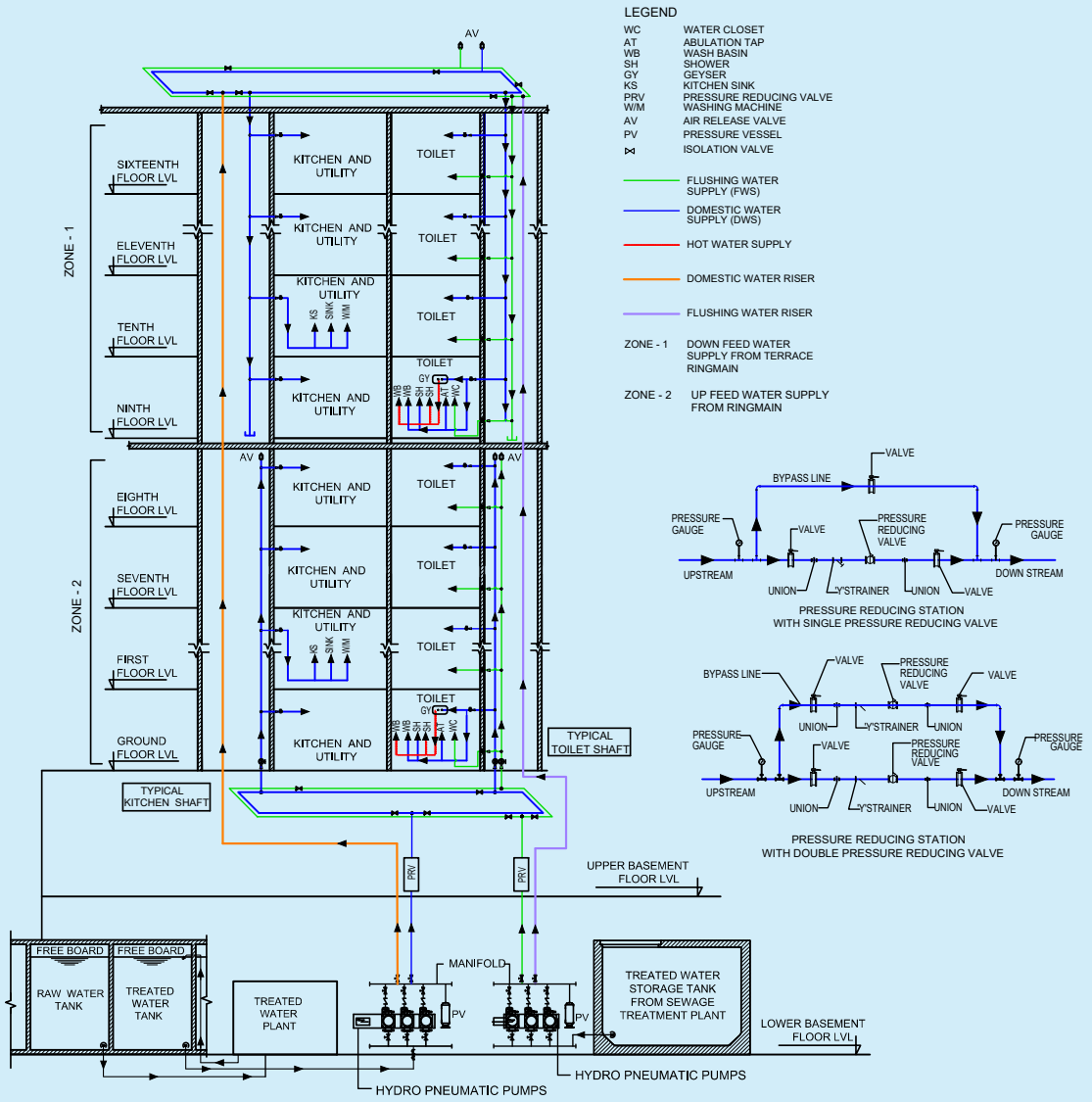

NOTES

1 THE GIVEN EXAMPLE IS FOR 16 STORIES BUILDING WITH CONCEPT OF UPFEED AND DOWN FEED RINGMAINS. THE CHOICE OF RINGMAIN IS ON DESIGNER PROPOSAL. FOR TALLER BUILDING, ZONES AND RINGMAINS SHALL BE PLANNED TO MEET MAXIMUM AND MINIMUM PRESSURE REQUIREMENTS. APPURTENANCE, SUCH AS PRV SHOULD BE PLANNED IN MAIN PIPING NETWORK OR BRANCH PIPING, AS REQUIRED, TO RESTRAIN PRESSURE TO UPPER LIMITS.

2 GUIDANCE REGARDING REQUIREMENTS FOR STORAGE AND USAGE OF FIRE WATER MAY BE AS PER PART F 'FIRE AND LIFE SAFETY' OF THIS NBCS.

FIG. 6 SCHEMATIC DIAGRAM SHOWING THE DISTRIBUTION SYSTEM IN RESPECT OF HYRDO PNEUMATIC SYSTEM FOR A MULTI-STOREYED BUILDING

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4.9 General Requirements for Pipe Work

4.9.1 *Mains*

The following principles shall apply for the mains:

a) Service mains shall be of adequate size to give the required rate of flow.

b) Mains shall be divided into sections by the provisions of sluice valves and other valves so that water may be shut off for repairs.

c) To avoid dead ends, the mains shall be arranged in a grid formation or in a network.

d) Where dead ends are unavoidable, a hydrant shall be provided to act as a wash-out.

e) Wash-out valve shall not discharge directly into a drain or sewer, or into a manhole or chamber directly connected to it; an effectively trapped chamber shall be interposed, into which the wash-out shall discharge.

f) Air valves shall be provided at all summits, and wash-out at low points between summits.

g) Mains need not be laid at unvarying gradients, but may follow the general contour of the ground. They shall, however, fall continuously towards the washout and rise towards the air valves. The gradient shall be such that there shall always be a positive pressure at every point under working conditions.

h) Cover for the mains shall be at least 900 mm under roadways and 750 mm in the case of footpaths. This cover shall be measured from the top of the pipe to the surface of the ground.

j) Mains shall be located sufficiently away from other service lines like electric and telegraph cables to ensure safety and where the mains cannot be located away from such lines, suitable protective measures shall be accorded to the mains. As far as possible, water supply and sewerage mains should be isolated from each other with certain minimum horizontal distance as per good engineering practice.

4.9.2 *Communication Pipes*

a) Every premises that is supplied with water by the Authority shall have its own separate communication pipe. In the case of a group or block of premises belonging to the same owner the same communication pipe may supply water to more than one premises with the prior permission of the Authority.

b) The communication pipe between the water main and the stop-cock at the boundary of the premises shall be laid by the Authority.

c) Connections up to 50 mm diameter may be made on the water main by means of screwed ferrules, provided the size of the connections does not exceed one third the size of the water main. In all other cases, the connection shall be made by a T-branch off the water main.

d) As far as practicable, the communication pipe and the underground service pipe shall be laid at right angles to the main and in approximately straight lines to facilitate location for repairs. It is also recommended that the communication pipe be laid in a pipe in pipe sleeve of larger diameter made of non-corrosive material to protect the communication pipe.

e) Every communication pipe shall have a stop-cock and meter inserted in it. The waterway of each such fitting shall not be less than the internal sectional area of the communication pipe and the fittings shall be located within the premises at a conspicuous place accessible to the Authority which shall have exclusive control over it.

4.9.3 *Consumer Pipes*

a) No consumer pipe shall be laid in the premises to connect the communication pipe without the approval of the Authority.

b) The consumer pipe within the premises shall be laid underground with a suitable cover to safeguard against damage from traffic and extremes of weather.

c) To control the branch pipe to each separately occupied part of a building supplied by a common service pipe, a stop valve shall be fixed to minimize the interruption of the supply during repairs. All such stop valves shall be fixed in accessible positions and properly protected. To supply water for drinking or for

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culinary purposes, direct taps shall be provided on the branch pipes connected directly to the consumer pipe. In the case of multi-storeyed buildings, down take taps shall be supplied from overhead tanks.

d) Pumps shall not be allowed on the service pipe, as they cause a drop in pressure on the suction side, thereby affecting the supply to the adjoining properties. In cases where pumping is required, a properly protected storage tank of adequate capacity shall be provided to feed the pump.

e) No direct boosting (by booster pumps) shall be allowed from the service pipes (communication and consumer pipes).

f) Consumer pipes shall be so designed and constructed as to avoid air-locks. Draining taps shall be provided at the lowest points from which the piping shall rise continuously to draw-off taps.

g) Consumer pipes shall be so designed as to reduce the production and transmission of noise as much as possible.

h) Consumer pipes in roof spaces and unventilated air spaces under floors or in basements shall be protected against corrosion.

j) Consumer pipes shall be so located that they are not unduly exposed to accidental damage and shall be fixed in such positions as to facilitate cleaning and avoid accumulations of dirt.

k) All consumer pipes shall be so laid as to permit expansion and contraction or other movements.

4.9.4 *Prohibited Connections*

a) A service pipe shall not be connected into any distribution pipe; such connection may permit the backflow of water from a cistern into the service pipe, in certain circumstances, with consequent danger of contamination and depletion of storage capacity. It might also result in pipes and fittings being subjected to a pressure higher than that for which they are designed, and in flooding from overflowing cisterns.

b) No pipe for conveyance or in connection with water supplied by the Authority shall communicate with any other receptacle used or capable of being used for conveyance other than water supplied by the Authority.

c) Where storage tanks are provided, no person shall connect or be permitted to connect any service pipe with any distributing pipe.

d) No service or supply pipe shall be connected directly to any water-closet or a urinal. All such supplies shall be from flushing cisterns/flush valves which shall be supplied from storage tank.

e) No service or supply pipe shall be connected directly to any hot water system or to any other apparatus used for heating other than through a feed cistern thereof.

4.10 Jointing of Pipes

4.10.1 *Cast Iron Pipes*

Jointing may be done by any of the following methods:

a) spigot and socket joints, or

b) flanged joints.

in accordance with good practice [E-1(10)]. Alternative jointing materials which are found to be equally effective, may be used in place of lead joints, with the approval of the Authority.

4.10.2 *Steel Pipes*

Plain-ended steel pipes may be joined by welding. Electrically welded steel pipes shall be jointed in accordance with good practice [E-1(11)].

4.10.3 *Wrought Iron and Steel Screwed Pipes*

Screwed wrought iron or steel piping may be jointed with screwed and socketed joints. Care shall be taken to

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remove any burr from the end of the pipes after screwing. A jointing compound approved by the Authority and containing no red lead composition shall be used. Screwed wrought iron or steel piping may also be jointed with screwed flanges.

4.10.4 *Asbestos Cement Pipes*

Asbestos cement pipes may be jointed in accordance with good practice [E-1(12)].

4.10.5 *Copper Pipes*

Copper pipes shall be jointed by internal solder ring joint, end-brazing joint or by use of compression fitting. The flux used shall be non-toxic and the solder used shall be lead free. The use of dezincification fittings shall be made in case of jointing of copper pipe and steel pipe. The jointing technology shall be used as per good engineering practice and as per manufacturers recommendations.

4.10.6 *Concrete Pipes*

Concrete pipes shall be jointed in accordance with good practice [E-1(13)].

4.10.7 *Polyethylene and Unplasticized PVC Pipes*

Polyethylene and unplasticized PVC pipes shall be jointed in accordance with good practice [E-1(14)].

4.11 Backflow Prevention

4.11.1 The installation shall be such that water delivered is not liable to become contaminated or that contamination of the public water supply does not occur.

4.11.2 The various types of piping and mechanical devices acceptable for backflow protection are:

a) Barometric loop,

b) Air gap,

c) Atmosphere vacuum breaker,

d) Pressure vacuum breaker,

e) Double check valve,

f) Reduced pressure backflow device.

4.11.3 The installation shall not adversely affect drinking water:

a) by materials in contact with the water being unsuitable for the purpose;

b) as a result of backflow of water from water fittings, or water using appliances into pipework connected to mains or to other fittings and appliances;

c) by cross-connection between pipes conveying water supplied by the water undertaker with pipes conveying water from some other source; and

d) by stagnation, particularly at high temperatures.

4.11.4 No pump or similar apparatus, the purpose of which is to increase the pressure in or rate of flow from a supply pipe or any fitting or appliance connected to a supply pipe, shall be connected unless the prior written permission of the water supplier has been obtained in each instance.

The use of such a pump or similar apparatus is likely to lead to pressure reduction in the upstream pipe work which, if significant, increase the risk of backflow from other fittings.

4.11.5 The water shall not come in contact with unsuitable materials of construction.

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4.11.6 No pipe or fitting shall be laid in, on or through land fill, refuse, an ash pit, sewer, drain, cesspool or refuse chute or any manhole connected with them.

4.11.7 No pipe susceptible to deterioration by contact with any substance shall be laid or installed in a place where such deterioration is likely to occur. No pipe that is permeable to any contaminant shall be laid or installed in any position where permeation is likely to occur.

4.11.8 If a liquid (other than water) is used in any type of heating primary circuit, which transfers heat to water for domestic use, the liquid shall be non-toxic and non-corrosive.

4.11.9 A backflow prevention device shall be arranged or connected at or as near as practicable to each point of delivery and use of water. Appliances with built-in backflow prevention shall be capable of passing the test. All backflow prevention devices shall be installed so that they are accessible for examination, repair or replacement. Such devices shall be capable of being tested periodically by the Authority to ensure that the device is functioning efficiently and no backflow is occurring at any time.

4.12 Conveyance and Distribution of Water within the Premises

4.12.1 Basic *Principles*

Wholesome water supply provided for drinking and culinary purposes shall not be liable to contamination from any less satisfactory water. There shall, therefore, be no cross-connection whatsoever between the distribution system for wholesome water and any pipe or fitting containing unwholesome water, or water liable to contamination, or of uncertain quality, or water which has been used for any other purpose. The provision of reflux or non-return valves or closed and sealed stop valves shall not be construed as a permissible substitute for complete absence of cross-connection.

4.12.2 The design of the pipe work shall be such that there is no possibility of backflow towards the source of supply from any cistern or appliance, whether by siphonage or otherwise. Reflux non-return valves shall not be relied upon to prevent such backflow.

4.12.3 Where a supply of less satisfactory water than wholesome water becomes inevitable as an alternative or is required to be mixed with the latter, it shall be delivered only into a cistern and by a pipe or fitting discharging into the air gap at a height above the top edge of the cistern equal to twice its nominal bore and in no case less than 150 mm. It is necessary to maintain a definite air gap in all appliances or taps used in water-closets.

4.12.4 All pipe work shall be so designed, laid or fixed and maintained as to remain completely water-tight, thereby avoiding wastage, damage to property and the risk of contamination.

4.12.5 No water supply line shall be laid or fixed so as to pass into or through any sewer, scour outlet or drain or any manhole connected therewith, nor through any ash pit or manure pit or any material of such nature that is likely to cause undue deterioration of the pipe.

4.12.5.1 Where the laying of any pipe through corrosive soil or pervious material is unavoidable, the piping shall be properly protected from contact with such soil or material by being carried through an exterior pipe sleeves as approved by the Authority. Any existing piping or fitting laid or fixed, which does not comply with the above requirements, shall be removed immediately by the consumer and re-laid by him in conformity with the above requirements and to the satisfaction of the Authority.

4.12.5.2 Where lines have to be laid in close proximity to electric cables or in corrosive soils, adequate precautions/protection should be taken to avoid corrosion.

4.12.6 Underground piping shall be laid at such a depth that it is unlikely to be damaged by frost or traffic loads and vibrations. It shall not be laid in ground liable to subsidence, but where such ground cannot be avoided, special precautions shall be taken to avoid damage to the piping. Where piping has to be laid across recently disturbed ground, the ground shall be thoroughly consolidated so as to provide a continuous and even support. In the case of frost conditions, the pipes shall be laid below the frost line with suitable insulation to the pipes.

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4.12.7 In designing and planning the layout of the pipe work, due attention shall be given to the maximum rate of discharge required, economy in labour and materials, protection against damage and corrosion, water hammer, protection from frost, if required, and avoidance of airlocks, noise transmission and unsightly arrangement.

4.12.8 To reduce frictional losses, piping shall be as smooth as possible inside. Methods of jointing shall be such as to avoid internal roughness and projection at the joints, whether of the jointing materials or otherwise.

4.12.9 Change in diameter and in direction shall preferably be gradual rather than abrupt to avoid undue loss of head. No bend or curve in piping shall be made which is likely to materially diminish or alter the cross-section.

4.12.10 No boiler for generating steam or closed boilers of any description or any machinery shall be supplied direct from a service or supply pipe. Every such boiler or machinery shall be supplied from a feed cistern.

4.13 Laying of Mains and Pipes on Site

4.13.1 The mains and pipes on site shall be laid in accordance with good practices [E-1(15)]. The pipes laid in buildings situated in seismic zone and across large building expansion joints should be installed with suitable expansion bellows and expansion loops to mitigate expansion of piping system for its intended function without failures.

4.13.2 *Excavation and Refilling*

The bottoms of the trench excavations shall be so prepared that the barrels of the pipes, when laid, are well bedded for their whole length on a firm surface and are true to line and gradient. In the refilling of trenches, the pipes shall be surrounded with fine selected material, well rammed so as to resist subsequent movement of the pipes. No stones shall be in contact with the pipes; when resting on rock, the pipes shall be bedded on fine-selected material or (especially where there is a steep gradient) on a layer of concrete.

4.13.2.1 The pipes shall be carefully cleared of all foreign matter before being laid.

4.13.3 *Laying Underground Mains*

Where there is a gradient, pipe laying shall proceed in ‘uphill’ direction to facilitate joint making.

4.13.3.1 Anchor blocks shall be provided to withstand the hydraulic thrust.

4.13.4 Iron surface boxes shall be provided to give access to valves and hydrants and shall be supported on concrete or brickwork which shall not be allowed to rest on pipes.

4.13.5 *Laying Service Pipes*

4.13.5.1 Service pipes shall be connected to the mains by means of right-hand screw down ferrule or T-branches. The ferrules shall conform to accepted standard [E-1(16)].

4.13.5.2 Precaution against contamination of the mains shall be taken when making a connection and, where risk exists, the main shall be subsequently disinfected. The underground water service pipe and the building sewer or drain shall be kept at a sufficient distance apart so as to prevent contamination of water. Water service pipes or any underground water pipes shall not be run or laid in the same trench as the drainage pipe. Where this is unavoidable, the following conditions shall be fulfilled:

a) the bottom of the water service pipe, at all points, shall be at least 300 mm above the top of the sewer line at its highest point;

b) the water service pipe shall be placed on a solid shelf excavated on one side of the common trench;

c) the number of joints in the service pipe shall be kept to a minimum; and

d) the materials and joints of sewer and water service pipe shall be installed in such a manner and shall possess such necessary strength and durability as to prevent the escape of solids, liquids and gases there from under all known adverse conditions, such as corrosion strains due to temperature changes, settlement, vibrations and superimposed loads.

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4.13.5.3 The service pipe shall pass into or beneath the buildings at a depth of not less than 750 mm below the outside ground level and, at its point of entry through the structure, it shall be accommodated in a sleeve which shall have previously been solidly built into the wall of the structure. The space between the pipe and the sleeve shall be filled with bituminous or other suitable material for a minimum length of 150 mm at both ends.

4.13.6 *Pipes Laid through Ducts, Chases, Notches or Holes*

Ducts or chases in walls for piping shall be provided during the building of the walls. If they are cut into existing walls, they shall be finished sufficiently smooth and large enough for fixing the piping.

4.13.6.1 Piping laid in notches or holes shall not be subjected to external pressure.

4.13.7 *Lagging of Pipes*

Where lagged piping outside buildings is attached to walls, it shall be entirely covered all round with water-proof and fire insulating material and shall not be in direct contact with the wall. Where it passes through a wall, the lagging shall be continued throughout the thickness of the wall.

4.14 Hot Water Supply Installations

4.14.1 *Design Consideration*

4.14.1.1 *General*

In electric water heating practice for domestic purposes, the accepted method is to use storage heaters in which water is steadily heated up to a predetermined temperature and stored until required for use. The heating by electricity of a large quantity of water, such as water required for a hot bath, within the time normally taken to run the water into the bath, requires a heater of too high a rating to be practicable in normal domestic premises. It should be ensured that such vents and pipes are above reach/inaccessible during daily use to avoid accidents such as accidental contact and burning.

4.14.1.2 In modern hotels and apartment blocks and service apartments, centralized storage and distribution systems are adopted, where other energy sources such as oil, gas, solar panels, etc, may be used for the generation of hot water as these options prove more economical and convenient in heating large volumes of water for storage.

4.14.1.3 The implementation of a hybrid heating system, integrating solar-based heating with electrical geysers, has demonstrated effectiveness in extreme cold conditions where water freezing occurs, and prolonged use of electric geysers presents challenges. When selecting such hybrid systems, the design shall ensure operational safety during both the heating process and the extraction of hot water.

4.14.1.4 When water supplied to the buildings contain dissolved salts resulting in hardness of water, measures such as installation of water softening plants, etc, shall be taken to avoid formation of scales in the hot water installations.

4.14.2 *Storage Temperature*

4.14.2.1 The design of hot water supply system and its appliances shall be based on the temperatures at which water is normally required for the various uses, namely:

Scalding	:	65 °C
Sink	:	60 °C
Hot bath	:	43 °C as run for use at 41 °C
Warm bath	:	37 °C
Tepid bath	:	29.5 °C

4.14.2.2 In order to minimize the danger of scalding, precipitation of scale from hard water, standing heat losses, risk of steam formation and the possibility of damage to porcelain or other fittings and to surface finishes, a storage

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temperature of 60 °C is recommended. If storage capacity is limited, a higher temperature up to 65 °C may be adopted when soft water is used.

4.14.3 *Storage Capacity*

The size of the storage vessel is governed by the maximum short time demand of the domestic premises. Depending on local conditions this shall be 50 litre to 75 litre at 60 °C in a dwelling with a bath tub and 25 litre at 60 °C for a shower or a tap (for bucket supply). The capacity of the storage vessel shall not be less than 20 percent in excess of the required maximum short time demand. In larger houses where a single hot water heater is intended to supply hot water to more than one bathroom or kitchen or both, the maximum short time demand shall be estimated and the capacity decided accordingly. Small electric or gas storage heaters of 15 litre to 25 litre capacity may be used to supply one or two points of draw off depending on the use of hot water.

4.14.4 *Rate of Flow*

With storage type installation, the recommended maximum rates of flow for different types of fixtures are given in Table 4.

Table 4 Rate of Hot Water Flow

(*Clause* 4.14.4)

Sl No. (1)	**Fixtures** (2)	**Rate of Flow** litre/min (3)
i)	Kitchen sink	5
ii)	Wash basin	5
iii)	Shower (spray type)	6.5

4.14.4.1 *Hot water supply systems*

Identification of water supply system is critical for safe functioning and protection of occupants. The first step is correct labelling of various water systems in the building. The requirements of identification/labelling shall be adhered on every installation where different water systems are provided.

While designing centralized hot water systems in major projects, the following points should be considered:

a) Fuel to be used,

b) Location and dimension of boiler house and calorifier chambers,

c) Location and dimension of fuel storage tank,

d) Means of ash disposal (in case of solid fuel),

e) Location and dimension of chimney,

f) Location of cold-water points,

g) Drainage facilities during emptying,

h) Quality of water supply,

j) Provision for air combustion and ventilation.

In laying hot water piping systems, the pressures of hot and cold water should be made equal at each fixture, especially where mixing faucets/thermostatic mixer are to be used. Otherwise, there would be imbalance of pressure where one pressure would be more than the other. These conditions should be avoided by proper design of the system.

Return circulation systems are recommended for energy conservation and user comfort.

In the inverted systems, hot water heaters and tanks are located at the highest point of water supply system and supply and return risers below the level of hot water source.

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Environmental and consumer requirements should be considered when planning the installation of a solar hot water system. Factors affecting the performance of a system and decisions about how the system should be installed, include:

a) the climate zone of the site and possibility of:
   1) shading;
   2) frost and freezing;
   3) wind;
   4) dust;
   5) hail; and
   6) corrosion and scaling.
b) the ambient air temperature;
c) the cold-water temperature;
d) the availability of space and pitch of a suitable south-facing roof;
e) the presence and location of an existing hot water service;
f) the available energy sources (for example, gas or electricity);
g) the householder's hot water usage; and
h) the householder's budget.

4.14.5 *Design of Storage Vessel*

Storage tanks shall be oblong or cylindrical in shape and shall be installed, preferably with the long side vertical in order to assist the effective stratification or 'layering' of hot or cold water. The ratio of height to width or diameter shall not be less than 2 : 1. An inlet baffle should preferably be fitted near the cold inflow pipe in order to spread the incoming cold water.

4.14.6 *Materials for Storage Vessel and Pipes*

4.14.6.1 Under no circumstances shall ungalvanized (black) mild steel pipes and fittings, such as sockets, bushes, etc, be used in any part of domestic hot water installation, including the cold feed pipe and the vent pipe. Materials resistant to the chemical action of water supplied shall be used in construction of vessels and pipes. Each installation shall be restricted to one type of metal only, such as all copper or all galvanized mild steel. When water supplied is known to have appreciable salt content, galvanized iron vessels and pipes shall not be used. However, it is advisable to avoid use of lead pipes in making connection to wash basins. Where required it is also advisable to use vessels lined internally with glass, stainless steel, etc.

4.14.6.2 In general, tinned copper and other metals such as monel metal, etc, are suitable for most types of water. The suitability of galvanized mild steel for storage tanks depends upon the *p*H value of the water and the extent of its temporary hardness. For values of *p*H 7.2 or less, galvanized mild steel should not be used. For values of *p*H 7.3 and above, galvanized mild steel may be used provided the corresponding temporary hardness is not lower than those given below:

Sl No.	*p*H *Value*	*Minimum Temporary Hardness Required* mg/l
(1)	(2)	(3)
i)	7.3	210
ii)	7.4	150
iii)	7.5	140
iv)	7.6	110
v)	7.7	90
vi)	7.8	80
vii)	7.9 to 8.5	70

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4.14.7 *Location of Storage Vessel*

The loss of heat increases in proportion to the length of pipe between the storage vessel and the hot water outlet since each time the water is drawn, the pipe fills with hot water which then cools. The storage vessel shall therefore be so placed that the pipe runs to the most frequently used outlets are as short as possible.

4.14.8 *Immersion Heater Installation*

4.14.8.1 If a domestic storage vessel is to be adopted to electric heating by the provision of an immersion heater and thermostat, the following precautions shall be observed:

a) *Location of immersion heaters* — The immersion heater shall be mounted with its axis horizontal, except in the case of the circulation type which is normally mounted with its axis approximately vertical.

b) In a tank with a flat bottom, a space of not less than 75 mm below the immersion heater and 50 mm below the cold feed connection shall be provided to allow for accumulation of sludge and scale, where it will not affect the working of the immersion heater.

c) In a cylindrical storage vessel with inwardly dished bottom, the inlet pipe shall be so arranged that the incoming cold water is not deflected directly into the hot water zone. The lowest point of the immersion heater shall be 25 mm above the centre line of the cold feed inlet, which, in turn, is usually 100 mm above the cylinder rim.

d) *Location of thermostat* — Where the thermostat does not form an integral part of the immersion heater, it shall be mounted with its axis horizontal, at least 50 mm away from and not lower than the immersion heater.

e) *Dual heater installations* — If desired, the principle of the dual heater may be adopted. In this case, one heater and its thermostat shall be installed at a low level as indicated in (b) and (c). The second heater and its thermostat shall be similarly disposed in the upper half of the cylinder at a level depending on the reserve of hot water desired for ordinary domestic use. The bottom heater shall be under separate switch control.

f) *Clearance around storage vessel* — Adequate clearance shall be provided between the tank and the cupboard, door or walls to allow convenient insertion and adjustment of the immersion heater and thermostat and to give space for thermal insulation.

4.14.8.2 *Rating of immersion heaters*

The rating of an immersion heater shall be determined according to the following factors:

a) proposed hot water storage capacity (the maximum with cold water as indicated in **4.14.3** shall be taken into account);

b) rate of utilization (draw off frequency);

c) permissible recovery period; and

d) inlet water temperature.

For details regarding rated input of water, refer to good practice [E-1(17)].

4.14.9 *Thermal Insulation*

The hot water storage vessel and pipes shall be adequately insulated, wherever necessary to minimize heat loss.

The whole external surface of the storage vessel including the cover to the man hole shall also be duly insulated.

Insulation may be provided by wrapping storage vessel and pipes with fibre glass, mineral wool or closed cell flexible elastomeric foam based materials of desired thickness, covered with cladding for protection from damage or from weather in case of external use.

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4.14.10 *Cold Water Supply to Heaters*

4.14.10.1 A storage water heater (pressure type) shall be fed from a cold water storage tank and under no circumstances connected directly to the water main, except the type which incorporates a feed tank with ball valves and overflow pipe arrangement (cistern type heaters) or non-pressure type heaters.

4.14.10.2 *Storage cisterns*

4.14.10.2.1 The storage capacity of a cold water tank shall be at least twice the capacity of the hot water heater. The capacity of the storage tank may, however, be 1.5 times when the number of heaters connected to one common tank exceeds 10.

4.14.10.2.2 The storage tank for supply of cold water to hot water heaters shall be separate, if practicable. In the case of a common tank which also supplies cold water to the fixtures, this cold water supply connection shall be so arranged that 50 percent of the net capacity, worked out as in **4.14.10.2.1**, shall be available for supply to the hot water heaters.

4.14.10.2.3 In the case of multi-storeyed buildings where a common overhead tank over the stair/lift well is generally installed, it is advisable to have one or more local tanks for supply to the hot water heaters or a compartment in the tank with required storage always available for hot water heater.

4.14.10.2.4 In tall multi-storeyed buildings where the static pressure increases with the height, the total static pressure on the hot water heaters on the lowest floor shall not exceed the rated working pressure of the hot water heater installed. Should the height of the building so require, additional tanks shall be provided on the intermediate floors to restrict the static head to permissible limits, or the pressure shall be reduced to working pressure by providing pressure reducing valves.

4.14.11 *Cold Water Feed*

4.14.11.1 The feed pipe connecting cold water tank with the hot water heater shall not be of less than 20 mm bore and it shall leave the cold water tank at a point not less than 50 mm above the bottom of the tank and shall connect into the hot water heater near its bottom. The feed pipe shall not deliver cold water to any other connection, but into the hot water cylinders only.

4.14.11.2 In the case of multi-storeyed buildings, a common cold water feed pipe may be installed, but each hot water heater shall be provided with a check valve (horizontal type check valve shall be preferred to vertical type for easy maintenance).

4.14.11.3 Care shall be taken in installing the piping to prevent air locks in the piping and negative pressure in the hot water heater. Cold water feed pipe shall not be cross-connected with any other source of supply under pressure.

4.14.12 *Hot Water Piping*

4.14.12.1 *Expansion pipe or vent pipe*

4.14.12.1.1 Each non-pressure type hot water heater or cylinder shall be provided with a vent pipe of not less than 20 mm bore. The vent pipe shall rise above the water line of the cold water tank by at least 150 mm plus 10 mm for every 300 mm height of the water line above the bottom of the heater. The vent shall discharge at a level higher than the cold water tank and preferably in the cold water tank supplying the hot water heaters. Care shall be taken to ensure that any accidental discharge from the vent does not hurt or scald any passer-by or persons in the vicinity.

It shall be ensured that such vents and pipes are so located so as not to encroach into the minimum maneuvering space and should be suitably insulated to avoid accidental contact and burns.

NOTE — Pressure type water heaters are very commonly used and non-pressure type is slowly phased out.

4.14.12.1.2 The vent pipe shall be connected to the highest point of the heater vessel and it shall not project downwards inside it, as otherwise air may be trapped inside, resulting in surging and consequent noises.

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4.14.12.1.3 At no point, after leaving the vessel, shall the vent pipe dip below the level of its connection with the vessel.

4.14.12.1.4 A vent pipe may, however, be used for supply of hot water to any point between the cold water tank and the hot water heaters.

4.4.12.1.5 The vent pipe shall not be provided with any valve or check valves.

4.4.12.2 *Hot water heaters*

4.4.12.2.1 The common hot water delivery pipe shall leave the hot water heater near its top and shall be of not less than 20 mm bore generally, not less than 25 mm bore if hot water taps are installed on the same floor as that on which the hot water heater is situated.

4.14.12.2.2 Hot water taps shall be of such design as would cause the minimum friction. Alternatively, oversized tap may be provided, such as a 20 mm tap on a 15 mm pipe.

4.14.12.2.3 The hot water distributing system shall be so designed as to ensure that the time lag between opening of the draw-off taps and discharge of hot water is reduced to the minimum to avoid wastage of an undue amount of water which may have cooled while standing in the pipes when the taps are closed. With this end in view, a secondary circulation system with flow and return pipes from the hot water tank shall be used where justified. Whether such a system is used or not, the length of pipe to a hot water draw-off tap, measured along the pipe from the tap to the hot water tank or the secondary circulation pipe, shall not exceed the lengths given in Table 5.

Table 5 Maximum Permissible Lengths of Hot Water Draw-Off Pipes

(*Clause* 4.14.12.2.3)

Sl No.	Largest Internal Diameter of Pipe	Length m
(1)	(2)	(3)
i)	Not exceeding 20 mm	12
ii)	Exceeding 20 mm but not exceeding 25 mm	7.5
iii)	Exceeding 25 mm	3.0

NOTE — In the case of a composite pipe of different diameters, the largest diameter is to be taken into consideration for the purpose of this table.

4.14.12.2.4 Wherever mixing of hot and cold water is done by a mixing fitting, that is, hot and cold stop-cocks deliver to a common outlet of mixed water (that is, showers, basin or bath supply fittings), the pressure in the cold and hot water systems shall be equal. This can be achieved by connecting the cold water supply from an overhead tank at the same static height as the overhead tank supplying cold water to the hot water heaters. In case this is not possible, hot and cold water should be supplied to the fixtures by separate supply taps.

The hot and cold water thermostatic mixers/diverters/faucets for public use should have ‘hot’ and ‘cold’ clearly marked in the form of colour coding and tactile information. The functioning of hot and cold water from the thermostatic mixer/diverter/faucet should be consistent, for example, a clockwise turn should result in discharge of hot water and counter clockwise for cold. It is recommended that a thermostat be installed to limit the temperature of the hot water to a maximum of 40 °C in order to prevent scalding. All faucets/mixers/diverts in public use shall be automatic (sensor operated) or lever type.

4.14.13 *Types of Hot Water Heaters*

The various types of water heaters used for preparation of hot water are as follows:

a) *Electric storage heaters*:

   1) Non–pressure or open outlet type,

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2) Pressure type,

3) Cistern type,

4) Dual heater type.

b) *Gas water heaters*:

1) Instantaneous type {*see* accepted standard [E-1(18)]},

2) Storage type.

c) *Solar heating systems*:

1) Independent roof mounted heating units,

2) Centrally banked heated system.

d) *Central hot water system*:

1) Oil fired,

2) Gas fired,

3) Electrical coil type,

4) Heat Pump.

4.14.13.1 The quality and construction of the different types of hot water heaters shall be in accordance with good practice [E-1(19)].

4.14.13.2 For solar water heating system and their installation reference shall be made to good practice [E-1(20)].

4.14.13.3 Requirements in regard to inspection and maintenance of hot water supply installations shall be in accordance with **4.15.1** to **4.15.4**.

4.15 Inspection and Testing

4.15.1 *Testing of Mains before Commencing Work*

All pipes, fittings and appliances shall be inspected, before delivery at the site to see whether they conform to accepted standards. All pipes and fittings shall be inspected and tested by the manufacturers at their factory and shall comply with the requirements of this Section. They shall be tested hydraulically under a pressure equal to twice this maximum permissible working pressure or under such greater pressure as may be specified. The pipes and fittings shall be inspected on site before laying and shall be sounded to disclose cracks. Any defective items shall be clearly marked as rejected and forthwith removed from the site.

4.15.2 *Testing of Mains after Laying*

After laying and jointing, the main shall be slowly and carefully charged with water by providing a 25 mm inlet with a stop-cock, so that all air is expelled from the main. The main is then allowed to stand full of water for a few days if time permits, and then tested under pressure. The test pressure shall be 0.5 N/mm^2 or double the maximum working pressure, whichever is greater. The pressure shall be applied by means of a manually operated test pump, or, in the case of long mains or mains of a large diameter, by a power-driven test pump, provided the pump is not left unattended. In either case, due precaution shall be taken to ensure that the required test pressure is not exceeded. Pressure gauges shall be accurate and shall preferably have been recalibrated before the test. The pump having been stopped, the test pressure shall maintain itself without measurable loss for at least 5 min. The mains shall be tested in sections as the work of laying proceeds; it is an advantage to have the joints exposed for inspection during the testing. The open end of the main may be temporarily closed for testing under moderate pressure by fitting a water-tight expanding plug of which several types are available. The end of the main and the plug shall be secured by struts or otherwise, to resist the end thrust of the water pressure in the mains.

4.15.2.1 If the section of the main tested terminates into a sluice valve, the wedge of the valve shall not be used to retain the water; instead the valve shall be temporarily fitted with a blank flange, or, in the case of a socketed valve, with a plug, and the wedge placed in the open position while testing. End support shall be given as in **4.15.2**.

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4.15.3 *Testing of Service Pipes and Fittings*

When the service pipe is complete, it shall be slowly and carefully charged with water, allowing all air to escape, care being taken to avoid all shock or water hammer. The service pipe shall then be inspected under working conditions of pressure and flow. When all draw-offs taps are closed, the service pipe shall be absolutely water-tight. All piping, fittings and appliances shall be checked for satisfactory support, and protection from damage, corrosion and frost. Because of the possibility of damage in transit, cisterns shall be re-tested for water-tightness on arrival at the site, before fixing.

4.15.4 In addition to the provisions given in **4.15.1**, provisions given in **4.15.4.1** to **4.15.4.3** shall also apply to hot water supply installations in regard to inspection and testing.

4.15.4.1 *Testing of the system after installation*

After the hot water system, including the hot water heaters, has been installed, it shall be carefully charged with water, so that all air is expelled from the system. The entire system shall then be hydraulically tested to a pressure of 0.5 N/mm^2 or twice the working pressure, whichever is greater, for a period of at least 30 min after a steady state is reached. The entire installation shall then be inspected visually for leakages, and sweating. All defects found shall be rectified by removing and remaking the particular section. Caulking of threads, hammering and welding of leaking joints shall not be allowed.

4.15.4.2 *Hot water testing*

After the system has been proved water-tight, the hot water heaters shall be commissioned by connecting the same to the electrical supply. The system shall then be observed for leakage in pipes due to expansion or overheating. The temperature of water at outlets shall be recorded. The thermostats of the appliances shall be checked and adjusted to temperatures specified in **4.14.2.1**.

4.15.4.3 *Electrical connection*

For relevant provisions regarding general and safety requirements for household and similar electrical appliances, reference may be made to good practice [E-1(17)]. The metal work of the water heating appliances and installation other than current carrying parts shall be bonded and earthed in conformity with the good practice [E-1(17)]. It should be noted that screwing of an immersion heater into a tank or cylinder cannot be relied upon to effect a low resistance earth connection, a satisfactory separate earthing of heater should be effected.

4.16 Cleaning and Disinfection of the Supply System

4.16.1 All water mains communications pipes, service pipes and pipes used for distribution of water for domestic purposes shall be thoroughly and efficiently disinfected before being taken into use and also after every major repair. The method of disinfection shall be subject to the approval of the Authority. The pipes shall also be periodically cleaned at intervals, depending upon the quality of water, communication pipes and the storage cisterns shall be thoroughly cleaned at least once every year in order to remove any suspended impurities that may have settled in the pipes or the tanks.

4.16.2 *Disinfection of Storage Tanks and Down Take Distribution Pipes*

The storage tanks and pipes shall first be filled with water and thoroughly flushed out. The storage tank shall then be filled with water again and a disinfecting chemical containing chlorine added gradually while the tanks are being filled, to ensure thorough mixing. Sufficient quantities of chemicals shall be used to give the water a dose of 50 parts of chlorine to one million parts of water. If ordinary bleaching powder is used, the proportions will be 150 g of powder to 1 000 litre of water. The powder shall be mixed with water to a creamy consistency before being added to the water in the storage tank. When the storage tank is full, the supply shall be stopped and all the taps on the distributing pipes opened successively working progressively away from the storage tank. Each tap shall be closed when the water discharged begins to smell of chlorine. The storage tank shall then be topped up with water from the supply pipe and with more disinfecting chemical in the recommended proportions. The storage tank and pipes shall then remain charged for at least 3 h. Finally, the tank and pipes shall be thoroughly flushed out before any water is used for domestic purposes.

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4.17 Water Supply Systems in High Altitudes and/or Sub-zero Temperature Regions

4.17.1 *Selection and Source*

In general, the site selected for a water source shall be such as to minimize the length of transmission line so as to reduce the inspection and upkeep. Attempt shall be made, where feasible, to locate the source near the discharge of waste heat, such as of power plants provided it does not affect the potability of water.

4.17.2 *Pumping Installation*

Pump and pumping machinery shall be housed inside well-insulated chambers. Where necessary, arrangements shall be made for heating the inside of pump houses. Pump houses, as far as possible, should be built directly above the water intake structures.

4.17.3 *Protection of Storage Water and Treatment*

Where ambient temperatures are so low as to cause danger of freezing, proper housing, insulation and protection shall be provided for all processes and equipment. If necessary, means shall be provided for proper heating of the enclosure.

4.17.4 *Transmission and Distribution*

Freezing of the buried pipe may be avoided primarily by laying the pipe below the level of the frost line; well consolidated bedding of clean earth or sand, under, around or over the pipe should be provided. For the efficient operation and design of transmission and distribution work, the available heat in the water shall be economically utilized and controlled. If the heat which is naturally present in water is made equate to satisfy heat losses from the system, the water shall be warmed. Where economically feasible, certain faucets on the distribution system may be kept in a slightly dripping condition so as to keep the fluid in motion and thus prevent is freezing. If found unsuitable for drinking purposes, such water may be used for heating purposes. Heat losses shall be reduced by insulation, if necessary. Any material that will catch, absorb or hold moisture shall not be used for insulation purposes. Adequate number of break pressure water tanks and air release valves shall be provided in the distribution system.

NOTE — The level of frost line is generally found to be between 0.9 m and 1.2 m below ground level in the northern regions of India, wherever freezing occurs.

4.17.4.1 *Materials for pipes*

Distribution pipes shall be made of any of the following materials conforming to Part B ‘Building Materials’ of this NBCS:

a) High density polyethylene pipes;

b) Asbestos cement pipes;

c) Galvanized iron pipes;

d) Cast iron pipes;

e) Copper pipes;

f) Chlorinated PVC pipes;

g) Unplasticized PVC pipes (where it is laid before frost line); and

h) Stainless steel pipes.

4.17.4.2 *Materials for insulation of pipes*

Insulation of pipes may be provided by wrapping the pipe with fibre glass, mineral wool or closed cell flexible elastomeric foam based insulation materials of desired thickness covered with cladding for protection from

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damage or from weather in case of external use/pipes laid in exposed conditions; other materials, like 85 percent magnesia, preformed pipe sections, etc, may also be used.

4.17.4.3 *Distribution methods*

Distribution by barrels or tank trucks shall be employed, where the water requirements are temporary and small. Utmost care shall be exercised for preventing the water from being contaminated by maintaining a residual of disinfecting agent at all times. Hoses, pails and the tank shall be kept free from dust and filth during all period of operation. Where winter temperatures are low, making frost penetration depths greater during the winter and where adequate facilities for heating the water in the distribution system do not exist, the use of tank trucks or barrels for delivery of water shall be considered only for cold weather; during the warm weather, piping system for seasonal use may be supplemented.

4.17.4.4 In the conventional distribution system involving the use of a network of pipelines requiring no auxiliary heat, it is essential that the pipelines are buried well below the frost line. Adequate facilities for draining the pipelines shall be provided where there is a danger of frost.

4.17.4.5 *House service connections*

House service connections shall be kept operative by the use of adequate insulation at exposed places extending below the frost line. Figure 7 shows a typical arrangement for providing insulation for house service connections.

4.17.5 For detailed information on planning and designing water supply system peculiar to high altitudes and/or sub-zero temperature regions of the country, reference may be made to good practice [E-1(2)].

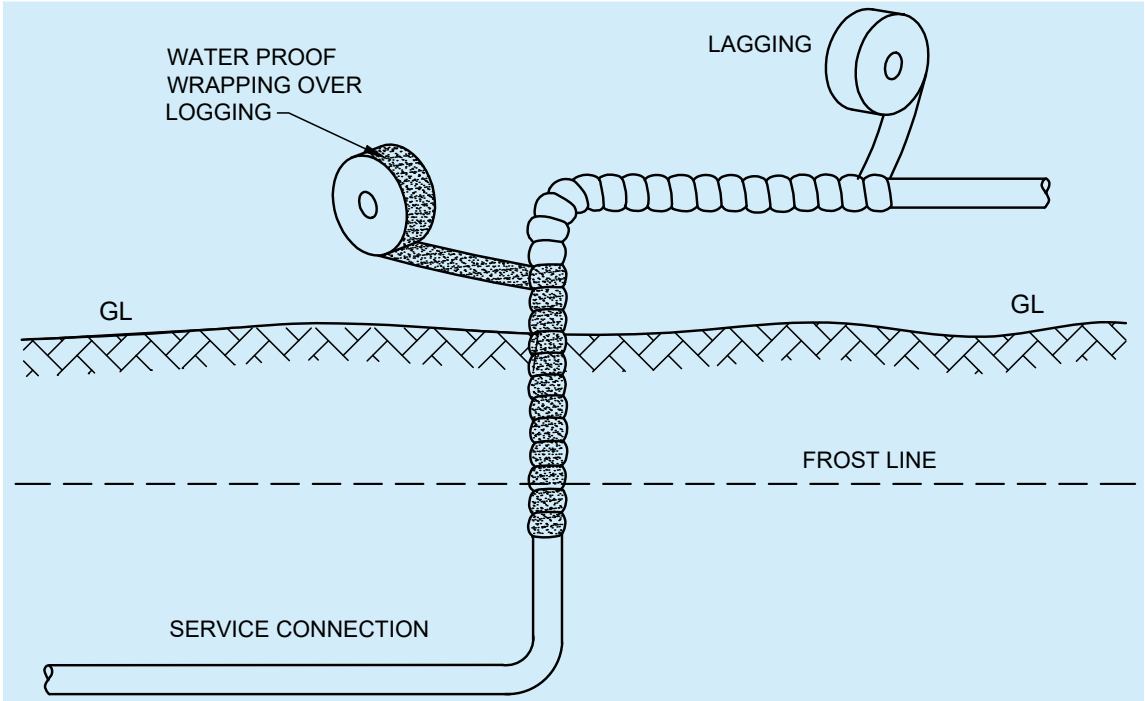

FIG. 7 INSULATION DETAILS AT SERVICE CONNECTION

4.18 Guidelines to Maintenance

4.18.1 Storage tanks shall be regularly inspected and shall be cleaned out periodically, if necessary. Tanks showing signs of corrosion shall be emptied, thoroughly wire brushed to remove loose material (but not scraped), cleaned and coated with suitable bituminous compositions or other suitable anti-corrosive material not liable to impart taste or odour or otherwise contaminate the water. Before cleaning the cistern, the outlets shall be plugged to prevent debris from entering the pipes. Tanks shall be examined for metal wastage and water tightness after cleaning.

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4.18.2 Record drawings showing pipe layout and valve positions shall be kept up to date and inspection undertaken to ensure that any maintenance work has not introduced cross-connections or any other undesirable feature. Any addition or alterations to the systems shall be duly recorded from time to time.

4.18.3 Any temporary attachment fixed to a tap or outlet shall never be left in such a position that back-siphonage of polluted water may occur into the supply system.

4.18.4 All valves shall periodically be operated to maintain free movement of the working parts.

4.18.5 All taps and ball valves shall be watertight, glands shall be made good, washers shall be replaced and the mechanism of spring operated taps and ball valves shall be repaired where required.

4.18.6 All overflow pipes shall be examined and kept free from obstructions.

4.18.7 The electrical installation shall be checked for earth continuity and any defects or deficiencies corrected in the case of hot water supply installations.

4.19 Swimming Pools

4.19.1 *General*

A swimming pool is a container that is filled with water to enable swimming or such other leisure activities. Pools can be sunk into the ground or built above ground (as a freestanding construction or as part of a building or other larger structure), and are also a standard feature aboard ocean liners and cruise ships. In-ground pools are most commonly constructed from materials such as concrete, natural stone, metal, plastic or fiberglass, and can be of a custom size and shape or built to a standardized size.

All pools open to public shall take care of the barrier-free design for accessibility and use by persons with disabilities. Reference shall also be made to good practice [E-1(3)] for applicable requirements.

4.19.1.1 Swimming pools shall be of three types, namely:

Type	*Characteristic*
Fill and draw	Clear water of potable quality is retained till it becomes turbid or unfit for use. Thereafter, the pool is drained, cleaned and refilled with clear water. This type is not recommended considering water conservation
Flow through	Clear water of hygienic quality flows continuously. This type requires more water for replenishment and so cautious decision of usage of such pools should be made; it is not recommended considering water conservation
Recirculating	Recirculation system shall be provided to minimize water wastage and disinfection shall be done to ensure hygiene. The recirculation system shall be based on the nature of usage such as private, public, wading and competition pools. The entire pool water should be filtered based on the turnover period for various types of pools.

4.19.1.2 *Turnover rate*

It is the amount of time it would take for the volume of the pool to pass through the filtration system one time. Turnover rate is measured in hours and is expressed as:

Turnover rate, in hours = Pool volume (in litres)/Flow (in litre/h)

NOTE — Pool volume comprises volume of the pool water, balancing tank, overflow gutter and circulation pipe.

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Typical turnover rates for the following pools are:

Sl No.	*Type of Pool*	*Turnover rate* h
(1)	(2)	(3)
i)	Swimming pool:	
	a) Private (outdoor);	6
	b) Private (indoor);	10
	c) Public; and	6
	d) Competition.	6
ii)	Wading Pool	1
iii)	Spa (public)	½
	Spa (private)	1

4.19.1.3 *Swimming pool user load*

The maximum load for the pool shall be:

a) For pool depth up to 1m : 2.2 m^2 surface area per user

b) For pool depth up to 1.5m : 2.7 m^2 surface area per user

c) For pool depth more than 1.5m : 4.0 m^2 surface area per user

4.19.1.4 Recommended dimensions of the swimming pools shall be:

a) Half sized olympic pools : 25 m (length) × 12 to 13 m (width) ×1.8 m (depth)

b) Full size olympic pools : 50 m (length) × 25 m (wide) × 2 m (depth)

c) Diving depth : 3.5 m for 1 m spring board; and
5 m for a 10 m platform

d) Maximum depth : *See* **4.19.2.7**

e) Ladders : 2 treads for 1.2 m depth;
3 treads for 1.2 m to 1.5 m depth; and
4 treads for 1.5 m depth

f) Displacement : 60 litre per user for deeper pools; and
45 litre for shallow pools

4.19.2 *Design*

4.19.2.1 The pool should be so designed to withstand all anticipated hydraulic structural loadings for both full and empty conditions. All appurtenances to the pool, such as diving boards and slides, shall be designed to carry the anticipated load. Any obstruction creating a safety hazard shall not extend into or above the pool, or shall not protrude from the floor of the pool. Designers may refer good practice [E-1(21)] for providing the guidance on the procedures and the precautions to be taken during construction of swimming pool to ensure the water tightness of the structure.

4.19.2.2 *Material*

Any suitable material that is non-toxic and provides a rigid watertight shell with a smooth, impervious, light colour finish should be used to construct the pool. The floor of shallow areas shall have a slip-resistant finish. Sand or earth shall not be permitted to use as an interior finish in a swimming pool.

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4.19.2.3 *Dimensions*

The shape and size of a pool largely depend on the usage. Shape should be considered from the standpoint of safety and circulation of the pool water.

NOTES

1 A long and rectangular pool may be ideal for sports and exercise as it gives length and breadth, but the shape of a pool for recreation largely depend on the choice of the owners, available space for making the pool and the design of the house.

2 In sports, normally the swimming pools are 50 m long, minimum 21 m wide and 1.8 m overall depth.

4.19.2.4 *Floor slopes*

Slope of the floor of the pool should be made downward toward the main drain. All slopes should be uniform. The slope in shallow areas should not exceed 300 mm vertical in 3.6 m horizontal except for a slope directed downward from a transition point, which shall not exceed 300 mm vertical in 1m horizontal. In portions of the pool with a depth greater than 1.5 m, the front slope of the deep area shall not be steeper than 300 mm in 1 m.

4.19.2.5 *Transition point*

Transition points should be marked with a stripe on the pool floor having a width of at least 100 mm and a colour that contrasts with that of the floor, and with a buoyed safety rope with colour buoys, installed at least 300 mm on the shallow side of the transition point. In other pools having adjoining shallow and deep areas, a safety rope with colour buoys shall be installed where the water depth reaches 1.5 m.

4.19.2.6 *Pool walls*

Where the pool depth is 1 m or less, pool walls shall be vertical to the floor and the junction of the wall with the floor shall consist of a cove with a radius not exceeding 150 mm. Where the pool depth exceeds 1 m, pool walls shall meet one of the following criteria:

a) The wall shall be vertical for a depth of at least 1.5 m below the water level, below which the wall may angle to the floor; or

b) The wall shall be vertical for a depth of at least 1 m below the water level, below which the wall shall form a curve to the floor. The curve shall be tangent to the pool wall.

4.19.2.7 *Water depth*

The depth of a swimming pool depends on the purpose of the pool, and whether it is open to the public or strictly for private use. If it is a private casual, relaxing pool, it may go from 1.0 m to 1.5 m deep. If it is a public pool designed for diving, it may slope from 3.5 m to 5.0 m in the deep end. A children's play pool may be from 0.3 m to 0.6 m deep. Public pools may have differing depths to accommodate different swimmer requirements. Water depths may be clearly marked on the pool walls.

The width between handrails of the pool stairs should be between 500 mm and 600 mm.

4.19.2.8 *Walkways and deck areas*

Pools shall be completely surrounded by a deck that is at least 1.2 m in width and extends completely around and adjacent to the pool. There shall be no obstructions or interruptions of the pool deck within the 1.2 m adjacent to the pool other than necessary structural supports, or appurtenances such as diving boards, slides, perimeter overflow systems, or handrails. A clear, unobstructed walkway at least 1.2 m in width shall be maintained at such obstructions or interruptions. A wheelchair turning space of minimum 1.5m × 1.5 m shall be provided at key places in the walkway.

Structural supports located within the minimum required deck width or within 1.2 m of the swimming pool shall be no closer than 3 m apart measured parallel to the adjacent perimeter of the pool, with the dimension of any single support in a plane parallel to the adjacent pool perimeter not greater than 1 m and the sum of all such support dimensions not greater than 10 percent of the pool perimeter.

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The deck between two adjacent swimming pools shall be at least 2.5 m wide. All decks and walkways shall have an unobstructed overhead clearance of at least 2 m.
Synthetic material which meets the following criteria may be installed for deck coverings:

a) Non-fibrous and allows drainage such that it will not remain wet or retain moisture;

b) Inert and will not support bacterial or fungal growth;

c) Durable;

d) Cleanable; and

e) Provides a slip-resistant finish.

The decks and walkways shall have a paved surface. The surface of the pool deck and other surfaces used for foot contact, such as gratings of perimeter overflow systems, shall be slip-resistant.

The outer perimeter of the deck for outdoor pools shall be at least 10 cm higher than the surrounding ground surface except where access is provided to adjacent turf areas.

The pool shall have an accessible entry and exit that is accessible to persons with disabilities. Accessible entry/exit may require provision of a transfer wall or/and a sloped entry with an aquatic chair. Installing a pool lifts may be another option for accessible entry/exit.

The transfer wall should have a minimum clear deck space of 1.5 m × 1.5m, with a slope not steeper than 1 : 48 at the base of the transfer wall. The height of the transfer wall should be 400 mm to 480 mm from the deck floor. The transfer wall should be 300 mm to 400 mm wide. The length should be minimum 1.5 m centered on the clear deck space. Surfaces of transfer walls shall not be sharp and shall have rounded edges.

A grab bar should be provided on the transfer wall. Grab bars shall be perpendicular to the pool wall and shall extend the full depth of the transfer wall. The top of the gripping surface shall be 100 mm to 150 mm above transfer walls. Clearance of 610 mm should be available on both sides of the grab bar.

4.19.2.9 *Starting platforms*

Starting platforms may be from 0.50 m to 0.75 m above the surface of water. The maximum height of the platform above the water shall be 0.75 m where the water depth is 1.2 m or greater, and 0.50 m when the water depth is less than 1.2 m. The surface area of each platform shall be 0.5 m × 0.5 m with a maximum slope of not more than 10°. Surface of each block shall be covered with non-slip material and with back stroke hand grip facility.

4.19.3 *Electrical Installation*

4.19.3.1 *Lighting*

Artificial lighting shall be provided at all indoor pools and at all outdoor pools that are open for use after sunset in accordance with one of the following:

a) Underwater lighting of at least 8.35 lumens or 5.5 W per square metre of pool water surface area, located to provide illumination of the entire pool floor; plus area lighting of at least 10 lumens or 6.6 W per square metre of deck area; and

b) If underwater lights are not provided, at least 33.5 lumens or 2.2 W per square metre of pool water surface area and deck area.

Where portable electric vacuum cleaning equipment is used, electrical receptacles with ground-fault circuit interrupter protection shall be provided. Separation between receptacles shall be a maximum of 30 m. All receptacles installed in the swimming pool area shall have waterproof covers and ground-fault circuit interrupter protection. Lighting controls should not be accessible to the public.

4.19.3.2 *Ventilation*

Adequate ventilation shall be provided in facilities to prevent objectionable odor.

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4.19.3.3 *Shower and bathroom*

Separate shower, dressing booth and sanitary facilities shall be provided for each gender. This may not be applicable for schools and other institutional use where a pool may be open to one gender at a time. The rooms should be well lit, drained, ventilated, and of good construction, using impervious materials. They should be developed and planned to ensure maintenance of good sanitation throughout the building at all times. Floors should have a slip-resistant surface and sufficiently smooth to ensure ease in cleaning.

Each shower and toilet block provided per pool, open for use by public, shall have a unisex accessible shower, dressing-cum-toilet facility for persons with disabilities. Design specifications of this accessible facility shall be as per good practice [E-1(3)].

4.19.4 *Water Treatment System*

4.19.4.1 *General*

A water treatment system shall be provided to filter, chemically balance and disinfect the swimming pool water.

4.19.4.2 *Hair and lint strainer*

A hair and lint strainer shall be installed on the suction side of the pump except on vacuum filter systems. The strainer basket shall be easily removable. Valves shall be installed to allow the flow to be shut off during cleaning, switching baskets or inspection.

4.19.4.3 *Inlets*

Inlets for filtered water shall be located and directed suitably to produce uniform circulation of water to facilitate the maintenance of a uniform disinfectant residual throughout the entire pool without the existence of dead spots, and to produce surface flow patterns that effectively assist skimming.

4.19.4.4 *Outlets*

Pools shall be provided with a minimum of two drains (outlets) at the deepest point. Centre-to-centre distance between drains shall not exceed 2.0 m. Drains shall not be more than 3.0 m away from the pool walls. The main drain may be connected to the recirculation system. Openings shall be covered by grating which cannot be removed without the use of tools. Openings of the grating shall be at least four times the area of the main drain pipe or have an open area. The maximum width of grate openings shall not exceed 8 mm. Main drains and all other suction outlets installed in the pool shall be designed to prevent bather entrapment and shall be of anti-vortex type. The velocity at outlet pipe shall not be more than 0.3 m/s.

4.19.4.5 *Velocities*

Maximum permissible velocities for various components of the pools are as follows:

a) Suction pipe: less than 1.5 m/s;

b) Return pipe: 1.5 to 2 m/s; and

c) Return/inlet fittings: 2.4 m/s to 2.75 m/s in private pools and 1.5 m/s to 2 m/s in public pools.

4.19.4.6 *Balancing* (*surge*) *tank*

Overflow system shall be designed for effective surge capacity. Balancing tank should be provided of capacity to accommodate surge storage and storage for makeup water. The volume of the balancing tank shall be the total of the above with equal proportions.

4.19.4.7 *Make-up water*

Make-up water shall be added through a fixed air gap of at least 150 mm to the pool, surge tank, vacuum filter tank, or other receptacle. When make-up water is added directly to the pool, the fill-spout should be located under a low diving board or immediately adjacent to a ladder rail, grab rail, or fixed lifeguard chair.

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4.19.4.8 *Filtration*

The design filtration rate in the particular application in which the filter is utilized shall not exceed the maximum design filtration rate for which the filter was installed. Wash or backwash water from diatomaceous earth filters shall be passed through a separation tank designed for removal of suspended diatomaceous earth and solids, prior to disposal.

NOTE — Filtration rates for various type of filters:

a) Low rate filter — 10 $m^3/m^2/h$.
b) Medium rate filter — 11 to 30 $m^3/m^2/h$.
c) High rate filter — 31 to 50 $m^3/m^2/h$.
d) Minimum flow rate for filter backwash — 30 $m^3/m^2/h$.

4.19.4.9 *Disinfection*

The pool water shall be continuously disinfected by suitable disinfecting agent that imparts easily measured residual. Gaseous chlorine, chlorine compounds, bromine compounds or other bactericidal agents should be used to maintain the quality parameters of water.

4.19.5 *Water Quality*

4.19.5.1 *Disinfectant residual*

Where chlorine is used as a disinfectant, the chlorine residual shall be maintained between 1.0 ppm and 4.0 ppm as free chlorine residual. A free chlorine residual of at least 2.0 ppm shall be maintained when the pool water temperature exceeds 30 ºC.

Where bromine is used as a disinfectant, a bromine residual shall be maintained between 2.0 ppm and 8.0 ppm as total bromine. A bromine residual of at least 4.0 ppm shall be maintained when the pool water temperature exceeds 30 ºC.

Where chlorinated cyanurates are used, the cyanuric acid concentration shall not exceed 100 ppm.

Where silver/copper or copper ion generators are used, the concentration of copper shall not exceed 1.3 ppm and the concentration of silver shall not exceed 0.05 ppm.

Where ozone is used, the ambient air ozone concentration shall be less than 0.1 ppm at all times either in the vicinity of the ozonator or at the pool water surface.

For all other physical, chemical and bacteriological parameters, the quality of water used in swimming pools in continuous circulation type shall conform to good practice [E-1(22)]. For safety aspects related to public swimming pools, the good practice [E-1(23)] shall be referred.

4.20 Allowance for Expansion

4.20.1 The allowances for expansion of the water pipes are recommended as given below:

a) All pipes should be installed at ambient temperature;
b) Pipes carrying hot fluids such as water or steam operate at higher temperatures. It follows that they expand, especially in length, with an increase from ambient to working temperatures. This will create stress upon certain areas within the distribution system, such as pipe joints, which, in the extreme, could cause fracture;
c) The pipe work system shall be sufficiently flexible to accommodate the movements of the components as they expand. In many cases, the flexibility of the pipe work system, due to the length of the pipe and number of bends and supports, means that no undue stresses are imposed. In other installations, however, it will be necessary to incorporate some means of achieving this required flexibility;
d) The expansion fitting is one method of accommodating expansion. These fittings are placed within a line and are designed to accommodate the expansion without the total length of the line changing. They are commonly called expansion bellows, due to the bellows construction of the expansion sleeve; and

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e) Other expansion fittings can be made from the pipe work itself. This can be a cheaper way to solve the problem, but more space is needed to accommodate the pipe.

4.20.2 *Full Loop*

a) This is simply one complete turn of the pipe and, on steam pipe work, should preferably be fitted in a horizontal rather than a vertical position to prevent condensate accumulating on the upstream side;

b) The downstream side passes below the upstream side and great care shall be taken that it is not fitted wrong way round, as condensate can accumulate in the bottom. When full loops are to be fitted in a confined space, care shall be taken to specify that wrong-handed loops are not supplied; and

c) The full loop does not produce a force in opposition to the expanding pipe work as in some other types, but with steam pressure inside the loop, there is a slight tendency to unwind, which puts an additional stress on the flanges.

4.21 Colour Codes for Different Types of Water Pipes

The following colour codes are recommended for pipes {*see also* good practice [E-1(24)]}:

Sl No.	*Contents*	*Ground Colour*	*First Colour Band*	*Second Colour Band*
(1)	(2)	(3)	(4)	(5)
i)	Cooling water	Sea green	French blue	—
ii)	Boiler feed water	Sea green	Gulf red	—
iii)	Condensate	Sea green	Light brown	—
iv)	Drinking water	Sea green	French blue	Signal red
v)	Treated water	Sea green	Light orange	—
vi)	Fire water	Fire red	Crimson red	—
vii)	Central heating below 60 °C	Sea green	Canary yellow	—
viii)	Central heating 60 °C to 100 °C	Sea green	Dark violet	—
ix)	Central heating above 100 °C	Sea green	Dark violet	Signal red
x)	Cold water down service from storage tanks	Sea green	French blue	Canary yellow
xi)	Domestic, hot	Sea green	Light grey	—
xii)	Hydraulic power	Sea green	Black	—
xiii)	Sea, river, untreated	Sea green	White	—
xiv)	Filtered water	Sea green	Light brown	—
xv)	Soft water	Sea green	Light brown	Signal red
xvi)	Warm water	Sea green	Light grey	Canary yellow
xvii)	Chilled water	Sea green	Black	Canary yellow
xviii)	Sprinkle and hydrant water	Sea green	White	Signal red
xix)	Waste water	Sea green	Canary yellow	Signal red
xx)	Demineralized water	Sea green	Gulf red	—
xxi)	Process water	Sea green	Oxide red	—

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Sl No.	*Contents*	*Ground Colour*	*First Colour Band*	*Second Colour Band*
(1)	(2)	(3)	(4)	(5)
xxii)	Wash water	Sea green	Canary yellow	—
xxiii)	Quench water	Sea green	Dark grey	—

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ANNEX A

(*Clause* 3.2.1)

APPLICATION FORM FOR TEMPORARY/PERMANENT SUPPLY OF WATER/FOR ADDITIONS AND/OR ALTERATIONS FOR SUPPLY OF WATER

I/We ……..hereby make application to the* …….. for the temporary/permanent supply of water for the following additions and/or alterations to the water supply requirements and water fittings at the premises……. Ward No. ……..Street No. ……Road/Street known as ……for the purpose described below and agreed to pay such charges as the Authority may from time to time be entitled to make and to conform to all their byelaws and regulations……licensed/registered plumber, has been instructed by me/us to carry out the plumbing work.

Description of the premises:……
Address :……..
Purpose for which water is required…….

……

The connection/connections taken by me/us for temporary use, shall not be used by me/us for permanent supply unless such a permission is granted to me/us in writing by the Authority.

I/We hereby undertake to give the*…….. due notice of any additions or alterations to the above mentioned supply which I/we may desire to make.

My/Our requirements of water supply are as under:

a) I/We request that one connection be granted for the whole of the premises.

b) I/We request that separate connections may be granted for each floor and I/we undertake to pay the cost of the separate connections.

c) My/Our probable requirements for trade purpose are ……litre per day and for domestic purposes are……..litre per day.

d) Our existing supply is ……..litre per day. Our additional requirement of supply is ……..litre per day.

e) The details as regards proposed additions and alterations in fittings are as follows:
……..
……..

Signature of the licensed/registered plumber……. Signature of the applicant……
Name and address of the licensed/registered Plumber……. Name and address of the Applicant ……

Date …… Date ……..

NOTES

1 Please strike out whatever is not applicable.

2 The application should be signed by the owner of the premises or his constituted attorney and shall be countersigned by the licensed/registered plumber.

* Insert here the name of the Authority.

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ANNEX B

(*Clause* 3.2.3)

FORM FOR LICENSED/REGISTERED PLUMBER'S COMPLETION CERTIFICATE

Certified that I/we have completed the plumbing work of water connection No……. for the premises as detailed below. This may be inspected and connection given.

Ward No…….. Road/Street……..

Locality…….

Block No…… House No……..

Existing water connection No. (if any)…….

Owned by…….

Owner's address…….

Applicant's name…… son of…….

Address……

Situation……...

Size of main……on…… street

Where main is situated……

Size of service pipe…….

Size of ferrule……

No. of taps…… No. of closets……

No. of other fittings and appliances……..

Road cutting and repairing fee …….

Paid Rs…….(Receipt No…….dated……) (receipt enclosed)

Dated ……... Signature of licensed/registered plumber……..
Name and address of the licensed/registered plumber
……

The Authority's Report

Certified that the communication and distribution pipes and all water fittings have been laid, applied and executed in accordance with the provisions of bye-laws, and satisfactory arrangements have been made for draining off waste water.

Connection will be made on……

Date…… The Authority……

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ANNEX C

(*Clause* 4.7.4)

NOMOGRAM OF HAZEN AND WILLIAM'S EQUATION

C-1 Examples of the use of nomogram are given below:

Example 1

Find the total friction loss in 25 mm diameter G.I. Pipe discharging 0.25 l/s in a total length of 300 m.

Procedure

Discharge, Q = 0.25 l/s

Pipe diameter = 25 mm

Frictional loss (from nomogram) = 30 m per 1 000 m

Total friction loss in 300 m length

$$= \frac{30}{1\,000} \times 300 = 9\,m$$

Example 2

Find suitable diameter pipe to carry 15 l/s from service line to overhead tank.

Total length of service main = 200 m

Residual pressure available at the take off point on supply line is 15 m.

Procedure

Available head = 15 m

Deduct residual head = 2 m

Deduct 10 percent for losses in bends and specials = 1.3 m

Friction head available for loss in pipe of 1 000 m

$$= \frac{11.7}{200} \times 1\,000 = 58.5\,m\ per\ 1\,000\,m$$

From the follwing nomogram, for a discharge of 15 l/s and friction loss of 58.5 m per 1 000 m, nearest commercial size (diameter) of pipe is 100 mm.

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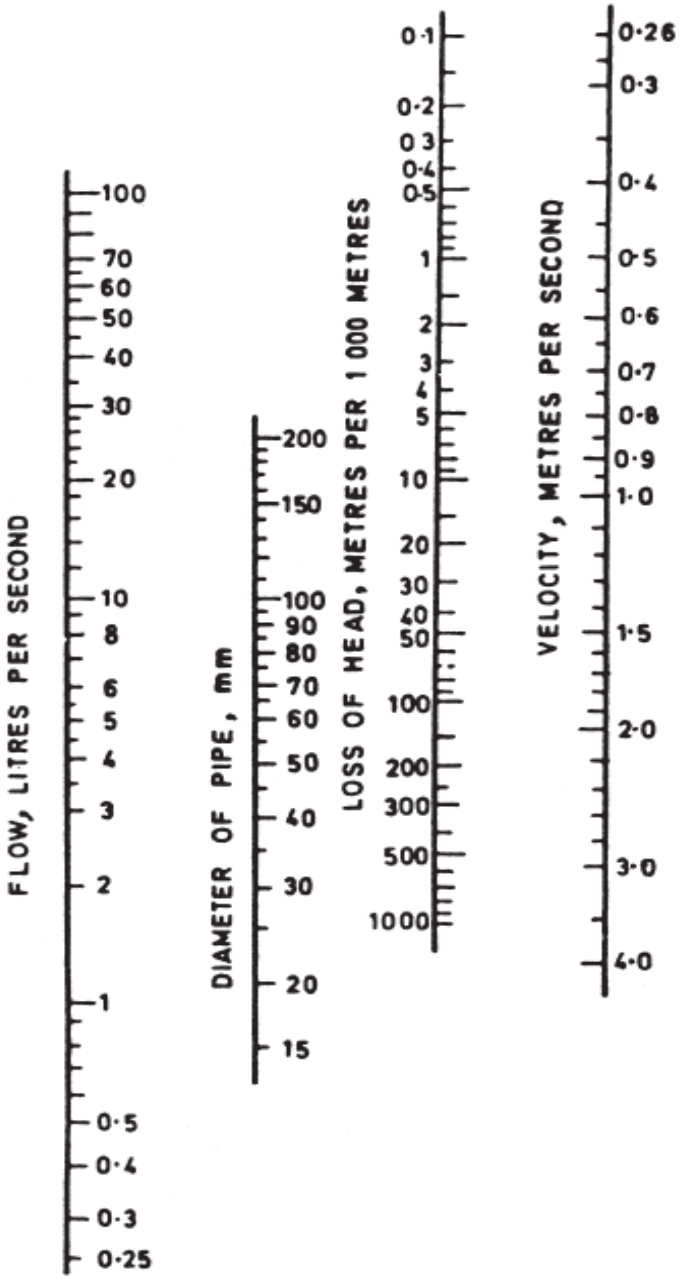

Nomogram of Hazen & Williams Equation (c = 100)

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used as a guide in conformance with the requirements of the referred clauses in this NBCS.

	IS No.	*Title*
(1)	IS 10446 : 1983	Glossary of terms relating to water supply and sanitation
(2)	IS 6295 : 1986	Code of practice for water supply and drainage in high altitudes and/or sub-zero temperature regions (*first revision*)
(3)	IS 4963 : 2025	Accessibility in built environment for older adults and persons with disabilities — Requirements (*second revision*)
(4)	IS 11208 :1985	Guidelines for registration of plumbers
(5)	IS 17650	Water efficient plumbing products — Requirements
	(Part 1) : 2021	Part 1 Sanitaryware
	(Part 2) : 2021	Part 2 Sanitary fittings
(6)	IS 10500 : 2012	Specification for drinking water (*second revision*)
(7)	IS 2041 : 2024	Steel plates and strips for pressure vessels used at moderate and low temperature — Specification (*fourth revision*)
	IS 804 : 1967	Specification for rectangular pressed steel tanks (*first revision*)
(8)	IS 4984 : 2016	Polyethylene pipes for water supply — Specification (*fifth revision*)
	IS 4985 : 2021	Unplasticized PVC pipes for water supplies — Specification (*fourth revision*)
	IS 15778 : 2007	Chlorinated polyvinyl chloride (CPVC) pipes for portable hot and cold water distribution supplies — Specification
(9)	IS 2065 : 1983	Code of practice for water supply in buildings (*second revision*)
(10)	IS 3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
(11)	IS 5822 : 1994	Code of practice for laying of electrically welded steel pipes for water supply (*second revision*)
(12)	IS 6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
(13)	IS 783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
(14)	IS 7634	Code of practice for plastics pipe work for potable waters supplies
	(Part 1) : 1975	Choice of materials and general recommendations
	(Part 2) : 2012	Laying and jointing of polyethylene (PE) pipes (*first revision*)
	(Part 3) : 2003	Laying and jointing of UPVC pipes (*first revision*)
(15)	IS 783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
	IS 3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
	IS 5822 : 1994	Code of practice for laying of welded steel pipes for water supply (*second revision*)
	IS 6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
	IS 7634	Code of practice for plastics pipe work for potable water supplies
	(Part 1) : 1975	Choice of materials and general recommendations
	(Part 2) : 2012	Laying and jointing of polyethylene (PE) pipes (*first revision*)
	(Part 3) : 2003	Laying and jointing of UPVC pipes (*first revision*)

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	IS No.	*Title*
(16)	IS 2692 : 1989	Ferrules for water services — Specification (*second revision*)
(17)	IS 302 (Part 1) : 2024 /IEC 60335-1 : 2020	Household and similar electrical appliances — Safety: Part 1 General requirements (*seventh revision*)
	IS 2082 : 2018	Stationary storage type electric water heaters — Specification (*fifth revision*)
(18)	IS 17150 : 2025	Mini domestic water heater for use with piped natural gas (PNG) — Specification (*first revision*)
(19)	IS 7558 : 1974	Code of practice for domestic hot water installations
	IS 16093 : 2013	Installation of gas based instantaneous water heater — Code of practice
(20)	IS 12976 : 2023	Solar water heating systems — Code of practice (*first revision*)
(21)	IS 6494 : 1988	Code of practice for water-proofing of underground water reservoirs and swimming pools (*first revision*)
(22)	IS 3328 : 2026	Quality requirements of water for swimming pools (*second revision*)
(23)	IS 16508 : 2017	Swimming pool for public — Code of safety
(24)	IS 2379 : 2024	Colour code for pipeline identification — Code of practice (*second revision*)

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART E PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

SECTION 2 DRAINAGE AND SANITATION

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part E/Section 2) covers the drainage and sanitation requirements of buildings, design, layout, construction and maintenance of drains inside buildings and from the buildings up to the connection to public sewer, private sewer, individual sewage disposal system, cesspool, or to other approved point of disposal/treatment work. It also covers drainage systems peculiar to high altitudes and/or sub-zero temperature regions of the country.

In the first version of the Code formulated in 1970, as part of the National Building Code of India, three separate sections of this Part on 'Plumbing Services', were brought out, namely, Section 1 'Water Supply', Section 2 'Drainage and Sanitation', and Section 3 'Gas Supply'. These sections were subsequently revised in 1983.

The major changes incorporated in the first revision in Section 2 'Drainage and Sanitation' were rationalization of definitions; modification of the requirements for fitments for drainage and sanitation in the case of buildings other than residences; addition of table for sanitation facilities in fruit and vegetable markets; introduction of table giving detailed guidance regarding the selection of plumbing system, depending on the nature of drainage load in buildings and height of buildings; amplification of provision relating to safeguards to be adopted in single stack system; modification of the values of gradients, pipe sizes and the corresponding discharges; rationalization of sizes of manholes/inspection chambers; modification of the sizing of rainwater pipe for roof drainage, to take into account rainfall intensities and recommend sizes on a more rational basis; addition of provisions for drainage and sanitation system peculiar to high altitudes and/or sub-zero temperature regions of the country; and inclusion of requirements of the refuse chute system.

As a result of experience gained in implementation of 1983 version of the Code and feedback received as well as revision of some of the standards based on which this Section was prepared, a need to revise this Section was felt. The second revision of 2005 was therefore prepared to take care of these. In the revision, the erstwhile two Sections were merged and a combined and comprehensive section, namely Section 1 Water Supply, Drainage and Sanitation (including solid waste management), was brought out. Gas supply was brought out as Section 2. Following significant changes were incorporated in the second revision of Section 1 on Water Supply, Drainage and Sanitation, in respect to drainage and sanitation: rationalization and addition of new definitions under terminology; enunciation of certain basic principles for water supply and drainage; addition of a new clause on sanitary appliances; updation of Table 1 to Table 14 of the existing version, regarding drainage and sanitation requirement; addition of additional requirements under layout clause of design considerations; modification and rationalization of provisions regarding choice of plumbing systems; addition of new clause on drain appurtenances having details on trap, floor drain and cleanout; incorporation of provisions on indirect wastes, special wastes (covering laboratory wastes, infected wastes, research laboratory wastes, etc), grease traps, oil interceptors, radio-active wastes, etc; revision of manhole details on size and enhancement of construction clause; inclusion of provisions on rainwater harvesting; revision of the minimum rainfall intensity which is drain design basis for discharge of storm water drain into a public storm water drain, to 50 mm/h; modification of the table for sizing of rainwater pipes for roof drainage, with inclusion of rainfall data which were not available in the earlier version; inclusion of figure on detail of subsoil drainage; and addition of details on support/protection of pipes. This revision also incorporated for the first time the provisions on solid waste management.

In the third revision in 2016, to comprehensively address the various and distinct features related to the plumbing aspects, this Part on 'Plumbing Services' was rearranged as follows:

Section 1 Water supply

Section 2 Drainage and sanitation

Section 3 Solid waste management

Section 4 Gas supply

In the 2016 version of this Section 2 on Drainage and Sanitation, several significant updates were incorporated to address contemporary needs and enhance the comprehensiveness of the provisions. Various tables on the requirements for fitments for drainage and sanitation across different occupancies were updated, including a new

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table specifically for shopping malls and retail buildings. Enabling provisions were introduced for the use of corrugated pipes, low-noise pipes and under-slung pipes, alongside information on bio-toilets. Typical mounting arrangements for plumbing fixtures and drainage systems were illustrated and a new table for single-stack sizing was included. Key updates also focused on drainage and sanitation system layouts, venting systems for high-rise buildings with detailed tables**,** and the gradients of drainage pipes. Fixture unit tables and maximum connections to branches, stacks, and sewers were revised, and new provisions for high-rise building drainage systems were added. Provisions for manhole covers, stormwater runoff estimation, rainwater pipe sizing, siphonic drainage, rainwater harvesting and artificial groundwater recharge were included, along with recommendations for septic tanks.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

In this revision, following significant changes have been incorporated:

a) Key terms along with their definition, such as emergency floor drain, flood level rim and yoke vent, have been included to enhance clarity and technical precisions in plumbing systems;

b) Tables on requirements for fitments in drainage and sanitation in various building occupancies, have been updated;

c) Provisions have been added for managing the horizontal and vertical distances of sanitary fixtures and connections to drainage stacks to ensure efficiency and prevent blockages;

d) Guidelines for packaged sewage treatment plant (PSTP) have been included to facilitate on-site treatment of grey and black water, particularly in areas without centralized sewer systems; and

e) Biodigesters have been included as a sustainable, non-sewer on-site waste treatment solution.

This Section is largely based on the following Indian Standards:

IS 1742 : 1983	Code of practice for building drainage (*second revision*)
IS 4111 (Part 1) : 1986	Code of practice for ancillary structures in sewage system: Part 1 Manholes (*first revision*)
IS 5329 : 1983	Code of practice for sanitary pipe work above ground for buildings (*first revision*)
IS 6295 : 1986	Code of practice for water supply and drainage in high altitudes and/or sub-zero temperature regions (*first revision*)

A reference to SP 35 : 1987 ‘Handbook on Water Supply and Drainage’ may be useful, from where also, assistance has been derived.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the formulation of this Section, reference has also been made to the following:

International Plumbing Code 2024, International Code Council, and

Uniform Illustrated Plumbing Code – India (Volume I and Volume II) 2022, IAPMO India Private Limited

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **"accepted standard"** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [E-2(1)] refers to the Indian Standard(s) given at serial number (1) of the list of standards given at the end of this Part E/Section 2, that is, IS 10446 : 1983 'Glossary of terms relating to water supply and sanitation'.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART E PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

SECTION 2 DRAINAGE AND SANITATION

1 SCOPE

1.1 This NBCS (Part E/Section 2) covers the design, layout, construction and maintenance of drains for foul water, surface water, subsoil water and sewage together with all ancillary works, such as connections, manholes and inspection chambers used within the building and from building to the connection to a public sewer, private sewer, individual sewage-disposal system, cess-pool, soakaway or to other approved point of disposal/treatment work.

NOTE — A sanitary drainage system consists of a building sewer, a building drain, a soil and/or waste stack, horizontal branches or fixture drain and vents. The sanitary drainage of a large building may have a number of primary and secondary branches and several soil and/or waste stacks, each of them in turn may have a number of horizontal branches.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply in addition to the definitions given in accepted standards [E-2(1)].

2.1 Air Admittance Valve — One way valves designed to allow air to enter drainage system when negative pressure develops in the system. The purpose is to provide a method of allowing air to enter the drainage system for prevention of siphonage of traps.

2.2 Air Break — Physical separation which may be a low inlet into the indirect waste receptor from the fixture or device indirectly connected.

2.3 Air Gap, Drainage — Unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe, plumbing fixture or appurtenance conveying waste to flood level of the receptor.

2.4 Back Up — A condition where the waste water may flow back into another fixture or compartment but not back into the potable water system.

2.5 Back Water Valve — Device installed in a drainage system to prevent reverse flow.

2.6 Bath Room Group — Group of fixtures consisting of water closet, lavatories bath tub or shower and other fittings with a floor drain located together.

2.7 Battery of Fixtures — Any group of two or more similar adjacent fixtures which discharge into a common horizontal waste or soil pipe.

2.8 Bed Pan Washer — A washer which is to be used for disposing human waste and sterilizing the bed pan for reuse. Bed pan washer requires water connection and electrical heating arrangement. This is to be considered as soil appliance.

2.9 Benching — Sloping surfaces constructed on either side of channels at the base of a manhole or inspection chamber for the purpose of confining the flow of sewage, avoiding the accumulation of deposits and providing a safe working platform.

2.10 Black Water — Waste water from water closet, bidet, urinals, kitchen sink and bed pan sink or similar contaminated sources.

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2.11 Branch

a) Special form of sewer pipe used for making connections to a sewer or water main. The various types are called 'T', 'Y', 'T-Y', double Y and V branches, according to their respective shapes; and

b) Any part of a piping system other than a main or stack.

2.12 Branch Soil Pipe (BSP) — A pipe connecting one or more soil appliances to the main soil pipe.

2.13 Branch Soil Waste Pipe (BSWP) — A pipe connecting one or more soil and/or waste appliances to the main soil waste pipe (one pipe system).

2.14 Branch Vent Pipe (BVP) — A pipe, one end of which is connected to the system adjacent to the trap of an appliance and the other to a main vent pipe or a drain-vent pipe. It is fitted to prevent loss of water seal from a trap owing to partial vacuum, back-pressure, or surging caused by air movement within the pipe system. It also provides ventilation for the branch waste pipe.

2.15 Branch Waste Pipe (BWP) — A pipe connecting one or more waste appliances to the main waste pipe.

2.16 Building Drain-Combined — A building drain which conveys both sewage and storm water or other drainage.

2.17 Building Drain-Sanitary — A building drain which conveys sewage and sullage only.

2.18 Building Drain-Storm — A building drain which conveys storm water or other drainage but no sewage or sullage.

2.19 Building Sewer — That part of the horizontal piping of a drainage system which extends from the end of the building drain and which receives the discharge of the building drain and conveys it to a public sewer, private sewer, individual sewage-disposal system or approved point of disposal.

2.20 Building Sub-Drain — That portion of a drainage system which cannot drain by gravity in the building sewer.

2.21 Building Trap — A device, fitting or assembly of fittings installed in the building drain to prevent circulation of air between the drainage of the building and the building sewer. It is usually installed as running trap.

2.22 Cesspool

a) An underground chamber for the reception and storage of foul water, the contents of which are periodically removed for disposal; and

b) A box-shaped receiver constructed in a roof or gutter for collecting rainwater which then passes into a rainwater pipe connected thereto.

2.23 Cleaning Eye — An access opening in a pipe or pipe fitting arranged to facilitate the cleaning of obstructions and fitted with removable cover.

2.24 Clear Waste Water — Cooling water and condensate drainage from refrigeration and air conditioning equipment, cooled condensate from steam heating systems, cooled boiler blow-down water, waste water drainage from equipment rooms and other areas where water is used without an appreciable addition of oil, gasoline, solvent, acid, etc, and treated effluent in which impurities have been reduced below a minimum concentration considered harmful.

2.25 Collection Chamber — A compartment situated at the lower end of the chute for collecting and housing the refuse during the period between two successive cleanings.

2.26 Connection — The junction of a foul water drain, surface water drain or sewer from building or building with public sewer treatment works, public sewer, private sewer, individual sewage-disposal system, cess-pool, soakaway or to other approved point of disposal/treatment work.

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2.27 Consumer — Any person who discharges waste or sewage to the public sewer installed by the Authority.

2.28 Crown of Trap — The topmost point of the inside of a trap outlet.

2.29 Deep Manhole — A manhole of such depth that an access shaft is required in addition to the working chamber.

2.30 Depth of Manhole — The vertical distance from the top of the manhole cover to the outgoing invert of the main drain channel.

2.31 Developed Length — The length measured along the centre line of a pipe and fittings.

2.32 Diameter — The nominal internal diameter of pipes and fittings.

2.33 Drain — A conduit, channel or pipe for the carriage of storm water, sewage, waste water or other water-borne wastes in a building drainage system.

2.34 Drain Vent Pipe (DVP) — A pipe installed to provide flow of air to or from a drain to prevent undue concentration of foul air in the drain. The main soil pipe or main waste pipe may serve as drain vent pipe wherever their upper portions, which do not receive discharges, are extended to the roof level and let open to air.

2.35 Drainage — The removal of any liquid by a system constructed for the purpose.

2.36 Drainage Fixture Unit (DFU) — A measure of probable discharge into the drainage system by various types of plumbing fixtures. The drainage fixture unit value for a particular fixture depends on its volume rate of drainage discharge, on the time duration of a single drainage operation and on the average time between successive operations.

2.37 Drainage Work — The design and construction of a system of drainage.

2.38 Drop Connection — A length of conduit installed vertically immediately before its connection to a sewer or to another drain.

2.39 Drop Manhole — A manhole installed in a sewer where the elevation of the incoming sewer considerably exceeds that of the outgoing sewer; a vertical waterway outside the manhole is provided to divert the waste from the upper to the lower level so that it does not fall freely into the manhole except at peak rate of flow.

2.40 Eco-Toilet (or Bio-toilet) — The dry toilet that uses a predominantly aerobic processing system to treat human excreta, by composting or managed-aerobic decomposition. It generally uses little to no water and may be used as an alternative to flush toilets.

2.41 Emergency Floor Drain — A floor drain that does not receive the discharge of any drain or indirect waste pipe, and that protects against damage from accidental spills, fixture overflows and leakage.

2.42 Fittings — The appurtenances such as coupling, flange, branch, bend, tees, elbows, unions, waste (with or without plug), P or S trap (with or without vent), stop ferrule, bib tap, pillar tap, bath faucet, water meter, garden hydrant, valves and any other article used in connection with water supply, drainage and sanitation.

2.43 Fixture Unit — A quantity in terms of which the load producing effects on the plumbing system of different kinds of plumbing fixtures is expressed on some arbitrarily chosen scale.

2.44 Formation — The finished level of the excavation at the bottom of a trench or heading prepared to receive the permanent work.

2.45 French Drain or Rubble Drain — A shallow trench filled with coarse rubble, clinker, or similar material with or without field drain pipes.

2.46 Frost Line — The line joining the points of greatest depths below ground level up to which the moisture in the soil freezes.

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2.47 Flood Level Rim — The edge of the receptacle from which water overflows.

2.48 Grease Interceptor (or Grease Trap) — A chamber, on the line of a drain or waste pipe, for preventing grease from passing into the drainage system. It reduces non-petroleum fats, oils and grease in effluent by separation and volume reduction to improve sewage treatment efficiency.

As it is used to intercept fats, oils and grease (FOG) from a waste water discharge, it is also known as FOG interceptor.

2.49 Grey Water — Waste water that has not encountered water closet, kitchen sink waste, or similar contaminated sources. Grey water includes waste water from bathtubs, showers, lavatories, clothes washers, dishwashers and domestic reverse osmosis (RO) reject water.

2.50 Gully Chamber — The chamber built of masonry round a gully trap for housing the same.

2.51 Gully Trap — A trap provided in a drainage system with a water seal fixed in a suitable position to collect wastewater from the scullery, kitchen sink, wash basins, baths and rainwater pipes.

2.52 High Altitudes — Elevations higher than 1 500 m above mean sea level (MSL).

2.53 Highway Authority — The public body in which is vested, or which is the owner of, a highway repairable by the inhabitants collectively; otherwise the body or persons responsible for the upkeep of the highway.

2.54 Horizontal Pipe — Any pipe of fitting which makes an angle of more than 45° with the vertical.

2.55 Indirect Waste Pipe — The pipe that does not connect directly with the drainage system but conveys liquid wastes by discharging into a plumbing fixture/interceptor that is directly connected to the drainage system.

2.56 Inlet Fittings — An arrangement of connecting the internal waste branch pipe from wash basin, sinks and shower drains to the main deep seal trap with the help of hopper extension.

2.57 Inlet Hopper — A receptacle fitting for receiving refuse from each floor and dropping it into the chute.

2.58 Insanitary — Condition that is contrary to sanitary principles or is injurious to health.

2.59 Inspection Chamber — A water-tight chamber constructed in any house-drainage system which takes wastes from gully traps and disposes to manhole with access for inspection and maintenance.

2.60 Interceptor — A device designed and installed so as to separate and retain deleterious, hazardous or undesirable matter from normal wastes and permit normal sewage or liquid wastes to discharge into the disposal terminal by gravity.

2.61 Interceptor Manhole or Interceptor Chamber — A manhole incorporating an intercepting trap and providing means of access thereto.

2.62 Invert — The lowest point of the internal surface of a pipe or channel at any cross section.

2.63 Junction Pipe — A pipe incorporating one or more branches.

2.64 Lagging — Thermal insulation or pipes.

2.65 Licensed (or Registered) Plumber — A person licensed (or registered) under the provisions of this NBCS.

2.66 Main Soil Pipe (MSP) — A pipe connecting one or more branch soil pipes to the drain.

2.67 Main Soil and Waste Pipe (MSWP) — A pipe connecting one or more branch soil and waste pipes to the drain.

2.68 Main Vent Pipe (MVP) — A pipe which receives a number of branch vent pipes.

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2.69 Main Waste Pipe (MWP) — A pipe connecting one or more branch waste pipes to the drain.

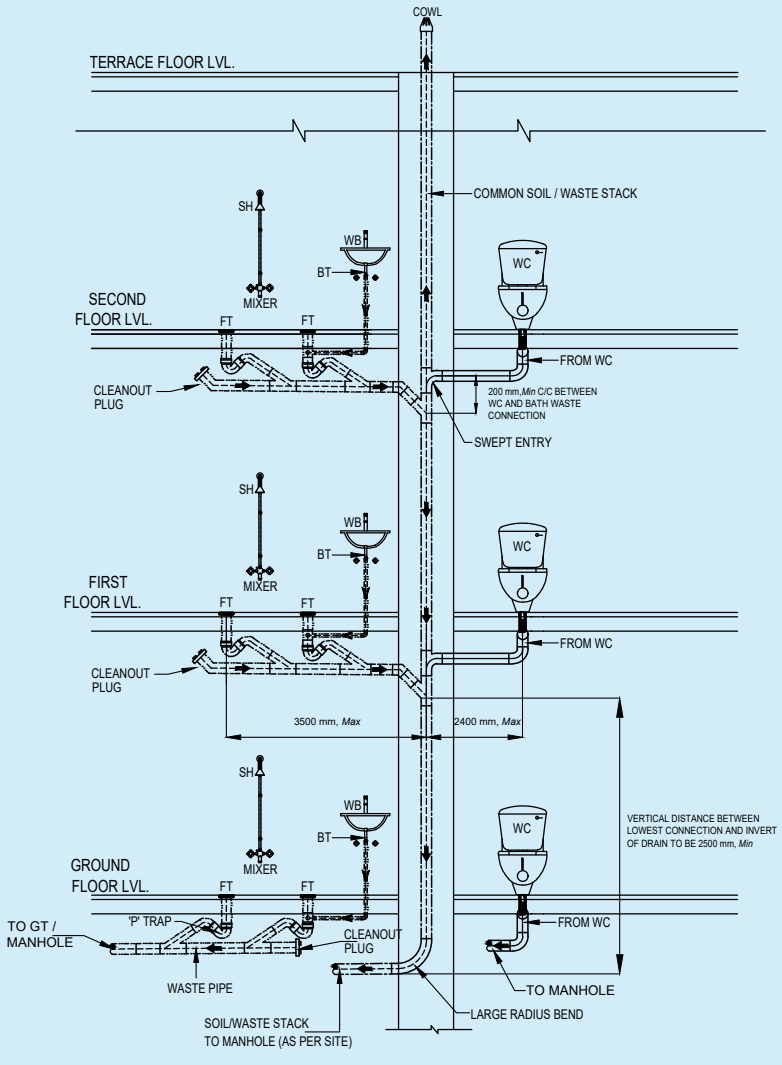
2.70 Manhole — An opening by which a man may enter or leave a drain, a sewer or other closed structure for inspection, cleaning and other maintenance operations, fitted with suitable cover.

2.71 Manhole Chamber — A Chamber constructed on a drain or sewer so as to provide access thereto for inspection, testing or clearance of obstruction.

2.72 Offset — A pipe fitting used to connect two pipes whose axes are parallel but not in line.

2.73 Pipe System — The system to be adopted will depend on the type and planning of the building in which it is to be installed and will be one of the following:

a) *Single stack system* (*see* Fig. 1) — The piping system in which there is no trap ventilation and the stack itself acts as vent through roof. In this system care shall be taken for proper sizing of the pipes and the trap arm distance, specially the horizontal distance of sanitary fixtures from the drainage stack and vertical distance between connection of branches from fixtures to drainage stack;



LEGEND

SH	SHOWER
WC	WATER CLOSET
WB	WASH BASIN
FT	FLOOR TRAP
BT	BOTTLE TRAP
GT	GULLY TRAP

NOTES

1 Presentation of type of fixtures/drains, and pipe route/layout is typical in nature.

2 Kitchen waste piping shall also be planned in a similar manner as for other waste appliances.

FIG. 1 SINGLE STACK SYSTEM

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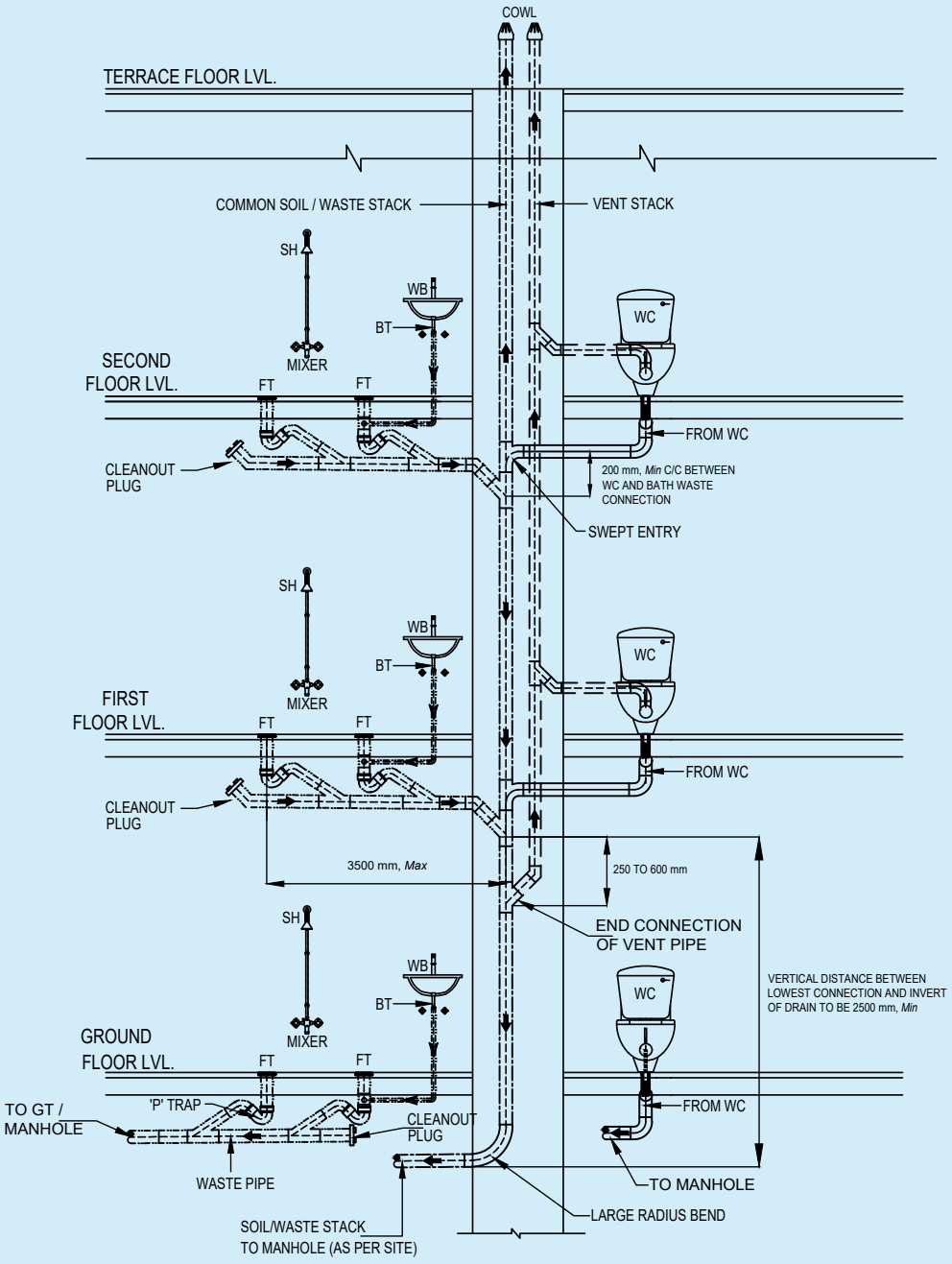
b) *One pipe — Partially ventilated system* (*see* Fig. 2) — The piping system in which soil and waste pipes are connected to a single vertical stack [as explained in **2.73(a)**] with additional vent pipe for ventilation of traps of water closets;



LEGEND

SH	SHOWER
WC	WATER CLOSET
WB	WASH BASIN
FT	FLOOR TRAP
BT	BOTTLE TRAP
GT	GULLY TRAP

NOTES

1 Presentation of type of fixtures/drains, and pipe route/layout is typical in nature.

2 Kitchen waste/vent piping shall also be planned in a similar manner as for other waste appliances.

FIG. 2 ONE PIPE — PARTIALLY VENTILATED SYSTEM

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c) *One pipe — Fully ventilated system* (*see* Fig. 3) — The piping system in which the waste pipes from the sinks, baths and wash basins, and the soil pipe from water closet are connected to a single vertical stack. The traps of the water closets, waste appliances, etc, are individually ventilated and connected with a separate stack to preserve the water seal;

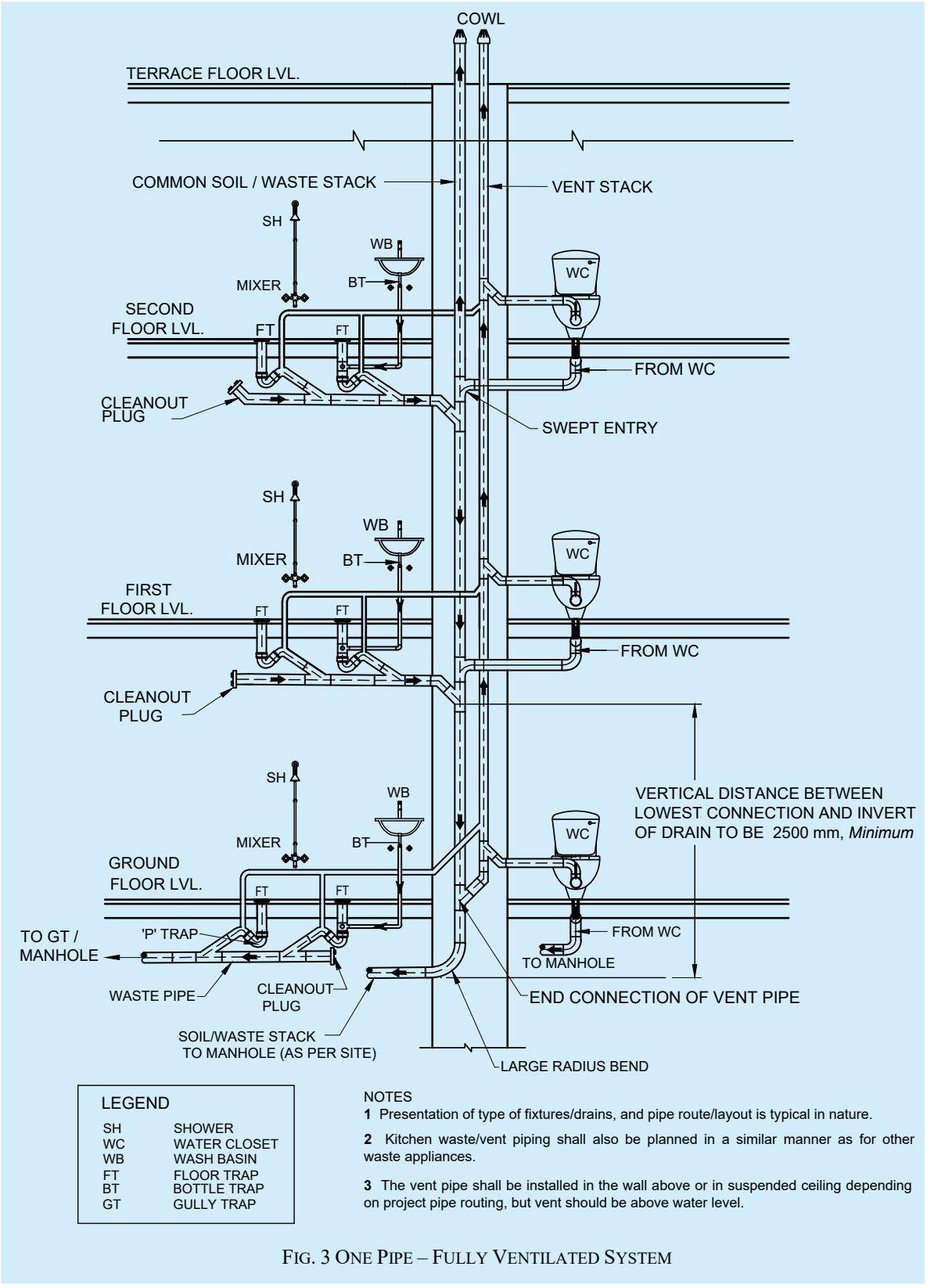

FIG. 3 ONE PIPE – FULLY VENTILATED SYSTEM

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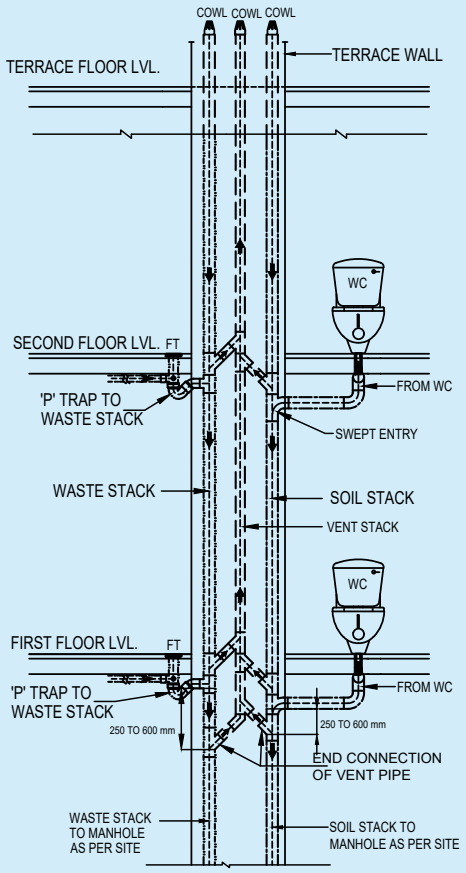
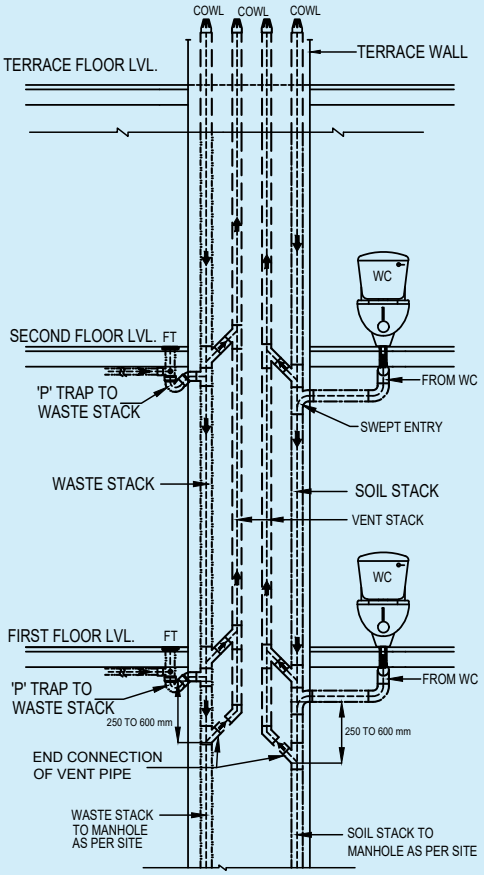
d) *Two pipe system*:

1) *Two pipe system with common vent pipe* (*see* Fig. 4A) — The piping system in which all soil appliances such as water closets, urinals, bidet and bedpan sinks are connected to soil stack and all other plumbing fixtures such as baths, sinks, and basins are connected to waste stack through deep seal trap. In addition, a common vent stack is provided for ventilation of soil and waste stacks; and

2) *Two pipe system with independent vent pipes* (*see* Fig. 4B) — The piping system in which all soil appliances such as water closets, urinals, bidet and bedpan sinks are connected to soil stack, and all other plumbing fixtures such as baths, sinks, and basins are connected to waste stack through deep seal trap. In addition, there are independent a vent stacks provided for respective ventilation of soil and waste stacks.



4A TWO PIPE SYSTEM WITH COMMON VENT PIPE



4B TWO PIPE SYSTEM WITH INDEPENDENT VENT PIPES

LEGEND

SH	SHOWER
WC	WATER CLOSET
WB	WASH BASIN
FT	FLOOR TRAP
BT	BOTTLE TRAP
GT	GULLY TRAP

NOTES

1 Presentation of type of fixtures/drains, and pipe route/layout is typical in nature.

2 Kitchen waste/vent piping shall also be planned in a similar manner as for other waste appliances.

FIG. 4 TWO PIPE SYSTEM

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2.74 Plumbing

a) The pipes, fixtures and other apparatus inside a building for bringing in the water supply and removing the liquid and water borne wastes; and

b) The installation of the foregoing pipes, fixtures and other apparatus.

2.75 Plumbing System ð The plumbing system shall include the water supply and distribution pipes; plumbing fittings and traps; soil, waste, ventilating pipes and anti-siphonage pipes; building drains and building sewers including their respective connections, devices and appurtenances within the property lines of the premises; and water-treating or water-using equipment.

2.76 Premises ð Premises shall include passages, buildings and lands of any tenure, whether open or enclosed, whether built on or not, and whether public or private in respect of which a water rate or charge is payable to the authority or for which an application is made for supply of water and disposal of waste to the public sewer.

2.77 Puff Ventilation ð The ventilation provided for waste traps in two-pipe system, in order to preserve the water seal.

2.78 Relief Vent ð An additional ventilating pipe connected to a discharge pipe at any point where excessive pressure fluctuation is likely to occur.

2.79 Saddle ð A purpose made fitting, so shaped as to fit over a hole cut in a sewer or drain used to form connections.

2.80 Sanitary Appliances ð The appliances for the collection and discharge of soil or waste matter.

2.81 Sewer ð A pipe or conduit, generally closed, but normally not flowing full for carrying sewage and/or other waste liquids.

2.82 Slop Hopper (Slop Sink) ð A hopper shaped sink, with a flushing run and outlet similar to those of a WC pan, for the reception and discharge of human excreta.

2.83 Soakaway ð A pit, dug into permeable ground lined to form a covered perforated chamber or filled with hard-core, to which liquid is led, and from which it may soak away into the ground.

2.84 Soffit (Crown) ð The highest point of the internal surface of a sewer or culvert at any cross section.

2.85 Soil Appliances ð A sanitary appliance for the collection and discharge of excretory matter.

2.86 Soil Pipe ð A pipe that conveys the discharge of water closets or fixtures having similar functions, with or without the discharges from other fixtures.

2.87 Soil Waste ð The discharge from water closets, urinals, slop hopper, stable yard or cowshed gullies and similar appliances.

2.88 Stack Vent ð The extension of a soil or waste stack above the highest horizontal drain connected to the stack.

2.89 Sub Soil Water ð Water occurring naturally in the subsoil.

2.90 Sub Soil Water Drain

a) A drain intended to collect and carry away subsoil water; and

b) A drain intended to disperse into the subsoil from a septic tank.

2.91 Sullage ð *See* **2.104**.

2.92 Supply Pipe ð So much of any service pipe as is not a communication pipe.

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2.93 Supports — Hangers and anchors or devices for supporting and securing pipe and fittings to walls, ceilings, floors or structural members.

2.94 Surface Water — Natural water from the ground surface, paved areas and roofs.

2.95 Surface Water Drain — A drain conveying surface water including storm water.

2.96 Systems of Drainage

a) *Combined system* — A system in which foul water (sewage) (black and grey water) and surface water are conveyed by the same sewers and drains;

b) *Separate system* — A system in which foul water (sewage) (black and grey water) and surface water are conveyed by the separate sewers and drains; and

c) *Partially separate system* — A modification of the separate system in which part of the surface water is conveyed by the foul (sanitary) sewers and drains.

2.97 Trade Effluent — Any liquid either with or without particles of matter in suspension which is wholly or in part produced in the course of any trade or industry, at trade premise. It includes farm wastes but does not include domestic sewage.

2.98 Trap — A fittings or device so designed and constructed as to provide, when properly vented, a liquid seal which will prevent the back passage of air without materially affecting the flow of sewage or waste water through it.

2.99 Vertical Pipe — Any pipe or fitting which is installed in a vertical position or which makes an angle or not more than 45° with the vertical.

2.100 Vent Stack/Vent Pipe — A vertical vent-pipe installed primarily for the purpose of proving circulation of air to and from any part of the drainage system. It also protects trap seals from excessive pressure fluctuation.

2.101 Vent System — A pipe or pipes installed to provide a flow of air to or from a drainage system or to provide a circulation of air with in such system to protect traps seals from siphonage and back-pressure.

2.102 Waste Appliance — A sanitary appliance for the collection and discharge of water after use for ablutionary, culinary and other domestic purpose.

2.103 Waste Pipe — In plumbing, any pipe that receives the discharge of any fixtures, except water closets or similar fixtures and conveys the same to the house drain or soil or waste stack. When such pipe does not connect directly with a house drain or soil stack, it is called an indirect waste pipe.

2.104 Waste Water (Sullage) — The discharge from wash basins, sinks and similar appliances, which does not contain human or animal excreta.

2.105 Water Closet — A water flushed plumbing fixture designed to receive human excrement directly from the user of the fixture. The term is used sometimes to designate the room or compartment in which the fixture is placed.

2.106 Water Seal — The water in a trap, which acts as a barrier to the passage of air through the trap.

2.107 Yoke Vent (**Cross-Vent**) — A short relief vent between the main soil or waste pipe and a main ventilating pipe.

3 GENERAL

3.1 Basic Principles

The basic principles of water supply, drainage and sanitation are given below and the design of drainage and sanitation should in general be guided by the applicable principles.

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3.1.1 *Potable Water*

All premises intended for human habitation, occupancy, or use shall be provided with supply of potable water. This water supply shall not be connected with unsafe water resources, nor shall it be subject to the hazards of backflow.

3.1.2 *Water Provision*

Plumbing fixtures, devices and appurtenances shall be provided with water in sufficient volume and at pressures adequate to enable them to function properly and without undue noise under normal conditions of use.

There should be at least a residual head of 0.018 N/mm^2 at the consumer's tap. There may be certain fixtures or appliances in the installation that may require a higher pressure, such as 0.05 N/mm^2 or even higher, in which case the system shall be designed using pumps, tanks or both to achieve the required minimum pressure.

NOTE — The residual head shall be taken at the highest/farthest outlets in the building.

3.1.3 *Water Efficiency*

Plumbing system shall be designed, installed and adjusted to use the optimum quantity of water consistent with proper performance and cleaning.

3.1.4 *Safety Devices*

Plumbing system shall be designed and installed with safety devices to safeguard against dangers from contamination, explosion, overheating, etc.

3.1.5 *Minimum Amenities*

Each dwelling unit on premises (abutting on a sewer or with a private sewage disposal system) shall have at least one water closet, one kitchen wash place or a sink and one bathing place or shower to meet the basic requirements of sanitation and personal hygiene.

In case of a group housing, the requirements relating to toilet or sanitary room and kitchen as given in good practice [E-2(2)] shall also be complied with.

3.1.6 *Drainage System*

The drainage system shall be designed, installed and maintained to guard against fouling, deposit of solids and clogging and with adequate cleanouts so arranged that the pipes may be readily cleaned.

3.1.7 *Materials and Workmanship*

The plumbing system shall have durable material, free from defective workmanship and so designed and installed as to give satisfactory service for its reasonable expected life. The accessories of the plumbing system should be of such specifications as to meet the functional requirements of the installation, so as to also avoid any inconsistency leading to leakage and resultant seepage.

3.1.8 *Fixture Traps and Vent Pipes*

Each fixture directly connected to the drainage system shall be equipped with a liquid seal trap. Trap seals shall be maintained to prevent sewer gas, other potentially dangerous or noxious fumes, or vermin from entering the building. Further, the drainage system shall be designed to provide an adequate circulation of air in all pipes with no danger of siphonage, aspiration, or forcing of trap seals under conditions of ordinary use by providing vent pipes throughout the system.

3.1.9 *Foul Air Exhaust*

Each vent terminal shall extend to the outer air and be so installed as to minimize the possibilities of clogging and the return of foul air to the building, as it conveys potentially noxious or explosive gases to the outside atmosphere. All vent pipes shall be provided with a cowl.

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3.1.10 *Testing*

The plumbing system shall be subjected to required tests to effectively disclose all leaks and defects in the work or the material.

3.1.11 *Exclusion from Plumbing System*

No substance that will clog or accentuate clogging of pipes, produce explosive mixtures, destroy the pipes or their joints, or interfere unduly with the sewage-disposal process shall be allowed to enter the drainage system.

3.1.12 *Light and Ventilation*

Wherever water closet or similar fixture is located in a room or compartment, it should be properly lighted and ventilated.

3.1.13 *Individual Sewage Disposal Systems*

If water closets or other plumbing fixtures are installed in buildings where connection to public sewer is not possible, suitable provision shall be made for acceptable treatment and disposal.

3.1.14 *Maintenance*

Plumbing systems shall be maintained in a safe and serviceable condition.

3.1.15 *Approach for Use and Cleaning*

All plumbing fixtures shall be so installed with regard to spacing as to be approachable for their intended use and for cleaning. All doors, windows and any other device needing access within the toilet shall be so located that they have proper approach.

3.1.16 *Accessibility for Persons with Disabilities*

All doors, windows and fixtures, including WC, urinals, grab bars, washbasin, mirror and all other accessories for use by persons with disabilities shall be so installed/located that they have proper access with appropriate width, height, space, centerlines and ease of operation {*see* good practice [E-2(2)]}.

3.1.17 *Structural Safety*

Plumbing system shall be installed with due regard to preservation of the structural members and prevention of damage to walls and other surfaces.

3.1.18 *Protection of Ground and Surface Water*

Sewage or other waste shall not be discharged into surface or sub-surface water without acceptable form of treatment.

3.2 Drainage and Sanitation

3.2.1 *Preparation and Submission of Plan*

No person shall install or carry out any water-borne sanitary installation or drainage installation or any works in connection with anything existing or new buildings or any other premises without obtaining the prior sanction of the Authority.

The owner shall make an application in the prescribed form (*see* Annex A) to the Authority to carry out such a work.

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3.2.2 *Site Plan*

A site plan of the premises on which the building is to be situated or any such work is to be carried out shall be prepared drawn to a scale not smaller than 1 in 500. The site plan of the building premises shall show:

a) The adjoining plots and streets with their names;

b) The position of the municipal sewer and the direction of flow in it;

c) The invert level of the municipal sewer, the road level, and the connection level of the proposed drain connecting the building in relation to the sewer,

d) The angle at which the drain from the building joints the sewer; and

e) The alignment, sizes and gradients of all drains and also of surface drains, if any.

A separate site plan is not necessary if the necessary particulars to be shown in such a site plan are already shown in the drainage plan.

3.2.3 *Drainage Plan*

The application (*see* **3.3.1**) shall be accompanied by a drainage plan drawn to a scale of not smaller than 1 in 100 and furnished along with the building plan. The plans shall show the following:

a) Every floor of the building in which the pipes or drains are to be used;

b) The position, forms, level and arrangement of the various parts of such building, including the roof thereof;

c) All new drains as proposed with their sizes and gradients;

d) Invert levels of the proposed drains with corresponding ground levels;

e) The position of every manhole, gully, soil and waste pipe, ventilating pipe, rainwater pipe, water closet, urinal, latrine, bath, lavatory, sink, trap or other appliances in the premises proposed to be connected to any drain and the following colours are recommended for indicating sewers, waste water pipes, rainwater pipes an existing work:

Sl No.	*Description of Work*	*Colour*
(1)	(2)	(3)
i)	Sewers	Red
ii)	Waste water pipes and rainwater pipes	Blue
iii)	Existing work	Black

f) The position of refuse chute, inlet hopper and collection chamber.

3.2.3.1 In the case of an alteration or addition to an existing building, this clause shall be deemed to be satisfied if the plans as furnished convey sufficient information for the proposals to be readily identified with previous sanctioned plans and provided the locations of tanks and other fittings are consistent with the structural safety of the building.

3.2.3.2 The plans for the building drainage shall in every case be accompanied by specifications for the various items of work involved. This information shall be supplied in the prescribed from given in Annex B.

3.2.4 In respect of open drains, cross-sectional details shall be prepared to a scale not smaller than 1 in 50 showing the ground and invert levels and any arrangement already existing or proposed for the inclusion of any or exclusion of all storm water from the sewers.

3.2.5 *Completion Certificate*

At the completion of the plumbing installation work, the licensed/registered plumber shall give a completion certificate in the prescribed form, which is given in Annex C.

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3.3 Licensing/Registration of Plumbers

3.3.1 *Execution of Work*

The work which is required to be carried out under the provisions of this Section, shall be executed only by a licensed/registered plumber under the control of the Authority and shall be responsible to carry out all lawful directions given by the Authority. No individual shall engage in the business of plumbing unless so licensed/registered under the provisions of this Section.

3.3.1.1 No individual, firm, partnership or corporation shall engage in the business of installing, repairing or altering plumbing unless the plumbing work performed in the course of such business is under the direct supervision of a licensed/registered plumber from approved Authority**.**

3.3.2 *Examination and Certification*

The Authority shall establish standards and procedure for the qualification, examination and licensing/registration of plumbers and shall issue licences to such persons who meet the qualifications thereof and successfully pass the examination.

3.3.3 For guidelines for registration of plumbers including the minimum standards for qualifications for the grant of licences, reference may be made to good practice [E-2(3)]. The Authority may also utilize the services of the certified plumbers who are certified for the required skill level under the appropriate scheme of the Government.

4 DRAINAGE AND SANITATION

4.1 Types of Sanitary Appliances

4.1.1 *Soil Appliances*

4.1.1.1 *Water closet*

It shall essentially consist of a closet consisting of a bowl to receive excretory matter, trap and a flushing apparatus. It is recommended to provide ablution tap adjacent to the water closet, preferably on right hand side wall. The various types/style of water closets may be:

a) Squatting Indian type water closet;

b) Washdown type water closet;

c) Siphonic washdown type water closet; and

d) Universal or Anglo-Indian water closet.

4.1.1.2 *Bidet*

Bidet is an ablution appliance for cleansing excretory organs with water for personnel hygiene. It may be pedestal type or wall hung with a shallow bowl. Hot and cold water supplied through a mixer is discharged from a spray installed over the rim of the appliance. The bidet outlet should essentially connect to soil pipe in a system.

4.1.1.3 *Urinal*

It is a soil appliance for urination and is connected to soil pipe after a suitable trap. Urinal should have adequate provision of flushing apparatus. The various types/style of urinal may be:

a) bowl type urinal: flat back or angle back;

b) slab (single) type urinal;

c) stall (single) type urinal;

d) squatting plate type urinal;

e) syphon jet urinal with integral trap; and

f) water less (non-water) urinal

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4.1.1.4 *Slop sink*

Slop sink is a large sink, generally of square shape. The appliance is used in hospitals and is installed in the dirty utility room, sluice room and similar locations for disposal of excreta and other foul waste and for washing bed pans and urine bottles/pans. It is provided with a flushing mechanism. It is also provided in Janitor's closet where it is used for cleaning the housekeeping mops, etc.

4.1.1.5 *Bed pan sink*

Bed pan sink, also known as bedpan washer and disinfector, is a part of medical equipment inventory which is used to clean manually or automatically, the hospital bedpans, urine bottles and other containers used for collecting body fluids. It is provided in dirty utility room, sluice room, similar locations for disposal of excreta and other foul waste and for washing bed pans, urine bottles/pans. It is a soil appliance and is connected to soil pipe after a suitable trap. In manual models, it has a flushing arrangement.

Provision for installing a bedpan washer and disinfector should be made in all intensive care units in hospitals.

4.1.2 *Waste Appliances*

4.1.2.1 *Wash basin*

It is of one-piece construction having a combined overflow and preferably should have soap holding recess or recesses that should properly drain into the bowl. Each basin shall have circular waste hole through which the liquid content of the basin shall drain.

4.1.2.2 *Wash-trough*

It is a linear trough for simultaneous use by number of persons.

4.1.2.3 *Sink*

It is used in kitchen and laboratory for the purpose of cleaning utensils/ apparatus and also serve the purpose of providing water for general usage. The sink may be made with or without overflow arrangement. The sink shall be of one-piece construction including combined over flow, where provided. The sink shall have a circular waste hole into which the interiors of the sink shall drain.

4.1.2.4 *Bath tub*

Bath tub may be of enameled steel, cast iron, gel-coated, glass fibre reinforced plastic or may be cast in-situ. It shall be stable, comfortable, easy to get in and out, water tight, with anti-skid base, and easy to install and maintain. The bath tub shall be fitted with overflow and waste pipe of nominal diameter of not less than 32 mm and 40 mm, respectively.

4.1.2.5 *Drinking fountain*

It is a bowl fitted with a push button tap and a water bubbler or a tap with a swan neck outlet fitting. It has a waste fitting, a trap and is connected to the waste pipe.

4.1.3 The requirements of various soil appliances and waste appliances shall be in accordance with accepted standards [E-2(4)].

4.2 Drainage and Sanitation Requirements

4.2.1 *General*

There should be at least one water tap and arrangement for drainage in the vicinity of each water closet or group of water closet in all the buildings.

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4.2.2 Each dwelling unit on premises (abutting on a sewer or with a private sewage disposal system) shall have at least one water closet, one kitchen wash place or a sink, and one bathing place or shower to meet the basic requirements of sanitation and personal hygiene.

In case of a group housing, the requirements relating to toilet or sanitary room and kitchen as given in good practice [E-2(2)] shall also be complied with.

4.2.3 All other structures for human occupancy or use on premises (abutting on a sewer or with a private sewage disposal system) shall have adequate sanitary facilities, but in no case less than one water closet and one other fixture for cleaning purposes.

4.2.4 *For Residences*

4.2.4.1 Dwelling with individual convenience shall have at least the following fitments:

a) One bathroom provided with a tap and a floor trap;

b) One water closet with flushing apparatus with an ablution tap; and

c) One tap with a floor trap or a sink in kitchen or wash place.

4.2.4.1.1 Where only one water closet is provided in a dwelling, it is desirable to have the bath and water closet separately accommodated.

4.2.4.2 Dwellings without individual conveniences shall have the following fitments:

a) One water tap with floor trap in each tenement;

b) One water closet with flushing apparatus and one ablution tap bath for every two tenements; and

c) One bath with water tap and floor trap for every two tenements

4.2.5 *For Buildings other than Residences*

4.2.5.1 The requirements for fitments for drainage and sanitation in the case of buildings other than residences shall be in accordance with Table 1 to Table 17.

The accessibility requirements for provision of these facilities for persons with disabilities shall be in accordance with good practice [E-2(2)].

The following shall be, in addition, taken into consideration:

a) The figures shown are based upon one (1) fixture being the minimum required for the number of persons indicated or part thereof;

b) Building categories not included in the tables shall be considered separately by the Authority;

c) Drinking fountains shall not be installed in the toilets;

d) Where there is the danger of exposure to skin contamination with poisonous, infectious or irritating material, washbasin with eye wash jet and an emergency shower (safety shower with eye wash unit) located in an area accessible at all times with the passage/right of way suitable for access to a wheel chair, shall be provided;

e) When applying the provision of these tables for providing the number of fixtures, consideration shall be given to the accessibility of the fixtures. Using purely numerical basis may not result in an installation suited to the need of a specific building. For example, schools should be provided with toilet facilities on each floor. Similarly, toilet facilities shall be provided for temporary workmen employed in any establishment according to the needs; and in any case one WC and one washbasin shall be provided;

f) All buildings used for human habitation for dwelling, work, occupation, medical care or any purpose detailed in the various tables, abutting a public sewer or a private sewage disposal system, shall be provided with minimum sanitary facilities as per the schedule in the tables. In case the disposal facilities are not available, they shall be provided as a part of the building design for ensuring high standards of sanitary conditions in accordance with this Section;

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g) Workplaces where crèches are provided, they shall be provided with one WC for 10 persons or part thereof, one wash basin for 15 persons or part thereof, one kitchen sink with floor trap for preparing food/milk preparations. The sink provided shall with a drinking water tap;

h) In all types of buildings, individual toilets and pantry should be provided for executives, and for meeting/seminar/conference rooms, etc as per the user requirement;

j) Where food is consumed indoors, water stations and handwashing points may be provided in place of drinking water fountains; and

k) All public areas where floating population is expected need to provide low-mounted urinals and washbasins for children/dwarfs, at least 1 percent or 10 percent of the total.

Table 1 Office Buildings

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public Toilets		Staff Toilets	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
	Executive rooms and conference halls in office buildings				
i)	Toilet suite comprising one WC, one washbasin (with optional shower stall if building is used round the clock at user's option) Pantry optional as per user requirement	Unit could be common for male/female or separate depending on the number of user of each facility		For individual officer rooms	
	Main office toilets for staff and visitors				
ii)	Water closets	*See* Note		1 per 25	1 per 15
iii)	Ablution tap with each water closet	← 1 in each water closet →			
iv)	Urinals	*See* Note	–	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100 From 101 to 200, add @ 3 percent For over 200, add @ 2.5 percent	–
v)	Wash basins	*See* Note		1 per 25	1 per 25
vi)	Drinking water fountain	*See* Note		1 per 100	1 per 100
vii)	Cleaner's sink	← 1 per floor →			

NOTES

1 Staff and public toilet utilities are generally common in office buildings. Where public toilets are to be provided independently, similar requirements as that of staff toilet may be provided.

2 Space for one janitor per toilet core shall to be planned.

3 The male population may be assumed as half and the female population as half.

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Table 2 Factories

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Offices/Visitors		Workers	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets (workers and staff)	1 for up to 25	1 for up to 15	1 for up to 15	1 for up to 12
		2 for 26 to 35	2 for 16 to 25	2 for 16 to 35	2 for 13 to 25
		3 for 36 to 65	3 for 26 to 40	3 for 36 to 65	3 for 26 to 40
		4 for 66 to 100	4 for 41 to 57	4 for 66 to 100	4 for 41 to 57
			5 for 58 to 77		5 for 58 to 77
			6 for 78 to 100		6 for 78 to 100
	For persons 101 to 200 add	3 percent	5 percent	3 percent	5 percent
	For persons over 200 add	2.5 percent	4 percent	2.50 percent	4 percent
ii)	Ablution tap	1 in each water closet	1 in each water closet	1 in each water closet	1 in each water closet
iii)	Urinals	Nil up to 6	–	Nil up to 6	–
		1 for 7 to 20		1 for 7 to 20	
		2 for 21 to 45		2 for 21 to 45	
		3 for 46 to 70		3 for 46 to 70	
		4 for 71 to 100		4 for 71 to 100	
		From 101 to 200, add @ 3 percent		From 101 to 200, add @ 3 percent	
		For over 200, add @ 2.5percent		For over 200, add @ 2.5 percent	
iv)	Wash basins	1 per 25 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof
	Wash basins in rows or troughs and taps spaced 750 mm c/c				
v)	Drinking water fountain	1 per every 100 or part thereof with minimum one on each floor		1 per every 100 or part thereof with minimum one on each floor	
vi)	Cleaner's sink	1 on each floor	1 on each floor	1 on each floor	1 on each floor
vii)	Showers/bathing rooms	← As per trade requirements →			
viii)	Emergency shower and eye wash fountain	–	–	1 per every shop floor per 500 persons	

NOTES

1 For factories requiring workers to be engaged in dirty and dangerous operations or requiring them to being extremely clean and sanitized conditions additional and separate (if required so) toilet facilities and if required by applicable Industrial and Safety Laws and the *Factories Act* shall be provided in consultation with the user.

2 Depending on the type of disability of a person and the hazard posed by the type of activities in the factory for a person with disabilities, if a person with disabilities is decided to be engaged for a particular activity, the requirements of accessibility shall be guided by the provisions given in good practice [E-2(2)].

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Table 3 Warehouse and Storage Area

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Offices/Visitors		Workers	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets (workers and staff)	1 for up to 25	1 for up to 15	1 for up to 15	1 for up to 12
	For persons 101 to 200 add	3 percent	5 percent	4 percent	5 percent
	For persons over 200 add	2.5 percent	4 percent	2.50 percent	4 percent
ii)	Ablution tap	1 in each water closet	1 in each water closet	1 in each water closet	1 in each water closet
iii)	Urinals	Nil up to 6	–	Nil up to 6	–
		1 for 7 to 20	–	1 for 7 to 20	–
		2 for 21 to 45	–	2 for 21 to 45	–
		3 for 46 to 70	–	3 for 46 to 70	–
		4 for 71 to 100	–	4 for 71 to 100	–
		From 101 to 200, add @ 3 percent	–	From 101 to 200, add @ 3 percent	–
		For over 200, add @ 2.5 percent	–	For over 200, add @ 2.5 percent	–
iv)	Wash basins	1 per 25 or part thereof	1 per 15 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof
	Wash basins in rows or troughs and taps spaced 750 mm c/c				
v)	Drinking water fountain	1 per every 100 or part thereof with minimum one on each floor		1 per every 100 or part thereof with minimum one on each floor	
vi)	Cleaner's sink	1 on each floor	1 on each floor	1 on each floor	1 on each floor
vii)	Showers/bathing rooms	← As per trade requirements →			
viii)	Emergency shower and eye wash fountain	–	–	1 per every shop floor per 500 persons	

NOTE — Emergency shower and eye wash as per trade requirement to be provided.

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Table 4 Cinema, Multiplex Cinema, Concerts and Convention Halls, Theatres and Stadia

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public		Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 100 up to 400	4 per 100 up to 200	1 for up to 15	1 for up to 12
				2 for 16 to 35	2 for 13 to 25
		Over 400 add at 1 per 250 or part thereof	Over 200 add at 2 per 100 or part thereof		
ii)	Ablution tap	1 in each water closet	1 in each water closet	1 in each water closet	1 in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iii)	Urinals	1 per 25 or part thereof	–	Nil up to 6	–
				1 for 7 to 20	
				2 for 21 to 45	
iv)	Wash basins	1 per 200 or part thereof		1 for up to 15	1 for up to 12
				2 for 16 to 35	2 for 13 to 25
v)	Drinking water fountain	← 1 per 100 persons or part thereof →			
vi)	Cleaner's sink	← 1 per floor →			
vii)	Showers/bathing rooms	← As per trade requirements →			

NOTES

1 Some WCs may be Indian style if desired.

2 Male population may be assumed as half and female population as half.

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Table 5 Art Galleries, Libraries, Indoor Activity/Sports Rooms and Museums

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public		Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 200 up to 400 Over 400 add at 1 per 250 or part thereof	1 per 100 up to 200 Over 200 add at 1 per 150 or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iii)	Urinals	1 per 50	–	Nil up to 6 1 per 7 to 20 2 per 21 to 45	–
iv)	Wash basins	1 for every 200 or part thereof. For over 400, add at 1 per 250 persons or part thereof	1 for every 200 or part thereof. For over 200, add at 1 per 150 persons or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
v)	Drinking water fountain	← 1 per 100 persons or part thereof →			
vi)	Cleaner's sink	← 1 per floor (Minimum) →			
vii)	Showers/bathing rooms	← As per requirements →			

NOTES

1 Some WCs may be Indian style if desired.

2 Male population may be assumed as half and female population as half.

3 Board game rooms, indoor sports and club house for community in residential premises can be considered as indoor activity areas.

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Table 6 Hospitals with Indoor Patient Wards

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Patient Toilets		Staff Toilets	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC and one washbasin and shower stall	Private room with up to 4 patients		For individual doctor's/officer's rooms	
	For General Wards, Hospital Staff and Visitors				
ii)	Water closets	1 per 5 beds or part thereof	1 per 5 beds or part thereof	1 for up to 15	1 for up to 12
				2 for 16 to 35	2 for 13 to 25
iii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iv)	Urinals	1 per 15 beds	–	Nil up to 6	–
				1 for 7 to 20	
				2 for 21 to 45	
v)	Wash basins	2 for every 30 beds or part thereof. Add 1 per additional 30 beds or part thereof		1 for up to 15	1 for up to 12
				2 for 16 to 35	2 for 13 to 25
vi)	Drinking water fountain	1 per ward		1 per 100 persons or part thereof	
vii)	Cleaner's sink	1 per ward		–	
viii)	Bed pan sink	1 per ward		–	
ix)	Kitchen sink	1 per ward		–	

NOTES

1 Some WCs may be of Indian style if desired.

2 Male population may be assumed as half and female population as half.

3 Provision for additional and special hospital fittings where required shall be made.

4 Drinking water fountains are not recommended for hospitals for reasons of infection control. This to be decided by the health authority recommendation.

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Table 7 Hospitals with Outdoor Patient Department

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Patient Toilets		Staff Toilets	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC and one washbasin (with optional shower stall if building used for 24 h)	For up to 4 patients		For individual doctor's/officer's rooms	
ii)	Water closets	1 per 100 persons or part thereof	2 per 100 persons or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
iii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iv)	Urinals	1 per 50 persons or part thereof	–	Nil up to 6 1 for 7 to 20 2 for 21 to 45	–
v)	Wash basins	2 per 100 persons of part thereof	2 per 100 persons or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
vi)	Drinking water fountain	*See* Note 2		1 per 100 persons or part thereof	

NOTES

1 Some WCs may be Indian style if desired.

2 Drinking water fountains are not recommended for hospitals for reasons of infection control. This to be decided by the health authority recommendation.

3 The WCs shall be provided keeping in view the location of main OPD waiting hall and sub-waiting halls, floor wise, so as to serve the people effectively. The number of patients shall be calculated floor wise. The OPD population shall include patient attendants @ at least 1 per patient.

4 Male population may be assumed as half and female population as half.

5 Provision for additional and special hospital fittings where required shall be made.

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Table 8 Hospitals, Administrative Buildings

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Staff Toilets	
		Males	Females
(1)	(2)	(3)	(4)
i)	Toilet suite comprising one WC, one urinal and one washbasin (with optional shower stall if building used for 24 h)	For individual doctor's/officer's rooms	
ii)	Water closets	1 per 25 persons or part thereof	1 per 15 persons or part thereof
iii)	Ablution tap	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals	
iv)	Urinals	1 for 6 to 15	–
		2 for 16 to 50	–
v)	Wash basins	1 per 25 persons or part thereof	1 per 25 persons or part thereof
vi)	Drinking water fountain	1 per 100 persons or part thereof (*See* Note 2)	
vii)	Cleaner's sink	1 per floor, *Min*	
viii)	Kitchen sink	1 per floor, *Min*	

NOTES

1 Some WCs may be Indian style if desired.

2 Drinking water fountains to be provided only when it is a separate block and patients will not use it.

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Table 9 Hospitals Staff Quarters and Nurses Homes

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Staff Quarters		Nurses Homes	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 4 persons or part thereof	1 per 4 persons or part thereof	1 per 4 persons or part thereof	1 per 4 persons or part thereof
				2 for 5 to 35	2 for 5 to 25
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iii)	Wash basins	1 per 8 persons or part thereof		1 per 8 persons or part thereof	
iv)	Bath (showers)	1 per 4 persons or part thereof		1 per 4 to 6 persons or part thereof	
v)	Drinking water fountain	1 per 100 persons or part thereof, *Min* 1 per floor		1 per 100 persons or part thereof, *Min* 1 per floor	
vi)	Cleaner's sink	1 per Floor		1 per Floor	

NOTES

1 Some WCs may be Indian style if desired.

2 For independent housing units, fixtures shall be provided as for residences.

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Table 10 Hotels

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public Rooms		Non-Residential Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC, wash basin with Shower or a bathtub	Individual guest rooms with attached toilets		_	
	Guest rooms with common facilities, and public areas like reception, health club, waiting lounge, business centre, recreation area				
ii)	Water closets	1 per 100 persons up to 300	2 per 100 persons up to 200	1 for up to 15	1 for up to 12
		Over 300 add at 1 per 200 or part thereof	Over 200 add at 1 per 100 or part thereof	2 for 16 to 35	2 for 13 to 25
				3 for 36 to 65	3 for 26 to 40
				4 for 66 to 100	4 for 41 to 57
					5 for 58 to 77
					6 for 78 to 100
iii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iv)	Urinals	1 per 50 persons or part thereof	_	Nil up to 6	_
				1 for 7 to 20	
				2 for 21 to 45	
				3 for 46 to 70	
				4 for 71 to 100	
v)	Wash basins	1 per WC/urinal	1 per WC	1 for up to 15	1 for up to 12
				2 for 16 to 35	2 for 13 to 25
				3 for 36 to 65	3 for 26 to 40
				4 for 66 to 100	4 for 41 to 57
vi)	Bath (showers)	1 per 10 persons or part thereof		–	–
vii)	Cleaner's sink	1 per 30 rooms, *Min* 1 per floor			
viii)	Kitchen sink	1 per kitchen			

NOTES

1 Some WCs may be Indian style if desired.

2 Male population may be assumed as half and female population as half.

3 Provision for additional and special fittings where required shall be made based on end user or operator guidelines.

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Table 11 Restaurants

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public Rooms		Non Residential Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 50 seats up to 200 Over 200 add at 1 per 100 or part thereof	2 per 50 seats up to 200 Over 200 add at 1 per 100 or part thereof	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iii)	Urinals	1 per 50 persons or part thereof	–	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	–
iv)	Wash basins	1 per WC	1 per WC	1 per WC	1 per WC
v)	Cleaner's sink	1 per each restaurant			
vi)	Kitchen sink/dish washer	1 per kitchen			

NOTES

1 Some WCs may be Indian style if desired.

2 Male population may be assumed as half and female population as half.

3 Provision for additional and special fittings where required shall be made.

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Table 12 Microbrewery, Special Restaurants and Food Court Area

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public Rooms		Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 50 seats up to 300 Over 300 add at 1 per 100 or part thereof	2 per 50 seats up to 200 Over 200 add at 1 per 100 or part thereof	3 percent for every 100	4 percent for every 100
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iii)	Urinals	3 percent for every 100	–	2.5 percent for every 100	–
iv)	Wash basins	1 per WC	1 per WC	1 per WC	1 per WC
v)	Cleaner's sink	1 per each floor			

NOTES

1 Some WCs may be Indian style if desired.

2 Male population may be assumed as half and female population as half.

3 Provision for additional and special fittings where required shall be made.

4 Kitchen sinks and washers shall be provided as per the kitchen design layout.

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Table 13 Schools, Colleges and Educational Institutions

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Nursery School	Non-Residential		Residential	
			Boys	Girls	Boys	Girls
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Water closets	1 per 15 pupils or part thereof	1 per 40 pupils or part thereof	1 per 25 pupils or part thereof	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals				
iii)	Urinals	–	1 per 20 pupils or part thereof	–	1 per 25 pupils or part thereof	–
iv)	Wash basins	1 per 15 pupils or part thereof	1 per 60 pupils or part thereof	1 per 40 pupils or part thereof	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
v)	Bath/showers	1 per 40 pupils or part thereof	–	–	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
vi)	Drinking water fountain or taps	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof
vii)	Cleaner's sink	1 per each floor				

NOTES

1 Some WCs may be Indian style if desired.

2 For teaching staff, the schedule of fixtures to be provided shall be the same as in case of office building.

3 Male population may be assumed as half and female population as half.

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Table 14 Hostels

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Resident		Non-Resident		Visitor/Common Rooms	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water closets	1 per 8 or part thereof	1 per 6 or part thereof	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 per 100 up to 400 Over 400 add at 1 per 250	2 per 100 up to 200 Over 200 add at 1 per 100
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals					
iii)	Urinals	1 per 25 or part thereof	–	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	–	1 per 50 or part thereof	–
iv)	Wash basins	1 per 8 persons or part thereof	1 per 6 persons or part thereof	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 per WC/ Urinal	1 per WC
v)	Bath/showers	1 per 8 persons or part thereof	1 per 6 persons or part thereof	–	–	–	–
vi)	Cleaner's sink	1 per each floor					

NOTE — Some WCs may be Indian style if desired.

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Table 15 Fruit and Vegetable Markets

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Shop Owners		Common Toilets in Market Building		Public Toilet for Floating Population	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water closets	1 per 8 or part thereof		1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 per 50 (Min 2)	1 per 50 (Min 2)
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided in receiving/ sale area of each shop and for every 50 persons or part thereof in the vicinity of water closets and urinals					
iii)	Urinals	–	–	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	–	1 per 50	–
iv)	Wash basins	1 per 8 or part thereof		1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57	–	–
v)	Bath/showers	1 per 8 persons or part thereof	1 per 6 persons or part thereof	–	–	1 per 50 persons	1 per 50 persons

NOTES

1 Toilet facilities for individual buildings in a market should be taken same as that for office buildings.

2 Common toilets in the market buildings provide facilities for persons working in shops and their regular visitors.

3 Special toilet facilities for a large floating population of out of town buyers/sellers, labour, drivers of vehicles for whom special toilet (public toilets).

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Table 16 Bus Stations, Airports and Railway Stations

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Junction Stations, Intermediate Stations and Bus Stations		Terminal Railway and Bus Stations		Domestic and International Airports	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water closets	3 for up to 1 000 Add 1 per additional 1 000 or part thereof	4 for up to 1 000 Add 1 per additional 1 000 or part thereof	4 for up to 1 000 Add 1 per additional 1 000 or part thereof	5 for up to 1 000 Add 1 per additional 1 000 or part thereof	*Min* 2 For 200 : 5 For 400 : 9 For 600 : 12 For 800 : 16 For 1 000 : 18	*Min* 2 For 200 : 8 For 400 : 15 For 600 : 20 For 800 : 26 For 1 000 : 29
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals					
iii)	Urinals	4 for up to 1 000 Add 1 per additional 1 000	–	6 for up to 1 000 Add 1 per additional 1 000	–	1 per 40 or part thereof	–
iv)	Wash basins	1 per WC/ Urinal	1 per WC	1 per WC/ Urinal	1 per WC	1 per WC/ Urinal	1 per WC
v)	Bath/showers	2 per 1 000		3 per 1 000		4 per 1 000	
vi)	Drinking water fountain or taps (in common lobby for male/female)	2 per 1 000 or part thereof		3 per 1 000 or part thereof		4 per 1 000 or part thereof	
vii)	Cleaner's sink	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's

NOTES

1 Some WCs may be Indian style if desired.

2 Male population may be assumed as three-fifth and female population as two-fifth.

3 Separate provision shall be made for staff and workers.

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Table 17 Shopping Malls and Retail Buildings

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Staff Toilets in Shopping Building		Public Toilet for Floating Population	
		Males	Females	Males	Females
(1)	(2)	(5)	(6)	(7)	(8)
i)	Water closets	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 per 50 (2, *Min*)	1 per 50 (2, *Min*)
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
iii)	Urinals	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	–	1 per 50	–
iv)	Wash basins	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57	1 per 50 (2, *Min*)	1 per 50 (2, *Min*)
v)	Bath/showers	1 per 100 persons	1 per 100 persons	–	–

NOTES

1 Toilet facilities for individual facilities in a shopping building should be taken same as that for office buildings.

2 Staff toilets in the shopping buildings provide facilities for persons working in shops and building, as well as for maintenance staff.

3 The number of persons against the fixture bath/showers represent the maintenance staff requiring such facility.

4 Public toilet facilities are provided for a large floating population for buyers and visitors.

5 Drinking water facility should be planned at two locations per floor, with water quality fit for drinking as per the applicable codes/standards.

4.3 Materials, Fittings and Appliances

4.3.1 *Standards for Materials, Fittings and Sanitary Appliances*

All materials, fittings and sanitary appliances shall conform to Part B 'Building Materials' of this NBCS.

4.3.2 *Choice of Material for Pipes*

4.3.2.1 *Salt glazed stoneware pipe*

For all sewers and drains in all soils, except where supports are required as in made-up ground, glazed stoneware pipe shall be used as far as possible in preference to other types of pipes. These pipes are particularly suitable

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where acid effluents or acid subsoil conditions are likely to be encountered. Salt glazed stoneware pipes shall conform to accepted standards [E-2(5)].

4.3.2.2 *Cement concrete pipes*

When properly ventilated, cement concrete pipes with spigot and socket or collar joints present an alternative to glazed stoneware sewers of over 150 mm diameter. These shall not be used to carry acid effluents or sewage under conditions favourable for the production of hydrogen sulphide and shall not be laid in those subsoils that are likely to affect adversely the quality or strength of concrete. However, where these pipes are employed for conveying liquid containing sulphates, the pipes used shall be manufactured using sulphate resisting Portland cement. Owing to the longer lengths of pipes available, the joints would be lesser in the case of cements concrete pipes. These pipes may be used for surface water drains in all diameters. Cement concrete pipes shall conform to accepted standards [E-2(6)].

4.3.2.3 *Cast iron pipes*

4.3.2.3.1 These pipes shall be used in the following situation:

a) In bed or unstable ground where soil movement is expected;

b) In made-up or tipped ground;

c) To provide for increased strength where a sewer is laid at insufficient depth, where it is exposed or where it has to be carried on piers or above ground;

d) Under buildings and where pipes are suspended in basements and like situations;

e) In reaches where the velocity is more than 2.4 m/s; and

f) For crossings of watercourses.

NOTE — In difficult foundation condition such as in the case of black cotton soil, the cast iron pipes shall be used only when suitable supporting arrangements are made.

4.3.2.3.2 It shall be noted that cast iron pipes even when given a protective paint are liable to severe external corrosion in certain soils; among such soils are:

a) Soils permeated by peaty waters; and

b) Soils in which the subsoil contains appreciable concentrations of sulphates. Local experiences shall be ascertained before cast iron pipes are used where corrosive soil conditions are suspected. Where so used, suitable measures for the protection of the pipes may be resorted to as an adequate safeguard.

4.3.2.3.3 Cast iron pipes shall conform to accepted standards [E-2(7)].

4.3.2.4 *Asbestos cement pipes*

Asbestos cement pipes are commonly used for house drainage systems and they shall conform to accepted standards [E-2(8)]. They are not recommended for underground situations. However, asbestos cement pressure pipes conforming to accepted standards [E-2(8)] may be used in underground situations also, provided they are not subject to heavy superimposed loads. These shall not be used to carry acid effluents or sewage under conditions favourable for the production of hydrogen sulphide and shall not be laid in those subsoils which are likely to affect adversely the quality or strength of asbestos cement pipes. Where so desired, the life of asbestos cement pipes may be increased by lining inside of the pipe with suitable coatings like epoxy/polyester resins, etc.

4.3.2.5 *PVC pipes*

Unplasticized PVC pipes may be used for drainage purposes; however, where hot water discharge is anticipated, the wall thickness shall be minimum 3 mm irrespective of the size and flow load.

PVC and HDPE pipes shall conform to accepted standards [E-2(9)].

NOTE — Where possible, high density polyethylene pipes (HDPE) and PVC pipes may be used for drainage and sanitation purposes, depending upon the suitability.

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4.3.2.6 *Corrugated pipes*

These pipes (externally corrugated) are used for sewerage and drainage applications. They are light weight and have long life. The leakage and infiltration at joints are less. The operational cost is low and can easily withstand natural settlements without suffering cracks or leakages. They consume fewer raw material and have less carbon dioxide emission.

4.3.2.7 *Low noise pipes*

Wastewater systems encompass the system of drainage and pressure relief pipes within a building and terminate 0.5 m outside the external wall. Waste water systems are based on the primary pressure-relief system in which water and air-flow occurs in the same pipe. The wastewater system shall be separated from the roof drainage system.

Noise is a variance in air pressure that spreads like a wave. If quick changes in pressure occur between 20 and 20 000 times a second (frequency 20 Hz and 20 kHz), they are audible to humans. The loudness of noise is determined by the amplitude of the wave, which is measured in decibels (dB).

The main cause of noise in indoor drainage systems (primarily focused on the downpipe) are the choice of the pipe system, the bracket type and the design of drainage system. Optimizing these factors will therefore have the best influence on noise reduction.

4.3.2.8 *Under slung pipes*

In under slung plumbing, the toilet slab is built at the same level as the slabs outside the toilet. Holes/core cuts are punctured through the slab wherever pipes have to pass through, and the plumbing is clamped to the bottom of the slab. It is then concealed above a false ceiling, which is accessible above the false ceiling for routine maintenance. In this type of plumbing, any leaks will drip onto the false ceiling which is easily detectable thus allow quick maintenance without much damage to the structure or occupied premises.

4.4 Preliminary Data for Design

4.4.1 *General*

Before the drainage system for a building or group of buildings is designed and constructed, accurate information regarding the site conditions is essential. This information may vary with the individual scheme but shall, in general, be covered by the following:

a) Site plan (*see* 3.2.2)*;*

b) Drainage plan (*see* 3.2.3);

c) *Use* — A description of the use for which the building is intended and periods of occupation in order that peak discharges may be estimated;

d) *Nature of waste* — While dealing with sewage from domestic premises, special problems under this head may not arise; however, note shall be taken of any possibility of trade effluents being discharged into the pipes at a future date;

e) *Outlet connection* — The availability of sewers or other outlets;

f) *Cover* — The depth (below ground) of the proposed sewers and drains and the nature and weight of the traffic on the ground above them;

g) *Subsoil condition*

1) The approximate level of the subsoil water, and any available records of flood levels shall be ascertained, as also the depth of the water table relative to all sewer connections, unless it is known to be considerably below the level of the latter;

2) In the case of deep manholes, this information will influence largely the type of construction to be adopted. The probable safe bearing capacity of the subsoil at invert level may be ascertained in the case of a deep manhole;

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3) Where work of any magnitude is to be undertaken, trial pits or boreholes shall be put at intervals along the line of the proposed sewer or drain and the data therefrom tabulated, together with any information available from previous works carried out in the vicinity. In general, the information derived from trial pits is more reliable than that derived from boreholes. For a long length of sewer or drain, information derived from a few trial pits at carefully chosen points may be supplemented by that obtained from number of intermediate boreholes;

Much useful information is often obtained economically and quickly by the use of a soil auger;

4) The positions of trial pits or boreholes shall be shown on the plans, together with sections showing the strata found and the dates on which water levels are recorded;

h) *Location of other services* — The position, depth and size of all other pipes, mains, cables, or other services, in the vicinity of the proposed work, may be ascertained from the Authority, if necessary;

j) *Reinstatement of surfaces* — Information about the requirements of the highway authority is necessary where any part of the sewer or drain is to be taken under a highway. Those responsible for the sewer or drain shall be also responsible for the maintenance of the surface until permanently reinstated. The written consent of the highway authority to break up the surface and arrangement as to the charges thereof and the method and type of surface reinstatement shall always be obtained before any work is commenced;

k) *Diversion and control of traffic*

1) In cases where sewers cross roads or foot-paths, cooperation shall be maintained with the police and Authorities regarding the control and diversion of vehicular and/or pedestrian traffic as may be necessary. Access to properties along the road shall always be maintained and adequate notice shall be given to the occupiers of any shops or business premises, particularly if obstruction is likely; and

2) During the period of diversion, necessary danger lights, red flags, diversion boards, caution boards, watchmen, etc, shall be provided as required by the Authority.

m) *Way-leaves* (*easements*) — The individual or authority carrying out the work is responsible for negotiating way-leaves where the sewer crosses land in other ownership. The full extend and conditions of such way-leaves shall be made known to the contractor and his employees, and prior notice of commencement of excavation shall always be given to the owners concerned, and cooperation with them shall be maintained at all stages, where sewers run across fields or open ground, the exact location of manholes shall be shown on way-leaves or easement plans. The right of access to manhole covers and the right to maintain the sewer shall be specifically included in any way-leave or easement arrangements which may be made with the owner of the land; and

n) *Damage to buildings and structures* — When sewer trenches have to be excavated near buildings or walls a joint inspection with the owners of the property shall be made to establish whether any damage or cracks exist before starting the work, and a properly authenticated survey and record of the condition of buildings likely to be affected shall be made. Tell tales may be placed across outside cracks and dated, and kept under observation. Un-retouched photographs taken by an independent photographer may provide useful evidence.

4.4.2 *Drainage into a Public Sewer*

Where public sewerage is available, the following information is particularly necessary and may be obtained from the Authority:

a) The position of the public sewer or sewers in relation to the proposed buildings;

b) The invert level of the public sewer;

c) The system on which the public sewers are designed (combined, separate or partially separate), the lowest level at which connection may be made to it, and the Authority in which it is vested;

d) The material of construction and condition of the sewer if connection is not to be made by the Authority;

e) The extent to which surcharge in the sewer may influence the drainage scheme;

f) Whether the connection to the public sewer is made, or any part of the drain laid, by the Authority, or whether the owner is responsible for this work; if the latter, whether the Authority imposes any special conditions;

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g) Whether an intercepting trap is required by the Authority on the drain near the boundary of the curtilage; and

h) Where manholes are constructed under roads, the approval of the Highway Authority for the type of cover to be fitted shall be obtained.

4.4.3 *Other Methods of Disposal of Sewage*

4.4.3.1 Where discharge into a public sewer is not possible, the drainage of the building/building campus shall be on a separate system. Foul water shall be disposed of by adequate treatment approved by the Authority on the site. The effluent from the plant shall be discharged after meeting the norms specified by the statutory authority into a natural watercourse or on the surface of the ground or disposed of subsoil dispersion preferably draining to a suitable outlet channel.

4.4.3.2 In the case of dilution into a natural stream course, the quality of the effluent shall conform and the requirements of the Authority controlling the prevention of pollution of streams.

4.4.3.3 In the case of subsoil dispersion, the requirements of the Authority for water supply shall be observed to avoid any possible pollution of local water supplies or wells.

4.4.3.4 The general subsoil water level and the subsoil conditions shall be ascertained, including the absorptive capacity of the soil.

4.4.3.5 A subsoil dispersion is not desirable near a building or in such positions that the ground below the foundations is likely to be affected.

4.4.3.6 Where no other method of disposal is possible, foul water may be diverted to cesspools and arrangements made with the Authority for satisfactory periodical removal and conveyance to a disposal works.

4.4.3.7 Under the separate system, drainage of the building shall be done through septic tanks of different sizes or by stabilization ponds or by any other treatment methods such as extended aeration activated process, sequential batch process, fluidized bio-reactors, membrane bio-reactor, submerged aerobic fixed film, rotating biological contactor, electrolyte process, etc, as approved by the Authority.

For detailed information on the design and construction of septic tanks and waste stabilization ponds, sewage treatment plants reference may be made to good practice [E-2(10)].

4.4.3.8 *Biodigester or bio-toilet* (or *eco-toilet*)

Refer **4.13.3(k)**, (*see* Fig. 5).

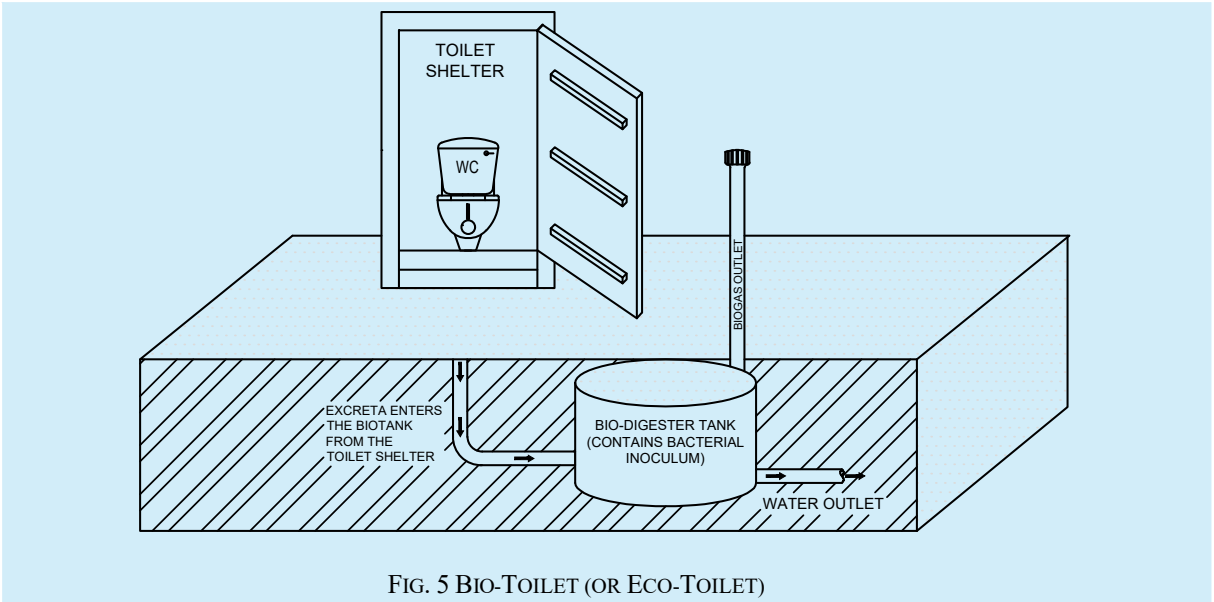

FIG. 5 BIO-TOILET (OR ECO-TOILET)

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4.4.3.9 *Packaged sewage treatment plant*

Refer **4.13.3(j)**.

4.4.4 *Disposal of Surface and Subsoil Waters*

All information which may influence the choice of methods of disposal of surface and/or subsoil waters shall be obtained. In the absence of surface water drainage system and if practicable and permissible, disposal into a natural water-course or soakaway may be adopted. The location and flood levels of the water course as also the requirements of the Authority controlling the river or the waterway shall be ascertained.

4.5 Planning and Design Considerations

4.5.1 *Aim*

The efficient disposal of foul and surface water from a building is of great importance to public health and is an essential part of the construction of the building. In designing a drainage system for an individual building or a housing colony, the aim shall be to provide a system of self-cleaning conduits for the conveyance of foul, waste, surface or subsurface waters and for the removal of such wastes speedily and efficiently to a sewer or other outlet without risk of nuisance and hazard to health. Also, intent should be to take into consideration that, waste water, storm water and solid waste are potential resources.

4.5.1.1 To achieve this aim, a drainage system shall satisfy the following requirements:

a) Rapid and efficient removal of liquid wastes without leakage;

b) Prevention of access of foul gases to the building and provision for their escape from the system.

c) Adequate and easy access for clearing obstructions;

d) Prevention of undue external or internal corrosion, or erosion of joints and protection of materials of construction; and

e) Avoidance of air locks, siphonage, proneness to obstruction, deposit and damage.

4.5.1.2 The realization of an economical drainage system is added by compact grouping of fitments in both horizontal and vertical directions. This implies that if care is taken and ingenuity brought into play when designing the original building or buildings to be drained, it is possible to group the sanitary fittings and other equipment requiring drainage; both in vertical and horizontal planes, as to simplify the drainage system and make it most economical.

4.5.1.3 Efficient and an economical plumbing system can be achieved by planning the toilets in compact grouping with the layout of the bathrooms and observing the following guidelines:

a) Placing of plumbing fixtures around an easily accessible pipe shaft; in high rise buildings the pipe shafts may have to be within the building envelope and easy provision for access panels and doors should be planned in advance, in such cases so as not to cause inconvenience during maintenance;

b) Adopting repetitive layout of toilets in the horizontal and vertical directions;

c) In planning for malls, the required public and toilet facilities shall be located not more than one storey above or below the space to be served with such facilities and the path of travel to such facilities shall not exceed 91 m;

   In other occupancies, the required public and toilet facilities shall be located not more than one storey above or below the space to be served with such facilities and the path of travel to such facilities shall not exceed 152 m.

   However, in the above buildings, toilet rooms shall not open directly into a room used for preparation of food for service to public.

d) Avoiding any conflict with the reinforced cement concrete structure by avoiding embedding pipes in it, avoiding pipe crossings in beams, columns and major structural elements;

e) Identifying open terraces and areas subject to ingress of rainwater directly or indirectly and providing for location of inlets at each level for down takes for disposal at ground levels;

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f) Avoiding crossing of services of individual property through property of other owners;

g) Planning to avoid accumulation of rainwater or any backflow from sewers particularly in planned low elevation areas in a building;

h) *Setting of sanitary fixtures* — A water closet, urinal, lavatory or bidet shall not be set closer than 380 mm from the centre to any side wall partition, vanity or other obstruction, or closer than 760 mm centre-to-centre between adjacent fixtures. There shall not be less than 530 mm clearance in front of the water closet, urinal, lavatory or bidet to any wall, fixture or door. Water closet compartment shall not be less than 760 mm in width and 1 520 mm in depth for floor mounted closets, and not less than 760 mm in width and 1 420 mm in depth for wall hung water closets;

The urinal partitions shall begin at a height not greater than 305 mm from and extend not less than 1 520 mm above the finished floor surface. The walls or partitions shall extend from the wall surface at each side of the urinal not less than 460 mm or to a point not less than 150 mm beyond the outermost front lip of the urinal measured from the finished back wall surface, whichever is greater.

j) Usually, the vertical distance between two horizontal connections to a vertical drain should be more than 200 mm in order to avoid back flow.

4.5.1.4 Typical mounting arrangements for various plumbing fixtures, including drainage systems and ventilation are illustrated in Annex D.

4.5.2 *Layout*

4.5.2.1 *General*

Rainwater should preferably be dealt separately from sewage and sullage. Sewage and sullage shall be connected to sewers. However, storm water from the courtyard may be connected to the sewer where it is not possible to drain otherwise; after obtaining permission of the authority.

4.5.2.2 *Additional requirements*

The following requirements are suggested to be considered in the design of drainage system:

a) The layout shall be as simple and direct as practicable;

b) The pipes should be laid in straight lines, as far as possible, in both vertical and horizontal planes;

c) Anything that is likely to cause irregularity of flow, such as abrupt changes of direction, shall be avoided;

d) The pipes should be non-absorbent, durable, smooth in bore and of adequate strength;

e) The pipes should be adequately supported without restricting movement;

f) Drains should be well ventilated, to prevent the accumulation of foul gases and fluctuation of air pressure within the pipe, which could lead to unsealing (siphoning) of gully or water closet traps;

g) All the parts of the drainage system should be accessible for feasibility of inspection and practical maintenance;

h) No bends and junctions whatsoever shall be permitted in sewers except at manholes and inspection chambers;

j) Sewer drain shall be laid for self-cleaning velocity of 0.75 m/s and generally should not flow more than half-full;

k) Pipes crossing in walls and floors shall be through mild steel sleeves of diameter leaving an annular space of 5 mm around the outer diameter of the pipe crossing the wall;

m) Pipes should not be laid close to building foundation;

n) Pipes should not pass near large trees because of possibility of damage by the roots;

p) Branch connections should be swept in the direction of flow;

q) Sewer pipes should be at least 900 mm below road and at least 600 mm below fields and gardens;

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r) Pipes should not pass under a building unless absolutely necessary. Where it is necessary to lay pipes under a building, the following conditions shall be observed:

1) Pipes shall be centrifugally cast (spun) iron pressure pipe as per good practice [E-2(11)];

2) The pipe shall be laid in straight line and at uniform gradient;

3) Means of access in form of manholes/inspection chamber shall be provided at each end, immediately outside the building;

4) In case the pipe or any part of it is laid above the natural surface of the ground, it shall be laid on concrete supports, the bottom of which goes at least 150 mm below the ground surface.

NOTE — It is desirable that pipe/drains should not be taken through a living room or kitchen and shall preferably be taken under a staircase room or passage.

s) Consideration shall be given to alternative layouts so as to ensure that the most economical and practical solution is adopted. The possibility of alterations shall be avoided by exercising due care and forethought.

4.5.2.3 *Protection against vermin and dirt*

The installation of sanitary fittings shall not introduce crevices which are not possible to inspect and clean readily.

Pipes, if not embedded, shall be run well clear of the wall. Holes through walls to lay pipes shall be made good on both sides to prevent entry of insects. Materials used for embedding pipes shall be rodent-proof. Passage of rodents from room-to-room or from floor-to-floor shall be prevented by suitable sealing. The intermediate lengths of ducts and chases shall be capable of easy inspection. Any unused drains, sewers, etc, shall be demolished or filled in to keep them free from rodents.

All pipe shafts shall be plastered before any pipes are installed in the shaft. It is advisable to lay pipes on the steel supports with adequate gap between plastered wall and support structure. This will provide a smooth surface and prevent location for survival of insects and vermins.

4.5.2.4 *Choice of plumbing system*

4.5.2.4.1 In selecting one or more of the type of piping systems, the building and the layout of toilets/fixtures, relationship with other services, acceptability to the Authority, and any special requirements of users, shall be studied.

a) *Single stack system* [*see* 2.73(a)]

1) The single stack system is ideal when the toilet/fixture layouts are repetitive and there is less space for pipes on the wall;

2) In any system so selected there should be not more than two toilet connections per floor;

3) The system requires minimum 100 mm diameter stack for a maximum of 5 floors in a building;

4) In this system, care shall be taken of the horizontal distance of sanitary fixtures from the drainage stack and vertical distance between connections of branches from fixtures to drainage stack; and

5) All the safeguards for the use of this system given in 4.5.2.4.2 shall be complied with.

b) *One pipe – partially ventilated system* [*see* 2.73(b)]

The system and the applicable safeguards under this system are the same as for single stack system. The prime modification is to vent the soil appliance(s).

c) *One pipe – fully ventilated system* [*see* 2.73(c)]

1) This system is suitable for buildings where the toilet/fixture layouts and the shafts are repetitive. It requires less shaft space and is economical;

2) Continuous flow of water in the pipe from waste appliances makes it less prone to blockage and makes the system more efficient;

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3) The system eliminates the need for a gully trap which requires constant cleaning;

4) This system requires individual vent pipes installed either in suspended ceiling or in the wall above the floor level in the toilet, provided construction details of the building allow provision of vent pipes for individual fixtures and routing of vent pipes to remote shafts where main vent stacks may have been located;

5) The system requires minimum 100 mm diameter stack;

6) The system is ideal when the main pipes run at the ceiling of the lowest floor or in a service floor.

d) *Two pipe system* [*see* 2.73(d)]

1) This system provides safety and flexibility in layouts for larger toilets and for buildings having higher requirement of performance due to its height and type of occupancy;

2) In large buildings and houses with open ground and gardens, the sullage water from the waste system can be suitably treated and usefully utilized for gardening and agriculture; and

3) In larger and multi-storeyed buildings, the sullage is treated within the building for reuse as makeup water for cooling towers for air conditioning system and is also used for flushing water closets provided it has absolutely no connection with any water supply line, tank or system used for domestic and drinking supply.

e) *Vacuum sewage system* — Vacuum based sewage disposal system is efficient and environmentally friendly alternative. This system is easier to construct compared to conventional systems. The system operates with a closed, leak-proof vacuum network and requires shallower excavation compared to conventional systems. It is suitable for flat terrain, high water table areas, seaside locations, and environmentally sensitive zones.

The system comprises the following:

1) House gravity connection;

2) Collection chamber with interface unit;

3) Vacuum connection and piping;

4) Vacuum station; and

5) Odour fitter and ring main.

One of the characteristic features of this system is the presence of the collection chamber. The collection chamber serves or reserve storage for a day, during any power failure.

Sewage flows by gravity into a collection chamber and remains for a short time with reserve storage availability. When the level rises, a starter valve activates the vacuum piston valve to open and to allow the sewage water with air to be derived in the vacuum network. Multiple connections can be linked to a single collection chamber.

The system can be used in the following applications:

i) Septic tank replacements;

ii) Ribbon development and new residential layouts;

iii) Villages;

iv) Industrial areas;

v) Islands;

vi) Rocky terrain; and

vii) Environmentally sensitive areas.

For detailed information regarding design and installation of soil, waste and vent pipes, reference may be made to good practice [E-2(12)].

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4.5.2.4.2 *Safeguards for single stack system*

a) As far as practicable, the fixtures on a floor shall be connected to stack in order of increasing discharge rate in the downward direction;

b) The size of the vent pipe (terminating to the outdoor) shall be same as the size of drainage stack in the case of single stack system;

c) Water closets shall be connected to the stack through a sanitary tee; the maximum horizontal distance from the stack being 2 400 mm;

d) For fixtures other than water closets, the maximum horizontal distance from the stack shall be 3 500 mm.

e) The vertical distance between the waste branch (from floor trap or from the individual appliance) and the soil branch connection, when soil pipe is connected to stack above the waste pipe, shall be not less than 200 mm;

f) Depth of water seal traps from different fixtures shall be as follows:

Water closets : 50 mm

Floor traps : 50 mm

Other fixtures directly connected to the stack:

1) Where attached to branch : 40 mm waste pipes of 75 mm dia or more

2) Where attached to branch : 75 mm waste pipes of less than 75 mm dia

NOTE — When connection is made through floor trap, no separate seals are required for individual fixtures.

g) Branches and stacks which receive discharges from WC pans should not be less than 100 mm, except where the outlet from the siphonic water closet is 80 mm, in which case a branch pipe of 80 mm may be used. For outlet of floor traps 75 mm dia pipes may be used;

h) The horizontal branch distance for fixtures from stack, bend(s) at the foot of stack to avoid back pressure as well as vertical distance between the lowest connection and the invert of drain shall be as good practice [E-2(12)]; and

j) For tall buildings, ground floor appliances are recommended to be connected directly to manhole/ inspection chamber.

4.5.2.4.2.1 Drainage stack shall be sized in accordance with Table 18. The drainage stack and branch piping shall be the vents for the drainage system. Stack shall be uniformly sized based on the total connected drainage fixture unit load.

Table 18 Single Stack Sizing

(*Clause* 4.5.2.4.2.1)

Sl No.	Stack Size	Maximum Connected Drainage Fixture Units (DFU)[2]		
	mm	Stacks Less than 23 m in Height	Stacks 23 m to Less than 49 m in Height	Stacks 49 m and Greater in Height[1]
(1)	(2)	(3)	(4)	(5)
i)	75	24	–	–
ii)	100	225	24	–
iii)	125	480	225	24
iv)	150	1 015	480	225
v)	200	2 320	1 015	480
vi)	250	4 500	2 320	1 015
vii)	300	8 100	4 500	2 320
viii)	375	13 600	8 100	4 500

[1] To be considered for one pipe – partially ventilated system only.

[2] 1 DFU may be taken as equivalent to 0.47 L/s.

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4.5.2.4.2.2 An alternative design approach for designing the single stack system is also used in some of the countries, which may be followed if approved by the Authority. Such an approach may utilize the following, and may also require reference to available specialist literature:

a) The size of the vent pipe (terminating to the outdoor) shall be same as the size of drainage stack in the case of single stack system;

b) Using branch discharge pipes, self and external siphonage of the water seal of traps can be avoided;

c) In respect of branch discharge pipes, the entire developed length including fittings up to farthest connection is 4.0 m;

d) A 45º bend shall be used for the horizontal branch pipe with a drop connection after the connection from the appliance;

e) To match the crowns of small and larger pipes, an eccentric reducer is used with straight portion on top;

f) A non-ventilated discharge pipe shall be connected to discharge stack with a sweep junction having an angle of 87º to 88.5º;

g) In respect of vertical discharge stacks, concentric or eccentric reducers may be permitted;

h) In respect of stacks not exceeding 10 m in height, from the upper most connection to change of direction, no branch discharge pipe shall be connected to the stack or horizontal side for a distance of 1.0 m. In respect of second change in direction, no branch discharge pipe shall be connected within a distance of 0.5 m after the change of direction. The pipe stack shall not be connected to sanitary appliances from the lowest floor;

j) In respect of stacks exceeding 10 m in height, from the upper most connection to change of direction, no branch discharge pipe shall be connected to the stack or horizontal side for a distance of 2.0 m. The connection of the ventilated branch to the main stack shall not be within 2.0 m from the change of direction. In respect of second change in direction, no branch discharge pipe shall be connected within a distance of 0.5 m after the change of direction. The pipe stack shall not be connected to sanitary appliances from the lowest floor;

k) The connection of branch discharge pipes to the vertical stack shall be such that back flow will not cross flow into fixtures on the opposite ends; and

m) The single stack system shall be designed and installed based on the principles of sanitary appliance usage, proper dimensioning, and installation guidelines.

4.5.3 *Drainage* (*Soil*, *Waste and Vent*) *Pipes*

4.5.3.1 *General considerations*

4.5.3.1.1 Drainage pipes shall be kept clear of all other services. Provisions shall be made during the construction of the building for the entry of the drainage pipes. In most cases this may be done conveniently by installing sleeves or conduit pipes into or under the structure in appropriate positions. This will facilitate the installation and maintenance of the services.

4.5.3.1.2 Horizontal drainage piping should be so routed as not to pass over any equipment or fixture where leakage from the line could possibly cause damage or contamination. Drainage piping shall never pass over switch-gear or other electrical equipment. If it is impossible to avoid these areas and piping shall run in these locations, then a pan or drain tray should be installed below the pipe to collect any leakage or condensation. A drain line should run from this pan to a convenient floor drain or service sink.

4.5.3.1.3 All vertical soil, waste, ventilating and anti-siphonage pipes shall be covered on top with a copper or heavily galvanized iron wire dome or cast iron terminal guards. All cast iron pipes, which are to be painted periodically, shall be fixed to give a minimum clearance of 50 mm clear from the finished surface of the wall by means of a suitable clamp.

NOTE — Asbestos cement cowls may be used in case asbestos cement pipes are used as soil pipes.

4.5.3.1.4 Drainage pipes shall be carried to a height above the buildings as specified for ventilating pipe (*see* 4.5.3.4).

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4.5.3.2 *Soil pipes*

A soil pipe, conveying to a drain, any solid or liquid filth, shall be circular and shall have a minimum diameter of 100 mm.

4.5.3.2.1 Except where it is impracticable, the soil pipe shall be situated outside the building or in suitably designed pipe shafts and shall be continued upwards without diminution of its diameter, and (except where it is unavoidable) without any bend or angle, to such a height and position as to afford by means of its open end a safe outlet for foul air. The position of the open end with its covering shall be such as to comply with the conditions set out in **4.5.3.4** relating to ventilating pipe. Even if the pipes are laid externally, the soil pipes shall not be permitted on a wall abutting a street unless the Authority is satisfied that it is unavoidable. Where shafts for pipes are provided, the cross section area of the shaft shall be suitable to allow free and unhampered access to the pipes and fittings proposed to be installed in the shaft. However, in no case cross section area of the shaft shall be less than a square of one-meter side. All pipe shafts shall be provided with an access door at ground level and facilities for shaft ventilation.

4.5.3.2.2 Soil pipes, whether inside or outside the building, shall not be connected with any rainwater pipe and there shall not be any trap in such soil pipe or between it and any drain with which it is connected.

4.5.3.2.3 The soil pipe shall be provided with heel rest bend which shall rest on sound footing, if terminating at firm ground level. When the stack is terminating at the ceiling of a floor, the bend shall be provided with sufficient structural support to cater for the stack dead weight and the thrust developed from the falling soil/waste. Vertical stack shall be fixed at least 50 mm clear of the finished surface of the wall by means of a suitable clamp of approved type.

4.5.3.3 *Waste pipes*

Every pipe in a building for carrying off the waste or overflow water from every bath, wash basin or sink to a drain shall be of 32 mm to 50 mm diameter, and shall be trapped immediately beneath such wash basins or sink by an efficient siphon trap – P trap with adequate means for inspection and cleaning. Such P traps shall be ventilated into the external air whenever such ventilation is necessary to preserve the seal of the trap. Waste pipes, P traps, etc, shall be constructed of iron, lead, brass, PVC, engineering plastics, stoneware, asbestos cement or other approved material. The overflow pipe from wash basin, sinks, etc, shall be connected with the waste pipe immediately above the trap. Vertical pipes carrying off waste water shall have a minimum diameter of 75 mm.

NOTE — Whenever wash basins and sinks have in-built overflow arrangements, there is no need to provide overflow pipes in such cases.

4.5.3.3.1 Every pipe in a building for carrying off waste water to a drain shall be taken through an external wall of the building by the shortest practicable line, and shall discharge below the grating or surface box of the chamber but above the inlet of a properly trapped gully. The waste pipe shall be continued upwards without any diminution in its diameter and (except when unavoidable) without any bend or angle to such a height and position as to afford by means of the open end of the waste pipe, a safe outlet for foul air, the position of the open end and its covering being such as to comply with the conditions.

4.5.3.3.2 Except where it is impracticable, the common waste pipe shall be situated outside the building and shall be continued upwards without diminution of its diameter (except where it is unavoidable) without any bend or angle being formed to such a height and position as to avoid by means of the open end a safe outlet for foul air, the position of the open end and the covering threat being such as to comply with the conditions set out in **4.5.3.4** relating to ventilating pipe.

4.5.3.3.3 If the waste pipe is of cast iron, it shall be firmly attached 50 mm clear of the finished surface of the wall by means of a suitable clamps or with properly fixed holder bats or equally suitable and efficient means.

4.5.3.4 *Vent pipes*

Ventilating pipes should be so installed that water cannot be retained in them. They should be fixed vertically. Whenever possible, horizontal runs should be avoided. Ventilating pipe shall be carried to such a height and in such a position as to afford by means of the open end of such pipe or vent shaft, a safe outlet for foul air with the least possible nuisance.

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4.5.3.4.1 The upper end of the main ventilating pipe may be continued to the open air above roof level as a separate pipe, or it may join the MSP and/or MWP above the floor level of the highest appliance. Its lower end may be carried down to join the drain, at a point where air relief may always be maintained.

4.5.3.4.2 Branch ventilating pipes should be connected to the top of the BSP and BWP between 75 mm and 450 mm from the crown of the trap.

4.5.3.4.3 The ventilating pipe shall always be taken to a point 1 500 mm above the level of the eaves or flat roof or terrace parapet whichever is higher or the top of any window within a horizontal distance of 3 m. The least dimension shall be taken as a minimum and local conditions shall be taken into account. The upper end of every ventilating pipe shall be protected by means of a cowl.

4.5.3.4.4 In case the adjoining building is taller, the ventilating pipe shall be carried higher than the roof of the adjacent building, wherever it is possible.

4.5.3.4.5 The building drain intended for carrying waste water and sewage from a building shall be provided with at least one ventilating pipe situated as near as practicable to the building from an inspection chamber and as far away as possible from the point at which the drain empties into the sewer or other carrier.

4.5.3.4.6 *Size of ventilating pipe*

a) The building drain ventilating pipe shall be of not less than 75 mm diameter. When, however, it is used as MSP or MWP, the upper portion, which does not carry discharges, shall not be of lesser diameter than the remaining portion;

b) The diameter of the main ventilating pipe in any case should not be less than 50 mm;

c) A branch ventilating pipe on a waste pipe in both one and two-pipe systems shall be of not less than two-thirds the diameter of the branch waste pipe, subject to a minimum of 25 mm;

d) A branch ventilating pipe on a soil pipe in both one and two-pipe systems shall be not less than 32 mm in diameter; and

e) Ventilating pipes to be sized/designed considering the drainage fixture units of individual fixtures/appliances as per good engineering practices (*see* 4.5.3.4.7).

4.5.3.4.7 *Venting system for high rise buildings*

In the case of fully ventilated system, suitable sized pipe stacks carry soil and waste drainage, wherein each sanitary fixture is individually vented. The practical way of implementation of this system is by venting each water closet and floor drain. A fully ventilated one pipe drainage system is most popular in advanced plumbing installations.

Properly sized ventilating pipe would ensure maintenance of atmospheric pressure within gravity drainage pipes.

Sizing of ventilating pipe is based on cumulative drainage fixture units of all fixtures served by the pipe. Sizing also depends on maximum permissible lengths. Maximum lengths are also subject to the limitation that one-third of length shall be horizontal. Horizontal pipes always rise towards termination point, avoiding vertical loops.

The minimum required diameter of stack vents and vent stacks shall be determined from the developed length and the total drainage fixture units (DFU) connected thereto, in accordance with Table 19. However, in no case, the diameter shall be less than half the diameter of the drain served or less than 32 mm.

NOTE — In case, if fully ventilated one-pipe system is not implemented then it shall indicate the case of two-pipe system along with common ventilating pipe for which the guideline for sizing shall be provided. Also, it shall provide a sketch for two-pipe system along with connection of branch pipes from wash basin to the deep seal trap through inlet fitting as per prevailing conditions as approved by Authority.

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Table 19 Size and Developed Length of Stack Vents and Vent Stacks

(*Clause* 4.5.3.4.7)

Sl No.	Diameter of Soil and/or Waste Stack mm	Total Fixture Units Being Vented (DFU)	Maximum Developed Length of Vent for the Diameter of Vent m										
			32 mm	40 mm	50 mm	65 mm	75 mm	100 mm	125 mm	150 mm	200 mm	250 mm	300 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	32	2	9	–	–	–	–	–	–	–	–	–	–
ii)	40	8	15	45	–	–	–	–	–	–	–	–	–
iii)	40	10	9	30	–	–	–	–	–	–	–	–	–
iv)	50	12	–	23	61	–	–	–	–	–	–	–	–
v)	50	20	9	15	45	–	–	–	–	–	–	–	–
vi)	65	42	8	9	30	91	–	–	–	–	–	–	–
vii)	75	10	–	13	45	110	317	–	–	–	–	–	–
viii)	75	21	–	10	34	82	247	–	–	–	–	–	–
ix)	75	53	–	8	29	70	207	–	–	–	–	–	–
x)	75	102	–	–	26	64	189	–	–	–	–	–	–
xi)	100	43	–	8	11	26	76	299	–	–	–	–	–
xii)	100	140	–	–	8	20	61	229	–	–	–	–	–
xiii)	100	320	–	–	7	17	52	195	–	–	–	–	–
xiv)	100	540	–	–	6	15	46	177	–	–	–	–	–
xv)	125	190	–	–	–	8.5	25	98	302	–	–	–	–
xvi)	125	490	–	–	–	6.4	19	76	232	–	–	–	–
xvii)	125	940	–	–	–	5.5	16	64	204	–	–	–	–
xviii)	125	1 400	–	–	–	4.9	15	58	180	–	–	–	–
xix)	150	500	–	–	–	–	10	40	122	305	–	–	–
xx)	150	1 100	–	–	–	–	8	30	94	238	–	–	–
xxi)	150	2 000	–	–	–	–	7	26	79	201	–	–	–

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Table 19 (*Concluded*)

Sl No.	Diameter of Soil and/or Waste Stack mm	Total Fixture Units Being Vented (DFU)	Maximum Developed Length of Vent for the Diameter of Vent m										
			32 mm	40 mm	50 mm	65 mm	75 mm	100 mm	125 mm	150 mm	200 mm	250 mm	300 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
xxii)	150	2 900	–	–	–	–	6	23	73	183	–	–	–
xxiii)	200	1 800	–	–	–	–	–	9	29	73	287	–	–
xxiv)	200	3 400	–	–	–	–	–	7	22	58	222	–	–
xxv)	200	5 600	–	–	–	–	–	6	19	49	186	–	–
xxvi)	200	7 600	–	–	–	–	–	5	17	43	171	–	–
xxvii)	250	4 000	–	–	–	–	–	–	9	24	94	293	–
xxviii)	250	7 200	–	–	–	–	–	–	7	18	73	226	–
xxix)	250	11 000	–	–	–	–	–	–	6	16	61	192	–
xxx)	250	15 000	–	–	–	–	–	–	5	14	55	174	–
xxxi)	300	7 300	–	–	–	–	–	–	–	9	37	116	287
xxxii)	300	13 000	–	–	–	–	–	–	–	7	29	91	219
xxxiii)	300	20 000	–	–	–	–	–	–	–	6	24	76	186
xxxiv)	300	26 000	–	–	–	–	–	–	–	5	22	70	152
xxxv)	375	15 000	–	–	–	–	–	–	–	–	12	40	94
xxxvi)	375	25 000	–	–	–	–	–	–	–	–	9	29	73
xxxvii)	375	38 000	–	–	–	–	–	–	–	–	8	25	61
xxxviii)	375	50 000	–	–	–	–	–	–	–	–	7	23	55

NOTE — The developed length shall be measured from the vent connection to the open air.

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4.5.3.5 *Design of drainage pipes*

A stack is the main vertical pipe that carries away discharge from water closets and urinals (soil stack) or other clear wastewater from equipment (waste stack) with adequate suitable fittings, which may be a long-turn, tee-wye or short-turn or sanitary tee. Special fittings may also be used, provided that their drainage capacity has been certified in accordance with the relevant Indian Standards or by approved laboratories. Depending on the rate of flow into the drain stack, the diameter of the stack, the type of stack fittings and the flow down the stack from higher levels (if any), the discharge from the fixture drain may or may not fill the cross section of the stack at the level of entry. In any event, as soon as the water enters the stack, the force of gravity rapidly accelerates it downward and before it travels very far, it assumes the form of a sheet around the wall of the stack, leaving the centre of the pipe open for the flow of air.

This sheet of water continues to accelerate until the frictional force exerted by the wall of the falling sheet of water equals the gravitational force. If the distance the water travel is sufficient enough and provided that no flow enters the stack at lower levels to interfere the sheet, the sheet remains unchanged in thickness and velocity until it reaches the bottom of the stack. The ultimate vertical velocity the sheet attains is called the 'terminal velocity'. The distance the sheet should fall to attain this terminal velocity is called the 'terminal length'.

Following formulae may be used for calculating the terminal velocity and terminal length:

$$V_t = 3.0\ (Q/d)^{2/5}$$

$$L_t = 0.052\ V_t^2$$

where

V_t = terminal velocity in the stack, m/s;

Q = quantity rate of flow, l/s;

d = diameter of stack, mm; and

L_t = terminal length below the point of flow entry, m;

At the centre of the stack is a core of air that is dragged along with the water by friction. A supply source of air shall be provided to avoid excessive pressures in the stack. The usual means of supplying this air are through the stack vent or vent stack. The entrained air in the stack causes a pressure reducing inside the stack, which is caused by the frictional effect of the falling sheet of water dragging the core of air with it.

4.5.3.5.1 *Estimation of maximum flow of sewer*

a) *Simultaneous discharge flow*

1) The maximum flow in a building drain or a stack depends on the probable maximum number of simultaneous discharging appliances. For the calculation of this peak flow certain loading factors have been assigned to appliances in terms of fixture units, considering their probability and frequency of use. These fixture unit values are given in Table 20;

2) For any fixtures not covered under Table 20, Table 21 may be referred to for deciding their fixture unit rating depending on their drain or trap size;

3) From Table 20 and Table 21, the total load on any pipe in terms of fixtures units may be calculated knowing the number and type of appliances connected to this pipe;

4) For converting the total load in fixture units to the peak flow in litre per minute, Fig. 6 is to be used.

5) The maximum number of fixture units that are permissible for various recommended pipe size in the drainage system are given in Table 22 and Table 23; and

6) Results should be checked to see that the soil, waste and building sewer pipes are not reduced in diameter in the direction of flow. Where appliances are to be added in fixture, these should be taken into account in assessing the pipe sizes by using the fixture units given in Table 20 and Table 21.

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b) *Maximum discharge flow* — The maximum rate of *discharge* flow shall be taken as thrice the average rate; allowance being made in addition for any exceptional peak discharges. A good average rule is to allow for a flow of liquid wastes from buildings at the rate of 3 litre per minute per 10 persons.

4.5.3.5.2 *Gradients*

4.5.3.5.2.1 The discharge of water through a domestic drain is intermittent and limited in quantity and, therefore, small accumulations of solid matter are liable to form in the drains between the building and the public sewer. There is usually a gradual shifting of these deposits as discharges take place. Gradients should be sufficient to prevent these temporary accumulations building up and blocking the drains:

a) *Drainage loads* — Single family dwellings contain plumbing fixtures, such as one or more bathroom groups, each consisting of a toilet, wash basin and bathtub or shower unit, a kitchen sink, dishwasher and washing machine. Large buildings also have other fixtures, slop sinks and drinking water coolers. The important characteristic of these fixtures is that they are not used continuously. Rather, they are used with irregular frequencies that vary greatly during the day. In addition, the various fixtures have quite different discharge characteristics regarding both the average flow rate per use and the duration of a single discharge. Consequently, the probability of all the fixtures in the building operating simultaneously is small; and

b) *Stack capacities* — The criterion of flow capacities in drainage stacks is based on the limitation of the water occupied cross section to a specified fraction of the cross section of the stack where terminal velocity exists, as suggested by earlier investigations.

Flow capacity can be expressed in terms of the stack diameter and the water cross section, as follows:

$$Q = 27.8 \times r_s^{5/3} \times D^{8/3}$$

where

Q = capacity, l/s;

r_s = ratio of the cross-sectional area of the sheet of water to the cross-sectional area of the stack; and

D = diameter of the stack, mm.

Table 20 Drainage Fixture Units (DFU) for Different Fixtures with Minimum Pipe Sizes

(*Clause* 4.5.3.5.1)

Sl No.	Type of Fixture	Application		Minimum Trap Size mm
		Private	Public	
(1)	(2)	(3)	(4)	(6)
i)	Bathroom group (water closet, wash basin, bidet and tub or shower):			
	a) Water closet (flush valve)	8	–	–
	b) Water closet (flush tank)	6	–	–
ii)	Bathtub	3	–	40
iii)	Bar sink	1	2	40
iv)	Ablution faucet/Bidet	1	2	40
v)	Clothes washer	3	3	50
vi)	Dishwasher	2	2	40
vii)	Drinking fountain	–	0.5 (0.75)	32
viii)	Floor drain	1	2	50

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Table 20 (*Concluded*)

Sl No.	Type of Fixture	Application		Minimum Trap Size mm
		Private	Public	
(1)	(2)	(3)	(4)	(6)
ix)	Wash basin	1	1	32
x)	Service or mop basin/sink	–	3	50
xi)	Kitchen sink	2	2	40
xii)	Shower	2	2	50
xiii)	Laundry sink	2	2	40
xiv)	Clinical or surgeon's scrub sink	–	6	80
xv)	Urinal (with flush valve)	2	2	50
xvi)	Urinal (with flush tank)	2	2	50
xvii)	Urinal with sensor operated	2	2	50
xviii)	Water closet (flush valve)	4	6 (8)	80
xix)	Water closet (flush tank)	3	4 (6)	80
xx)	Combination fixture (faucet)	1	2	40

NOTES

1 A shower head over a bath tub does not increase the fixture unit value.

2 Size of floor trap shall be determined by the area of surface water to be drained.

3 Wash basins with 32 mm and 40 mm trap have the same load value.

4 Trap size shall be consistent with the fixture outlet size.

5 For fixtures added to bathroom group, the DFU value is added to those additional fixtures to the bathroom group fixture count.

6 No floor traps to be provided inside operating rooms, procedure rooms, AIIR isolation rooms and PE isolation rooms.

7 The values given in parentheses pertain to such public use buildings where an enhanced requirement is expected to be encountered as compared to the normal maximum use in public use buildings.

Table 21 Fixture Unit Values for Fixtures Based on Fixture Drain on Trap Size

(*Clause* 4.5.3.5.1)

Sl No.	Fixture Drain on Trap Size	Fixture Unit Value
(1)	(2)	(3)
i)	32 mm and smaller	1
ii)	40 mm	2
iii)	50 mm	3
iv)	65 mm	4
v)	80 mm	5
vi)	100 mm	6

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Table 22 Horizontal Fixture Branches and Stacks[1)]

(*Clause* 4.5.3.5.1)

Sl No.	Diameter of Pipe	Maximum Number of Drainage Fixture Units[2)] (DFU) that can be Connected to			
		Branch Total for Horizontal Branch	Stacks[3)]		
	mm		Total Discharge into One Branch Interval	Total for Stack of Three Branch Intervals or Less	Total for Stack Greater than Three Branch Intervals
(1)	(2)	(3)	(4)	(5)	(6)
i)	32	1	2	2	2
ii)	40	3	2	4	8
iii)	50	6	6	10	24
iv)	65	12	9	20	42
v)	75	20	20	48	72
vi)	100	160	90	240	500
vii)	125	360	200	540	1 100
viii)	150	620	350	960	1 900
ix)	200	1 400	600	2 200	3 600
x)	250	2 500	1 000	3 800	5 600
xi)	300	3 900	1 500	6 000	8 400
xii)	375	7 000	*See* Note	*See* Note	*See* Note

NOTE — Sizing load based on design criteria.

[1)] Does not include branches of the building sewer.

[2)] Depending upon the probability of simultaneous use of appliances considering the frequency of use and peak discharge rate.

[3)] Stacks shall be sized based on the total accumulated connected load at each story or branch interval. As the total accumulated connected load decreases, stacks are permitted to be reduced in size. Stack diameters shall not be reduced to less than one-half of the diameter of the larger stack size required.

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Table 23 Building Drains and Sewers[1)]

(*Clause* 4.5.3.5.1)

Sl No.	Diameter of Pipe	Maximum Number of Drainage Fixture Units (DFU) that can be Connected to any Portion of the Building Drain or the Building Sewer Including Branches of the Building Drain[2)], for Slope			
	mm	1/200	1/100	1/50	1/25
(1)	(2)	(3)	(4)	(5)	(6)
i)	32	–	–	1	1
ii)	40	–	–	3	3
iii)	50	–	–	21	26
iv)	65	–	–	24	31
v)	75	–	36	42	50
vi)	100	–	180	216	250
vii)	125	–	390	480	575
viii)	150	–	700	840	1 000
ix)	200	1 400	1 600	1 920	2 300
x)	250	2 500	2 900	3 300	4 200
xi)	300	3 900	4 600	5 600	6 700
xii)	375	7 000	8 300	10 000	12 000

[1)] Includes branches of the building sewer.

[2)] The minimum size of any building drain serving a water closet shall be 75 mm.

c) *Design requirement for high rise buildings drainage system* — Drainage pipe stacks are sized for one third of their carrying capacity. Plumbing codes provides values of drainage fixture units for each fixture. Different values for fixture units are based on the nature of occupancy and the place of installation. Sizing of drainage pipes is based on the cumulative values of drainage fixture units connected to the pipe. A vertical pipe shall always have larger carrying capacity when compared to horizontal pipe of same size. Carrying capacity of horizontal pipe is dependent on gradient provided. Carrying capacities of vertical pipes are restricted by their maximum permissible lengths. This restriction does not apply to horizontal pipes. Irrespective of drainage fixture units, the minimum size for the fixture shall be adopted. The minimum size of horizontal pipe is critical to ensure self cleansing velocities in sewers.

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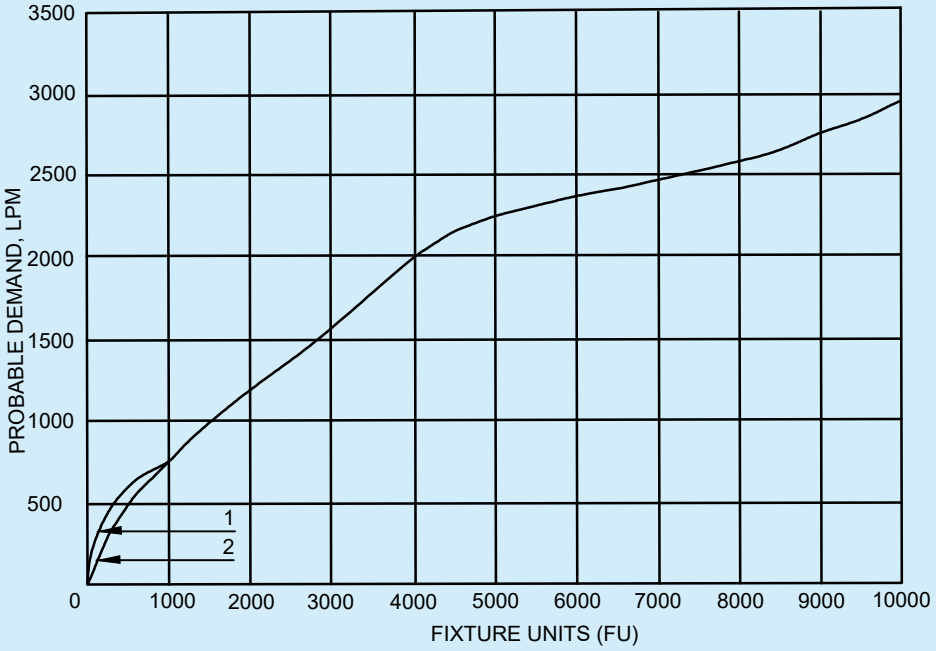
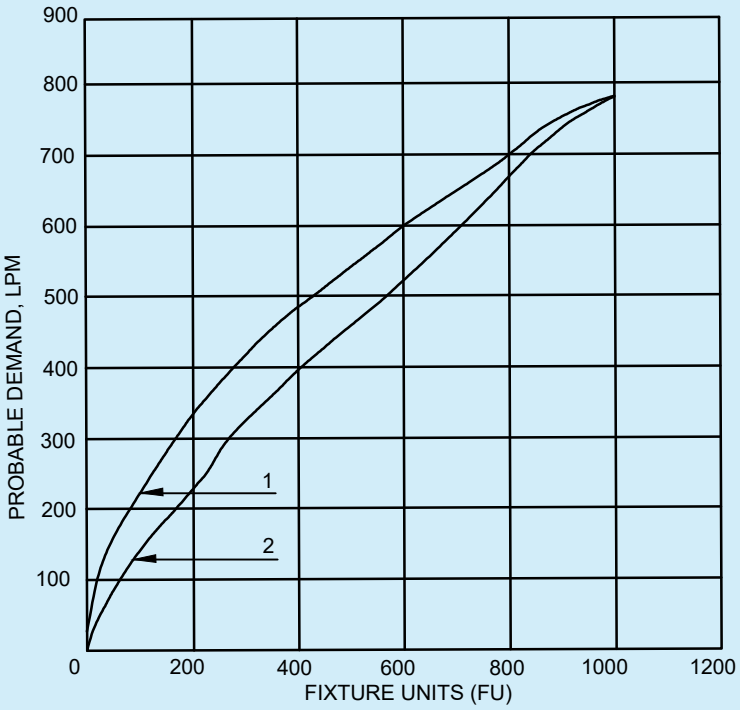


6A GRAPH FOR PROBABLE DEMAND UP TO 10 000 FU



6B GRAPH FOR PROBABLE DEMAND UP TO 1000 FU

CURVE 1 - SYSTEM WITH FLUSH VALVES
CURVE 2 - SYSTEM WITH FLUSH TANKS

FIG. 6 GRAPH FOR PROBABLE DEMAND

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4.5.3.5.2.2 When flow occurs in drain piping, it should not entirely fill the cross section of the pipe under flow condition. If the pipe were to flow full, pressure fluctuations would occur which could possibly destroy the seal of the traps within the building. Normally, the sewer shall be designed for discharging the peak flow as given in 4.5.3.5.1, flowing half-full with a minimum self-cleansing velocity of 0.75 m/s. The approximate gradients which give this velocity for the sizes of pipes likely to be used in building drainage and the corresponding discharges when following half-full are given in Table 24.

4.5.3.5.2.3 In cases where it is practically not possible to conform to the ruling gradients, a flatter gradient may be used, but the minimum velocity in such cases shall on no account be less than 0.61 m/s and adequate flushing should be done.

NOTE — Where gradients are restricted, the practice of using a pipe of larger diameter than that required by the normal flow, in order to justify laying at a flatter gradient does not result in increasing the velocity of flow, further this reduces the depth of flow and thus for this reasons the above mentioned practice should be discouraged.

4.5.3.5.2.4 On the other hand, it is undesirable to employ gradients giving a velocity of flow greater than 2.4 m/s. Where it is unavoidable, cast iron pipes shall be used. The approximate gradients, which give a velocity of 2.4 m/s for pipes of various sizes and the corresponding discharge when flowing half-full are given in Table 24.

4.5.3.5.2.5 The discharge values corresponding to nominal diameter and gradient given in Table 24 are based on Manning's formula (n = 0.015).

NOTE — Subject to the minimum size of 100 m, the sizes of pipes shall be decided in relation to the estimated quantity of flow and the available gradient.

Table 24 Different Diameter Pipes Giving Velocity and Corresponding Discharge at Minimum and Maximum Gradient

(*Clauses* 4.5.3.5.2.2, 4.5.3.5.2.4 *and* 4.5.3.5.2.5)

Sl No.	Diameter	Minimum Gradient (Velocity : 0.75 m/s)	Discharge at the Minimum Gradient	Maximum Gradient (Velocity : 2.4 m/s)	Discharge at the Maximum Gradient
	(mm)		m^3/min		m^3/min
(1)	(2)	(3)	(4)	(5)	(6)
i)	100	1 in 57	0.18	1 in 5.6	0.59
ii)	150	1 in 100	0.42	1 in 9.7	1.32
iii)	200	1 in 145	0.73	1 in 14	2.40
iv)	230	1 in 175	0.93	1 in 17	2.98
v)	250	1 in 195	1.10	1 in 19	3.60
vi)	300	1 in 250	1.70	1 in 24.5	5.30

4.5.3.6 *Drain appurtenances*

4.5.3.6.1 *Trap*

All traps shall be protected against siphonage and back pressure ensuring access to atmospheric air for air circulation and preserving the trap seal in all conditions.

4.5.3.6.1.1 A trap may be formed as an integral trap with the appliance during manufacture or may be a separate fitting called an attached trap which may be connected to the waste outlet of the appliance.

4.5.3.6.1.2 Traps should always be of a self-cleansing pattern. A trap, which is not an integral part of an appliance, should be directly attached to its outlet and the pipe should be uniform throughout and have a smooth surface.

4.5.3.6.1.3 The trap should have minimum size of outlet/exit, same as that of largest waste inlet pipe.

4.5.3.6.1.4 Traps for use in domestic waste installations and all other traps should be conveniently accessible and provided with cleansing eyes or other means of cleaning.

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4.5.3.6.1.5 The minimum internal diameter for sanitary appliances shall be as follows:

Sl No.	*Sanitary Appliance*	*Minimum Internal Diameter of Waste Outlet* mm
(1)	(2)	(3)
i)	*Soil appliances:*	
	a) Indian and European type water closets	100
	b) Bed pan washers and slop sinks	100
	c) Urinal with integral traps	75
	d) Stall urinals (with not more than 120 mm of channel drainage)	50
	e) Lipped urinal small/large	40
ii)	*Waste appliances:*	
	a) Drinking fountain	25
	b) Wash basin	32
	c) Bidets	32
	d) Domestic sinks and baths	40
	e) Shower bath trays	40
	f) Domestic bath tubs	50
	g) Hotel and canteen sinks	50
	h) Floor traps (outlet diameter)	75

4.5.3.6.2 *Floor drains*

All toilets/bathrooms in a building desirably should be provided with floor drains to facilitate cleaning.

4.5.3.6.2.1 Floor drains shall connect into a trap so constructed that it can be readily cleaned and of a size to serve efficiently the purpose for which it is intended. The trap shall be either accessible from the floor drain or by a separate cleanout within the drain.

4.5.3.6.2.2 Floor drain also receives, waste piping which does not connect to the sanitary system, known as indirect waste. This discharge from an indirect waste should be conveyed into a water supplied, trapped and vented floor drain.

4.5.3.6.2.3 Floor drain should be provided in mechanical equipment rooms, where pumps, boilers, water chillers, heat exchangers and other air conditioning equipment are periodically drained for maintenance and repair. Boiler requires drain at safety relief valve discharge.

4.5.3.6.2.4 Strategically floor drains are required to be located in buildings with wet fire protection sprinkler systems to drain water in case of activation of sprinkler heads.

4.5.3.6.2.5 The minimum diameter for floor drains outlets before connecting to floor trap is 75 mm.

4.5.3.6.3 *Cleanouts*

The cleanout provides access to horizontal and vertical lines and stacks to facilitate inspection and means to remove obstructions common to all piping systems, such as solid objects, greasy wastes, hair and the like.

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4.5.3.6.3.1 Cleanouts in general should be gas and water tight, provide quick and easy plug removal, allow ample space for rodding tools, have means of adjustments to finished floor level, be attractive and be designed to support whatever load is directed over them.

4.5.3.6.3.2 Waste lines are normally laid beneath the floor slab at a sufficient distance to provide adequate back-fill over the joints. Cleanouts are then brought up to floor level grade by pipe extension pieces.

4.5.3.6.3.3 The size of the cleanout within a building should be the same size as the piping up to 100 mm. For larger size piping 100 mm cleanouts are adequate for their intended purpose.

4.5.3.6.3.4 Cleanouts are suggested to be provided at the following locations:

a) Inside the building at a point of exit. Use a wye branch or a trap;

b) At every change of direction greater than 45°;

c) At the base of all stacks; and

d) At the horizontal header, receiving vertical stacks and serving the purpose of offset header.

4.5.3.6.3.5 *Supports for drainage and sewerage pipes*

The supports for the above pipes and fittings shall be in accordance with manufacturer's recommendations and shall comply with the applicable standards.

4.5.4 *Indirect Wastes*

4.5.4.1 *General*

Waste, overflow and drain pipes from the following types of equipment shall not be connected into any drainage system directly to prevent backflow from the drainage system into the equipment/installation:

a) *Plumbing and kitchen appliances*:
   1) Underground or overhead water tanks;
   2) Drinking water fountains;
   3) Dishwashing sinks and culinary sinks used for soaking and preparation of food;
   4) Cooling counters for food and beverages;
   5) Kitchen equipment for keeping food warm; and
   6) Pressure drainage connections from equipment.

b) *Air conditioning, heating and other mechanical equipment*:
   1) Air handling equipment;
   2) Cooling tower and other equipment;
   3) Condensate lines from equipment;
   4) Storage tanks;
   5) Condensate lines;
   6) Boiler blow down lines; and
   7) Steam trap drain lines.

c) *Laboratories and other areas:*
   1) Water stills;
   2) Waste from laboratory in specified sinks;
   3) Sterlizers and similar equipment; and
   4) Water purification equipment.

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4.5.4.2 *Indirect waste receptors*

All plumbing fixtures or other receptors receiving the discharge of indirect waste pipes shall be of such shape and capacity as to prevent splashing or flooding and shall be located where they are readily accessible for inspection and cleaning.

4.5.4.3 *Pressure drainage connections*

Indirect waste connections shall be provided for drains, overflows or relief vents from the water supply system, and no piping or equipment carrying wastes or producing wastes or other discharges under pressure shall be directly connected to any part of the drainage system.

The above shall not apply to any approved sump pump or to any approved plumbing fixture discharging pressurized waste or device when the Authority has been satisfied that the drainage system has the capacity to carry the waste from the pressurized discharge.

An indirect waste is required for any type of fixture or equipment that may come in contact with the food. The purpose is to isolate the fixture or equipment from drainage system waste.

Indirect waste piping shall be a minimum of 25 mm in size, but not smaller than drain of the equipment or fixture. There is no limitation on the length of indirect waste piping.

4.5.5 *Special Wastes*

4.5.5.1 *General*

Wastes having characteristics which may be detrimental to the pipes in which it is disposed as well as to the persons handling it. Such wastes used in a building need to be specially identified and a suitable and safe method of its disposal installed to ensure that the piping system is not corroded nor the health and safety of the occupants is affected in any way.

Whenever the occupant or the user of any wastes is unaware of the dangers of the consequences of disposing the waste, he shall be made aware of the dangers of his action along with providing suitable warning and instruction for correct disposal be provided to him.

Piping system for all special wastes should be separate and independent for each type of waste and should not be connected to the building drainage system. Other applicable provisions for installation of soil and waste pipe system shall be however be followed.

4.5.5.2 *Laboratory wastes*

A study of the possible chemical and corrosive and toxic properties of wastes handled and disposed of in a laboratory need to be ascertained in advance. The relevant statutory rules and regulation regarding the method of disposal of strong and objectionable wastes shall be followed.

All sinks, receptacles, traps, pipes, fittings and joints shall be of materials resistant to the liquids disposed of in the system.

In laboratories for educational, research and medical institutions, handling mildly corrosive and toxic wastes, they may be neutralized in chambers using appropriate neutralizing agents. The chamber shall be provided with chambers at inlet and outlet for collecting samples of the incoming and outgoing waste for monitoring its characteristics.

4.5.5.3 *Infected wastes*

Infected liquid wastes are generated in hospitals from patient excreta, operation theatres, laboratories testing samples of stools, urine, blood, flesh, etc, which shall not be disposed of into the drainage system. Such waste shall be collected separately and pre-treated, and sterilized, if required, before disposal into the building drainage system.

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Soiled linen from infectious patients needs to be collected from the respective areas of the hospital in separate linen bins and pre-washed in dirty utility room in a sluice tub and sterilized in the laundry (sluice machine) before its regular washing in the hospital laundry. Liquid wastes from the washing operations shall be neutralized to prevent any cross contamination before discharge in the building's drainage system.

4.5.5.4 *Research laboratory wastes*

Research laboratories conducting research in all areas of science and technology, for example, chemical industry, pharmacy, metallurgy, bio-sciences, agriculture, atomic energy, medicine, etc, shall follow the established procedures laid down by statutory bodies to handle, treat and dispose wastes which are highly toxic, corrosive, infectious, inflammable, explosive and having bacterial cultures, complex organic and inorganic chemicals. Such wastes shall not be disposed of in a building drainage system or the city sewerage system unless they are pre-treated and meet the disposal criteria in accordance with the relevant rules/regulations.

It requires a liquid waste decontamination system which consists of at least one reactor or sterilizer plus a holding tank. An ideal system would consist of two or more sterilizers to provide redundancy with two or more tanks. There should be a sampling tank between this system and building drainage. The final treated waste water should flow to ETP and not STP.

4.5.6 *Grease Traps*

Oil and grease are found in wastes generated from kitchens in hotels, industrial canteens, restaurant, food and beverage areas, butcheries, some laboratories and manufacturing units having a high content of oil and greases in their final waste.

Waste exceeding temperature of 60 ºC should not be allowed in the grease trap. When so encountered, it may be allowed to cool in a holding chamber before entering the grease trap.

Oil and greases tend to solidify as they cool within the drainage system. The solidified matter clogs the drains and the other matter in the waste stick to it due to the adhesion properties of the grease. Oil and greases are lighter than water and tend to float on the top of the wastewater.

Grease traps shall be installed in building having the above types of wastes. In principle the grease laden water is allowed to retain in a grease trap which enables any solids to be settled or separated for manual disposal. The retention time allows the incoming waste to cool and allow the grease to solidify. The clear waste is then allowed to discharge into the building's drainage system.

4.5.7 *Oil Interceptors*

Oils and lubricants are found in wastes from vehicle service stations, workshops manufacturing units whose waste may contain high content of oils. Oils for example, petroleum, kerosene and diesel used as fuel, cooking, lubricant oils and similar liquids are lighter than water and thus float on water in a pipe line or in a chamber when stored. Such oils have a low ignition point and are prone to catch fire if exposed to any flame or a spark and may cause explosion inside or outside the drainage system. The flames from such a fire spread rapidly if not confined or prevented at the possible source. Lighter oils and lubricants are removed from the system by passing them through an oil interceptor/petrol gully. They are chambers in various compartments which allow the solids to settle and allow the oils to float to the top. The oil is then decanted in separate containers for disposal in an approved manner. The oil free waste collected from the bottom of the chamber is disposed in the building drainage system.

4.5.8 *Radioactive Waste*

Scientific research institutions, hospital and many types of manufacturing processes use radioactive material in the form of radio-isotopes and other radioactive sources for their activities. Manufacture, sale, use and disposal of radioactive material is regulated by the statutory rules and regulation. Proposal for usage and disposal of radioactive materials shall be done in consultation with and prior permission of the Authority by the users of the materials. No radioactive material shall be disposed off in any building drainage system without the authorization of the Authority.

NOTE — All procedures followed and precautions taken shall be in accordance with AERB regulations, including regarding employing delay and decay tanks. Where applicable, the toilets may be designated as 'hot toilets' and should be clearly indicated. All drainage plumbing needs to be isolated and connected to delay and decay tanks (usually required for PET CT scan room, SPECT CT scan room and iodine therapy ward, and may be also required for cyclotron liquid waste).

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4.5.9 *Special Situations of Waste Water Disposal*

Buildings may generate uncontaminated waste water from various sources continuously, intermittently or in large volumes for a short time for example, emptying any water tanks or pools, testing fire and water lines for flow conditions, etc. Connections from all such sources shall be made to the building drainage system indirectly through a trap. It should be ensured in advance that the building drain or a sump with a pump has the capacity to receive to rate of flow. In case the capacity is less the rate of discharge from the appliances should be regulated to meet the capacity of the disposal. Under no circumstances shall any waste water described above shall be disposed of in any storm water drains.

4.5.10 *Manholes*

4.5.10.1 *General*

A manhole or inspection chamber shall be capable of sustaining the loads which may be imposed on it, exclude subsoil water and be water tight. The size of the chamber should be sufficient to permit ready access to the drain or sewer for inspection, cleaning and rodding and should have a removable cover of adequate strength, constructed of suitable and durable material. Where the depth of the chamber so requires, access rungs, step irons, ladders or other means should be provided to ensure safe access to the level of the drain or sewer. If the chamber contains an open channel, benching should be provided having a smooth finish and formed so as to allow the foul matter to flow towards the pipe and also ensure a safe foothold.

No manhole or inspection chamber shall be permitted inside a building or in any passage therein. The minimum depth of the manhole shall not be less than 800 mm to facilitate gully trap connection. Further, ventilating covers shall not be used for domestic drains. At every change of alignment, gradient or diameter of a drain, there shall be a manhole or inspection chamber. Bends and junctions in the drains shall be grouped together in manholes as far as possible.

Alternative materials of manholes using RCC rings and PVC in sewer lines are being used in some sites. These may be considered subject to ensuring their proper design, keeping in view the lateral and vertical loads at the place of installation.

The holes over the surfaces of covers/gratings of various manholes, gullys and other chambers/drains shall comply with the requirements given in good practice [E-2(2)].

4.5.10.2 *Spacing of manholes*

The spacing of manholes for a given pipe size should be as follows:

Sl No.	*Pipe Diameter* mm	*Spacing of Manhole* m
(1)	(2)	(3)
i)	Up to 300	45
ii)	301 to 500	75
iii)	501 to 900	90
iv)	Beyond 900	Spacing shall depend upon local condition and shall be gotten approved by the Authority

Where the diameter of a drain is increased, the crown of the pipes shall be fixed at the same level and the necessary slope given in the invert of the manhole chamber. In exceptional cases and where unavoidable, the crown of the branch sewer may be fixed at a lower level, but in such cases the peak flow level of the two sewers shall be kept the same.

4.5.10.3 *Size of manhole*

The manhole or chamber shall be of such size as will allow necessary examination or clearance of drains. The size of shall be adjusted to take into account any increase in the number of entries into the chamber.

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4.5.10.3.1 Manholes may be rectangular, arch or circular type. The minimum internal size of manholes, chambers (between faces of masonry) shall be as follows:

a) Rectangular manholes:

1) For depths less than 0.90 m : 900 mm × 800 mm
2) For depths from 0.90 m and up to 2.5 m : 1 200 mm × 900 mm

NOTE — For depths up to 0.60 m, 600 mm × 600 mm manhole may be used.

b) Arch type manholes:

For depths of 2.5 m and above : 1 400 mm × 900 mm

NOTE — The width of manhole chamber shall be suitably increased more than 900 mm on bends, junctions or pipes with diameter greater than 450 mm so that benching width in either side of channel is minimum 200 mm.

c) Circular manholes:

1) For depths above 0.90 m and up to 1.65 m : 900 mm diameter
2) For depths above 1.65 m and up to 2.30 m : 1 200 mm diameter
3) For depths above 2.30 m and up to 9.00 m : 1 500 mm diameter
4) For depths above 9.00 m and up to 14.00 m : 1 800 mm diameter

NOTES

1 In adopting the above sizes of chambers, it should be ensured that these sizes accord with full or half bricks with standard thickness of mortar joints so as to avoid wasteful cutting of bricks.

2 The sizes of the chambers/manhole may be adjusted to suit the availability of local building materials, economics of construction and to meet local authority approval.

3 The access shaft shall be corbelled inwards on three sides at the top to reduce its size to that of the cover frame to be fitted or alternatively the access shaft shall be covered over by a reinforced concrete slab of suitable dimensions with an opening for manhole cover and frame.

4 The minimum sewer pipe diameter is 200 mm based on good practice [E-2(13)].

4.5.10.4 *Construction*

4.5.10.4.1 *Excavation*

The manhole shall be excavated true to dimensions and levels as shown on the plan. The excavation of deep manholes shall be accompanied with safety measures like timbering, staging, etc. In areas where necessary, appropriate measures for dewatering should be made.

4.5.10.4.2 *Bed concrete*

The manhole shall be built on a bed of concrete 1 : 4 : 8 (1 cement : 4 coarse sand : 8 graded stone aggregate 40 mm nominal size). The thickness of bed concrete shall be at least 150 mm for manholes up to 0.9 m in depth, at least 200 mm for manholes from 0.90 m up to 2.5 min depth and at least 300 mm for manholes of greater depth, unless the structural design demands higher thickness.

This thickness may be verified considering the weight of wall, cover, the wheel loads, impact of traffic which are transmitted through cover and the shaft walls and for water pressure, if any. In case of weak soil, special foundation as suitable shall be provided

4.5.10.4.3 *Brickwork*

The thickness of walls shall be designed depending upon its shape and taking onto account all loads coming over it, including earth pressure and water pressure.

Generally, the brickwork shall be with first class bricks in cement mortar 1 : 5 (1 cement : 5 coarse sand). All brickwork in manhole chambers and shafts shall be carefully built in English Bond, the jointing faces of each

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brick being well 'buttered' with cement mortar before laying, so as to ensure a full joint. The construction of walls in brickwork shall be done in accordance with good practice [E-2(14)].

For various depths the recommended thickness of wall may be as follows:

	Depth of the Chamber		*Thickness of Wall*
a)	Up to 2.25 m	:	200 mm (one brick length)
b)	From 2.25 m up to 3.0 m	:	300 mm (one and half brick length)
c)	From 3.00 m up to 5.0 m	:	400 mm (two brick length)
d)	From 5.00 m up to 9.0 m	:	500 mm (two and half brick length)
e)	Above 9.00 m	:	600 mm (three brick length)

The actual thickness in any case shall be calculated on the basis of engineering design. Typical sections of the manholes are illustrated in Fig. 7, Fig. 8 and Fig. 9.

NOTES

1 Rich mix of cement mortar, not weaker than 1 : 3, should be used in brick masonry, where subsoil water conditions are encountered.

2 For arched type of manholes, the brick masonry in arches and arching over pipes shall be in cement mortar 1 : 3.

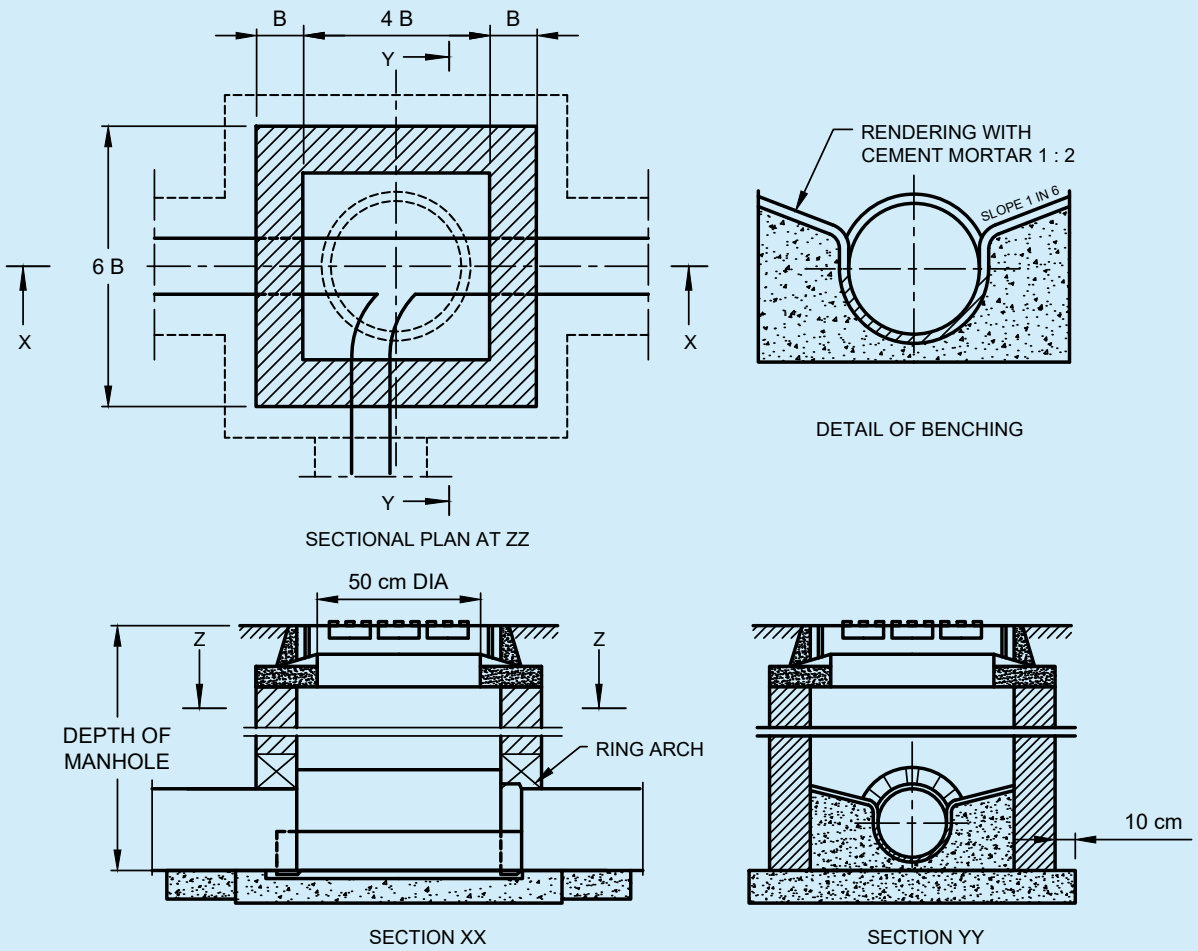

FIG. 7 DETAIL OF MANHOLE (DEPTH LESS THAN 0.90 m)

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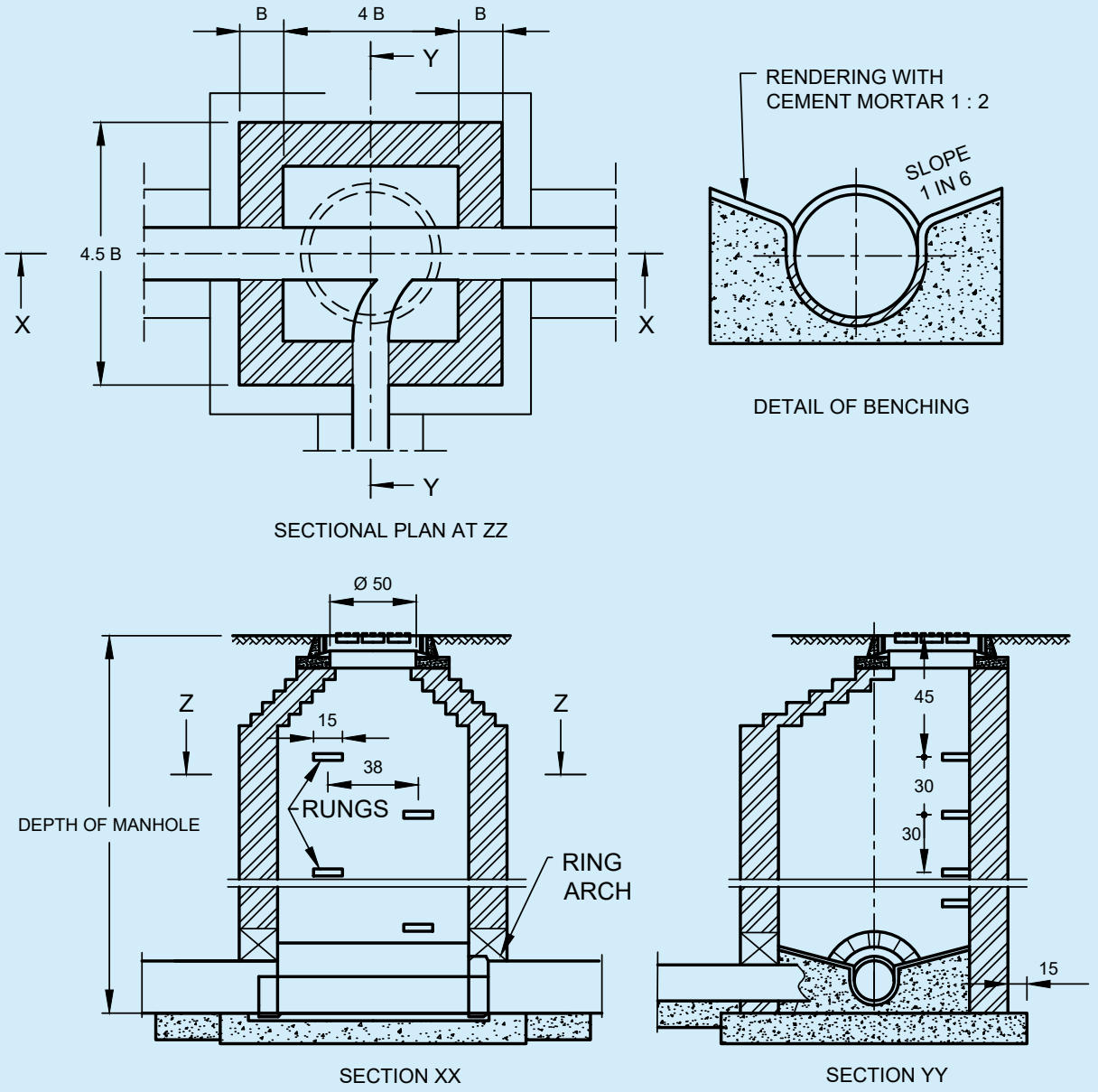

All dimensions in centimetres.

FIG. 8 DETAIL OF MANHOLE (DEPTH FROM 0.9 m AND UP TO 2.5 m)

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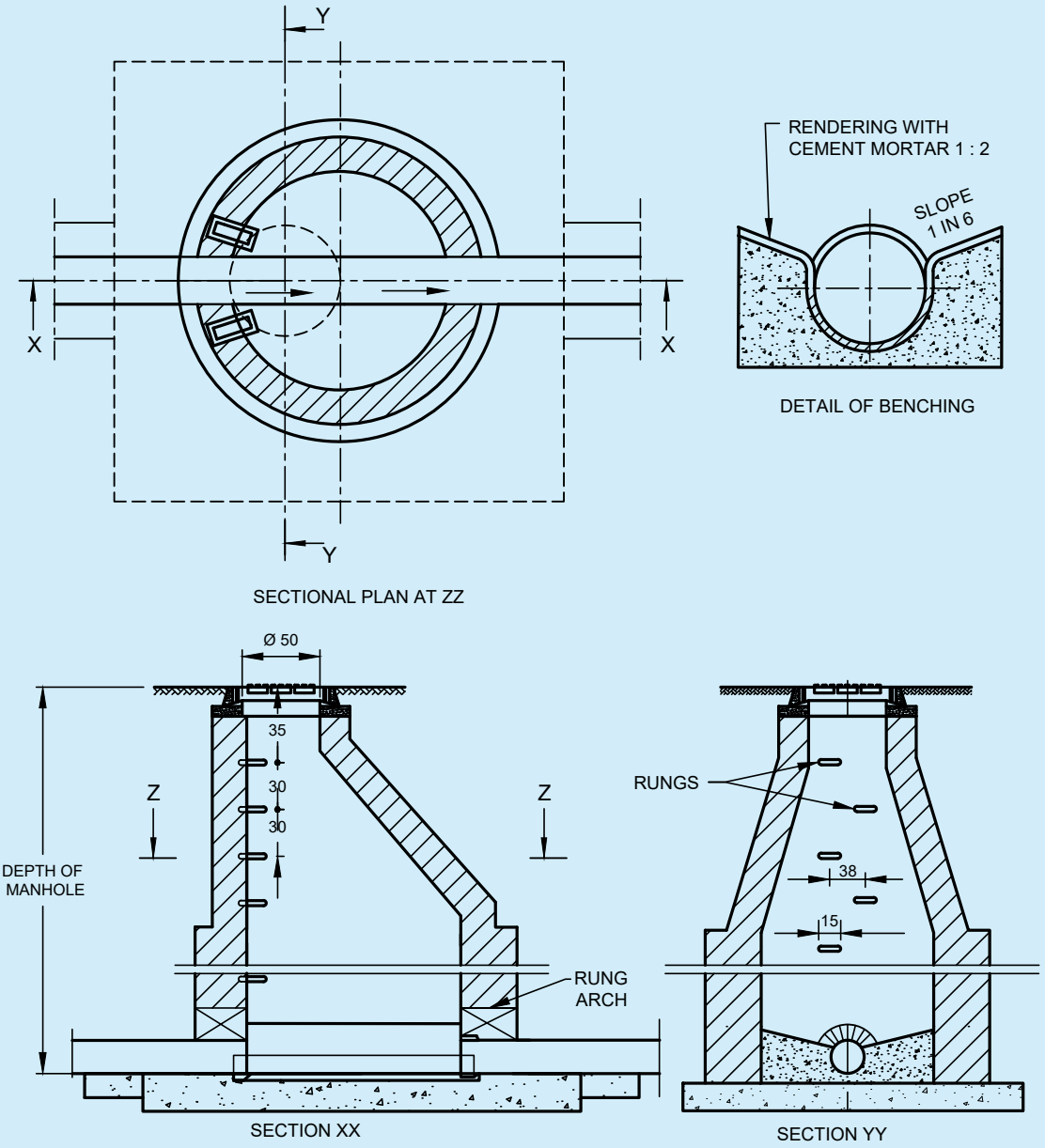

All dimensions in centimetres.

FIG. 9 DETAIL OF MANHOLE (DEPTH 2.5 m AND ABOVE)

4.5.10.4.4 *Plastering*

The wall shall be plastered (15 mm, min) both inside and outside within cement mortar 1 : 3 and finished smooth with a coat of neat cement. Where subsoil water conditions exit, a richer mix may be used and it shall further be waterproofed with addition of approved waterproofing compound in a quantity as per manufacturer specifications.

All manholes shall be so constructed as to be water-tight under test.

All angles shall be rounded to 75 mm radius and all rendered internal surface shall have hard impervious finish obtained using a steel trowel.

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4.5.10.4.5 *Channels and benching*

These shall be semi-circular in the bottom half and of diameter equal to that of the sewer. Above the horizontal diameter, the sides shall be extended vertically 50 mm above the crown of sewer pipe and the top edge shall be suitably rounded off. The branch channels shall also be similarly constructed with respect to the benching, but at their junction with the main channel an appropriate fall, if required suitably rounded off in the direction of flow in the main channel shall be given.

The channel/drain and benching at the bottom of the chamber shall be done in cement concrete 1 : 2 : 4 and subsequently plastered with cement mortar of 1 : 2 proportion or weaker cement mortar with a suitable waterproofing compound and finished smooth, to the grade (where required). The benching at the sides shall be carried up in such a manner as to provide no lodgment for any splashing in case of accidental flooding of the chamber.

Channels shall be rendered smooth and benchings shall have slopes towards the channel.

4.5.10.4.6 *Rungs*

Rungs shall be provided in all manholes over 0.8 m in depth and shall be of cast iron, or PVC encapsulated or composite non-corrosive materials, and of suitable dimensions, conforming to accepted standards [E-2(15)]. These rungs may be set staggered in two vertical rungs which may be 300 mm apart horizontally as well as vertically and shall project a minimum of 100 mm beyond the finished surface if the manhole wall. The top rung shall be 450 mm below the manhole cover and the lowest not more than 300 mm above the benching.

4.5.10.4.7 *Manhole covers and frames*

The size of manhole covers shall be such that there shall be a clear opening of at least 500 mm in diameter for manholes exceeding 0.90 m in depth. The manhole covers and frames used shall conform to accepted standards [E-2(16)].

The frame of manhole shall be firmly embedded to concrete alignment and level in plain concrete on the top of masonry.

4.5.10.5 *Drop manhole*

Where it is uneconomic or impracticable to arrange the connection within 600 mm height above the invert of the manholes, the connection shall be made by constructing a vertical shaft outside the manhole chamber, as shown in Fig. 10. If the difference in level between the incoming drain and the sewer does not exceed 600 mm and there is sufficient room in the manhole, the connecting pipe may be directly brought through the manhole wall and the fall accommodated by constructing a ramp in the benching of the manhole.

For detailed information regarding manholes in sewerage system, reference may be made to good practice [E-2(17)].

4.5.10.6 *Manhole covers and recommended locations*

Manhole covers were traditionally and presently manufactured from concrete, steel fibre reinforced concrete, cast iron and ductile iron or PVC materials and these materials are used based on the load carrying capacity and for the following type of applications:

a) Inspection chambers for sewerage;

b) Underground electrical cabling;

c) Telecom cabling;

d) Water, gas and petroleum installations; and

e) Beautification of gardens and landscapes.

Recommended locations conforming to load capacity shall be as per accepted standard [E-2(16)].

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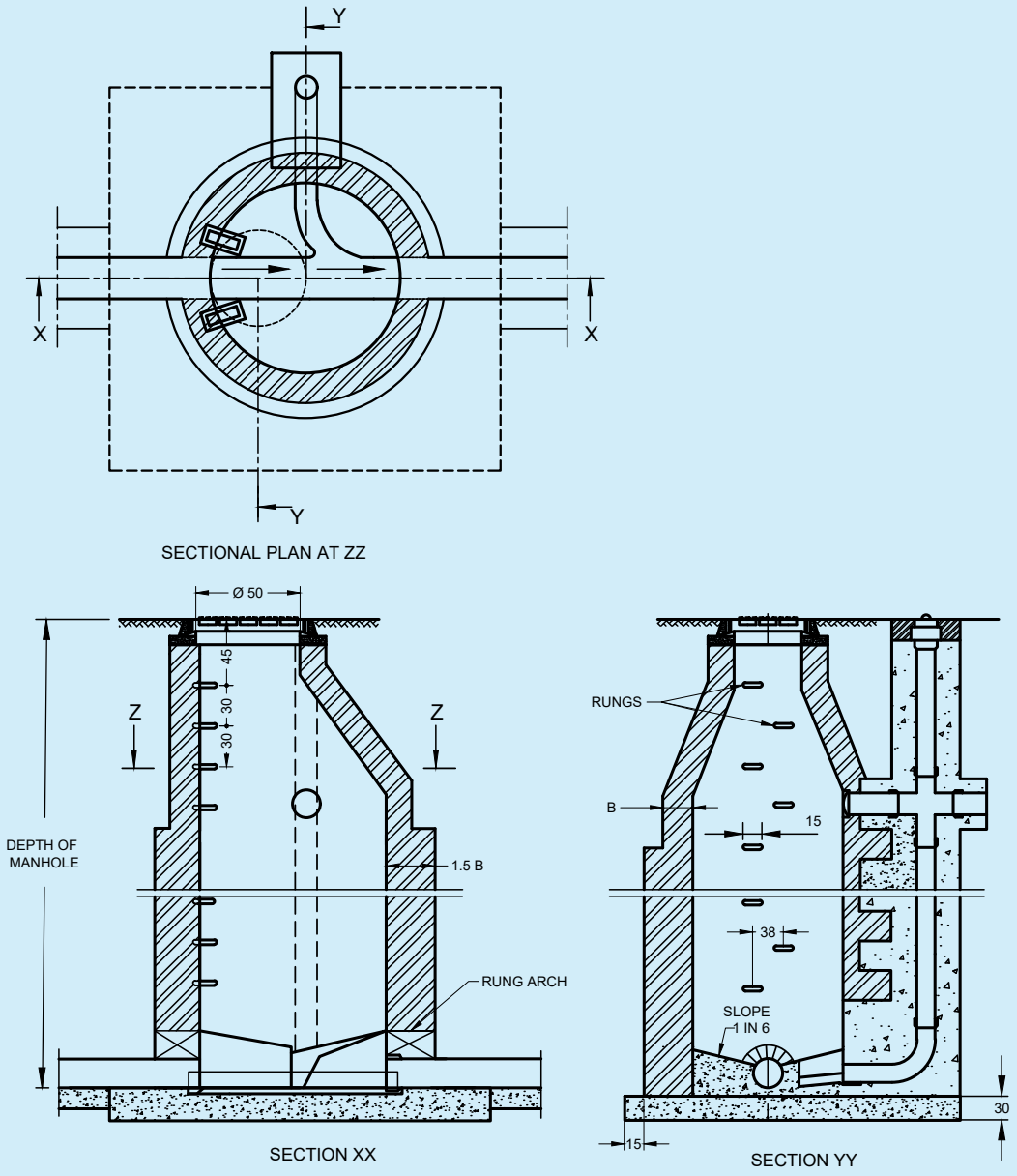

NOTE – Wall thickness have been indicated in brick length to provide for use of modular bricks or traditional bricks. In the figure, B = one brick length, 1.5 B = one and a half brick length, etc.

All dimensions in centimetres.

FIG. 10 DROP MANHOLE

4.5.11 *Storm Water Drainage*

4.5.11.1 *General*

The object of storm water drainage is to collect and carry, the rainwater collected within the premises of the building, for suitable disposal.

4.5.11.2 *Design factors*

Estimate of the quantity that reaches the storm water drain (runoff) depends on the following factors:

a) Type of soil and its absorption capacity determined by its soil group;

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b) Ground slope and the time in which the area is drained;

c) Intensity of the rainfall for a design period; and

d) Duration of the rain/storm.

The runoff reaching the sewer may be given by the expression:

$$Q = 10\ C \times i \times A$$

where

Q = runoff, m^3/h;

C = coefficient of runoff;

i = intensity of rainfall, mm/h; and

A = area of the drainage district, hectares.

Coefficient of runoff for various surfaces may be taken as:

Sl No.	*Type of Surface*	*Coefficient of Runoff*
(1)	(2)	(3)
i)	Concrete roof area	0.9
ii)	Paved podium areas and asphalted roads	0.8
iii)	Unpaved ground	0.3
iv)	Lawns and parks	0.15

4.5.11.2.1 *Imperviousness*

The soil conditions and the ground slope determine the impermeability factor. Impermeability factor is the proportion of the total rainfall received on the surface which will be discharging into a storm water drain after allowing for initial abstraction (in local pond and lakes), ground absorption by evaporation, vegetation and other losses. The net flow reaching the storm water drain is called runoff.

The percentage of imperviousness of the drainage area may be obtained from available data for a particular area. In the absence of such data, the following figures may serve as a guide:

Sl No.	*Type of Area*	*Imperviousness Factor* Percent
(1)	(2)	(3)
i)	Commercial and industrial areas	70 to 90
ii)	Residential areas (high density)	60 to 75
iii)	Residential areas (low density)	35 to 60
iv)	Parks and underdeveloped areas	10 to 20

4.5.11.2.2 *Terrain modelling*

Areas planned for urbanization from agricultural land, forest or low grade land for example, low lying areas prone to flooding, marshy or abandoned quarries, etc, need detailed and careful consideration with respect to its drainage. A detailed contour survey shall be carried out not only with respect to the site but also the surrounding areas to verify the quantity/area contributing runoff, presence of any low lying and natural water body acting as holding pond or any natural drain passing through the area and beyond whose filling up or diversion may cause water logging problem on the site or to the surrounding areas.

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The planning of the area should ensure that:

a) All areas become self draining by gravity with respect to the high flood level of the area or the drainage channels passing, whichever is higher;

b) As far as possible, natural drainage pattern with respect to the whole area be maintained except when low lying areas need to be filled up for grading purposes;

c) The drainage in the area shall be planned in accordance with the natural slopes; and

d) Levels of the main highway or road connecting to the property shall be determined to ensure proper drainage and protection of the site.

The formation levels of the entire area shall be prepared to determine proposed formation levels by preparing a terrain model which will show the proposed site contours, ground and road levels and connections to all services including storm water disposal system.

4.5.11.2.3 *Rainfall intensity*

The intensity of rainfall is the amount of rain falling in unit time and is expressed in centimetre or millimetre per hour. For design purposes, the mean rainfall intensity is collected for 50 years.

NOTE — For storm water drainage design, the hourly maximum rainfall may be referred from the relevant Indian Roads Congress guidelines.

4.5.11.2.4 *Design frequency*

Storm water drainage system for an urbanized area is planned on the basis of the design frequency of the storm which shall be determined by the designer. Frequency is the period in which the selected design intensity recurs in a given period of time in years.

NOTE — The rainfall intensity varies with the period, which includes good, bad and average years of rainfall. Meteorological department has long term data regarding the rainfall and have graphs for different periods, and the designers are advised to consult the department before designing any scheme.

4.5.11.2.5 *Time of concentration*

Time of concentration is the time required for the rainwater to flow to reach the farthest point of the drainage system or the outfall under consideration. Time of concentration is equal to the inlet time plus the time required for the flow to reach the main or branch drain. The inlet time is the time dependent on the distance of the farthest point in the drainage area to the inlet of the manhole and the surface slopes, etc, and will vary between 5 min and 30 min.

In highly developed sections for example with impervious surfaces it may be as low as 3 min or lower (with good slopes) as in building terraces and paved areas. Correspondingly the design intensity for the drainage for such areas will be much higher. Rainwater pipes have to be designed for an intensity for a very low time of concentration.

4.5.11.2.6 *Natural infiltration*

In planning any area with buildings, layout with paved and non-permeable surfaces, care should be taken to allow maximum discharge of the rainwater to flow directly or indirectly to permeate into the ground for enabling the ground water to be recharged. Some of the techniques which allow infiltration that may be considered are:

a) Use of brick paved open jointed storm water drains;

b) Providing bore holes in the storm water drains; and

c) Using paving tiles with open joints which enable water to percolates as it flows on it.

4.5.11.3 *Combined system*

A combined system of drainage is one which carries the sewerage as well as the runoff from the storm water drainage. Relevant applicable statutory rules/regulations may not allow such system in new areas and the sewerage and the storm water drainage have to be separate and independent of each other. Such systems are

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however existing in many old cities and the storm water may have to be discharged into the combined drainage system.

Where levels do not permit for connection to a public storm water drain, storm water from courtyards of buildings may be connected to the public sewer, provided it is designed to or has the capacity to convey combined discharge. In such cases, the surface water shall be admitted to the soil sewer through trapped gullies in order to prevent the escape of foul air.

4.5.11.4 *Discharging into a watercourse*

It may often be convenient to discharge surface water to a nearby stream or a watercourse. The invert level of the outfall shall be about the same as the normal water level in the watercourse or ideally should be above the highest flood level of the watercourse. The out-fall shall be protected against floating debris by a screen.

4.5.11.5 *Discharge to a public storm water drain*

Where it is necessary to connect the discharge rainwater into a public storm water drain, such drains shall be designed for the intensity of rain based on local conditions, but in no case shall they be designed for intensity of rainfall of less than 50 mm/h. Rainwater from each building plot shall be connected to the storm water drainage through a separate pipe or an open public drain directly. No trap shall be installed before the connection.

4.5.11.6 *Rainwater pipes for roof drainage*

4.5.11.6.1 The roofs of a building shall be so constructed or framed as to permit effectual drainage of the rainwater therefrom by means of a sufficient number of rainwater pipes of adequate size so arranged, jointed and fixed as to ensure that the rainwater is carried away from the building without causing dampness in any part of the walls or foundations of the building or those of an adjacent building.

4.5.11.6.2 The rainwater pipes shall be fixed to the outside of the external walls of the building or in recesses or chases cut or formed in such external wall or in such other manner as may be approved by the Authority.

4.5.11.6.3 Rainwater pipes conveying rainwater shall discharge directly or by means of a channel into or over an inlet to a surface drain or shall discharge freely in a compound, drained to surface drain but in no case shall it discharge directly into any closed drain.

4.5.11.6.4 Whenever it is not possible to discharge a rainwater pipe into or over an inlet to a surface drain or in a compound or in a street drain within 30 m from the boundary of the premises, such rainwater pipe shall discharge into a gully trap which shall be connected with the street drain for storm water and such a gully-trap shall have a screen and a silt catcher incorporated in its design.

4.5.11.6.5 If such streets drain is not available within 30 m of the boundary of the premises, a rainwater pipe may discharge directly into the kerb drain and shall be taken through a pipe outlet across the foot path, if any, without obstructing the path.

4.5.11.6.6 A rainwater pipe shall not discharge into or connect with any soil pipe or its vent pipe or any waste pipe or its vent pipe nor shall it discharge into a sewer unless specifically permitted to do so by the Authority, in which case such discharge into a sewer shall be intercepted by means of a gully trap.

4.5.11.6.7 Rainwater pipes shall be constructed of cast iron, PVC, asbestos cement, galvanized sheet or other equally suitable material and shall be securely fixed.

4.5.11.6.8 The factors that decide the quantity of rainwater entering are:

a) Intensity of rainfall; and

b) Time of concentration selected for rainwater pipe.

A bell mouth inlet at the roof surface is found to give better drainage effect, provided proper slopes are given to the roof surface. The spacing of rainwater pipes depends on the locations available for the down takes and the area which each pipe serves. The spacing will also be determined by the amount of slopes that can be given to the roof. The recommended slopes for the flat roofs with smooth finish would be 1 : 150 to 1 : 133, with rough

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stone/tiles 1 : 100 and for gravel set in cement or loosely packed concrete finish 1 : 75 to 1 : 66. The effective strainer area should preferably be 1.5 times to 2 times the area of pipe to which it connects to considerably enhance the capacity of rainwater pipes.

The rainwater pipes of cast iron (coefficient of roughness 0.013) shall normally be sized on the basis of roof areas according to Table 25. The vertical down take rainwater pipes, having a bell mouth inlet on the roof surface with effective cross sectional area of grating 1.5 to 2 times the rainwater pipe area, may be designed by considering the outlet pipe as weir.

For full circumference of pipe acting as weir, the roof area (RA) for drainage may be worked out by using:

$$RA = 0.084 \times d^{5/2}/I$$

where

RA = roof area, m^2 (*see* Note);

d = pipe diameter, mm; and

I = intensity of rainfall, mm/h.

NOTES

1 For one adjacent wall, add 50 percent of the wall area to the roof.

2 For two adjacent walls, add 35 percent of the wall area to the roof.

Table 25 Sizing of Rainwater Pipes for Roof Drainage

(*Clause* 4.5.11.6.8)

Sl No.	Diameter of Pipe mm	Roof Area, in m^2 for Average Rate of Rainfall in mm/h					
		50	75	100	125	150	200
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	50	29.70	19.80	14.85	11.88	9.90	7.42
ii)	65	57.23	38.15	28.61	22.89	19.08	14.31
iii)	75	81.84	54.56	40.92	32.74	27.28	20.46
iv)	100	168.00	112.00	84.00	67.20	56.00	42.00
v)	125	293.48	195.66	146.74	117.39	97.83	73.37
vi)	150	462.95	308.64	231.48	185.18	154.32	115.74

NOTE — For rainwater pipes of other materials, the roof areas shall be multiplied by (0.013/coefficient of roughness of surface of that material). For example, for rainwater pipes of PVC (coefficient of roughness = 0.009), the above values of roof area shall be multiplied by 0.013/0.009 = 1.44.

4.5.11.6.9 The storm water may be led off in a suitable open drain to a watercourse. The open drain, if not a *Pucca* masonry throughout, shall be so at least where there is either a change in direction or gradient.

4.5.11.6.10 Flat roof should have an emergency drain as secondary drain, in the form of down take or spout. Horizontal outlets should be considered for 100 percent flow and side gratings to be considered for 50 percent flow (*see* Fig. 11).

NOTE — Care should be taken to design the roof for the additional load due to ponded water.

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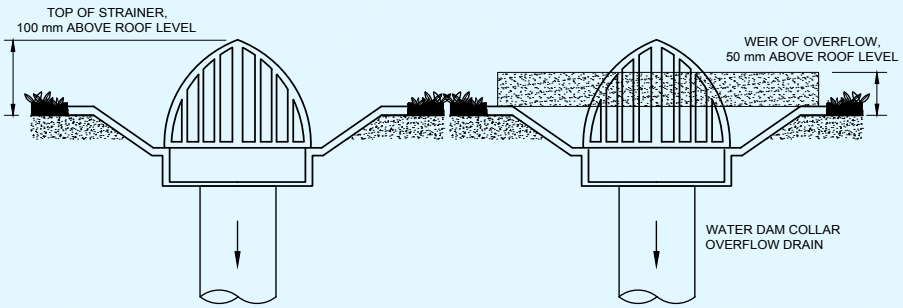

FIG. 11A TYPICAL VIEW OF ROOF DRAIN (LEFT) AND ROOF DRAIN WITH WEIR (RIGHT)

FIG. 11B ACTUAL DEPICTION OF ROOF DRAIN (LEFT) AND ROOF DRAIN WITH WEIR (RIGHT)

FIG. 11 ROOF DRAIN IN FLAT ROOFS

4.5.12 *Rainwater Harvesting*

4.5.12.1 *General*

To supplement the ever growing shortage of protected, pure and safe water supply for human consumption, rainwater is an ideal source which can be conserved and used in a useful manner by the people. The amount of rainfall available varies from region to region. Each area has to develop its own method and system to conserve, store and use it to suit its requirement and local conditions. There are several methods by which rainwater can be stored, used and conserved. Each system depends on the amount of precipitation, the period in which the rainfall occurs in a year and the physical infrastructure, for example space available to store the water, etc.

There are several techniques available for catching and storing the rainwater. Most of the techniques are applicable for large open areas, farms, sloping grounds, etc, with a low population base. Two major systems that are ideal for urban and semi-urban developed areas are:

a) Artificial ground water recharge; and

b) Roof top rainwater harvesting.

NOTE — Type and number of recharge pits and roof top rainwater harvesting capacity shall be provided as per the local/state bye-laws.

4.5.12.2 *Artificial ground water recharge*

With increase in the impermeable surfaces in modern built up areas, there is gross reduction in the original catchment area. This prevents the natural percolation that would have recharged the area in the normal course if the ground was in its natural condition, for example a farm, open ground, forest, etc. This results in a large quantity of water, normally percolating into the ground, running off to the natural drains and into the rivers, causing increased runoff and flooding of downstream areas.

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It is therefore essential to catch the runoff and use it for augmentation of ground water reservoir by modifying the natural movement of surface water by recharging it by artificial means, for example construction of recharge structures (*see* Fig. 12). The main objectives achieved may be:

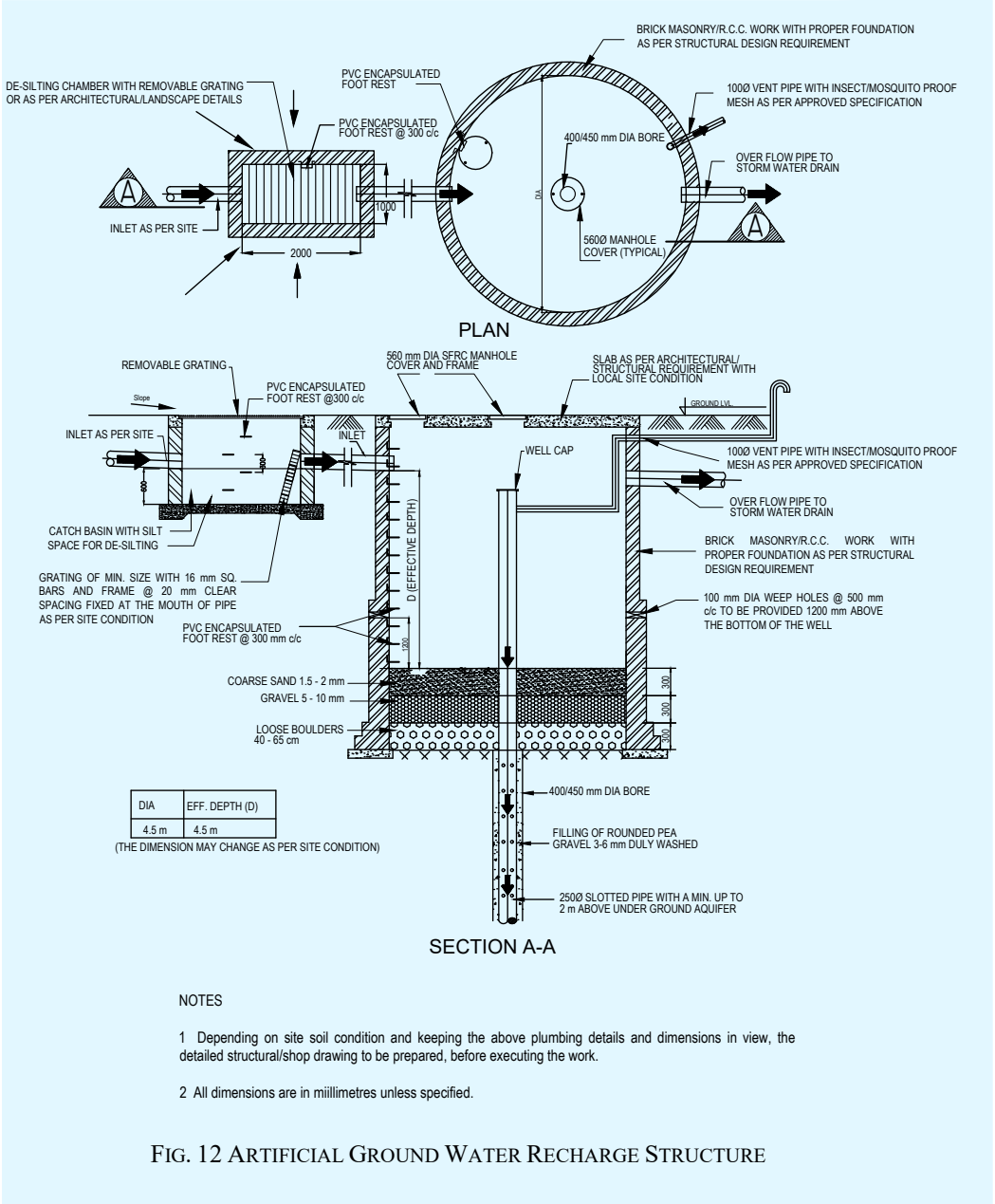
a) Enhancement of sustainable yield in areas where over development and depletion of the aquifers;

b) Conservation and storage of excess surface water in the aquifers;

c) Improve the quality of the existing ground water through dilution;

d) Remove bacteriological and suspended impurities during the surface water transition within the subsoil; and

e) Maintain the natural balance of the ground water and its usage as the rainwater is a renewable supply source. A well managed and controlled tapping of the aquifers will provide constant, dependable and safe water supply.



NOTES

1 Depending on site soil condition and keeping the above plumbing details and dimensions in view, the detailed structural/shop drawing to be prepared, before executing the work.

2 All dimensions are in miillimetres unless specified.

FIG. 12 ARTIFICIAL GROUND WATER RECHARGE STRUCTURE

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In planning and designing the ground water recharge structures, following should be taken into consideration:

a) Annual rainfall (for estimating approximately rainwater recharge per year);

b) Peak intensity and duration of each storm;

c) Type of soil and subsoil conditions and their permeability factor;

d) Ground slopes and run off which cannot be caught;

e) Location of recharge structures and its overflow outfall; and

f) Rainwater measuring devices for finding the flow of water in the system.

For artificial recharge to ground water, good practice [E-2(18)] may be referred.

NOTE — Rainwater harvesting with underground recharging will depend from region to region as per the climatic, topography, soil conditions and data about intensity of rainfall and retention time for calculating the capacity of recharge wells to be obtained from reference documents from the Authority.

4.5.12.3 *Roof top rainwater harvesting*

4.5.12.3.1 *Harvesting in regular rainfall areas*

In areas having rainfall over a large period in a year, for example in hilly areas, coastal regions, etc, constant and regular rainfall can be usefully harvested and stored in suitable water tanks. Water shall be collected through roof gutters and down take pipes. Provision should be made to divert the 1st rainfall after a dry spell so that ant dust, soot and leaves, etc are drained away before the water is collected into the water tank. The capacity of the water tank should be enough for storing water required for consumption between two dry spells. The water tank shall be located in a well protected area and shall not be exposed to any hazards of water contamination from any other sources. The water shall be chlorinated using chlorine tablets or solution to maintain a residual chlorine of approximately 1 mg/l. The tank shall have an overflow leading to natural water courses or to any additional tanks (*see* Table 26).

4.5.12.3.2 *Harvesting in limited rainfall areas*

In areas with the rainfall limited during the monsoon period (usually from 15 days to 90 days), roof top rainwater can be stored and used for non-potable purposes, after proper treatment, in the premises itself as mentioned above; excess water, if any, is best used for recharging the ground water. For individual properties and plots the roof top rainwater can be diverted to underground or above ground water storage tank(s), pretreated, stored and used for non-potable purposes. Excess water, if any, may be discharged to existing open or abandoned tube wells. In a well-planned building complex, a system should be laid out so that the runoff is collected in underground or above ground water storage tank(s), pretreated, stored, and used for non-potable purposes. Excess water, if any, shall be discharged in bore-wells as per designs specified by the Central Ground Water Board of the Government of India.

For roof top rainwater harvesting, reference may be made to good practice [E-2(19)].

4.5.12.4 *Care to be taken in rainwater harvesting*

Water conservation technique discussed above shall be constructed with due care taking following precautions:

a) No sewage or waste water should be admitted into the system;

b) No waste water from areas likely to have oil, grease or other pollutants should be connected to the system;

c) Each structure/well shall have an inlet chamber with a silt trap to prevent any silt from finding its way into the subsoil water;

d) The wells should be terminated at least 5 m above the natural static subsoil water at its highest level so that the incoming flow passes through the natural ground condition and prevent contamination hazards; and

e) No recharge structure or a well shall be used for drawing water for any purpose.

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Table 26 Rainwater Available from Roof Top Harvesting

(*Clause* 4.5.12.3.1)

Rain fall, mm →	100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000
Roof Top Area m^2 ↓	Harvested Water from Roof Tops, m^3 (80 percent of gross precipitation)																			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
20	2	3	5	6	8	10	11	13	14	16	18	19	21	22	24	26	27	29	30	32
30	2	5	7	10	12	14	17	19	22	24	26	29	31	34	36	38	41	43	46	48
40	3	6	10	13	16	19	22	26	29	32	35	38	42	45	48	51	54	58	61	64
50	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80
60	5	10	14	19	24	29	34	38	43	48	53	58	62	67	72	77	82	86	91	96
70	6	11	17	22	28	34	39	45	50	56	62	67	73	78	84	90	95	101	106	112
80	6	13	19	26	32	38	45	51	58	64	70	77	83	90	96	102	109	115	122	128
90	7	14	22	29	36	43	50	58	65	72	79	86	94	101	108	115	122	130	137	144
100	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160
110	9	18	26	35	44	53	62	70	79	88	97	106	114	123	132	141	150	158	167	176
120	10	19	29	38	48	58	67	77	86	96	106	115	125	134	144	154	163	173	182	192
130	10	21	31	42	52	62	73	83	94	104	114	125	135	146	156	166	177	187	198	208
140	11	22	34	45	56	67	78	90	101	112	123	134	146	157	168	179	190	202	213	224
150	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240
200	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320
250	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
300	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480
400	32	64	96	128	160	192	224	256	288	320	352	384	416	448	480	512	544	576	608	640
500	40	80	120	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800
1 000	80	160	240	320	400	480	560	640	720	800	880	960	1 040	1 120	1 200	1 280	1 360	1 440	1 520	1 600
2 000	160	320	480	640	800	960	1 120	1 280	1 440	1 600	1 760	1 920	2 080	2 240	2 400	2 560	2 720	2 880	3 040	3 200
3 000	240	480	720	960	1 200	1 440	1 680	1 920	2 160	2 400	2 640	2 880	3 120	3 360	3 600	3 840	4 080	4 320	4 560	4 800

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4.5.12.5 *Siphonic drainage system*

It is an installation generally used for special situations such as roofs with large spans for structures like hangars, airport terminals, stadia and industrial sheds, where the number of down pipes has to be limited. These are designed for full flow of pipes and the roof outlets are different from conventional ones.

Siphonic roof drainage systems are engineered on the concept of a full bore (a fill rate of 100 percent). This implies that rainwater flows at high speed through small diameter pipe work, at normally zero gradient.

This siphonic effect is created by the (kinetic) energy derived from the hydraulic head, caused by the difference in height between the roof outlet and the discharge point in a building. Specialist roof outlets prevent air being sucked into the system (*see* Fig. 13).

The engineering principle of siphonic roof drainage design is based on the Bernoulli energy equation for a steady flow of an incompressible fluid with constant density. In order to balance the equation, and to guarantee the required siphonic effect according to the rainfall intensity, the ideal pipe dimensions per flow path need to be determined.

In case of syphon system, the outlets of drainage system prevent vortex formation, thereby preventing air from entering the pipeline ensuring the entire system is running at full flow. It uses design that complies with Bernoulli's principle where equal energy is created under positive and negative pressure.

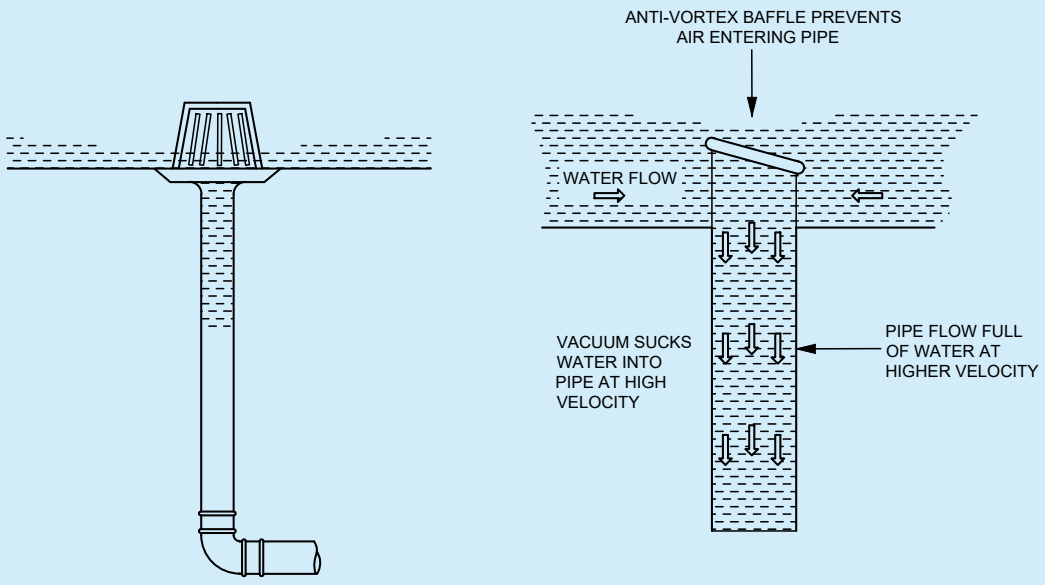

FIG. 13 SIPHONIC DRAINAGE SYSTEM

4.5.12.6 *Rainwater harvesting for plotted/group housing developments*

The rainwater harvesting methods adopted for plotted and group housing are through collection of rooftop rainwater and surface runoff harvesting.

A network of storm water drains in the entire residential area is used for harvesting rooftop rainwater and surface runoff. Appropriate number of recharge wells measuring 1 m × 1 m × 2 m may be constructed in the storm water drain for facilitating groundwater recharge. The quality of runoff, which passes through the borewell installed inside the recharge well, is ensured through a filter bed of pebbles (*see* Fig. 12).

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4.5.12.7 *Other methods of rainwater harvesting*

a) *Creation of artificial reservoirs/lakes for utilization of available storm water* — This shall be based on estimation of amount of runoff volume based on rainfall data (for a period of 10 years) considering the percolation and evaporation losses and efforts to be made to collect all available runoff for proper utilization; and

b) *Water balancing methods* — This refers to optimum utilization of available water from different sources, namely ground water, recycled waste water, storm water and municipal supply and its adoption would ensure that there is no wastage of water.

4.5.13 *Subsoil Water Drainage*

4.5.13.1 *General*

Subsoil water is that portion of the rainfall which is absorbed into the ground.

The drainage of subsoil water may be necessary for the following reasons:

a) To increase the stability of the surface;

b) To avoid surface flooding;

c) To alleviate or to avoid causing dampness in the building, especially in the cellars;

d) To reduce the humidity in the immediate vicinity of the building; and

e) To increase the workability of the soil.

4.5.13.2 *Depth of water table*

The standing level of the subsoil water will vary with the season, the amount of rainfall and the proximity and level of drainage channels. Information regarding this level may be obtained by means of boreholes or trial pits, preferably the latter. It is desirable though not always practicable to ascertain the level of the standing water over a considerable period so as to enable the seasonal variations to be recorded and in particular the high water level. The direction of flow of the subsoil water may usually be judged by the general inclination of the land surface and the main lines of the subsoil drains shall follow the natural falls, wherever possible.

4.5.13.3 *Precautions*

Subsoil drains shall be so sited as not to endanger the stability of the buildings or earthwork. In some portions of the drain, it may be necessary to use non-porous jointed pipes.

4.5.13.3.1 No field pipe shall be laid in such a manner or in such a position as to communicate directly with any drain constructed or adopted to be used for conveying sewage, except where absolutely unavoidable and in such case a suitable efficient trap shall be provided between subsoil drain and such sewer.

4.5.13.4 *Systems of subsoil drainage*

Clay or concrete porous field drain pipes may be used and shall be laid in one of the following ways (*see also* Fig. 14):

a) *Natural* — The pipes are laid to follow the natural depressions or valleys of the site; branches discharge into the main as tributaries do into a river;

b) *Herringbone* — The system consists of a number of drains into which discharges from both sides smaller subsidiary branch drains parallel to each other, but an angle to the mains forming a series of herringbone pattern. Normally these branch drains should not exceed 30 m in length;

c) *Grid* — A main or mains drain is laid to the boundaries if the site into which subsidiary branches discharge from one side only;

d) *Fan-shaper* — The drains are laid converging to a single outlet at one point on the boundary of a site, without the use of main or collecting drains; and

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e) *Moat or cut-off system* — This system consists of drains laid on one or more sides of a building to intercept the flow of subsoil water and carry it away, thereby protecting the foundations of a building.

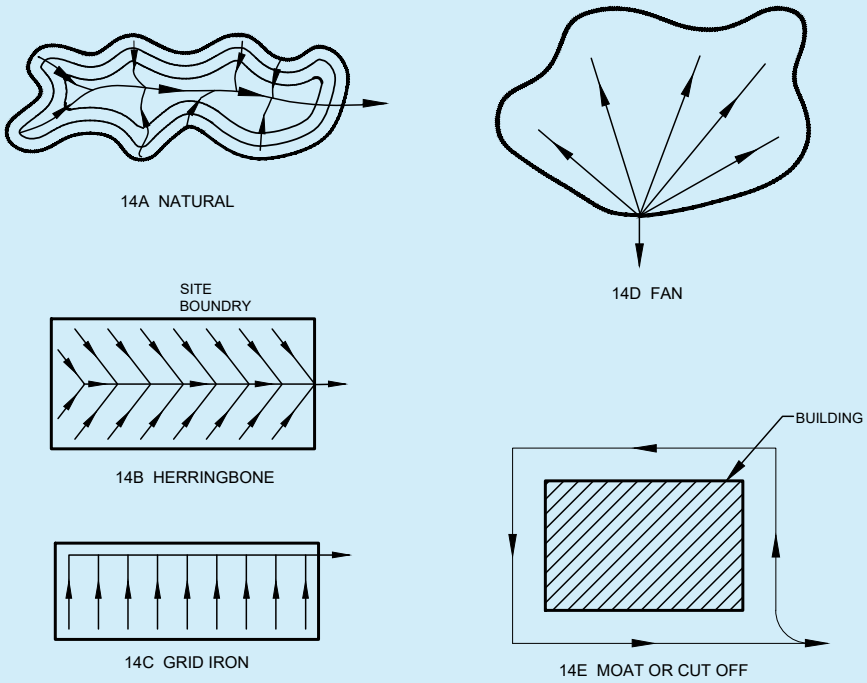

FIG. 14 DETAILS OF SUBSOIL DRAINAGE SYSTEM

The choice of one or more of these systems will naturally depend on the local conditions of the site. For building sites, the mains shall be not less than 75 mm in diameter and the branches not less than 65 mm in diameter but normal practice tends towards the use of 100 mm and 75 mm, respectively. The pipes shall generally be laid at 60 cm to 90 cm depth, or to such a depth to which it is desirable to lower the water-table and the gradients are determined rather by the fall of the land than by considerations of self-cleansing velocity. The connection of the subsidiary drain to the main drain is best made by means of a clayware or concrete junction pipe. The outlet of a subsoil system may discharge into a soakaway or through a catch pit into the nearest ditch or watercourse. Where these are not available, the subsoil drains may be connected, with the approval of the Authority, through an intercepting trap to the surface water drainage system.

NOTE — Care shall be taken that there is no backflow from sub-surface drains during heavy rains.

4.5.13.5 *Deep well/borewell recharging*

Recharge well is one which pushes back surface water into ground water system. The recharge well may be of 1 m in diameter and 6 m deep lined with concrete rings having perforations.

Direct recharge is recommended when the well has gone dry and is yielding negligible amount of water. Indirect recharge is adopted for functioning borewells.

4.5.14 *Waste Disposal Systems in High Altitudes and/or Sub-zero Temperature Regions*

4.5.14.1 In general, all the care to be exercised regarding water supply systems shall also be applicable in the case of waste disposal systems. The biological and chemical reduction of organic material proceeds slowly under low temperature conditions, consequently affecting the waste disposal systems. The waste disposal methods given in 4.5.14.2, 4.5.14.3 and 4.5.14.4 shall be used only where it is not practical to install water carriage system.

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4.5.14.2 *Box and can system*

Where box and can systems are employed, adequate arrangements shall be made for the cleaning and disinfection of the can after it is emptied of its contents. The excrement from the can shall be disposed of by burial in isolated spots far from habitation or by incineration, where feasible. The can shall be fitted with a tight fitting lid for use when it is carried for emptying.

4.5.14.3 *Trench or pit latrines*

Trench or pit latrines shall be used only where soil and subsoil conditions favour their use. Whenever they are used, they shall not be closer than 18 m from any source of drinking water, such as well, to eliminate the possibility of bacterial pollution of water.

4.5.14.4 *Chemical toilets*

For the successful functioning of chemical toilets, they shall preferably be installed in heated rooms or enclosures.

NOTE — Chemical toilet essentially consists of small cylindrical tanks with a water-closer seat for the use of 8 persons to 10 persons. A ventilation pipe is fitted to the seat. A strong solution of caustic soda is used as a disinfectant. It kills bacteria, liquefies the solids and thus checks the decomposition of organic matter. The tank is provided with a drain plug for which liquid runs to a soak pit at the time of disposal.

4.5.14.5 *Water-borne sanitation systems*

Water-borne sanitation systems shall be used, where practicable. Sanitation systems for the collection of sewage should be constructed in such a manner that maximum heat is retained by insulation, if necessary.

4.5.14.5.1 *Sewerage laying*

Under normal circumstances, sewers shall be laid below the frost line. Manholes shall be made of air-tight construction so as to prevent the cold air from gaining access inside and freezing the contents. The trenches for sewers shall be loosely filled with earth after laying sewers, since loose soil is a better insulator than compacted soil. Consequently, sewers laid under traffic ways and other places where soil compaction may be expected are required to be given adequate insulation. Where feasible, sewers shall be so located that the trench line is not in shadow, when the sun is shining. Concrete, cast iron and stoneware pipes conduct heat relatively rapidly and as such should be adequately insulated.

4.5.14.5.2 *Septic tanks*

Septic tanks can function only when it can be ensured that the contents inside these do not freeze at low temperature. For this purpose, the septic tanks shall be located well below the frost line. The location of manhole openings shall be marked by staves. Fencing around the septic tanks shall be provided for discouraging traffic over them. As the rate of biological activity is reduced by 50 percent for every 10 °C fall in temperature, the capacity of septic tanks shall be increased by 100 percent for operation at 10 °C over that for operation at 20 °C.

The construction of septic tanks is preferred in rural and fringe areas of suburban and isolated buildings where underground system may neither be feasible nor economical. Septic tanks are only recommended for small communities and institutions whose contributory population does not exceed 300.

For other details, refer good practice [E-2(10)].

4.5.14.5.3 *Seepage pits*

Seepage pits can function only when the soil and subsoil conditions are favourable. Frozen soil extending to a great depth would preclude the use of such disposal devices in view of the lower water absorption capacity. The discharge of effluent should be made below the frost line.

4.5.14.5.4 *Sewage treatment plants*

Suitable design modifications for sedimentation, chemical and biological processes shall be applied to sewage treatment plants for satisfactory functioning (*see also* 4.13).

NOTE — Lavatories and bathrooms shall be kept heated to avoid freezing of water inside traps and flushing cisterns.

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4.6 Construction Relating to Conveyance of Sanitary Wastes

4.6.1 *Excavation*

4.6.1.1 *General*

The safety provisions as given in relevant guidelines/best practices (Handbook on 'Construction Management, Practices and Safety in Buildings') should be referred for guidance purpose.

4.6.1.2 Turf, topsoil or other surface material shall be set aside, turf being carefully rolled and stacked for use in reinstatement. All suitable broken surface material and hard-core shall be set on one side for use in subsequent reinstatement.

4.6.1.3 Excavated material shall be stacked sufficiently away from the edge of the trench and the size of the spoil bank shall not be allowed to become such as to endanger the stability of the excavation. Spoil may be carried away and used for filling the trench behind the work.

4.6.1.4 Excavation shall proceed to within about 75 mm of the finished formation level. This final 75 mm is to be trimmed and removed as a separate operation immediately prior to the laying of the pipes or their foundations.

4.6.1.5 Unless specified otherwise by the Authority, the width at bottom of trenches for pipes of different diameters laid at different depths shall be as given below:

a) For all diameters, up to an average depth of 1 200 mm,

   Width of trench, in mm = Diameter of pipe + 300 mm;

b) For all diameters for depths above 1 200 mm,

   Width of trench, in mm = Diameter of pipe + 400 mm; and

c) Notwithstanding (a) and (b), the total width of trench at the top should not be less than 750 mm for depths exceeding 900 mm.

4.6.1.6 Excavation in roads shall be so arranged, in agreement with the proper authority, as to cause the minimum obstruction to traffic. The methods to be adopted shall depend on local circumstances.

4.6.1.7 All pipes, ducts, cables, mains or other services exposed in the trench shall be effectively supported by timber and/or chain or rope-slings.

4.6.1.8 All drainage sumps shall be sunk clear of the work outside the trench or at the sides of manholes. After the completion of the work, any pipes or drains leading to such sumps or temporary subsoil drains under permanent work shall be filled in properly with sand and consolidated.

4.6.2 *Laying of Pipes*

Laying of pipes shall be done in accordance with good practice [E-2(20)].

4.6.3 *Jointing*

All soil pipes, waste pipes, vent pipes and other such pipes above ground shall be gas-tight. All sewers and drains laid below the ground shall be water-tight. Jointing shall be done in accordance with good practice [E-2(20)].

4.6.4 *Support or Protection for Pipes*

4.6.4.1 *General*

It may be necessary to support or surround pipe sewers or drains by means of concrete in certain circumstances. Some of the suggested methods are given in **4.6.4.2** to **4.6.4.4**.

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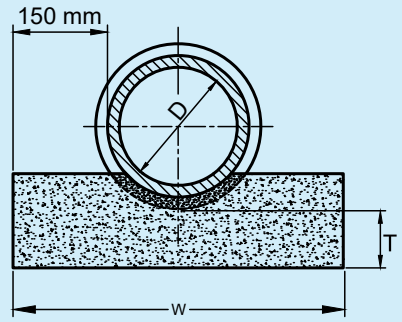
4.6.4.2 *Bedding*

Bedding (*see* Fig. 15) shall be rectangular in section and shall extend laterally at least 150 mm beyond and on both sides of the projection of the barrel of the pipe. The thickness of the concrete below the barrel of the pipe shall be not less than 100 mm for pipes under 150 mm diameter and 150 mm for pipes 150 mm and over in diameter. Where bedding is used alone, the concrete shall be brought up at least to the invert level of the pipe to form a cradle and to avoid line contact between the pipe and the bed.



W = D + 300 mm
where D is external diameter of the pipe

T = { 100 mm for pipes under 150 mm nominal dia
150 mm for pipes of 150 mm nominal dia and over

FIG. 15 BEDDING

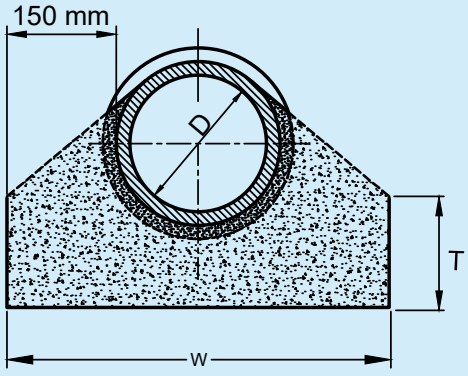
4.6.4.3 *Haunching*

Concrete haunching (*see* Fig. 16) shall consist of:

a) a concrete bed as described for bedding (*see* **4.6.4.2**);

b) the full width of the bed carried up to the level of the horizontal diameter of the pipe; and

c) splays from this level carried up on both sides of the pipe, from the full width of the bed to meet the pipe barrel tangentially.



W = D + 300 mm
where D is external diameter of the pipe

T = { 100 mm for pipes under 150 mm nominal dia
150 mm for pipes of 150 mm nominal dia and over

FIG. 16 HAUNCHING

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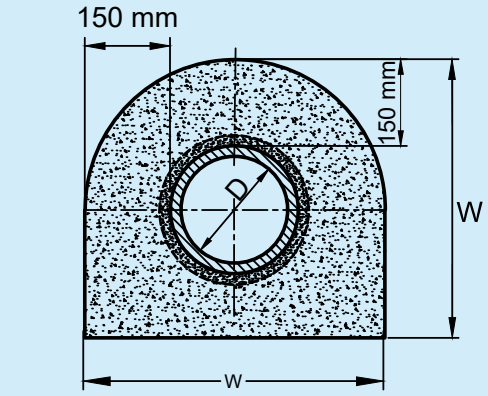
4.6.4.4 *Surround or encasing*

The surround or encasing (*see* Fig. 17) shall be similar to haunching up to the horizontal diameter of the pipe and the top portion over this shall be finished in a semicircular form to give a uniform encasing for the top half of the pipe.



W = D + 300 mm
where D is external diameter of the pipe

FIG. 17 SURROUND OR ENCASING

4.6.5 *Connection to Existing Sewers*

The connection to an existing sewer shall, as far as possible, be done at the manholes. Where it is unavoidable to make connection in between two manholes, the work of breaking into the existing sewer and forming the connection shall be carried out by the Authority or under its supervision.

4.6.5.1 Breaking into the sewer shall be effected by the cautious enlargement of a small hole and every precaution shall be taken to prevent any material from entering the sewer. No connection shall be formed in such a way as to constitute a projection into the sewer or to cause any diminution in its effective size.

4.6.6 *Back-Filling*

4.6.6.1 Filling of the trench shall not be commenced until the length of pipes therein has been tested and passed (*see* **4.10.2**).

4.6.6.2 All timber which may be withdrawn with safety shall be removed as filling proceeds.

4.6.6.3 Where the pipes are unprotected by concrete haunching, the first operation in filling shall be carefully done to hand-pack and tamp selected fine material around the lower half of the pipes so as to buttress them to the sides of the trench.

4.6.6.4 The filling shall then be continued to 150 mm over the top of the pipe using selected fine hand-packed material, watered and rammed on both sides of the pipe with a wooden rammer. On no account shall material be tipped into the trench until the first 150 mm of filling has been completed. The process of filling and tamping shall proceed evenly so as to maintain an equal pressure on both sides of the pipeline.

4.6.6.5 Filling shall be continued in layers not exceeding 150 mm in thickness, each layer being watered and well rammed.

4.6.6.6 In roads, surface materials previously excavated shall be replaced as the top layer of the filling, consolidated and maintained satisfactorily till the permanent reinstatement of the surface is made by the Authority.

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4.6.6.7 In gardens, the top soil and turf, if any, shall be carefully replaced.

4.7 Construction Relating to Conveyance of Rain or Storm Water

4.7.1 *Roof Gutters*

Roof gutters shall be of any material of suitable thickness. All junctions and joints shall be water-tight.

4.7.2 *Rainwater Pipes*

Rainwater pipes shall conform to the accepted standards [E-2(21)].

4.7.3 *Subsoil Drain Pipes*

4.7.3.1 *Field drain pipes*

Suitable pipes for this purpose are plain cylindrical glazed water pipes, or concrete porous pipes, though the latter may prove unsuitable where subsoil water carries sulphates or is acidic owing to the presence of peat. Trenches for these pipes need be just wide enough at the bottom to permit laying the pipes, which shall be laid with open joints to proper lines and gradients.

It is advisable to cover the pipes with clinker free from fine ash, brick ballast or other suitable rubble, or a layer of inverted turf, brush-wood or straw before refilling the trench, in order to prevent the infiltration of silt through the open joints. Where the subsoil drain is also to serve the purpose of collecting surface water, the rubble shall be carried up to a suitable level and when required for a lawn or playing field, the remainder of the trench shall be filled with pervious top soil. When refilling the trenches, care shall be taken to prevent displacement of pipes in line of levels. When they pass near trees or through hedges, socket pipes with cement or bitumen joints shall be used to prevent penetration by roots.

4.7.3.2 *French drain*

A shallow trench is excavated, the bottom neatly trimmed to the gradient and the trench filled with broken stone, gravel or clinker, coarse at the bottom and finer towards the top.

4.8 Selection and Installation of Sanitary Appliances

Selection, installation and maintenance of sanitary appliances shall be done in accordance with good practice [E-2(22)].

4.9 Refuse Chute System

The refuse chute system provided shall be in accordance with Part E ‘Plumbing Services, Section 3 Solid Waste Management’ of this NBCS.

4.10 Inspection and Testing

4.10.1 *Inspection*

4.10.1.1 All sanitary appliances and fitments shall be carefully examined for defects before they are installed and also on the completion of the work.

4.10.1.2 Pipes are liable to get damaged in transit and, not withstanding tests that may have been made before despatch, each pipe shall be carefully examined on arrival on the site. Preferably, each pipe shall be rung with a hammer or mallet and those that do not ring true and clear shall be rejected. Sound pipes shall be carefully stored to prevent damage. Any defective pipes shall be segregated, marked in a conspicuous manner and their use in the works prevented.

4.10.1.3 Cast iron pipes shall be carefully examined for damage to the protective coating. Minor damage shall be made good by painting over with hot tar or preferably bitumen. But if major defects in coating exist, the pipes shall not be used unless recoated. Each pipe shall be carefully re-examined for soundness before laying.

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4.10.1.4 Close inspection shall be maintained at every stage in the work, particularly as to the adequacy of timber supports used in excavation and the care and thoroughness exercised in filling.

4.10.1.4.1 Careful note shall be kept of the condition of any sewer, manhole or other existing work which may be uncovered and any defects evident shall be pointed out immediately to the Authority.

4.10.1.4.2 No work shall be covered over or surrounded with concrete until it has been inspected and approved by the Authority.

4.10.2 *Testing*

4.10.2.1 Comprehensive tests of all appliances shall be made by simulating conditions of use. Overflow shall be examined for obstructions.

4.10.2.2 *Smoke test*

All soil pipes, waste pipes, and vent pipes and all other pipes when above ground shall be approved gas-tight by a smoke test conducted under a pressure of 25 mm of water and maintained for 15 min after all trap seals have been filled with water. The smoke is produced by burning only waste or tar paper or similar material in the combustion chamber of a smoke machine. Chemical smokes are not satisfactory.

4.10.2.3 *Water test*

4.10.2.3.1 *For pipes other than cast iron*

Glazed and concrete pipes shall be subjected to a test pressure of at least 1.5 m head of water at the highest point of the section under test. The tolerance figure of 2 litre/cm of diameter/km may be allowed during a period of 10 min. The test shall be carried out by suitably plugging the low end of the drain and the ends of connections, if any, and filling the system with water. A knuckle bend shall be temporarily jointed in at the top end and a sufficient length of the vertical pipe jointed to it so as to provide the required test head, or the top end may be plugged with a connection to a hose ending in a funnel which could be raised or lowered till the required head is obtained and fixed suitably for observation.

Subsidence of the test water may be due to one or more of the following causes:

a) Absorption by pipes and joints;

b) Sweating of pipes or joints;

c) Leakage at joints or from defective pipes; and

d) Trapped air.

Allowance shall be made for (a) by adding water until absorption has ceased after which the test proper should commence. Any leakage will be visible and the defective part of the work should be cut out and made good. A slight amount of sweating which is uniform may be overlooked, but excessive sweating from a particular pipe or joint shall be watched for and taken as indicating a defect to be made good. A slight amount of sweating which is uniform may be overlooked, but excessive sweating from a particular pipe or joint shall be watched for and taken as indicating a defect to be made good.

NOTE — This test will not be applicable to sanitary pipe work above ground level.

4.10.2.3.2 *For cast iron pipes*

Cast iron sewers and drains shall be tested as for glazed and concrete pipes. The drain plug shall be suitably strutted to prevent their being forced out of the pipe during the test.

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4.10.2.4 *Tests for straightness and obstruction*

The following tests shall be carried out:

a) By inserting at the high end of the sewer or drain a smooth ball of a diameter 13 mm less than the pipe bore. In the absence of obstruction, such as yarn or mortar projecting through the joints, the ball should roll down the invert of the pipe and emerge at the lower end; and

b) By means of a mirror at one end of the line and lamp at the other. If the pipeline is straight, the full circle of light may be observed. If the pipe line is not straight, this will be apparent. The mirror will also indicate obstruction in the barrel.

4.10.2.5 *Test records*

Complete records shall be kept of all tests carried out on sewers and drains both during construction and after being put into service.

4.11 Maintenance

4.11.1 *General*

Domestic drainage system shall be inspected at regular intervals. The system shall be thoroughly cleaned out at the same time and any defects discovered shall be made good.

4.11.2 *Cleaning of Drainage System*

4.11.2.1 Sewer maintenance crews, when entering a deep manhole or sewer where dangerous gas or oxygen deficiencies may be present, shall follow the following procedures:

a) Allow no smoking or open flames and guard against parks;

b) Erect warning signs;

c) Use only safety gas-proof, electric lighting equipment;

d) Test the atmosphere for noxious gases and oxygen deficiencies (presence of hydrogen sulphide is detected using lead acetate paper and that of oxygen by safety lamps);

e) If the atmosphere is normal, workmen may enter with a safety belt attached and with two men available at the top. For extended jobs, the gas tests shall be repeated at frequent intervals, depending on circumstances;

f) If oxygen deficiency or noxious gas is found, the structure shall be ventilated with pure air by keeping open at least one manhole cover each on upstream and downstream side for quick exit of toxic gases or by artificial means. The gas tests shall be repeated and the atmosphere cleared before entering. Adequate ventilation shall be maintained during this work and the tests repeated frequently;

g) If the gas or oxygen deficiency is present and it is not practicable to ventilate adequately before workers enter, a hose mask shall be worn and extreme care taken to avoid all sources of ignition. Workers shall be taught how to use the hose equipment. In these cases, they shall always use permissible safety lights (not ordinary flash lights), rubber boots or non-sparking shoes and non-sparking tools;

h) Workmen descending a manhole shaft to inspect or clean sewers shall try each ladder step or rung carefully before putting the full weight on it to guard against insecure fastening due to corrosion of the rung at the manhole wall. When work is going on in deep sewers, at least two men shall be available for lifting workers from the manhole in the event of serious injury; and

j) Portable air blowers, for ventilating manhole, are recommended for all tank, pit or manhole work where there is a question as to the presence of noxious gas, vapours or oxygen deficiency. The motors for these shall be of weather proof and flame-proof types; compression ignition diesel type (without sparking plug) may be used. When used, these shall be placed not less than 2 m away from the opening and on the leeward side protected from wind, so that they will not serve as a source of ignition for any inflammable gas which might be present. Provision should be made for ventilation and it should be of the forced type which can be provided by a blower located at ground level with suitable flexible ducting to displace out air from the manhole.

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4.11.2.2 The following operations shall be carried out during periodical cleaning of a drainage system:

a) The covers of inspection chambers and manholes shall be removed and the side benching and channels scrubbed;

b) The interceptive trap, if fitted, shall be adequately cleaned and flushed with clean water. Are shall be taken to see that the stopper in the rodding arm is securely replaced;

c) All lengths of main and branch drains shall be rodded by means of drain rods and a suitable rubber or leather plunger. After rodding, the drains shall be thoroughly flushed with clean water. Any obstruction found shall be removed with suitable drain cleaning tools and the system thereafter shall be flushed with clean water;

d) The covers of access plates to all gullies shall be removed and the traps plunged and flushed out thoroughly with clean water. Care shall be taken not to flush the gully deposit into the system;

e) Any defects revealed as a result of inspection or test shall be made good;

f) The covers or inspection chambers and gullies shall be replaced, bedding them in suitable grease or other materials; and

g) Painting of ladders/rings in deep manholes and external painting of manhole covers shall be done with approved paints.

4.11.3 All surface water drains shall be periodically rodded by means of drain rods and a suitable rubber or leather plunger. After rodding, they shall be thoroughly flushed with clean water. Any obstruction found shall be removed with suitable drain cleaning tools.

4.11.4 All subsoil drains shall be periodically examined for obstruction at the open joints due to the roots of plants or other growths.

4.12 Pumping of Sewage

4.12.1 In the design of sewerage system, it is necessary to collect the sewage of a low lying area at some convenient point from which it shall be lifted by pumps. At the treatment plant also, lifting of sewage may be necessary to provide head for the flow by gravity of sewage.

4.12.2 *Sewage Pump Stations, Sizing of Sumps and Pumps*

They are required as onsite pump stations to cater to sewage from toilets and kitchen. The stations would be located in basement floors and leading the sewage to onsite treatment plants. Submersible centrifugal pumps are used for pumping the sewage. The sump capacity depends on effective holding capacity considering the flow from drainage fixtures. Usually, retention period of 15 min is adopted. The size of sump depends on the availability of space. The size of the discharge pipe shall be one nominal size higher than the design size or the pump outlet, with a velocity of 1 m/s. Pumps are sized for 100 percent design flow.

NOTE — For other details reference to good practice [E-2(13)] shall be made.

4.13 Sewage Treatment Systems

4.13.1 Sewage treatment is the process of removing contaminants from waste water, primarily from domestic sewage. It includes physical, chemical and biological processes to remove these contaminants and produce environmentally safe treated water (or treated effluent). Sewage treatment is normally carried out by aerobic bacteria (aerobic process; *see* Fig. 18) or anaerobic bacteria (anaerobic process; *see* Fig. 19), which metabolize the organic matter, multiply, and are subsequently settled out and disposed of as sludge.

The by-product of sewage treatment is usually a semisolid waste or slurry, called sewage sludge, that has to undergo further treatment before being suitable for disposal or further application.

4.13.2 The main objective of treating waste water is to stabilize decomposable organic matter present in the sewage to produce treated effluent and sludge, which can be disposed of in the environment without causing health hazards or nuisance.

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The microbial population in treatment process can be cultured using the following systems:

a) *Suspended growth system* — In this system, microorganisms remain in suspension, and their concentration is related to mixed liquor suspended solids (MLSS);

b) *Attached growth system* — In this system, microorganisms are developed over mobile or immobile solid covered in biomass (slime);

c) *Combined growth system* — In this system, both systems are used to attain the shock loads.

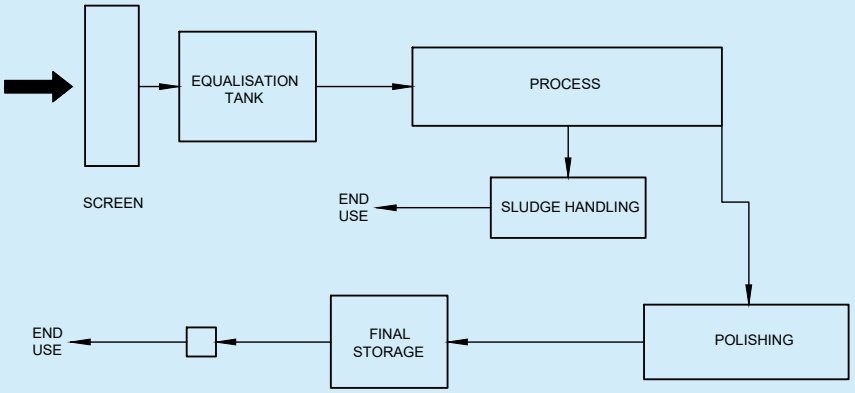

FIG. 18 TYPICAL SCHEME FOR SEWAGE TREATMENT (AEROBIC PROCESS)

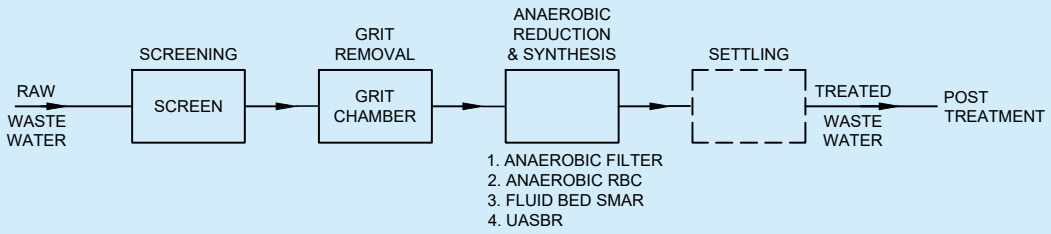

FIG. 19 TYPICAL SCHEME FOR SEWAGE TREATMENT (ANAEROBIC PROCESS)

4.13.3 *Technologies*

Following technologies for sewage treatment shall be considered based on the requirement:

a) *Extended aeration with activated sludge process* (*EAASP*) — Activated sludge process is the aerobic biological process by which non-settleable substances occurring in dissolved and colloidal forms are converted into settleable sludge which is removed from the liquid carrier (water);

This process is well suitable for completely populated community and does not require skilled labour for handling the plant. It is time tested and requires more number of units to achieve biological oxygen demand (BOD) less than 10 ppm, like coagulants required for better quality;

b) *Sequential batch reactor* (*SBR*) — It is an activated sludge process designed to operate under non-steady state conditions. An SBR operates in a true batch mode with aeration and sludge settlement both occurring in the same tank. There is a degree of flexibility associated with working in a time rather than in a space sequence;

Plant for this process requires less space due to batch process, well suitable for modular growth. It can handle smallest flows and the desired quality can be achieved without coagulants. It requires good quality of decanters and skilled labour as the process is timer-based automation;

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c) *Membrane bio-reactor* (*MBR*) — It is a continuous process of activated sludge treatment, but solids separation is done through pressurised system or through media. As there is physical barrier for solid separation, quality of treatment is good;

It is suitable for any type of growth pattern and can handle smaller flows. It requires less space, and skilled labours to handle.

d) *Rotating bio bed reactor* (*RBBR*) — It is combined growth process (aerobic and anaerobic). Bacteria are allowed to grow on media, which is exposed to atmospheric air. It is also known as rotating biological contactor (RBC);

It is suitable for smaller capacities and does not require skilled labour to handle. The quality of treatment is good.

e) *Fluidized bio bed reactor* (*FBBR*) — In this process, cells are immobilized in small particles which move with the fluid. The small particles create a large surface area for cells to stick and enable a high rate of transfer of oxygen and nutrients to the cells. It is also known as moving bed bio reactor (MBBR). It is suitable for all type of communities, does not require skilled labour and requires less space. It can be installed for all capacities, and the quality of treatment is good;

f) *Submerged aerobic fixed film reactor* (*SAFF*) — It is a combined growth process in which bio-media is fixed and bacteria are allowed to grow on media, which has air supply from below;

It does not require skilled labour. Supporting structure for media should be anti-corrosive to enable media fixing.

g) *Trickling filters* — It is an attached growth process where media is used to grow bacteria by trickling sewage over the media. It is an old concept and is not now widely used;

h) *Oxidation ponds/lagoons* — Oxidation ponds, also called lagoons or stabilization ponds are large shallow ponds designed to treat waste water through the interaction of sunlight, bacteria and algae;

j) *Packaged sewage treatment plants* (*PSTPs*) — Packaged sewage treatment plants enable on-site treatment of domestic waste water, including grey and black water. These systems are designed as turnkey solutions, catering to the advanced treatment needs of individual communities or decentralized community setups. PSTPs are particularly effective in areas lacking centralized sewerage systems or where such systems are impractical. The design, structural integrity, installation, operation, and maintenance of PSTPs shall comply with the provisions of accepted standard [E-2(23)];

k) *Biodigestor* — Biodigester is a non-sewer on-site human waste treatment system that operates under anaerobic conditions to breakdown organic waste into simpler molecules, water, and biogas. It primarily consists of a specially designed biodigester tank and a bacterial consortium, known as anaerobic microbial inoculum (AMI). The anaerobic digestion process significantly reduces organic matter, minimizes sludge generation, and lowers pathogen transmission. Effluent from biodigesters can also be introduced into centralized sewer systems, reducing the organic load on sewage treatment plants (STPs) and improving their efficiency. The design, construction, installation and effluent standards of biodigester systems shall adhere to good practices specified in [E-2(24)]; and

m) Another option for on-site sanitation (OSS) systems in both urban and rural areas is the use of septic tanks. Septic tanks may be either prefabricated or constructed on site using suitable materials of construction. Precast concrete septic tanks have been in use in the country. Precast concrete septic tank have been is use in the country another type of septic tank is the rotationally moulded polyethylene septic tank (RMPST). RMPST could be single/multiple piece factory made unit, including inlet and outlet level openings which leaves the factory completed, controlled and ready for installation. These tanks are manufactured using rotational moulding technique which is a method for producing hollow plastic objects by placing finely divided plastic powder particles in a hollow mould that is rotated about two axes or given rock and roll type of motion, exposing it to heat and then to cold. RMPST is thus suitable for installation at standard temperature and pressure conditions. These septic tanks shall meet the accepted standards [E-2(25)].

4.14 Treatment of Wastewater and Usage of Recycled Water

See 4.2.4 of Part E ‘Plumbing Services, Section 1 Water Supply’ of this NBCS.

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ANNEX A

(*Clause* 3.2.1)

APPLICATION FOR DRAINAGE OF PREMISES

I/We hereby make application to the *……..……. …… for permission to drain the premises……Ward No……..…… Street No…… Road/Street known as……..…….....

The sanitary arrangement and drains of the said premises are shown in the accompanying plans and a description of the specification of the work/material used is also appended (Annex B).

I/We undertake to carry out the work in accordance with Part E 'Plumbing Services, Section 2 Drainage and Sanitation' of the National Building Construction Standards (NBCS).

……..……...	……
Signature of the licensed/registered plumber	Signature of the owner
Name and address of the	Name and address……
……	……
……	……
Date……..…	Date……..……

NOTE — The application should be signed by the owner of the premises and shall be countersigned by the licensed/registered plumber.

_____

* Insert the name of the Authority.

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ANNEX B

(*Clause* 3.2.3.2 *and Annex* A)

FORM FOR DETAILED DESCRIPTION OF WORK AND SPECIFICATION OF MATERIALS

a) Separation of rainwater and foul water……

b) Rainwater drains, curbs and points of discharge……..

c) Rainwater gutters, pipes or spouts where discharging…….

d) Open-full-water drains, materials, sizes, curbs and other means places, verandahs, latrines

e) Silt-catcher and grating, size and position……

f) Drains…….

1) Main sewage drains: Fall ……..
   Size…….
2) Branch drains : Fall ……..
   Size……
3) Materials……
4) Method of jointing……

g) Bedding of pipes:

1) Method of bedding……..
2) Thickness and width of beds of concrete……
3) Thickness of concrete round pipes……..

h) Protection of drain laid under wall……

j) Traps, description and intercepter:

1) Lavatory waste pipes……
2) Bath waste pipes…….
3) Sink……
4) Gully-traps……
5) Water closet traps……
6) Grease traps…….
7) Slop sink……..
8) Urinal……..
9) Others…….

k) Manholes and inspection chambers:

1) Thickness of walls…….
2) Description of bricks……..
3) Description of rendering……
4) Description of invert channels…….

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5) Depth of chambers……

6) Size and description of cover and manner of fixing…….

m) Ventilation of drain:

1) Position – Height above nearest ground level……..

2) Outlet shaft position of terminal at top……

n) Soil pipe, waste pipe and ventilating pipe connections:

1) Lead and iron pipes……..

2) Lead pipe of trap with cast iron pipe……..

3) Stoneware pipe or trap with lead pipe……

4) Lead soil pipe or trap with stoneware pipe or trap……

5) Cast iron pipe with stoneware drain……

6) Stoneware trap with cast iron soil pipe……..

p) Ventilation of water closet trap sink, lavatory and other traps material and supports.

q) Water closets (apartments):

1)

i) At or above ground level……..

ii) Approached from……

iii) Floor material……..

iv) Floor fall towards door……

v) Size of window opening in wall made to open……

vi) Position of same…….

vii) Means of constant ventilation……

viii) Position of same……..

2) Water closet apparatus:

i) Description of pan, basin, etc……

ii) Kind……...

iii) Flushing cistern…….

iv) Material of flushing pipe…….

v) Internal diameter…….

vi) Union with basin…….

r) Sanitary fittings, water storage tank, etc:

1) Number and description of sanitary fittings in room and rooms in which they are to be installed…….

2) Capacity and position of water storage tanks……..…….

3) Size and number of draw off taps and whether taken off storage tanks or direct from main supply……...

4) Details of draw off taps, that is, whether they are of plain screw down pattern or ‘waste not’ and description of any other sanitary work to be carried out not included under above headings……..

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s) Depth of sewer below surface of street……...

t) Level of invert of house drain at point of junction:

1) With sewer…….

2) Level of invert of sewer at point of junction with house drain……..

3) Distance of nearest manhole on sewer from the point at which the drain leaves the premises……

u) Schedule of pipes:

Sl No.	*Description of Pipe/Drain*	*Materials*	*Diameter*	*Weight*	*Method of Jointing*
(1)	(2)	(3)	(4)	(5)	(6)
i)	Subsoil drains				
ii)	Main sewage drains				
iii)	Branch sewag drains				
iv)	Soil pipes				
v)	Ventilating pipes other than soil pipes				
vi)	Waste pipes				
vii)	Rainwater pipes				
viii)	Anti-syphon pipes				

Signature of the licensed/registered plumber……..…

Name and address of the licensed/registered plumber…….……...

……....

……....

…….…..

Date……...……..

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ANNEX C

(*Clause* 3.2.5)

FORM FOR LICENSED/REGISTERED PLUMBER'S COMPLETION CERTIFICATE

Certified that I/we have completed the plumbing work of drainage and sanitation system for the premises as detailed below. This may be inspected, approved and connection given.

Ward No……..….

Street…….…..…..

Locality……..……..…

Block No……..……..

House No……

Details of work……...…….
……
……

The work was sanctioned by the Authority*
vide
…….……. ……..……

Signature of the owner

Name and address……

……

Signature of the licensed/registered plumber

Name and address …….……

……..

Date……

The Authority's Report

Certified that the plumbing work of drainage and sanitation system for the premises, have been laid, applied, executed in accordance with Part E 'Plumbing Services, Section 2 Drainage and Sanitation' of the National Building Construction Standards (NBCS).

Drainage Connection to the main sewer will be made on……

Date…… The Authority……..…

* Insert the name of the Authority

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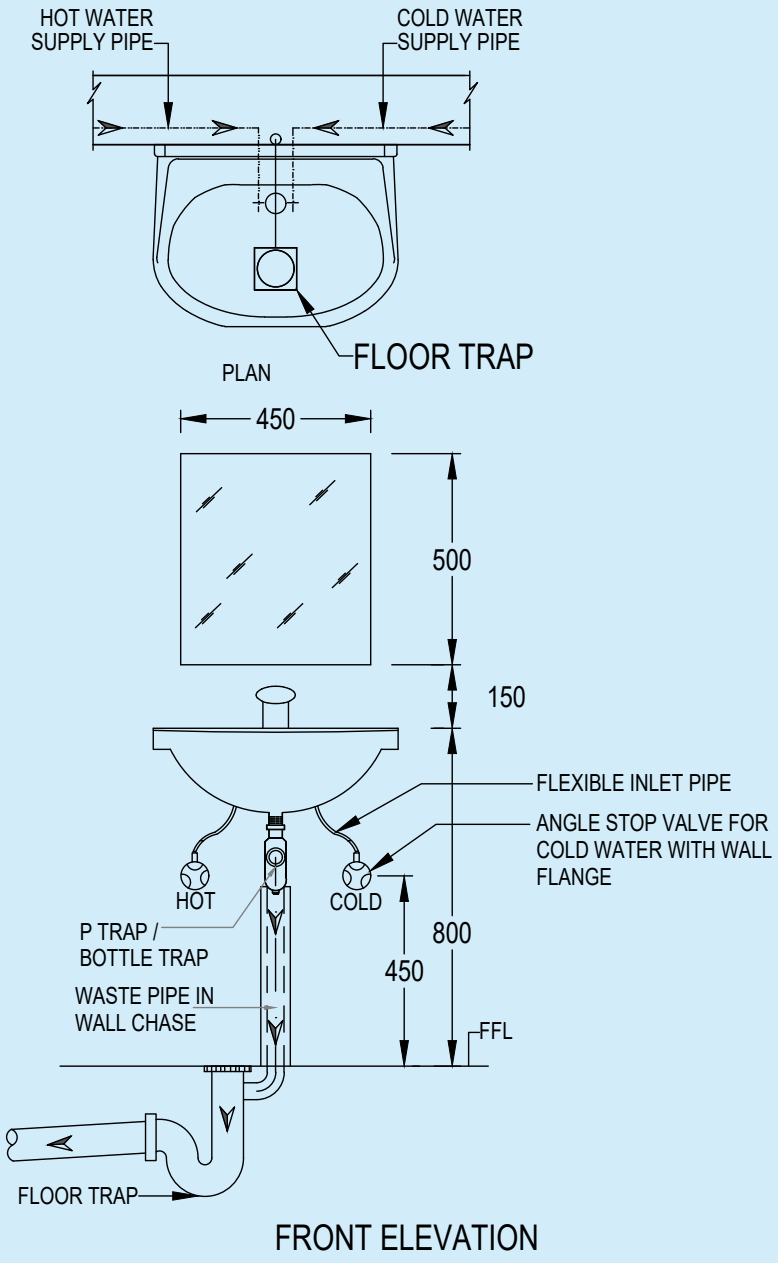
ANNEX D

(*Clause* 4.5.1.4)

TYPICAL MOUNTING ARRANGEMENTS FOR VARIOUS PLUMBING FIXTURES, INCLUDING DRAINAGE SYSTEMS AND VENTILATION

D-1 ARRANGEMENT FOR RECTANGULAR WASH BASIN — *See* Fig. 20



All dimensions in millimetres.

FIG. 20 RECTANGULAR WASH BASIN

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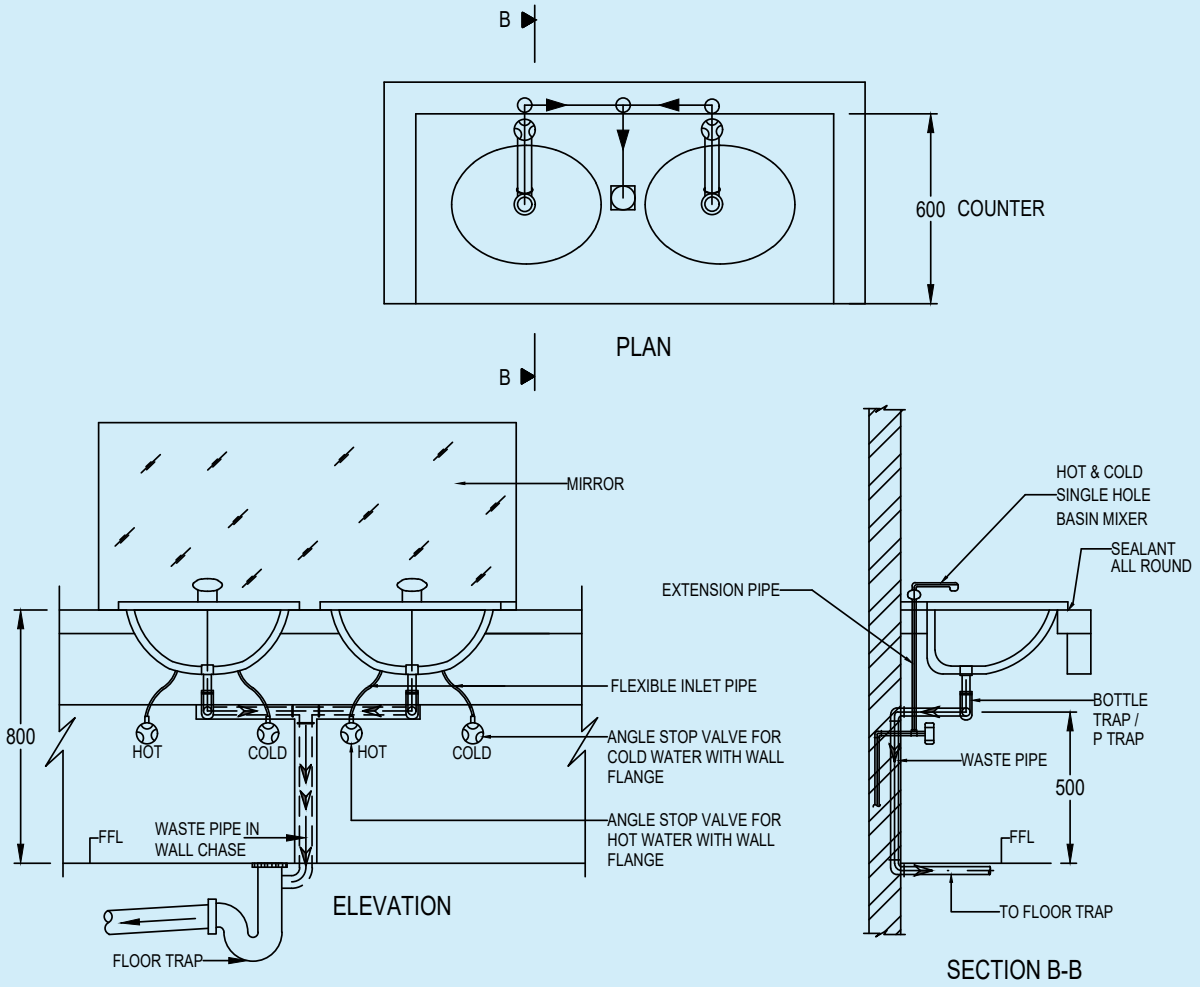
D-2 ARRANGEMENT FOR OVAL WASH BASIN (ABOVE COUNTER) — *See* Fig. 21



All dimensions in millimetres.

FIG. 21 OVAL WASH BASIN (ABOVE COUNTER)

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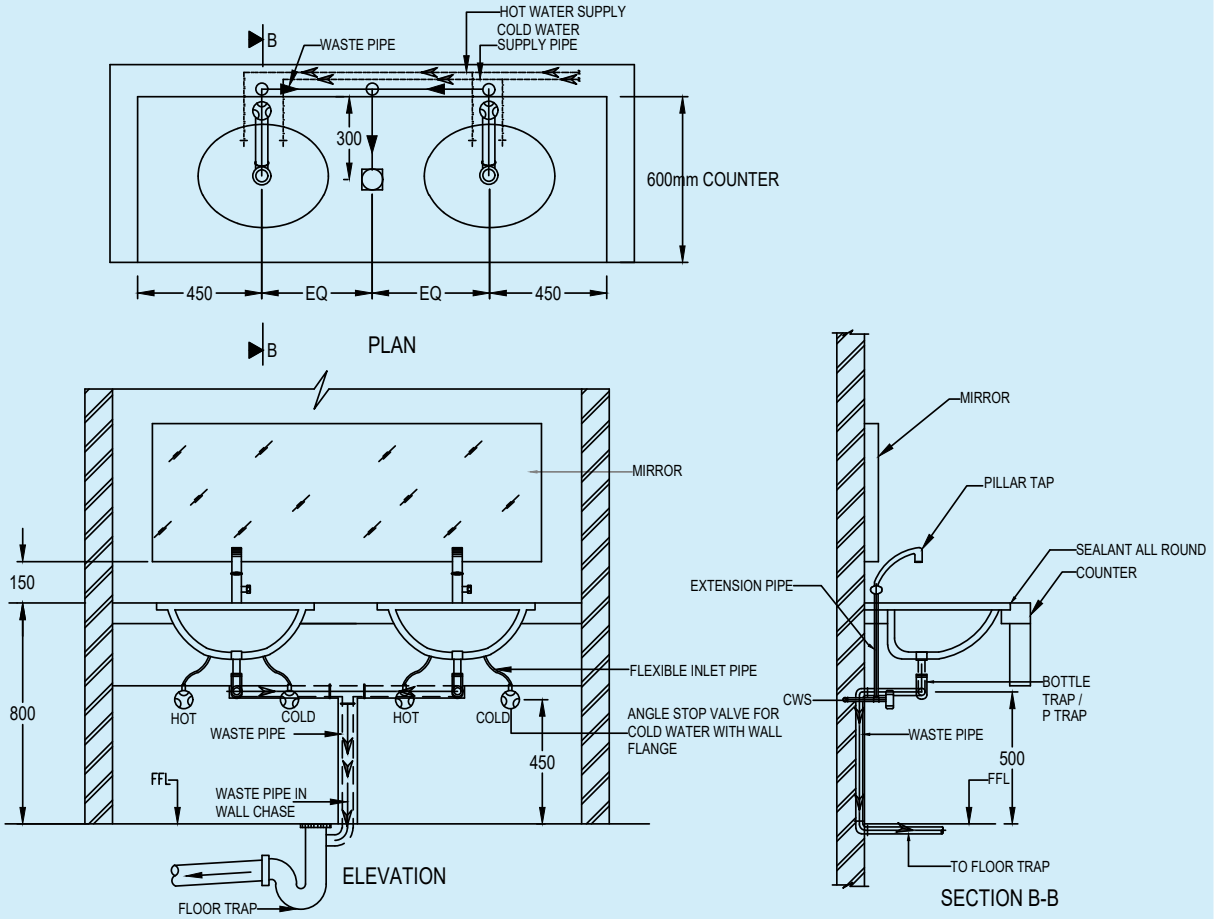
D-3 ARRANGEMENT FOR OVAL WASH BASIN (BELOW COUNTER) — *See* Fig. 22



All dimensions in millimetres.

FIG. 22 OVAL WASH BASIN (BELOW COUNTER)

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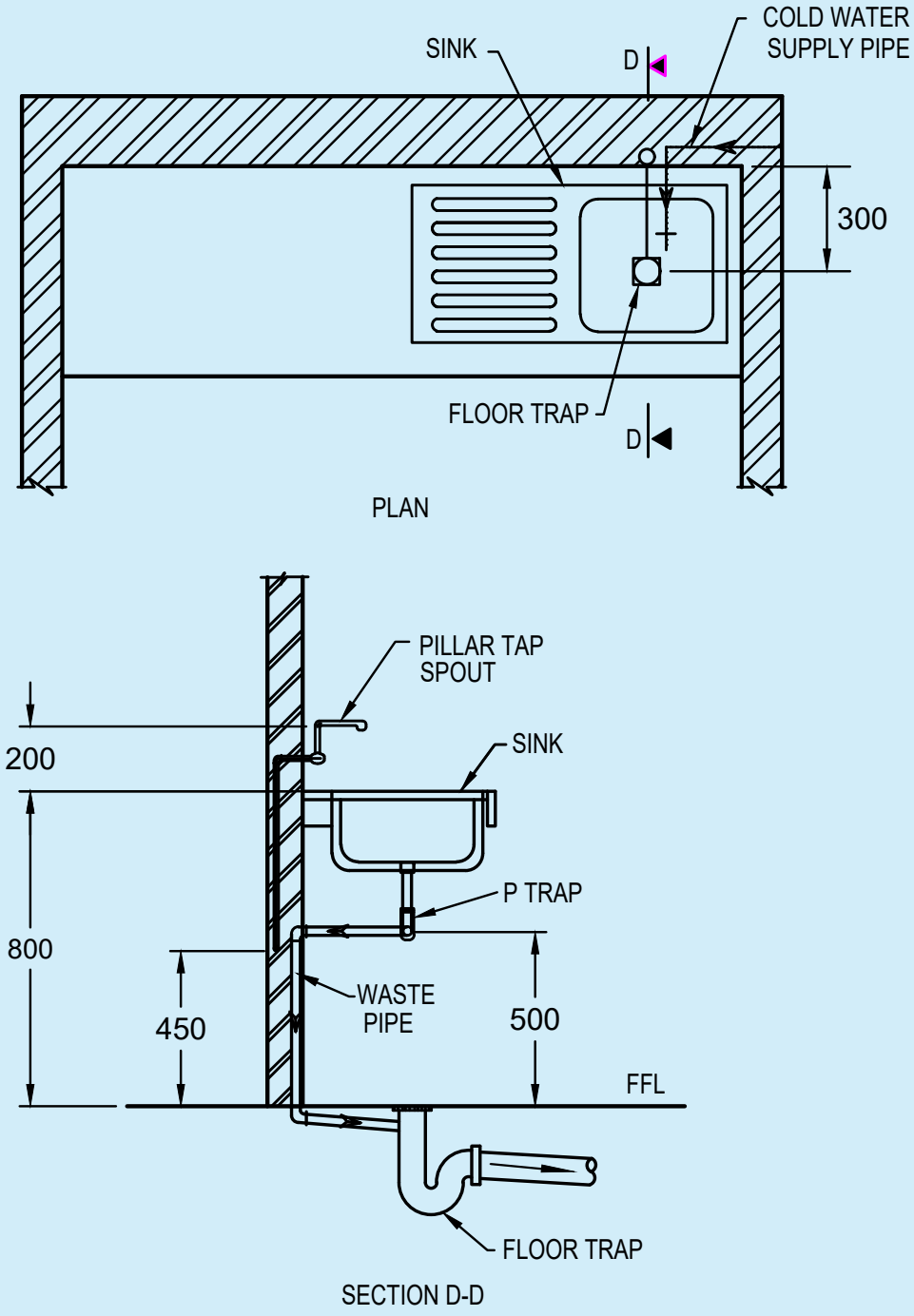
D-4 ARRANGEMENT FOR SINK — *See* Fig. 23



All dimensions in millimetres.

FIG. 23 SINK

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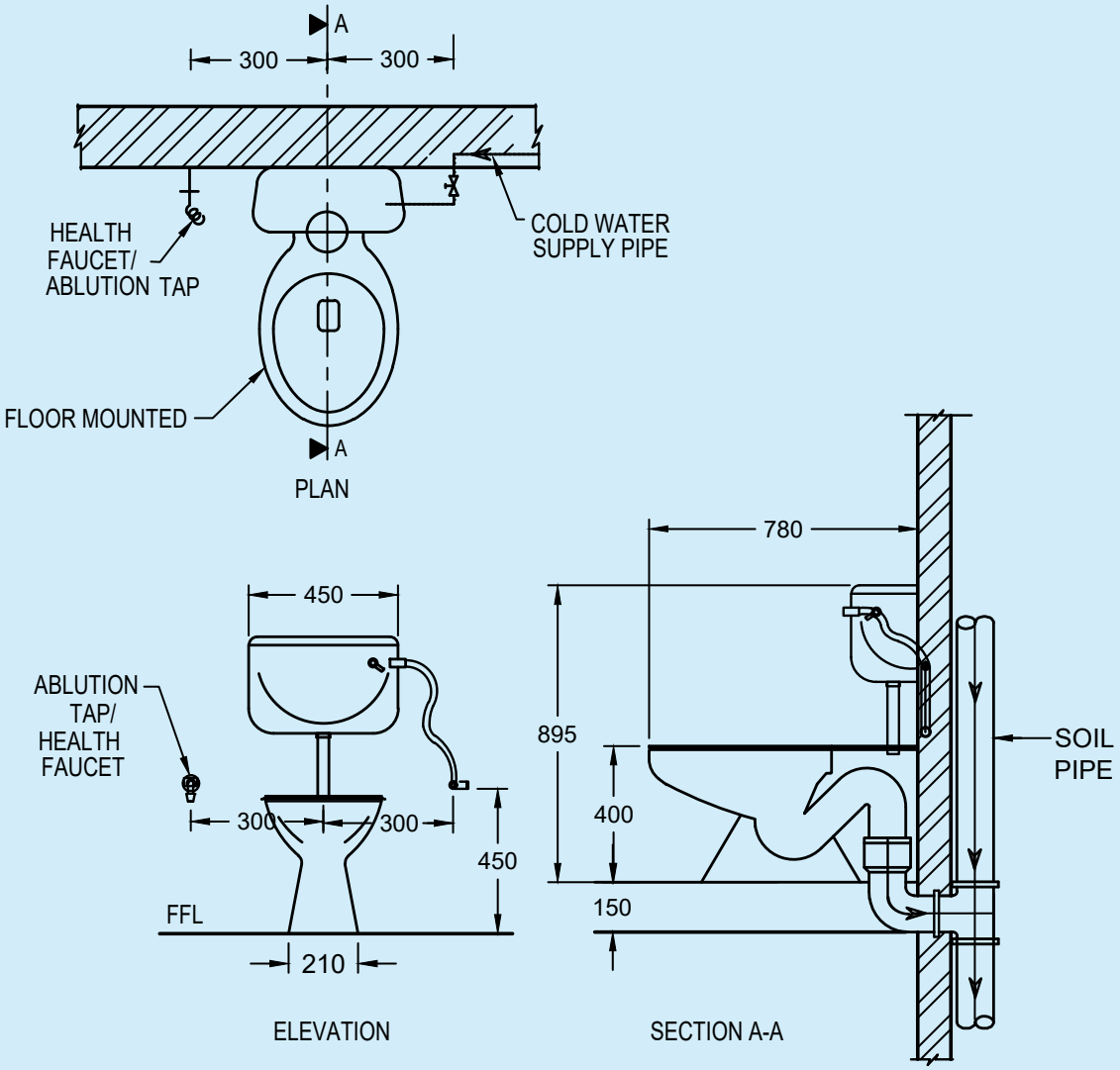
D-5 ARRANGEMENT FOR EUROPEAN WATER CLOSET (FLOOR MOUNTED WITH FLUSH TANK AND S-TRAP) — *See* Fig. 24



All dimensions in millimetres.

FIG. 24 EUROPEAN WATER CLOSET
(FLOOR MOUNTED WITH FLUSH TANK AND S-TRAP)

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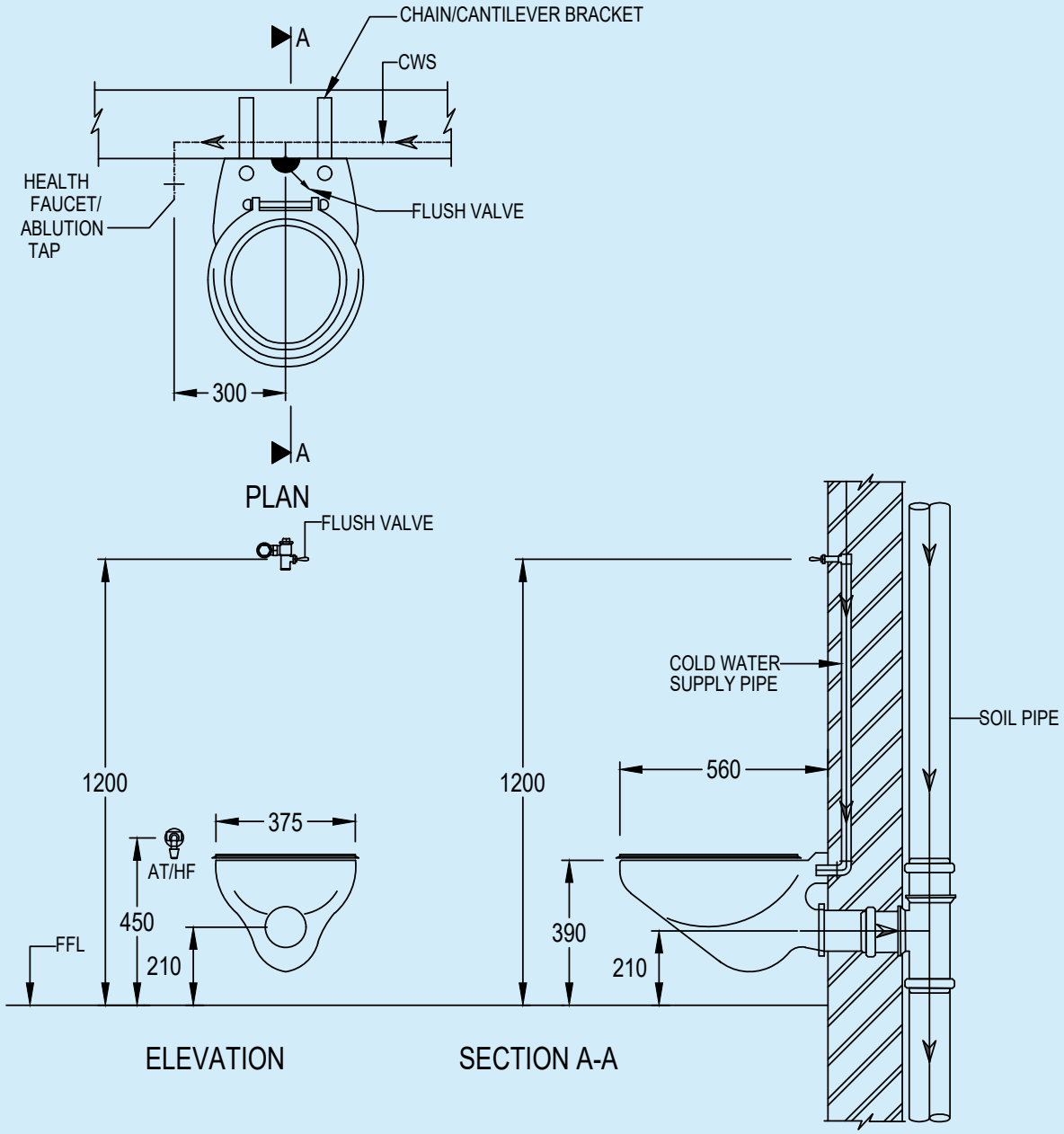
D-6 ARRANGEMENT FOR EUROPEAN WATER CLOSET (WALL HUNG WITH FLUSH VALVE) — *See* Fig. 25



All dimensions in millimetres.

FIG. 25 EUROPEAN WATER CLOSET (WALL HUNG WITH FLUSH VALVE)

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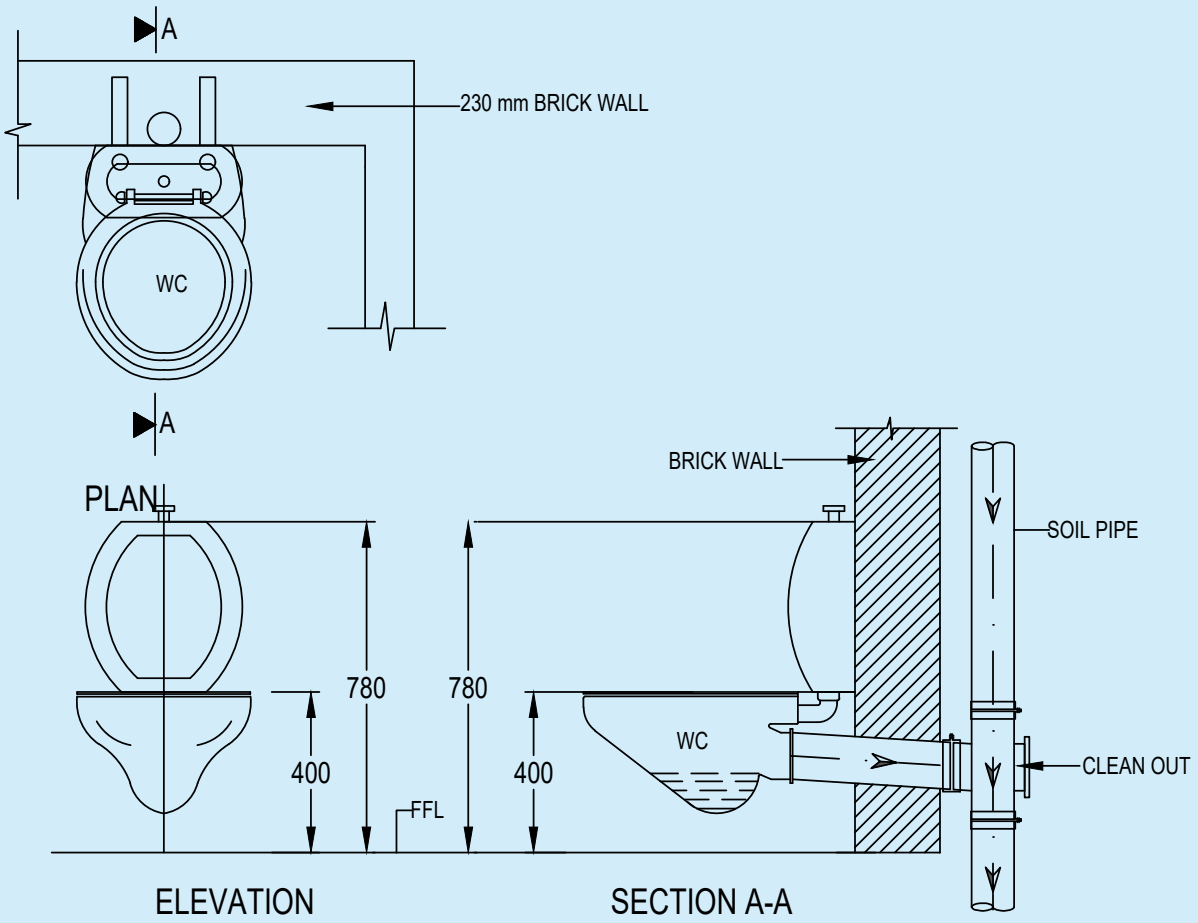
D-7 ARRANGEMENT FOR EUROPEAN WATER CLOSET (WALL HUNG WITH FLUSHING CISTERN) — *See* Fig. 26



All dimensions in millimetres.

FIG. 26 EUROPEAN WATER CLOSET
(WALL HUNG WITH FLUSHING CISTERN)

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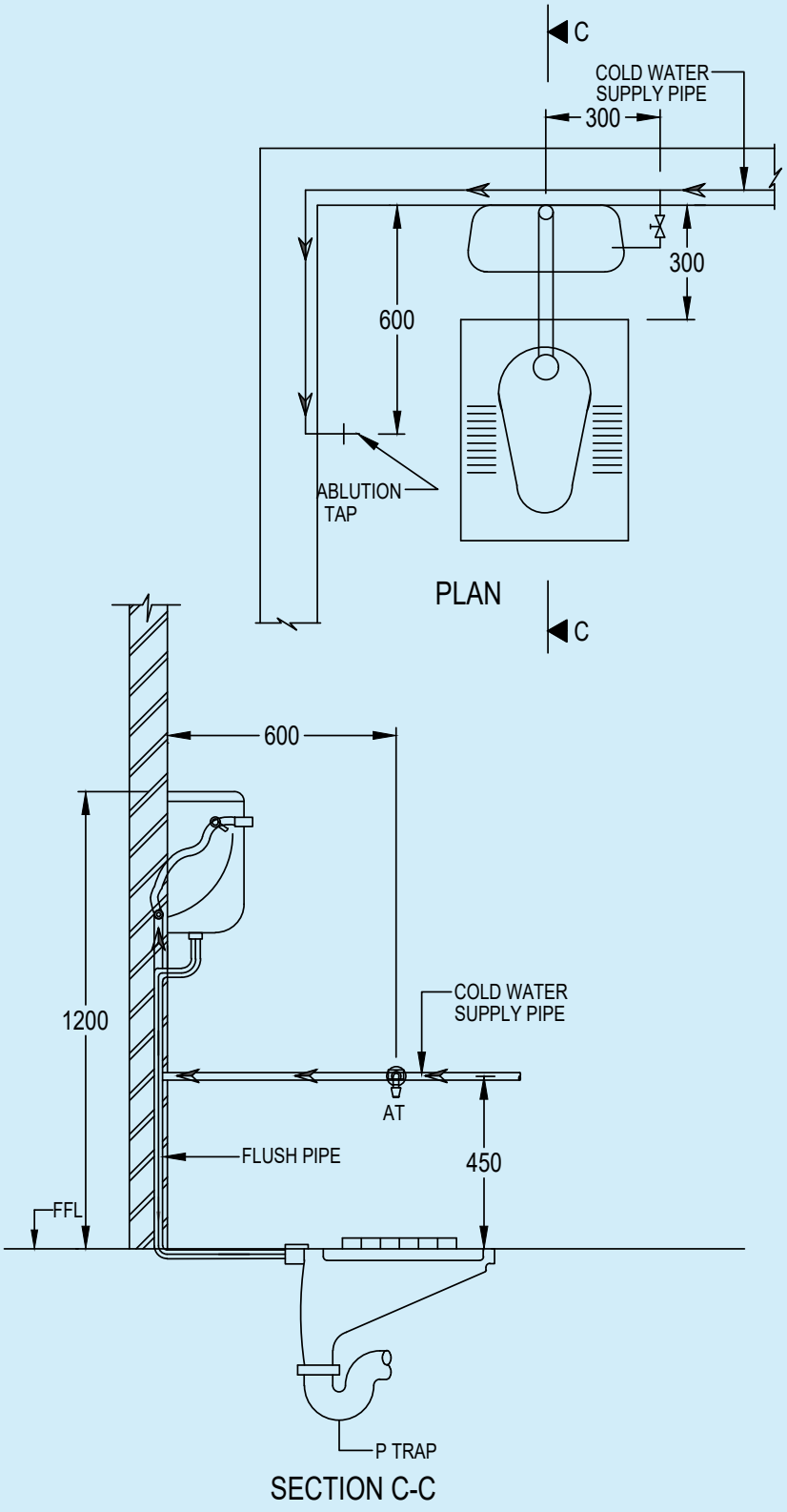
D-8 ARRANGEMENT FOR ORISSA PAN INDIAN WATER CLOSET — *See* Fig. 27



All dimensions in millimetres.

FIG. 27 ORISSA PAN INDIAN WATER CLOSET

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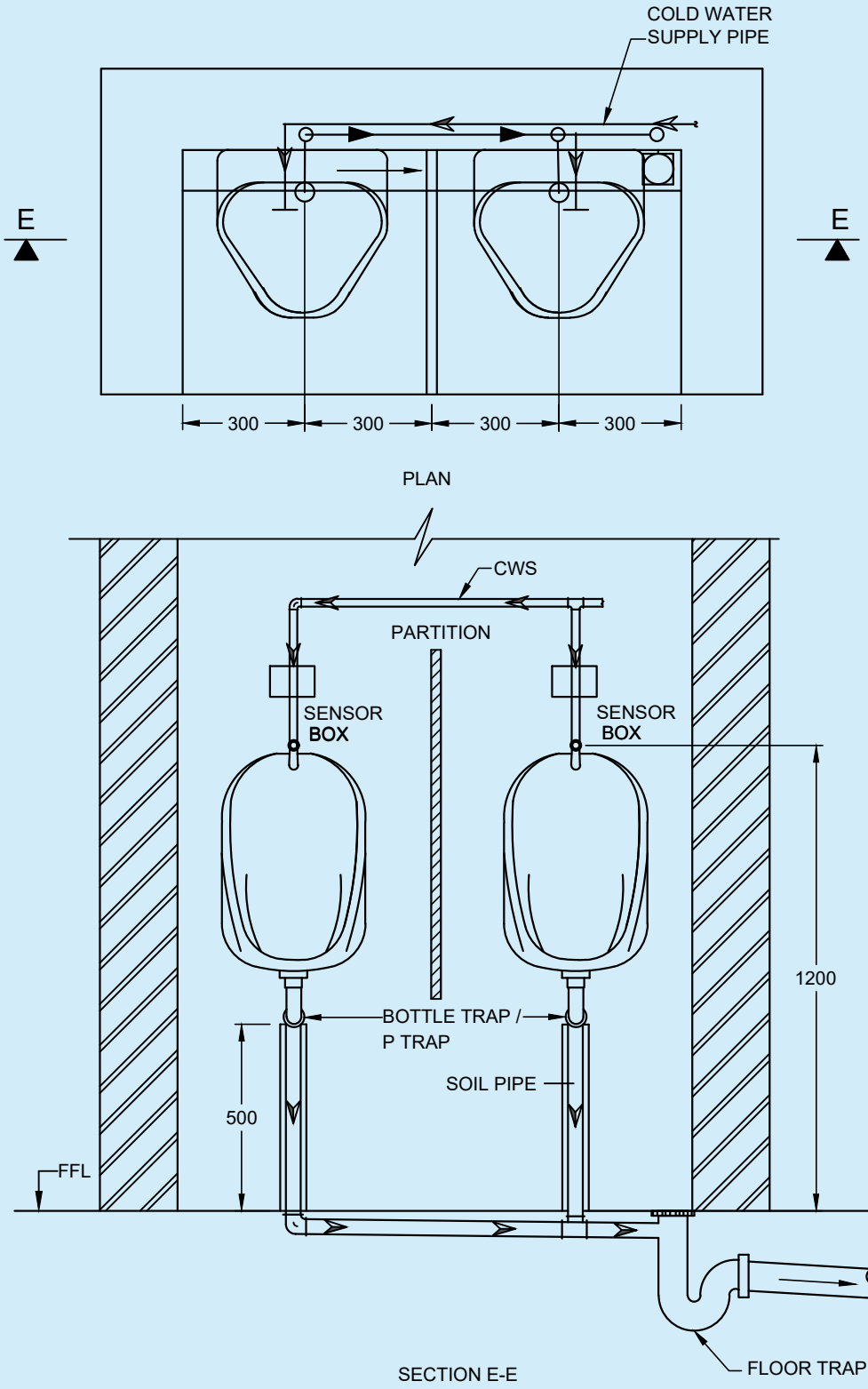
D-9 ARRANGEMENT FOR URINAL — *See* Fig. 28



All dimensions in millimetres.

FIG. 28 URINAL

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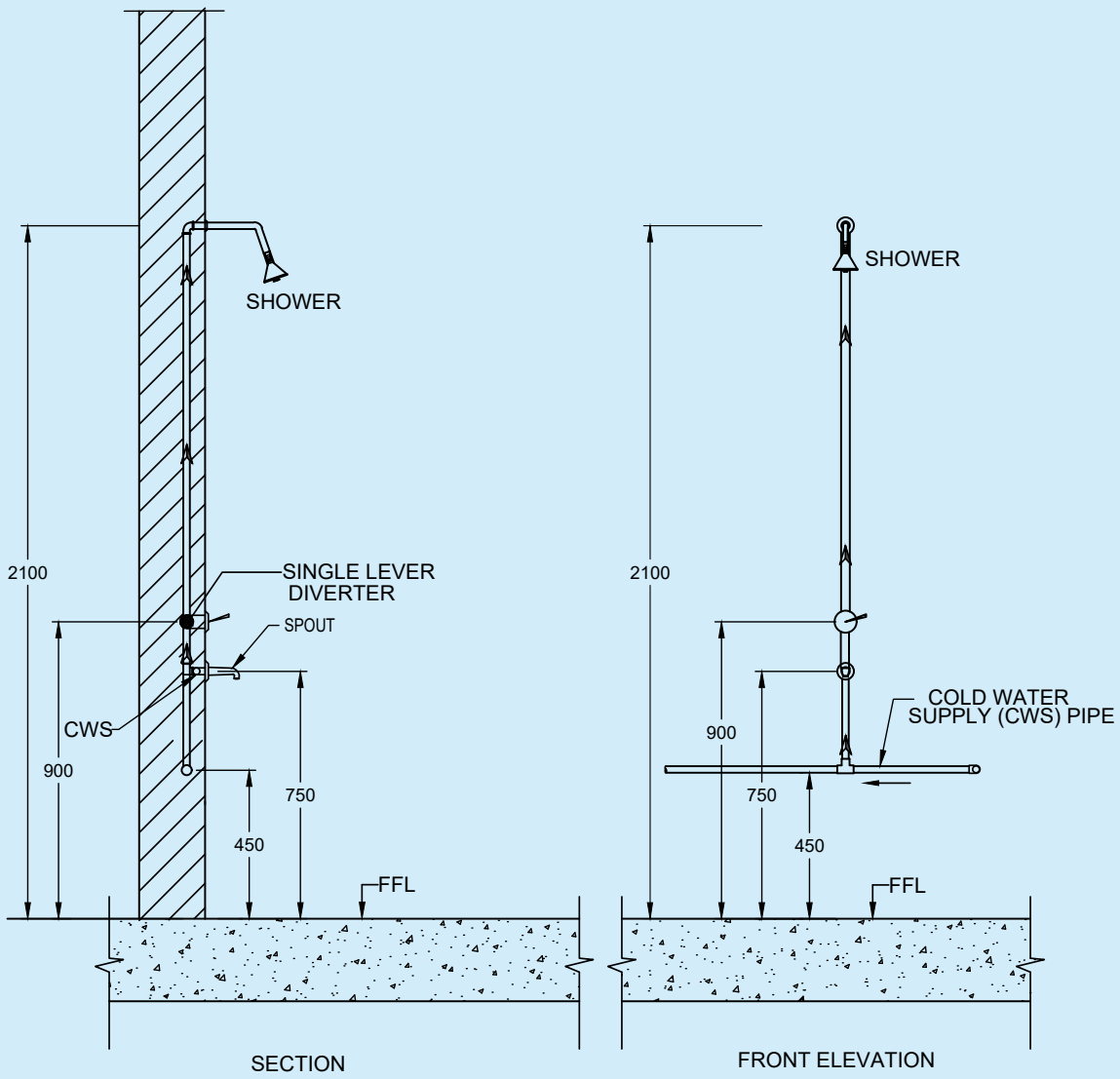
D-10 ARRANGEMENT FOR SHOWER — *See* Fig. 29



All dimensions in millimetres.

FIG. 29 SHOWER

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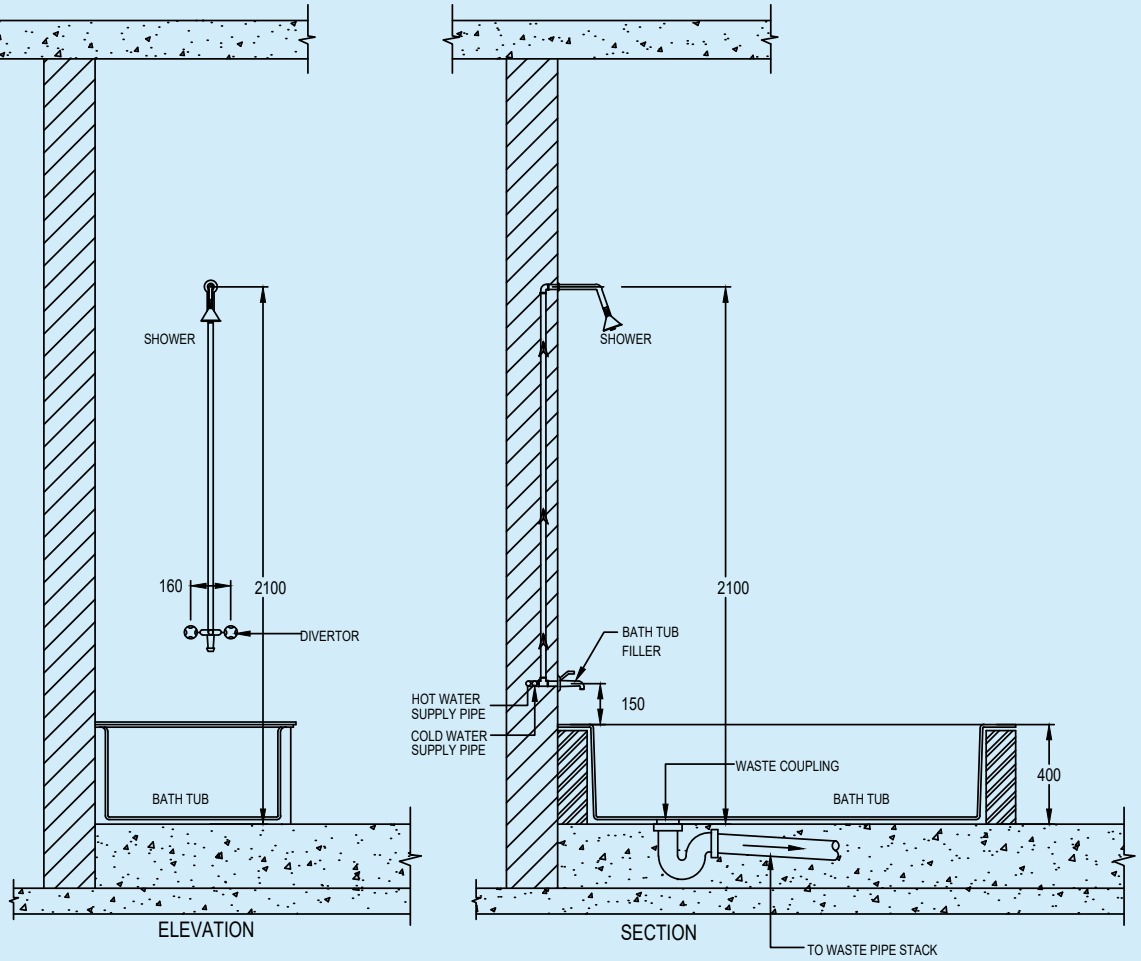
D-11 ARRANGEMENT FOR BATH TUB/SHOWER — *See* Fig. 30



All dimensions in millimetres.

FIG. 30 BATH TUB/SHOWER

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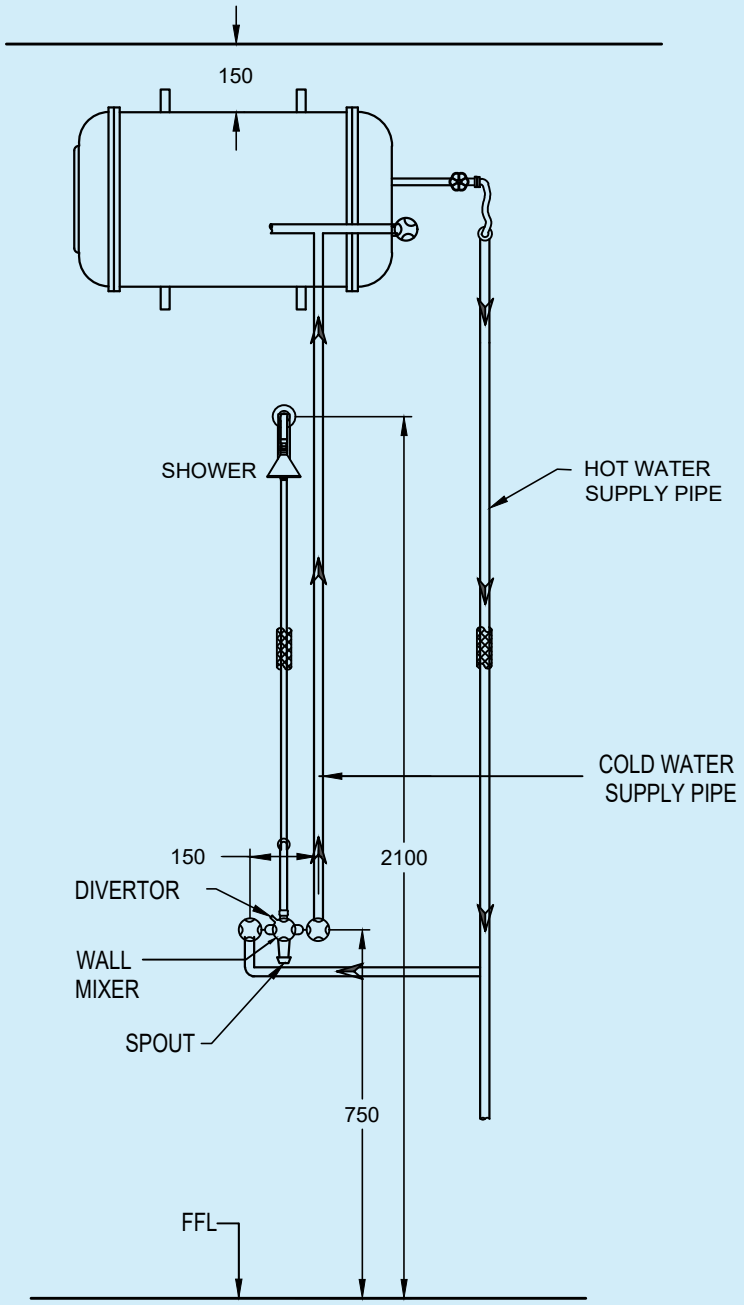
D-12 ARRANGEMENT FOR SHOWER AND ELECTRIC WATER HEATER (HORIZONTAL MOUNTED TYPE) — *See* Fig. 31



All dimensions in millimetres.

FIG. 31 SHOWER AND ELECTRIC WATER HEATER (HORIZONTAL MOUNTED TYPE)

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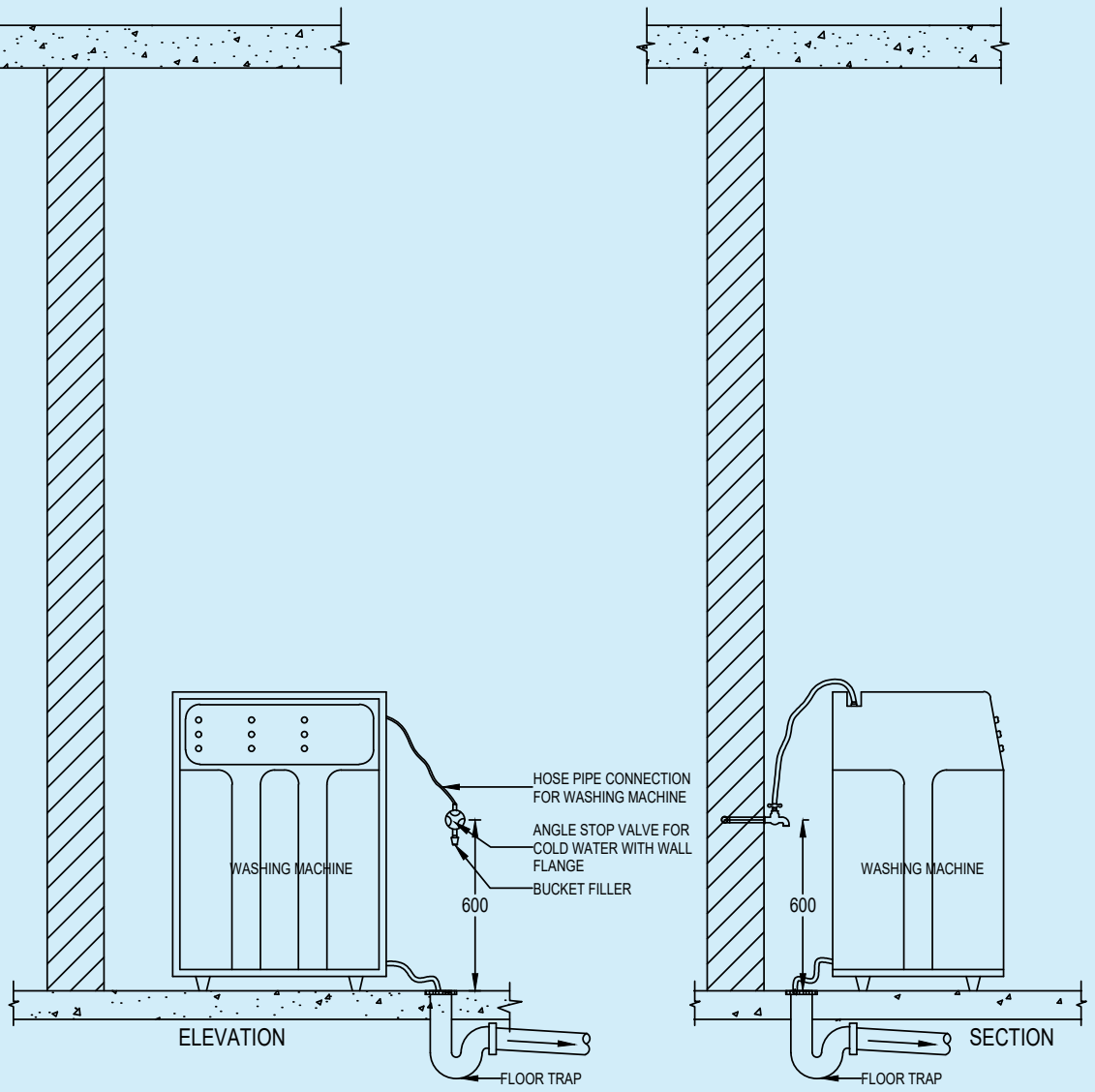
D-13 ARRANGEMENT FOR WASHING MACHINE — *See* Fig. 32



NOTE – Manual type washing machine : waste lead into floor trap.
Automatic type washing machine : waste outlet should be 300 mm above FFL (and as per manufacturer's technical specifications).

All dimensions in millimetres.

FIG. 32 WASHING MACHINE

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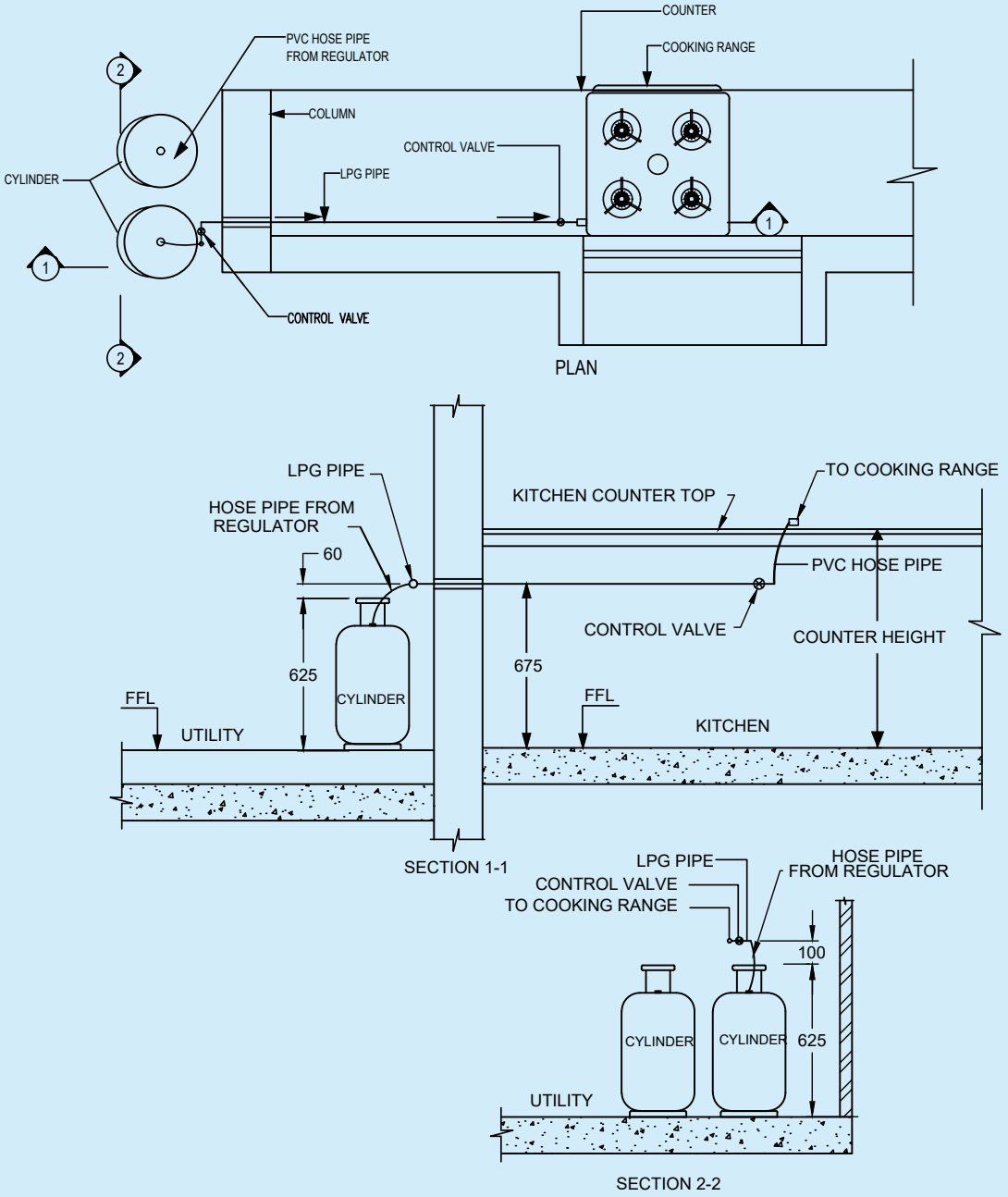
D-14 ARRANGEMENT FOR LPG PIPING — *See* Fig. 33



All dimensions in millimetres.

FIG. 33 LPG PIPING

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used as a guide in conformance with the requirements of the referred clauses in this NBCS.

	IS No.	*Title*
(1)	IS 10446 : 1983	Glossary of terms relating to water supply and sanitation
(2)	IS 4963 : 2025	Accessibility in built environment for older adults and persons with disabilities — Requirements (*second revision*)
(3)	IS 11208 : 1985	Guidelines for registration of plumbers
(4)	IS 774 : 2021	Ceramic (vitreous china) flushing cisterns for water closets and urinals — Specification (*sixth revision*)
	IS 2548	Plastic seats and covers for water-closets — Specification:
	(Part 1) : 1996	Thermoset seats and covers (*fifth revision*)
	(Part 2) : 1996	Thermo plastic seats and covers (*fifth revision*)
	IS 2556	Vitreous china sanitary appliances — Specification:
	(Part 1) : 2021	General requirements (*fourth revision*)
	(Part 2) : 2024	Specific requirements of washdown water closets (*sixth revision*)
	(Part 3) : 2024	Specific requirements of squatting pans (*sixth revision*)
	(Part 4) : 2004	Specific requirements of wash basins (*fourth* revision)
	(Part 5) : 1994	Specific requirements of laboratory sinks (*third revision*)
	(Part 6) : 2021	Specific requirements of urinals and partition plates (*fifth revision*)
	(Part 7) : 1995	Specific requirements of accessories for sanitary appliances (*third revision*)
	(Part 8) : 2021	Specific requirements of close-coupled and one-piece pedestal washdown and syphonic water closets (*sixth revision*)
	(Part 9) : 2004	Specific requirements of pedestal type bidets (*fifth revision*)
	(Part 14) : 2024	Specific requirements of integrated squatting pans (*second revision*)
	(Part 15) : 2024	Specific requirements of universal water closets (*third revision*)
	(Part 16) : 2024	Specific requirements of washdown wall mounted water closets (*first revision*)
	(Part 17) : 2001	Specific requirements for wall mounted bidets
	IS 6411 : 1985	Specification for gel-coated glass fibre reinforced polyester resin bath tubs (*first revision*)
	IS 7231 : 2021	Plastic flushing cisterns for water closets and urinals — Specification (*third revision*)
	IS 11246 : 1992	Glass fibre reinforced polyester resins (GRP) squatting pans — Specification (*first revision*)
	IS 13983 : 1994	Stainless steel sinks for domestic purposes — Specification
(5)	IS 651 : 2007	Glazed stoneware pipes and fittings — Specification (*sixth revision*)
	IS 3006 : 1979	Specification for chemically resistant glazed stoneware pipes and fittings (*first revision*)

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	IS No.	*Title*
(6)	IS 458 : 2021	Precast concrete pipes (with and without reinforcement) — Specification (*fifth revision*)
	IS 784 : 2019	Prestressed concrete pipes (including specials) — Specification (*third revision*)
	IS 1916 : 2018	Steel cylinder pipes with concrete lining and coating (*second revision*) — Specification
	IS 4350 : 1967	Specification for concrete porous pipes for under drainage
	IS 7319 : 1974	Specification for perforated concrete pipes
(7)	IS 1536 : 2023	Centrifugally cast (spun) iron pressure pipes for water, gas and sewage — Specification (*fifth revision*)
	IS 1537 : 1976	Specification for vertically cast iron pressure pipes for water, gas and sewage (*first revision*)
	IS 1538 : 1993	Cast iron fittings for pressure pipes for water, gas and sewage — Specification (*third revision*)
	IS 3989 : 2024	Centrifugally cast (spun) spigot and socket pipes, fittings and accessories — Specification (*fourth revision*)
	IS 7181 : 1986	Specification for horizontally cast iron double flanged pipes for water, gas and sewage (*first revision*)
(8)	IS 1592 : 2003	Asbestos cement pressure pipes and joints — Specification (*fourth revision*)
	IS 1626	Asbestos cement building pipes and pipe fittings, gutters and gutter fittings, and roofing fittings — Specification:
	(Part 1) : 1994	Pipes and pipe fittings (*second revision*)
	(Part 2) : 1994	Gutters and gutter fittings (*second revision*)
	(Part 3) : 1994	Roofing fittings (*second revision*)
	IS 6908 : 1991	Asbestos cement pipes and fittings for sewerage and drainage — Specification (*first revision*)
(9)	IS 13592 : 2013	Unplasticized polyvinyl chloride (PVC-U) pipes for soil and waste discharge system for inside and outside buildings including ventilation and rain water Ssystem — Specification (*first revision*)
	IS 14333 : 2022	Polyethylene pipes for sewerage and industrial chemicals and effluent — Specification (*first revision*)
	IS 14735 : 1999	Unplasticized polyvinyl chloride (UPVC) injection moulded fittings for soil and waste discharge system for inside and outside buildings including ventilation and rain water system — Specification
	IS 15328 : 2003	Unplasticized non-pressure polyvinyl chloride (PVC-U) pipes for use in underground drainage and sewerage systems — Specification
(10)	IS 2470	Code of practice for installation of septic tanks:
	(Part 1) : 1985	Design criteria and construction (*second revision*)
	(Part 2) : 1985	Secondary treatment and disposal of septic tank effluent (*second revision*)
(11)	IS 1536 : 2023	Centrifugally cast (spun) iron pressure pipes for water, gas and sewage — (*fifth revision*)
(12)	IS 5329 : 1983	Code of practice for sanitary pipe work above ground for buildings (*first revision*)
(13)	SP 35 : 1987	Handbook on water supply and drainage with special emphasis on plumbing

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	IS No.	*Title*
(14)	IS 2212 : 1991	Brick works — Code of practice (*first revision*)
(15)	IS 5455 : 1969	Specification for cast iron steps for manholes
(16)	IS 1726 : 1991	Cast iron manhole covers and frames — Specification (*third revision*)
	IS 12592 : 2002	Precast concrete manhole covers and frames — Specification (*first revision*)
(17)	IS 4111 (Part 1) : 1986	Code of practice for ancillary structures in sewerage system : Part 1 Manholes (*first revision*)
(18)	IS 15792 : 2008	Artificial recharge to ground water — Guidelines
(19)	IS 14961 : 2024	Surface water management in hilly areas (including rainwater harvesting) — Guidelines (*first revision*)
	IS 15797 : 2008	Roof top rainwater harvesting — Guidelines
(20)	IS 783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
	IS 1742 : 1983	Code of practice for building drainage (*second revision*)
	IS 3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
	IS 4127 : 2023	Laying of glazed stoneware pipes — Code of practice (*second revision*)
	IS 6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
(21)	IS 2527 : 1984	Code of practice for fixing rainwater gutters and downpipes for roof drainage (*first revision*)
	IS 1729 : 2023	Sand cast iron spigot and socket pipes, fittings and accessories — Specification (*third revision*)
	IS 1626 (Part 1) : 1994	Asbestos cement building pipes and pipe fittings, gutters and gutter fittings and roofing fittings: Part 1 Pipe and pipe fittings (*second revision*)
	IS 1239 (Part 1) : 2004	Steel tubes, tubulars and other wrought steel fittings: Part 1 Steel tubes — Specification (*sixth revision*)
	IS 13592 : 2013	Unplasticized polyvinyl chloride (PVC-U) pipes for soil and waste discharge systems inside buildings including ventilation and rainwater system — Specification (*first revision*)
(22)	IS 2064 : 1993	Selection, installation and maintenance of sanitary appliances — Code of practice (*second revision*)
(23)	IS 18797 : 2024	Packaged sewage treatment plant — Specification
(24)	IS 18150 : 2023	Non-sewered on-site santitation system — Design, fabrication and installation of biodigesters for human waste decomposition — Code of practice
(25)	IS 9872 : 1981	Specification for precast concrete septic tanks
	IS 18666 : 2024	Rotationally moulded polyethylene septic tanks — Specification

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART E PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

SECTION 3 SOLID WASTE MANAGEMENT

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part E/Section 3) covers the solid waste management systems, assessment of per solid waste quantities and treatment of solid waste within the building, building complexes and their built environments.

In the first version of the Code formulated in 1970, as part of the National Building Code of India, three separate sections of this Part on 'Plumbing Services', were brought out, namely, Section 1 Water Supply, Section 2 Drainage and Sanitation, and Section 3 Gas Supply. These sections were subsequently revised in 1983 and in 2005.

In the second revision in 2005, the Part 9 was renamed as 'Plumbing Services (Including solid waste management)' and provisions on solid waste management were included for the first time under Section 1 which contained in it, Water supply, drainage and sanitation including solid waste management. Gas Supply was covered in Section 2 of Part 9 of the Code.

In the third revision in 2016, to comprehensively address the various and distinct features related to the plumbing aspects, this Part 9 was rearranged as follows:

Section 1 Water supply

Section 2 Drainage and sanitation

Section 3 Solid waste management

Section 4 Gas supply

The significant changes included in the 2016 version of NBC included: Elaborative provisions on solid waste management systems; inclusions of the provisions for persons with disabilities towards operation of refuse chutes; recommendation of electrically operated dumb waiters for 5 storied (and above); inclusion of assessment of per capita waste quantity; referencing the latest statutory rules and regulations; inclusion of detailed provisions on treatment methods; inclusion of annexes namely Annex A on municipal solid waste generation, Annex B on treatment of food wastes; and review of terminology.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

The significant changes incorporated in this revision include:

a) References to the latest rules and regulations have been made;

b) Terminology clause has been reviewed and updated;

c) Circularity aspects of solid waste management has been included;

d) Domestic waste now covers all the remaining types of wastes generated;

e) Caution with respect to plastic waste by avoiding their down cycling is included;

f) Primary segregation and secondary segregation have been detailed in sorting at source;

g) Additional options towards efficient use of refuse chutes are included;

h) Treatment options namely aerobic processes, vermi-composting have been updated taking care of the best practices in these activities;

j) Provisions for the colour coding of waste bins have been incorporated to ensure proper segregation of solid waste;

k) Provisions have been incorporated for the treatment of biodegradable waste by household and commercial facilities; and

m) References to all the concerned Indian Standards have been updated.

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Reference may also be made to the Municipal Solid Waste Management Manual — Part I — An Overview and Part II — The Manual, 2016, CPHEEO, Ministry of Urban Development, Government of India.

All Indian Standards, cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **'accepted standard'** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [E-3(1)] refers to the Indian Standard(s) given at serial number (1) of the list of standards given at the end of this Part E/Section 3, that is, IS 9569 : 2022 'Solid waste management — Glossary (*first revision*)'.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART E PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

SECTION 3 SOLID WASTE MANAGEMENT

1 SCOPE

This NBCS (Part E/Section 3) covers the solid waste management systems, assessment of per capita solid waste quantities and treatment of solid waste within the building, building complexes and their built environments.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply, and for other terms those given in the accepted standard [E-3(1)] shall apply.

2.1 Anaerobic Digestion — A controlled process involving microbial decomposition of organic matter in the absence of oxygen.

2.2 Authorization — The consent given by the State Pollution Control Board or Pollution Control Committee, as the case may be, to the operator of a facility.

2.3 Biodegradable Substance — A substance that can be degraded by microorganisms into simpler stable compounds.

2.4 Biomethanation — A process which entails enzymatic decomposition of the organic matter by microbial action to produce methane rich biogas.

2.5 Collection — Lifting and removal of solid wastes from door step, collection points or any other designated position in segregated manner as per *Solid Waste Management Rules*/local bylaws.

2.6 Composting — A controlled process involving microbial decomposition of organic matter.

2.7 Construction and Demolition Waste — Wastes from building materials debris and rubble resulting from construction, re-modelling, repair and demolition operation.

2.8 Disposal — Final disposal of non-biodegradable and non-recyclable part of municipal solid wastes in accordance with the specified measures to prevent contamination of groundwater, surface water and ambient air quality.

2.9 Generator of Wastes — Persons or establishments generating municipal solid wastes.

2.10 Landfilling — Disposal of residual solid wastes on land in a facility designated and with protective measures against pollution of groundwater, surface water and air fugitive dust, wind-blown litter, bad odour, fire hazard, bird menace, pests or rodents, greenhouse gas emissions, slope instability and erosion.

2.11 Leachate — Liquid that seeps through solid wastes or other medium and has extracts of dissolved or suspended material from it.

2.12 Municipal Authority — Municipal Corporation, Municipality, Nagar Palika, Nagar Nigam, Nagar Panchayat, Municipal Council including notified area committee (NAC) or any other local body constituted under the relevant statutes and, where the management and handling of municipal solid waste is entrusted to such agency.

2.13 Municipal Solid Waste — Commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form, excluding industrial hazardous wastes and construction and demolition waste but including treated bio- medical wastes.

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2.14 Operator of a Facility — A person who owns or operates a facility for collection, segregation, storage, transportation, processing and disposal of municipal solid wastes and also includes any other agency appointed as such by the municipal authority for the management and handling of municipal solid wastes in the respective areas.

2.15 Pelletization — A process whereby pellet are prepared which are small cubes or cylindrical pieces made out of solid wastes and includes fuel pellets which are also referred as refuse derived fuel.

2.16 Processing — The process by which solid wastes are transformed into new or recycled products.

2.17 Recycling — The process of transforming segregated solid wastes into raw materials for producing new products, which may or may not be similar to the original products.

2.18 Segregation — To separate the municipal solid wastes into the groups of bio-degradable, recyclables, hazardous and inert wastes.

2.19 Storage — The temporary containment of municipal solid wastes at a designated place in a manner so as to prevent littering, attraction to vectors, stray animals and excessive foul odour.

2.20 Transportation — Conveyance of municipal solid wastes from place to place hygienically and covered through specially designed transport system so as to prevent foul odour, littering, unsightly conditions and accessibility to vectors.

2.21 Vermi-composting — A process of using earthworms for conversion of biodegradable wastes into compost.

3 GENERAL

3.1 Solid waste is generated from various human activities and is normally disposed as useless and unwanted by the primary user because of end-of-life condition.

Broadly, depending upon the type of building and built environment, it includes solid or semi-solid domestic waste, such as sanitary waste, commercial waste, office waste, catering and market waste and other non-residential wastes, street sweepings, silt removed or collected from the surface drains, horticulture waste and construction and demolition waste. Further, there may be industrial hazardous waste, bio-medical waste and e-waste.

The primary objective of solid waste management is to collect, treat and dispose of solid wastes in an environmentally and socially satisfactory manner using the most economical means available. Ideally, solid waste should not contain faecal matter or urine but despite all precautions, some pathogens and chemical residues inevitably may be present in the waste. Uncontrolled or poorly managed intermediate decomposition of organic components of solid waste can contaminate air, water and soil resources. Implementation of integrated solid waste management practices benefits substantially, both the public health and the quality of the environment. It is also an integral part of an efficient solid waste management (SWM) system to create circularity by ensuring the maximum recycling and recovery of solid waste generated and avoiding/reducing of landfillable waste and dumping.

3.2 Based on source of generation, solid waste can be broadly categorized as follows:

a) *Domestic waste* — It is generated in residential units, commercial and educational entities; and consists of food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (for example, bulky items, consumer electronics, white goods, batteries, oil and tyres), and household hazardous wastes including domestic sanitary, expired/discarded household usage chemicals, paints, automobiles batteries, household cleaners, swimming pool chemicals, and domestic e-waste;

b) *Industrial waste* — It is generated in manufacturing units, fabrication plants, construction sites, power and chemical plants; and consists of packaging, hazardous wastes, ashes, special wastes, wood, steel, concrete, dirt, etc;

c) *Institutional and commercial waste* — It is generated in schools, hospitals, prisons, government centers, stores, hotels, restaurants, markets, office buildings, etc; and consists of domestic wastes, paper, cardboard, plastics, wood, glass, metals, special wastes and hazardous wastes; and

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d) *Horticulture waste* — It is generated in landscaping, parks, orchards, dairies, and consists of street sweepings; landscape and tree trimmings; etc.

3.3 Based on suitability for handling and disposal, solid waste can also be categorized as follows:

a) *Garbage* — Garbage is the term applied to animal and vegetable waste resulting from the handling, storage, sale, cooking and serving food. Such wastes contain putrescible organic matter, which produces strong odours and therefore attracts rats, flies and other vermin. It requires immediate attention in its storage, handling and disposal;

b) *Municipal waste* — Municipal waste includes waste resulting from municipal activities and services such as street wastes, dead animals, market wastes and abandoned vehicles. However, the term is commonly applied in a wider sense to incorporate domestic wastes and commercial wastes;

c) *Hazardous wastes* — Hazardous wastes may be defined as wastes of industrial, institutional or consumer origin which because of their physical, chemical or biological characteristics are potentially dangerous to human and the environment. It includes any waste that exhibits one of the hazardous characteristics, such as ignitability, corrosivity, reactivity, or toxicity, whether alone or when in contact with other wastes or substances. In some cases although the active agents may be liquid or gaseous, they are classified as solid waste because they are confined in solid containers. Typical examples are solvents, paints and pesticides whose spent containers are frequently mixed with municipal wastes. Good waste management should ensure that hazardous wastes are stored, collected, transported and disposed of separately, preferably after suitable treatment to render them innocuous;

   A sub-category of household hazardous waste, is post-consumer utilization waste which qualifies as hazardous waste when discarded. It includes household chemicals and other consumer products used in home care, personal care, automotive care, pest control, etc. These products exhibit characteristics of reactivity, ignitability, corrosivity, toxicity, or persistence;

d) *Bio-medical waste* — Bio-medical waste is any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biologicals. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc. It has been estimated that hospitals generate total waste at a rate of 1.5 kg per bed per day, out of which approximately 25 percent is bio-medical waste. Generally, these wastes are handed over to common bio-medical treatment and disposal facilities for suitable treatment and final disposal.

   Biological means any preparation made from organisms or microorganisms or product of metabolism and biochemical reactions intended for use in the diagnosis, immunization or the treatment of human beings or animals or in research activities pertaining thereto.

   Bio-medical waste treatment facility means any facility wherein treatment, disposal of bio-medical waste or processes incidental to such treatment and disposal is carried out, and includes common treatment facilities. The common bio-medical treatment facilities are set up based on the need for ensuring environmentally sound management of bio-medical waste keeping in view the techno-economic feasibility and viable operation of the facility with minimal impacts on human health and environment.

   All healthcare establishments including hospitals, research facilities and laboratories generate solid waste in course of performing their intended functions. 75 percent to 90 percent of such solid waste is non-risk healthcare waste, comparable to domestic waste. It requires minimal treatment and is safely handled by housekeeping staff. The remaining 10 percent to 25 percent of healthcare waste is designated as bio-hazardous waste and is designated bio-medical waste. It carries a variety of health risks in its handling and disposal. It is handled by trained staff and many safety devices and apparels are deployed. In addition, bio-medical waste includes the waste originating from minor or scattered sources, such as that produced in the course of healthcare undertaken in the home (dialysis, insulin injections, etc);

e) *Plastics* — Plastics, due to their non-biodegradable nature, versatility in use and impact on environment, can be grouped under a different category of solid waste. Significant quantity of the plastic waste

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generated in our country is recycled and used in the manufacture of various plastic products. Careless disposal of plastic in various forms chokes drains, blocks the porosity of the soil, causes problems for groundwater recharge, disturbs the soil microbe activity, contaminates foodstuff and when ingested by animals, it can kill them; apart from impacting the marine life when they end up in river/water bodies. Down cycling of plastics degrades their quality in each cycle and hence the same should be least preferred; and

f) *E-waste* — It refers to discarded electrical and electronic equipment and their components that are no longer in use or functional. It encompasses a wide range of household appliances, office equipment, and related devices. E-waste contains hazardous substances such as lead, mercury, cadmium and beryllium, which can contaminate soil, water and air, thereby adversely affecting ecosystems and human health. Proper e-waste management through formal recycling processes enables recovery of valuable materials, reduces environmental pollution, and minimizes health hazards.

3.4 Efficient collection and disposal of domestic garbage from a building or activity area is of significant importance to public health and environmental sanitation and, therefore, an essential part of the built environment. Notwithstanding the provisions given herein, the solid waste management shall have to comply with relevant statutory Rules and Regulations in force from time-to-time. The provisions of the following shall, as amended from time to time, govern the procedures for handling, treatment, etc, of solid wastes as applicable to the concerned building occupancy:

a) *The Environment* (*Protection*) *Act*, 1986;

b) *The Solid Waste Management Rules*, 2016;

c) *The Bio-Medical Waste Management Rules*, 2016;

d) *The E-Waste* (*Management*) *Rules*, 2022;

e) *The Battery Waste Management Rules*, 2022;

f) *The Hazardous and Other Wastes* (*Management and Transboundary Movement*) *Rules*, 2016;

g) *Plastic Waste Management* (*Amendment*) *Rules,* 2024; and

h) *Environment* (*Construction and Demolition*) *Waste Management Rules,* 2025.

NOTE — Radioactive wastes are covered under the provisions of *The Atomic Energy Act*, 1962 and rules made thereunder and the enforcement agency for these is Atomic Energy Regulatory Commission (AERC).

3.5 The provisions relating to solid waste management given in 4 are applicable to municipal solid waste and specifically exclude the hazardous chemical wastes, bio- medical waste and radioactive waste.

4 SOLID WASTE MANAGEMENT SYSTEMS

4.1 ln designing a system dealing with collection of domestic garbage for a built premises/community/environment, the aim shall be to provide speedy and efficient conveyance as an essential objective for design of the system. The various available systems may be employed in accordance with 4.2 to 4.4, which may be adopted individually or in combination as appropriate in specific situations.

4.1.1 The basic stages of the municipal solid waste management system include the following:

a) Waste sorting at source, collection and transportation;

b) Resource recovery through centralized sorting and recycling;

c) Resource recovery through waste processing, that is, recovery of energy; and

d) Waste transformation without recovery.

4.1.2 The functional elements of municipal solid waste management system include the following:

a) *Waste generation* — Activity in which the waste gets generated as material no longer having any value to the primary consumer;

b) *Waste handling, sorting, storage and processing at site* — Waste handling and sorting involves the activities associated with management of waste until they are placed in storage container for collection;

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c) *Collection* — Gathering of solid wastes in segregated form including transportation; and

d) *Transfer and transport* — Transfer of waste from smaller collection vehicle to larger transport equipment and subsequent transport of wastes over long distances to a designated processing or disposal site.

4.2 Sorting at Source

Sorting shall be planned based on the existing markets for recyclable materials. It is preferable to have coloured-bin system based on the usage of the facility and the types of the waste likely to be generated in the facility. Colour code for bins/bags shall be as follows:

a) Green — for bio-degradable waste;

b) White or Blue — for dry waste (excluding biomedical waste/hazardous waste); and

c) Red — for bio-medical waste and rejects.

All bins shall be covered with lid. Reference shall be made to good practice [E-3(2)] for detailed provisions on the colour coding of bins.

Common sorting methods involve sorting into;

a) dry recyclable materials, for example, glass, paper, plastics, metals, etc;

b) bio-waste and garden waste;

c) bulky waste;

d) hazardous material in household waste;

e) construction and demolition waste; and

f) mingled MSW (mixed waste).

In case of sorting not done at source, it is required to plan centralized sorting. The types of sorting that may be adopted, are:

a) Hand sorting from a raised picking belt; and

b) Mechanized sorting facilities using magnetic and electric field separation, density separation, etc.

Sorting at source (also known as primary segregation) normally recovers most of the recyclable materials for reuse. However, a small fraction of such materials may escape the sorting process. Sorting may therefore be also undertaken just prior to waste processing (secondary segregation), waste transformation or landfilling to recover such recyclable materials.

Wherever manual sorting is adopted, care shall be taken to ensure that sorters are protected from all disease pathways and work in hygienic and safe conditions using necessary safety gear including aprons, protective mask, gloves and boots/shoes. The movement of waste shall be planned by suitable mechanism and building shall be planned for easy movement of waste by means of garbage/material lift, ramps, etc, meeting the good engineering practices and minimum handling of waste as well as no contact with ground during the whole process or littering.

4.3 Refuse Chute System

4.3.1 *General*

Refuse chute system is a convenient and safe mode of transportation and collection of domestic solid wastes from buildings exceeding 5 storeys from floors at different heights. The refuse is received from the successive floor through the inlets located on the vertical system of pipes that convey refuse through it and discharge it into the collecting chamber, located at ground level, from where the refuse is cleared at suitable intervals. This system has got four functionally important components, namely, the chutes, the inlet hopper, the collection chamber and the cleaning and disinfecting arrangements.

The chute may be carried through service shafts meant for carrying drainage pipes. However, the location shall be mostly determined by the position of the inlet hopper and the collecting chamber that is most convenient for the user. It should also be considered to locate the chute away from living rooms in order to avoid noise and smell

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nuisance. The internal diameter of the chute shall be at least 300 mm.

In individual chute system, the inlet hopper shall be located in the passage near the kitchen and in the common chute system towards the end of the common passage. Natural ventilation should be adequate to prevent any possible odour nuisance. There should be adequate lighting at this location. For ground floor (floor 1), the inlet hoppers may be placed at a higher level, but should be easily accessible. The access to the refuse chute shall be provided from well ventilated and well illuminated common corridor or lobby and preferably it should not be located opposite or adjacent to entry of individual flats or lift.

4.3.2 *Opening for Feeding of Refuse Chute*

Opening, with top or bottom hinged shutters with appropriate lockable latch, shall be provided for convenient accessing of the refuse chute by users. It facilitates total building garbage collection at one single point and provides separate collection for dry and wet garbage. The opening of the refuse chute may have separate receptacles for both wet and dry waste. Mixed waste disposal may not be allowed. For wet waste, there should be a provision for collection of leachate. Chute system shall have the following features:

a) Sanitation system for internal cleaning of chutes, with sprinklers at every floor intake level, with disinfectant cleaning, which may preferably be automatic in operation;

b) Exhaust system with 25 to 35 air changes per hour;

c) Discharge end fire resistant door;

d) Chute may be of masonry, R.C.C pipe, asbestos cement pipe or suitable non- corrosive material, preferably stainless steel. It should be rigid with smooth internal finish, high ductility and alkali/acid resistant properties {*see also* good practice [E-3(3)]};

e) For fire rating, reference should be made to relevant clauses of Part F 'Fire and Life Safety' of this NBCS;

f) Fire sprinklers shall be provided inside chute;

g) Vent shall be installed at roof level to remove foul smell and gases generated;

h) Chute should discharge to trolley directly;

j) Necessary automation of the system may be planned to avoid malfunction by manual operation; and

k) All care shall be taken for ensuring accessibility to the chute for persons with disabilities. The opening of the chute shall not be higher than 700 mm and there shall be a clear space of minimum 1 500 mm × 1 500 mm in front of the chute opening to gain easy access even for persons using wheelchairs. There may be high colour contrast provided around the chute opening to make it easy to identify it. The flooring in front of the chute opening may be texturally highly different from the rest of the floor.

4.3.3 *Refuse Collection Chamber*

The collection chamber may be located in ground floor or basement level, provided appropriate arrangement is made for drainage of the collection pit by gravity flow to ensure its dryness, an appropriate ramp access is provided for convenient removal of garbage from the collection pit, and satisfactory ventilation is provided for escape of gas and odour.

The floor of the chamber shall be provided with drainage through a 100 mm diameter trap and screen to prevent any solid matters flowing into the drain and the drain shall be connected to the sewer line. The floor shall be finished with smooth hard surface for convenient cleaning.

The height of the collection chamber and vertical clearance under the bottom level of garbage chute shall be such that the garbage trolley can be conveniently placed.

The collection chamber shall be provided with appropriate shutter to prevent access of scavenging animals like cattle, dogs, cats and rats.

Building owners and associations should be encouraged about proper usage of this system which otherwise can be clogged and malfunction. They may also be encouraged to have a single agent/person for door to door collection having effective segregation at source and ensuring hygienic conditions and authorizing only such

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agent/person operate the chute. This system is quite effective in industrial and commercial buildings which are professionally controlled all the time and also typically having one type of waste or largely dry waste only.

4.3.4 *Refuse Collection Room*

The refuse collection room should be planned in ground or basement level with appropriate ventilation and proper drainage. The room should have access for vehicle or trolley transfer of garbage.

4.3.5 *See also* accepted standards [E-3(4)].

4.4 Dumb-Waiter or Service Lift

In high rise buildings with more than 5 storeys, electrically operated dumb-waiters may be used for carrying domestic garbage in packets or closed containers. For handling of garbage by dumb-waiters in a building, a garbage chamber shall have to be provided either at ground floor or basement level and the provisions of garbage collection chamber for chute as given in 4.3 shall apply.

5 ASSESSMENT OF PER CAPITA WASTE QUANTITY

5.1 For purposes of this Section, the following municipal refuse generation rates are recommended:

a) Residential refuse : 0.3 kg/capita/day to 0.6 kg/capita/day

b) Commercial refuse : 0.2 kg/capita/day to 0.6 kg/capita/day

c) Street sweepings : 0.34 kg/capita/day to 0.7 kg/capita/day

d) Institutional refuse : 0.25 kg/capita/day to 0.6 kg/capita/day

Out of the total solid waste generated, 40 percent may be considered inorganic waste, which includes a proportion of inert waste, and 60 percent as organic waste. The knowledge of chemical characteristics of waste is important for selecting and designing the waste processing and disposal facilities.

5.2 These generation rates are subject to considerable site-specific factors, such as degree of urbanization, economic level, geographical terrain and other site-specific factors and are required to be supported by field data studies. The waste contains a high percentage of ash and fine earth. The calorific value of Indian solid waste generally varies between 800 kcal/kg and 1 000 kcal/kg and the density varies between 300 kg/m^3 and 500 kg/m^3.

5.3 Other than municipal solid waste, the following types of waste may also be generated in urban centres:

a) *Industrial waste* — Hazardous and non-hazardous waste from industrial areas within municipal limits;

b) *Bio-medical waste* — Waste from hospitals, slaughter houses, etc;

c) *Thermal power plant waste* — Fly ash from coal-based electricity generating plant within municipal limits;

d) *Effluent treatment plant waste* — Sludge from sewage treatment plants and industrial effluent treatment plants;

e) *Construction and demolition waste* — Generated from demolition, remodelling of existing buildings and new construction; and

f) *Other wastes* — Special wastes from non-conforming areas or special units.

All waste streams shall be managed by their own waste management system.

6 TREATMENT

6.1 Garbage collected at one location may be treated for organic portion, and inorganic portion shall be handed over to vendors carrying out recycling. Organic waste generated in building/premises/community/environment may be treated and reused as manure and as per *The Solid Waste Management Rules*, 2016, preferably should be recycled at source site itself for bulk waste generators. The norms prescribed by the pollution board authorities shall be followed, keeping hygiene and safe operation for the working/operating people.

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Biological or thermal treatment of waste can result in recovery of useful products such as compost or energy.

6.2 Biological Processes

Biological treatment involves using microorganisms to decompose the biodegradable components of waste. The following two types of processes may be typically used, the former being used more commonly:

a) *Aerobic processes* — It may comprise composting, aerated static pile composting and in-vessel composting; vermi-culture, etc. In the aerobic process the utilizable product is compost and high microbial liquid drained out which can be recollected and used as liquid manure after dilution or as for sprinkling over new manure to quicken the process as bioenzyme;

b) *Anaerobic processes* — It may comprise low-solids anaerobic digestion (wet process), high solids anaerobic digestion (dry process) and combined processes. In the anaerobic process the utilizable product is methane gas (for energy recovery).

6.2.1 *Composting*

Decomposition and stabilization of organic waste matter is a natural phenomenon. Composting is an organized method of producing compost manure by adopting this natural phenomenon.

a) *Manual composting* — It is an anaerobic method conventionally carried out in pits. Initially the waste is anaerobically stabilized in pits where alternate layers of solid waste and night soil are laid. The pit is completely filled and a final soil layer is laid to prevent fly breeding, entry of rain water into the pit and for conservation of the released energy. The material is allowed to decompose for 4 to 6 months after which the stabilized material is taken out and used as compost;

b) *Mechanical composting* — Mechanical processes are preferred where higher labour costs and limitations of space exist. It is the process using a combination of aerobic and anaerobic decomposition in enclosed containers. Organic wet waste composter is used where raw refuse is composted in large vessel, which are turned at intervals by mobile pedals or plates. Several other processes have now been developed, using different methods of processing of solid waste, using different designs of digester.

   Latest technology uses electrically operated rapid processing organic waste convertor with different capacities as mechanical composters. The organic wet and dry waste is separated and shredder is used to homogenize the materials and blenders are used under controlled temperature and bio-enzyme addition in closed containers. These output manure may be used for horticultural/agriculture works; and

c) *Vermi-composting* — Vermi-compost treatment shall be provided to the organic wastes in composting pits located in shade. The pits shall be used to receive the garbage in a predetermined (periodic) cyclic order (for example, 5 pits to receive garbage in 5 days and these 5 pits together accepting daily load of garbage). The gross area of the composting pits may be about 0.1 m^2 per person.

   The site for vermi-composting shall be enclosed from all sides with appropriate fencing (for keeping scavenging animals away) and provided with a small door for accessing the enclosed premises.

   Composting pits shall be constructed either under the shade of trees (except Neem tree) or created under sheeting or shade-net, so as to keep the pits under shade. The pits shall be easily accessible for convenience of receiving of garbage through trolleys.

   The composting pits shall be made in a manner that the pits do not have the risk of inundation by water. This may be achieved by appropriately raising the base level of the pit and providing weep holes from sides. Height of side walls of compost pits shall be 0.6 m to 0.75 m high. However, the same can be lined to avoid any contamination of ground waste or ground by providing proper slope and drainage arrangement; optionally, empty green coconuts (after the removal of coconut water) is used as bottom layer considering their long life and ability to decompose at a very slow pace.

   Initiation of composting pits shall be done by providing a 75 mm thick layer of cow dung (fresh or partially decomposed), spreading 1 kg of vermi-compost and covering it with 75 mm to 100 mm thick layer of dry leaves/grass, etc, and sprinkling of water and allowing to decompose naturally for about 10 to 15 days.

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Sorted garbage free from inert and toxic matters shall be applied in the composting pit in layers of 75 mm and spread, and covered with a layer of 75 mm thick dry leaves, followed by sprinkling of water or, by sprinkling cow urine or cow dung plus water slurring or bioenzymes prepared by mixing cow waste and jaggery and kept covered for a few days for fermentation. Apart from these, microbial culture application may also be considered for odour control and rapid biodegradation.

The compost may be removed from the bottom of the compost pit after intervals of 3 months to 6 months. The compost so made needs to be taken out and aired for 1 to 2 days post that it stabilizes fully and is ready to be used after sieving it. May be used in appropriate horticultural and related applications.

See also accepted standard [E-3(5)] for manure grade municipal solid waste compost.

6.3 Thermal Processes

Thermal treatment involves conversion of waste into gaseous, liquid and solid conversion products with concurrent or subsequent release of heat energy.

Three types of systems can be adopted, namely:

a) *Combustion Systems* (*Incinerators*) — Thermal processing with excess amounts of air;

b) *Pyrolysis Systems* — Thermal processing in complete absence of oxygen (low temperature); and

c) *Gasification Systems* — Thermal processing with less amount of air (high temperature).

6.4 Land Filling

6.4.1 Disposal of waste on lands identified for the purpose is typical of this method of waste disposal. The depth of filling depends upon the site topography and location and varies from deep to shallow filling. A municipal solid waste landfill plant is an engineered facility used for disposal of solid waste. Landfills in which municipal waste is placed are designated as 'MSW landfills'.

The main considerations in respect of landfill sites are:

a) Specifications for landfill sites;

b) Site selection;

c) Facilities at site; and

d) Specification of land filling.

6.4.2 Improper landfill generally impacts the environment in the following ways:

a) Ground water contamination by the leachate generated by the waste dump;

b) Surface water contamination by the run-off from the waste dump;

c) Bad odour, pests, rodents and wind-blown litter in and around the waste dump;

d) Generation of inflammable gas (for example, methane) within the waste dump;

e) Bird menace above the waste dump which affects flight of aircraft;

f) Fires within the waste dump;

g) Erosion and stability problems relating to slopes of the waste dump;

h) Epidemics through stray animals;

j) Acidity to surrounding soil; and

k) Release of greenhouse gas.

6.5 Some recycling/treatment methods for food waste are given in Annex B for guidance.

6.6 *See also* accepted standards [E-3(6)] for solid waste management, and for analysis and testing of solid wastes.

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6.7 Households and communities shall be highly encouraged to practice various methods such as home composting, bio-methanation, etc, listed in Annex C of good practice [E-3(7)] for treatment of bio-degradable waste. In case of treatment of bio-degradable waste at community level, conventional facilities/ modern technologies such as composting, biogas plants, biomethanation facilities, etc, as provided by Urban Local Bodies/Regulatory Authorities shall be used.

6.8 Commercial facilities like markets, malls, where group of wet waste generators are clustered, shall be highly encouraged to practice various methods such as community composting/bio-methanation etc, listed in Annex B of good practice [E-3(8)] for treatment of bio-degradable waste. In case of treatment of bio-degradable waste at local level, conventional facilities/modern technologies such as composting, biogas plants, bio-methanation facilities or any other suitable technology as provided by urban local bodies/regulatory authorities shall be used.

6.9 Other/special wastes shall be dealt with in accordance with the statutory provisions in respect of the same (*see* **3.4**). See various other good practice [E-3(9)] for segregation, collection and treatment of different types of wastes.

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ANNEX A

(*Foreword*)

MUNICIPAL SOLID WASTE GENERATION

A-1 WASTE GENERATION

A-1.1 The typical type of wastes generated may be as follows:

Sl No.	*Types of Solid Waste*	*Description*	*Sources*
(1)	(2)	(3)	(4)
i)	Food waste (garbage)	Wastes from the preparation, cooking, and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meats and vegetable	Households, institutions and commercial such as hotels, stores, restaurants, markets, etc
ii)	Rubbish	a) *Combustible* (*primary organic*) — Paper, cardboard, cartons wood, boxes, plastics, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings	-do-
		b) *Non-combustible* (*primary inorganic*) — Metals, tin cans, metal foils dirt, stones, bricks, ceramics, crockery, glass bottles, other mineral refuse	
iii)	Ashes and residues	Residue from fires used for cooking and for heating buildings, cinders, clinkers, thermal power plants	-do-
iv)	Bulky waste	Large auto parts, tyres, stoves refrigerators, others large, appliances, furniture, large crates, trees, branches, palm fronts, stumps	-do-
v)	Street waste	Street sweepings, dirt, leaves, catch basin dirt, animal droppings, contents of litter receptacles, dead animals	Streets, sidewalks, alleys, vacant lots, etc
vi)	Dead animals	*Small animals* — Cats, dogs, poultry, etc *Large animals* — Horses, cows, etc	-do-
vii)	Construction and demolition waste	Lumber, roofing and sheathing scraps, crop residues, rubble, broken concrete, plaster, conduit pipe, wire, insulation, etc	Construction and demolition sites, remodelling, repairing sites
viii)	Industrial waste and sludge	Solid wastes resulting from industry processes and manufacturing operations, such as food processing wastes and boiler	Factories, power plants, treatment plants, etc
		House cinders, wood, plastic and metal scraps and shaving, etc. Effluent treatment plant sludge of industries and sewage treatment plant sledges, coarse screening, grit and septic tank	
ix)	Hazardous wastes	Pathological waste, explosives, radioactive material, toxic waste, etc	Households, hospitals, institution, stores, industry, etc
x)	Horticulture wastes	Tree-trimmings, leaves, waste from parks and gardens, etc	Parks, gardens, roadside trees, etc

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A-1.2 The typical quantity of waste generated measured per capita in urban areas may be as follows:

Sl No.	*Population Range Million*	*Average Per Capita Value* kg/capita/day
(1)	(2)	(3)
i)	0.1 to 0.5	0.21
ii)	0.5 to 1.0	0.25
iii)	1.0 to 2.0	0.27
iv)	2.0 to 5.0	0.35
v)	More than 5.0	0.50

A-2 INDUSTRIAL WASTE

The major generators are thermal power plants, integrated iron and steel mills, non- ferrous industries, pulp and paper industries and fertilizer and allied industries. Following are the source and quantum of generation of some major industrial wastes.

Sl No.	*Name of Industry*	*Quantity Million tonne per annum*
(1)	(2)	(3)
i)	Steel and blast	35.0
ii)	Brine mud	0.02
iii)	Copper slag	0.016 4
iv)	Fly ash	30.0
v)	Kiln dust	1.6
vi)	Lime sludge	3.0
vii)	Mica scraper waste	0.005
viii)	Phospho-gypsum	4.5
ix)	Red mud/bauxite	3.0

A-3 SLAUGHTER HOUSE WASTE

Slaughtering of animals generates waste consisting of non-edible offal (lungs, large intestines, etc), stomach/intestinal contents, dung, sludge from waste water and bones, etc. These have to be disposed of by methods like rendering/controlled incineration/burial/composting/anaerobic digestion, etc. The estimated waste generation may be as per the following:

Sl No.	*Type of Slaughter House*	*Annual Capacity*	*Dry Waste Generated* (tonne per day)
(1)	(2)	(3)	(4)
i)	Large	Large animals more than 40 000 Small animals more than 600 000	6 to 7
ii)	Medium	Large animals — 10 001 to 40 000 Small animals — 100 001 to 600 000	2 to 6
iii)	Small	Large animals up to 10 000 Small animals up to 100 000	0.5 to 1.0

NOTES

1 Animals are commonly classified as ‘large’ or ‘small’ according to species, which affects handling, processing, and facility requirements.

2 Large animals typically include bovines such as cattle and buffalo, as well as horses and camels.

3 Small animals generally refer to species like sheep, goats, and calves. Processing these animals is less equipment-intensive than processing large animals.

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A-4 BIO-MEDICAL WASTE

The waste generated from medical activities can be hazardous, toxic and even lethal because of their high potential for disease transmission.

The components of bio-medical waste include:

a) Human anatomical waste (tissues, organs, body parts, etc);

b) Animal waste (as above, generated during research/experimentation, from veterinary hospitals, etc);

c) Microbiology and biotechnology waste, such as, laboratory cultures, microorganisms, human and animal cell cultures, toxins, etc;

d) Waste sharps, such as hypodermic needles, syringes, scalpels, broken glass, etc;

e) Discarded medicines and cyto-toxic drugs;

f) Soiled waste, such as dressing, bandages, plastercasts, material contaminated with blood, etc;

g) Solid waste (disposable items like tubes, catheters, etc, excluding sharps);

h) Liquid waste generated from any of the infected areas;

j) Incineration ash; and

k) Chemical waste.

The estimated generation of total waste is 1.5 kg/bed and the estimated generation of bio-medical waste at 25 percent of total waste generation.

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ANNEX B

(*Foreword* and *Clause* 6.5)

TREATMENT OF FOOD WASTE

B-1 FOOD WASTE

Food waste represents a large percentage of the solid waste. For establishments that serve food, the waste generated per meal varies significantly; however, on average, 60 g of food waste is generated per meal served when both pre-service and post-service waste is considered. The organic nature of food waste makes it unsuitable for disposal by landfills, though it is bio-degradable.

In order to use the nutrient and calorific value of the food waste, it is collected, stored and then recycled. When collecting, it should be ensured that food waste does not enter the drainage system. When providing temporary storage, the risk of physical contamination of kitchen working areas should be avoided. It should be a separate ventilated room with 6 total air changes per hour. In hot climates, it shall be cooled to a temperature of 24 °C to minimize odour generation. The storage area should be cleaned at least once every day.

A brief overview of some of the ways of food waste recycling/treatment is given in **B-2** to **B-4**. Before recycling/treatment, it requires non-organic materials to be removed from food waste.

B-2 FEEDING ANIMALS

Food discards can be made available for feeding animals. This may involve provisions for farmers, zoos, piggeries (very common) and many other applications. Converting food discards to animal feed and pet food is common and a suitable option for recycling food scraps. Vegetable market waste to cow shelters, slaughter house waste to dog shelters, food waste from events, weddings, etc to piggeries, fish market waste to ducks, etc are suggested aiding to circularity.

B-3 INDUSTRIAL USES

Food waste can be used in the rendering industry for converting these materials to soaps, cosmetics and biodiesel fuel.

B-4 ANAEROBIC DIGESTION

This process involves breaking down organic matter in an oxygen-free environment in order to generate biogas, which is a combination of methane and carbon dioxide. The methane is burned for energy. The material that remains after digestion (digestate) should then be composted aerobically to complete the process and produce a valuable soil amendment.

Food waste drying system can provide a fast, simple and user friendly onsite process for decomposing and dehydrating food scraps into rich soil sediments. These systems do not require microorganisms, enzymes, fresh water or other additives.

Food cycler sterilizes, deodorizes and turns potentially harmful food scraps into safe, sterilized compost that can be reused as a soil amendment. It is a multi-phase, onsite organic food waste recycling machine that dehydrates and converts daily food waste into a sterile biomass. The sterilization process takes place at 82 °C and reduces the waste volume by 85 percent to 93 percent. After sterilization, the food waste is converted into compostable humus-rich, high-carbon organic particles. The by-products of the process can be reused as soil amendment, compost accelerant, biofuels, animal feed, pet food, etc. Further benefits can be obtained by mixing the water produced from the food cycler units with potable or non-potable supplies to reduce the amount of water used from mains for use in gardens and landscaping.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used for conformance with the requirements of the referred clauses in this NBCS.

	IS No.	*Title*
(1)	IS 9569 : 2022	Solid waste management — Glossary (*first revision*)
(2)	IS 16557 : 2016	Solid waste management — Segregation, collection and utilization at household/community level — Guidelines
	IS18520 : 2024	Solid waste management — Segregation, collection and utilization at commercial facilities (shops, markets, malls etc) — Guidelines
(3)	IS 6924 : 1973	Code of practice for the construction of refuse chutes in multi-storeyed buildings
(4)	IS 12402	Specification for mobile containers for solid waste:
	(Part 1) : 1988	General characteristics
	(Part 2) : 1988	Methods of test
	IS 12647 : 2021	Solid waste management system collection equipment – Requirements and Guidelines (*first revision*)
	IS 12662	Guidelines for use of vehicles for collection and transportation of solid wastes:
	(Part 1) : 2021	Selection of vehicles (*first revision*)
	(Part 2) : 2025	Guidelines for maintenance (*first revision*)
(5)	IS 16556 : 2016	Specification for municipal solid waste compost, manure grade
(6)	IS 9234	Methods of sampling and test for solid waste:
	(Part 1) : 2021	Preparation of samples for analysis (*first revision*)
	(Part 2) : 2021	Determination of moisture content (excluding industrial solid wastes) (*first revision*)
	(Part 3) : 2023	Chemical analysis (excluding industrial solid wastes) (*first revision*)
	IS 16557 : 2016	Solid waste management — Segregation, collection and utilization at household/community level — Guidelines
	IS 18520 : 2024	Solid waste management — Segregation, collection and utilization at commercial facilities (shops, markets, malls etc) — Guidelines
(7)	IS 16557 : 2016	Solid waste management — Segregation, collection and utilization at household/community level — Guidelines
(8)	IS 18520 : 2024	Solid waste management — Segregation, collection and utilization at commercial facilities (shops, markets, malls etc) — Guidelines
(9)	IS 17862 : 2022	Storage, collection, dismantling and recycling of E-waste — Guidelines
	IS 14534 : 2023	Plastics — Recovery and recycling of plastics waste — Guidelines (*second revision*)

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART E PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

SECTION 4 GAS SUPPLY

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This NBCS (Part E/Section 4) covers the safe use of gases for purposes like fuel, lighting and medical in buildings.

The use of gases for fuel and lighting purposes in buildings is becoming more and more common in different parts of the country, and with the advent of new petroleum complexes and piped gas system, community gas supply is bound to become one of the important services like electricity and water supply in buildings.

The use of liquefied petroleum gas supplied in containers and cylinders is already quite popular. On release of pressure, by opening the valve, they readily convert into the gaseous phase. In this state they present a hazard comparable to any inflammable natural or manufactured gas, except that being heavier than air, low level ventilation is necessary to avoid inflammable concentration of gas. Similarly, a series of precautions and regulations are necessary for laying of natural gas pipelines from city gas distribution entity to building premises and finally in the use location. Of late, the use of medical gases in hospitals through pipelines has become quite prevalent due to associated advantages; however, this needs to be supplemented with required care and precautions.

A minimum set of safety provisions are, therefore, laid down to safeguard the gas piping installation and the mode of operation in the interest of public safety.

In the first version formulated in 1970, as part of the National Building Code of India, three separate sections of this Part on 'Plumbing Services' were brought out, namely, Section 1 Water Supply, Section 2 Drainage and Sanitation, and Section 3 Gas Supply. These sections were subsequently revised in 1983.

In the first revision of the Code, in 1983, the safe distance between gas piping and electrical wiring system was modified as well as between gas piping and steam piping was incorporated. Additional information regarding the handling, use, storage and transportation of LPG in cylinders exceeding 500 ml water capacity were included. Provisions relating to LPG cylinders, installations regarding some aspects, such as jointing compound used at joints, painting of gas piping, details of fire extinguishers, total quantity of LPG at stationary and portable installations in proportion to the floor area were added. Also, some provisions of LPG bulk storage installations were introduced.

In the second revision of the Code in 2005, the Part 9 was renamed as 'Plumbing Services (Including Solid Waste Management)' and provisions on solid waste management were included for the first In the second revision, provisions with regard to pressure regulations were modified; in the provision of service shut-off valves, number of additional shut-off valves were specified; in the provision of installation of gas pipe, new materials for pipes were mentioned; the minimum diameter for gas pipe was reduced to 8 mm; the colour for pipe line for supplying natural gas was specified; the provisions regarding protection against the corrosion were modified; the process of installation of meters were clarified; and additional method for detection of leakage of gas was recommended.

In the third revision of the Code in 2016, to comprehensively address the various and distinct features related to the plumbing aspects, this Part 9 was rearranged as follows:

Section 1 Water supply

Section 2 Drainage and sanitation

Section 3 Solid waste management

Section 4 Gas supply

In the revision in 2016, in Section 4, several key updates were made to enhance the safety and clarity of the guidelines. Certain terminologies were included and updated to reflect current practices, while a provision for the use of fire stops/sleeves at openings was introduced to ensure better fire safety. The clause on the use of liquefied petroleum gas was completely revised for improved accuracy, and a new detailed clause on the use of piped natural gas was added to address emerging needs. Additionally, a new clause on the medical gas pipeline system was

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included to ensure proper installation and safety measures in healthcare facilities. Further, cross-referenced standards were updated to align with the latest industry practices and regulations.

In this revision, this publication has been renamed as National Building Construction Standards (NBCS).

Based on the experience gained in the use of this Section, the provisions have been modified in this revision. The significant changes incorporated in this revision include the following:

a) New provisions have been introduced for the installation of sloped piping and drips to prevent gas system blockages, ensure proper condensate drainage, and facilitate cleaning, especially in systems handling wet gas.

b) Comprehensive guidelines for the installation of shutoff valves have been added to ensure proper control, easy accessibility, and maintenance, with specific provisions for individual shutoff valves for each meter and tenant in multi-tenant buildings.

c) The inclusion of over-pressure protection devices for gas systems has been mandated to ensure safe operation and prevent appliance damage due to excessive pressure.

d) Detailed provisions for the installation and safe operation of equipment powered by internal combustion engines and gas turbines have been added, with guidelines for flexible gas supply connections to prevent system stress from equipment movement.

e) References to all the concerned Indian Standards have been updated.

It may also be noted that the following Indian Standards have also been formulated on design and installation of natural gas pipelines:

IS 15663	Code of practice for design and installation of natural gas pipelines:
(Part 1) : 2006	Laying of pipelines
(Part 2) : 2006	Laying of pipelines in crossings
(Part 3) : 2006	Pre-commissioning and commissioning of pipelines

While implementing this NBCS, compliance with statutory regulations shall be ensured.

The information regarding the use of liquefied petroleum gas has been largely based on the following Indian Standards:

IS 6044	Liquefied petroleum gas storage installations — Code of practice:
(Part 1) : 2018	Residential, commercial and industrial cylinder installations (*third revision*)
(Part 2) : 2021	Commercial, industrial and domestic bulk storage installations (*second revision*)

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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Important Explanatory Note for Users of this NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **"accepted standard"** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/ Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

Accepted standards [E-4(1)] refers to the Indian Standard(s) given at serial number (1) of the list of standards given at the end of this Part E/Section 4, that is, IS 14885 : 2022 'Specification for polyethylene pipe for the supply of gaseous fuel' (*first revision*) and IS 17544 : 2022 Multilayer (PE-AL-PE) plastic piping system for indoor gas installations with a maximum operating pressure up to and including 500 kPA (5 bar) — Specification.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART E PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

SECTION 4 GAS SUPPLY

1 SCOPE

This NBCS (Part E/Section 4) covers the requirements regarding safety of persons and property for all piping uses and for all types of gases for purposes like fuel, lighting and medical in buildings.

1.2 This Section does not cover safety rules for gas burning appliances.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

2.1 Appliance Valve — A device that will shut-off the gas supply to the burner(s).

2.2 Approved Agency — Person or agency or a corporate body approved by competent authority or distribution company to execute the job of designing, erection and maintenance of multi cylinder installation.

2.3 Authority Having Jurisdiction — The authority which has been created by a statute and which, for the purpose of administering this NBCS /Part, may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.4 Competent Authority — The Authority designated or otherwise recognized under *Gas Cylinder Rules*, 2004 for approving LPG cylinders, valves and regulators.

2.5 Customer's/Consumer's Connection — Piping tapped on riser to supply each individual customer/consumer.

2.6 Distribution/Distributing Company — The company which is in the field of marketing LPG and PNG, and is the owner of LPG cylinders.

2.7 Gas Fitter — A qualified personnel of the authorized gas supplying organization.

2.8 Installation — A designated premise in an establishment where the complete multi-cylinder-system comprising cylinder, piping manifold, vaporizers, etc, is installed.

2.9 Manifold — A pipe header provided with several opening to which the cylinders are connected by using suitable pipe fittings.

2.10 Pilot — A small flame which is utilized to ignite the gas at the main burner(s).

2.11 Pressure Regulator — A device designed to lower the pressure of gas coming from the distribution main and to maintain it practically constants downstream. This normal operation pressure shall be practically in all cases that of the gas appliances used.

2.12 Purge — To free a gas conduit of air or gas or a mixture of gas and air.

2.13 Qualified Installing Agency — An individual, firm or agency which either in person or through a representative is engaged in and is responsible for the installation or replacement of gas piping on the outlet side of the gas meter, or the connection, installation or repair of gas supply piping and appliances within a building, and who is experienced in such work, familiar with all precautions required, and who has complied with all the requirements as to qualification, registration, licensing, etc, of the Authority.

2.14 Riser — Piping usually vertical on most of its length that supplies gas from the service to the various storeys

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of the building.

2.15 Service Pipe — Pipe that runs between the distribution main in the street and the riser in the case of multistoried building or the meter in the case of an individual house.

2.16 Service Shut-Off Valve (Isolation Valve) — A device installed outside the premises to cut-off the main supply of gas from pipeline by the supplier.

2.17 Vent Pipe — A safety device to which certain regulators are connected to evacuate outside gas that may escape from the normal circuit when some part of system gets damaged or malfunctions or a safety valve is open.

3 PRESSURE REGULATIONS

3.1 Pressure regulation is required to economize the sizing of piping system. Where the pressure of gas supplied to domestic system or other low pressure gas piping system in buildings is in excess of the pressure to be used in the appliance, a gas pressure regulator of suitable specification shall be installed in service pipe of each system to prevent excess pressure reaching the appliance. The pressure regulators to be used can be from 400 kN/m^2 upstream pressure to 2.1 kN/m^2 for domestic consumers and 10 kN/m^2, 30 kN/m^2, 200 kN/m^2 for commercial consumers, as the case may be.

3.1.1 In some place the reduction of pressure from main distribution source of 400 kN/m^2 to intermediate pressure (say 7 kN/m^2) and then to operating pressure of 2.1 kN/m^2 is achieved.

3.1.2 Whereas in most of the other places the reduction of pressure from main distribution source of 400 kN/m^2 to directly operating pressure (say 2.1 kN/m^2, 10 kN/m^2, 30 kN/m^2, 200 kN/m^2) is achieved in single stage pressure reduction.

3.2 If located inside a building, the required regulator shall comply with the following:

a) If any of the diaphragms of the regulator ruptures, the gas shall be sent to an outlet vent pipe made of brass or plastic in order to ventilate or drain the gas out of the building. The vent pipe will, however, lead to outer air about 1 m above the topmost storey of the building. Means shall be employed to prevent water from entering this pipe and also to prevent stoppage of it by insects or other foreign bodies;

b) If the gas pressure at the outlet of the regulator falls below 50 percent of the operating gas pressure or rises above twice the operating gas pressure, the gas input to the pressure regulator shall be cut off; and

c) In the event of malfunctioning of this safety device, a supplementary device shall connect the low pressure circuit to the outlet circuit (vent pipe) as soon as the exit pressure reaches 7 kN/m^2.

3.3 It shall also be ensured by the supply authority that the calorific value and supply pressure of gas shall not exceed the values for the type of gas used.

4 SERVICE SHUT-OFF VALVES

4.1 Service shut-off valves shall be installed on all new services including replacements in a readily accessible location.

4.2 Service shut-off valves shall be located upstream of the meter if there is no regulator or upstream of the regulator, if there is one.

4.2.1 Service shut-off valves shall be located in the upstream of the meter, if a single regulator is supplying more than one consumer and each such stream shall have one additional shut-off valve upstream of regulator.

4.3 All gas services operating at pressure greater than 7 kN/m^2 shall be equipped with an approved service shut-off valve located on the service pipe outside the building.

4.4 Underground shut-off valves shall be located in a covered durable curb box, manhole, vault or stand pipe which is designed to permit ready operation of the valve and the covers of which shall be clearly marked ‘Gas’.

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5 EXISTING WORK

Nothing herein shall prohibit the continued use of existing system of the gas piping without further inspection or test, unless the Authority has reason to believe that defects which make the system dangerous to life or property exist.

6 RULES FOR TURNING GAS ON

6.1 No person, unless is the employ of the gas company or having permission from the gas company, shall turn on the gas at a service shut-off valve or at any valve that controls the supply of gas to more than one consumer.

6.2 Gas shall not be turned on at any meter valve without specific permission from the gas company or other authority if any of the following conditions exists:

a) If the gas piping appliances or meter supply through the meter valve are known to leak or otherwise to be defective (*see* **10**);

b) If required inspection of the piping or appliance has not been made;

c) If the gas company or other authority has requested that the gas be left turned off; and

d) If the meter valve is found shut-off for some reason not known to the gas fitter.

The gas shall not be turned on in the event of fire.

6.3 Gas shall not be turned on at any branch line valve if any of the conditions specified in **6.2** prevails. Where a branch line valve is found closed, a gas fitter shall again turn the gas on at such valve only if proper precautions to prevent leakage are taken and no other unsafe conditions are created thereby.

6.4 Gas shall not be turned on at either the meter valve or service line unless all gas keys or valves provided on all outlets in the piping system are closed or all outlets in the piping system are capped or plugged.

7 RULES FOR SHUTTING OFF THE GAS

7.1 The gas fitter shall put the gas off to any appliance, pipe or piping system and shall leave the gas turned off, until the causes for interrupting the supply has been removed in any one of the following cases:

a) If ordered to do so by the Authority;

b) If leakage of gas is noted, which appears to be sufficient to cause fire, explosion or asphyxiation;

c) If an installation of some gas appliance is found to be such as to cause a serious hazard to persons or property; and

d) If any condition exists which threatens interruption of gas supply which may cause burner outage or otherwise prove dangerous.

7.2 It shall be the duty of the installing agency when the gas supply is to be turned off to notify all affected consumers.

7.3 Before turning off the gas at the meter, for the purpose of installation, repair, replacement or maintenance of piping or appliance, all burner and pilot valves on the premises supplied with gas through the meter shall be turned off and the meter test hand observed for a sufficient length of time to ascertain that there is no gas passing through the meter. Where there is more than one meter on the premises, precaution shall be exercised to ensure that the concerned meter is turned off.

8 INSTALLATION OF GAS PIPES

8.1 Installation, repair and replacement of gas piping or appliances shall be performed only by a qualified installing agency.

8.2 Piping

8.2.1 Piping shall be of wrought iron, steel, copper, stainless steel or cast iron when the gas pressure is less than 7 kN/m^2; with higher gas pressure use of cast iron shall be prohibited.

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8.2.1.1 SS 316/304/321 and flexible PE coated flexible pipe in rolls shall be permitted in low pressure system provided the pipe meets the required standard, to avoid the bends, fittings and leakages from the joint which are potential leakage points. Also, reference may be made to accepted standards [E-4(1)]. Heavy rubber flexible tube shall be permitted only as direct connection to burner from appliance valve.

8.2.1.2 For details regarding medical gas pipeline systems, a reference may be made to good practice [E-4(2)].

8.2.2 *Size of Gas Piping*

Gas piping shall be of such size and so installed as to provide supply of gas sufficient to meet the maximum demand without undue loss of pressure between the meter or service regulator when a meter is not provided, and the appliance(s).

8.2.2.1 The size of gas piping depends upon the following factors:

a) Allowable loss in pressure from meter or service regulator, when a meter is not provided, to appliance;

b) Maximum consumption to be provided;

c) Length of piping and number of fittings; and

d) Specific gravity of gas.

8.2.2.2 No gas pipe smaller than 8 mm shall be used.

8.2.3 As far as possible, straight lengths of piping should be used. Where there are bends in the pipe line, these should have a radius of at least five times the diameter of the pipe.

8.2.4 For any thread joint proper sealant shall be used on male threads only.

8.3 The gas piping shall be of the colour stipulated by explosive authority to distinguish it from other piping and the piping shall be painted silver grey with red band of 150 mm width. The gas pipeline shall be painted canary yellow in case of natural gas.

8.4 Piping Underground

8.4.1 *Protection of Piping*

Piping shall be buried to a minimum depth of 1 m or covered in a manner so as to protect the piping from physical damage.

8.4.2 *Protection Against Corrosion*

Generally, all the piping within the premises where it has to run on the wall shall be exposed and should not be in contact with wall to ensure that no corrosion takes place. Epoxy sealant or polyethylene conduit shall be used to ensure no contact of pipe with the wall in the situation of pipe crossing the wall. Underground or concealed gas pipeline in contact with earth or other materials which may corrode the piping shall be protected against corrosion by application of adequate corrosion resistant coating backed up by cathodic protection system.

8.5 The building shall not be weakened by the installation of any gas piping.

8.6 Gas piping in building shall be supported with pipe hooks, metal pipe straps, bonds or hangers suitable for the size of piping and of adequate strength and quality and located at proper intervals so that the piping may not be moved accidentally from the installed position.

8.7 Pipe Entrance to Buildings

Where gas pipe enters a building through a wall or floor of masonry or concrete, any gas piping or other piping entering the walls or floors shall be suitably sealed against the entrance of water/moisture or gas.

The openings or imperfection of fit or design are also source of possible fire and smoke passing through them. Fire stops shall be provided to fill the openings around penetrating items such as gas pipes, etc, through the wall

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or floor openings. Non-combustible sleeving may also be used as an alternative to proprietary seals for penetration of pipes of lead, aluminium, aluminium alloy, fibre cement or uPVC up to a specified nominal internal diameter. Proprietary fire stopping and sealing systems which have been shown by test to maintain the fire resistance of the wall or other elements, are available and may be used. Other fire stopping materials include cement mortar; gypsum-based plaster; cement or gypsum vermiculite/perlite mixes; glass fibre, crushed rock, blast furnace slag, or ceramic based products (with or without resin binders), and intumescent mastics. These may be used in situations appropriate to the particular material. Not all of them will be suitable in every situation. When sleeving is used, its length should be greater than the thickness of wall or floor. The sleeve shall be properly grouted to maintain fire/smoke separation.

Regarding protection of openings in walls or floors, from fire, reference may be made to Part F 'Fire and Life Safety' of this NBCS.

8.7.1 *Piping in Floors*

Piping in solid floors, such as concrete, shall be laid in channels in the floor suitably covered to permit access to the piping with a minimum damage to the building.

8.7.2 Single pipe without joint shall be used for wall crossing in any building.

8.8 Gas pipe shall not be bent. Fittings shall be used when making turns in gas pipe.

8.9 Generally concealed piping shall not be allowed. However, if it is necessary then it shall be under the **8.4** of underground piping and all protection such as coating, cathodic protection shall be done.

8.10 A drip shall be provided in the gas distribution system, if the moisture contents in the gas is likely to reach saturation point at any stretch of pipe line in the system; a drip shall, however, be provided at any suitable point in the line of the pipe where condensate may collect and from where it can be easily removed. This drip should be so installed as to constitute a trap where in an accumulation of condensate will shut-off the flow of gas before it will run back into the meter.

8.10.1 Drip has to be provided in the case of gas consisting moisture content.

8.11 Prohibited Devices

No device shall be placed inside the gas piping or fittings that will reduce the cross- sectional area or otherwise obstruct the free flow of gas.

8.12 Piping shall be electrically continuous throughout its length and properly earthed except in stretches where cathodic protection system is used for protection against corrosion. It shall not, however, be used to earth any electrical equipment.

8.12.1 The distance between gas piping and electrical wiring system shall be at least 60 mm and, where necessary, they shall be securely fixed to prevent contact due to movement. The gas piping should run above the electrical wiring. In this type of installation in the event of any leakage of natural gas, the gas would move up (natural gas being lighter than air) and would not come directly in contact with the electrical wiring. If the gas to be supplied is heavier than the air then the gas piping should run below the electrical wiring.

8.13 The distance between the gas piping and steam piping, if running parallel, shall be at least 150 mm. The gas piping should preferably run below the steam piping.

8.14 Piping installation shall be thoroughly gastight.

8.15 Smoking shall not be permitted when working on piping which contains or has contaminated gas.

8.16 Meters shall be installed in such a way that there shall be no load transfer from the pipeline to the inlet/outlet of the meter and shall be easily accessible.

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8.17 Sloped Piping and Drips

Piping systems designed for gas flow, particularly those handling wet gas, should include provisions to ensure the smooth and safe operation of the system by adhering to the guidelines given in **8.17.1** **to** **8.17.3**.

8.17.1 *Slopes*

Pipes shall be installed with a slope of not less than 1/6.3 mm per 4 572 mm to prevent the formation of traps.

8.17.2 *Drips*

Where conditions involve wet gas, drips shall be installed at points where condensate may accumulate, such as the outlet of meters, to act as traps. These traps should allow for the collection of condensate and prevent its backflow into the meter or other critical components. Drips shall be located in accessible areas to facilitate cleaning or removal of condensate, and they shall be positioned to avoid freezing conditions that may compromise functionality.

8.17.3 *Sediment Trap*

Where a sediment trap is not incorporated as part of the appliance, a sediment trap shall be installed down-stream of the appliance shutoff valve as close to the inlet of the appliance as practical. The sediment trap shall be either a tee fitting having a capped nipple of any length installed vertically in the bottommost opening of the tee as illustrated in Fig. 1 or other device approved as an effective sediment trap. Illuminating appliances, ranges, clothes dryers, decorative vented appliances for installation in vented fireplaces, gas fireplaces and outdoor grills need not be so equipped.

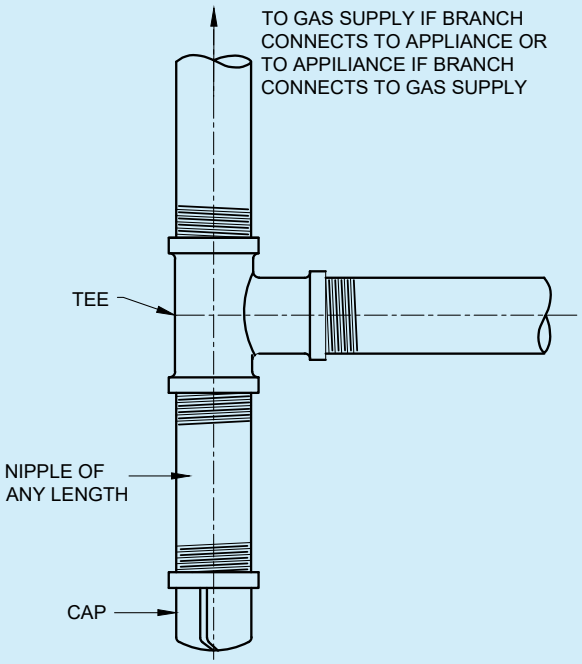

FIG. 1 METHOD OF INSTALLING A TEE FITTING SEDIMENT TRAP

8.18 Shutoff Valves

Piping systems shall be equipped with shutoff valves to ensure proper control and isolation of the system as required. The following guidelines shall be followed for the installation and use of shutoff valves in piping systems:

a) Shutoff valves shall be of a suitable type and constructed from materials that are compatible with the piping system. They shall meet the necessary standards for the pressure and specific application of the system;

b) Shutoff valves shall not be installed in concealed spaces, furnace plenums, or locations where access may

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be hindered;

c) Shutoff valves shall be installed in locations that allow easy access for operation. They should also be protected from potential damage;

d) Each meter installation shall include a shutoff valve on the supply side of the meter to allow isolation of the gas supply;

e) For systems supplying gas to multiple buildings or tenants from a single meter, each building or tenant shall have an individual shutoff valve;

f) In buildings with multiple tenants, a shutoff valve shall be provided for each tenant, ensuring they have access to the valve controlling their space;

g) Each shutoff valve serving a house line shall be clearly marked with an identification tag to facilitate easy identification of the systems it controls;

h) Each appliance shall be equipped with a shutoff valve installed in close proximity, allowing easy isolation of the appliance;

j) Laboratories with multiple fuel gas outlets shall be provided with a dedicated shutoff valve. This valve shall be readily accessible, located within the laboratory, and clearly identified with signage; and

k) Valves installed in tubing systems shall be securely supported independently of the tubing to maintain system integrity.

8.19 Over-pressure Protection Devices

Over-pressure protection devices are essential for ensuring the safe operation of gas systems by preventing excessive pressure that could damage appliances or pose safety risks. The guidelines cover when and where these devices are required, their pressure limitation capabilities, and the materials and construction standards to ensure reliable performance. Proper installation and maintenance of over-pressure protection devices are critical to ensure compliance with safety standards and protect both equipment and personnel.

The following steps and guidelines shall be followed for the installation and use of over-pressure protection devices in gas piping systems:

a) Over-pressure protection devices shall be installed in piping systems serving appliances designed to operate at a gas pressure of 3.5 kPa or less, when the serving gas supplier delivers gas at a pressure greater than 13.8 kPa. Piping systems serving equipment with higher inlet pressures shall also be equipped with over-pressure protection devices as specified by the appliance manufacturer.

b) The pressure limitation for over-pressure protection devices shall comply with the relevant guidelines for systems designed to operate at specific gas supply pressures, as follows:

   1) *Pressure under* 3.5 kPa — Over-pressure protection devices shall limit the gas pressure to 13.8 kPa or less when the line pressure regulator fails;

   2) *Pressure over* 3.5 kPa — Over-pressure protection devices shall limit the gas pressure to the requirements specified by the appliance manufacturer's installation instructions when the system operates with pressures above 3.5 kPa;

   3) *Device capability* — Over-pressure protection devices shall be capable of independently limiting the gas pressure to the appliances as required, without relying on other pressure control equipment in the system; and

   4) *Failure detection* — Systems requiring over-pressure protection shall be designed so that any failure of the primary pressure control device is easily detectable. If a relief valve is used for over-pressure protection, it shall maintain pressure within safe limits under all failure conditions, including the failure of the line pressure regulator.

c) *Types of Over-Pressure Protection Devices* — The over-pressure protection device shall be one of the following:

   1) Pressure relief valve;

   2) Monitoring regulator;

   3) Series regulator; and

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4) Automatic shutoff device.

These devices shall either be integrated with the service or line pressure regulator or installed separately, in compliance with the relevant guidelines.

i) *Construction and installation* — Over-pressure protection devices shall be constructed from materials that prevent impairment due to corrosion and shall be designed for easy operation, testing, and examination for leakage when closed;

ii) *External control piping* — Control piping shall be installed to avoid damage that could render both the regulator and the over-pressure protection device inoperative;

iii) *Setting* — The over-pressure protection devices shall be set to ensure the gas pressure supplied to connected appliances does not exceed the limits established by the relevant pressure guidelines;

iv) *Unauthorized operation* — Measures shall be taken to prevent unauthorized operation of shutoff valves that could disable the over-pressure protection device. This may include locking the valve in the open position or installing duplicate relief valves;

v) *Vents* — Discharge stacks, vents, and outlets of over-pressure protection devices shall be directed outdoors, designed to prevent blockages, and sized to match the outlet of the relieving device; and

vi) *Size of fittings, pipe, and openings* — All fittings, pipes, and openings between the protected system and the over-pressure device shall be properly sized to prevent hammering and ensure adequate relief capacity.

8.20 Engine and Gas Turbine Powered Equipment

The requirements for the installation and operation of equipment powered by internal combustion engines and gas turbines shall be followed towards reducing fire hazards both during installation and operation. Proper installation is essential to ensure safe operation, minimize risks, and enhance the equipment's performance and longevity. The following guidelines cover the installation practices and considerations necessary for integrating these systems safely into the overall setup.

a) *Powered Equipment* — Permanently installed equipment powered by internal combustion engines and turbines shall be installed according to the manufacturer's instructions. This ensures that the equipment operates as intended, with all safety and operational specifications followed.

b) *Gas Supply Connection* — Equipment powered by internal combustion engines and turbines shall not be rigidly connected to the gas supply piping. Flexible connections shall be used to prevent stress or strain on the piping system caused by movement or vibration of the equipment, ensuring safe and reliable operation.

9 INSPECTION OF SERVICES

9.1 No person shall use or permit the use of a new system or an extension of an old system of gas piping in a building or structure before the same has been inspected and tested to ensure the tightness of the system, and a certificate has been issued by the Authority.

9.1.1 *Test of Piping for Tightness*

Before any system of gas piping is finally put in service, it shall be carefully tested to ensure that it is gastight. Where any part of the system is to be enclosed or concealed, this test should precede the work of closing in. To test for tightness, the piping may be filled with city gas, air or inert gas but not with any other gas or liquid. In no case shall oxygen be used. The piping shall stand a pressure of at least 20 kN/m^2 measured with a manometer or slope gauge, for a period of not less than 10 min without showing any drop in pressure.

9.1.2 When the gas pressure exceeds 7 kN/m^2, the piping shall withstand a pressure of 0.6 MN/m^2 for 4 h (this test is for piping designed for working pressure less than 0.4 MN/m^2).

9.2 The Authority shall, within a reasonable time after being requested to do so, inspect and test a system of gas piping that is ready for such inspection and test, and if the work is found satisfactory and test requirements are complied with, it shall issue the certificate.

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10 LEAKAGE CHECK

10.1 Before turning gas under pressure into any piping, all openings from which gas may escape shall be closed.

10.2 Checking for Gas Leakage

No matches, flame or other sources of ignition shall be employed to check for gas leakage from meters, piping or appliances. Checking for gas leakage with soap and water solution is recommended.

10.3 Use of Lights

Artificial illumination used in connection with a search of gas leakage shall be restricted to electric hand flash lights (preferably of the safety type) or approved safety lamps. In searching for leaks, electric switches should not be operated. If electric lights are already turned on, they should not be turned off.

10.4 Checking for Leakage with Meter

Immediately after turning gas into the piping, the system shall be checked to ascertain that no gas is escaping. This may be done by carefully watching the test dial of the meter to determine whether gas is passing through the meter. In no case should a leakage test be made using a gas meter unless immediately prior to the test it has been determined that the meter is in operating condition.

10.5 Checking of Leakage Without Using a Meter

This may be done by attaching to an appliance, orifice or a manometer or equivalent device and momentarily turning on the gas supply and deserving the gauging device for pressure drop with the gas supply shut-off. No discernible drop in pressure shall occur during a period of 3 min.

10.6 After piping has been checked, all gas piping shall be fully purged. Piping shall not be purged into the combustion chamber of an appliance. A suggested method for purging the gas piping to an appliance is to disconnect the pilot piping at the outlet of the pilot valve.

10.7 After the gas piping has been effectively purged, all appliances shall be purged and the pilots lighted.

10.8 In addition to the checking of gas leakage with soap and water solution, a suitable gas detector is also recommended for use.

11 USE OF LIQUEFIED PETROLEUM GAS (LPG)

11.1 The cylinders used for the storage and transportation of liquefied petroleum gas (LPG) shall conform to accepted standards [E-4(3)] approved by the statutory authority.

11.2 The handing, use, storage and transportation of liquefied petroleum gas in cylinders exceeding 500 ml water capacity shall be done in accordance with good practice [E-4(4)].

11.3 LPG Cylinder Installation

The following recommendations apply to installation in commercial, industrial, educational and institutional premises.

11.3.1 *General Recommendations*

11.3.1.1 Those responsible for the installation of cylinders, equipment and piping should understand the characteristics of LPG and be trained in good practice of handling, installing and maintaining installations.

11.3.1.2 The jointing compound used at different joints in the system shall be decided by the Qualified Installing Agency. Hemp and similar materials shall not be used at the joint. In any joint in which the thread provides a gastight seal, jointing compound shall be used only on the male thread.

11.3.1.3 Fire extinguishers of dry powder type or carbon dioxide type conforming to accepted standard [E-4(5)]

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shall be provided in places where LPG cylinder installations are situated and shall be located near such installations. Two buckets filled with sand and two with water shall also be installed nearby. The number, type and size of the fire extinguishers shall be as follows:

		Number	*Type*	*Capacity*
a)	For installations with LPG 40 kg to 200 kg	2	Dry powder	9 kg
b)	For installations with LPG more than 200 kg and up to 320 kg	3	Dry powder	9 kg
c)	For installations with LPG more than 320 kg and up to 1 000 kg	4	Dry powder	9 kg

NOTE — For electrical installations, one number CO_2 fire extinguisher (4.5 kg capacity) shall be provided.

11.3.1.4 Liquefied petroleum gas shall not be transferred from the cylinders in which it is received to any other container.

11.3.2 *Cylinder Location*

11.3.2.1 *Stationary installations*

a) Stationary installation not exceeding 50 kg of LPG may be installed indoors on any floor. It is recommended to have a minimum floor area of 5 m^2 for such an installation.

b) Stationary installations each not exceeding 50 kg of LPG may be installed indoors on any floor and within the same workspace provided the minimum distance between two such installations is 3 m, the proportion of such installations to floor area is one installation per 5 m^2 and the aggregate quantity of gas of all such installations does not exceed 200 kg.

c) Stationary installation not exceeding 100 kg of LPG may be installed indoors on any floor provided the floor area for such an installation is not less than 12 m^2.

d) Stationary installations each not exceeding 100 kg of LPG may be installed indoors on any floor and within the same workspace provided the minimum distance between two such installations is 3 m, the proportion of such installations to floor area is one installation per 12 m^2 and the aggregate quantity of gas of all such installations does not exceed 200 kg.

e) Stationary installation not exceeding 400 kg of LPG may be installed indoors in an enclosed section of a building or a room reserved exclusively for this purpose and ventilated at low level directly to the outside air.

f) Stationary installations above 400 kg [200 kg in case provision as in (e) is not possible] but not exceeding 1 000 kg shall be installed outdoors on ground floor level only. A minimum distance of 3 m shall be maintained between an installation and any building, public place, roadways, and other surroundings. The installation shall be protected from excessive weathering by sun, rain, etc, and from tampering by unauthorized persons. A lean-to roof with expanded metal on angle-iron framework on the sides is considered suitable for this purpose. In any case, adequate ventilation at ground level to the outside air shall be provided.

g) If the storage per installation is more than 1 000 kg, installations in multiples of 1 000 kg with manifold, safety devices, change over mechanism may be provided with minimum inter distance of 3 m from all sides. Total number of such installations shall not exceed 4 including stand by installation. If more than two installations are used, then number of cylinders per installations should not exceed 30.

h) For storage installations of 1 000 kg or installations in multiple of 1 000 kg the number of cylinders to be connected per manifold shall not exceed 15 and for each 1 000 kg installation two such manifolds shall be provided.

j) Cylinders shall be installed upright with the valves uppermost.

k) Cylinder containing more than 20 kg of gas shall not be located on floors above ground level.

m) Cylinders shall be located on a concrete or brick floor, preferably raised in case of outdoor installations.

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n) In order to prevent the hazardous collection of gas, cylinders shall be placed at least 1 m away from culverts, depressions, or openings leading to below ground level compartment and drains.

p) Cylinders which have safety relief valves or similar devices incorporated in them shall be so positioned so that if the relief device operates, escaping gas is not hazardous;.

q) Cylinder installation for commercial/industrial/domestic/residential complexes, etc, or at any public place shall meet the following requirements:

1) For commercial and industrial cylinder installation for any public places like mall, buildings, industries, hotels, etc, the sum total of all stationery installations inside the building shall not exceed 400 kg of LPG in any case. In case sum total of net weight of all the cylinders installed indoors exceed 400 kg provision for outdoor installations shall be made. For installations where the sum total is less than 400 kg of LPG provisions of (b) to (e) shall apply;

2) For commercial and industrial cylinder installation for any public place, industry, etc, if the net weight of all the cylinders installed is more than 400 kg but less than 1 000 kg, than the installation shall be provided outdoors in line with (f). The cylinder installation shall be provided in a covered industrial shed but open from all sides for proper ventilation. In case the installed capacity increases more than 1 000 kg, than the installation shall be provided in line with (g). Two separate installations shall be provided and distance between each of the installations shall be minimum 3 m (this distance shall be between the outer edge of the two sheds);

3) For multistoried buildings, flats housing society the reticulated installation of any capacity shall be provided at a safe place especially earmarked for this purpose. The installation shall not be provided by the side of road where there is continuous movement of vehicles or is approachable to residents especially children. The installation should be secured and should be provided in a covered shed open from all sides for ventilation. The area shall be demarcated by 1.5 m high chain link fencing having one gate. There should be minimum 3 m clear space all around the fencing and the space between the fencing and the edge of the shed should be minimum 2 m all around;

4) If the requirement is more than 1 000 kg, installations in multiples of 1 000 kg with manifold, safety devices, change over mechanism, not exceeding 4 such installations (including stand by) may be provided with minimum distance of 3 m from all sides. The number of cylinders per installations should not exceed 30; and

5) Location of cylinder bank:

i) The site for LPG cylinder manifold shall be located away from the kitchen/LPG utility area/residential building. Installation shall be slightly raised minimum 100 mm from surrounding ground level;

ii) Cylinders installation should not be located in inaccessible location, under a stairway, basements, cellars, where air movement across cylinders is very low/not present, to prevent the cylinders from getting inadequate latent heat and unapproachable during emergency;

iii) Cylinders installation should not be close to steam pipes, boilers, transformers, DG sets, etc, to prevent cylinders from getting affected due to radiant heat;

iv) Cylinders shall not be installed at a place where they are likely to cause obstruction, suffer damage or be exposed to conditions likely to affect safety;

v) Cylinders installation should not be located along the drive way. Under unavoidable conditions, minimum distance of 3 m from drive way shall be maintained. Brick masonry (minimum 230 mm thick)/concrete (minimum 100 mm thick) walls or metallic shields/barriers (minimum 1.63 mm sheet) and of minimum 2 m height should be erected between drive way and cylinder installation for the safety and security of the installation;

vi) Cylinders shall be located on a concrete or brick floor that is firm, at level, smooth, drained in case of outdoor installation; and

vii) The cylinder shall be installed in upright position with the valve pointing upwards and minimum 1 m away from any combustible materials.

r) Cylinder storage room:

1) The cylinder storage room shall be made out of non-flammable material that is concrete (minimum 100 mm thick) or brick masonry walls (minimum 230 mm thick) or steel structures made out of minimum 5 mm thick MS angle iron structure and 1.63 mm MS wire mesh of size minimum 11;

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2) Since LPG is heavier than air, ventilation shall be provided at floor level, that is 100 mm above inside cylinder bank room, open to atmosphere. The ventilators shall be provided with 2 layers' copper or non-corroding metal wire mesh not less than 11 to the linear centimetre. The size of the ventilators should be minimum 500 mm long and 300 mm height;

3) The storage room shall be well ventilated, that is openings/ventilators shall be provided in the walls of cylinder storage covering minimum 25 percent of wall area. It should also have adequate lighting. Both exteriors and interiors should be painted with weather proof paints. FLP fittings, approved by statutory authorities shall be provided for electrical use;

4) The doors of the room where cylinders are installed shall open outwards and shall have louvers/wire mesh to ensure visibility and ventilation; and

5) Flammable materials like wood and plastic shall not be used. The cylinder bank storage room shall not use for storing any other materials.

11.3.2.2 *Portable installations*

When portability of cylinders is necessary, the following requirements shall be fulfilled:

a) The sum total of capacity of the cylinders connected to each manifold shall not exceed 100 kg of LPG. The total quantity of gas thus installed in a workspace shall not exceed 200 kg.

b) If cylinders are mounted on a trolley, the trolley shall be stable. Where necessary, the cylinders shall be secured to prevent them from falling.

c) The regulator shall be connected directly to the cylinder valve or to a manifold which shall be connected to the cylinder valves by means of rigid connections to give adequate support to the regulator. The only exception to this requirement is where cylinders are mounted on a trolley and the manifold is rigidly supported on the trolley. In such a case flexible or semi-flexible connections may be used between the cylinder valves and the manifold but not between the manifold and the regulator.

d) Anytime the total quantity of gas at portable installations shall be in proportion to the floor area as specified in **11.3.2.1 (a)** to **(f)**.

e) At any time, the provisions at **11.3.2.1 (a)** to **(r)** shall be ensured for all installations.

11.3.3 *Cylinder Manifolds*

11.3.3.1 All materials, fittings, etc, used in cylinder manifold systems shall comply with the statutory provisions or relevant Indian Standards. In absence of any such provisions or Indian Standards, equivalent international norms shall be followed.

11.3.3.2 The individual component parts of manifolds, that is piping, fittings, pigtails, etc, which are subject to cylinder pressure shall be capable of withstanding a test pressure without bursting of 2.5 N/mm^2 or one and a half times the developed pressure at 65 °C, whichever is more.

11.3.3.3 Where cylinder installations are made up with service and reserve batteries of cylinders, suitable change-over devices or valves shall be incorporated in the manifold header to prevent undue escape of the gas when cylinders are changed.

11.3.3.4 In case pressure regulators, manifold headers and automatic change-over devices are connected to cylinder by semi-flexible connectors, these shall be rigidly supported. Copper tube pigtails are considered to be semi-flexible for this purpose.

11.3.3.5 It is recommended that joints in manifold headers which do not have to be broken in normal use should be welded or brazed using a material which shall have a melting point of at least 540 °C.

11.3.3.6 All joints between manifold headers and cylinder connectors shall be readily accessible.

11.3.3.7 All joints in the manifold should be welded (except for valve fixation) and be easily accessible for inspection/repairs, etc.

11.3.3.8 Each manifold arm shall be fabricated in such a way that minimum joints are provided. Only seamless pipes are recommended for use in manifolds. There should be a minimum gap of 300 mm between the manifold

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and valve protection ring of the LPG cylinders.

11.3.3.9 The cylinders connected to a manifold shall be safely spaced for easy and safe replacement of cylinder when empty. A minimum distance of 400 mm shall be maintained between two nipples provided on the manifold for connecting the cylinders to the manifold. In case the diameter of the cylinder is higher than 400 mm then the distance between the two nipples shall be diameter of the cylinder plus 100 mm.

11.3.3.10 A pressure gauge of 100 mm dial shall be provided in the manifold to indicate the gas pressure in the manifold. The pressure gauge shall be suitable for a pressure range 0 to 1.0 N/mm^2.

11.3.4 *Pressure Regulators*

11.3.4.1 Pressure regulators and other devices used to control the gas shall comply with the distributing company's stipulations and accepted standards [E-4(6)].

11.3.4.2 Pressure regulator fitted with a safety valve shall be either,

a) Installed in the open air; or

b) Vented to the open by means of a metal vent pipe connected to the safety valve outlet.

11.3.4.3 Care shall be taken that safety valve outlets do not become choked with dust or other foreign matter.

11.3.4.4 If the regulator is fitted with a relief valve, care should be taken in positioning the regulator to avoid unnecessary hazards if the relief valve functions.

11.3.4.5 Pressure regulators and other control devices shall be adequately supported.

11.3.5 *Instructions to Consumers*

Consumers shall be instructed by the distribution company on the following, through appropriate written instructions:

a) Operation of the whole system;

b) How to recognize gas leaks;

c) Action to be taken in case of leakage;

d) Action to be taken in case of fire; and

e) Action to be taken in case of damage to, or failure of, any part of the installation.

11.3.6 For detailed information regarding installation of LPG cylinders in commercial, industrial, educational and institutional premises, reference may be made to good practice [E-4(7)].

11.4 LPG Bulk Storage Installations

The following recommendations apply to LPG bulk storage installations where storage tanks over 450 ℓ water capacity are used at industrial, commercial and domestic consumers' premises.

The maximum capacity of an individual tank and group of tanks at industrial, commercial and domestic premises shall be as follows:

Sl No.	*Premises*	*Maximum Water Capacity of an Individual Tank* ℓ	*Maximum Water Capacity of Group of Tanks* ℓ
(1)	(2)	(3)	(4)
i)	Industrial	130 000	260 000
ii)	Commercial	40 000	80 000
iii)	Domestic	20 000	80 000

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11.4.1 *Location and Spacing of Storage Tanks*

11.4.1.1 Storage tanks shall be located outside the buildings and shall not be installed one above the other.

11.4.1.2 Each individual tank shall be located with respect to the nearest important building or group of buildings or line of adjoining property which may be built in accordance with Table 1. The distances given refer to the horizontal distance in plan between the nearest point of the storage tank and building/property line.

11.4.1.3 In heavily populated or congested areas the authority may determine the need for other reasonable protective methods to be taken, such as provision of fire walls, etc. If fire walls are to be provided, the authority may determine the extent to which the safety distances for above ground tanks may be reduced.

11.4.1.4 No LPG tank(s) shall be located within the bonded enclosures of any petroleum installation. The minimum distance of separation between LPG storage tanks and any petroleum installation shall be as prescribed under the *Petroleum Rules*, 1976 or as specified in Table 1, whichever is more.

11.4.1.5 The number of storage tanks in one storage installation shall not exceed six. In case there are more than one storage installations, the safety distance between two installations shall be the same as the distance between the tanks and the property line in accordance with Table 1.

Table 1 Minimum Safety Distances

(*Clauses* 11.4.1.2, 11.4.1.4 *and* 11.4.1.5)

Sl No.	LPG Storage Water Capacity of Individual Tank	Distance from Building/ Property Line		Distance between Tanks	
		Above Ground	Under Ground	Above Ground	Under Ground
	ℓ	m	m	m	m
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to 2 000	5	5	1	1.5
ii)	Above 2 000 and up to 10 000	10	7.5	1	1.5
iii)	Above 10 000 and up to 20 000	15	10	1.5	1.5
iv)	Above 20 000 and up to 40 000 adjacent	20	15	2	0.25 × diameter of vessel or 1.5 m (*Min*)
v)	Above 40 000 and above adjacent	30	15	2	0.25 × diameter of vessel or 1.5 m (*Min*)

NOTE — If the aggregate water capacity of a multi-tank installation is 40 000 ℓ or greater, the above minimum safety distances shall apply to the aggregate storage capacity rather than the capacity per individual storage tank.

11.4.2 *Bunding*

Since LPG is heavier than air, storage tank shall not be enclosed within bund walls. The accumulation of flammable liquid under LPG tanks shall be prevented by suitably slopping the ground.

11.4.3 *Protection*

11.4.3.1 To prevent trespassing or tampering, the area which includes tanks, direct fired vaporizers, pumping equipment and loading and unloading facilities shall be closed by an industrial type fence at least 2 m high along the perimeter of the safety zone. Any fence shall have at least two means of exit. Gates shall open outwards and shall not be self-locking.

11.4.3.2 When damage to LPG systems from the LPG tank lorry is a possibility, precautions against such damage shall be taken.

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11.4.3.3 Underground tanks shall be protected from above ground loading by providing a suitable kerb to prevent a possible accidental damage to the tank and its fittings by LPG tank lorry.

11.4.4 *Grass and Weed Removal*

Road ignitable material, such as weeds, long grass or any combustible material shall be removed from an area within 3 m from the shell of any LPG tank of up to 2 000 litre water capacity, and within 6 m from the shell of larger tanks. If weed killers are used, chemicals which are a potential source of fire hazard shall not be selected for this purpose.

11.4.5 *Warning Signs*

No smoking or naked flames shall be permitted within the safety zone of the installation. Prominent notices to this effect shall be posted at access point. From accessibility point of view, the signs shall be in accordance with good practice [E-4(8)].

11.4.6 *Fire Protection*

The possibility of a major fire outbreak, leading to direct flame impingement of the storage tank, shall be minimized by sound engineering in plant design and layout, good operating practice, and proper education and training of personnel on both routine operations and on action to be taken in an emergency.

11.4.6.1 *Water supply*

Provision shall be made for an adequate supply of water and fire protection in the storage area according to the local hoses and mobile equipment, fixed monitors or by fixed spray systems which may be automatic. Control of water flow should be possible from outside any danger area.

11.4.6.2 *Fire extinguishers*

At least two dry chemical powder type fire extinguishers of 9 kg capacity each, conforming to the quality requirements in accordance with the accepted standard [E-4(5)], shall be installed at points of access to the storage installations. The fire extinguishers should be mounted keeping in view the ease of accessibility in accordance with good practice [E-4(9)] and Part F 'Fire and Life Safety' of this NBCS.

11.4.7 For detailed information regarding LPG bulk storage installations, reference may be made to good practice [E-4(10)].

12 USE OF PIPED NATURAL GAS (PNG)

12.1 The PNG infrastructure shall be in complete compliance with all the requirements of *Petroleum and Natural Gas Regulatory Board* (*Technical Standards and Specifications including Safety Standards for City or Local Natural Gas Distribution Network*) *Regulations*, 2008.

12.1.1 The user-group/housing society concerned (referred hereinafter in these clauses as 'society') should contact the local city gas distribution (CGD) entity at the stage of the design of the building. This ensures that all the adequate provisions are incorporated in the design itself, as also the compliance with all the safety standards stipulated/required by the regulations/gas entities, as applicable from time-to-time. This ensures avoidance/mitigation of any rework at a later stage, or even situations where incorporation of any changes may become impractical or not possible, thereby rendering the building devoid of PNG infrastructure.

12.1.2 The entire gas pipeline infrastructure proposed to be laid in the premises of the society shall be easily accessible in future by the representatives of the CGD entity. Provision should be made by the builder for the same. Builder/society should ensure communication of the same to the future customer and should incorporate it in their agreements with the customer.

12.1.3 No permanent/temporary structure shall be erected on the ground along the paths where gas pipeline exists underground.

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12.2 The PNG infrastructure inside the premises of societies primarily comprises the following:

a) Underground medium pressure (MP) pipeline networks, comprising mainly polyethylene pipes and fittings;

b) Underground low pressure (LP) pipeline networks, comprising mainly polyethylene (PE) pipes and fittings;

c) Service regulator modules;

d) Above ground riser and lateral system, comprising mainly electric resistance welded GI pipes and fittings; and

e) Pipeline inside premise and/or kitchen of individual customer, comprising various components like meter regulator, diaphragm gas meter, copper pipe, brass fittings, brass valves, etc.

The guidelines mentioned under **12.3** to **12.6** give the minimum requirements to be complied with.

12.3 Guidelines for MP and LP Pipeline Networks

12.3.1 Gas pipelines are required to be laid at a minimum top cover of 1 m from the finished surface level. Underground PE pipeline shall not be laid through the basement.

12.3.2 A minimum clearance of at least 300 mm is required to be maintained between the gas pipelines and any other obstacles/services.

12.3.3 Gas pipelines should not be laid closer to properties than as stipulated below:

Sl No.	*Pressure*	*Minimum Proximity*
(1)	(2)	(3)
i)	Up to 0.01 N/mm^2	0.25 m
ii)	Up to 0.4 N/mm^2	3.00 m

12.3.4 Laying of underground natural gas pipelines within the premises of society shall be in accordance with *Petroleum and Natural Gas Regulatory Board* (*Technical Standards and Specifications including Safety Standards for City or Local Natural Gas Distribution Network) Regulations*, 2008.

12.3.5 A dedicated utility corridor may be provided in the society for natural gas pipelines. However, if provision of dedicated utility corridor for natural gas pipeline is not feasible inside the society premises due to space constraints, then, provisions pertaining to safety inter-distances of natural gas pipelines with other utilities as mentioned in *Petroleum and Natural Gas Regulatory Board* (*Technical Standards and Specifications including Safety Standards for City or Local Natural Gas Distribution Network*) *Regulations*, 2008 shall be followed.

12.3.6 In case of contradiction between the provisions of this NBCS and *Petroleum and Natural Gas Regulatory Board* (*Technical Standards and Specifications including Safety Standards for City or Local Natural Gas Distribution Network) Regulations*, 2008, then, provision of *Petroleum and Natural Gas Regulatory Board* (*Technical Standards and Specifications including Safety Standards for City or Local Natural Gas Distribution Network*) *Regulations*, 2008 shall prevail.

12.4 Guidelines for Service Regulator Modules

The user-group/society should provide adequate open spaces in the premises for installation of gas equipment like regulating stations, which will be required to facilitate supply of PNG to the residents of the building/premise.

The identified location shall be such that it does not obstruct any vehicular movement and is at a safe location in the premise.

12.5 Guidelines for Above Ground Riser and Lateral System

12.5.1 The riser and lateral system supplying gas to multistoried residential buildings shall be in compliance with

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the requirements of the PNGRB regulations.

12.5.2 Multi-occupancy buildings having eight floors or more should have purpose- built utility shafts/ducts for accommodating riser and lateral system, which should be preferred route for constructing/locating the riser.

12.5.3 Provision shall be made for safe access to the riser and lateral system by the representatives of the CGD entity for future maintenance and repair. In the case of a continuous shaft, a concrete slab or similar flooring shall be provided for maintenance work at each floor.

12.5.4 *Ventilation*

12.5.4.1 Adequate provision for natural ventilation shall be provided in the building where PNG infrastructure is laid, so as to prevent any potential gas leaks from accumulating in the atmosphere to an unsafe level. Mechanical ventilation shall not be used to achieve the required ventilation levels. The minimum levels of ventilation in riser's ducts/shafts shall be as given below:

Sl No.	*Cross Sectional Area (CSA) of Riser Duct*	*Minimum Free Area of Each High and Low Level Ventilation (Open Ventilator)*	*Typical Air Duct Size*	*Typical Ventilator Size*
	m^2	m^2	mm	mm
(1)	(2)	(3)	(4)	(5)
i)	Less than 0.01	0.002	Ø50	Ø70
ii)	0.01 to 0.375	0.010	Ø100	100 × 100
iii)	0.375 to 0. 5	0.02	Ø150	100 × 200
iv)	0. 5 to 7. 5	0.05	Ø250	200 × 250
v)	More than 7.5	1 percent CSA of the duct	–	–

12.5.4.2 Where the duct has a single ventilator that is part of the architectural design of the building, the free area of the ventilator to outside area shall be a minimum of 0.04 m^2 or 4 percent of the CSA of the duct, whichever is greatest.

12.5.4.3 Pipe work shall be installed in an unventilated void.

12.5.4.4 The pipe may enter the building to gain access to the riser shaft through a basement or car parking area, provided the area is well ventilated.

12.5.4.5 Any duct containing a riser or lateral shall be ventilated either directly to outside air, or indirectly to outside air *via* an area that is normally occupied and is itself ventilated to outside.

12.5.4.6 The provision of ventilation should be through permanent ventilators within the area/duct containing pipe-work.

12.5.4.7 All flammable release sources shall be at a lower elevation than the bottom of the highest ventilation opening.

12.5.4.8 Pipes may run in the same duct (subject to availability of adequate clearance from other utilities and ventilation) as most other services, including hot and cold water services, heating pipes, electrical conduits and cables and pipes containing other fuels. However, the following services shall not be installed in the same duct as gas pipes:

a) Ventilation ducts and vacuum pipes that operate at sub-atmospheric pressure and that are not of all-welded or all-brazed construction; and

b) Services containing oxidizing or corrosive fluids.

12.5.5 There shall be provision for installing risers and laterals such that a minimum distance of 300 mm is ensured

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from any electrical equipment or installations and associated excess current control boxes of fuse boxes, and 25 mm is ensured from the electricity supply and distribution cables and other metal piped services.

12.5.6 In case where the gas pipeline is required to cross through a wall, provisions (like core cutting) or holes of adequate size drilled through the wall/building structure, to accommodate an easy passage of the gas pipelines through them, shall be made. The elevation of these provisions/holes shall be near the roof and not near the floor of the room.

12.6 Guidelines for Pipeline Inside Premise and/or Kitchen of Individual Customer

12.6.1 Meters will normally be located inside the property on an outside wall with a minimum length of inlet pipe-work inside the property. Kitchen is the preferred room to locate the meter, thereby minimizing the length of the outlet pipe work.

12.6.2 The gas meter shall be installed in an area with adequate ventilation and at a proper location to facilitate safe and convenient meter reading and maintenance activities in future. A minimum ventilation area of 2 percent of the internal floor area of the room shall be provided in the room where the gas meter is located. The gas pipeline inside the kitchen shall be laid along the walls of the kitchen and in a ventilated area.

12.6.3 In case pipe work is required to be laid in solid floors inside the kitchen, adequate provisions (in the shortest possible route and a minimum of 75 mm screed to provide an approximate cover of at least 50 mm over the gas pipe) shall be provided to protect the pipeline against corrosion and failure caused by movement. This method of construction consists of a base concrete raft foundation onto which a cement screed is subsequently laid in order to obtain a satisfactory surface to accept the floor finish. Provision of preformed ducts with protective covers should be made to facilitate laying of gas pipeline. It is advisable to contact the CGD entity at the designing stage so that adequate provisions are incorporated in the design of the kitchen/floor plan to facilitate easy and safe installation of PNG system.

12.6.4 Installation pipe work shall not be placed within the cavity of a cavity wall. Every pipe passing through a cavity wall shall take the shortest possible practicable route and shall be sleeved.

12.6.5 In case of provision of sleeve, the same should be of a diameter that provides a sliding fit to the pipe allowing normal pipe expansion/contraction.

13 USE OF MEDICAL GAS PIPELINE SYSTEM (MGPS)

13.1 General

A medical gas pipeline system (MGPS) is installed to provide a safe, convenient and cost effective system for the provision of medical gases to the clinical and nursing staff at the point of use. It reduces the problems associated with the use of gas cylinders such as safety, porterage, storage and noise.

MGPS generally handles distribution of oxygen, nitrous oxide, medical air, surgical air, medical vacuum only; and sometimes provides an aesthetic gas scavenging systems. All other gases used in hospitals have low volume use and are provided through cylinders at the point of use.

It is essential to ensure that there is no possibility of a cross-connection between any system and that all parts of each system to which connections can be made by users are gas specific.

Separate installations are provided for pathology, general laboratories and special laboratories. These are designated Laboratory Gases (Pipeline) Supply System (LGSS). LGSS is provided with valve controlled outlets and shall never be provided with medical gas terminal units.

Use and storage of medical gases is governed by *Indian Drugs and Cosmetics Act*, 1940.

13.2 Design and Installation

13.2.1 *Pipelines Systems for Compressed Medical Gases and Vacuum*

The design, installation, performance, documentation, testing and commissioning of pipeline systems for

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compressed medical gases, gases for driving surgical tools and vacuum in healthcare facilities to ensure continuous delivery of the correct gas and the provision of vacuum from the pipeline system, shall be in accordance with the good practice [E-4(11)]. This is inclusive of the requirements for supply systems, pipeline distribution systems, control systems, monitoring and alarm systems and non-interchangeability between components of different gas systems.

13.2.2 *Anaesthetic Gas Scavenging Disposal Systems*

The design, installation, performance, documentation, testing and commissioning of an aesthetic gas scavenging disposal systems to ensure patient safety and to minimize exposure of the operator and other persons to an aesthetic gases and vapours, shall be in accordance with the good practice [E-4(12)]. This is inclusive of requirements for the power device, pipeline system, performance, non- interchangeability between key components and avoidance of cross connections between an aesthetic gas scavenging (AGS) disposal systems and medical gas and vacuum pipeline systems.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of this NBCS. The latest version of a standard shall be adopted at the time of enforcement of this NBCS. The standards listed may be used for conformance with the requirements of the referred clauses in this NBCS.

	IS No.	*Title*
(1)	IS 14885 : 2022	Polyethylene pipes for the supply of gaseous fuels — Specification (*first revision*)
	IS 17544 : 2022	Multilayer (PE-AL-PE) plastic piping system for indoor gas installations with a maximum operating pressure up to and including 500 kPA (5 bar) — Specification
(2)	IS 18466 (Part 1) : 2024/ ISO 7396-1 : 2016	Medical gas pipeline systems: Part 1 Pipeline systems for compressed medical gases and vacuum (*first revision*)
	IS/ISO 7396-2 : 2007	Medical gas pipeline systems: Part 2 Anaesthetic gas scavenging disposal systems
(3)	IS 3196 (Part 1) : 2013	Welded low carbon steel cylinders exceeding 5 litres water capacity for low pressure liquefiable gases: Part 1 Cylinders for liquefied petroleum gases (LPG) — Specification (*sixth revision*)
	IS 7142 : 2025	Welded low carbon steel cylinders for low pressure liquefiable gases not exceeding 5 litre water capacity — Specification (*second revision*)
(4)	IS 8198 (Part 5) : 2022	Code of practice for steel cylinders for compressed gases: Part 5 Liquefied petroleum gas (LPG) (*second revision*)
(5)	IS 15683 : 2018	Portable fire extinguishers — Performance and construction — Specification (*first revision*)
(6)	IS 9798 : 2013	Low pressure regulators for use with liquefied petroleum gas (LPG) — Specification (*second revision*)
	IS 16280 : 2021	High pressure regulators and adaptors for use with liquefied petroleum gases (LPG) — Specification (*first revision*)
(7)	IS 6044 (Part 1) : 2018	Liquefied petroleum gas storage installations — Code of practice: Part 1 Residential, commercial and industrial cylinder installations (*third revision*)
(8)	IS 4963 : 2025	Accessibility in built environment for older adults and persons with disabilities — Requirements (*second revision*)
(9)	IS 2190 : 2024	Selection, installation and maintenance of first-aid fire extinguishers — Portable and mobile — Code of practice (*fifth revision*)
(10)	IS 6044 (Part 2) : 2021	Liquefied petroleum gas storage installations — Code of practice: Part 2 Commercial, industrial and domestic bulk storage installations (*second revision*)
(11)	IS 18466 (Part 1) : 2024/ ISO 7396-1 : 2016	Medical gas pipeline systems: Part 1 Pipeline systems for compressed medical gases and vacuum (*first revision*)
(12)	IS/ISO 7396-2 : 2007	Medical gas pipeline systems: Part 2 Anaesthetic gas scavenging disposal systems

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART F FIRE AND LIFE SAFETY

The Fire Services is a State subject and has been included as a Municipal function in the XIIth Schedule of the Constitution of India under Article 243(w). It is therefore primarily the responsibility of the State Governments to ensure safety of life and property in their area of jurisdiction. State/Union Territories (UTs) in the country are implementing fire safety measures either through the provisions as stipulated in their State Fire Services Act or through their building byelaws. The construction of any building and its fire safety thereof has to be ensured as per the norms and standards prescribed by the State Building Bye Laws/Development Control Regulations of the State/UTs.

The Department of Fire Services in the States/UTs is one of the agencies to issue NOC to the buildings from fire and life safety aspects and it is for the State/UT Governments to provide stringent norms for issuing NOC for the same.

This Part of NBCS is only for guidance and referral for the state government/local authority in respect of fire safety in buildings.

BUREAU OF INDIAN STANDARDS

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FOREWORD

The first version of this Part was formulated as Part 4, in the National Building Code of India 1970 (NBC 1970) and was revised in 1983. Subsequently the first revision of this Part was modified in 1997 through Amendment No. 3 to 1983 version of NBC. The modified version of this Part included a few tables for the fire resistance ratings of various building components, such as walls, columns, beams and floors. The requirements for wet riser, down-comer, automatic sprinkler installation, high velocity (10 m/s to 15 m/s) water spray or foam generating system, etc, for buildings were modified. Annex giving guidelines for selection of fire detectors had been deleted and relevant Indian Standards on fire alarm system and smoke detectors had been referred. Also, an annex for determination of fire loads and flue load density for arriving at the classification of occupancy hazard and calorific values of some common materials was included. Annex for broad classification of industrial and non-industrial occupancies into low, moderate and high hazard had also been included.

The NBC was then revised in 2005. In this revision, the significant modifications incorporated were: The text was divided into the following broad clauses: (a) *Fire prevention* – Covering aspects of fire prevention pertaining to design and construction of buildings on passive fire protection measures, also describing the various types of building materials and their fire rating; (b) *Life safety* – Covering life safety provisions in the event of fire and similar emergencies, also addressing construction and occupancy features that are necessary to minimize danger to life from fire, smoke, fumes or panic; (c) *Fire protection* – Covering the significant appurtenances and their related components and guidelines for selecting the correct type of equipment and installation meant for fire protection of the building, depending upon the classification and type of the building. Also, the classification of building based on occupancy was elaborated, wherein, starred hotels were covered as a new Subdivision A-6 under occupancy Group A Residential; heritage structures and archaeological monuments were covered under Subdivision D-3 occupancy Group D Assembly buildings; mixed assembly occupancies were covered as a new Subdivision D-6; underground elevated railways were covered as a new Subdivision D-7 under occupancy Group D Assembly buildings; and TV stations were covered under Subdivision E-5 of occupancy Group E Business buildings. Further, for the external stairs for exit requirements, the width and treads were increased to 1 250 mm and 250 mm, respectively; under the requirements for institutional buildings the clear width of all required exits which serve as egress from hospital or infirmary section was increased from 1.5 m to 2 m. Also, provision of patient-lift was included; and due cognizance of halon phase out programme was taken, while specifying provisions in this Part with respect to fire protection using fire extinguishers/systems. Based on various comments received from time-to-time, an Amendment No. 2 relating to Part 4 of the 2005 version of NBC, was issued.

In the 2016 revision of NBC, the following changes were made:

General:

1) The scope of application of provisions of this Part of NBC for different occupancies was clarified.
2) Definitions of various new terms were included and definitions of some of the existing terms were updated based on latest developments and use.

Fire Prevention:

3) Based on the experience in the use of the provisions of NBC in relation to various occupancies and subdivision classification under various building occupancy types, the same were reviewed and updated. Also, mixed occupancy and minor occupancy were further clarified.
4) Table 1 on fire resistance ratings of structural and non-structural elements was updated.
5) The provisions relating to fire separating walls, fire separating floors and fire partitions were detailed.
6) Provisions of fire safety requirements of services shafts were rationalized and updated.
7) A separate comprehensive clause on electrical power supply distribution for fire and life safety systems was included.
8) Detailed clauses on air conditioning systems towards safety and smoke control integration were provided.

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9) Glass facade requirements were detailed towards fire protection and smoke exhaust aspects.

10) A separate comprehensive clause on Fire Command Centre (FCC) was introduced covering various requirements.

Life Safety:

11) The components of means of egress were comprehensively brought out covering specific aspects relating to exit access, exit and exit discharge. The relationship of occupant load, exit width requirements and travel distances were duly detailed enabling efficient planning for enhanced life safety provisions. The table on capacity factors was modified based on aspect of width per person approach used globally.

12) Requirement for displaying the occupancy load for assembly buildings and call centres, was included.

13) The concept of firefighting shaft for safe and efficient use by the fire fighters to access the floor on fire and also allow egress/evacuation of the occupants with simultaneous use of refuge area used as staging of the occupants, were well integrated, including in the annex for high rise buildings.

14) Aspects of compartmentation with fire barrier and its passive fire safety requirements were detailed for respective occupancies.

15) Pressurization of exits and smoke extraction requirements for respective areas including car parking were updated with an approach towards selecting alternative means therefor.

16) The clause on gas supply was comprehensively updated.

17) The clause on fire detection and alarm system was completely reviewed and updated as per the latest practices.

Fire Protection:

18) The table on minimum requirements for firefighting installations (erstwhile Table 23 renumbered as Table 7) was comprehensively updated.

19) Detailed provisions were included on fire water storage, fire pump room, sprinkler system and various alternative fire suppression systems.

Additional Occupancy-wise Requirements:

20) Concept of progressive evacuation in case of hospital buildings was included in detail to ensure life safety of the inmates.

21) Provisions relating to requirement of refuge area were updated including for D-6 occupancy and introduced for apartment buildings of height 60 m and above.

22) Separate provisions on atrium were included in Annex E.

23) Detailed separate provisions were included on commercial kitchens as an Annex.

24) Detailed separate provisions were included on car parking facilities in Annex G.

25) Separate provisions on fire and life safety requirements for metro stations and metro trainways were included in Annex J and Annex K, respectively.

In this revision, the publication is renamed as National Building Construction Standards (NBCS).

This NBCS (Part F) deals with safety from fire. It specifies the demarcation of fire zones, restrictions on construction of buildings in each fire zone, classification of buildings based on occupancy, types of building construction according to fire resistance of the structural and non-structural components and other restrictions and requirements necessary to minimize danger to life from fire, smoke, fumes, or panic before the buildings can be evacuated. The NBCS recognizes that safety of life is more than a matter of means of egress and accordingly deals with various matters which are considered essential to the safety of life. The NBCS therefore covers provisions relating to means of egress covering various components thereof namely exit access, exit, and exit discharge. It also covers provisions relating to fire protection of buildings through portable and fixed firefighting installations.

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Fire protection techniques have to be based on the fire behaviour characteristics of different materials and structural elements of buildings. The activities pursued by the occupants of buildings must also be taken into consideration for assessing the extent of hazards, and method should then be devised by which the hazards could be minimized. An indefinite combination of variables is involved in the phenomenon of fire, all of which cannot be quantified. The requirements of this NBCS should, therefore, be taken as a guide and an engineering design approach should be adopted for ensuring a fire safe design for buildings. Depending upon the type and complexities in a building, qualified and trained fire protection engineers should be associated with the planning of buildings, so that adequate fire and life safety measures could be incorporated in the building design right from the beginning.

Absolute safety from fire is not attainable in practice. The objective of this Part is to specify measures that will provide that degree of safety from fire which can be reasonably achieved. The NBCS endeavours to avoid requirements that might involve unreasonable hardships or unnecessary inconvenience or interference with normal use and occupancy of buildings but insists upon compliance with minimum standards of fire safety necessary for building occupants and users. For ensuring compliance of fire protection equipment/installations to the laid down quality requirements, it is desirable to use such equipment/installation duly certified under the BIS, Certification Marks Scheme.

While providing guidelines for minimizing chances of occurrence of fire through passive fire protection measures, this Part does not intend to cover all aspects of general fire prevention including sources of ignition. Nor does it cover the prevention of accidental personal injuries from fire during the course of normal occupancy of buildings.

This Part while recognizing that panic in a building on fire may be uncontrollable, deals with the potential panic hazard through measures designed to prevent the development of panic. Experience indicates that panic seldom develops even in the presence of potential danger, so long as occupants of buildings are moving towards exits which they can see within a reasonable distance and with no obstruction or undue congestion in the path of travel. However, any uncertainty as to the location or adequacy of means of egress, the presence of smoke or fumes and the stoppage of travel towards the exit, such as may occur when one person stumbles and falls on stairs, may be conducive to panic. Danger from panic is greater when a large number of people are trapped in a confined area particularly when people are not adequately guided towards egress and safety notifications are not implemented or practiced. Consideration towards announcements and annunciations needs to be given to guide the occupants to safe egress routes and to control panic during situation of distress. These aspects are addressed in this Part.

Experience has shown that concealed spaces within a building, such as, space between ceiling and false ceiling, horizontal and vertical ducts, and shafts, etc, tend to act as flues/tunnels during a fire. Provisions therefore exist to provide fire stopping within such spaces.

Nothing in this Part of the NBCS should be construed to prohibit better types of building construction, more exits, or otherwise safer conditions than the minimum requirements specified in this Part.

Compliance with this Part should not be construed as eliminating or reducing the necessity for other provisions for safety of persons using a building or structure under normal occupancy conditions. Nor should any provision of this Part be construed as requiring or permitting any addition that maybe hazardous under normal occupancy conditions.

One of the major points brought out then in this Part (until NBC 2016) is the limitation of heights and areas of buildings based on fire safety of the occupants. Individual municipal corporations were free to alter the then Table 2 (of NBC 2016) based on local conditions, but the ratios of areas as maintained in the table for different occupancies and types of construction should be adhered to.

Advantage has been taken of the developments, particularly in fire resistance rating of materials, designating types of construction in a rational manner and relating the area limitations of different occupancies to different types of construction.

Halons (halogenated hydrocarbons) which exhibit exceptional firefighting and explosion prevention/ suppression characteristics have been found to possess high ozone depleting potential. They come under Group II of Annex A of the Montreal Protocol on Substances that Deplete the Ozone Layer, the international environmental agreement for phasing out ozone depleting substances. Due to increasing evidence that the ozone layer is getting depleted at a faster rate than thought earlier, the NBCS continues to take into cognizance the need to promote use of halon alternatives as fire extinguishing media.

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In this revision, the following significant changes have been made:

a) Minor occupancies have been clarified, in **3.1.1.1**;

b) Mixed occupancy has been detailed in **3.1.11**;

c) Fire resistance rating of roofs located over 6.7 m has been updated in Table 1;

d) Occupant load factor for various occupancies has been clarified in Table 2, also with respect to the net or gross floor area;

e) Various provisions on life safety have been updated in **4**;

f) Travel distance values have been updated in Table 4;

g) Compartmentation related provisions have been comprehensively updated in **4.5**;

h) Fire detection and suppression systems based on the specific type and intensity of industrial hazards has been introduced under **5.4**;

j) Table 7 on firefighting requirements for various occupancies has been reviewed and separately detailed (in Table 7A to Table 7J) for all the occupancies;

k) Basis for water quantity required for fire-fighting are recommended for combined system protection (using sprinkler and hose) and similarly for hose protection system in Table 7K and Table 7M, respectively;

m) Fire protection of commercial kitchen has been elaborated through reference to the detailed Indian Standard, IS 18271 : 2023 'Fire safety in commercial kitchen — Guidelines';

n) Water curtain requirement for basement compartmentation has been reviewed and deleted;

p) Annex H on fire and life safety requirements for metro stations has been elaborated;

q) Annex J on fire and life safety requirements for metro trainways has been updated;

r) A new Annex M on performance based design has been introduced;

s) A new Annex N on fire protection for specific industries is included as an informative guide; and

t) Height restrictions of buildings have been eliminated.

All standards cross-referred to in the main text of this Part, are subject to revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

As the regulation of land development and buildings is a State subject and is dealt by the States and local bodies such as urban local bodies within their jurisdiction through building regulatory documents like building regulations, building byelaws, and fire regulations, this document is voluntary in nature and is non-binding. The implementation depends on adoption by concerned parties or stipulations in a contract or by appropriate adoption by the concerned authorities.

For the purpose of deciding whether a particular requirement of this Part of the NBCS is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Part.

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Important Explanatory Note for Users of the NBCS

In any Part/Section of this NBCS, where reference is made to **'good practice'** in relation to design, constructional procedures or other related information, and where reference is made to **'accepted standard'** in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practices [F(4)] refers to the Indian Standards give at serial number (4) of the list of standards given at the end of this Part F, that is, IS 8758 : 2013 'Recommendations for fire precautionary measures in the construction of temporary structures and pandals (*second revision*); and

b) Accepted standards [F(1)] refers to the Indian Standards given at serial number (1) of the list of standards given at the end of this Part F, that is, IS 3808 : 1979 'Method of test for non-combustibility of building materials (*first revision*)'.

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NATIONAL BUILDING CONSTRUCTION STANDARDS

PART F FIRE AND LIFE SAFETY

1 SCOPE

1.1 This NBCS (Part F) covers the requirements for fire prevention, life safety in relation to fire, and fire protection of buildings. This NBCS (Part F) specifies occupancy-wise classification, constructional aspects, egress requirements and protection features that are necessary to minimize danger to life and property from fire.

1.2 The provisions of this Part are applicable to those high rise buildings having a height exceeding a certain value, or, to special buildings (having a certain area exceeded on any floor), as given below, unless otherwise mentioned specifically in this Part:

Sl No.	*Occupancy Type*	*Height beyond which Provisions of this Part are Applicable*	*Floor Area beyond which Provisions of this Part are Applicable*
(1)	(2)	(3)	(4)
i)	Residential	24 m	750 m^2
ii)	Educational	9 m	500 m^2
iii)	Institutional	15 m	500 m^2
iv)	Assembly	9 m	750 m^2
v)	Business	15 m	750 m^2
vi)	Mercantile	15 m	1 000 m^2
vii)	Industrial – Low hazard (G-1)	Any height and the total area of the building exceeds 2 000 m^2	
viii)	Industrial – Moderate hazard (G-2)	Any height and the total area of the building exceeds 2 000 m^2	
ix)	Industrial – High hazard (G-3)	15 m	500 m^2
x)	Storage	9 m	500 m^2
xi)	Hazardous	9 m	500 m^2
xii)	Mixed Use	15 m	1 000 m^2

NOTES

1 State/Local Authority may consider modifying the above values depending on the fire vulnerability and preparedness.

2 In the case of buildings (lesser than the height or area as above) with a single staircase, the same should be of firefighting shaft type and located only on the external periphery, with its lobby and stairwell both ventilated (having 1.6 m^2 minimum size opening through fixed louvres kept permanently open). A 2 h fire door for lobby and 1 h fire door for stairwell should be provided.

1.3 Also, the provisions of this Part are applicable when buildings are altered (on an area 1 000 m^2 or more) or when change of occupancies are made to buildings.

1.4 The provisions of performance-based design (Annex M) are applicable only to validate the fire safety aspects for heritage buildings that are either made accessible to public or are converted to other building occupancy (and are constrained to provide exits as per the codal requirements, as that could damage the heritage nature). For the applicability of such performance-based approach to other buildings such as large assembly buildings, air traffic control towers, special museums, and existing buildings being modified for occupancy change, careful consideration of Annex M should be done by the state/local fire authorities on the basis of detailed performance-based calculations/report.

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2 TERMINOLOGY

For the purpose of this Part, the following definitions will apply.

2.1 Assisted Evacuation — Strategy that exists during which a designated person or persons provide assistance, during an emergency, to another person(s) to leave a building or a specific part of the built environment and to reach a final place of safety.

2.2 Atrium — A large-volume space created by a floor opening or series of floor openings connecting two or more stories that is covered at the top of the series of openings and is used for purposes other than an enclosed stairway; lifts hoist-way; an escalator opening; or as a utility shaft used for plumbing, electrical, air conditioning, or communications facilities.

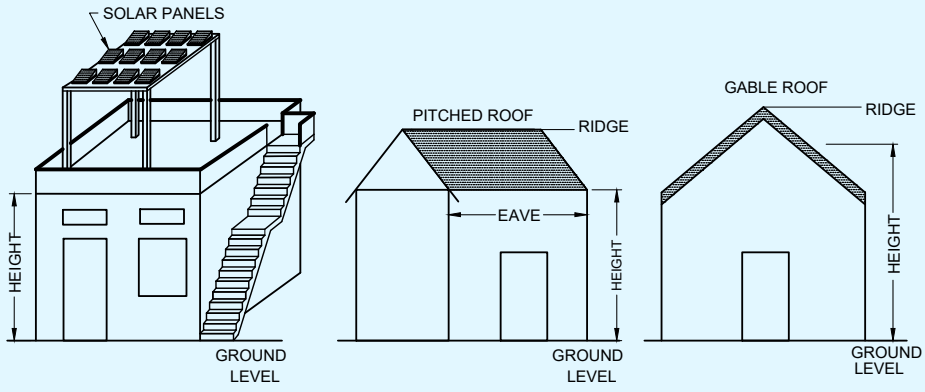
2.3 Authorities Concerned (known as Authority Having Jurisdiction) — An organization, office, or individual responsible for enforcing the requirements of a Code or standard, or for approving or accepting equipment, materials, an installation, or a procedure.

2.4 Automatic Fire Detection and Alarm System — A system comprising components and sub-systems required for automatically detecting smoke, heat or fire initiating an alarm and other actions as appropriate. This system also includes manually operated electronic fire alarm (MOEFA) system.

NOTE — MOEFA system (with or without automatic fire detection and alarm system) includes all or some of the components such as manual call stations (initiating an alarm for fire and other actions as required), talk-back system and public address system.

2.5 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, veranda, balcony, cornice or projection, part of a building or anything affixed thereto, or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents, *Shamianahs*, tarpaulin shelters, etc erected for temporary and ceremonial occasions with the permission of the Authority should not be considered as building.

2.6 Building, Height of — For the purposes of fire safety, the height of the multistoried building may be measured up to the floor level of the last occupiable floor from the grade level (where the fire tender/rescue vehicle will be located). In cases when the building height is measured up to the roof of the top-most floor, the following depictions may be considered. *See* Fig. 1.



(1A) 1-STORIED BUILDING (1B) DOOR ON EAVES WALL (1C) DOOR ON GABLE WALL

NOTES

1 Where a building is located in sloped terrain, height should be determined from the lowest level (that is approachable by the fire service vehicle) to the roof level.

2 The heights for design or sprinkler systems should be as per good practice [F(20)].

FIG. 1 BUILDING HEIGHT

2.7 Combustible Material — A material which either burns itself or adds heat to a fire, when tested for non-combustibility in accordance with accepted standard [F(1)].

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2.8 Common Path of Travel — That portion of the exit access which the occupants are required to traverse before two (or more) separate and distinct routes to two (or more) exits become available. Common paths of travel are part of the travel distance. *See* Fig. 2.

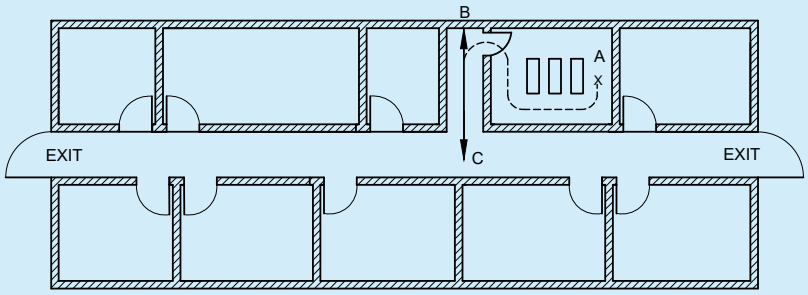

FIG. 2 COMMON PATH OF TRAVEL (A TO C) AND DEAD END (C TO B)

2.9 Covered Area (*also* Built-up Area)— Ground area covered by the building immediately above the plinth level. The area covered by the following in the open spaces is excluded from covered area:

a) Garden, rockery, well and well structures, plant nursery, water pool, swimming pool (if uncovered), platform a round a tree, tank, fountain, bench, *Chabutara* with open top and unenclosed on sides by walls and the like;

b) Drainage culvert, conduit, catch-pit, gully pit, chamber, gutter, and the like;

c) Compound wall, gate, unstoreyed porch and portico, slide, swing, uncovered staircases, ramp areas covered by *Chhajja* and the like; and

d) Watchman's booth, pump house, garbage shaft, electric cabin or substations, and such other utility structures meant for the services of the building under consideration.

NOTE — For the purpose of this Part, covered area equals the plot area minus the area due for open spaces in the plot.

2.10 Down-comer — An arrangement of firefighting within the building by means of down-comer pipe connected to terrace tank through terrace pump, gate valve and non-return valve and having mains not less than 100 mm internal diameter with landing valves on each floor/landing. It is also fitted with inlet connections at ground level for charging with water by pumping from fire service appliances and air release valve at roof level to release trapped air inside.

2.11 Dry Riser — An arrangement of firefighting within the building by means of vertical rising mains not less than 100 mm internal diameter with landing valves on each floor/landing which is normally dry but is capable of being charged with water usually by pumping from fire service appliances.

2.12 Emergency Lighting — Lighting provided for use when the supply to the normal lighting fails.

2.13 Emergency Lighting System — A complete but discrete emergency lighting installation also fed from the standby power source to the emergency lighting lamp(s), for example, self-contained emergency luminaire or a circuit from central battery (with or without monitoring system) connected through wiring to several escape lighting luminaries.

2.14 Escape Lighting — That part of the emergency lighting which is provided to ensure that the escape route is illuminated at all material times, for example, at all times when persons are on the premises, or at times the main lighting is not available, either for the whole building or for the means of egress.

2.15 Evacuation Lift — Lift that can be used, during an emergency, for self-evacuation.

2.16 Fire Exit — That unobstructed component of means of egress which is between the exit access and the exit discharge or public way. Exit components include exterior exit doors at the level of exit discharge, interior exit stairways (pressurised), exit stairway with external wall (pressurized or natural ventilated), exterior exit stairways, exit passageways, and exterior exit ramps (*see* Fig. 3). Fire exits should be provided with panic bar as applicable to facilitate entry of occupant into it.

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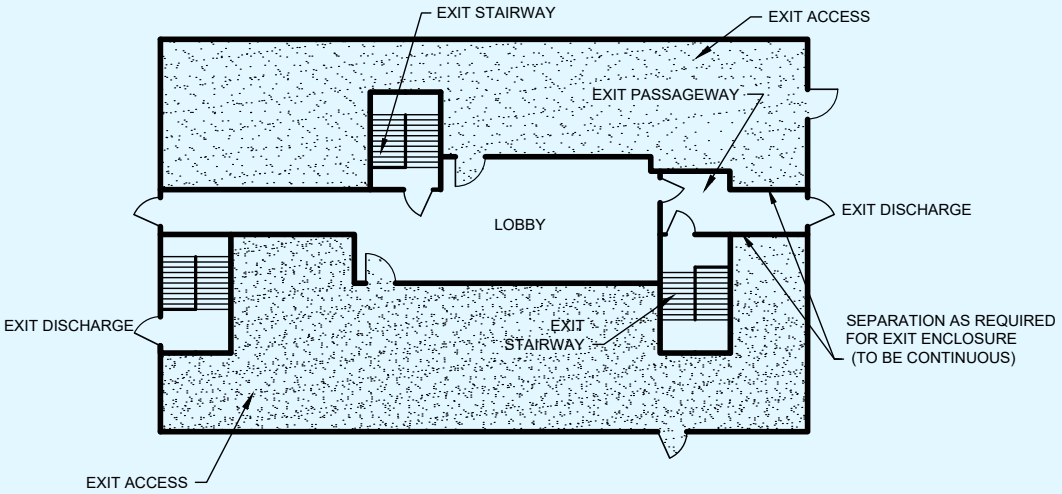

FIG. 3 COMPONENTS OF MEANS OF EGRESS

2.17 Exit Access — That portion of a means of egress that leads to fire exit (for example, habitable floor area, doorways, staircase lobby, ramps, veranda, corridor, or passageway leading to an exit) (*see* Fig. 3).

2.18 Exit Access Corridor — A corridor in exit access which may not necessarily have the requirement of exits being met.

2.19 Exit Discharge — The component of a means of egress between the termination of an exit and a public way (*see* Fig. 3).

2.20 Fire Barrier (or Fire Resisting Barrier) — A fire barrier is a vertically or horizontally aligned member such as a wall or a fire curtain, or a floor. These may be with discontinuities created by openings with a specified fire resistance rating, where such members are designed and constructed with a specified fire resistance rating to limit the spread of fire that also restricts the movement of smoke.

2.21 Fire Compartment — A space within a building that is enclosed by fire barrier or fire resistant walls on all sides, including the top and bottom.

2.22 Fire Door and Fire Door Assembly — Any combination of fire door, frame, hardware and other accessories that together provide a specific fire resistant rating to the opening in terms of its stability, integrity and insulation properties, when installed in the openings in fire separation walls. Fire door {*see* accepted standard [F(33)]} is a component of fire door assembly.

NOTES

1 Wherever reference has been made to fire door or fire check door in this Part, the same should be construed as fire door assembly.

2 Fire doors in exits should have fire rating as required in this Part to meet the requirement of integrity and stability; and the minimum insulation criteria should be 30 min.

3 Fire doors in exits should be provided with intumescent seal or such other globally accepted technologies/ devices (that expand upon contact with heat/hot gases, thereby forming an effective seal and aiding in integrity).

4 Fire doors in exits should not be allowed to be on hold open position and kept closed and to close by 'door closure - spring mechanism'.

5 Fire curtains should not be allowed as fire exits. If so provided for compartmentation, independent fire door should be provided meeting the requirement for fire door in exits as above (of the width as required) within the prescribed travel distance requirement.

6 Fire doors provided with panic bar should also be provided with the door handle on the other side on those levels to permit re-entry in designated floors.

2.23 Exit — A way out leading from exit access towards fire exit (fire exit is basically a protected staircase, *see* **2.16**). Exits not leading to fire exits should be displayed with signage as 'NOT A FIRE EXIT'.

2.24 Firefighting Shaft (Fire Tower) — An enclosed shaft having a protected area of 120 min fire resistance rating comprising a protected lobby, staircase, and fireman's lift, connected directly to the exit discharge or

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through an exit passageway with 120 min fire resistant wall at the level of exit discharge to exit discharge. These should also serve the purpose of exit requirement/strategy for the occupants. The lobby space should have arrangement to accommodate minimum two wheel chairs, and a minimum specified area for respective occupancy. The respective floors should be approachable from firefighting shaft enabling the fire fighters to access the floor and also enabling the fire fighters to assist in evacuation through fireman's lift. The firefighting shaft should be equipped with 120 min fire doors. The firefighting shaft should be equipped with firemen talk back, wet riser and landing valve in its lobby, to fight fire by fire fighters (*see* Fig. 4 for a typical firefighting shaft).

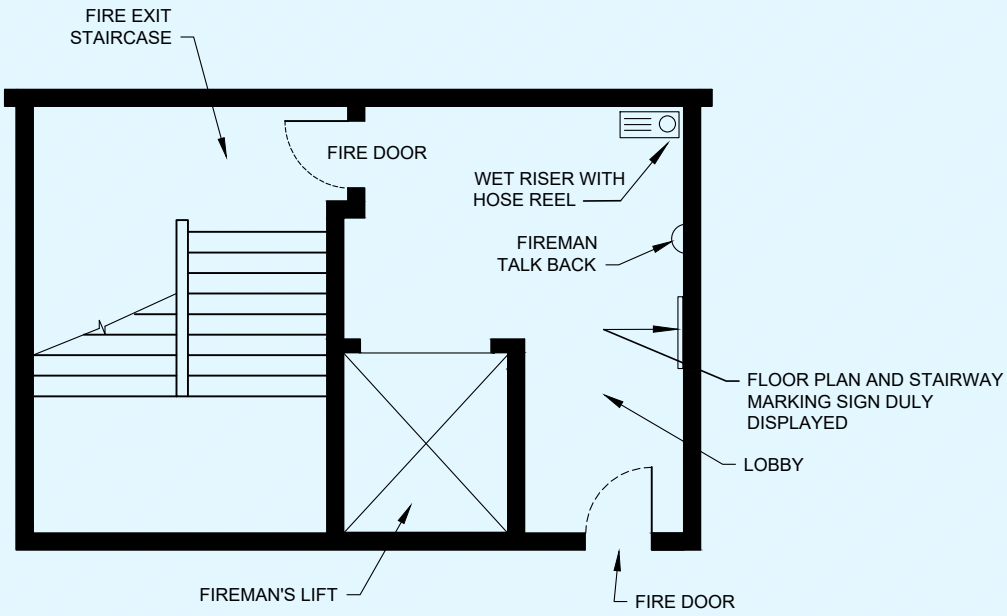

FIG. 4 TYPICAL FIREFIGHTING SHAFT

2.25 Fire Load — The total amount of energy that could be released during a fire in a given compartment, floor or building; usually expressed in Mega Joules (MJ) (or equivalent units).

2.26 Fire Load Density — Fire load per unit area of the compartment, floor or building concerned. It is obtained by dividing the fire load by the floor area of the concerned compartment, floor or building. It is usually expressed in megajoule (MJ) per m^2, or equivalent units with respect to wood, as below:

Sl No.	*Building Type*	*Fire Load Density (Expressed as Wood Equivalent kg/m^2)*
(1)	(2)	(3)
i)	Residential (A)	25
ii)	Institutional (B) and Educational (C)	25
iii)	Assembly (D)	25 to 50
iv)	Business (E)	25 to 50
v)	Mercantile (F)	Up to 250
vi)	Industrial (G)	Up to 150
vii)	Storage (H) and Hazardous (J)	Up to 500

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2.27 Fireman's Lift — A lift or a group of lifts invariably associated with all the features and requirements of a firefighting shaft. Such lift(s) are installed to enable fire services personnel to reach different floors with minimum delay, and meets the additional features as required in accordance with this Part. This lift also serves the purpose of meeting the requirement of evacuation lift for assisted evacuation.

NOTES

1 Lifts in firefighting shaft and fireman's lift are required to go to basements and the lobby should be pressurized.

2 Regular lifts serving floors above should terminate at the level of exit discharge. Lifts serving basements should be separate. In the case of lift bank, it is preferred to have all the lifts as fireman's lift instead of one or few lifts.

3 Lifts in the firefighting shaft should reach the terrace level, in the case of habitable spaces in terrace.

2.28 Fire Resistance — Fire resistance is a property of an element of building construction and is the measure of its ability to satisfy for a stated period, some, or all of the following criteria:

a) *Load bearing capacity* (*Stability*) (*R*) – The ability of a load bearing element to withstand fire exposure without any loss of structural stability.

b) *Integrity* (*E*) – Resistance to penetration of flame and hot gases.

c) *Insulation* (*I*) – Resistance to temperature rise on the unexposed face up to a maximum of 180 °C at any single point and average temperature of 140 °C.

NOTE — Radiation (W) can be used as one of the criteria for glass used in building, which refers to the ability to resist the passage of heat from one side to another.

2.29 Fire Resistance Rating — The time that a material or construction will withstand the standard fire exposure as determined by fire test done in accordance with the standard methods of fire tests of materials/structures as per the accepted standard [F(2)].

NOTES

1 The requirement of rating of various building elements as given in this Part should be applicable in accordance with the provisions given in the accepted standard [F(2)].

2 The fire resistance rating should be specified in terms of minutes.

3 Fire resistance rating for non-structural material/assembly should bear a label of compliance to such rating as per the approval of competent authority based on testing and evaluation. The label should be permanently affixed to the material/assembly and may carry other relevant details such as name and type of the product, and manufacturer's details.

2.30 Fire Resistant Wall — Fire resistance rated wall, having opening(s) with specified fire resistant rating, which restricts the spread of fire from one part of a building to another part of the same building.

2.31 Fire Separation — The distance in metre, measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of street or other public space for the purpose of preventing the spread of fire.

2.32 Fire Stop — A fire resistant material, or construction, having a fire resistance rating of not less than the fire separating elements, installed in concealed spaces or between structural elements of a building to prevent the spread/propagation of fire and smoke through walls, ceilings, and the like as per the laid down criteria. See accepted standard [F(34)].

NOTES

1 Fire stop assembly for through penetrations is a combination of firestop compatible for use with the penetrant, penetration items such as cables, cable tray, conduits, ducts, pipes, etc, and their means of support through the wall or opening that together restores the fire resistance rating of the fire separating elements in terms of its integrity and/or insulation properties.

2 Fire stop assembly for joints is the one where fire stop with movement capability is used to seal the linear joints between adjacent fire separating elements, to maintain the fire resistance of the separating elements, which should be installed within its tested design limits with regard to size of the joint, type of assembly, and anticipated compression and extension of the joint.

2.33 Fire Suppression Systems

a) *Gas Based Systems* — Systems that use gaseous agents as fire suppression media, such as, all agents alternate to halon gases, as conforming to relevant Indian Standards; other methods/types of gas based systems where their protection is equal to or better than what is suggested above for the type of application subject to the acceptance of Authorities concerned may also fall under such systems; and

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b) *Water Based Systems* — Systems that use mainly water as firefighting media such as hydrant system, sprinkler system, water spray system, foam system and water mist system.

2.34 Fire Wall or Fire Separating Wall — A fire resistance rated wall having fire protected openings, which restricts the spread of fire and extends continuously from the foundation to the roof (and through the roof at least 1 m above the roof in case of combustible roof), with sufficient structural stability under fire conditions to allow collapse of construction on one side or either side without collapse of the wall.

2.35 Floor Area (Gross) — The area of the floor within the inside perimeter of the outside walls of the floor of the building under consideration with no deductions for corridors and passage-ways, stairs, closets, thickness of interior walls, columns, lifts and building shafts or other features. Typically used for low density occupant load calculations.

2.36 Floor Area (Net) –The area of the floor within the inside perimeter of the outside walls of the floor of the building under consideration obtained after deducting the areas of corridors and passage-ways, stairs, closets (toilets and bathrooms), thickness of interior walls, columns, lifts, building shafts, services (floor mounted AHU, electrical, and the like), area of atrium, and escalator cut out. Typically used for high density occupant load calculations thus, net floor area is not the carpet area.

2.37 Floor Area Ratio (FAR) — The quotient obtained by dividing the total covered area (plinth area) on all floors by the area of the plot:

$$\text{FAR} = \frac{\text{Total covered area of all floors}}{\text{Plot area}}$$

2.38 Fire Exit Hardware — A door-latching assembly incorporating an actuating member or panic bar that releases the latch bolt upon the application of a force in the direction of egress travel, provided on exits.

2.39 High Rise Building — A building 24 m or above in height (irrespective of its occupancy).

2.40 Horizontal Exit — A defend in place or a staging arrangement, providing safety from fire and smoke originating from the area of incidence, by allowing alternative egress from a compartment to an area of refuge or another compartment at or near the same level. This also includes such egress from a compartment to an adjoining building. A horizontal exit is thus through a fire door of 120 min rating in a fire-resistant wall. Horizontal exit requires separation from the refuge area or adjoining compartment through 120 min fire barrier. The adjoining compartment of the horizontal exit should allow for unlocked and ease of egress and exits for the occupants using defend in place strategy.

2.41 Internal (Interior) Exit Stairway – A stairway that is enclosed with a fire-rated enclosure (towards building occupancy) in order to provide a protected path between the exit access and exit discharge. This enclosure must extend directly to the exterior at grade; extend through an exit passageway to grade; or comply with one of the allowances for exit discharge through a lobby, vestibule or horizontal exit.

2.42 External (Exterior) Exit Stairway – A stairway that is located on an exterior wall of the building, is open to external environment on at least one side and meets the requirements for openness as specified under 4.4.2.4.3.4, and is separated from the interior of the building by construction with the fire resistance rating required for enclosed stairs. The external exit stair leads directly to an open courtyard or public way at the level of exit discharge.

2.43 Lift Lobby — A space from which people directly enter a lift car(s) and into which people directly enter upon exiting a lift car(s).

2.44 Means of Egress — A continuous way of travel from any point in a building or structure to a public way, consisting of three separate and distinct parts, that is, exit access, exit, and exit discharge.

2.45 Means of Escape — A way out of a building or structure that does not conform to the strict definition of 'means of egress' but does provide an alternate way out.

2.46 Metro Station

2.46.1 *Concourse* — Intermediate level(s) or area(s) connecting a station platform(s) to a public way through stairs, escalators, or corridors.

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2.46.2 *Crush Train Load* — The number of passengers inside a train when it is filled to maximum capacity permissible by rolling stock design.

2.46.3 *Entraining Load* —The number of passengers boarding a train at a platform.

2.46.4 *Headway* — The interval of time between the arrivals of consecutive trains at a platform in a station.

2.46.5 *Mass Rapid Transit* — Any station building or part thereof, permanent, or temporary, through which people transit for the duration of time required to enter the building and board the train to depart the station platform or to alight from the train and depart from the station building.

2.46.6 *Non-transit Occupancy* — Occupancy not under the control of the system operating authority.

2.46.7 *Point of Safety* — One of the following: (a) An enclosed exit that leads to a public way or safe location outside the station, trainway, or vehicle, (b) An at-grade point beyond the vehicle, enclosing stations, or trainway, (c) A point on open track beyond the open or enclosed station or enclosed train-way, and (d) Any other location approved by the Authorities concerned.

2.46.8 *Station* — A place designated for the purpose of loading and unloading passengers, including service area and ancillary spaces associated with the same structure.

2.46.8.1 *Composite station* — A transit station that is constructed contiguous with non-transit occupancy.

2.46.8.2 *Enclosed station* — A station or portion thereof that does not meet the definition of an open station.

2.46.8.3 *Open station* — A station that is constructed such that it is directly open to the atmosphere, and smoke and heat are allowed to disperse directly into the surrounding open atmosphere.

2.46.9 *Station Platform* — The area of a station immediately adjacent to a guideway, used primarily for loading and unloading passengers.

2.46.10 *Link Load* — The number of passengers travelling between two stations on board a train or trains during peak headway.

2.46.11 *Incidental Occupancy within Station* — An occupancy within a station that provides additional services which are not directly related to transportation operation or transportation services.

2.47 Mixed Occupancy — A multiple occupancy where the occupancies are intermingled.

2.48 Multiple Occupancy — A building or structure in which two or more classes of occupancy exist.

2.49 Occupancy or Use Group — The principal occupancy for which a building or a part of a building is used or intended to be used. For the purpose of classification of a building according to the occupancy, an occupancy should be deemed to include subsidiary occupancies which are contingent upon it.

2.50 Occupant Load — Maximum number of persons that might occupy a building or portion thereof at any one time.

2.51 Place of Comparative Safety — Places within a building where people can stay little longer until evacuation, for example, refuge areas, terraces, fire/smoke separated compartments, etc.

2.52 Pressurization — The establishment of a pressure difference across a barrier to protect exit, stairway, lobby, exit passageway or room of a building from smoke penetration.

2.53 Performance Based Design — An engineering approach to fire protection design based on (1) agreed upon fire safety goals and objectives, (2) deterministic and/or probabilistic analysis of fire scenarios, and (3) quantitative assessment of design alternatives against the fire safety goals and objectives using accepted engineering tools, methodologies, and performance criteria.

2.54 Pressurization Level — The pressure difference between the pressurized space and the adjoining area served by the pressurized space expressed in Pascal (Pa).

2.55 Public Way — A street, alley, or other similar parcel of land essentially open to the outside air, dedicated,

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or otherwise permanently appropriated to the public for public use and having a clear width and height of not less than 3 m.

2.56 Ramp — The construction, in the form of an inclined plane that is steeper than or equal to 1 : 20 (5 percent) from the horizontal, together with any intermediate landing, that makes it possible to pass from one level to another.

2.57 Refuge Area — An area within the building for a temporary use during egress. It generally serves as a staging area which is protected from the effect of fire and smoke. The lift lobby spaces provided with adequate area (called refuge spaces) on all floors within the firefighting shaft can also serve as an alternate to refuge areas.

NOTE — Such refuge areas/spaces on every floor of firefighting shaft's lift lobby provide staging opportunity to those persons residing on any floor and are incapable of rescuing out of the building themselves.

2.58 Roof Exits — A means of escape on to the roof of a building, where the roof has access to it from the ground through alternative staircase or adjacent building.

2.59 Separated Occupancy — A multiple occupancy where the occupancies are separated by fire resistance–rated assemblies.

NOTE — Separate occupancy of a building is not incidental to the principal/main occupancy of that building.

2.60 Site (Plot) — A parcel (piece) of land enclosed by definite boundaries.

2.61 Smoke Barrier — A continuous membrane, or a membrane, where such membrane is designed and constructed to restrict the movement of smoke.

2.62 Smoke Compartment — A space within a building enclosed by smoke barriers on all sides.

2.63 Stack Pressure — Pressure difference caused by a temperature difference creating an air movement within a duct, chimney, or enclosure.

2.64 Travel Distance — The distance to be travelled from any point in a building to a protected exit or external escape route or final exit measured along the line of travel.

2.65 Ventilation — Supply of outside air into, or the removal of inside air from, an enclosed space.

2.66 Venting Fire — The process of facilitating heat and smoke to leave a building as quickly as possible by such paths so that lateral spread of fire and heat is checked, firefighting operations are facilitated, and minimum fire damage is caused.

2.67 Visual Strobes/Flashing — It is an audio-visual fire alarm for alerting persons with hearing impairment with flashing light. The strobe frequency should be from 0.5 Hz to 4.0 Hz, or as may be decided by the State Fire Authority, subject to performance required in smoke scenario.

NOTE — Care should be taken to ensure that overlapping strobes do not combine to result in a higher frequency of flashing.

2.68 Volume to Plot Area Ratio (VPR) — The ratio of volume of building measured in cubic metre to the area of the plot measured in square metre and expressed in metre.

2.69 Water Based Systems

2.69.1 *Hydrant System* — A distribution system having a network of piping installed underground/above-ground around and/or through inside of a building with internal and/or external hydrants fitted with landing valves at regular intervals according to the occupancy. The distribution system is connected to water supply system for firefighting.

2.69.2 *Automatic Sprinkler System* — A system of water pipes fitted with sprinkler heads at suitable intervals and heights and designed to actuate automatically, control and extinguish a fire by the discharge of water.

2.69.3 *Automatic Water Spray Systems* — A special fixed pipe system connected to a reliable source of fire protection water supply and equipped with water spray nozzles for specific water discharge and distribution over the surface or area to be protected. The piping system is connected to the water supply through an automatically actuated deluge valve which initiates flow of water. Automatic actuation is achieved by operation of automatic detecting equipment installed along with water spray nozzles. There are two types of systems namely high

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velocity and medium velocity systems.

2.69.4 *Water Mist Systems* — A distribution system connected to a pumping and water supply system that is equipped with nozzles capable of delivering water mist to the part/entire enclosure or area, intended to control, suppress, or extinguish fire and is capable of meeting the specified performance requirements.

2.69.5 *Foam Protection System* — Firefighting systems where foam is made by mechanically mixing air with a solution consisting of fresh water to which a foaming agent (liquid concentrate) has been added. Firefighting foam is a stable aggregation of small bubbles of density lower than oil or water, and shows tenacious qualities for covering horizontal surfaces. There are three types of foam applications, that is, low, medium, and high expansion foams depending upon the application.

2.70 Wet Riser — An arrangement for firefighting within the building by means of vertical rising mains not less than 100 mm nominal diameter with landing valves on each floor/landing for firefighting purposes and permanently charged with water from a pressurized supply.

NOTE — For definition of other terms, reference be made to accepted standards [F(3)].

3 FIRE PREVENTION

3.1 Classification of Buildings Based on Occupancy

3.1.1 *General Classification*

All buildings, whether existing or hereafter erected, should be classified according to use or the character of occupancy in one of the following groups:

Group A: Residential

Group B: Educational

Group C: Institutional

Group D: Assembly

Group E: Business

Group F: Mercantile

Group G: Industrial

Group H: Hazardous

Group J: Storage

Group K: Mixed use

The details of each occupancy and example of buildings in each group are given in **3.1.2** to **3.1.11**.

3.1.1.1 *Minor occupancy*

This is purely incidental to operations in a main occupancy, which should be considered as part of the main occupancy and should be classified under the relevant group for the main occupancy. Minor occupancy should not exceed 30 percent of the floor area. When the area exceeds 30 percent, it should be categorized as mixed occupancy (**3.1.11**).

3.1.1.2 *Mixed occupancy*

Where two or more types of occupancies intermingle in the same building, the entire building should be treated as mixed occupancy and the same should comply with **3.1.11**.

3.1.2 *Group A*: *Residential Buildings*

These include any building in which sleeping accommodation is provided for normal residential purposes with or

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without cooking or dining or both facilities, except any building classified under Group C.

Buildings and structures under Group A are subdivided as follows:

a) *Subdivision A*-I *Lodging and rooming houses* — These include any building or group of buildings under the same management, in which separate sleeping accommodation on a transient or permanent basis, with or without dining facilities but without cooking facilities for individuals is provided. This includes inns, clubs, motels, and guest houses. If sleeping accommodation for more than 20 persons is provided in any one residential building, it is classified here OR as a building in Subdivision A-III as the case may be.

NOTE — A lodging or rooming house is classified as a one or two family dwelling, if no room in any of its private dwelling units is rented to more than three persons.

b) *Subdivision A*-II *Dormitories* — These include any building in which group sleeping accommodation is provided, with or without dining facilities for persons who are not members of the same family, in one room or a series of closely associated rooms under joint occupancy and single management, for example, school and college dormitories, students, and other hostels and military barracks.

c) *Subdivision A*-III *Apartment houses* — These include any building or structure in which living quarters are provided for three or more families, living independently of each other and with independent cooking facilities, for example, apartment houses, mansions and Chawls.

d) *Subdivision A*-IV *Hotels* — These include any building or group of buildings under single management, in which sleeping accommodation is provided, with or without dining facilities for hotels classified up to Four Star Category.

e) *Subdivision A*-V *Starred hotels* — These include the hotels duly approved by the concerned authorities as Five Star and above hotels.

3.1.3 *Group B*: *Educational Buildings*

These include any building used for school, college, other training institutions involving assembly for instruction, education, or recreation for not less than 20 students.

In the case of temporary buildings/structures which are utilized for educational purposes, the provisions of **3.2.3** apply.

If residential accommodation is provided in the schools/institutions, that portion of occupancy should be classified as a building in Subdivision A-II.

3.1.4 *Group C*: *Institutional Buildings*

These include any building which is used for purposes, such as medical or other treatment or care of persons suffering from physical or mental illness, disease, or infirmity; care of infants, convalescents, or aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants.

Buildings and structures under Group C are further subdivided as follows:

a) *Subdivision C*-I *Hospitals and sanatoria* — This subdivision includes any building or a group of buildings under single management, which is used for housing persons suffering from physical limitations because of health or age and those incapables of self-preservation, for example, hospitals, infirmaries, sanatoria, and nursing homes;

b) *Subdivision C*-II *Custodial institutions* — This subdivision includes any building or a group of buildings under single management, which is used for the custody and care of persons, such as children, convalescents and the aged who are incapable of self-preservation, for example, homes for the aged and infirm, convalescent homes and orphanages; and

c) *Subdivision C*-III *Penal and mental institutions* — This subdivision includes any building or a group of buildings under single management, which is used for housing persons under restraint, or who are detained for penal or corrective purposes, in which the liberty of the inmates is restricted, for example, jails, prisons, mental hospitals, mental sanatoria and reformatories.

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3.1.5 *Group D*: *Assembly Buildings*

These include any building where not less than 50 persons congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes, for example, shopping malls, theatres/multiplexes, motion picture houses; assembly halls; auditoria; exhibition halls; museums; skating rinks; gymnasiums; restaurants/food courts; places of worship; dance halls; club rooms; passenger stations and terminals of air, surface and marine public transportation services; stadia; and underground and elevated railways.

3.1.6 *Group E*: *Business Buildings*

These include any building which is used for transaction of business for keeping of accounts and records and similar purposes, professional establishments, service facilities, etc, city halls, town halls, courthouses and libraries are classified in this group so far as the principal function of these is transaction of public business and keeping of books and records. These occupancies also include laboratories, outpatient clinics, research establishments, libraries, test houses, electronic data processing centres, computer installations, information technology parks and call centres; telephone exchanges; broadcasting stations, T.V. stations, and air traffic control towers; and datacentres.

Buildings under Group E are further subdivided as follows:

a) Subdivision E-I Business buildings (human occupied); and

b) Subdivision E-II Datacentres (machine environment).

3.1.7 *Group F Mercantile Buildings*

These include any building which is used as shops, stores, market, for display and sale of merchandise, either wholesale or retail.

Mercantile buildings are further subdivided as follows:

a) Subdivision F-I Shops, stores, departmental stores, markets; and

b) Subdivision F-II Underground shopping centres.

3.1.8 *Group G*: *Industrial Buildings*

These include any building or structure, in which products or materials of all kinds and properties are fabricated, assembled, manufactured, or processed, for example, assembly plants, industrial laboratories, dry cleaning plants, power plants, generating units, pumping stations, fumigation chambers, laundries, buildings or structures in gas plants, refineries, dairies and saw-mills, etc.

Buildings under Group G are further subdivided as follows:

a) Subdivision G-I Buildings used for low hazard industries;

b) Subdivision G-II Buildings used for moderate hazard industries; and

c) Subdivision G-III Buildings used for high hazard industries.

The hazard of occupancy, for the purpose of this NBCS, should be the relative danger of the start and spread of fire, the danger of smoke or gases generated, the danger of explosion or other occurrences potentially endangering the lives and safety of the occupants of the buildings.

Hazard of occupancy should be determined by the Authority on the basis of the fire loads of the contents, and the processes or operations conducted in the building, provided, however, that where the combustibility of the material, the flame spread rating of the interior finish or other features of the building or structure are such as to involve a hazard greater than the occupancy hazard, the greater degree of hazard should govern the classification.

For determination of fire loads for arriving at the classification of occupancy hazard, guidance on calorific values of some common materials is given at Annex A.

A broad classification of industrial occupancies based on ‘fire hazard only’ into low, moderate, and high hazard

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classes is given at Annex B, for guidance. Any occupancy not covered in Annex B, should be classified in the most appropriate class depending on the degree of hazard.

NOTE — This Annex B is only based on 'fire hazard'. Other classification of industries based on chemical hazard, pollution, etc, are not addressed in this NBCS.

Where different degrees of hazard of occupancy exist in different parts of a building, the most hazardous of those should govern the classification for the purpose of this NBCS, except in cases where hazardous areas are segregated or protected as specified in this NBCS.

a) *Subdivision G*-I — This subdivision includes any building in which the contents are of such comparative low combustibility and the industrial processes or operations conducted therein are of such a nature that there is hardly any possibility for any self-propagating fire to occur and the only consequent danger to life and property may arise from panic, fumes or smoke, or fire from some external source;

b) *Subdivision G*-II — This subdivision includes any building in which the contents or industrial processes or operations conducted therein are liable to give rise to a fire which will burn with moderate rapidity or result in other hazardous situation and may give off a considerable volume of smoke, but from which neither toxic fumes nor explosions are to be feared in the event of fire; and

c) *Subdivision G*-III — This subdivision includes any building in which the contents or industrial processes or operations conducted therein are liable to give rise to a fire which will burn with extreme rapidity or result in other hazardous situation or from which poisonous fumes or explosions are to be feared in the event of a fire.

3.1.9 *Group H*: *Storage Buildings*

These include any building primarily for the storage or sheltering (including servicing, processing or repairs incidental to storage) of goods, ware or merchandise (except those that involve highly combustible or explosive products or materials), vehicles or animals, for example, warehouses, cold storages, freight depots, transit sheds, storehouses, truck and marine terminals, garages, hangars, grain elevators, barns and stables. Storage properties are characterized by the presence of relatively small number of persons in proportion to the area. Any new use which increases the number of occupants to a figure comparable with other classes of occupancy should change the classification of the building to that of the new use, for example, hangars used for assembly purposes, warehouses used for office purposes, garage buildings used for manufacturing.

3.1.10 *Group J*: *Hazardous Buildings*

These include any building which is used for the storage, handling, manufacture or processing of highly combustible or explosive materials or products which are liable to burn with extreme rapidity and/or which may produce poisonous fumes or explosions for storage, handling, manufacturing or processing which involve highly corrosive, toxic or noxious alkalis, acids or other liquids or chemicals producing flame, fumes and explosive, poisonous, irritant or corrosive gases; and for the storage, handling or processing of any material producing explosive mixtures of dust which result in the division of matter into fine particles subject to spontaneous ignition. Examples of buildings in this class are those buildings which are used for,

a) storage, under pressure of more than 0.1 N/mm^2 and in quantities exceeding 70 m^3, of acetylene, hydrogen, illuminating and natural gases, ammonia, chlorine, phosgene, sulphur dioxide, carbon dioxide, methyl oxide and all gases subject to explosion, fume or toxic hazard, cryogenic gases, etc;

b) storage and handling of hazardous and highly flammable liquids, liquefiable gases like LPG, rocket propellants, etc;

c) storage and handling of hazardous and highly flammable or explosive materials (other than liquids); and

d) manufacture of artificial flowers, synthetic leather, ammunition, explosives, and fireworks.

NOTE — A list of hazardous substances giving quantities, for which or exceeding which owners handling such substances are required to be covered under The *Public Liability Insurance Act*, 1991, has been notified under the 'Rules on Emergency Planning, Preparedness and Response for Chemical Accidents' by the Government of India, Ministry of Environment and Forests Notification No. G.S.R. 347(E) dated 01 August 1996.

3.1.11 *Group K*: *Mixed Occupancy*

3.1.11.1 These include any building having multiple occupancy where the occupancies are intermingled. The following table guides on the possible mixing of occupancies (two or more occupancies may be mixed) in a building.

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Sl No.	*Occupancy to be Mixed with*	*Minimum Required Fire Resistance Rating for the Separation between Any Two Occupancies* in min										
		Residential	**Educational**	**Institutional**	**Assembly**	**Business**	**Mercantile**	**Industrial**			**Storage**	**Hazardous**
								Low (G-1)	**Moderate (G-2)**	**High (G-3)**		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	**Residential**	–	120	120	120	120	120	120	NP	NP	NP	NP
ii)	**Educational**	120	–	120	120	120	120	NP	NP	NP	NP	NP
iii)	**Institutional**	120	120	–	120	120	120	NP	NP	NP	NP	NP
iv)	**Assembly**	120	120	120	–	120	120	120	120	NP	NP	NP
v)	**Business**	120	120	120	120	–	120	120	120	240	NP	NP
vi)	**Mercantile**	120	120	120	120	120	–	120	120	NP	120	NP
vii)	**Industrial – Low (G-1)**	120	NP	NP	120	120	120	–	120	240	120	NP
viii)	**Industrial – Moderate (G-2)**	NP	NP	NP	120	120	120	120	–	240	180	240
ix)	**Industrial – High (G-3)**	NP	NP	NP	NP	240	NP	240	240	–	240	240
x)	**Storage**	NP	NP	NP	NP	NP	120	120	180	240	–	240
xi)	**Hazardous**	NP	NP	NP	NP	NP	NP	NP	240	240	240	–
NP – Not permitted, being highly dangerous/vulnerable.												

3.1.11.2 For mixed occupancy building typology as above, if these co-exist in a building (such as large retail occupancy and business occupancy), in so far as fire protection is concerned, the entire building should be governed by the most restrictive provisions of this NBCS among those applicable for individual occupancies. However, the exits can be shared between mixed occupancies provided its aggregate provision meets the requirement of the mixed occupancy, and should be permitted if such exits are with unrestricted egress of the occupants based on the business operational hours of the occupancies sharing such exits. If such unrestricted egress of the mixed-use occupancy is not planned, each occupancy should be provided with its independent exits.

Exits in such mixed occupancy should be so arranged as to ensure that means of egress is not decreased in the direction of egress travel.

Further, in such mixed occupancies, the occupancies are also required to be separated (horizontally and/or vertically as the case may be) by fire resistance rating, *see* 3.1.11.1.

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3.1.12 Where change in the occupancy of any building places it in a different group or in a different subdivision of the same group, such building should be made to comply with the requirements of this NBCS for the new group or its subdivision.

3.1.13 Where the new occupancy of a building is less hazardous, based on life and fire risk, than its existing occupancy, it should not be necessary to conform to the requirements of this NBCS for the new group or its subdivision.

3.1.14 A certificate of occupancy should be necessary, before any change is effected in the character of occupancy of any building.

3.2 Temporary Buildings or Structures

3.2.1 Temporary buildings and structures may be permitted according to the purpose for which these are to be used, by special permit from the Authority for a limited period and subject to such conditions as may be imposed in the permit.

3.2.2 Such buildings and temporary structures should be completely removed on the expiry of the period specified in the permit.

3.2.3 Adequate fire precautionary measures in the construction of temporary structures and *Pandals* should be taken in accordance with good practice [F(4)].

3.3 Existing Buildings

The existing buildings need not be required to comply with the requirements of this part unless these are altered, or in the opinion of the Local Authority, such building constitutes a hazard to the safety of the adjacent property or to the occupants of the building itself or is an unsafe building. In the event of alteration, it should be necessary to obtain permission of the Authority for such alteration consistent with fire hazard.

Alterations/modifications/renovations should be accomplished so as to ensure conformity with all the safety requirements of the new buildings. Such alterations should not in any way bring down level of fire and life safety below that which existed earlier. Any addition or alterations or construction of cubicles or partitioning (that will effect/increase the travel distance requirement), changes in the typology of the occupancy or densification of an existing occupancy for floor area exceeding 1 000 m^2 should be with the approval of local fire authority.

3.4 Types of Construction

3.4.1 The design of any building and the type of materials used in its construction are important factors in making the building resistant to a complete burn-out and in preventing the rapid spread of fire, smoke, or fumes, which may otherwise contribute to the loss of lives and property.

The fire resistance of a building or its structural and non-structural elements is expressed in minutes against a specified fire load which is expressed in kcal/m^2, and against a certain intensity of fire. The fire-resistance test for structural element should be done in accordance with accepted standards [F(2)]. For the purpose of this Part, the types of construction according to fire resistance should be classified into four categories, namely, Type 1 Construction, Type 2 Construction, Type 3 Construction and Type 4 Construction. The minimum fire resistance ratings of structural and non-structural members for various types of construction is given in Table 1.

Non-combustible materials should be used for construction of buildings, and the internal walls of staircase enclosures should be of brick work or reinforced concrete or any other material of construction with minimum of 120 min rating. The walls for the chimney should be of Type 1 or Type 2 Construction depending on whether the flue gas temperature is above 200 °C or less, respectively.

3.4.2 It is required that a structural and/or non-structural element/component to have the requisite fire resistance rating as per Table 1. The fire resistance rating for the structural and non-structural elements are based on guidelines as per approved and accepted standards. The fire rating should be validated and certified with a view to meeting the requirements of Table 1. In the absence of any validated/certified rating, guidance may be obtained from the information available in Annex C.

3.4.3 Load bearing steel beams and columns of buildings having total covered area of 500 m^2 and above need to be protected against failure/collapse of structure in case of fire. This could be achieved by use of appropriate

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methodology using suitable fire resistance rated materials along with suppression system (*see* Annex C, Table 25, and Table 26).

3.4.4 The false ceiling, including all fixtures used for its suspension, need to be of non-combustible material. To provide adequate fire resistance to the ceiling in order to prevent spread of fire across ceiling.

3.5 General Requirements of All Individual Occupancies

3.5.1 *General*

All buildings should satisfy certain requirements, which contribute, individually and collectively, to the safety of life from fire, smoke, fumes, and panic arising from these or similar causes. There are, however, certain general principles and common requirements, which are applicable to all or most of the occupancies.

Table 1 Fire Resistance Ratings of Structural and Non-Structural Elements (in minutes)

(*Clauses* 3.4.1, 3.4.2, 3.5.9.1, 3.5.9.2 *and* F-2.1)

Sl No.	Structural/Non-Structural Element	Fire Resistance Ratings (min) for Type of Construction			
		Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	Exterior walls:				
	a) Fire separation less than 3.7 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	120	90	60	60
	b) Fire separation of 3.7 m or more but less than 9 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	90	60	60	60
	c) Fire separation of 9 m or more:				
	1) Bearing	240	120	120	60
	2) Non-bearing	60	60	60	60
ii)	Fire separation assemblies (like fire check doors)	120	120	120	120
iii)	Fire enclosures of exits	120	120	120	120
iv)	Shafts for services, lift hoistway and refuse chutes	120	120	120	120
v)	Vertical separation between adjacent tenant spaces	60	60	60	60
vi)	Dwelling unit separation:				
	a) Load bearing	120	120	60	60
	b) Non-load bearing	60	60	30	30
vii)	Interior bearing walls, bearing partitions, columns, beams, girders, trusses (other than roof trusses) and framing				
	a) Supporting more than one floor	240	120	120	120
	b) Supporting one floor only	180	90	60	60
	c) Supporting a roof only	180	90	60	60

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Sl No.	Structural/Non-Structural Element	Fire Resistance Ratings (min) for Type of Construction			
		Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)	(6)
viii)	Walls supporting structural members	180	90	60	60
ix)	Floor construction	120	90	60	60
x)	Roof construction:				
	a) 5 m or less in height to lowest member	120	90	60	60
	b) More than 5 m but less than 6.7 m in height to lowest member	60	60	60	60
	c) 6.7 m or more in height to lowest member	0 60*	0 60*	0 60*	0 60*
* 60 min should be adopted when associated building services/cables are running at higher levels and supported from/near the roof, like in airports.					

3.5.2 *Exceptions and Deviations*

Exceptions and deviations to the general provisions of requirements of individual occupancies are given as applicable to each type of occupancy in 6.1 to 6.9. In case of practical difficulty or to avoid unnecessary hardship, without sacrificing reasonable safety, local head, fire services may consider exemptions from this Part.

3.5.3 *Occupation of Buildings under Construction*

3.5.3.1 A building or portion of the building may be occupied during construction, repairs, alterations, or additions only if all means of exit and fire protection measures are in place and continuously maintained for the occupied part of the building.

3.5.3.2 A high rise building during construction should be provided with the following fire protection measures, which should be maintained in good working condition at all the times:

a) Dry riser of minimum 100 mm diameter pipe with hydrant outlets on the floors constructed with a fire service inlet to boost the water in the dry riser and maintenance should be in accordance with good practice [F(5)].

b) Drums of 2 000 litre capacity filled with water with two fire buckets on each floor;

c) A water storage tank of minimum 20 000 litre capacity, which may be used for other construction purposes also.

3.5.4 *Openings in Fire Resistant Walls and Floors*

3.5.4.1 At the time of designing openings in fire-resistant walls and floors, particular attention should be paid to all such factors which limit fire spread through these openings and maintain fire rating of the structural members.

3.5.4.2 For Types 1 to 3 constructions, a doorway or opening in a fire resistant wall on any floor should be limited to 5.6 m^2 in area with a maximum height/width of 2.75 m. Every wall opening should be protected with fire-resisting doors, having the fire rating of not less than 120 min. The openings in the floors should be protected by vertical enclosures extending above and below such openings, such enclosures having a fire resistance of not less than 120 min and all openings therein being protected with a fire-resisting assembly as specified in 3.5.4.6.

For escalator-like openings, the smoke spill should be avoided by provision of smoke barrier (of 450 mm to 600 mm) thereby creating smoke compartment. Further, the protection should be ensured through installation of sprinklers on all sides of the cut out opening on each floor (*see* Fig. 5 for details).

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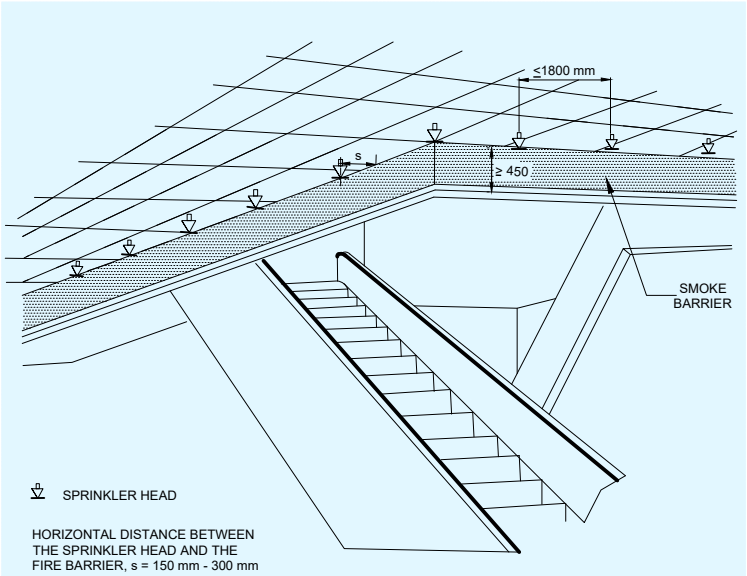

FIG. 5 SPRINKLERS AROUND ESCALATOR OPENING

3.5.4.3 For Type 4 construction, openings in the fire separating walls or floors should be fitted with 120 min fire-resistance rated assemblies.

3.5.4.4 *Service ducts and shafts*

Openings in walls or floors which are necessary to be provided to allow passages of all building services like cables, electrical wirings, telephone cables, plumbing pipes, etc, should be protected by enclosure in the form of ducts/shafts having a fire resistance not less than 120 min. The inspection door for electrical shafts/ducts should be not less than 120 min, with 30 min insulation. Further, medium, and low voltage wiring running in shafts/ducts, should either be armoured type or run through metal conduits.

The space between the electrical cables/conduits and the walls/slabs should be filled in by a fire stop material {see accepted standard [F(34)]} having fire resistance rating of not less than 120 min. This should exclude requirement of fire stop sealing for low voltage services shaft.

For plumbing shafts in the core of the building, with shaft door opening inside the building, the shafts should have inspection doors having fire resistance rating not less than 30 min.

For plumbing shafts doors which open in wet areas or in naturally ventilated areas or on external wall of the building, the shafts may not require doors having any specified fire rating.

NOTE — In the case of buildings where it is necessary to lower or lift heavy machinery or goods from one floor to the other, it may be necessary to provide larger openings in the floor. Such openings should be provided with removable covers which should have the same strength and fire resistance as the floor.

3.5.4.5 *Refuse chutes*

Refuse chutes, if any provided in a building, should have opening at least 1 m above roof level for venting purpose and they should have an enclosure wall of non-combustible material with fire resistance of not less than 120 min. They should not be located within the staircase enclosure or service shafts, or air conditioning shafts. Refuse chutes inspection panel and doors should be tight fitting with 60 min fire resistance. Sprinkler protection system should be provided for the refuse chutes. Refuse chutes should be at least 3 m away from exits.

3.5.4.6 *Vertical opening*

Every vertical opening between the floors of a building should be suitably enclosed or protected, as necessary, to provide the following:

a) Reasonable safety to the occupants while using the means of egress by preventing spread of fire, smoke,

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or fumes through vertical openings from floor to floor to allow occupants to complete their use of the means of egress. Further it should be ensured to provide a clear height of 2 100 mm in the exit access.

b) Limitation of damage to the building and its contents.

3.5.5 *Electrical Installation*

3.5.5.1 For requirements regarding electrical installations from the point of view of fire safety, reference may be made to good practice [F(6)] and Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS.

In general, it is desirable that the wiring and cabling are with flame retardant property. Medium and low voltage wiring running in shafts, and within false ceiling should run in metal conduit. Any 230 V wiring for lighting or other services, above false ceiling, should have 660 V grade insulation. See also Part D/Sec 2 for wires having options of fire resistance.

The electric distribution cables/wiring should be laid in a separate shaft. The shaft should be sealed at every floor with fire stop materials, see accepted standard [F(34)] having the same fire resistance as that of the floor. High, medium, and low voltage wiring running in shaft and in false ceiling should run in separate shaft/conduits.

Water mains, gas pipes, telephone lines, intercom lines or any other service line should not be laid in the duct for electrical cables; use of bus ducts/solid rising mains instead of cables is preferred.

All metallic items like steel structural members, etc, should be bonded properly to the earthing system.

3.5.5.2 *Emergency power for fire and life safety systems*

Emergency power supplying distribution system for critical requirement for functioning of fire and life safety system and equipment should be planned for efficient and reliable power and control supply to the following systems and equipment where provided:

a) Fire pumps;

b) Pressurization and smoke venting; including its ancillary systems such as dampers and actuators;

c) Fireman's lifts (including all lifts);

d) Exit signage lighting;

e) Emergency lighting;

f) Fire alarm system;

g) Public address (PA) system (relating to emergency voice evacuation and annunciation);

h) Magnetic door hold open devices; and

j) Lighting in fire command centre and security room.

Power supply to these systems and equipment should be from normal and emergency (standby generator) power sources with changeover facility (*see* Fig. 6A and Fig. 6B indicating options). If power supply is from HV source and HV generation, the transformer should be planned in standby capacity to ensure continuity of power to such systems. Wherever transformers are installed at higher levels in buildings and backup DG sets are of higher voltage rating, then dual redundant cables should be taken to all transformers. The generator should be capable of taking the starting current of all the fire and life safety systems and equipment as above. Where a parallel HV/LV supply from a separate substation fed from a different grid is provided with an appropriate transformer for emergency, the provision of generator may be waived in consultation with the Authority.

The power supply to the panel/distribution board of these fire and life safety systems should be through fire proof enclosures (tested and certified) or fire survival cables or through alternate route in the adjoining fire compartment to ensure supply of power is reliable to these systems and equipment. It should be ensured that the cabling from the adjoining fire compartment is protected within the compartment of vulnerability. The location of the panel/ distribution board feeding the fire and life safety system should be in fire safe zone ensuring supply of power to these systems.

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Circuits of such emergency system should be protected at origin by an automatic circuit breaker with its no-volt coil removed. Master switches controlling essential service circuits should be clearly labelled.

Cables for fire alarm and PA system should be laid in metal conduits or armoured to provide physical segregation from the power cables.

3.5.5.3 *Substation/Transformers*

Areas in substation should not be used as storage/dump areas or for other utility purposes other than those required for the functioning of the substation.

The substation area should be adequately ventilated.

An independent, ventilated or air conditioned electrical substation and LT panel room/area should be provided on the ground level or first basement. They should be provided with access from outside (or through exit passageway accessible from outside). The electrical substation and LT panel room/area should be provided with fire resistant walls and doors of fire resistance of not less than 120 min.

If the licensees agree to provide meters on upper floors, the licensees' cables should be segregated from consumers' cables by providing a partition in the shaft. Meter rooms on upper floors should not open into staircase enclosures and should be ventilated directly to open air outside or in electrical room of 120 min fire resistant walls.

Electrical MV main distribution panel and lift panels should be provided with CO_2/inert gas flooding system for all panel compartments with a cylinder located beside the panel.

3.5.5.3.1 *Oil filled substation*

A substation or a switch-station with oil filled equipment should be limited to be installed in utility building or in outdoor location. Such substation/utility building should be at least 6 m away (or as per local requirements/actual width of fire driveway) from the adjoining building(s).

Substation equipment (exceeding aggregate oil capacity of 2 000 litre) in utility building should have fire rated baffle walls of 240 min rating constructed between such equipment, raised to at least 600 mm above the height of the equipment (including height of oil conservators/explosion vents) and exceeding 300 mm on each side of the equipment.

All transformers where capacity exceeds 10 MVA should be protected by high velocity water spray systems/ high pressure water mist system. In addition, nitrogen injection systems may also be provided where applicable.

3.5.5.3.2 *Dry type substation*

Transformers located inside a building should be of dry type and all substation/switch room walls, ceiling, floor, opening including doors should have a fire resistance rating of 120 min. Access to the substation should be provided from the nearest fire exit/exit staircase for the purpose of electrical isolation.

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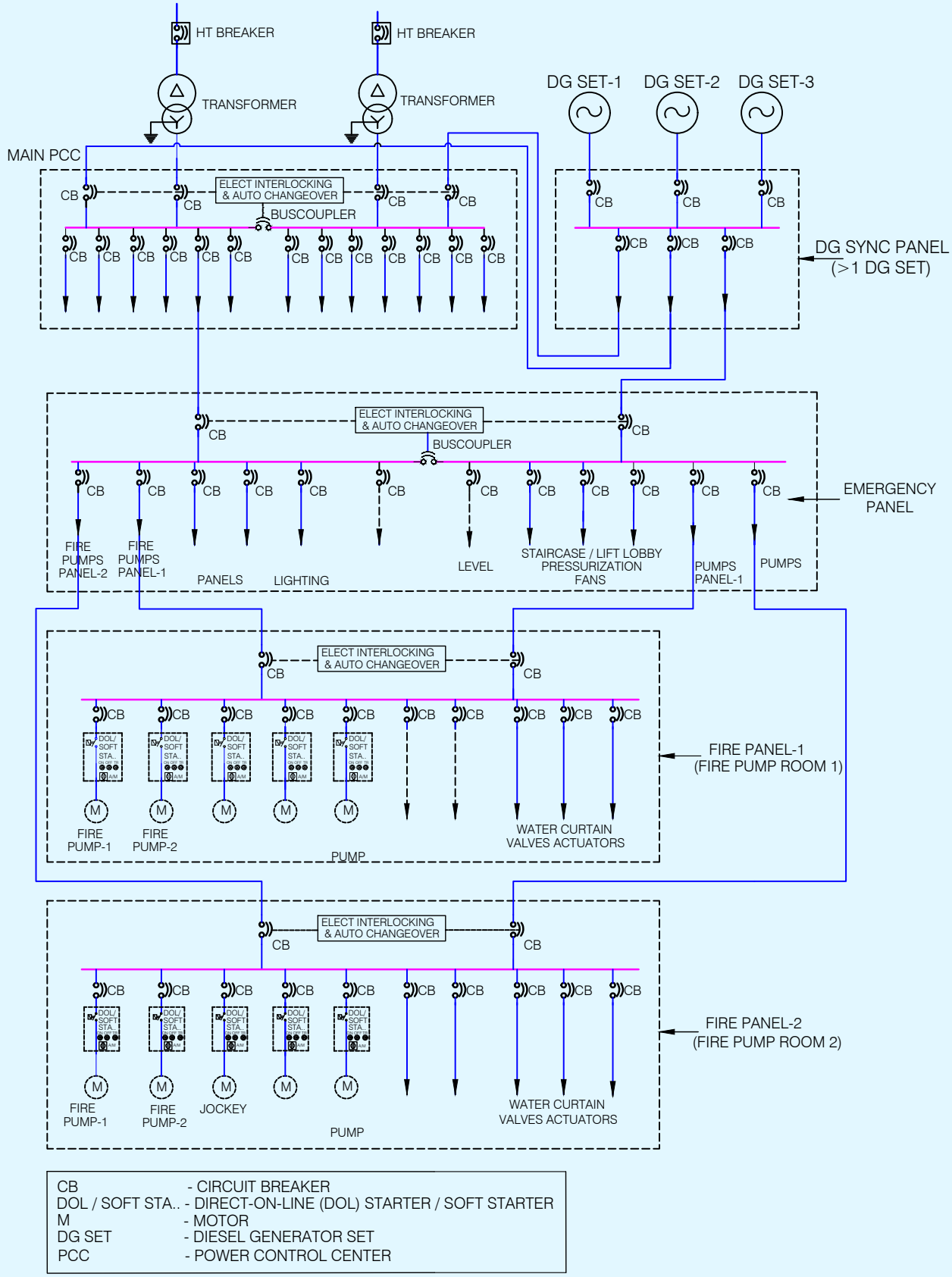

6A FIRE PUMP CIRCUIT DEPICTING DISTRIBUTION SCHEME WITH MULTIPLE TRANSFORMERS AND DG SETS

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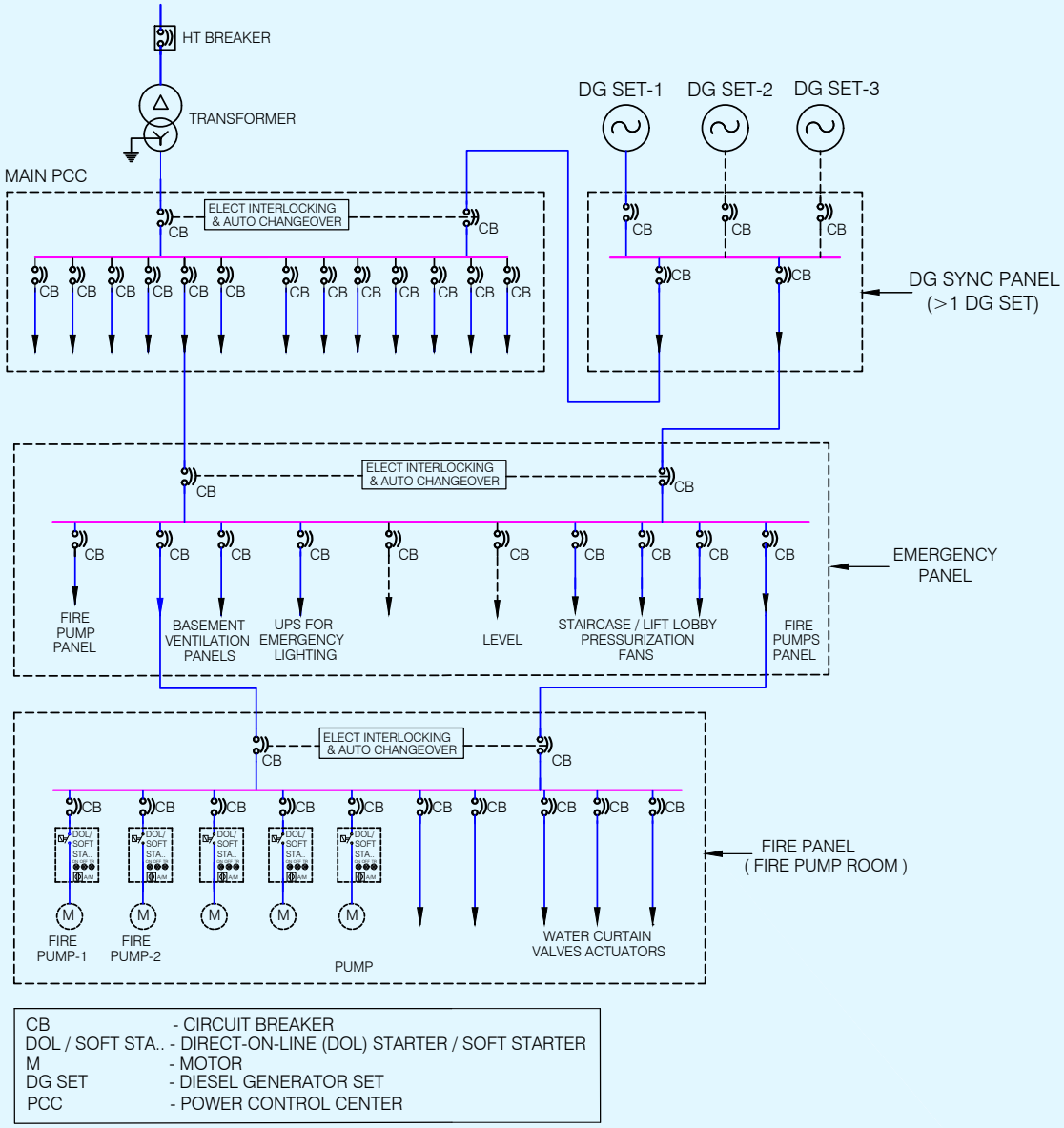

6B FIRE PUMP CIRCUIT DEPICTING DISTRIBUTION SCHEME WITH SINGLE TRANSFORMER AND DG SETS

FIG. 6 FIRE PUMP CIRCUIT DRAWINGS

3.5.5.4 *Standby supply*

Diesel generator set(s) should not be installed at any floor other than ground/first basement. If the same are installed indoors, proper ventilation and exhaust should be planned. The DG set room should be separated by 120 min fire resistance rated walls and doors.

The oil tank for the DG sets (if not in the base of the DG) should be provided with a dyked enclosure having a volumetric capacity of at least 10 percent more than the volume of the oil tank. The enclosure should be filled with sand for a height of 300 mm.

See Table 9 for specific fire protection guidelines. For detailed information regarding fire safety requirements for hazardous petroleum products, reference may be made to *The Petroleum Act*, 1934 and the Rules framed thereunder.

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3.5.5.5 *Lightning protection of buildings*

Routing of down conductors (insulated or uninsulated) of lightning protection through electrical or other service shafts are not allowed as it can create fire and explosion during lightning. For details, *see* Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS.

3.5.6 *Escape Lighting and Exit Signage*

Exit access, exits, and exit discharge should be properly identified, with adequate lighting maintained in the elements of the egress systems so that all occupants should be able to leave the facility safely.

3.5.6.1 *Lighting*

a) The exit, exit access and exit discharge systems should be illuminated continuously. The floors of the means of egress should be illuminated at all points, including angles and intersections, in corridors and passageways, stairwells, landings of stairwells and fire exit;

b) Emergency lighting should be powered from a source independent of that supplying the normal lighting;

c) Escape lighting should be capable of,

   1) indicating clearly and unambiguously the escape routes;

   2) providing adequate illumination along such routes to allow safe movement of persons towards and through the fire exits; and

   3) ensuring that fire alarm call points and firefighting equipment provided along the escape routes can be readily located.

d) The horizontal luminance at floor level on the centreline of an escape route should not be less than 10 lumen/m^2. In addition, for escape routes up to 2 m wide, 50 percent of the route width should be lit to a minimum of 5 lumen/m^2. In auditoriums, theatres, concert halls and such other places of assembly, the illumination of floor exit/access may be reduced during period of performances to values not less than 2 lux;

e) Required illumination should be arranged such that the failure of any single lighting unit, such as the burning out of one luminaire, will not leave any area in darkness and does not impede the functioning of the system further;

f) The emergency lighting should be provided to be put on within 5 s of the failure of the normal lighting supply. Also, emergency lighting should be able to maintain the required illumination level for a period of not less than 90 min in the event of failure of the normal lighting even for smaller premises;

g) Battery pack emergency lighting, because of its limited duration and reliability, should not be allowed to be used in lieu of a diesel engine driven emergency power supply;

h) Escape lighting luminaires should be sited to cover the following locations:

   1) Near each intersection of corridors,

   2) At exits and at each exit door,

   3) Near each change of direction in the escape route,

   4) Near each staircase so that each flight of stairs receives direct light,

   5) Near any other change of floor level,

   6) Outside each final exit and close to it,

   7) Near each fire alarm call point,

   8) Near firefighting equipment, and

   9) To illuminate exit and safety signs as required by the enforcing authority.

   NOTE — For the purpose of this clause 'near' is normally considered to be within 2 m measured horizontally.

j) The luminaires should be mounted as low as possible, but at least 2 m above the floor level; and

k) Signs are required at all exits, emergency exits and escape routes, which should comply with the graphic requirements of the relevant Indian Standards.

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3.5.6.2 Exit passageway and staircase lighting should also be connected to alternative supply. The alternative source of supply may be provided by battery continuously trickle charged from the electric mains. Suitable arrangements should be made by installing double throw switches to ensure that the lighting installed in the staircase and the corridor does not get connected to two sources of supply simultaneously. Double throw switch should be installed in the service room for terminating the stand-by supply.

3.5.6.3 The emergency lighting system should be well maintained by periodical inspections and tests so as to ensure their perfect serviceability at all times.

3.5.6.4 *Exit signage*

Where exit access is provided through corridors/paths, the occupants should be able to easily identify the way to exits. Exit signs should be provided such that no point in an exit access is more than 30 m from a visible exit directional sign. An exit sign indicating the direction to an exit should be provided at all changes in direction.

Exits should be clearly visible and the route to reach the exits should be clearly marked and signs posted to guide the occupants of the floor concerned. Signs should be illuminated and wired to an independent electrical circuit on an alternative source of supply. The sizes and colours of the exit signs should be in accordance with good practice [F(7)]. The colour of the exit signs should be green.

NOTE — This provision should not apply to A-II and A-IV occupancies less than 15 m in height.

The exit sign with arrow indicating the way to the escape route should be provided at a suitable height from the floor level on the wall and should be illuminated by electric light connected to corridor circuits. All exit way marking signs should be so installed that no mechanical damage should occur to them due to moving of furniture or other heavy equipment. Further, all landings of floor should have floor indicating boards prominently indicating the number of the floor.

Photo luminescent markings should be pasted at internal hydrant boxes.

3.5.7 *Air Conditioning, Ventilation and Smoke Control*

3.5.7.1 Air conditioning and mechanical ventilation requirements of different rooms or areas in any occupancy should be as given in Part D ‘Building Services, Section 1 Lighting and Natural Ventilation' and ‘Section 3 Air conditioning, Heating and Mechanical Ventilation’ of this NBCS.

Air conditioning and ventilating systems should be so installed and maintained as to minimize the danger of spread of fire, smoke, or fumes from one floor to another or from outside to any occupied building or structure.

Many high-rise buildings integrate smoke management systems into their conventional HVAC systems. In such installation, it requires special design considerations, including safe and adequate controls, acceptable and documented testing, and regular maintenance systems.

Wherever batteries are provided, the same should be segregated by 120 min fire rated construction. Ventilation to the room should be provided as per manufacturer's instructions.

3.5.7.2 *Air handling unit*

3.5.7.2.1 From fire safety point of view, separate air handling units (AHU) for each floor should be provided so as to avoid the hazards arising from spread of fire and smoke through the air conditioning ducts. The air ducts should be separate from each AHU to its floor and in no way should interconnect with the duct of any other floor. Within a floor it would be desirable to have separate air handling unit provided for each compartment.

Air handling unit should be provided with effective means for preventing circulation of smoke through the system in the case of a fire in air filters or from other sources drawn into the system, and should have smoke sensitive devices for actuation in accordance with the accepted standard [F(8)] and control.

3.5.7.2.2 Shafts or ducts, if penetrating multiple floors, should be of masonry construction with fire damper in connecting ductwork or should have fire rated ductwork with fire dampers at floor crossing. Alternatively, the duct and equipment may be installed in room having walls, doors and fire damper in duct exiting/entering the room of 120 min fire resistance rating. Such shafts and ducts should have all passive fire control meeting 120 min fire resistance rating requirement to meet the objective of isolation of the floor from spread of fire to

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upper and lower floors through shaft/duct work.

NOTE — Zoned and compartmented HVAC systems are encouraged with an approach to avoid common exhaust shafts and fresh air intake shafts which will limit the requirement of such passive measure and fire rated duct work and dampers.

3.5.7.2.3 The air filters of the air handling units should be made of non-combustible materials.

3.5.7.2.4 The air handling unit room should not be used for storage of any combustible materials.

3.5.7.3 *Duct work*

3.5.7.3.1 Air ducts serving main floor areas, corridors, etc, should not pass through the fire exits/exit passageway/ fire exit enclosure. Fire exits and lift lobbies, etc, should not be used as return air passage.

3.5.7.3.2 As far as possible, metallic ducts (of suitable rating) should be used even for the return air instead of space above the false ceiling.

3.5.7.3.3 Wherever the ducts pass through fire walls or floors, the opening around the ducts should be sealed with materials having fire resistance rating of the compartment {*see* accepted standard [F(34)]}. Such duct should also be provided with fire dampers at all fire walls and floors unless such ducts are required to perform for fire safety operation; and in such case fire damper may be avoided at fire wall and floor while integrity of the duct should be maintained with 120 min fire resistance rating to allow the emergency operations for fire safety requirements.

3.5.7.3.4 The ducting within compartment would require minimum fire resistance rating of 30 min. Such ducting material in substantial gauge should be in accordance with good practice [F(9)]. If such duct crosses adjacent compartment/floor and not having fire dampers in such compartment/floor, it would require fire resistance duct work rating of 120 min. The requirements of support of the duct should meet its functional time requirement as above.

3.5.7.3.5 The materials used for insulating the duct system (inside or outside) should be of non-combustible type. Any such insulating material should not be wrapped or secured by any material of combustible nature.

3.5.7.3.6 Inspection panels should be provided in the ductwork to facilitate the cleaning of accumulated dust in ducts and to obtain access for maintenance of fire dampers.

3.5.7.4 *Fire or fire/smoke dampers*

3.5.7.4.1 These dampers should be evaluated to be located in supply air ducts, fresh air and return air ducts/ passages at the following points:

a) At the fire separation wall,

b) Where ducts/passages enter the vertical shaft,

c) Where the ducts pass through floors, and

d) At the inlet of supply air duct and the return air duct of each compartment on every floor.

3.5.7.4.2 Damper should be of motorized type/fusible link. Damper should be so installed to provide complete integrity of the compartment with all passive fire protection sealing. Damper should be accessible to maintain, test and also replace, if so required. Damper should be integrated with fire alarm panel and should be sequenced to operate as per requirement and have interlocking arrangement for fire safety of the building. Manual operation facilities for damper operation should also be provided. Tested and certified dampers for dynamic condition are preferable.

3.5.8 *Heating*

3.5.8.1 Installation of chimney and heating apparatus should be in accordance with good practice [F(10)].

3.5.8.2 *Boiler rooms*

3.5.8.2.1 Provisions of boiler and boiler rooms should conform to *The Boilers Act*, 1923.

3.5.8.2.2 Further, the following additional aspects may be taken into account in the location of boiler room:

a) The boilers should be installed in a fire resisting room of 180 min fire resistance rating;

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b) Entry to this room should be provided with a composite door of 120 min fire resistance rating;

c) The boiler room should be provided with its dedicated natural or mechanical ventilation system. Mechanical ventilation system for the boiler room would be accepted with 120 min fire resistance rating ductwork if it has interface with other mechanical areas. Ventilation system should not be allowed to be routed through electrical room area or through exit corridor/exits; and

d) The oil tank for the boiler should be provided with a dyked enclosure having a volumetric capacity of at least 10 percent more than the volume of the oil tank. The enclosure should be filled with sand for a height of 300 mm.

3.5.9 *Glazing*

3.5.9.1 The glazing should be in accordance with Part C 'Structural Design, Section 8 Glass and Glazing' of this NBCS. The entire glazing assembly should be rated to that type of construction as given in Table 1. This should be applicable along with other provisions of this Part related to respective uses as specified therein. The use of glass should not be permitted for enclosures of exits and exit passageway.

3.5.9.2 Glass facade should be in accordance with the following:

a) For fully sprinklered buildings having fire separation of 9 m or more, tempered glass in a non-combustible assembly, with ability to hold the glass in place, should be provided. It should be ensured that sprinklers are located within 600 mm of the glass facade providing full coverage to the glass. Where the fire separation is less than 9 m, additional protection such as using a minimum 900 mm spandrel panel of 1 h fire resistance rating should be provided;

NOTE — In case of all other buildings, fire resistance rating of glass facade should be in accordance with Table 1.

b) All gaps between floor-slabs and facade assembly should be sealed at all levels by approved fire resistant sealant material of equal fire rating as that of floor slab to prevent fire and smoke propagation from one floor to another. *See also* accepted standard [F(35)]; and

c) Openable panels should be provided on each floor and should be spaced not more than 10 m apart measured along the external wall from centre-to-centre of the access openings. Such openings should be operable at a height between 1.2 m and 1.5 m from the floor, and should be in the form of openable panels (fire access panels) of size not less than 1 000 mm × 1 000 mm opening outwards. The wordings, 'FIRE OPENABLE PANEL — OPEN IN CASE OF FIRE, DO NOT OBSTRUCT' of at least 25 mm letter height should be marked on the internal side. Such panels should be suitably distributed on each floor based on occupant concentration. These should not be limited to cubicle areas and should be also located in common areas/corridors to facilitate access by the building occupants and fire personnel for smoke exhaust in times of distress.

3.5.10 *Surface Interior Finishes*

3.5.10.1 The use of combustible surface finishes on walls (including facade of the building) and ceilings affects the safety of the occupants of a building. Such finishes tend to spread the fire and even though the structural elements may be adequately fire resistant, serious danger to life may result. It is, therefore, essential to have adequate precautions to minimize spread of flame on wall, facade of building and ceiling surfaces. The finishing materials used for various surfaces and decor should be such that it should not generate toxic smoke/fumes.

3.5.10.2 The susceptibility of various types of wall surfaces to fire is determined in terms of the rate of spread of flame. Based on the rate of spread of flame, surfacing material should be considered as divided into four classes as follows {*see* also good practice [F(11)]}:

a) Class 1 Surfaces of very low flame spread;

b) Class 2 Surfaces of low flame spread;

c) Class 3 Surfaces of medium flame spread; and

d) Class 4 Surfaces of rapid flame spread.

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3.5.10.3 The uses for which surface materials falling into various classes should be adopted in building construction are given below:

Class 1	*Class 2*	*Class 3*
(1)	(2)	(3)
May be used in any situation	May be used in any situation, except on walls, facade of the building, staircase, and corridors	May be used only in living rooms and bed rooms (but not in rooms on the roof) and only as a lining to solid walls and partitions; not on staircases or corridors or facade of the building.
NOTE — Panelling (lining) may be permitted in a limited area; and is not to be permitted in a vestibule.		

3.5.10.4 Materials of Class 4 which include untreated wood fibreboards may be used with due fire-retardant treatment as ceiling lining, provided the ceiling is at least, 2.4 m from the top surface of the floor below, and the wall surfaces conform to requirements of the class [*see* Note under **3.5.10.3**]. Class 4 materials should not be used in kitchens, corridors, and staircases. Some materials contain bitumen and, in addition to risk from spread of fire, emit dense smoke on burning; such materials should be excluded from use under these conditions and should also not be used for construction of ceiling where the plenum is used for return air in air-conditioned buildings.

3.5.10.5 When frames, walls, partitions, or floors are lined with combustible materials, the surfaces on both sides of the materials should conform to the appropriate class, because there is considerable danger from fire starting and rapidly spreading within the concealed cavity unknown to the occupants whose escape may be hampered thereby. For detailed information on materials and details of construction with their fire resistance rating, reference may be made to good practice [F(12)].

3.5.10.6 The use of aluminium composite panels as external facade of the buildings should be avoided; if used, such panels should have a minimum of 70 percent mineral core and pass the tests as in accepted standards (*see* Note 2).

NOTES

1 When combustible materials are used for lining frames, walls, partitions, or floors, the surfaces on both sides of the materials must meet the required fire resistance class. This precaution helps mitigate the risk of fire spreading within concealed cavities, which may not be immediately visible to occupants and can hinder evacuation.

2 Accepted standards can be ISO 3957 or ISO 13785 (Part 1 and Part 2).

3.5.11 *Fire Command Centre* (*FCC*)

a) Fire command centre should be on the entrance floor of the building having direct access. The control room should have the main fire alarm panel with communication system (suitable public address system) to aid floors and facilities for receiving the message from different floors;

b) Fire command centre should be constructed with 120 min rating walls with a fire door and should be provided with emergency lighting. Interior finishes should not use any flammable materials. All controls and monitoring of fire alarm systems, pressurization systems, smoke management systems should happen from this room. Monitoring of integrated building management systems, CCTVs or any other critical parameters in building may also be from the same room.

c) Details of all floor plans along with the details of firefighting equipment and installations (2 sets laminated and bound) should be maintained in fire command centre. The fire staff in charge of the fire command centre should be responsible for the maintenance of the various services and firefighting equipment and installations in coordination with security, electrical and civil staff of the building.

NOTE — Panelling (lining) should be permitted in a limited area. It should not be permitted in a vestibule.

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4 LIFE SAFETY

4.1 General

Every building should be so designed, constructed, equipped, maintained, and operated as to provide adequate means of egress to avoid undue danger to the life and safety of the occupants from fire, smoke, fumes, or panic during the time period necessary for escape.

For high occupancy areas, it may be required to have annunciation, announcements, and voice guided/aided system to direct the occupants towards safe egress routes, areas of comparative safety or exits, and to avoid situation of panic during distress.

Every main occupancy may have certain occupancies which may be incidental to the main occupancy. The exit requirements pertaining to such incidental occupancies from the floor of the occupancy to the level of exit discharge should be calculated to meet the requirement of the actual occupancy of such type, to ensure adequate means of egress of the occupants.

See also good practice [F(31)] for accessibility for elderly and persons with disabilities, for various requirements for enabling a smooth and safe egress.

4.2 General Exit Requirements

4.2.1 Fire exits are unobstructed component of means of egress which is between the exit access and the exit discharge or public way. Exit components include exterior exit doors at the level of exit discharge, interior exit stairways (pressurised), exit stairway with external wall (pressurised or naturally ventilated), exterior exit stairways, exit passageways, and exterior exit ramps. Fire exits should be provided with panic bar to facilitate entry of occupant into fire exit.

An exit may also include a horizontal exit leading to an adjoining building/fire compartment having its further access to unlocked/public exit at the same level.

4.2.2 Unless otherwise specified, lifts, escalators, moving walks and revolving doors should not be considered as fire exits and should not constitute any part of the required fire exit.

4.2.3 Every fire exit, exit passageway and exit discharge should be continuously maintained free of all obstructions or impediments to full use in the case of fire or other emergency.

4.2.4 Every building having human occupancy should be provided with fire exits sufficient to permit safe egress of occupants, in case of fire or other emergency.

4.2.5 In every building or structure, fire exits should comply with the minimum requirements of this Part, except those not accessible for general public use.

4.2.6 No building should be so altered as to reduce the number, width, or protection of fire exits to less than that required.

4.2.7 For non-naturally ventilated areas (that is, pressurized areas), fire doors with 120 min fire resistance rating should be provided and particularly at the entrance to lift lobby and stair well where a 'funnel or flue effect' may be created, inducing an upward spread of fire, to prevent spread of fire and smoke.

4.2.8 Fire exits should be so arranged that they may be reached without passing through another occupied unit/passage in others control if they pose challenge or restriction in means of egress.

4.2.9 Doors in fire exits should open in the direction of exit. In case of assembly buildings (Group D) and institutional buildings (Group C-1), exit door should not open immediately upon a flight of stair and all such entries to the stair should be through a landing, so that such doors do not impede movement of people descending from a higher floor when fully opened (*see* Fig. 7A). While for other occupancies, such doors should not reduce the pathway in the landing by more than half the width of such staircase (*see* Fig. 7B). Over- head or sliding doors should not be installed.

4.2.10 At least half of the required exit stairs from upper floors (rounded to the next higher number) should discharge directly to the exterior or through exit passageways. For buildings less than 60 m in height, firefighting

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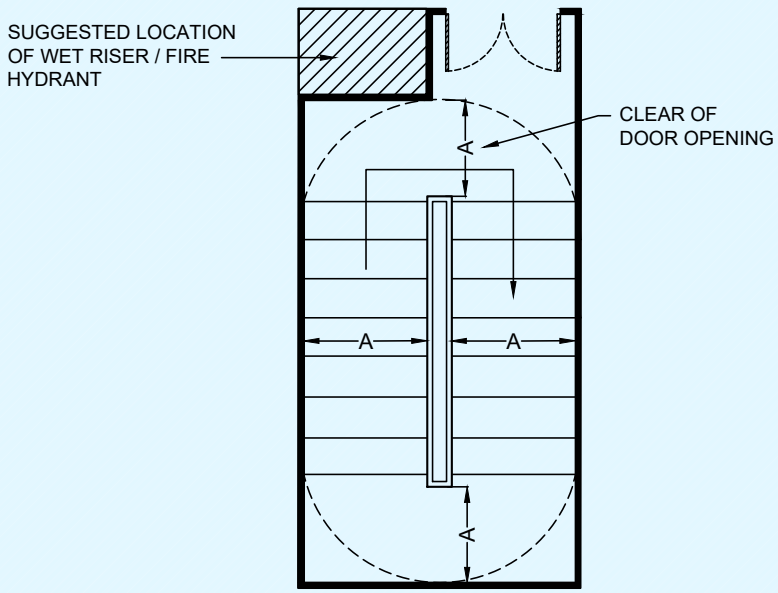
shaft should be planned having one side on the external wall and discharging directly to the exterior. In the case of tall buildings (60 m and above), where structural design requires the location of firefighting shaft along with the structural core members, firefighting shaft(s) in the building should discharge directly to the exterior (through exit passageway).

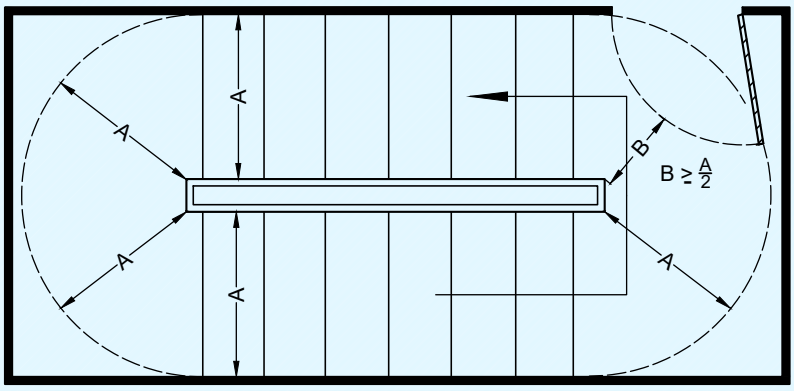
4.2.11 Unless otherwise specified, all the fire exits and exit passageways to exit discharge should have a clear ceiling height of at least 2.4 m. However, the height of fire exit door should be at least 2.0 m (*see* Fig. 8).

4.2.12 Where changes in elevation of more than 300 mm are encountered in the exits, ramps or sloped surfaces should be used with handrails and floor finish materials that contrast with the adjacent finish materials.



NOTE — DOOR WIDTH SHALL BE BASON TYPE OF OCCUPANCY

7A MINIMUM REQUIRED UNOBSTRUCTED CLEARANCE WITH DOOR LEAF ENCROACHING ON LANDING IN INSTITUTIONAL AND ASSEMBLY BUILDING



A - REQUIRED WIDTH

7B MINIMUM REQUIRED UNOBSTRUCTED CLEARANCE WITH DOOR LEAF ENCROACHING ON LANDING

FIG. 7 DOOR LOCATION AT LANDING IN FIRE EXITS

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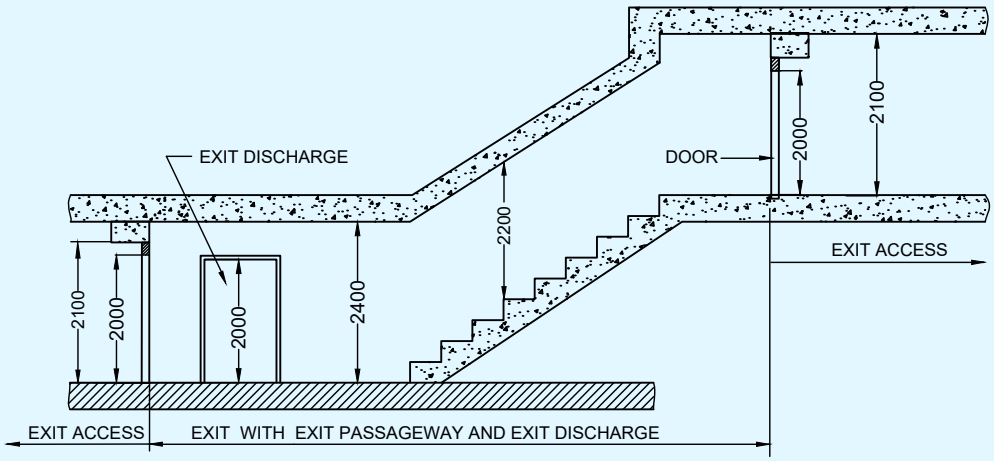

FIG. 8 MINIMUM HEAD ROOM MEASUREMENT

4.2.13 The capacity of the means of egress required from any storey of the building should-not be reduced along the path of egress travel until arrival to the exit discharge.

4.2.14 The lifts, escalators, moving walks, turnstiles and revolving doors should not be considered in determining the required capacity of means of egress for the individual floor(s) or the building.

4.2.15 Turnstiles or similar devices that restrict travel to one direction or that are used to restrict unauthorized entry should not be so placed as to obstruct any required means of egress. Alternative door openings of required exit width should be available within 3 m of such devices, if installed.

4.2.16 Suitable means should be provided so that all access-controlled exit doors, turnstiles, boom barriers and other such exits should automatically operate to open mode during emergencies like fire, smoke, acts of terrorism, etc, so that people can safely and quickly egress into safe areas outside. If required, a master controlling device may be installed at a strategic location to achieve this.

4.2.17 Penetrations into and openings through fire exit are prohibited except those necessary, like for the fire protection piping, ducts for pressurization and similar life safety services. Such openings as well as vertical passage of shaft through floors should be protected by passive systems, {see accepted standard [F(34)]}.

4.2.18 Walking surfaces in exit access should comply with the following requirements for smooth exit:

a) Walking surfaces should be nominally level;

b) The slope of walking surface in the direction of travel should not exceed 1 in 20 unless the ramp requirements are met (*see* **4.4.2.4.3.5**);

c) Slope perpendicular to the direction of travel should not exceed 1 in 48; and

d) Walking surfaces should be slip-resistant along the entire path of travel.

4.2.19 *Basement*

4.2.19.1 The basement should not be used for hazardous and vulnerable activities, like sleeping purposes, class rooms, hazardous industries, restaurant kitchen (*see also* **4.7.9**), battery rooms, UPS rooms, fuel oil storage, etc However, the State Authorities may prescribe the list of such activities based on their own assessment. Basements should have smoke ventilation systems, high-density sprinkler systems, and redundant/enclosed exits.

4.2.19.2 The fire exits in a basement should be sufficient to provide for the capacity of the basement occupancy as determined in accordance with **4.4.2.1**. In no case should there be fewer than two independent basement exits.

4.2.19.3 Basements with incidental occupancies to the main occupancy should be planned with exit requirements for the actual occupancy within the basement.

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4.2.19.4 Where a basement is used for car parking and also there is direct approach from any occupancy above to the basement, door openings leading to the basement should be protected with fire doors with 120 min fire resistance rating, except for exit discharge doors from the basements.

4.2.19.5 Basements should have a minimum clear height of 3.4 m towards effective performance in the event of fire/smoke. Impulse or duct ventilation system needs to be designed to ensure removal of hot gases and smoke from each compartment to achieve reasonable visibility and heat reduction for firefighting operations.

4.3 Occupant Load

For determining the fire exits required, the number of persons within any floor area or the occupant load should be based on the actual number of occupants declared, but in no case less than that specified in Table 2. The occupant load of a mezzanine floor discharging to a floor below should be added to that floor occupancy and the capacity of the fire exits should be designed for the total occupancy load thus established.

The occupant load of each storey considered individually should be required to be used in computing the number of means of egress at each storey, provided that the required number of means of egress is not decreased in the direction of egress travel.

Table 2 Occupant Load

[*Clauses* 4.3, 4.4.2.1 *and* H-4.1(j)]

Sl No.	Building Occupancy	Net Occupant Load Factor (m^2/person) (*see* Note 7)	Gross Occupant Load Factor (m^2/person) (*see* Note 1)
(1)	(2)	(3)	(4)
i)	Group A: Residential	12.5	-
ii)	Group B: Educational	3.0	-
iii)	Group C: Institutional (*see* Note 2)		
	a) Nursing homes	-	12.0
	b) Clinic (daycare)	-	12.0
	c) Inpatient area in hospital (like ward, sleeping area)	11.0	-
	d) Outpatient area in hospital	7.0	-
iv)	Group D: Assembly		
	a) Concentrated use without fixed seating	0.65	-
	b) Less concentrated use without fixed seating such as pre-function, multipurpose hall)	1.40	-
	c) Fixed seating	*see* Note 4	-
	d) Dining areas and restaurants with seating and table	1.80	-
	e) Gymnasium, sports room, library and alike with equipment, stacks and the like. This includes performance stages, indoor badminton court, squash court with	4.6	-

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Table 2 (*Continued*)

Sl No.	Building Occupancy	Net Occupant Load Factor (m^2/person) (*see* Note 7)	Gross Occupant Load Factor (m^2/person) (*see* Note 1)
(1)	(2)	(3)	(4)
	limited number of performers and player (while audience for the same if any should be under (c) as above).		
	f) Swimming pool		
	1) Water surface	3.5	-
	2) Deck	2.0	-
	g) Mall – Basement with sales floor	2.1	-
	h) Mall – Street floor	2.1	-
	j) Mall – Upper sales floor	4.3	-
	k) Mall – Food court	-	1.8
	m) Mall – Theatre screens	-	*see* Note 4
	n) Storage/warehouse, receiving and the like	14.3	-
v)	Group F: Mercantile		
	a) Street floor and above	-	2.1
	b) Below street floor	-	3.0
vi)	Group E: Business	7.1	-
vii)	Group E: For Datacentres	-	20.0
	a) Admin areas	-	10.0
	b) Data hall, server room, equipment room areas	- *see* Annex G	50.0 *see* Annex G
viii)	Group G: Industrial	-	
	a) Low hazard	-	20.0
	b) Moderate hazard	-	15.0
	c) High hazard	-	10.0
ix)	Group H: Storage (*see* Note 5)	-	30.0
x)	Group J: Hazardous	-	10.0

NOTES

1 Gross area is the floor area as defined in **2.35**.

2 Occupant load factor in dormitory portions of homes for the aged, orphanages, insane asylums, etc, where sleeping

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Table 2 (*Concluded*)

Sl No.	Building Occupancy	Net Occupant Load Factor (m^2/person) (*see* Note 7)	Gross Occupant Load Factor (m^2/person) (*see* Note 1)
(1)	(2)	(3)	(4)

accommodation is provided, should be calculated at not less than 7.5 m^2 gross floor area/person.

3 Commercial kitchen in the above occupancies should be calculated at 9.3 m^2 net floor area/person.

4 In case of assembly occupancy having fixed seats, the occupant load should be determined by multiplying the number of seats by 1.2.

5 Car parking areas under occupancy other than storage should also be 30 m^2 per person.

6 Usable carpet area is the total of all corridors, passages, enclosed offices/rooms excluding rack and UPS/battery foot print

7 Net area is not the carpet area. *See* **2.36**.

* Gross area is highly recommended to be used than the net area, to avoid double counting. Net area is possible to be indicated for spaces having concentration of people is typical in certain occupancies; and other common spaces/areas in a floor plate may be used by the same set of occupants. Moreover, gross area provides a safer, more conservative occupant load for the entire floor, ensuring exits are sized for the maximum possible capacity. Further, net area is used for specific rooms (like classrooms or assembly halls) where the furniture and layout are predictable, but using it for an entire floor plate often underestimates the total population because it excludes corridors, closets, and wall thicknesses where people still circulate.

4.4 Egress Components

Egress components to be considered are the number of exits to which access is provided, capacity of exit access, travel distance to a fire exit, the obviousness of the direction to a fire exit, and any hindrance including due to security issues involved.

4.4.1 *Exit Access*

a) A common path of travel is desirable in exit access which leads to two independent directions to separate fire exits;

b) *Capacity of Exit Access* — The width of corridors, aisles or ramps required for exit access should be sufficient to ensure a smooth flow of occupants to the fire exit. Where a corridor is the only way of access to a fire exit, the corridor width should not be less than the calculated exit width;

c) Objects like tables, chairs or any other temporary/permanent structures in exit access corridors should be avoided as this may result in congestion and also impeding smooth flow of personnel during emergencies;

d) In order to ensure that each element of the means of egress can be effectively utilized, they should all be properly lit and marked. Lighting should be provided with emergency power back-up in case of power failures. Also, exit signs of adequate size, marking, location, and lighting should be provided so that all those unfamiliar with the location of the fire exits may safely find their way;

e) Exit access to fireman's lift and refuge area/spaces on the floor should be step free and clearly signposted with the international symbol of accessibility;

f) Exit access should not pass through storage rooms, closets or spaces used for similar purpose; and

g) The calculation of capacity of exit access should be in accordance with **4.4.2.4**.

4.4.2 *Exits*

4.4.2.1 *Number of fire exits*

The minimum required number of exits in a building should be determined based on occupant load (*see* Table 2) and width required per person (*see* Table 3) as appropriate to the type of exit for respective occupancies, subject to complying with maximum travel distance requirement (*see* Table 4).

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4.4.2.2 *Arrangement of fire exits*

a) Fire exits should be so located that the travel distance on the floor should not exceed the distance given in Table 4.

b) Travel distance should be measured from the most remote point within a storey or a mezzanine floor along the natural and unobstructed path of horizontal or vertical egress travel to the door of a fire exit.

c) The dead-end corridor length in exit access should not exceed 6 m for educational, institutional and assembly occupancies. For other occupancies, the same should not exceed 15 m (*see* Fig. 9).

d) Fire exits should be placed as remote from each other as possible and should be arranged to provide direct access in separate directions from any point in the area served (*see* Fig. 10).

4.4.2.3 *Capacities of means of egress*

a) Exit capacity is the number of people that can pass through a stairway, and level components (door and corridor) and ramps. The total capacity of all the respective means of egress serving a floor should be sufficient to allow egress of the entire population of the floor.

b) The unit of exit width, used to measure the capacity of any exit, is 500 mm. A clear width of 250 mm needs to be counted as an additional half unit. Clear widths less than 250 mm need not be counted for exit width.

c) Width per person for stairways, and level components and ramps are to be determined using the capacity factors in accordance with Table 3.

   For example, if an exit doorway measures 1 000 mm in clear width its capacity factor being 6.5, it would be defined as providing exit capacity for 1 000/6.5 occupants, that is, 153 persons (say 150 persons) and number of such exit doorways can then be calculated depending on the occupant load.

d) When calculating stairways, level components and ramps and other exit means, the capacity of the entire system should have to be based upon the minimum capacity available from any part of the system. The corridor, if so provided, should also to be planned with consideration of exit access adequacy for the number of occupants. Further, consider the situation of doors opening to an exit stairway. If the stairway provides an exit capacity of 150 persons, and the doors leading into the stairway provide an exit capacity of 153 persons, the overall exit system would be considered to provide the minimum exit capacity of only 150 persons afforded by the stairway. The exit planning will be limited by the most restrictive exit calculation under the means of egress.

e) In the procedures for determining required egress capacity, the number of required means of egress is based on a floor-by-floor consideration, rather than the accumulation of the occupant loads of all the floors. However, the number of means of egress cannot decrease as an occupant proceeds along the egress path.

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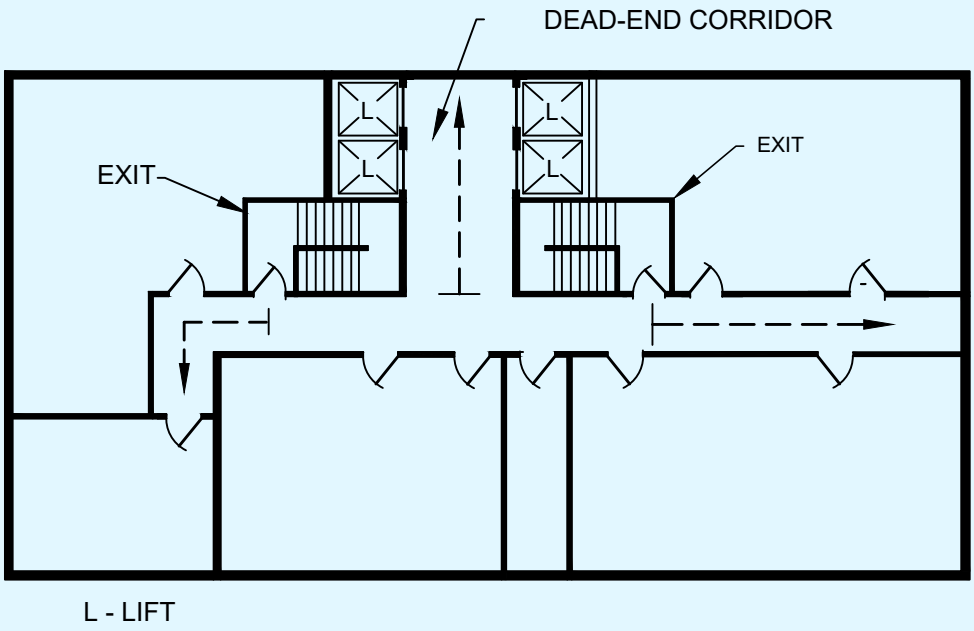
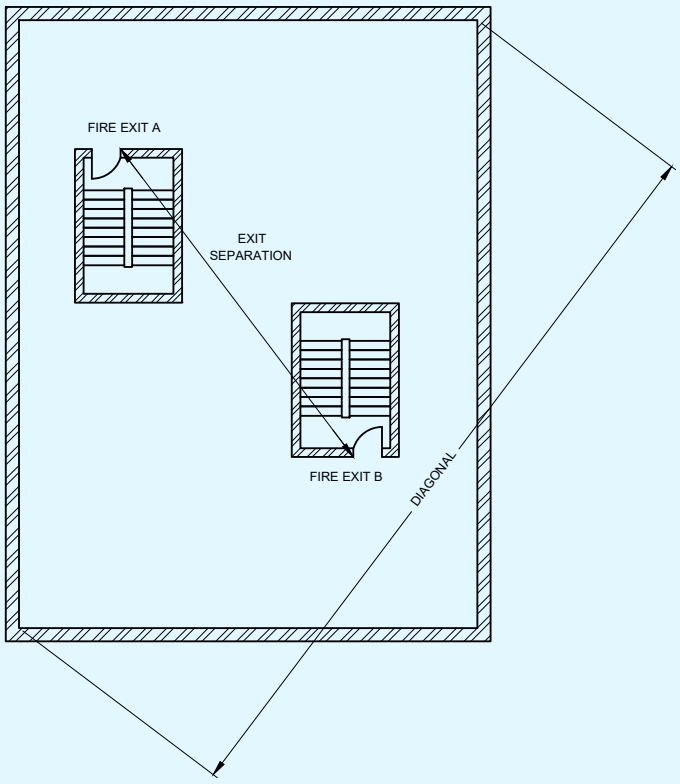


FIG. 9 DEAD END CORRIDOR



NOTE — MINIMUM EXIT SEPARATION = DIAGONAL/2 (FOR UNSPRINKLERED)
= DIAGONAL/3 (FOR SPRINKLERED)

FIG. 10 FIRE EXIT SEPARATION

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Table 3 Capacity Factors

[*Clauses* 4.4.2.1, 4.4.2.3(c), 4.4.2.4.1(b), 4.4.2.4.2(a) *and* 4.4.2.4.3.5(a)]

Sl No.	Occupancy Group	Width per Person mm	
		Stairways	Level Components and Ramps
(1)	(2)	(3)	(4)
i)	Residential (Group A)	10	6.5
ii)	Educational (Group B)		
iii)	Institutional (Group C)	15	13
iv)	Assembly (Group D)	10	6.5
v)	Business (Group E)		
vi)	Mercantile (Group F)		
vii)	Industrial (Group G)		
viii)	Storage (Group H)		
ix)	Hazardous (Group J)	18	10

4.4.2.4 *Types of exit access and exits*

Various types of exit access and exits are doorways, corridors and passageways, horizontal exits, internal staircases, exit passageways, external staircases, and ramps.

4.4.2.4.1 *Doorways*

a) Every exit doorway should open into an enclosed stairway or a horizontal exit of a corridor or passageway providing continuous and protected means of egress (*see* Fig. 11 on unaccepted arrangement of doors in a stair).

b) No exit doorway should be less than 1 000 mm in width. Door width in exits should also meet requirement of level components given in Table 3 except assembly buildings, where door width should be not less than 2 000 mm (*see* Fig. 12). Doorways should be not less than 2 000 mm in height.

c) Exit doorways should be operable from the side which they serve, without the use of a key.

d) Mirrors should not be placed on exit doors and in exits, to avoid confusion regarding the direction of exit.

e) Revolving doors can be accepted as a component in a means of egress where the following requirements are fully complied with:

   1) Doors should be capable of collapsing to a book fold position with parallel egress paths, of width not less than 1 000 mm.

   2) Doors should not be located within 3 m of the foot or top of stairs or escalators. A dispersal area should be provided between the stairs or escalators and the doors.

   3) Each revolving door should be provided with a hinged door in the same wall within 3 m thereof, with same exiting capacity.

   4) Each revolving door should be considered as capable of exiting only 50 persons.

f) All fire rated doors and assembly should be provided with certificate and labels prominently indicating

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the manufacturer's identification, door details covering door type, serial/batch number, month and year of manufacture, fire resistance rating, etc. The doors and assembly should be certified with all prescribed hardware such as hinges, locks, panic bars, door closers, and door viewers.

g) *Access controlled doors* — Access controlled doors and electromagnetic doors should fall under this category. These should meet the following requirements:

1) Doors should have fire rating as per the requirements at the location of installation;

2) Activation of the building automatic sprinkler or fire detection system, if provided, should automatically unlock the doors in the direction of egress, and the doors should remain unlocked until the automatic sprinkler system or fire-alarm system has been manually reset;

3) Loss of power to the part of the access control system that locks the doors should automatically unlock the doors in the direction of egress;

4) A manual release device should be provided in the readily accessible vicinity of the egress door with a signage 'PUSH TO EXIT' and when the same is operated, it should result in direct interruption of power to the lock, independent of the access control system electronics.

h) *Turnstiles* — Turnstiles or similar devices that restrict travel to one direction or are used to collect fares or admission charges should not be placed so as to obstruct any required means of egress unless door openings of required width are available within 3 m thereof.

Turnstiles or such similar devices should also be disengaged through automatic or manual intervention to allow egress in the direction of exit.

j) Doors in folding partition should not be treated as approved means of egress.

Table 4 Travel Distance (Based on Occupancy and Construction Type)

[*Clauses* 4.4.2.1, 4.4.2.2 (a), 4.4.2.4.2 (a) *and* 6.8.1.1]

Sl No.	Occupancy Group	Maximum Travel Distance m		
		Types 1 and 2 (Unsprinklered)	Types 1 and 2 (Sprinklered)	Types 3 and 4
(1)	(2)	(3)	(4)	(5)
i)	Residential (Group A)	30.00	60.00	22.5
ii)	Educational (Group B)	30.00	45.00	22.5
iii)	Institutional (Group C)	30.00	45.00	22.5
iv)	Assembly (Group D)	30.00	45.00	30.00
v)	Business (Group E)			
	Businesses (including admin area of Datacentre building)	30.00	60.00	30.00
	Datacentre building	N.A.	60.00	N.A.
vi)	Mercantile (Group F)	30.00	45.00	30.00

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Table 4 (*Concluded*)

Sl No.	Occupancy Group	Maximum Travel Distance m		
		Types 1 and 2 (Unsprinklered)	Types 1 and 2 (Sprinklered)	Types 3 and 4
(1)	(2)	(3)	(4)	(5)
vii)	Industrial (Group G)			
	G-1, G-2	45.00	60.00	*see* Note 3
	G-3	22.50	45.00	
viii)	Storage (Group H)	30.00	90.00	
ix)	Hazardous (Group J)	22.50	30.00	

NOTES

1 The common path of travel should be not more than 50 percent of the above distances.

2 Ramps are not to be counted as an exit in case of basements below the first basement in car parking.

3 Construction of Type 3 or Type 4 is not permitted.

4 Utility service areas and equipment areas may be exempt from the measurement of travel distance from within the room.

5 For ceiling height 10 m or above at ground floor in buildings such as airports, exhibition halls, convention centres, atrium in shopping malls, entrance lobbies and the like and provided with sprinkler system, the travel distance in such areas may be increased by 100 percent of the values specified. This is not to be applied to the values given in col (4) above.

6 In such buildings having ceiling heights 17 m or more and would have sprinkler exemption, the travel distance of such areas may be allowed to be increased by 100 percent of the values specified. This is not to be applied to the values given in col (4) above. In such cases, to prevent heat build-up at ceiling level, suitable smoke/heat venting systems are recommended.

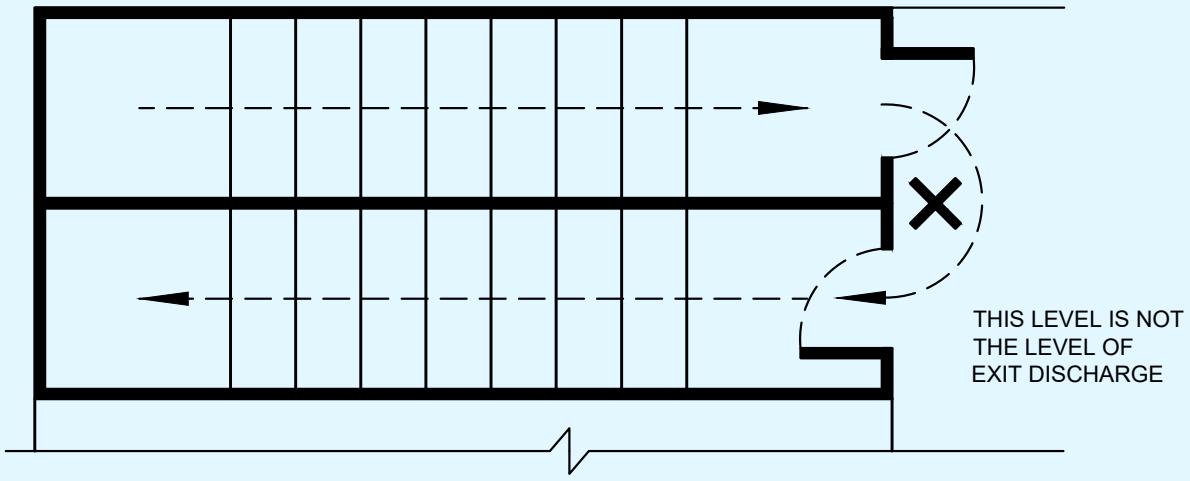

FIG. 11 UNACCEPTABLE ARRANGEMENT FOR ENCLOSING A STAIR SERVING AS A REQUIRED EXIT

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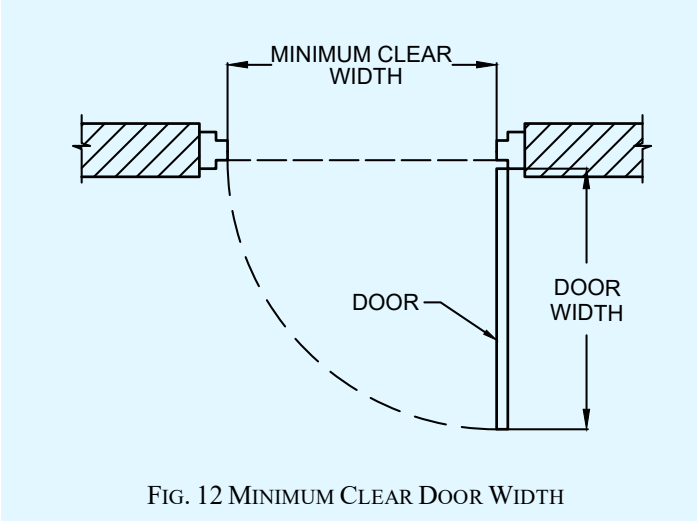

FIG. 12 MINIMUM CLEAR DOOR WIDTH

4.4.2.4.2 *Corridors and passageways of means of egress*

a) Corridors and passageways should be of width not less than the calculated aggregate width of exit doorways leading from them in the direction of travel to the exit (*see* Table 3 and Table 4); and

b) In the case of buildings where there is a central corridor, which is part of exit access, the doors of rooms (except for rooms having assembly occupancy) should open inwards to permit smooth flow of traffic in the corridor.

4.4.2.4.3 *Staircases*

4.4.2.4.3.1 *General*

The requirements of number of staircases should supplement the requirement of different occupancies in **6.1** to **6.9**.

All high rises and special buildings, as mentioned in **1.2**, should have a minimum of two staircases. The actual number of staircases should comply with the requirement of **4.4.2.1**.

NOTE — These required fire exit staircases calculated as per the laid down provisions, are recommended to be free of FAR.

All exit staircases should discharge, at the level of exit discharge, to the exit discharge, either,

a) directly, or

b) through an exit passageway, or

c) through a large lobby.

At least 50 percent of the staircases should discharge as per (a) and/or (b) above. For firefighting shafts, it is preferred to have the discharge through (a), or as an alternate through (b). Option (c) is not applicable for firefighting shafts. In case of residential buildings and educational buildings, firefighting shafts should discharge through (a) only.

Each compartment should be planned with its access to the firefighting shaft. In buildings/floors having three or more compartments, there should be at least two firefighting shafts to serve the compartments. In buildings/floors having three or more compartments, there should be at least two firefighting shafts to serve the compartments.

The minimum width of tread without nosing should be 250 mm for staircase of residential buildings. This should be minimum 300 mm for assembly, hotels, educational, institutional, business, and other buildings. The treads should be constructed and maintained in a manner to prevent slipping. The maximum height of riser should be 175 mm for staircase of one or two family dwelling residential buildings and 150 mm for other buildings. The number of risers in a flight is recommended as 12. However, considering the floor-to-floor height, there should not be more than 15 risers in a flight.

The staircases may be internal staircases or external staircases.

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4.4.2.4.3.2 *Internal staircases*

The internal staircases may be constructed with an external wall, or otherwise, and should comply with the following:

a) Internal stairs should be constructed of non-combustible materials throughout, and should have fire resistant rating of minimum 120 min.

b) A staircase should not be arranged round a lift shaft.

c) Fire exits should not be used as a portion of a supply, return or exhaust air system serving adjoining areas. Any opening(s) should not be permitted in walls or in doors, separating fire exits from adjoining areas.

d) No flue chimney, electromechanical equipment, air conditioning units, gas piping or electrical panels should be allowed in the stairway.

e) Notwithstanding the detailed provision for exits in accordance with **4.2** and **4.3**, the following minimum width should be provided for staircases for respective building typology:

1) Residential building (One or two family dwellings) : 1.00 m

NOTE — For row housing with 2 storeys, the minimum width should be 0.75 m.

2) Residential building (A-I, A-II and A-III) : 1.25 m

3) Residential hotel building (A-IV and A-V) : 1.50 m

4) Assembly building : 2.00 m

NOTE — The width of stairs may be accepted to be 1.50 m in case of assembly occupancy having less than 150 persons.

5) Educational building : 1.50 m

6) Institutional building : 2.00 m

Maximum width of stairs in hospitals should be 2.00 m.

7) All other buildings : 1.50 m

NOTE — Where staircase width is above 2.00 m, it is recommended to provide a central handrail.

f) A handrail should be provided on one side of the staircase of width less than 1 500 mm, and on both sides of the staircase of width 1 500 mm and more. The projection of handrail(s) in the staircase width should not be more than 90 mm.

g) Handrails may project inside the measured width by not more than 90 mm.

h) The design of staircase should also take into account the following:

1) The minimum headroom in a passage under the landing of a staircase and under the staircase should be 2.2 m.

2) Access to fire sexit staircase should be through a fire door of a minimum 120 min fire resistance rating.

3) No living space, store or other fire risk should open directly into staircases.

4) The exit (including staircases) should be continuous from refuge floors or terrace level, as applicable, to the level of exit discharge.

5) No electrical shafts/air conditioning ducts or gas pipes, etc, should pass through or open in the staircases.

6) Lifts should not open in staircase (or in mid-landings).

7) No combustible material should be used for decoration/wall panelling in the staircase.

8) Beams/columns and other building features should not reduce the head room/width of the staircase.

9) The floor indication board, indicating the location/designated number of staircase, respective floor number and direction to exit discharge should be placed inside the staircase, on the wall nearest to the fire door. It should be of size not less than 300 mm × 200 mm (*see* Fig. 13).

10) Individual floors should be prominently indicated on the wall outside the staircase and facing it.

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11) All staircase should terminate at the level of exit discharge. The access to the basement should be by a separate staircase.

12) Scissors type staircases (of type where intermingling of persons in the landing is possible or of type where both stairs use the common air space) should not be treated as part of exit.

4.4.2.4.3.3 *Curved stairs*

Curved stairs should not be treated as part means of egress. However, these may be used as part of exit access provided the depth of tread is not less than 280 mm at a point 350 mm from the narrower end of the tread and the smallest radius is not less than twice the stair width.

4.4.2.4.3.4 *External staircases*

The external staircases are the staircases provided on the external wall/facade, and should comply with the following:

a) External stairs should always be kept in sound and usable condition;

b) All external stairs should be directly connected to the ground;

c) Entrance to the external stairs should be separate and remote from the internal staircase;

d) Where an external staircase is provided, it should be ensured that the use of it at the time of fire is not prejudiced by smoke and flame from openings (for example, windows, doors) in the external face of the building. Care should be taken to ensure that no external wall or window opening opens on to or close to an external stair. If such openings exists within 3 m from an external staircase, they should be protected with fire rated doors/window assemblies with rating of at least 60 min (*see* Fig. 14);

e) The external stairs should be constructed of non-combustible materials, and any doorway leading to it should have minimum 120 min fire resistance;

f) No external staircase, should be inclined at an angle greater than 45° from the horizontal;

g) External stairs should have straight flight not less than 1 500 mm wide;

h) Handrails, to be provided on both sides, should be of a height not less than 1 000 mm and not exceeding 1 200 mm. There should be provisions of balusters with maximum gap of 150 mm; and

j) The use of spiral staircase should be limited to low occupant load and to a building not exceeding 9 m in height. A spiral staircase should be not less than 1 500 mm in diameter and should be designed to give adequate headroom.

4.4.2.4.3.5 *Ramps*

a) Ramps should comply with all the applicable requirements for staircases regarding enclosure, capacity (*see also* Table 3) and limiting dimensions, except where specified in **6.1** to **6.9** for special uses and occupancies;

b) The slope of a ramp should not exceed 1 in 12 (8 percent);

c) Ramp(s) should be surfaced with approved slip resistant materials that are securely attached. No perforations are permissible on ramp floors;

d) Any changes in travel direction in ramp should be preceded by landings of minimum 1.5 m × 1.5 m size;

e) Ramps and intermediate landings should continue with no decrease in width along the direction of egress travel;

f) Outside ramps and landings should be designed to minimize water accumulation on their surfaces;

g) Ramps should have landings located at the top, at the bottom, and at doors opening onto the ramp;

h) Every landing should be not less than 1 500 mm long in the direction of travel;

j) Where the ramp is not part of an accessible route, the ramp landings should not be required to exceed 1 250 mm in the direction of travel, provided that the ramp has a straight run; and

k) Handrails should be provided on all ramps on both sides (*see* **4.4.2.4.3.4**).

NOTE — Above requirements are not applicable to basement car parking ramps.

The ramps should, in addition, comply with the requirements given in good practice [F(31)].

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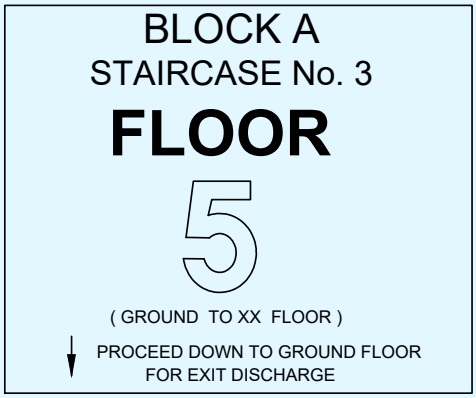
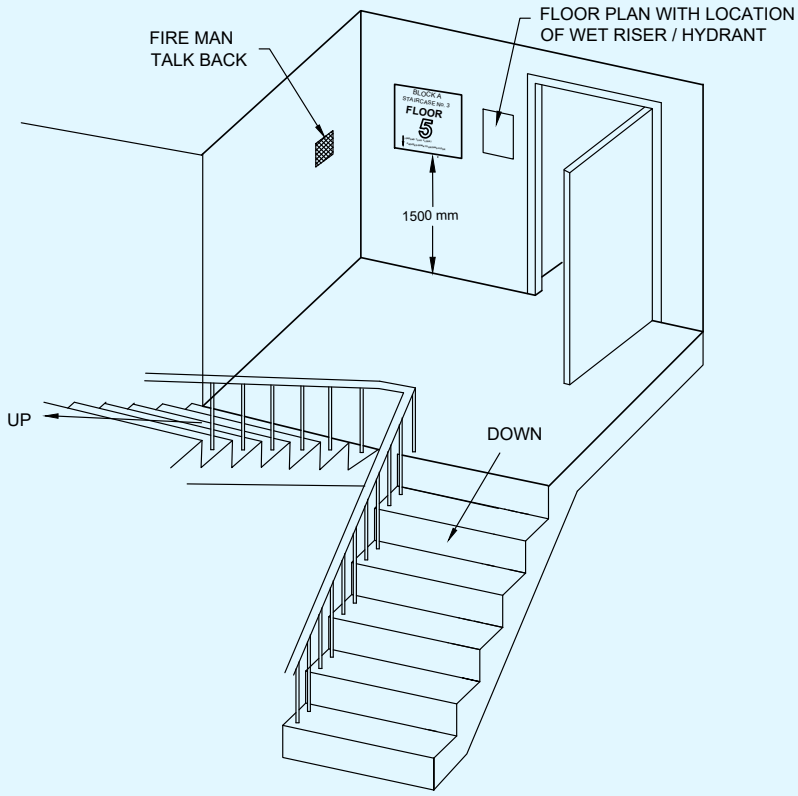


9A EXAMPLE OF A STAIRWAY MARKING SIGN (FLOOR INDICATION BOARD)



9B STAIR SIGN PLACEMENT

NOTE — BLOCK/WING/BUILDING NAME TO BE PROJECT SPECIFIC. STAIRCASE No. SHOWN AS "3" IS INTENDING TO SHOW THE NUMBER ASSIGNED TO THE STAIRCASE. ALL EXITS PREFERABLY TO BE ASSIGNED WITH NUMBER /IDENTIFICATION ENABLING OCCUPANT/FIRE MAN TO DECLARE LOCATION / POSITION.

FIG. 13 SIGN MARKING AND REQUIREMENT IN EXIT

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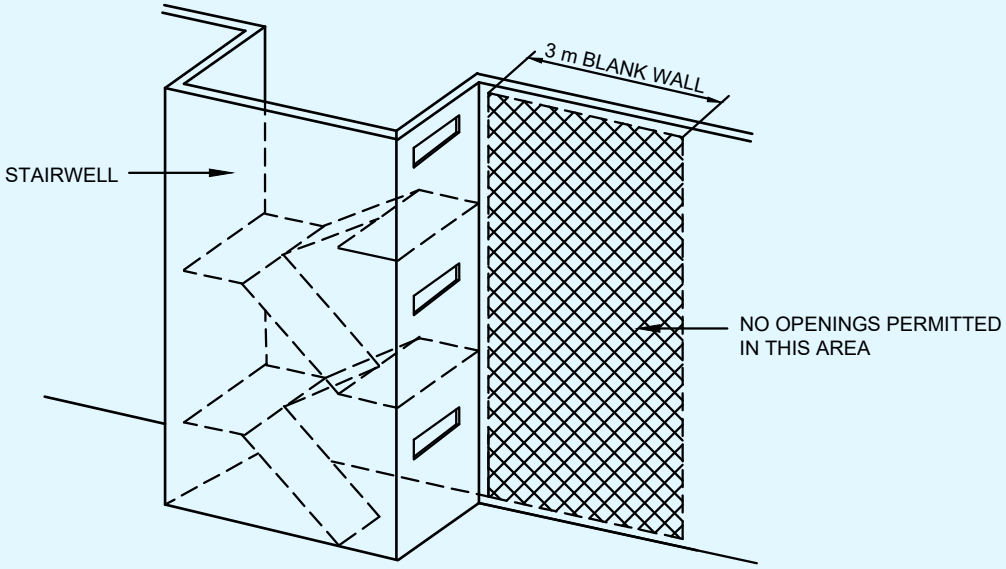
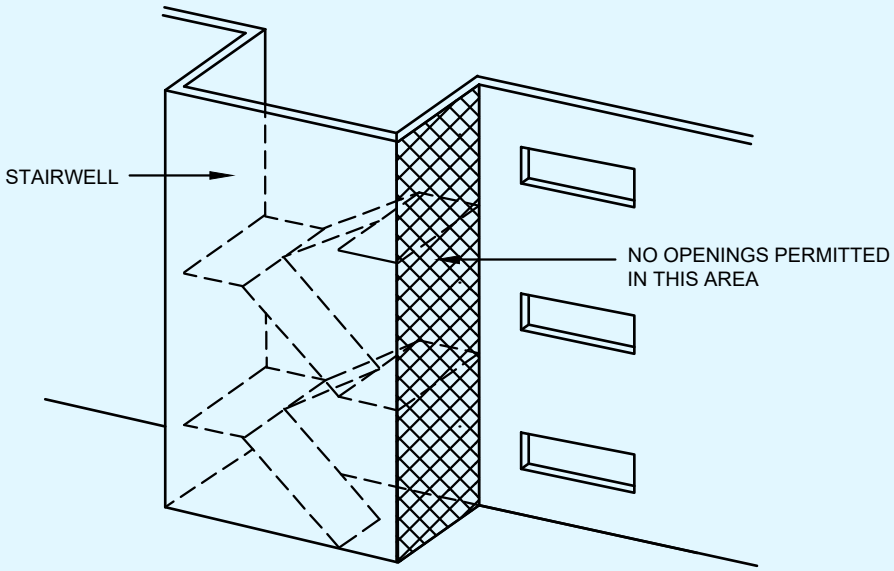


14A LIMITATIONS ON OPENINGS NEAR STAIRWELL



14B OPENING RESTRICTIONS ON STAIRWELL WALLS

FIG. 14 OPENING RESTRICTIONS

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4.4.2.5 *Smoke control of exits*

a) In building design, compartmentation plays a vital part in limiting the spread of fire and smoke. The design should ensure avoidance of spread of smoke to adjacent spaces through the various leakage openings in the compartment enclosure, such as cracks, openings around pipes ducts, airflow grills and doors. In the absence of proper sealing of all these openings, smoke and toxic gases will obstruct the free movement of occupants of the building through the exits. Pressurization of staircases is of great importance for the exclusion of smoke and toxic gases from the protected exit.

b) Pressurization is a method adopted for protecting the exits from ingress of smoke, especially in high-rise buildings. In pressurization, air is injected into the staircases, lobbies, etc, as applicable, to raise their pressure slightly above the pressure in adjacent parts of the building. As a result, ingress of smoke or toxic gases into the exits will be prevented. The pressurization of staircases and lift lobbies should be adopted as given in Table 5.

   The pressure difference for staircases should be 50 Pa.

   Pressure differences for lobbies (or corridors) should be between 25 Pa and 30 Pa. Further, the pressure differential for enclosed staircase adjacent to such lobby (or corridors) should be 50 Pa. For enclosed staircases adjacent to non-pressurized lobby (or corridors), the pressure differential should be 50 Pa.

c) Equipment and ductwork for staircase pressurization should be in accordance with one of the following:

   1) Directly connected to the stairway by ductwork enclosed in non-combustible construction.

   2) If ducts used to pressurize the system are passed through shafts and grilles are provided at each level, it should be ensured that hot gases and smoke from the building cannot ingress into the staircases under any circumstances.

d) The normal air conditioning system and the pressurization system should be designed and interfaced to meet the requirements of emergency services. When the emergency pressurization is brought into action, the following changes in the normal air conditioning system should be effected:

   1) Any re-circulation of air should be stopped and all exhaust air vented to atmosphere.

   2) Any air supply to the spaces/areas other than exits should be stopped.

   3) The exhaust system may be continued provided,

      i) the positions of the extraction grills permit a general air flow away from the means of egress;

      ii) the construction of the ductwork and fans is such that, it will not be rendered inoperable by hot gases and smoke; and

      iii) there is no danger of spread of smoke to other floors by the path of the extraction system which can be ensured by keeping the extraction fans running.

e) For pressurized stair enclosure systems, the activation of the systems should be initiated by signalling from fire alarm panel.

f) Pressurization system should be integrated and supervised with the automatic/manual fire alarm system for actuation.

g) Wherever pressurized staircase is to be connected to unpressurized area, the two areas should be segregated by 120 min fire resistant wall.

h) Fresh air intake for pressurization should be away (at least 4 m) from any of the exhaust outlets/grille.

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Table 5 Pressurization of Staircases and Lift Lobbies

[*Clauses* 4.4.2.5 (b) *and* D-2]

Sl No.	Component	Height of the Building		
		Less than 15 m	15 m to 30 m	More than 30 m
(1)	(2)	(3)	(4)	(5)
i)	Internal staircase not with external wall	Pressurized except for residential buildings (apartment houses and one or two family dwellings)	Pressurized	Pressurized
ii)	Internal staircase with external wall	Pressurized except for residential buildings (Apartment houses and one or two family dwellings) or Naturally ventilated	Naturally ventilated or Pressurized	Cross-ventilated or Pressurized
iii)	Lift lobby	Not required at ground and above. However, lift lobby segregation and pressurization is required for lift commuting from ground to basement	Naturally ventilated or Pressurized[1)]	Cross-ventilated or Pressurized[1)]

NOTES

1 The natural ventilation requirement of the staircase should be achieved through opening at each landing, of an area 0.5 m^2 to 1.5 m^2 (as defined earlier) in the external wall. A cross ventilated staircase should have 2 such openings in opposite/adjacent walls or the same should be cross-ventilated through the corridor.

2 Enclosed staircase leading to more than one basement should be pressurized.

[1)] Lift lobby with fire doors (120 min) at all levels with pressurization of 25 Pa to 30 Pa is required. However, if lift lobby cannot be provided at any of the levels in air-conditioned buildings or in internal spaces where funnel/flue effect may be created, lift hoistway should be pressurized at 50 Pa. For building greater than 30 m, multiple point injection air inlets to maintain desired pressurization level should be provided. If the lift lobby, lift, and staircase are part of firefighting shaft, lift lobby necessarily has to be pressurized in such case, unless naturally ventilated.

4.5 Compartmentation

4.5.1 *General*

It is important to limit the spread of a fire in special/high rise buildings, usually through the use fire barriers. In some instances, these barriers need to be penetrated for ductwork, plumbing and electrical systems, and in such cases, use of passive fire protection measures should be done so that the integrity of these barriers is not compromised.

4.5.2 The compartmentation can be achieved with following type of construction/type of fire barrier with protected openings:

a) Type A — Masonry construction with fire rated door assembly;

b) Type B — Fire rated fabric dropdown curtain assembly;

c) Type C — Fire rated glazed partition and door assembly;

d) Type D — Fire rated gypsum board/cementitious board assembly; and

e) Type E — Masonry construction with fire rated metal sliding door.

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Integrity (E) is the ability of the fire curtain assembly when exposed to fire from one side to withstand temperature up to 1 050 °C, to resist passage of flames and hot gases for a period of 120 min.

Radiation control (EW) is the ability of the fire curtain assembly when exposed to fire from one side to resist transfer of heat on the other side. When measured, it should does not exceed 15 kW/m^2 at 1 m distance.

Insulation (EI) is the ability of the fire curtain assembly when exposed to fire from one side to limit temperature rise on the other not exceeding 140 °C above the ambient.

Smoke control (Sa) is the ability of fire curtain assembly when exposed to a fire from one side resist passage of hot/cold smoke not exceeding 3 m^3/m/h at a pressure of smoke leakage rate of 25 Pa.

4.5.2.1 *Type B — Fire rated fabric dropdown curtain assembly*

The fire rated fabric should be tested and certified by any reputed third-party independent certification body for following parameters:

a) Type 1 — Integrity (E) of 120 min + Radiation (EW) of 60 min + Smoke control (Sa);

b) Type 2 — Integrity (E) of 120 min + Radiation (EW) of 120 min + Smoke control (Sa); and

c) Type 3 — Integrity + Radiation (EW) of 120 min + Insulation (EI) of 60 min + Smoke control (Sa).

4.5.2.2 *Type C — Fire rated glazed partition and door assembly*

The fire rated glazed partition and door assembly should be tested and certified by any reputed third-party independent certification body for following parameters:

a) Type 1 — Integrity (E) of 120 min + Radiation (EW) of 120 min + Insulation (EI) of 30 min + Smoke control (Sa); and

b) Type 2 — Integrity (E) of 120 min + Radiation (EW) of 120 min + Insulation (EI) of 60 min + Smoke control (Sa)

4.5.3 Floor(s) should be compartmented with area as given in Table 6. The maximum size of the compartment is suggested as follows. However, State/Local Authorities may prescribe their own requirements based on their risk assessment and other fire safety provisions.

Table 6 Compartmentation

(*Clause* 4.5.3)

Sl No.	Type of Building	Floor Area Compartmentation Area (without Sprinkler) m^2	Floor Area Compartmentation (when Sprinklered) m^2	Type of Construction/ Type of Fire Barrier with Protected Openings
(1)	(2)	(3)	(4)	(5)
i)	Enclosed basement vehicle parking in residential, educational, institutional, assembly, business, mercantile, industrial or storage occupancies	750	5 000	E - Barrier between the designated fire compart-ments/zones B - Limited to driveway not exceeding 9 m with Type-2 only.

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Table 6 (*Continued*)

Sl No.	Type of Building	Floor Area Compartmentation Area (without Sprinkler) m^2	Floor Area Compartmentation (when Sprinklered) m^2	Type of Construction/ Type of Fire Barrier with Protected Openings
(1)	(2)	(3)	(4)	(5)
ii)	Basements other than car parking in residential, educational, institutional, assembly, business, mercantile, industrial and storage occupancies	750	2 000	A/D - barrier between the designated fire compartments/zones
iii)	Hospitals and nursing homes with beds/sleeping patients in institutional occupancies	750	2 000	Any combination of A, B (Type-3 only), D - barrier between the designated fire compartments/zones
iv)	Buildings used for custody and care of children, convalescents, aged people who are incapable of self-preservation	750	1 500	Any combination of A, B (Type-3 only), D - barrier between the designated fire compartments/zones
v)	Mercantile buildings, multistorey mercantile buildings consisting of shops, departmental stores, markets	750	Not essential	Any combination of A, B (Type 2 only), D - barrier between the designated fire compartments/zones
vi)	Assembly buildings with/without atriums	1 500	Not essential	Any combination of A, B (Type 2 only), D - barrier between the designated fire compartments/zones
vii)	Buildings under business occupancy	750	3 000	Any combination of A, B, C (Type 1), D - barrier between the designated fire compart-ments/zones
viii)	Datacentre buildings	*See* Note 1	2 000	Any combination of A, C (Type 2) , D - barrier between the designated fire compartments/zones
ix)	Hotel building with or without dining facilities	750	3 000	Any combination of A, C (Type 1) , D - barrier between the designated fire compartments/zones
x)	Industrial buildings less than 6.7 m in height	1 500	10 000	Any combination of A, E - barrier between the designated fire compart-ments/zones

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Table 6 (*Concluded*)

Sl No.	Type of Building	Floor Area Compartmentation Area (without Sprinkler) m^2	Floor Area Compartmentation (when Sprinklered) m^2	Type of Construction/ Type of Fire Barrier with Protected Openings
(1)	(2)	(3)	(4)	(5)
xi)	Hazardous or high hazard buildings	*See* Note 1	500	A-barrier between the designated fire compart-ments/zones
xii)	Buildings with atrium with smoke management system	*See* Note 1	Not required	Subject to compliance of atrium as in Annex E
xiii)	Warehouses less than 5.0 m in height	*See* Note 1	5 000	*See* also good practice [F(142)]

NOTES

1 Compartmentation size is not specified, as the buildings have to be sprinklered.

2 Ceiling level partition may be considered (from ceiling level to 25 percent of floor height) to act as a smoke reservoir and venting thereof.

4.5.3.1 For space with large heights [such as airports, exhibition halls, convention centres, atrium in shopping-malls, warehouses (of height beyond 5 m), industrial (of height beyond 6.7 m), double height entrance lobbies and the like], these may be exempted from above requirement of compartmentation.

4.5.3.2 In addition to the above floor area compartmentation, all critical utility rooms within each compartment area construction should be 2 h fire rated. Rooms such as electrical room, server room, uninterrupted power supply (UPS) room, battery room, lift machine rooms, IT networking room, main distribution frame (MDF), intermediate distribution frame (HUB/IDF rooms), main communication room (MCR room), network switch rooms, multiplexer (MUX) rooms, telecom equipment room, janitor storage room, chemical storage room, QA and QC laboratories, etc, should be enclosed from all sides and construction should be 2 h fire rated irrespective of the size/area.

4.5.3.3 Guest rooms, guest room corridors, banquets, should be 60 m fire compartmented with 30 min fire rated doors, in addition to above area of compartmentation.

4.5.3.4 In buildings with open atrium, the effect of compartmentation on the atrium should be disregarded, provided the fire safety requirements given in Annex E on atrium are complied.

4.5.3.5 In industrial and storage occupancies, all hazardous areas irrespective of area/size should be compartmented namely, vehicle charging areas, ignitable chemical storage areas, hazardous waste storage areas, flammable scrap storage areas, unless these are located 30 m away from any adjacent occupied buildings.

4.5.3.6 All live cooking areas with any type of fuel (induction, LPG, PNG, etc) in hotels, IT parks, business buildings cafeteria, hostels, educational facility, food courts, malls, any commercial kitchens should be 120 min fire rated segregated from other areas.

4.5.3.7 Pantries without live cooking, buffet setting counters (*bain-marie* serving) (with/without re-heating facility), breakout areas with microwave stations, water and dispensing areas, collaboration areas, tea coffee maker areas should be exempted from above compartmentation requirements.

4.6 Smoke Control

4.6.1 *Smoke Exhaust and Pressurization of Areas Above Ground*

Corridors in exit access (exit access corridor) are created for meeting the requirement of use, privacy, and layout

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in various occupancies. These are most often noted in hospitality, health care occupancies and sleeping accommodations.

Exit access corridors of guest rooms and indoor patient department/areas having patients lacking self-preservation and for sleeping accommodations such as service apartments, custodial, penal, and mental institutions, etc, should be provided with 60 min fire resistant wall and 30 min self-closing fire doors along with all fire stop sealing of penetrations.

Smoke exhaust system having make-up air and exhaust air system or alternatively pressurization system with supply air system for these exit access corridors should be required.

Smoke exhaust system having make-up air and exhaust air system should also be required for theatres/auditoria.

Such smoke exhaust system should also be required for large lobbies and which have exit through staircase leading to exit discharge. This would enable eased exit of people through smoke-controlled area to exit discharge.

All exit passageway (from exit-to-exit discharge) should be pressurized or naturally ventilated. The mechanical pressurization system should be automatic in action with manual controls in addition. All such exit passageway should be maintained with integrity for safe means of egress and evacuation. Doors provided in such exit passageway should be fire rated doors of 120 min rating.

Smoke exhaust system where provided, for above areas and occupancies should have a minimum of 12 air changes per hour smoke exhaust mechanism.

Pressurization system where provided, should have a minimum pressure differential of 25-30 Pa in relationship to other areas.

The smoke exhaust fans in the mechanical ventilation system should be fire rated, that is, 250 °C for 120 min.

For naturally cross-ventilated corridors or corridors with operable windows, such smoke exhaust system or pressurization system will not be required.

4.6.2 *Smoke Exhaust and Pressurization of Areas Below Ground*

a) Each basement should be separately ventilated;

b) Vents with cross-sectional area (aggregate) not less than 2.5 percent of the floor area spread evenly round the perimeter of the basement should be provided in the form of grilles, or breakable stall board lights or pavement lights or by way of shafts.

   Alternatively, a system of mechanical ventilation system may be provided. Mechanical ventilation system should be designed to permit 12 air changes per hour (ACPH) in case of fire or distress call. However, for normal operation, air changes schedule should be as given in Part D 'Building Services, Section 3 Air conditioning, Heating and Mechanical Ventilation' of this NBCS. In case of single basement, fresh-air may be considered from ramp and perimeter opening to achieve 12 ACPH ventilation requirement.

c) In multi-level basements, independent air intake and smoke exhaust shafts (masonry or reinforced concrete) for respective basement levels and compartments therein should be planned with its make-up air and exhaust air fans located on the respective level and in the respective compartment. Alternatively, in multi-level basements, common intake masonry (or reinforced cement concrete) shaft may serve respective compartments aligned at all basement levels. Similarly, common smoke exhaust/outlet masonry (or reinforced cement concrete) shafts may also be planned to serve such compartments at all basement levels. All supply air and exhaust air fans on respective levels should be installed in fire resisting room of 120 min. Exhaust fans at the respective levels should be provided with back draft damper connection to the common smoke exhaust shaft ensuring complete isolation and compartmentation of floor isolation to eliminate spread of fire and smoke to the other compartments/floors.

d) Due consideration should be taken for ensuring proper drainage of such shafts to avoid insanitation condition. Inlets and extracts may be terminated at ground level with stall board or pavement lights as before. Stall board and pavement lights should be in positions easily accessible to the fire brigade and clearly marked 'AIR INLET' or 'SMOKE OUTLET' with an indication of area served at or near the opening.

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e) Smoke from any fire in the basement should not obstruct any fire exit serving the ground and upper floors of the building.

f) The smoke exhaust fans in the mechanical ventilation system should be fire rated, that is, 250 °C for 120 min.

g) The smoke ventilation of the basement car parking areas should be through provision of supply and exhaust air ducts duly installed with its supports and connected to supply air and exhaust fans. Alternatively, a system of impulse fans (jet fans) may be used for meeting the requirement of smoke ventilation complying with the following:

    1) Structural aspects of beams and other down stands/services should be taken care of in the planning and provision of the jet fans.

    2) Fans should be fire rated, that is, 250 °C for 120 min.

    3) Fans should be adequately supported to enable operations for the duration as above.

    4) Power supply panels for the fans should be located in fire safe zone to ensure continuity of power supply.

    5) Power supply cabling should meet circuit integrity requirement in accordance with accepted standard [F(13)].

The smoke extraction system should operate on actuation of flow switch actuation of sprinkler system. In addition, a local and/or remote 'manual start-stop control/switch' should be provided for operations by the fire fighters.

Visual indication of the operation status of the fans should also be provided with the remote control.

No system relating to smoke ventilation should be allowed to interface or cross the transformer area, electrical switchboard, electrical rooms or exits.

Smoke exhaust system having make-up air and exhaust air system for areas other than car parking should be required for common areas and exit access corridor in basements/underground structures and should be completely separate and independent of car parking areas and other mechanical areas.

Supply air should not be less than 5 m from any exhaust discharge openings.

For specific details on smoke management using mechanical means, *see* Part D ‘Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation’ of this NBCS.

4.7 Gas Supply

4.7.1 *Town Gas/LPG Supply Pipes*

Where gas pipes are run in buildings, the same should be run in separate shafts exclusively for this purpose and these should be on external walls, away from the staircases. Gas distribution pipes should always be below the false ceiling. The length of these pipes should be as short as possible. In the case of kitchen cooking range area, hood should have grease filters using metallic grille to trap oil vapours escaping into the fume hood.

NOTE — For detailed information on gas pipe installations, reference may be made to Part E ‘Plumbing services, Section 4 Gas supply’ of this NBCS.

4.7.2 *Thermal Detectors*

These should be installed into fume hoods of large kitchens for hotels, hospitals, and similar areas located in high rise buildings. Arrangements should be made for automatic tripping of the exhaust fan in case of fire. If gas is used, the same should be shut off. The voltage should be 24 V or 100 V d.c. operated with external rectifier. The valve should be of the hand re-set type and should be located in an area segregated from cooking ranges. Valves should be easily accessible. The hood should have manual facility for steam or suitable hood extinguishing gas released depending on duty condition.

4.7.3 Gas cylinders and manifold should need to be housed in a detached location with no other occupancy within distances prescribed in good practice [F(14)] thereof. There should be an enclosure suitably ventilated. It is desirable to provide medium velocity spray nozzles which can be operated by quick opening valve situated away

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from the enclosure.

4.7.4 In the case of gas cylinders, if manifold has to be installed on podium/close to podium, the same should be away from any air intakes/smoke exhaust openings/any windows.

4.7.5 Pressure regulating stations should be designed and installed at critical locations for excess flow shut off valves. Seismic shut off valve at the main distribution point should be installed for buildings having mixed use assembly occupancy (like malls) and institutional occupancy above 15 m.

4.7.6 Gas meters should be housed in a suitably constructed metal cupboard located in a well-ventilated space, keeping in view the fact that LPG is heavier than air and natural gas is lighter than air.

4.7.7 Wherever LPG reticulation/cylinders are used in buildings above 100 m, gas leak detectors should be provided at the usage points and monitored from fire command centre. The cables used for signalling should be circuit integrity cables.

4.7.8 The gas lines should not be installed through any enclosed staircase or electrical shafts, escape routes, refuge areas/refuge floors.

4.7.9 Kitchens working on LPG fuel should not be permitted in basements. Small kitchen using other than LPG fuel, such as induction/PNG/electricity-based, may be permitted in incidental occupancies in the basement.

4.8 Hazardous Areas, Gaseous, Oil Storage Yard, etc

Rooms containing high pressure boilers, refrigerating machinery, transformers, or other service equipment subject to possible explosion should not be located directly under or adjacent to fire exits. All such rooms should be effectively cut-off from other parts of the building and should be provided with adequate vents to the outside air.

All rooms or areas of high hazard in additions to those hereinbefore mentioned, should be segregated, or should be protected with fire resistant walls having fire rating of 120 min as fire, explosion or smoke therefrom is likely to interfere with safe egress from the building. Further,

a) each building should be provided with an approved outside gas shut-off valve conspicuously marked. The detailed requirements regarding safe use of gas should be as specified in Part E 'Plumbing services, Section 4 Gas Supply' of this NBCS; and

b) all exterior openings in a boiler room or rooms that contain central heating equipment, if located below opening in another storey or if less than 3 m from other doors or windows of the same building should be protected by a fire assembly as in **3.5.4**. Such assemblies should be fixed, automatic or self-closing.

4.9 Fire Detection and Alarm

a) The requirements of fire detection and alarm systems are covered for each occupancy in Table 7A to Table 7J and under **6.1** to **6.9** for annunciation to occupants in view of the ensuing vulnerability and to warn occupants early of the existence of fire, so as to facilitate orderly and safe egress;

b) Fire detection and alarm systems in buildings should be so planned and programmed so as to enable operations of various systems and equipment to facilitate requirements leading to life safety, compartmentation and fire protection. These systems and equipment may include electromechanical systems such as air handling units; pressurization systems; smoke management systems; creation of compartmentation through the release of fire barrier, hold-up fire doors, etc; and monitoring of fire water storage tanks and pumps, pressures in hydrant and sprinkler system, etc. These planning and requirements should be based on building occupancy and other requirements on case-to-case basis;

c) Voice evacuation systems should employ English, Hindi and vernacular language using pre-recorded messages and integrate with fire alarm panels for alerting the zone of fire and surrounding zones/floors as required for annunciation (*see also* Table 7A to Table 7J);

d) Appropriate visual warning arrangement through visual strobes/beacons may be considered in appropriate situations particularly in public buildings, at required locations to ensure visual as well as alarm for persons with hearing impairment;

e) For assembly buildings, institutional buildings and all buildings above 30 m in height where fire alarm system is provided in accordance to Table 7A to Table 7J, detectors should also be provided inside the electrical shafts, lift machine rooms, etc, besides occupancy areas;

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f) Fire alarm panels should be connected in peer-to-peer network or with redundant cables, run in different shafts. Each panel should be able to work in standalone mode and master slave architecture may be used where required;

g) The fire detection system should be in accordance with accepted standards [F(15)];

h) Guidelines for selection of various types of fire detectors for different occupancies and their installation and maintenance should be in accordance with good practice [F(16)]. *See also* Handbook for 'Asset and Facility Management' for guidance;

j) In buildings where automatic fire alarm system is provided, the following should be monitored from fire alarm panel:

   1) Water level in all tanks.

   2) Hydrant and sprinkler pressures of respective zones, as provided.

   3) Pump ‘ON/OFF’ status.

   4) All isolation valves, wherever provided with supervisory switch (non-padlock valves).

   5) Other requirements to meet electro-mechanical services interface.

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Table 7A Requirements for Firefighting Installations – For Residential Buildings

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f) *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Fire Detection and Alarm System and LPG/PNG Gas Detector	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	RESIDENTIAL BUILDINGS (A)								
a)	**Lodging and Rooming Houses (A- I)**	**Up to 500 m^2 area and up to 24 m height (both conditions to be met), self-certification by a certified and State approved building professional should be treated acceptable**							
1)	24 m and above in height and, having any area Or Less than 24 m in height but of area,								
i)	floor area on any single floor 501 m^2 to 1 000 m^2 **(HL-1)** *See* Notes 1, 2, 3 and 4	R	R	NR	NR	NR	NR	R	NR
ii)	1 001 m^2 and above **(HL-2)** *See* Notes 2, 3 and 4	R	R	R	NR	NR	NR	R	R

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Table 7A (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Fire Detection and Alarm System and LPG/PNG Gas Detector	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
b)	**Dormitories (A-II)**	**Up to 500 m^2 area and up to 24 m height (both conditions to be met), self-certification by a certified and State approved building professional should be treated acceptable**							
1)	501 m^2 to 1 000 m^2 **(HL-1)** *See* Notes 1, 2, 3 and 4	R	R	NR	NR	NR	NR	NR	NR
2)	1 001 m^2 and above **(HL-2)** *See* Notes 2, 3 and 4	R	R	R	NR	NR	NR	R	NR
c)	**Apartment Houses (A-III)**	**Up to 500 m^2 area and up to 24 m height (both conditions to be met), self-certification by a certified and State approved building professional should be treated acceptable**							
1)	24 m and above but not exceeding 60 m in height; and, height less than 24 m, but of area:								
i)	501 m^2 to 1 000 m^2 **(HL-2)** See Notes 2, 3, 4, 7 and 9	R	R	R	NR	NR	NR	NR	NR

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Table 7A (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Fire Detection and Alarm System and LPG/PNG Gas Detector	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ii)	1 001 m^2 and above **(HL-3)** *See* Notes 2, 3, 4, 5, 7, 9 and 10	R	R	NR	R	R	NR	R	R
2)	Above 60 m height **(CL-4)** *See* Notes 3, 4, 5, 7, 8, 9, and 10	R	R	NR	R	R	R	R	R
d)	**Hotels (A-IV)**	**Up to 500 m^2 area and up to 24 m height (both conditions to be met), self-certification by a certified and State approved building professional should be treated acceptable**							
1)	Up to 24 m in height, but of area:								
i)	501 m^2 to 1 000 m^2 **(HL-3)** *See* Notes 2, 3, 4, 7 and 9	R	R	R	NR	NR	NR	R	NR
ii)	1 001 m^2 and above **(CL-3)** *See* Notes 3, 4, 7 and 9	R	R	NR	R	NR	R	R	R

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Table 7A (*Concluded*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Fire Detection and Alarm System and LPG/PNG Gas Detector	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2)	24 m and above but not exceeding 60 m in height OR 3/4 Star Hotels **(CL-4)** *See* Notes 3, 4, 5, 7, 8 and 9	R	R	NR	R	R	R	R	R
3)	Above 60 m – *See* Note 5								
e)	**Starred (Franchise – 5 Star) Hotels (A-V)**								
1)	Up to 60 m **(CL-5)** *See* Note 4	R	R	NR	R	R	R	R	R
2)	Above 60 m – *See* Note 5								

R – Required NR – Not Required

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REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24 × 7 uninterrupted, such states/areas/ jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL Protection is required as per above Table**.**

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

NOTES

1 If the building has kitchen, the protection level will be **HL-2**.

2 If the building has basement to be protected with sprinklers, the protection level should comply with **CL-3**.

3 If the building has electrical vehicles (EV) parks in podium or basements, it should be protected with sprinklers and complying to **CL-5**.

4 Rate of rise of heat sensor/detection system should be provided in EV (Electrical Vehicles) parks and charging areas. Smoke sensor/detectors should be provided in all basements in all areas other than internal combustion engine (ICE) vehicles parks as part of the fire alarm system. ICE vehicle parks should be provided with carbon monoxide sensors as part of fire alarm system to activate ventilation system.

5 If the building height exceeds 60 m the hydraulic calculations meeting recommended system architecture with multi-level pumping and storage with gravity redundant down comer may be considered. The pumps considered should not exceed 12 bar shutoff pressure.

6 Pump pressure and quantity should be supported by hydraulic calculations.

7 2,500 lpm at 10 bar common pumping and water storage of 2,55,000 litre should be provided for a cluster of maximum 5 buildings, with or without common basement. The buildings should not be closer than 9 m. If the buildings are closer than 9 m, or the basement is used for EV parking and or charging facilities, the protection level should comply with **CL-5**.

8 Multi-level pumping and water storage as per schematic line drawing (SLD) may be considered for cluster buildings more than 45 m in height; and water storage at every 45 m above should be provided for individual buildings.

9 If the cluster of buildings exceeds 5, another set of pumps and water storage of similar capacity should be provided. A maximum of two such sets is recommended, provided it satisfies the hydraulic requirements and functioning at the remotest point.

10 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

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Table 7B Requirements for Firefighting Installations – For Educational Buildings

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f) *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	EDUCATIONAL BUILDINGS (B)	**Up to 500 m^2 area and up to 24 m height (both conditions to be met), self-certification by a certified and State approved building professional should be treated acceptable**							
1)	24 m and above but not exceeding 45 m; And, height less than 24 m, but of area:								
i)	501 m^2 to 1 000 m^2 **(HL-3)** *See* Notes 1, 2, 3, 5, 7 and 9	R	R	NR	R	R	NR	R	R
ii)	1 001 m^2 and above **(CL-4)** *See* Notes 3, 5, 7, 9 and 10	R	R	NR	R	R	R	R	R
2)	45 m and above but not exceeding 60 m in height **(CL-4)** (*See* Notes 5, 6, 7, 8, 9 and 10)	R	R	NR	R	R	R	R	R
3)	Above 60 m – *See* Note 5								

R – Required NR – Not Required

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REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24 × 7 uninterrupted, such states/areas/ jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL Protection is required as per above Table**.**

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

NOTES

1 If there are laboratories, AV/computer rooms, auditoriums, they should be protected with sprinkler and the protection level should comply with **CL-3**.

2 If the building has basement to be protected with sprinklers, the protection level should comply with **CL-3**.

3 If the building has electrical vehicles (EV) parks in podium or basements, it should be protected with sprinklers and complying to **CL-5**.

4 Rate of rise heat sensor/detection system should be provided in Electrical Vehicles (EV) parks and charging areas. Smoke sensor/detectors should be provided in all basements in all areas other than internal combustion engine (ICE) vehicles parks as part of the fire alarm system. ICE vehicle parks should be provided with carbon monoxide sensors as part of fire alarm system to activate ventilation system.

5 If the building height exceeds 60 m the hydraulic calculations meeting recommended system architecture with multi-level pumping and storage with gravity redundant down comer may be considered. The pumps considered should not exceed 12 bar shutoff pressure.

6 Pump pressure and quantity should be supported by hydraulic calculations.

7 2,500 lpm at 10 bar common pumping and water storage of 2,55,000 litre should be provided for a cluster of maximum 5 buildings, with or without common basement. The buildings should not be closer than 9 m. If the buildings are closer than 9 m, or the basement is used for EV parking and or charging facilities, the protection level should comply with **CL-5**.

8 Multi-level Pumping and water storage as per schematic line drawing (SLD) may be considered for cluster buildings more than 45 m; and water storage at every 45 m above should be provided for individual buildings.

9 If the cluster of buildings exceeds 5, another set of pumps and water storage of similar capacity should be provided. A maximum of two such sets is recommended, provided it satisfies the hydraulic requirements and functioning at the remotest point.

10 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

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Table 7C Requirements for Firefighting Installations – For Institutional Buildings

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f) *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	INSTITUTIONAL BUILDINGS (C)								
a)	**Nursing homes and sanatoria**	**Up to 500 m^2 area and up to 24 m height (both conditions to be met), self-certification by a certified and state approved building professional should be treated acceptable**							
i)	(*see* Note 1) Building height above 15 m; and, for heights up to 15 m, and area 501 m^2 and above **(HL-3)** *See* Notes 1, 2, 4, 6 and 9	R	R	R	NR	NR	NR	R	NR
b)	**Hospitals (C-I)**	**Up to 500 m^2 area and up to 24 m height (both conditions to be met), self-certification by a Certified and State Approved building professional should be treated acceptable**							
1)	For heights not exceeding 45 m in height								

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Table 7C (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	501 m^2 to 1 000 m^2 **(CL-3)** *See* Notes 2, 4, 6, 7, 9 and 10	R	R	NR	R	R	R	R	NR
ii)	Above 1 001 m^2 **(CL-4)** *See* Notes 2, 4, 6, 7, 9 and 10	R	R	NR	R	R	R	R	R
2)	Above 45 m but not exceeding 60 m in height **(CL-5)** *See* Notes 4, 6, 7, 9 and 10	R	R	NR	R	R	R	R	R
3)	Above 60 m – *See* Note 3								
b)	**Custodial, Penal and Mental Institutions (C-II and III)**	**Up to 500 m^2 area and up to 24 m height (both conditions to be met), self-certification by a Certified and State Approved building professional should be treated acceptable**							

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Table 7C (*Concluded*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1)	For heights not exceeding 45 m in height								
i)	501 m^2 to 1 000 m^2 **(HL-2)** *See* Notes 1, 2, 4 and 6	R	R	R	NR	NR	NR	NR	R
ii)	1 001 m^2 and above **(HL-3)** *See* Notes 1, 2, 4, 6 and 9	R	R	NR	R	R	NR	R	R
2)	Above 45 m **(HL-4)** *See* Notes 1, 2, 3, 6, 8 and 9	R	R	NR	R	R	NR	R	R

R – Required NR – Not Required

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REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24 × 7 uninterrupted, such states/areas/jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL Protection is required as per above Table**.**

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

NOTES

1 Basement area or storage of oxygen or any medical gases or any gas fuel, laundry or linen/waste, transformer/HT rooms within the building foot print or in basement should be protected with sprinkler and the protection level should comply with **CL-3**.

2 If the building has electrical vehicles (EV) parks in podium or basements, it should be protected with sprinklers and complying to **CL-5**.

3 If the building height exceeds 60 m the hydraulic calculations meeting recommended system architecture with multi-level pumping and storage with gravity redundant down comer may be considered. The pumps considered should not exceed 12 bar shutoff pressure.

4 Protection should comply to supplementary protection for specific hazard/critical rooms as per Table 9/ Table 10/ Table 11 as applicable.

5 Pump pressure and quantity should be supported by hydraulic calculations.

6 Rate of rise heat sensor/detection system should be provided in electrical vehicles (EV) parks and charging areas. Smoke sensor/detectors should be provided in all basements in all areas other than internal combustion engine (ICE) vehicles parks as part of the fire alarm system. ICE vehicle parks should be provided with carbon monoxide sensors as part of fire alarm system to activate ventilation system. (recommendation only for parking and podium)

7 3785/2500 lpm at 10 bar common pumping and water storage of 3,50,000/2,55,000 litre should be provided of cluster of maximum 5 building 45 m height, with or without common basement. The buildings should not be closer than 9 m. If the buildings are closer than 9 m, or the basement is used for Electric Vehicles (EV) parking and or charging facilities, the protection level should comply with **CL-5**.

8 Multi-level pumping and water storage as per schematic line drawing (SLD) may be considered for cluster buildings more than 45 m; and water storage at every 45 m above should be provided for individual buildings.

9 If the cluster of buildings exceeds 5, another set of pumps and water storage of similar capacity should be provided. A maximum of two such sets is recommended, provided it satisfies the hydraulic requirements and functioning at the remotest point.

10 If the building height exceeds 30 m it should comply hydraulic calculations meeting recommended system architecture.

11 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

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Table 7D Requirements for Firefighting Installations – For Assembly Buildings

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f) *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	ASSEMBLY BUILDINGS (D) *See* Note 4								
a)	**Assembly Buildings**	**Up to 500 m^2 area and up to 9 m height (both conditions to be met), self-certification by a certified and State approved building professional should be treated acceptable**							
1)	9 m and above but not exceeding 15 m in height; and, for heights less than 9 m; and area *See* Note 6								
i)	501 m^2 to 1 000 m^2 **(HL-3)** *See* Notes 1, 2, 3, 5 and 8	R	R	NR	R	NR	NR	R	NR

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Table 7D (*Concluded*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ii)	1 001 m^2 and above **(CL-4)** *See* Notes 2, 5, 8 and 9	R	R	NR	R	R	R	R	NR
2)	Above 15 m in height **(CL-4)** *See* Notes 2, 5, 6, 7, 8 and 9	R	R	NR	R	R	R	R	NR

R – Required NR – Not Required

REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24×7 uninterrupted, such states/areas/ jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL Protection is required as per above Table**.**

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

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NOTES

1 If the building has basement to be protected with sprinklers, the protection level should comply with **CL-3**.

2 If the building has electrical vehicles (EV) parks in podium or basements, it should be protected with sprinklers and complying to **CL-5**.

3 Live cooking kitchens, boiler/furnace rooms, laundry or linen/waste rooms, transformer/HT rooms within the building foot print or in basement the area should be protected with sprinkler protection and should comply with **CL-4**.

4 Pump pressure and quantity should be supported by hydraulic calculations.

5 Rate of rise heat sensor/detection system should be provided in electrical vehicles (EV) parks and charging areas. Smoke sensor/detectors should be provided in all basements in all areas other than internal combustion engine (ICE) vehicles parks as part of the fire alarm system. ICE vehicle parks should be provided with carbon monoxide sensors as part of fire alarm system to activate ventilation system. (recommendation only for parking and podium).

6 2,500 lpm at 10 bar common pumping and water storage of 2,55,000 litre should be provided for a cluster of maximum 5 buildings, with or without common basement. The buildings should not be closer than 9 m. If the buildings are closer than 9 m, or the basement is used for EV parking and or charging facilities, the protection level should comply with **CL-5**.

7 Multi-level pumping and water storage as per schematic line drawing (SLD) may be considered for cluster buildings more than 45 m; and water storage at every 45 m above should be provided for individual buildings.

8 If the cluster of buildings exceeds 5, another set of pumps and water storage of similar capacity should be provided. A maximum of two such sets is recommended, provided it satisfies the hydraulic requirements and functioning at the remotest point.

9 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

Table 7E Requirements for Firefighting Installations – For Business Buildings

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f) *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	BUSINESS BUILDINGS (E) *See* Notes 5								
a)	**Business Buildings (Human Occupied)**	**Up to 500 m^2 area and up to 15 m height (both conditions to be met), self-certification by a Certified and State approved building professional should be treated acceptable**							

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Table 7E (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1)	15 m and above but not exceeding 45 m in height; and, for heights less than 15 m and area								
i)	500 m^2 to 1 000 m^2 **(CL-2)** *See* Notes 1, 2, 3, 6, 7, 9 and 11	R	R	R	NR	NR	R	R	R
ii)	1 001 m^2 to 3 000 m^2 **(CL-3)** *See* Notes 2, 3, 6, 7, 9 and 11	R	R	NR	R	R	R	R	R
iii)	3 001 m^2 and above **(CL-4)** *See* Notes 2, 3, 6, 7, 9 and 11	R	R	NR	R	R	R	R	R

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Table 7E (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2)	Above 45 m but not exceeding 60 m height **(CL-5)** *See* Notes 3, 4, 6, 7, 8, 9 and 11	R	R	NR	R	R	R	R	R
3)	For buildings over 60 m height	*See* Note 4							
b)	**Data Centres (Machine Environment)** *See* Notes 3, 12 ,13 and 15								
1)	Less than 15 m in height								
i)	Floor Area on any single floor up to 1 000 m^2	R	R	NR	R	R	R	R	R
ii)	1 001 m^2 and above	R	R	NR	R	R	R	R	R

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Table 7E (*Concluded*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2)	Above 15 m in height								
i)	Floor area on any single floor up to 1 000 m^2	R	R	NR	R	R	R	R	R
ii)	1 001 m^2 and above	R	R	NR	R	R	R	R	R

R – Required NR – Not Required

REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24 × 7 uninterrupted, such states/areas/jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL protection is required as per above table.

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

NOTES

1 If the building has basement to be protected with sprinklers, the protection level should comply with **CL-3**.

2 If the building has Electrical Vehicles (EV) parks in podium or basements, it should be protected with sprinklers and complying to **CL-5**.

3 Protection should comply to supplementary protection for specific hazard/critical rooms as per Table 9/ Table 10/ Table 11 as applicable.

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4 If the building height exceeds 60 m the hydraulic calculations meeting recommended system architecture with multi-level pumping and storage with gravity redundant down comer may be considered. The pumps considered should not exceed 12 bar shutoff pressure.

5 Pump pressure and quantity should be supported by hydraulic calculations.

6 2500 lpm at 10 bar common pumping and water storage of 2,55,000 litre should be provided for a cluster of maximum 5 buildings, with or without common basement. The buildings should not be closer than 9 m. If the buildings are closer than 9 m, or the basement is used for EV parking and or charging facilities, the protection level should comply with **CL-5**.

7 3785 lpm at 10 bar common pumping and water storage of 3,50,000 litre should be provided of cluster of maximum 5 building, with or without common basement. The buildings should not be closer than 9 m. If the buildings are closer than 9 m, or the basement is used for Electric Vehicles (EV) parking and or charging facilities, the protection level should comply with **CL-5**.

8 Multi-level pumping and water storage as per schematic line drawing (SLD) (*see* Fig. 20) may be considered for cluster buildings more than 45 m; and water storage at every 45 m above should be provided for individual buildings.

9 If the cluster of buildings exceeds 5, another set of pumps and water storage of similar capacity should be provided. A maximum of two such sets is recommended, provided it satisfies the hydraulic requirements and functioning at the remotest point.

10 The entire building it should be protected with sprinkler and the protection level should comply with **CL-5**. IT/Data Hall should be protected with suitable clean agent gas suppression only if the racks are without BBU (not exceeding 20 kWh backup battery units).

11 All internet data centres or hyper scales or colocation data centres comply with protection level **CL6**.

12 If the IT/data hall (DC) racks are with BBUs with Lithium-ion batteries not exceeding 20 kWh/rack, wet or dry sprinkler/pre-action/water mist (3rd party tested for lithium ion BBUs) should be deployed. If the BBUs exceed 20 kWh/rack, water mist should not be installed.

13 If the cluster of data centre buildings to a maximum of 3, common pumping system and storage may be with an additional diesel engine pump, with double water storage.

14 If the any of the building houses lithium-ion energy storage systems exceeding 600 kWh/floor, the building should comply to protection level **CL-6**.

15 Lithium-ion battery energy storage systems (BESS) room should be protected with wet/single interlock pre action sprinkler only, considering entire room as “assumed area of operation”. Pump and water storage should be calculated based on maximum design and hydraulic calculations whichever is higher.

16 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

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Table 7F Requirements for Firefighting Installations – For Mercantile Buildings

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f) *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	MERCANTILE BUILDINGS (F) *See* Note 4								
a)	**Mercantile Buildings (F)**	**Up to 500 m^2 area and up to 15 m height (both conditions to be met), self-certification by a certified and State approved building professional should be treated acceptable**							
1)	Above 15 m but not exceeding 30 m in height; and, for heights less than 15 m and area								
i)	501 m^2 to 1 000 m^2 **(HL-3)** *See* Notes 1, 2, 3, 5, 6 and 7	R	R	R	NR	NR	NR	R	NR
ii)	1 001 m^2 and above **(CL-4)** *See* Notes 2, 3, 5, 6, 7 and 8	R	R	NR	R	R	R	R	NR

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Table 7F (*Concluded*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2)	Above 30 m	See Note 5							
b)	**Underground Shopping Complex** **(CL-5)** *See* Note 3	R	R	NR	R	R	R	R	R

R – Required NR – Not Required

REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24 × 7 uninterrupted, such states/areas/ jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL Protection is required as per above table.

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

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NOTES

1 If the building has basement to be protected with sprinklers, the protection level should comply with **CL-3**.

2 If the building has electrical vehicles (EV) parks in podium or basements, it should be protected with sprinklers and complying to **CL-5**.

3 Protection should comply to supplementary protection for specific hazard/critical rooms as per Table 9/ Table 10/ Table 11 as applicable.

4 Pump pressure and quantity should be supported by hydraulic calculations.

5 If the building height exceeds 30 m it should comply hydraulic calculations meeting recommended system architecture.

6 If the building height exceeds 60 m multi-level pumping and storage with gravity redundant down comer. The pumps considered should not exceed 12 bar shutoff pressure.

7 Rate of rise heat sensor/detection system should be provided in electrical vehicles (EV) parks and charging areas. Smoke sensor/detectors should be provided in all basements in all areas other than internal combustion engine (ICE) vehicles parks as part of the fire alarm system. ICE vehicles parks should be provided with carbon monoxide sensors as part of fire alarm system to activate ventilation system.

8 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

Table 7G Requirements for Firefighting Installations – For Industrial Buildings

(*See also* Annex N on Fire Protection for Specific Industries)

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f), Annex N *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Industrial Buildings (G) *See* Note 5								
a)	**Low Hazard (G-1)** *See* Notes 1 and 6								

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Table 7G (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Built up area up to 1 000 m^2 (Including the MSMEs) **(HL-1)**	R	R	NR	NR	NR	NR	NR	NR
ii)	Built up area from 1 001 m^2 to 2 000 m^2 **(HL-2)**	R	R	R	NR	NR	NR	NR	NR
iii)	Built up area from 2 001 m^2 up to 3 000 m^2 **(HL-3)**	R	R	NR	NR	R	NR	R	NR
iv)	Above 3 001 m^2 **(HL-4)** *See* Note 1	R	R	NR	NR	R	NR	R	NR

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Table 7G (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
b)	**Moderate Hazard (G-2)** *See* Notes 1, 4 and 6								
i)	Built up area up to 500 m^2 **(HL-2)**	R	R	R	NR	NR	NR	NR	NR
ii)	Built up area from 501 m^2 to 2 000 m^2 **(HL-3)**	R	R	NR	R	R	NR	R	NR
iii)	Built up area from 2 001 m^2 to 3 000 m^2 **(HL-4)**	R	R	NR	R	R	NR	R	NR
iv)	Built up area above 3 001 m^2 **(CL-5)**	R	R	NR	R	R	R	R	NR

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Table 7G (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
c)	**High Hazard (G- 3)**								
i)	Built up area up to 250 m^2 **(CL-4)** *See* Notes 1, 2, 3 and 7	R	R	NR	R	R	R	NR	NR
ii)	Built up area from 251 m^2 to 1 000 m^2 **(CL-5)** *See* Notes 1, 2, 3, 4 and 7	R	R	NR	R	R	R	R	NR

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Table 7G (*Concluded*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
iii)	Built up area above 1 001 m^2 **(CL-6)** *See* Notes 2, 3, 4 and 7	R	R	NR	R	R	R	R	R

R – Required NR – Not Required

REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24×7 uninterrupted, such states/areas/ jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL Protection is required as per above Table**.**

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

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NOTES

1 If the building has any type of combustible storage, combustible packing, fuel storage, boilers, furnaces such areas should be protected and should comply to protection level **CL-6**.

2 Alternate suppression agent should be considered as per relevant Indian Standards if water is not a suitable agent for materials protected.

3 Oxidizing materials, ignitable liquids, water resistive chemicals, explosives, aluminium dust, or any other explosive environment should be treated separately.

4 Protection should comply to supplementary protection for specific hazard/critical rooms as per Table 9/ Table 10/ Table 11 as applicable.

5 Pump pressure and quantity should be supported by hydraulic calculations.

6 If the cluster of buildings exceeds 5, another set of pumps and water storage of similar capacity should be provided. A maximum of two such sets is recommended, provided it satisfies the hydraulic requirements and functioning at the remotest point.

7 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

Table 7H Requirements for Firefighting Installations – For Storage Buildings

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f) *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Storage Buildings (H) (*See* Note 1, 2 and 3)								
i)	Built-up area up to 500 m^2 **(HL-4)**	R	R	NR	R	NR	NR	R	NR
ii)	501 m^2 to 1 000 m^2 **(HL-5)**	R	R	NR	R	R	NR	R	NR

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Table 7H (*Concluded*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
iii)	1 001 m^2 to 2 000 m^2 or building ridge height up to 7.6 m **(CL-6)**	R	R	R	NR	R	R	R	NR
iv)	Above 2 001 m^2 or Building ridge height above 7.6 m and up to 9.0 m **(CL-7)**	R	R	NR	R	R	R	R	R
v)	Building of any height with rack storage	R	R	NR	R	R	R	R	R

R – Required NR – Not Required

REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24×7 uninterrupted, such states/areas/ jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL Protection is required as per above table.

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

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NOTES

1 Pump pressure mentioned in above table is considering minimum requirement, it should be supported hydraulic calculations. The above Table applies to the below Storage categories only, stored on ground, not exceeding 3.7 m, (12 feet) excluding tyre storage. In addition, they should also comply with supplementary protection for all hazard/critical rooms as per Table 9/Table 10/ Table 11:

a) Packaging materials stored on ground with or without pallets

b) Raw materials storage, in solid pile, shelves, pallets

c) Finished goods storage, solid pile, shelves, pallets

d) Miscellaneous storage in and around manufacturing/assembly/packaging areas

e) Retail storage in shelves other than catwalk storage

2 For rack storages, with plastic/combustible packaging (exposed/cartoned unexpanded or exposed/ cartoned expanded), water reactive solids/liquid storages, lithium battery storages, ignitable chemical storages, or retail cat walk, any other oxidizing agent storages, relevant Indian Standards should be followed, and pumping capacities and water storage should be justified by way of hydraulic calculations.

3 If the cluster of buildings exceeds 5, another set of pumps and water storage of similar capacity should be provided. A maximum of two such sets is recommended, provided it satisfies the hydraulic requirements and functioning at the remotest point

4 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

Table 7J Requirements for Firefighting Installations – For Hazardous Buildings

[*Clauses* 4.9 (a), 4.9 (c), 4.9(e), 5.1.1 (a), 5.1.1(d), 5.1.2.1, 5.1.3 (a), D-6.1, G-2(f) *and* Table 31]

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Hazardous Buildings (J) (*See* Notes 1 and 2)								
1)	Up to 15 m in height								
i)	Single storey building **(CL-7)**	R	R	NR	R	R	R	R	NR

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Table 7J (*Concluded*)

Sl No.	Type of Building Occupancy	Type of Installation							
		Fire Extinguisher	First Aid Hose Reel	Down Comer	Wet Riser	Yard Hydrant	Automatic Wet Sprinkler System	Automatic Detection and Alarm System	Public Address and Voice Evacuation System
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
ii)	More than one floor building but not exceeding 15 m **(CL-8)**	R	R	NR	R	R	R	R	R

R – Required NR – Not Required

REMARK 1: Any state or area where the municipal supply caters to municipal/public yard hydrant system with hydrant outlets provided throughout the premises with adequate water supply meeting the wet riser requirement demand flow and pressure 24 × 7 uninterrupted, such states/areas/ jurisdiction can replace the wet riser system and its associated pumping with water storage with a dry riser system. Dry riser system is also recommended for areas where ambient temperature below is 4 °C and has facility of connecting the yard hydrant to the dry riser in any event of fire in the building. This system is to be maintained with quarterly checks to ensure the system integrity to handle the required flow and pressure. This is applicable for buildings height only up to 24 m where HL Protection is required as per above Table.

REMARK 2: Sharing of water storage tank may be permitted between the adjacent neighbouring properties including industry clusters, without any loss of hydraulic effects (which is essential to fight the fire during an emergency).

NOTES

1 These buildings should deploy specific tailor-made systems and solutions in terms of water hydrant/sprinklers, dry chemical, dry powder, water mist, gas/ wet chemical suppression, foam or/and any other as per relevant Indian Standards and international standards (wherever Indian Standards are not available) in consultation with local fire services or Authority having Jurisdiction (AHJ).

2 Pump pressure and quantity should be supported by hydraulic calculations.

3 Table 7K and Table 7M suggesting the basis for water quantity required for fire-fighting, respectively for combined (sprinkler and hose) protection and hose protection be considered.

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Table 7K Base Calculations for Combined Protection System (Sprinkler System and Hose Stream)

[*Clause* 5.1.1 (a)]

Sl No.	Combined System	Hazard Classification	Sprinkler Demand		Hose Stream Flow @ 3.5 bar	Number of Hose Streams	Pump Capacity and Quantity	Duration min
(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)
i)	Level of Protection – **CL-1**	Extra Low Hazard -1	2.25	84	50	2	379 lpm × 1	30 – 60
ii)	Level of Protection – **CL-2**	Extra Low Hazard -2	4.1	140	170	2	946 lpm × 1	30 – 60
iii)	Level of Protection – **CL-3**	Low Hazard	6.1	230	285	3	1 892 lpm × 1	30 – 60
iv)	Level of Protection – **CL-4**	Moderate Hazard -1	8.1	230	285	3	2 500 lpm × 1	60 – 120
v)	Level of Protection – **CL-5**	Moderate Hazard -2	12.2	230	475	3	3 785 lpm × 1	60 – 120
vi)	Level of Protection – **CL-6**	Extra Hazard -1	16.3	230	475	3	4 731 lpm × 1	60 – 120
vii)	Level of Protection – **CL-7**	Extra Hazard -2	18.3	280	670	4	7 570 lpm × 1	60 – 120
viii)	Level of Protection – **CL-8**	High Hazard	24.5	280	1050	4	4731 lpm x 2	60 – 120
Pump capacity = Total flow with 20 percent overflow and operating at 140 percent capacity. For example, for **CL-5**, capacity will be (12.2 × 230) + (475 × 3) = 4 231 litre; with overflow margin works to 5 077.2 litre; and pump selection will be 5 077.2/140*100 = 3 627 lpm (and the nearest Indian Standard pump is 3 785 lpm).								

NOTES

1 'Pump' implies, providing an electric pump and 'Standby pump of equivalent capacity'. For loss in pressure, jockey pump is also to be provided.

2 The duration of firefighting may be decided from 30 min to 120 min based on the hazard, fire preparedness, local conditions, to name a few.

3 The required quantity of water may be calculated as per the respective Indian Standards (where available); or based on the Table 7K and Table 7M.

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Table 7M Base Calculations for Hose Stream Protection System

[*Clause* 5.1.1 (a) *and* D-6.1]

Sl No.	Hose Stream Only	Hazard Classification	Hose Stream Flow	Number of Hose Streams	Pump Capacity and Quantity	Duration min
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Level of Protection – **HL-1**	Extra Light -1	50	4	379 lpm × 1	30 – 60
ii)	Level of Protection – **HL-2**	Extra Light -2	170	4	946 lpm × 1	30 – 60
iii)	Level of Protection – **HL-3**	Low Hazard	270	4	1 514 lpm × 1	30 – 60
iv)	Level of Protection – **HL-4**	Moderate -1	475	4	2 839 lpm × 1	60 – 120
v)	Level of Protection – **HL-5**	Moderate -2	670	5	4 731 lpm × 1	60 – 120
vi)	Level of Protection – **HL-6**	Extra Hazard	670	6	5 677 lpm × 1	60 – 120

Pump capacity = Total flow with 40 percent overflow and operating at 140 percent capacity. For example, for **HL-3**, capacity will be 270 × 4 = 1 080 litre; together with overflow margin works to 1 512 litre; and pump selection will be 1 512/140 × 100 = 1 514 lpm (nearest Indian Standard pump).

NOTES

1 'Pump' implies, providing an Electric pump and 'Standby pump of equivalent capacity'. For loss in pressure, jockey pump is also to be provided.

2 The duration of firefighting may be decided from 30 min to 120 min based on the hazard, fire preparedness, local conditions, to name a few.

3 The required quantity of water may be calculated as per the respective Indian Standards (where available); or based on the Table 7K and Table 7M.

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4.10 Fire Officer

The essential capabilities of the Fire Officer should be to maintain fire equipment, develop and implement fire safety operational plans, train occupants on fire tools and evacuation, and coordinate with the city fire brigade to ensure constant safety compliance. It is recommended that a qualified Fire Officer should be stationed on-site for large building complexes and specific high-rise or high-risk buildings.

4.11 Fire Drills and Fire Orders

Fire notices/orders should be prepared to fulfil the requirements of firefighting and evacuation from the buildings in the event of fire and other emergency. The occupants should be made thoroughly conversant with their action in the event of emergency, by displaying fire notices at vantage points and also through regular training. Such notices should be displayed prominently in bold lettering. The State/Local Authorities may also decide on the nature and frequency of fire drills to be carried out in buildings.

5 FIRE PROTECTION

5.1 Fire Extinguishers/Fixed Firefighting Installations

5.1.1 All buildings depending upon the occupancy use and height should be protected by fire extinguishers, hose reels, wet riser, down-comer, yard hydrants, automatic sprinkler installation, deluge system, high/medium velocity water spray, foam, water mist systems, gaseous or dry powder system, manual/automatic fire alarm system, etc, in accordance with the provisions of various clauses given below, as applicable:

a) These fire extinguishing equipment and their installation should be in accordance with accepted standards [F(17)]. The extinguishers should be mounted at a convenient height to enable its quick access and efficient use by all in the event of a fire incidence. The requirements of fire extinguishers/yard hydrant systems/wet riser/down-comer installation, etc, should be as specified in Table 7A to Table 7J. *See also* Table 7K and Table 7M for guidance, on base calculation for capacity of water storage tanks and fire pumps. The requirements regarding size of mains/risers should be as given in Table 8. The typical arrangements of down-comer and wet riser installations, as also the pumping system are shown in Fig. 15, Fig. 16 and Fig. 17. The wet riser should be designed for zonal distribution ensuring that unduly high pressures are not developed in risers and hose-pipes.

b) First-aid firefighting appliances should be provided and installed in accordance with good practice [F(18)]. The firefighting equipment and accessories to be installed in buildings for use in firefighting should also be in accordance with the accepted standard [F(17)] and should be maintained periodically so as to ensure their perfect serviceability at all times.

c) Valves in fixed firefighting installations should have supervisory switch with its signalling to fire alarm panel or to have chain(s), pad lock(s), label, and tamper-proof security tag(s) with serial number to prevent tampering/unauthorized operation. These valves should be kept in their intended 'open' position.

d) In addition to wet riser or down-comer, first-aid hose reels should be installed in buildings (where required under Table 7A to Table 7J) on all the floors, in accordance with accepted standard [F(19)]. The first-aid hose reel should be connected directly to the riser/down-comer main and diameter of the hose reel should not be less than 19 mm.

e) Wet risers should be interconnected at terrace level to form a ring and cut-off should be provided for each connection to enable repair/ maintenance without affecting rest of the system.

f) Pressure at the hydraulically remote hydrant and at the highest hydrant should not be less than 3.5 bar. The pressure at the hydrants should however not exceed 7.0 bar, considering the safety of operators. It may be planned to provide orifice plates for landing valves to control pressure to desired limit especially at lower levels. This could also be achieved through other suitable means of pressure reducing devices such as pressure-controlled hydrant valves.

g) Hydrants for firefighting and hose reels should be located in the lobby in firefighting shaft. Those hydrants planned to be provided near fire exit staircase on the floor should be within 5 m from fire exit door in exit access. Such hydrant cabinet may finish with doors to meet interior finishes with requirement of glass panel to provide visibility to the installations inside and inscribed with the word: 'FIRE HOSE CABINET' of letter size 75 mm in height and 12 mm in width. Such door of the fire hose cabinet need not be fire resistant rated. The location of such cabinets should be shown on floor plan and duly displayed in the landing of the respective fire exit staircase.

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5.1.2 *Static Water Storage Tanks and Pump House*

5.1.2.1 *Static water storage tanks*

A satisfactory supply of water for the purpose of firefighting should always be available in the form of underground/terrace level static storage tank with capacity specified for each building with arrangements or replenishment.

Water for the hydrant services should be stored in an easily accessible surface/underground lined reservoir or above ground tanks made of steel or concrete or masonry. The effective capacity of the reservoir above the top of the pump casing (flooded suction) for various types of occupancies should be as indicated in Table 7A to Table 7J.

Water for firefighting should be stored in two or more interconnected compartments of equal size to facilitate cleaning and maintenance of the tanks without interrupting the water availability for firefighting.

To prevent stagnation of water in the static water storage tank, the suction tank of the domestic water supply should be fed only through an overflow arrangement from the fire water storage tanks to maintain the level therein at the minimum specified capacity.

Alternatively, domestic and fire water can be stored in two interconnected compartments as mentioned above. The suction inlet(s) for the domestic water pumps should be so located at an elevation that minimum water requirements for firefighting as stated in Table 7A to Table 7J will be always available for fire pumps.

The static storage water supply required for the above-mentioned purpose should entirely be accessible to the fire engines of the local fire service. Sufficient number of manholes should be provided for inspection, repairs, insertion of suction hose, etc. As an alternative to the arrangement of manholes to allow access from the top, suitable arrangement to enable efficient access to the tank by the firemen from the adjoining fire pump room having direct access from the ground level, should be made. The underground fire water storage tank(s) should not be more than 7 m in depth from the level having fire brigade draw-out connection, while the draw-out connection should not be more than 5 m away from the tank wall.

The covering slab and its supporting wall/supporting system should be able to withstand a total vehicular load of 45 tonnes (or higher as applicable) equally divided as a four-point load when the slab forms a part of fire apparatus pathway/driveway.

The static water storage tank should be provided with a fire brigade collecting head with 4 number 63 mm diameter (2 number 63 mm diameter for pump with capacity 1 400 litre/min) instantaneous male inlets arranged in a valve box at a suitable point at street level. The same should be connected to the static tank by a suitable fixed galvanized iron pipe not less than 150 mm in diameter to discharge water into the tank when required at the rate of 2 250 litre/min if tank is in the basement or not approachable for the fire engines.

Each of the static water storage tanks should also be provided with a fire brigade draw out collecting head with 63 mm diameter instantaneous male draw out arranged in a valve box at a suitable point at street level. This draw out should be connected to galvanized iron pipe of 100 mm diameter with foot valve arrangement in the tank.

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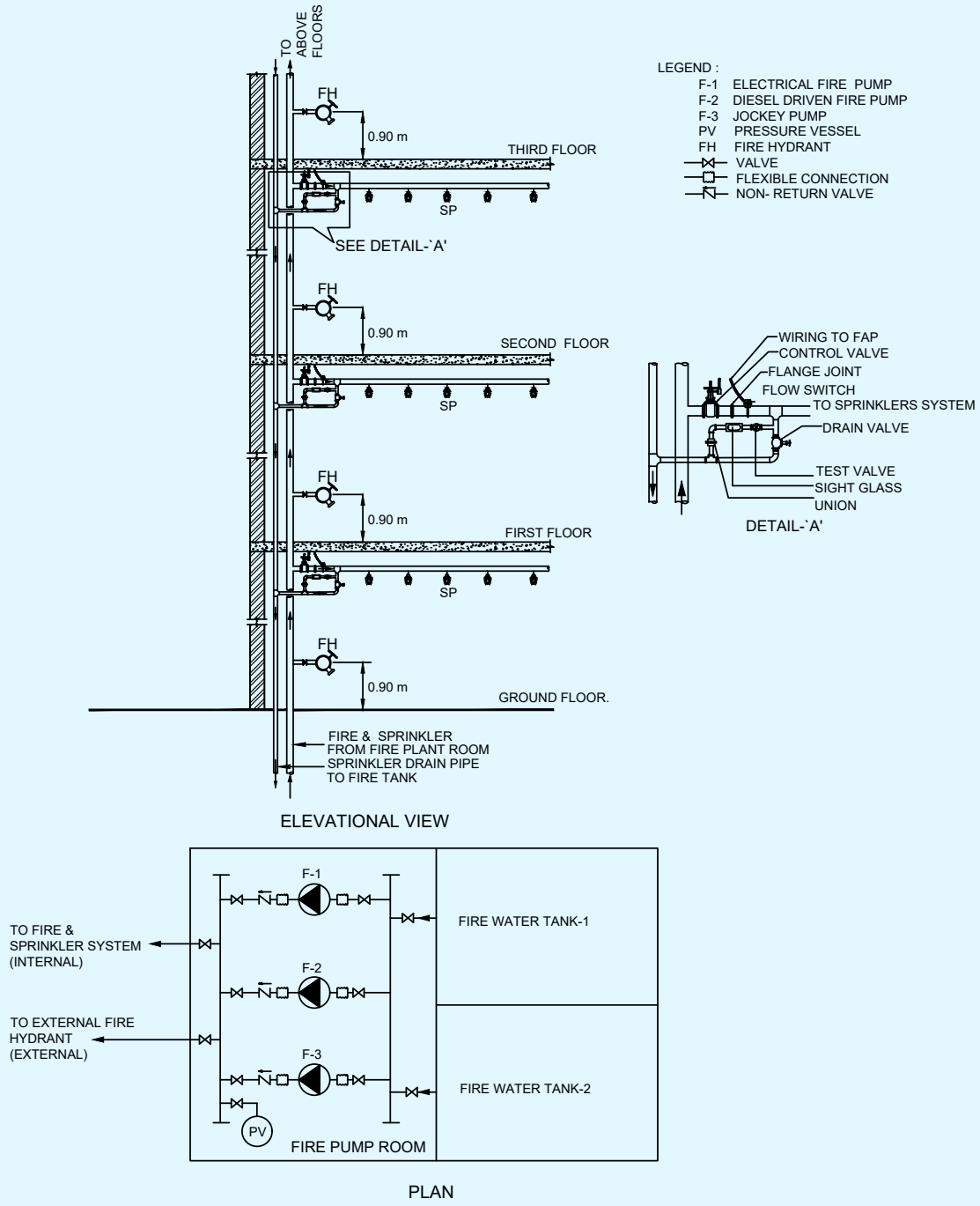

FIG. 15 TYPICAL SYSTEM OF PUMPING WITH ONE ELECTRIC, ONE DIESEL FIRE PUMP

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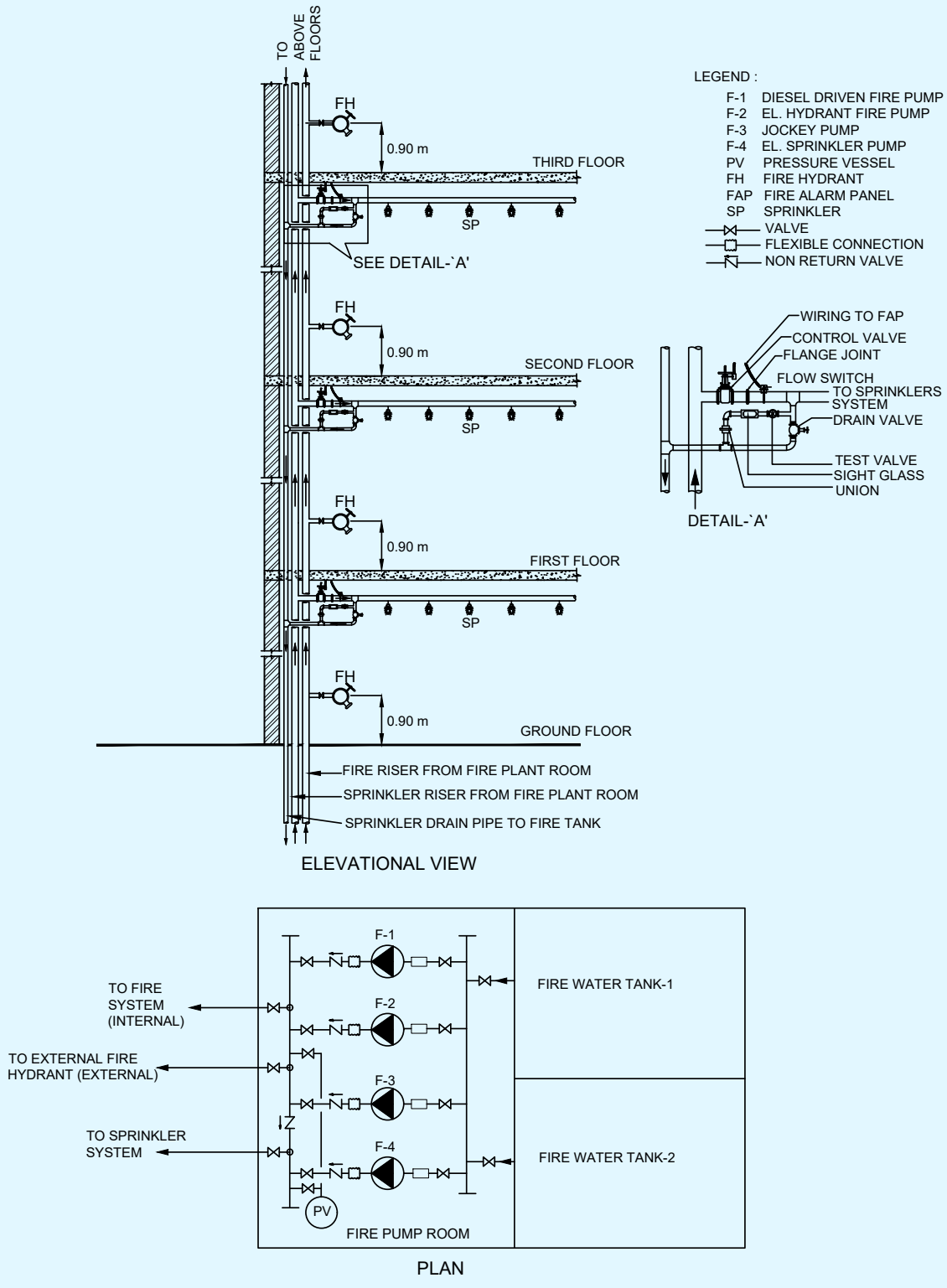

FIG. 16 TYPICAL SYSTEM OF PUMPING WITH TWO ELECTRIC, ONE DIESEL FIRE PUMP

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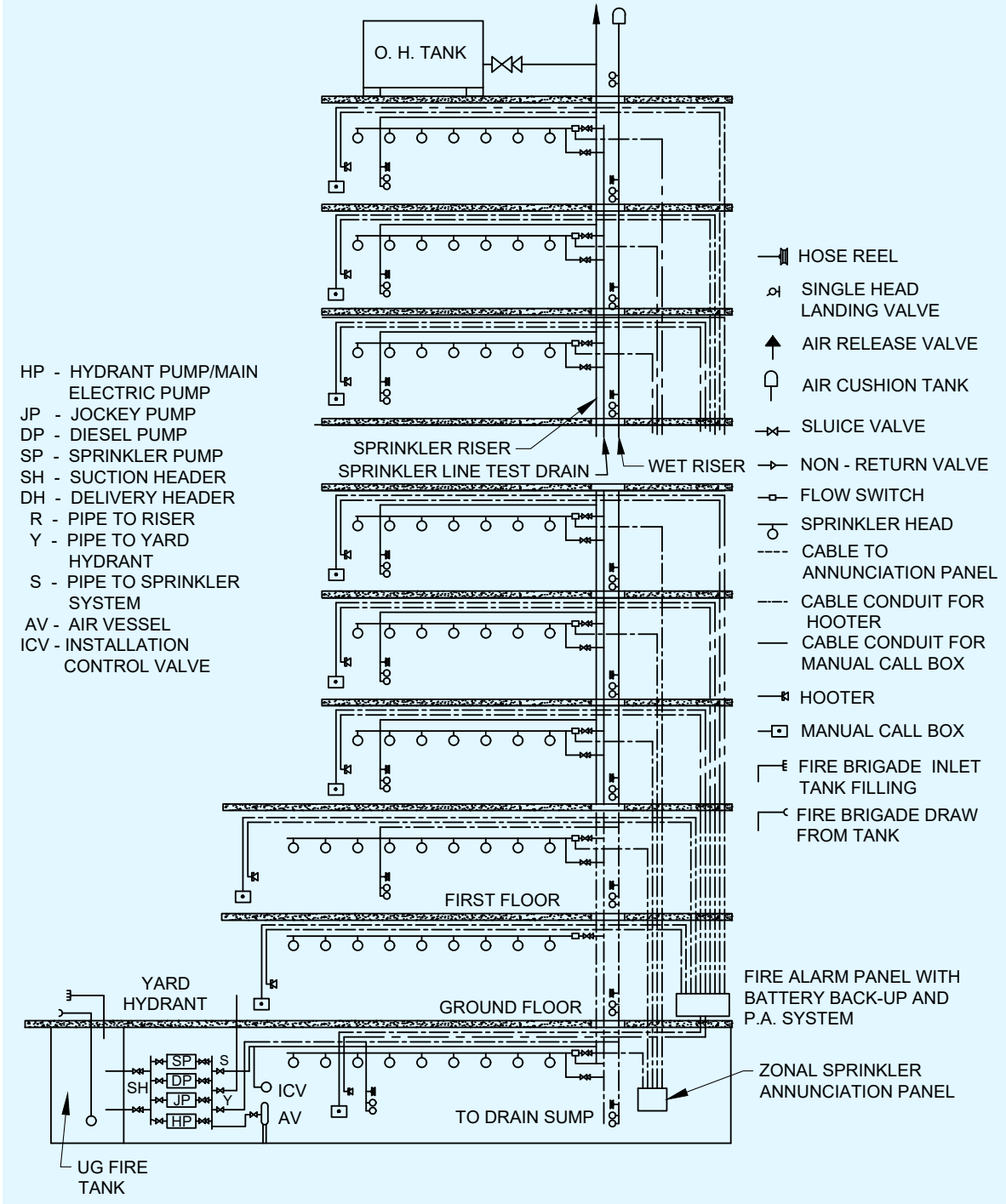

FIG. 17 TYPICAL ARRANGEMENT OF WET RISER AND TOTAL SPRINKLER SYSTEM OF BUILDING

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Table 8 Size of Mains

[*Clause* 5.1.1(a)]

Sl No.	Minimum Size of the Mains mm	Type of Building		Building Height m
(1)	(2)	(3)		(4)
i)	100 mm with single outlet 63 mm landing valve	a)	Residential buildings (A)	
			1) Dormitories	–
			2) Apartments	Up to 15 m
			3) Hotels	Up to 15 m
		b)	Educational buildings (B)	Up to 15 m
		c)	Institutional buildings (C)	Up to 15 m
		d)	Assembly buildings (D)	Up to 15 m
		e)	Business buildings (E)	Up to 15 m
		f)	Mercantile buildings (F)	Up to 9 m
		g)	Industrial buildings (G)	Up to 9 m
ii)	150 mm with single outlet 63 mm landing valve	a)	Hotels	Above 15 m
		b)	Starred hotels	–
		c)	Institutional buildings (C)	Above 15 m
		d)	Business buildings (E)	Above 15 m
		e)	Industrial buildings (G)	Up to 15 m
		f)	Storage buildings (H)	Up to 15 m
		g)	Hazardous buildings (J)	Up to 15 m

5.1.2.2 *Firefighting pump house*

The requirements should be as given below:

a) Pump house should be situated so as to be directly accessible from the surrounding ground level. In the case of industrial occupancies, it is preferable to install the pump house at ground level.

b) When located below ground, the pump house is much preferred in the first basement and should not be installed lower than the second basement (in which case the pumping efficiency should be ascertained). When installed in the basement, staircase with direct accessibility (or through enclosed passageway with 120 min fire rating) from the ground, should be provided. Access to the pump room should not require to negotiate through other occupancies within the basement.

c) Pump house need to be separated by fire walls all around and doors to be protected by fire doors (120 min rating).

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d) Pump house should be well ventilated and due care should be taken to avoid water stagnation.

e) No other utility equipment should be installed inside fire pump room.

f) Insertions like flexible couplings, bellows, etc, in the suction and delivery piping should be suitably planned and installed.

g) Installation of negative suction arrangement and submersible pumps should not be allowed.

h) Pump house should be sufficiently large to accommodate all pumps, and their accessories like pressure reducing valves (PRVs), installation control valves (ICVs), diesel tank and electrical panel. ICV for the towers (superstructure) is allowed to be installed in the first basement, in a duly protected room of 120 min fire resistance rating.

j) Battery of diesel engine operated fire pump should have separate charger from emergency power supply circuit.

k) Exhaust pipe of diesel engine should be insulated as per best engineering practice and taken to a safe location at ground level, considering the back pressure.

m) Fire pump is to be provided with soft starter or variable frequency drive starter.

5.1.3 *Automatic Sprinkler Installation*

The requirements should be as given below:

a) Automatic sprinklers should be installed wherever required in terms of Table 7A to Table 7J throughout the building, for uses as specified in, and in accordance with good practice [F(20)].

b) If selective sprinklering is adopted, there is a real danger of a fire starting in one of the unsprinklered area gathering momentum spreading to other areas and reaching the sprinklered areas as a fully developed fire. In such an event, the sprinklers can be rendered useless or ineffective.

c) Automatic sprinklers should be installed in false ceiling voids exceeding 800 mm in height.

d) Installation of sprinklers may be excluded in any area to be used for substation and DG set.

e) In areas having height 17 m or above such as in atria, sprinkler installations may be rendered ineffective and hence may be avoided.

f) Pressure in sprinkler system should not exceed 12 bar or else high pressure sprinkler to be installed for above 12 bar operations.

g) The maximum floor area on any one floor to be protected by sprinklers supplied by any one sprinkler system riser from an installation control valve should be based on system protection area limitations considering maximum floor area on any one floor to be 4 500 m^2 for all occupancies except industrial and hazardous occupancies, where Authorities should be consulted for advice based on type and nature of risk.

h) Sprinkler installation control valves, should be installed inside the fire pump room.

j) For industrial buildings, such installation control valves may be installed outside the building and Authorities should be consulted in situations where it is not possible to locate them inside the buildings. It is advisable to provide electrically operated siren for each valve outside the buildings in addition to water gongs in such case.

k) The sprinkler flow switches provided should be monitored by fire alarm panel.

m) It is essential to make provisions for avoiding water from sprinkler/hydrant operation entering lifts and electrical rooms.

n) Ramps at all levels should be protected with sprinklers.

p) The water based sprinkler systems are not suited for specific buildings for example, areas manufacturing electronic equipment, in which case alternate type of protection should only be provided.

q) Colour of the sprinkler piping may be matched to suit the interiors; however, in such case, the piping should be provided with red colour band of about 100 mm wide, every 3 m along the length of the pipe. In no case, the sprinkler heads should be painted.

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r) Based on interior design or interior requirements where it is necessary to provide pendent sprinkler with no false ceiling, to achieve the sprinkler response/activation, it is required to provide about 250 mm diameter circular plate around the sprinkler.

5.1.4 *Automatic High Velocity and Medium Velocity Water Spray Systems*

Automatic high velocity water spray or emulsifying system should be provided for protection of outdoor and/or indoor oil-cooled transformers as applicable in accordance with good practice [F(21)] where applicable (*see* Annex D). Also, medium velocity water spray system should be provided for tankage (where applicable), conveyors, cable galleries and other occupancies listed in good practice [F(21)].

5.1.5 *Fixed Foam Installation*

Fixed foam generating system should be provided for protection of oil storage area for boilers with its ancillary storage of furnace oils in basement. Fixed foam installations can be low, medium, or high expansion types, which can be provided based on the type of fire hazards identified in the facility. High expansion foams are used for cable tunnels and other confined areas. Design and installation of foam systems should be governed by good practice [F(22)].

5.1.6 *Gas Based Suppression System*

Gas based fire extinguishing installation should be provided in accordance with good practice on premises where water or foam cannot be used for fire extinguishing because of the special nature of the contents of the buildings/areas to be protected where either the building(s) have very limited manpower or unmanned. The protection design for fixed carbon dioxide fire extinguishing system should conform to good practice [F(23)] in all respects. For some special fire risk/essential applications, carbon dioxide may not be suitable and alternate provisions should be made as per relevant standards (*see* **5.1.9**).

NOTE — Hypoxic air technology should not be used in occupiable areas (considering the tenability aspects), and specific caution should be exercised in consultation with the Authority, regarding its applicability.

5.1.7 Firefighting equipment should be suitably located and clearly marked by luminous signs.

5.1.8 *Automatic Water Mist Systems*

These systems involve the use of fine water sprays for the efficient extinguishment of fires. These systems may be provided to protect areas in buildings for the uses as specified in good practice [F(24)].

5.1.9 *Extinguishing Systems with Clean Agents*

Alternative systems for halon gas protection systems should be provided where necessary as prescribed in this Part. These should be in accordance with the accepted standards [F(25)].

5.2 Fire Detection and Alarm System

See also **4.9**.

5.2.1 *Automatic Detection System*

5.2.1.1 *Pneumatic linear high-sensitivity heat detection*

Pneumatic linear high-sensitivity heat detection is a gas-pressure-based linear detector. The tube material (copper/steel/Teflon) is selected based on the environmental and operational needs, copper for fast response and standard indoor use, steel for rugged corrosive areas, and Teflon for chemically aggressive or electrically sensitive spaces.

5.2.1.2 *Flame/gas/spark detection*

A flame detector works by sensing the electromagnetic radiation and, through algorithms and filters, discriminates it from false sources (sunlight, hot machinery). The following are the characteristic radiation emitted by the flames/gas/spark:

a) Ultraviolet (UV) 180 nm to 260 nm, from most hydrocarbon and hydrogen flames;

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b) Infrared (IR) 2 μm to 6 μm, from hot CO_2/H_2O in the flame; and

c) Some systems also use visible light (VIS).

5.2.1.3 *Video detection*

Video-based fire detection (VFD) is an advanced fire detection technology that uses CCTV cameras combined with image-processing software to automatically detect visible signs of fire, such as smoke, flames, or heat distortions, and alert emergency systems for early fire response. The system is capable of simultaneous fire detection and visual verification. The system can use infrared (IR) or thermal imaging cameras for low-light or dusty conditions.

5.2.1.4 *Gas detection*

To detect accumulation of combustible gases or vapours (for example, methane, propane, jet fuel vapours) or toxic gases (for example, carbon monoxide, hydrogen sulphide, ammonia) before they ignite or endanger personnel**.** Common sensor types used are: catalytic, infrared (IR), electrochemical, or semiconductor.

5.2.1.5 *Spark detection*

To detect ignition sources (sparks, hot particles, embers) transported by air or material flow before they enter dust collectors, filters, or silos and ignite an explosion.

This detection uses infrared photo-sensors tuned to glowing particle radiation (approx. 0.8 μm to 1.1 μm). The same is installed in dark ducts or pneumatic conveying lines. The system should detect sparks within milliseconds (≤ 10 ms). The system should be integrated with automatic extinguishing systems (for example, water spray or deluge system) in industrial processes.

5.2.1.6 *Fuel leak detection*

Fuel leak detection (FLD) is a safety and monitoring system designed to identify and alert operators to the accidental release of fuel or flammable liquids from storage tanks, pipelines, or equipment. The system helps prevent fires, explosions, environmental contamination, and operational hazards by detecting leaks early.

5.2.1.7 *High ceiling beam detector*

The beam detector works like an electronic eye and keeps watching a clear light path; when smoke blocks the beam, it raises the alarm. A high-ceiling beam detection system is a projected or reflected IR smoke detection technology designed for large, tall spaces where spot detectors are ineffective. The system works works by sensing reduction in light intensity caused by smoke particles in the beam path and provides early warning for fast-developing fires in high-volume spaces.

5.2.1.8 *Linear heat sensing cable*

A linear heat sensing cable (digital/analogue) is a wire-type, continuous heat detector that triggers an alarm when it gets hot at any point, making it ideal for protecting long or irregular spaces where many spot-type heat detectors would otherwise be needed.

5.2.1.9 *Probe type heat detector*

A probe type heat detector is essentially a temperature-sensing probe that extends into the area to detect fire or abnormal heat early, especially in confined, harsh, or high-risk industrial environments. The probe is usually metallic (steel, copper) for good thermal conduction. Its length allows it to reach inside equipment, ducts, or confined spaces where smoke detectors may not work effectively.

5.2.1.10 *Aspiration high-sensitivity smoke detection*

Aspiration high-sensitivity smoke detection is a pipe-based, actively sampled smoke detection system that can detect smoke at very low concentrations, giving earliest possible warning of fire, especially in high-value, high-ceiling, or challenging environments. It continuously samples air from the protected area through a network of pipes and detects smoke at very low concentrations, providing early warning of fire before visible smoke accumulates.

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5.2.2 *Automatic Fire Suppression Systems*

5.2.2.1 *Water spray system*

A water spray system is a fixed fire protection system that delivers water through a network of piping and specially designed spray nozzles to cool surfaces, control, or extinguish a fire. It is similar to a sprinkler system but is designed to protect specific equipment or areas, rather than an entire room, by spraying water in a predetermined pattern and density.

5.2.2.2 *Wet/Dry pre-action*

A pre-action system is a special hybrid system used in areas where accidental water discharge would cause serious damage, such as data centres, archives, museums, cleanrooms. A wet sprinkler system is the simplest and most common type of sprinkler system. The pipes are always filled with water under pressure up to each sprinkler head**.** A dry sprinkler system is used in areas subject to freezing temperatures (for example, unheated warehouses, loading docks). The pipes are filled with pressurized air or nitrogen, and not water.

5.2.2.3 *Modular panel/rack suppression system*

A modular panel/rack suppression system with heat-sensitive tubing is a self-contained automatic fire protection system that uses a pressurized agent cylinder and flexible heat-sensitive tubing. The tube detects heat, ruptures at the fire spot, and releases the agent directly, providing fast, localized suppression for sensitive enclosures.

5.2.2.4 *Nitrogen injection*

The system is used for oil filled transformer system in which an overheating triggering the nitrogen gas displaces air/oxygen above the oil surface, preventing further combustion. The increased pressure helps to seal the transformer tank and suppress vapour formation, thereby preventing transformer fires and minimizing damage.

5.2.2.5 *Water mist system*

A water mist system is a specialized fire suppression system that uses very fine water droplets (mist) – typically less than 1 000 µ in diameter – to control, suppress, or extinguish fires. A water mist firefighting system suppresses fire by discharging a fine spray of water droplets that cools the fire, displaces oxygen, and reduces radiant heat, offering effective protection with minimal water use.

5.2.2.6 *Foam sprinkler system*

A foam sprinkler system automatically discharges a water-foam mixture through sprinkler heads to cool, smother, and suppress flammable liquid fires, providing effective fire protection for high-risk liquid storage and handling areas. It operates like a conventional sprinkler system; sprinkler heads open when heat rises above a preset temperature. It is primarily designed to suppress flammable liquid (Class B) fires, such as oil, fuel, or chemical storage, by cooling the fire and forming a foam blanket that smothers vapours.

5.2.2.7 *Wet chemical kitchen suppression system*

A wet chemical kitchen suppression system is a specialized fire suppression system designed to extinguish fires in commercial cooking areas, especially those involving cooking oils and grease (Class K fires). It uses a liquid wet chemical agent that reacts with hot grease to form a soapy foam layer (saponification), which cools and smothers the fire.

5.2.2.8 *Dry powder flooding system*

A dry powder flooding system is a fixed fire suppression system that floods a hazard area with dry chemical powder, quickly extinguishing flammable liquid, combustible metal, or electrical fires by interrupting the combustion reaction and isolating fuel from oxygen.

The dry chemical powder (for example, sodium bicarbonate, potassium bicarbonate, or special metal powders) is stored in pressurized vessels or storage tanks. Upon activation, the powder is discharged through a network of piping and nozzles into the protected space.

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5.2.2.9 *Clean agent total flooding*

A clean agent total flooding system is a fixed fire suppression system that protects an enclosed space by discharging a gaseous extinguishing agent (clean agent) to rapidly suppress fire without leaving any residue. The term "total flooding" indicates that the agent fills the entire protected volume to extinguish the fire. The agent absorbs heat and/or interrupts the chemical reaction of the fire.

5.2.2.10 *Carbondioxide flooding*

A carbon dioxide flooding firefighting system is a fixed system that rapidly floods an enclosed area with carbon dioxide, extinguishing fire by removing oxygen and cooling while leaving no residue, but it requires evacuation of personnel due to asphyxiation risk. It is fast-acting and effective for flammable liquid and electrical fires.

5.2.2.11 *Aerosol-based fire suppression system*

An aerosol-based fire suppression system is a fixed or modular fire protection system that extinguishes fires by releasing a fine particulate aerosol a mixture of solid microscopic particles suspended in inert gas which interrupts the chemical reactions of combustion. When triggered, it rapidly vapourizes and condenses into ultra-fine particles (1 microns to 10 microns) suspended in gas. It is highly effective for enclosed spaces.

5.3 The fixed firefighting installations and systems should be maintained in accordance with good practice [F(26)]. *See also* the 'Handbook on Asset and Facility Management'.

5.4 Fire Detection and Suppression Systems Based on the Specific Type and Intensity of Industrial Hazards

Table 9 serves as a guiding tool for designers, fire safety engineers, and facility managers in selecting appropriate fire detection and suppression systems based on the specific type and intensity for G to J occupancy hazards. Table 9 supports a risk-based approach, recognizing that fire protection requirements vary with operational processes, materials handled, and business continuity considerations. It moves away from a one-size-fits-all model and promotes hazard-specific fire safety planning to ensure enhanced protection, system reliability, and life safety in special industrial occupancies.

5.5 Supplementary Protection for Specific Areas/Hazards

Table 10 provides a guide for the structured classification of automatic detection systems, and Table 11 provides for automatic fire suppression systems, based on the specific type and intensity for G to J occupancy hazards. The tables serve as a reference for designers, fire safety engineers, and regulatory authorities to determine the appropriate supplementary protection measures based on the specific fire risks present in a building or facility.

The automatic detection systems covered in the table include high-sensitivity pneumatic linear (or tubing) heat detection, aspiration high-sensitivity smoke detection, gas/flame/visual detection, fuel leak detection, and linear heat detection (LHS). The automatic fire suppression systems include water mist, clean agent gas suppression, wet/dry pre-action sprinkler systems, water spray protection, carbon dioxide flooding, etc.

Each system is marked as either 'S' (Suitable) or 'NS' (Not Suitable) depending on its effectiveness for a given hazard scenario. The selection of a special protection system should be based on a comprehensive fire risk assessment, considering factors such as fuel type, occupancy, fire growth rate, and critical infrastructure protection. These tables provides essential guidance for ensuring compliance with fire safety regulations and enhancing fire protection strategies in buildings.

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Table 9 Fire Detection and Suppression Systems

(Based on the Specific Type and Intensity of A to F Occupancies)

(*Clauses* 3.5.5.4 *and* 5.4)

Sl No.	Type of Risk/ Hazard	Types of Special Protection System											
		Automatic Detection System					Automatic Fire Suppression Systems						
		Pneumatic Linear (Copper/ Steel/ Teflon Tubing) High Sensitivity Heat Detection	Aspiration High Sensitivity Smoke Detection	Gas/ Flame/ Video Detection	Fuel Leak Detection	Linear Heat Sensing Cable (LHS)	Water Mist Low/High Pressure	Clean Agent Gas Suppression	Water Pre-Action Sprinkler	Modular Panel/ Rack Suppression with Heat Sensitive Tubing	Water Spray Protection	Wet Chemical Kitchen Suppre-ssion	Aerosol Based Fire Suppre-ssion
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	UPS room without batteries	NS	S	S	NS	NS	S	S	S	NS	NS	NS	NS
ii)	UPS room with batteries (except Lithium ion)	NS	S	S	NS	NS	S	S	S	NS	NS	NS	NS
iii)	Battery room with Lithium ion	S	S	S	NS	NS	NS	NS	S	NS	S	NS	NS
iv)	Server room/data halls	NS	S	NS	NS	NS	S	S	S	NS	NS	NS	NS
v)	Kitchen with any type of fuel, (live cooking)	NS	NS	S	NS	S	S	NS	NS	NS	NS	NS	NS
vi)	Network/ Electrical rooms	NS	S	NS	NS	NS	S	S	S	NS	NS	NS	NS

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Table 9 (*Continued*)

Sl No.	Type of Risk/ Hazard	Types of Special Protection System											
		Automatic Detection System					Automatic Fire Suppression Systems						
		Pneumatic Linear (Copper/ Steel/ Teflon Tubing) High Sensitivity Heat Detection	Aspiration High Sensitivity Smoke Detection	Gas/ Flame/ Video Detection	Fuel Leak Detection	Linear Heat Sensing Cable (LHS)	Water Mist Low/High Pressure	Clean Agent Gas Suppression	Water Pre-Action Sprinkler	Modular Panel/ Rack Suppression with Heat Sensitive Tubing	Water Spray Protection	Wet Chemical Kitchen Suppre-ssion	Aerosol Based Fire Suppre-ssion
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
vii)	Electrical/ MCC panels	NS	S	NS	NS	NS	NS	S	NS	S	NS	NS	S
viii)	Cable cellar and trenches and trays over 1.5 m wide	S	NS	NS	NS	S	S	NS	NS	NS	S	NS	S
ix)	Dry transformer indoor	S	NS	S	NS	NS	NS	NS	NS	NS	NS	NS	NS
x)	Oil transformer outdoor more than 2.0 MVA or 2 000 litre oil	S	NS	S	NS	NS	NS	NS	NS	NS	S	NS	NS
xi)	DG rooms	S	NS	S	S	S	S	NS	NS	NS	S	NS	S
xii)	Cold/freezer rooms	S	S	NS	NS	NS	NS	NS	S	NS	NS	NS	NS

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Table 9 (*Concluded*)

Types of Special Protection System													
Sl No.	**Type of Risk/ Hazard**	**Automatic Detection System**					**Automatic Fire Suppression Systems**						
		Pneumatic Linear (Copper/ Steel/ Teflon Tubing) High Sensitivity Heat Detection	Aspiration High Sensitivity Smoke Detection	Gas/ Flame/ Video Detection	Fuel Leak Detection	Linear Heat Sensing Cable (LHS)	Water Mist Low/High Pressure	Clean Agent Gas Suppression	Water Pre-Action Sprinkler	Modular Panel/ Rack Suppression with Heat Sensitive Tubing	Water Spray Protection	Wet Chemical Kitchen Suppre-ssion	Aerosol Based Fire Suppre-ssion
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
xiii)	MRI/ scanning rooms	NS	S	NS	NS	NS	S	NS	NS	NS	NS	NS	NS
xiv)	Operation theatres	NS	S	NS	NS	NS	S	NS	S	NS	NS	NS	NS
xv)	Tunnel protection	S	NS	S	NS	S	S	NS	NS	NS	S	NS	NS

NS = Not Suitable

S = Suitable

NOTES

1 Wet sprinklers are acceptable for all areas where pre-action sprinklers or closed water mist is suitable.

2 DG rooms should be protected with total flooding open nozzles where water mist is being deployed.

3 Spray system should be supplemented with suitable foam, if ignitable liquids or water miscible liquids are involved.

4 Water mist system should be selected based on 3rd party independent test carried out for the specific application, flow rate, density, etc. The products in terms of functionality and the performance should be based on actual test results and certifications, and should NOT be prescriptive.

5 Water mist solution selected, total flooding with sprinklers, total flooding with open nozzles, wet system, pre-action system should comply based on actual test results, and certifications.

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Table 10 Special Protection Systems — Automatic Detection Systems for G to J Occupancies

(*Clause* 5.5)

Sl No.	Type of Risk/Hazard	Pneumatic Linear (Copper/Steel/Teflon Tubing) High Sensitivity Heat Detection	Flame/Gas/ Spark Detection	High Ceiling Beam Detection System	Linear Heat Sensing Cable	Probe Type Heat Detector	Aspiration High Sensitivity Smoke Detection
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Generator room	S	S	NS	S	S	NS
ii)	Water reactive chemical store	S	S	NS	S	S	NS
iii)	Chemical store	S	S	NS	S	S	NS
iv)	Paint booth	S	S	NS	S	S	NS
v)	Paint/varnish storage	S	S	NS	S	S	NS
vi)	Warehouse	NS	S	S	NS	NS	S
vii)	Above ground fuel oil storage	S	S	NS	S	NS	NS
viii)	Oil transformers	S	S	NS	NS	NS	NS
ix)	Diesel/HSD tanks	S	S	NS	S	NS	NS
x)	LPG bullets/Benzene, Xylene, Toulene tanks	NS	NS	NS	NS	NS	NS
xi)	Airport hanger	S	S	S	S	S	S
xii)	Hydrogenation rooms	NS	S	NS	S	S	S
xiii)	Sulphur storage	S	S	NS	S	S	NS
xiv)	Tanker loading/unloading bay	NS	S	NS	NS	NS	NS
xv)	Kitchen	S	S	NS	S	S	NS
xvi)	Conveyors	S	S	NS	S	NS	NS

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Table 10 (*Concluded*)

Sl No.	Type of Risk/Hazard	Pneumatic Linear (Copper/Steel/Teflon Tubing) High Sensitivity Heat Detection	Flame/Gas/ Spark Detection	High Ceiling Beam Detection System	Linear Heat Sensing Cable	Probe Type Heat Detector	Aspiration High Sensitivity Smoke Detection
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
xvii)	QA/QC labs	S	S	NS	S	S	NS
xviii)	Open large atriums	NS	NS	NS	NS	NS	S
xix)	Floating roof tanks	S	S	NS	S	NS	NS
xx)	Oil fire boiler room, oil quenching tank	S	S	NS	S	S	NS
xxi)	Cooling tower	NS	NS	NS	S	NS	NS
xxii)	MCC room	S	NS	NS	S	S	S
xxiii)	Cable cellar/trenches	S	NS	NS	S	S	NS
xxiv)	Electrical panels	S	NS	NS	S	NS	NS

NOTE

NS = Not Suitable

S = Suitable

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Table 11 Special Protection Systems — Automatic Fire Suppression Systems for G to J Occupancies

(*Clause* 5.5)

Sl No.	Type Of Risk/Hazard	Water Spray System	Wet/Dry Pre-action	Nitrogen Injection	Water Mist	Foam Sprinkler System	Dry Powder Flooding System	Clean Agent Total Flooding	Carbon-Dioxide Flooding
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Generator room	S	NS	NS	S	NS	NS	NS	NS
ii)	Water reactive chemical store	NS	NS	NS	NS	NS	S	NS	S
iii)	Chemical store	S	NS	NS	S	S	NS	NS	NS
iv)	Paint booth	S	NS	NS	S	NS	NS	NS	NS
v)	Paint/varnish storage	S	NS	NS	S	S	S	NS	NS
vi)	Warehouse	NS	NS	NS	NS	NS	NS	NS	NS
vii)	Above ground fuel oil storage	S	NS	NS	NS	S	NS	NS	NS
viii)	Oil transformers	S	NS	S	S	NS	NS	NS	NS
ix)	Diesel / HSD tanks	S	NS	NS	NS	S	NS	NS	NS
x)	LPG bullets/Benzene, Xylene, Toulene tanks	S	NS	NS	NS	NS	NS	NS	NS
xi)	Airport hanger	NS	NS	NS	NS	S	NS	NS	NS
xii)	Hydrogenation rooms	S	NS	NS	S	NS	NS	NS	NS
xiii)	Sulphur storage	NS	NS	NS	S	NS	NS	NS	NS
xiv)	Tanker loading/unloading bay	S	NS	NS	NS	NS	NS	NS	NS
xv)	Kitchen	NS	NS	NS	S	NS	NS	NS	NS
xvi)	Conveyors	S	NS	NS	S	NS	NS	NS	NS
xvii)	QA/QC labs	NS	S	NS	S	S	S	S	NS
xviii)	Open large atriums	NS	NS	NS	S	NS	NS	NS	NS
xix)	Floating roof tanks	S	NS	NS	NS	S	NS	NS	NS

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Table 11 (*Concluded*)

Sl No.	Type Of Risk/Hazard	Water Spray System	Wet/Dry Pre-action	Nitrogen Injection	Water Mist	Foam Sprinkler System	Dry Powder Flooding System	Clean Agent Total Flooding	Carbon-Dioxide Flooding
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
xx)	Oil fire boiler room, oil quenching tank	S	NS	NS	S	S	NS	NS	NS
xxi)	Cooling tower	S	NS	NS	NS	NS	NS	NS	NS
xxii)	MCC room	NS	S	NS	S	NS	NS	S	S
xxiii)	Cable cellar/trenches	S	NS	NS	S	NS	NS	NS	S
xxiv)	Electrical panels	NS	NS	NS	NS	NS	NS	S	S

NS = Not Suitable

S = Suitable

NOTES

1 Spray system should be supplemented with suitable foam, if ignitable liquids or water miscible liquids are involved.

2 Chemical material safety data sheet (MSDS) as per manufacture should be referred to select the right suppression agent.

3 Water mist system should be selected based on third party independent test carried out for the specific application, flow rate, density, etc. The products in terms of functionality and the performance should be based on actual test results and certifications, and should not be prescriptive.

4 Water mist solution selected, total flooding with sprinklers, total flooding with open nozzles, wet system, pre-action system should comply based on actual test results, and certifications.

5 Oxygen-reduction systems, which is not listed but area proactive fire prevention solutions by maintaining the oxygen percentage below the threshold needed for ignition and sustained combustion but suitable for human occupancy. These systems should be carefully evaluated and used for normally unoccupied areas with proper monitoring of oxygen levels. Fully enclosed very sensitive and critical high valve equipment rooms, rooms in heritage buildings for storing archives or ancient manuscripts, areas where no other fire protection system are effective and feasible are a few areas where it can be implemented. The implementer should ensure all 3rd party product/system accreditations certifications for specific applications and approval from local statutory bodies and AHJs in place before use.

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6 SPECIFIC OCCUPANCY WISE REQUIREMENTS

Apart from the general requirements on fire prevention given in 3, the life safety requirements given in 4, and the fire protection requirements given in 5, the following specific requirements should also be complied with for each type of occupancy.

For specific requirements for high rise buildings, the provisions as given in Annex D should apply.

Atriums in building occupancies should comply with the provisions as given in Annex E.

For specific requirements for data centres, the provisions as given in Annex F should apply.

For fire protection requirements of commercial kitchen, cooking facilities with or without restaurants, the provisions of good practice [F(30)] should be referred.

6.1 Residential Buildings (Group A)

6.1.1 *Life Safety*

6.1.1.1 *Subdivision A*-I

a) All locking devices, which would impede or prohibit exit, such as chain type bolts, limited opening sliding type locks and burglar locks, which are not disengaged easily by quick- releasing catches, should be prohibited.

b) All bathroom door locks or fasteners should be designed to permit the opening of the locked or closed door from the outside in an emergency without the use of a special key.

c) No lodging or rooming house should have its sole means of egress pass through any non-residential occupancy in the same building.

d) Rooming and lodging houses having floor area of 500 m^2 on any one or more floors should have access to minimum two separate means of exits, at least one of which should be so arranged as to have direct exit discharge.

6.1.1.2 *Subdivision A*-II

a) Requirements of 6.1.1.1 should be applicable.

b) All sleeping rooms having occupancy of more than 10 persons should have two separate and distinct exit access in different directions.

6.1.1.3 *Subdivision A*-III

In case of high-rise apartments, of the minimum exits as specified in 4.4.2.4.3.1, the naturally ventilated/cross-ventilated exit staircases may not require the provision of fire door. However, fire door should be provided for all other staircases and pressurized staircases.

6.1.1.4 *Subdivision A*-IV

a) Panic bars should be provided in the fire exits. Panic bars should be located at a height between 865 mm and 1 220 mm from the floor level.

b) All guest rooms and suites should be protected by extended throw or quick response type sprinklers only. Also, these areas should be provided with audio-based detectors, having a sound level of at least 75 dB.

c) Horizontal-sliding doors should not be used for door openings across corridors.

6.1.1.5 *Additional Precautions*

a) Flammable liquids for household purposes should be kept in tightly stoppered or sealed containers. For the limits of quantities of flammable liquids to be allowed in various occupancies, reference may be made to appropriate regulations.

b) No stove or combustion heater should be located directly under or immediately at the foot of stairs or otherwise so located as to block escape in case of malfunctioning of the stove or heater.

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c) All kitchen exhaust fans, where provided, should be fixed to an outside wall or to a duct of non-combustible material, which leads directly to the outside. The ducts should not pass through areas having combustible materials. However, in case of centralized ducting, the duct should be provided with adequate protection to limit the spread of fire.

d) Stores, engineering workshops, areas of high hazard, etc used for storage of substantial amount of flammable liquids should be of 120 min fire resistance rated wall. Such areas should be provided with fire doors, to be kept closed and should be posted with a sign on each side of the door prominently in block letters stating — 'FIRE DOOR — KEEP CLOSED'.

6.2 Educational Buildings (Group B)

6.2.1 *Fire Prevention*

a) Buildings intended for educational occupancy should not be used for storage of any hazardous material.

b) Gymnasiums, indoor stadiums, and similar occupancies are permitted to have floors/running tracks of wood, cinder, synthetic or the like.

6.2.2 *Life Safety*

a) Every room with a capacity of over 45 persons in area should have at least two doorways. Exit doors should be operated by panic bars except that doors leading from classrooms directly to the outside may be equipped with the same type of lock as is used on classroom doors leading to corridor, with no provision whatsoever for locking against egress from the classroom.

b) A building, which will have only the first floor and is accessible to not more than 20 pupils at any time, may be used for school purposes with the following exceptions:

   1) Exterior walls or parts of walls which are less than 900 mm from adjacent property lines should have no openings therein.

   2) Classrooms may have only one exit not less than 900 mm wide.

c) Rooms or areas for use by the preschool, kindergarten, Class/Grade 1 students should be located on ground floor/level of exit discharge. Rooms or areas occupied by Class/Grade II students should be located not above one floor higher than ground floor/level of exit discharge.

d) Of the minimum exits as specified in 4.4.2.4.3.1, the naturally ventilated exit staircases, may not require provision of fire door. However, fire door should be provided for all other staircases and pressurized staircases.

6.2.3 *Special Precautions*

a) Storage of volatile flammable liquids should be prohibited and the handling of such liquids should be restricted to science laboratories only; and

b) All exterior openings in a boiler room or rooms containing central heating equipment, if located below an opening in another storey or if less than 3 m from other doors or windows of the same building, should be protected by a fire assembly as in 3.5.4. Such assemblies should be of fixed, automatic, or self-closing type.

6.3 Institutional Buildings (Group C)

6.3.1 *Fire Prevention*

No combustible material of any kind should be stored or used in any building or section thereof used for institutional occupancy, except as necessary to normal occupancy and use of the building.

6.3.2 *Life Safety*

a) The common path of travel should be up to 30 m. The maximum dead end of corridor distance should not exceed 6 m;

b) Principle of progressive horizontal evacuation is of paramount consideration for hospital patients particularly those lacking self-preservation. This calls for moving occupants from a fire affected area to

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an adjoining area at the same level through a fire resistant wall, to protect them from the immediate dangers of fire and smoke (*see* Fig. 18);

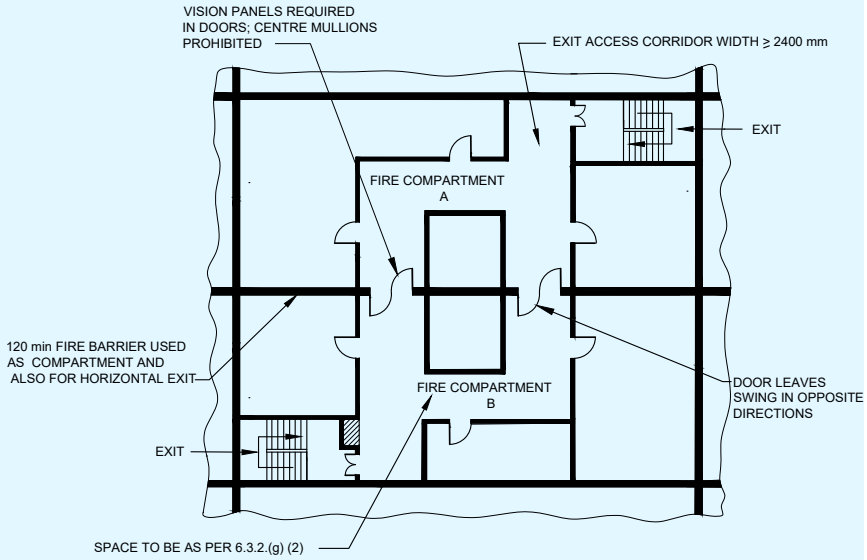

FIG. 18 PART PLAN INDICATING CONCEPT OF HORIZONTAL EXIT IN HOSPITAL

c) Progressive horizontal evacuation operates on the basis of evacuation from compartment to compartment and on use of adjacent compartments as temporary means of refuge. All compartments should be divided with self-closing (door closers) fire doors with electromagnetic hold open. A coordinator should be provided to sequence the closing of double leaf in case of emergency;

d) Doors in fire resistant walls should be so installed that these may normally be kept in open position, but will close automatically. Corridor door openings should be not less than 2.0 m in width of double swing double leaf type door. A coordinator should be provided as above, for closing of double leaf in case of emergency;

e) Exits and other features for penal and mental institutions, and custodial institutions should be the same as specified for hospitals [*see* **6.3.2** (g)], in so far as applicable. Reliable means should be provided to permit the prompt release of inmates from any locked section in case of fire or other emergency;

f) All buildings or sections of buildings in penal and mental institution used for manufacturing, storage or office purposes should have exits in accordance with the provisions of this Part for those occupancies;

g) For hospitals (Subdivision C-I), the following should also be complied with:

1) Compartmentation should meet the requirement as per **4.5.2**.

2) Each compartment (*see* **4.5.3**) should be able to accommodate, in addition to its own, the patients from adjoining compartment also considering 3.5 m^2 per person. If patients are not bed-ridden, a factor of 0.6 m^2 per person is recommended. This is towards achieving horizontal evacuation.

3) All critical patients incapable of self-preservation and those having physical impairment should preferably be housed within 45 m height. For hospitals exceeding 45 m in height, where such occupants are located above this level, the following non-exhaustive additional provisions should be complied with in consultation with local fire authorities:

i) The general life safety and protection aspects and fire protection features, as in heights up to 45 m should be provided to the entire height, including progressive horizontal evacuation.

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ii) Further, the alternate floors (particularly those housing all such patients) should have refuge terraces (basically a covered area with place of safety directly exposed to atmosphere at least one side) of sufficient area (as prescribed by the local authorities) with provisions for medical gases to support patients on ventilators temporarily during evacuation during the staging/evacuation period, to ensure uninterrupted care. The refuge terraces should have:

a) direct access to the fire-fighting shaft/fire tower,

b) access through fire rated door having a minimum 2 h fire resistant rating,

c) automatic sprinkler system, public announcement system, fire detection and alarm system, dedicated and separate shaft for medical gas pipelines, utility services and for electrical services,

d) dedicated emergency power supply back up (UPS and DG), particularly for all life-saving equipment, and

e) washroom facility within it or directly accessible.

iii) A dedicated firefighting team should be available round the clock, and having relevant qualification, competence and necessary experience, as may be required by the competent authority.

4) Basement should not be used to store flammables or for pathological or other laboratories particularly those involving usage of inflammable chemicals. Medical health care services involving radiation facilities may be housed in the basements as per medical planning along with radiation therapy allied services like bunkers, SIM CT, brachytherapy, nuclear medicine, hot lab, patient hold and waiting area, consultant room, mould room, TPS room, subject to compliance of all requirements for fire safety.

5) Operation theatres, delivery rooms, intensive care units, recovery rooms, etc, that containing patients lacking self-preservation in case of emergencies should be fire/smoke separated (120 min minimum rating) from all the adjoining areas.

6) Aisles, corridors, ramps, etc, through which patients are moved, should have a minimum width of 2.4 m throughout. Aisles, corridors, and ramps in other areas not intended for the housing, treatment, or use of inpatients should be not less than 1.5 m in width.

7) All exits from hospital or infirmary sections should be not less than 2.0 m in width.

8) Minimum width of door of single or double occupancy patient room should be 1.25 m, while for the wards for 3 to 5 patient beds should be 1.50 m, to enable movement of patients. The minimum width of door for wards for more than 5 patient beds and for areas necessarily requiring patient evacuation on bed (such as ICU, recovery units, delivery rooms, etc), should have door width of 2.0 m. The width of 2.0 m may be reduced to minimum of 1.5 m where two such doors are provided in such areas.

9) Any sleeping accommodation or suite exceeding 100 m^2 in area should have at least two doorways leading to the exit access corridors.

10) Exit access corridors from a compartment to another compartment should be divided at the compartment intersection by a fire door of 120 min fire rating in the fire compartment wall.

11) Rooms designated for laboratory and the like should not exceed 100 m^2 in area, and if additional space is required, fire separation of 120 min should be provided.

12) A stretcher lift in a lift bank should also act as fireman's lift meeting the requirements of Part D 'Building Services, Section 5 Installation of Lifts, Escalators, Moving Walks and Power Driven Parking Systems, Subsection 5A Lifts' of this NBCS.

h) *Progressive evacuation strategy — See* Fig. 19, in which, as an example, the exit calculations at two locations should be based on requirements of total occupancy for area (A, B and C) divided by 2 considering progressive evacuation strategy.

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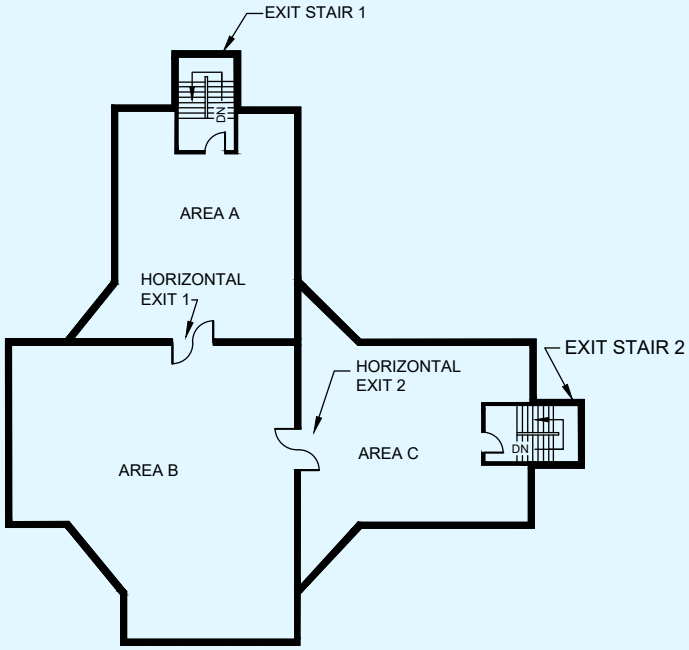

FIG. 19 MINIMUM OF TWO EXITS ACCESSIBLE FROM ALL PARTS OF FLOOR

6.3.3 *Exception and Deviation*

It is recognized that in institutions or part of buildings housing various types of psychiatric patients, or used as mental institutions and penal institutions, it is necessary to maintain locked doors and barred windows; and to such extent the necessary provision in other sections of this Part requiring the keeping of exits unlocked may be waived. It is also recognized that certain type of psychiatric patients are not capable of seeking safety without adequate guidance. In buildings where this situation prevails, reliable means for the rapid release of occupants should be provided, such as remote control of locks, or by keying all locks to keys commonly used by attendants.

6.4 Assembly Buildings (Group D)

6.4.1 *Fire Prevention*

6.4.1.1 The following should be applicable*:*

a) Decorations of places of assembly should be of non-flammable materials. Fabrics and papers used for such purpose should be treated with an effective flame-retardant material. Stage settings made of combustible materials should likewise be treated with fire retardant materials of Class 1 flame spread; and

b) Gymnasiums, indoor stadiums, and similar occupancies are permitted to have floors/running tracks of wood, cinder, synthetic or the like.

6.4.1.2 *Additional fire prevention requirements for mixed use assembly buildings* (*including malls*)

Buildings provided with multiple services/facilities like shopping, cinema theatres, multiplexes, restaurants/food court as part of mixed use assembly/mercantile occupancy should preferably limit the height of the assembly/ mercantile occupancy portion of the buildings to 30 m. Above this height the buildings may be used for business or residential occupancies with 240 min separation. Independent exits should be provided for such occupancy above 30 m and should not interface with exits of assembly/mercantile occupancy.

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6.4.2 *Life Safety*

6.4.2.1 The following should be applicable:

a) Exit door width for assembly buildings should not be less than 2.0 m.

b) At least four separate exits as remote from each other as practicable are required from every place of assembly in buildings primarily meant for theatrical or operatic performances and which has a stage, proscenium curtain, fixed or portable scenery or scenery loft, lights, mechanical appliances or other theatrical accessories and equipment for example, theatres, motion picture houses, auditoria, concert halls, television and radio studios admitting an audience and which are provided with fixed seats for over 1 000 persons.

c) At least two separate exits as remote from each other as practicable are required in buildings primarily meant for or theatrical or operatic performances and which has a stage, proscenium curtain, fixed or portable scenery or scenery loft, lights, mechanical appliances or other theatrical accessories and equipment for example, theatres, motion picture houses, auditoria, concert halls, television and radio studios admitting an audience and which are provided with fixed seats. Those building having a capacity from 600 and up to 1 000 persons, at least three exits should be provided with each exit not less than of 2.0 m width.

d) Clear aisles not less than 1.2 m in width should be formed at right angles to the line of seating in such number and manner that no seat should be more than seven seats away from an aisle. Rows of seats opening on to an aisle at one end only should have not more than seven seats. Under the conditions, where all these aisles do not directly meet the exit doors, cross-aisles should be provided parallel to the line of seating so as to provide direct access to the exit, provided that not less than one cross aisle for every 10 rows should be required. The width of cross-aisles should be minimum of 1 m. Steps should not be placed in aisles to overcome differences in levels unless the gradient exceeds 1 in 10.

e) The fascia of boxes, balconies and galleries should have substantial railings not less than 1 000 mm high above the floor. The railings at the end of aisles extending to the fascia should be not less than 1 100 mm high for the width of the aisle or 1.2 m high at the foot of steps.

f) Cross-aisles, except where the backs of seats on the front of the aisle project 600 mm or more above the floor of the aisle, should be provided with railings not less than 900 mm high.

g) Turnstiles or other devices to restrict the movement of persons should not be installed in any place of assembly in such a manner as to interfere in any way with the required exit facilities.

h) In theatres and similar places of public assembly where persons are admitted to the building at a time when seats are not available for them and are allowed to wait in a lobby or similar space until seats are available, such use of lobby or similar space should not encroach upon the required clear width of exits. Such waiting should be restricted to areas separated from the required exit ways by substantial permanent partitions or fixed rigid railing not less than 1 050 mm high. Exit should be provided for such waiting spaces on the basis of maximum capacity of two largest screen of multiplex (considering the staggered movie timings). Such exits should be in addition to the exits specified for the main auditorium area and should conform in construction and arrangement to the general rules of exits given above.

j) Display or exhibit should not be so installed or operated as to interfere in any way with access to any required exit, or with any required exit sign.

k) All displays or exhibits of combustible material or construction and all booths and temporary construction in connection therewith should be so limited in combustibility or protected as to avoid any undue hazard of fire which might endanger occupants before they have opportunity to use the available exits, as determined by the authority.

m) Places of assembly in buildings of other occupancy may use exits common to the place of assembly and the other occupancy, provided the assembly area and the other occupancy are considered separately, and each has exits sufficient to meet the requirements of this Part.

n) Exits should be sufficient for simultaneous occupancy of both the places of assembly and other parts of the building.

p) For detailed information regarding cinema buildings, reference may be made to good practice [F(27)].

q) Seats in places of public assembly, accommodating more than 300 persons, should be securely fastened

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to the floor, except as permitted in (r) below. All seats in balconies and galleries should be securely fastened to the floor, except that in nailed-in enclosures, boxes with level floors and having not more than 14 seats, the seats need not be fastened.

r) Chairs not secured to the floor may be permitted in restaurants, night clubs and other occupancies where the fastening of seats to the floor may not be practicable, provided that in the area used for seating, excluding dance floor, stage, etc, there should be not more than one seat for each 1.4 m^2 of floor area and adequate aisles to reach exits should be maintained at all times. The arrangements should be as follows in general:

1) Rows of seats between aisles should have not more than 14 seats.

2) Rows of seats opening on to an aisle at one end only should have not more than 7 seats.

3) Seats without dividing arms should have their capacity determined by allowing 450 mm per person.

s) The spacing of rows of seats from back to back should be neither less than 850 mm nor less than 700 mm plus the sum of the thickness of the back and inclination of the back. There should be a space of not less than 350 mm between the back of one seat and the front of the seat immediately behind it as measured between plumb lines.

t) *Lighting* — No open flame lighting devices should be used in any place of assembly, except in the following cases:

1) Where necessary for ceremonial purposes, the enforcing Authority may consider permiting open flame lighting under such restrictions as are necessary to avoid danger of ignition of combustible materials or injury to occupants.

2) Candles may be used on restaurant tables if securely supported on non-combustible bases and so located as to avoid danger of ignition of combustible materials.

3) Open flame devices may be used on stages where they are a necessary part of theatrical performance, provided adequate precautions, satisfactory to the Authority are taken to prevent ignition of combustible materials.

6.4.2.2 *Life safety provisions for mall-like* (*Assembly*, *Mercantile*, *Cinema hall*, *Restaurant*) *occupancy*

The following additional requirements should be applicable:

a) Assembly occupancies of theatres, cinema halls and multiplexes should be so located in the mall building that their exits will be separate and lead the occupant directly to exit discharge.

b) The common path of travel should be 30 m. The maximum dead end of corridor distance should not exceed 6 m.

c) The minimum width of an exit passageway should be 2.0 m.

d) Where wheeled carts or buggies are used by customers, adequate provision should be made for the transit and parking of such carts to minimize the possibility that they might obstruct means of egress. Any other storage or hindrances causing obstruction in exits should be avoided.

e) Car parking facilities should comply with Annex G. Car parking areas at upper levels adjacent to shops, food courts or multiplex should be separated by 120 min fire rated construction and building elements;

f) 50 percent lifts in common areas in the mal-like occupancies should be with features and requirement of fireman's lift.

g) The manual call points should be break glass and not pull stations.

h) Photoluminescent markings should be done along the width and length of treads in all enclosed exits staircases. Exit directional arrow on the wall (in the direction of egress) should be 175 mm × 50 mm in size.

j) Refuge area to be provided on the floor at or immediately above 18 m should be not less than 10 percent of gross area of floor. Next refuge area to be at/on the floor immediately above 24 m. The refuge area should be 10 percent of the respective floor, which may be divided into two or more separate refuge areas at each of the respective floors, with each being not less than 100 m^2. Refuge area should also meet all the requirements of life safety as per **4**.

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k) When refuge spaces are resorted to, every floor should be provided with space for 20 percent of the respective occupants of that floor.

6.4.3 *Fire Protection*

a) Every stage equipped with fly galleries, grid irons and rigging for movable theatre type scenery, should have a system of automatic sprinklers over and under such stage areas or spaces and auxiliary spaces, such as dressing rooms, store rooms and workshops, and the proscenium opening should be provided with a fire resisting curtain, capable of withstanding a lateral pressure of 4 kN/m^2 over the entire area. The curtain should have an emergency closing device capable of causing the curtain to close without the use of power and when so closed, it should be reasonably tight against the passage of smoke.

b) The stage roof of every theatre using movable scenery or having a motion picture screen of highly combustible construction should have a ventilator or ventilators in or above it, openable from the stage floor by hand and also opening by fusible links or some other approved automatic heat/smoke actuated device, to give a free opening equal to at least one-eighth the area of the floor of the stage.

c) The proscenium wall of every theatre using movable scenery of decorations should have, exclusive of the proscenium opening, not more than two openings entering the stage, each not to exceed 2 m^2 and fitted with self-closing fire resistant doors.

d) Every place of assembly in which projection of motion pictures by light is made should have the projection apparatus enclosed in a fire resisting fixed booth in accordance with good practice [F(27)], except that such booth should not be required where no nitrocellulose motion picture film is used.

6.4.4 *Fire Protection and Firefighting System for Metro Stations and Metro Trainways Occupancy*

Fire and life safety requirements for metro stations and metro trainways should be in accordance with Annex H and Annex J, respectively. In case of any ambiguity with respect to provisions in Part F or any other Part of this NBCS, the respective provisions given in Annex H and Annex J should be applicable.

6.5 Business Buildings (Group E)

6.5.1 *Life Safety*

Not less than two exits should be provided for every floor, including basements occupied for office purposes or uses incidental thereto.

6.5.2 *Fire Protection*

a) For business buildings (namely laboratories, outpatient clinics, research establishments, libraries, and test houses) the requirement should be provision of automatic fire detection alarm system, while for fire protection, CO_2 and/or foam-based installation to be planned based on the requirements; and

b) For business buildings (namely electronic data processing centres, computer installations, information technology parks and call centres, telephone exchanges, broadcasting stations, T.V. stations, and air traffic control towers) the requirement should be provision of automatic fire detection alarm system, while for fire protection, any or combination of clean agents, mist technologies, etc, may be planned for appropriate/special situations/locations. Electrical panels may be provided with CO_2/inert gas flooding system based on the requirement and reliability of power for the functional requirement and performance.

6.6 Mercantile Buildings (Group F)

6.6.1 *Life Safety*

6.6.1.1 Open air mercantile operations, such as open air markets, petrol filling stations, roadside stands for the sale of a farm produce and other outdoor mercantile operations should be so arranged and conducted as to maintain free and unobstructed ways of travel at all times to permit prompt escape from any point of danger in case of fire or other emergency, but having no dead-ends in which persons might be trapped due to display stands, adjoining buildings, fences, vehicles or other obstructions.

6.6.1.2 If such mercantile operations are conducted in roofed-over areas, these should be treated as mercantile buildings, provided canopies over individual small stands to protect merchandise from the weather should not be

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construed to constitute buildings for the purpose of this Part.

6.6.2 *Exception and Deviation*

Any mercantile occupancy, where goods of a highly hazardous nature are predominant, should be considered under Group J occupancy for the purpose of this Part.

6.7 Industrial Buildings (Group G)

6.7.1 *Fire Prevention*

6.7.1.1 *Fire separating walls, fire separating floors and fire partitions*

Fire separating walls should be provided between two buildings or between two blocks inside a building, having different fire hazards in accordance with the provisions of this Part. The areas having storage, manufacturing, hazardous activities such as paint store, oil storage, spray booths, etc, should be separated from non-hazardous areas like administrative office, staff canteen, etc by fire rated walls/doors of 120 min fire resistance rating. The fire resistance rating of high hazardous areas like petrochemical, explosives should be 240 min.

The fire separating wall where provided should comply with the following requirements:

a) The separating wall should be carried through the roof. This portion of the wall extending above the roof, known as 'screen wall' should be of such a height (in no case less than 600 mm) that the horizontal distance at the level of the top of the screen wall between the roofs of the buildings/compartments being segregated is at least 6 m.

b) The screen wall should be of not less than 230 mm in thickness if it is an extension of a masonry wall, and not less than 150 mm in thickness if it is an extension of a reinforced concrete wall.

c) The separating wall need not be extended as a screen wall if the roof of one or both of the buildings/blocks being segregated is of reinforced concrete construction (RCC).

d) In the case of buildings of unequal height, windows, or other openings in the wall of the higher building overlooking the roof of the lower building and within 6 m, thereof, should be protected by fire resistant glass assembly or by approved type fire doors unless the roof of the lower building is of reinforced concrete.

e) In case the eaves of the higher building fall within 6 m of the roof of the lower building such eaves should be cut-off and the screen wall raised as a parapet, 600 mm high over the roof of the higher building, unless the roof of the lower building is of RCC construction.

f) Fire separating walls should also be extended outwards on both sides by at least 450 mm.

g) Doors and window openings in external walls within 3 m of the fire separating walls should be protected by fire doors having a rating of at least 60 min and window openings may be protected by fire resistant glass assembly having same fire rating.

h) In the case of buildings/compartments having north-light roofs when a separating wall runs parallel to the axis of the north-light opening, the screen wall should be carried through and 600 mm above the ridge of the north light. If, however, the separating wall is at right angles to the axis of the north-light opening, the saw tooth gaps should be bricked up and the screen wall extended 600 mm above the ridge of the north light as well as beyond the extreme north-light opening.

j) Similarly, the thickness of the floor slabs in case of buildings having upper levels should be designed to provide fire rating as mentioned above.

k) Storage areas should be separated from the remainder of the building/block by fire walls. Moderate and high hazard areas in industries should have two fire doors each having 180 min fire resistance rating.

6.7.2 *Life Safety*

6.7.2.1 In buildings used for aircraft assembly or other occupancy requiring undivided floor areas so large that the distances from points within the area to the nearest outside walls where exit doors could be provided are in excess of 45 m, requirements for distance to exits may be satisfied by providing stairs leading to exit tunnels or to overhead passageways. In cases where such arrangements are not practicable, the Authority may, by special

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ruling, permit other exit arrangements for single storeyed buildings with distances in excess of the maximum distances specified in 4, if completely automatic sprinkler protection is provided and if the heights of ceiling curtain boards and roof ventilation are such as to minimize the possibility that employees will be overtaken by the spread of fire or smoke within 1.8 m of the floor level before they have time to reach exits, provided, however, that in no case may the distance of travel to reach the nearest exit exceed 65 m where smoke venting is required as a condition for permitting distances of travel to exits in excess of the maximum otherwise allowed.

6.7.2.2 The following applies to special purpose industrial occupancies:

a) Exits need be provided only for the persons actually employed; spaces not subject to human occupancy because of the presence of machinery or equipment may be excluded from consideration.

b) Where unprotected vertical openings are necessary to manufacturing operations, these may be permitted beyond the limits specified for industrial occupancy, provided every floor level has direct access to one or more enclosed stairways or other exits protected against obstruction by any fire in the open areas connected by the unprotected vertical openings or smoke therefrom.

6.7.2.3 The following applies to high hazard industrial occupancies:

a) From every point in every floor area, there should be at least two exits accessible in different directions; where floor areas are divided into rooms, there should be at least two ways of escape from every room, however small rooms, except toilet rooms, so located that the points of access thereto are out of or suitably shielded from areas of high hazard.

b) In addition to types of exits for upper floors specified for Group G occupancies, slide escapes may be used as required exits for both new and existing buildings.

NOTE — All high hazard industrial occupancies should have automatic sprinkler protection or such other protection as may be appropriate to the particular hazard, including explosion venting for any area subject to explosion hazard, designed to minimize danger to occupants in case of fire or other emergency before they have time to utilize exits to escape.

6.7.3 *Additional Precautions*

a) In any room in which volatile flammable substances are used or stored, no device generating a glow or flame capable of igniting flammable vapour should be installed or used, such a room should be provided with a suitably designed exhaust ventilation system (*see* Annex K).

b) For detailed information on fire safety of certain individual (specific) industrial occupancies, reference may be made to good practice [F(28)].

c) Fire protection considerations for venting industrial occupancies should be as in Annex K.

6.8 Storage Buildings (Group H)

6.8.1 *Life Safety*

6.8.1.1 Every area used for the storage of hazardous commodities should have an exit within 30.0 m (*see* Table 4) of any point in the area where persons may be present or 35 m where automatic sprinkler protection is provided.

6.8.1.2 Every storage area or space exceeding 1 400 m^2 gross area, or where more than 10 persons may be normally present should have at least two exit access doors leading to the corridors in exit access, which can be readily opened. This should not be subject to locking so long as any persons are inside and should not depend on power operation. Exits in such cases should be as remote from each other as practicable.

For warehouses, natural draft smoke venting should utilize roof vents or vents in walls at or near the ceiling level; such vents should be normally open, or, if closed, should be designed for automatic opening in case of fire, by release of smoke sensitive devices.

6.8.1.3 The following special provisions should apply to aircraft hangers:

a) Exits from aircraft hangers (storage or servicing areas) should be provided at intervals of not more than 45 m on all exterior walls of aircraft hangers. There should be a minimum of two exits serving each aircraft storage or servicing areas. Horizontal exits through interior fire walls should be provided at intervals of not more than 30 m. 'Dwarf' or 'Smash' doors accommodating aircraft may be used to comply with these requirements. All doors designated as exits should be kept unlocked in the direction

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of exit travel while the area is occupied; and

b) Exits from mezzanine floors in aircraft storage or servicing areas should be so arranged that the maximum travel to reach the nearest exits from any point on the mezzanine should not exceed 22.5 m. Such exits should lead directly to a properly enclosed stairwell discharging directly to the exterior or to a suitably cut-off area or to outside fire escape stairs.

6.8.1.4 The following special provisions should apply to grain elevators:

a) There should be at least one stair tower from basement to first floor and from the first floor to the top floor of workhouse which is enclosed in a dust tight non-combustible shaft.

b) Non-combustible doors of self-closing type should be provided at each floor landing.

c) An exterior fire escape of the stair or basket ladder type should be provided from the roof of the workshop to ground level or the roof of an adjoining annexe with access from all floors above the first.

d) An exterior fire escape of either the stair or basket ladder type should be provided from the roof of each storage annexe to ground level.

6.8.1.5 For provisions relating to car parking facilities, *see* Annex G.

6.8.2 *Additional Precautions*

Requirements specified in **6.7.3 (a)** should apply to Group H occupancies also.

6.9 Hazardous Uses (Group J)

6.9.1 *Life Safety*

Requirements specified in **6.7.2.3** should apply to Group J occupancies also.

6.9.2 *Additional Precautions*

The following requirements should apply to all Group J occupancies, as applicable:

a) Hazardous buildings should have vapour/flame/ember/spark detectors and explosion suppression systems depending on the type of fire hazard involved;

b) Each building where gas is employed for any purpose should be provided with an approved outside gas shut-off valve conspicuously marked. The detailed requirements regarding safe use of gas should be as specified in Part E 'Plumbing Services, Section 4 Gas Supply' of this NBCS;

c) Each boiler room or room containing a heating plant should be separated from the rest of the building by a separating wall;

d) In any room in which volatile flammable substances are used or stored, no device generating a spark, or glow flame capable of igniting flammable vapour should be installed or permitted unless it is enclosed in a flameproof enclosure;

e) The use, handling, storage and sale of gasoline, fuel oil and other flammable liquids should not be permitted in Group J occupancies unless such use, handling, storage, and sale is in accordance with appropriate legislation in force;

f) All openings in exterior walls except wall vents should be protected by a fire stop assembly as in **4** and they should be fixed, automatic or self-closing. Wall vents having an area of not less than 100 cm^2 each should be placed in the exterior walls near the floor line, not more than 1 800 mm apart horizontally. Each building should be provided with a power driven fan exhaust system of ventilation which should be arranged and operated so as to produce a complete change of air in each room every 3 min;

g) Each machine in dry-cleaning establishments which uses flammable liquid should have an adequate steam line or any other suitable extinguishing agent directly connected to it, so arranged as to have the agent automatically released to the inside of each machine should an explosion occur in the machine; and

h) Equipment or machinery which generates or emits combustible or explosive dust or fibres should be provided with an adequate dust collecting and exhaust system.

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ANNEX A

(*Clause* 3.1.8)

CALORIFIC VALUES OF COMMON MATERIALS

A-1 The calorific values of some common materials are given in Table 12 for guidance.

Table 12 Calorific Values of Common Materials

(*Clause* A-1)

Sl No.	Material	Calorific Value (10^3 kJ/kg)[1)]	Wood Equivalent (kg/kg)
(1)	(2)	(3)	(4)
i)	**Solid Fuels**		
	a) Anthracite	28.6	1.66
	b) Bituminous coal	30.8	1.75
	c) Charcoal	28.4	1.61
	d) Coke (average)	27.5	1.56
	e) Peat	20.9	1.19
	f) Sub-bituminous coal	22.0	1.25
	g) Woods (hard or softwood)	17.6	1.00
ii)	**Hydrocarbons**		
	a) Benzene	39.6	2.25
	b) Butane	47.1	2.68
	c) Ethane	49.1	2.79
	d) Ethylene	47.7	2.71
	e) Fuel oil	41.6	2.36
	f) Gas oil	42.9	2.44
	g) Hexane	44.9	2.55
	h) Methane (natural gas)	52.8	3.00
	j) Octane	45.3	2.58
	k) Paraffin	39.6 to 44.0	2.3 to 2.5
	m) Pentane	46.0	2.61
	n) Propane	47.3	2.69
	p) Propylene	46.2	2.63
iii)	**Alcohols**		
	a) Ethyl alcohol	28.4	1.61
	b) Methyl alcohol	21.1	1.20

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Table 12 (*Continued*)

Sl No.	Material	Calorific Value (10^3 kJ/kg)[1)]	Wood Equivalent (kg/kg)
	c) Propyl alcohol	31.9	1.81
iv)	**Polymers**		
	a) Casein	23.1	1.31
	b) Cellulose	16.5	0.94
	c) Cellulose acetate	17.8	1.01
	d) Polyethylene	48.4	2.75
	e) Polypropylene	48.4	2.75
	f) Polystyrene	41.8	2.38
	g) Polyvinylchloride	20.9	1.19
	h) Polymethyl methacrylate	24.6	1.40
	j) Polyurethane	35.2	2.00
	k) Polyamide (nylon)	22.0	1.25
	m) Polyester	22.0	1.25
v)	**Common Solids**		
	a) Asphalt	38.3	2.13
	b) Bitumen	33.4	1.90
	c) Carbon	32.1	1.83
	d) Cotton (dry)	15.8	0.90
	e) Flax	14.3	0.81
	f) Furs and skins	18.7	1.06
	g) Hair (animal)	20.9	1.19
	h) Leather	17.6	1.00
	j) Ozokerite (wax)	43.5	2.46
	k) Paper (average)	15.4	0.88
	m) Paraffin wax	40.9	2.33
	n) Pitch	33.0	1.88
	p) Rubber	37.4	2.13
	q) Straw	13.2	0.75
	r) Tallows	37.6	2.14
	s) Tan bark	20.9	1.19

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Table 12 (*Concluded*)

Sl No.	Material	Calorific Value (10^3 kJ/kg)[1)]	Wood Equivalent (kg/kg)
	t) Tar (bituminous)	35.2	2.00
	u) Wool (raw)	21.6	1.23
	w) Wool (scoured)	19.6	1.11
vi)	**Foodstuffs**		
	a) Barley	14.1	0.80
	b) Bran	11.0	0.63
	c) Bread	9.9	0.56
	d) Butter	29.5	1.68
	e) Cheese (Cheddar)	18.1	1.03
	f) Corn meal	14.1	0.80
	g) Flour	14.1	0.80
	h) Margarine	29.5	1.68
	j) Oatmeal	15.8	0.90
	k) Rice	13.9	0.79
	m) Soya bean flour	16.1	0.91
	n) Sugar	15.4	0.88
	p) Whole wheat	14.3	0.81
vii)	**Miscellaneous**		
	a) Acetone	29.7	1.69
	b) Acetaldehyde	25.1	1.43
	c) Formaldehyde	17.6	1.00
	d) Hydrogen	134.2	7.63
	e) Magnesium	24.0	1.36

[1)] 1 kJ is approximately equal to 1 Btu, so the figures in the tables are also equivalent to Btu/kg.

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ANNEX B

(*Clause* 3.1.8)

BROAD CLASSIFICATION OF INDUSTRIAL OCCUPANCIES INTO DIFFERENT DEGREE OF FIRE HAZARD

G1 – Low Hazard	G2 – Moderate Hazard	G3 -High Hazard
Abrasive Manufacturing Premises	Aluminium Factories	**SUB-CATEGORY (A)**
Aerated Water Factories	Atta and Cereal Grinding units	Aircraft Hangers units
Agarbatti Manufacturing	Auto Components (excluding plastics and foam components) manufacturing	Aluminium/Magnesium Powder Plants
Areca nut slicing and/or Betel nut Factories	Bakeries and Biscuit Factories	Auto Components (including Plastics and Foam Components)
Analytical and/or Quality Control Laboratories	Beedi Factories	Auto Mobiles and other Motor Vehicles powered by Lithium or Lithium-Ion Batteries manufacturing
Athletic Equipment manufacturing	Bobbin Factories	Battery Charging/Battery Service Stations
Asbestos Steam Packing and Lagging Manufacturing	Bookbinders, Envelopes and Paper bag Manufacturing	Battery Manufacturing
Auto mobiles and other motor vehicles	Cable manufacturing	Bituminized Paper and/or Hessian Cloth/Tar Felt Manufacturing
Breweries	Camphor Boiling facilities	Chemical Store (water reactive)
Brick Works	Candle Works	Cotton Waste Factories
Canning Factories	Carbon Paper/Typewriter Ribbon Manufacturing	Celluloid Goods Manufacturing
Cardamom Factories	Cardboard Box Manufacturing	Chemical Manufacturing using raw materials having flash points below 23 °C
Cement Factories and/or Asbestos or Concrete Products Manufacturing	Carpenters, Wood wool and Furniture Manufacturing	Cigarette Filter Manufacturing
Ceramic Factories and Crockery and Stoneware Pipe Manufacturing	Carpet and Durries Factories	Diesel Generator Room
Clay Works	Cashewnut Factories	Fire-works Manufacturing
Clock and Watch Manufacturing	Chemical Manufacturing using raw materials having flash points above 23 ºC	Foam Plastics Manufacturing and/or Converting Plants
Coffee Curing Roasting and grinding Premises	Chemical Store (non-water reactive)	Godowns and Warehouses (storing combustible/flammable goods)
Condensed Milk Factories, Milk Pasteurizing Plant and Dairies	Cinema Films and T.V. Production Studios	Grass, Hay, Fodder and Bhoosa (chaff) Pressing Factories
Confectionery Manufacturing	Cigar and Cigarette Factories	Hydrogenation rooms (involving Flammable Hydrogen)
Cooling Towers	Coal and/or Coke and/or Charcoal Ball and Briquettes Manufacturing	Industrial Gas Manufacturing (other than Inert/Halogenated Hydrocarbon Gases)
Electric Generating Houses (Hydroelectric)	Coir Factories	

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G1 – Low Hazard	G2 – Moderate Hazard	G3 -High Hazard
Incandescent and Fluorescent and TV Picture Tube Manufacturing	Coir Carpets, Rugs, Tobacco, Hides and Skin Presses	Jute mills and jute presses
Electro-plating Works	Cold storage premises	Linoleum Factories
Engineering Workshops	Cold Freezer Room	Lithium Ion Battery Manufacturing Plants
Fruits and Vegetables Dehydrating and Drying Factories	Collieries	LPG Bottling Plants (Mini)
Fruit Products and Condiment Factories	Conveyors	Man-made Fibres (Acrylic fibres/yarn manufacturing)
Garages	Cork products manufacturing	Match Factories
Glass and Glass Fibre Manufacturing	Cotton Seed Cleaning or De-linting Factories	Metal or Tin Printers (where more than 50 percent of floor area is occupied as Engineering Workshop; this may be taken as Ordinary Hazard Risk)
Godowns and Warehouses storing non-combustible goods only	Distilleries	Oil Mills
Green houses	Dry Cleaning, Dyeing and Laundries	Oil Extraction Plants
Gold Thread/Gilding Factories	Duplicating/Stencil Paper Manufacturing	Oil Fire Boiler Room/ Oil Quenching Tank
Gum and/or Glue and Gelatine Manufacturing	Electric substations/Distribution stations	Oil Terminals/Depots handling flammable liquids having flash point of 23 °C and below
Ice, Ice Candy, and Ice-cream Manufacturing	Electric Generating stations (other than Underground power houses)	Oil Transformer Room
Ink (excluding Printing Ink) Factories	Electric Lamps Manufacturing	Paints and Varnish Factories
Mica Products Manufacturing	Electrical Appliances Manufacturing	Paint Booths
Multiple block apartment buildings	Electrical/Motor Control Centre (MCC) Panel Rooms	Paint/Varnish Storage
Open Large Atriums	Electronic Products Manufacturing	Paper and Cardboard Mills having raw material yards
Pottery Works	Enamelware Factories	Piers, Wharfs and Jetties – Handling Extra Hazardous Materials
Poultry Farms	Filter and Wax paper Manufacturing	Printing Ink Manufacturing.
QA/QC Laboratories	Flour Mills	Rosin Lamp black and Turpentine Factories
Salt Crushing Factories and Refineries	Food Processing establishments	Saw Mills
Stables	Garment Makers	Spray painting facilities
Sugar Candy Manufacturing	Ghee Factories (other than vegetable)	Server room
Tanneries/Leather Goods Manufacturers	Godowns and Warehouses (other than those under light and high hazard A categories)	Surgical Cotton Manufacturing
Umbrella Assembling Factories		Tanker Loading/Unloading Bay
Vermicelli Factories		Tarpaulin and Canvas Proofing Factories

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G1 – Low Hazard	G2 – Moderate Hazard	G3 -High Hazard
Water Treatment/Filtration Plants and Water Pump Houses Zinc/Copper Factories	Grain and/or Seeds Disintegrating and/or Crushing Factories Grease Manufacturing Hosiery, Lace, Embroidery and Thread Factories Incandescent Gas Mantle Manufacturing Indoor Dry Transformer Room Industrial Gas Manufacturing (Inert/halogenated hydrocarbon gases) Kitchen with any type of fuel (Live cooking) MRI/scanning room Man-made Yarn/Fibre Manufacturing (other than acrylic fibres/yarn Manufacturing) Manure and Fertilizer Works (Blending, Mixing, and granulating) Mattress and Pillow Making Mineral Oil Blending and Processing Multiple block business buildings Multiple block star hotel buildings Musical Instruments Manufacturing Network/electrical room Oil and Leather Cloth Factories Oil Terminals/Depots other than those categorized under High hazard A Open storage of flammable liquids in drums, cans, etc Operation Theatre Rooms Optical Goods facilities Oxygen Plants Paper and Cardboard Mills without Raw Material Yards	Turpentine and Rosin Distilleries Tyre Retreading and Resoling Factories Tunnel Protection UPS Room with batteries Battery Room with Lithium-ion batteries **SUB-CATEGORY (B)** Ammonia and Urea Synthesis Plants Benzene/ Xylene/ Toluene Tanks CNG Compressing and Bottling Plants Coal based methane plants LPG bullets Explosive Factories Oil Storage (above ground) Outdoor Oil Transformer Room NOTE — In case of complexes having separate plants having varying degrees of hazard, authority having jurisdiction should be consulted to decide on level of protection to be provided.

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G1 – Low Hazard	G2 – Moderate Hazard	G3 -High Hazard
	Pharmaceuticals Piers, Wharves, Jetties and Dockyards other than those categorized under High hazard A Plastic Goods Manufacturing Plywood/Wood Veneering Factories Printing Press Premises Pulverising and Crushing Mills Rice Mills Rope Works Rubber Goods Manufacturing Rubber Tyres and Tubes Manufacturing Semiconductors Manufacturing Sulphur Storage Sugar Factories and Refineries Shellac Factories Silk Filatures Soaps and Glycerine Factories Solar Cells and Modules manufacturing Sponge Iron Steel Plants (Gas Based) Starch Factories Tea Factories Textile Mills Tobacco (Chewing) and Pan-Masala Making facilities Tobacco Grinding and Crushing Tobacco Redrying Factories UPS Room without batteries Woollen Mills	

NOTES

1 Any occupancy that is not covered in this Annex should be classified in the most appropriate class which resembles the proposed occupancy.

2 For classification of industries based on 'chemical hazard', pollution, etc, the respective state/central guidelines/documents/rules may be referred.

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ANNEX C

(*Clauses* 3.4.2, 3.4.3 *and* F-2.1)

AVAILABLE DATA REGARDING FIRE RESISTANCE RATING OF VARIOUS BUILDING COMPONENTS

C-1 The following tables (*see* Table 13 to Table 29) may be used, in the absence of any validated/certified rating regarding the materials used in the structural and/or non-structural element/component.

Table 13 Masonry Walls: Solid (Required to Resist Fire from One Side at a Time)

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish, for a Fire Resistance (*min*) of									
		Load Bearing					Non-Load Bearing				
		60	90	120	180	240	60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	Reinforced cement concrete[1)]	120 (25)[2)]	140 (25)[2)]	160 (25)[2)]	200 (25)[2)]	240 (25)[2)]	–	–	–	–	–
ii)	Unreinforced cement concrete	150	175	–	–	–	–	–	–	–	–
iii)	No-fines concrete with: a) 13 mm cement/ sand or gypsum/ sand	–	–	–	–	–	150	150	150	150	150
	b) 13 mm light weight aggregate gypsum plaster	–	–	–	–	–	150	150	150	150	150
iv)	Bricks of clay: a) Without finish	90	100	100	170	170	75	90	100	170	170
	b) With 13 mm light weight aggregate gypsum plaster	90	90	90	100	100	75	90	90	90	100
v)	Bricks of sand lime: a) Without finish	90	100	100	190	190	75	90	100	170	170
	b) With 13 mm light weight aggregate gypsum plaster	90	90	90	100	100	75	90	90	90	100
vi)	Blocks of concrete: a) Without finish	90	100	100	–	–	75	90	100	140	150

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Table 13 (*Concluded*)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish, for a Fire Resistance (*min*) of									
		Load Bearing					Non-Load Bearing				
		60	90	120	180	240	60	90	120	180	240
	b) With 13 mm light weight aggregate gypsum plaster	90	90	90	100	100	75	75	75	90	100
	c) With 13 mm cement/sand or gypsum/sand	–	–	–	–	–	75	90	90	100	140
vii)	Blocks of light weight concrete: a) Without finish	90	100	100	140	150	75	75	75	125	140
	b) With 13 mm light weight aggregate gypsum plaster	90	90	90	100	100	50	63	75	75	75
	c) With 13 mm cement/sand or gypsum/sand	–	–	–	–	–	75	75	75	90	100
viii)	Blocks of aerated concrete: a) Without finish	90	100	100	140	180	50	63	63	75	100
	b) With 13 mm light weight aggregate gypsum plaster	90	90	100	100	150	–	–	–	–	–

[1] Walls containing at least 1 percent of vertical reinforcement.

[2] Minimum thickness of actual cover to reinforcement.

Table 14 Masonry Walls: Hollow (Required to Resist Fire from One Side at a Time)

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish, for a Fire Resistance (*min*) of										
		Load Bearing						Non-load Bearing				
		60	90	120	180	240	30	60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1)	Bricks of clay: a) Without finish	170	170	170	200	200	75	75	90	100	170	170

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Table 14 (*Concluded*)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish, for a Fire Resistance (*min*) of										
		Load Bearing						Non-load Bearing				
		60	90	120	180	240	30	60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	b) With 13 mm lightweight aggregate gypsum plaster	170	170	170	200	200	75	75	90	100	170	170
ii)	Blocks of concrete:											
	a) Without finish	–	–	–	–	–	90	125	125	140	140	150
	b) With 13 mm cement/sand or gypsum/ sand	–	–	–	–	–	90	125	125	140	140	140
	c) With 13 mm lightweight aggregate gypsum plaste	190	200	200	–	–	75	90	90	100	125	125
iii)	Blocks of lightweight concrete:											
	a) Without finish	100	100	100	–	–	75	90	90	100	140	150
	b) With 13 mm cement/sand or gypsum/sand	–	–	–	–	–	75	75	75	100	140	140
	c) With 13 mm lightweight aggregate gypsum plaster	–	–	–	–	–	63	63	63	75	90	100

Table 15 Framed Construction, Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* C-1)

Sl No.	Nature of Construction and Materials/Timber Studs at Centres not Exceeding 600 mm, Faced on Each Side with	Minimum Thickness (mm) of Protection for a Fire Resistance of 60 min
(1)	(2)	(3)
i)	Plasterboard layers with joints staggered, joints in outer layer taped and filled — Total thickness for each face	25
ii)	One layer of 12.7 mm plasterboard with a finish of lightweight aggregate gypsum plaster	13
iii)	Metal lath and plaster, thickness of plaster:	
	a) Sanded gypsum plaster (metal lathing grade)	22
	b) Lightweight aggregate gypsum plaster	13

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Table 16 Framed Construction, Non-Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* C-1)

Sl No.	Nature of Construction and Materials/Steel or Timber Frame at Centres not Exceeding 600 mm, Facings on Both Sides of	Stud Construction	Minimum Thickness (mm) of Protection for a Fire Resistance (min)			
			30	60	90	120
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Dry lining with materials fixed direct to studs, without plaster finish					
	a) One layer of plasterboard with taped and filled joints	Timber or steel	12.7	–	–	–
	b) Two layers of plasterboard with joints staggered, joints in outer layer taped and filled – Total thickness for each face	Timber or steel	19	25	–	–
	c) One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	Timber or steel	9	12	–	–
	d) One layer of wood wool slabs	Timber	25	–	–	–
	e) One layer of chipboard or of plywood	Timber or steel	18	–	–	–
ii)	Lining with materials fixed direct to suds, with plaster finish					
	a) Plasterboard of thickness:					
	1) With not less than 5 mm gypsum plaster finish	Timber or steel	9.5	–	–	–
	2) With not less than 13 mm gypsum plaster finish	Timber or steel	–	12.7	–	–
iii)	Wet finish					
	a) Metal lath and plaster, thickness of plaster:					
	1) Sanded gypsum plaster	Timber or steel	13	–	–	–
	2) Lightweight aggregate gypsum plaster	Timber	–	13	19	25
		Steel	–	13	–	–

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Table 17 Framed External Walls Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of 60 min
(1)	(2)	(3)
i)	Timber studs at centres not exceeding 600 mm with internal linings of: Plasterboard layers with joints in outer layer taped and filled, total thickness of plasterboard	31

Table 18 Framed External Walls Non-Load Bearing [Required to Resist Fire from Inside the Building (A)]

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance (min) of					
		30	60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Steel frame with an external cladding of non-combustible sheets (excluding sheet steel), with a steel supporting framework and internal lining of:						
	a) Metal lath and plaster, thickness of plaster:						
	1) Sanded gypsum plaster (metal lathing grade)	13	13	–	–	–	–
	2) Lightweight aggregate gypsum plaster	10	13	15	15	15	19
	b) Two layers of plasterboard with joints staggered joints in outer layer taped and filled — Total thickness	21	32	–	–	–	–
	c) Plasterboard of thickness:						
	1) With not less than 5 mm gypsum plaster finish	12.7	–	–	–	–	–
	2) With not less than 13 mm gypsum plaster finish	9.5	–	–	–	–	–
	3) With not less than 10 mm lightweight aggregate gypsum plaster	9.5	–	–	–	–	–
	d) One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating	9	9	12	12	12	12

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Table 18 (*Concluded*)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance (min) of					
		30	60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	board not less than 9 mm thick, or by timber						
	e) One layer of wood/wool slabs without finish	–	50	–	–	–	–
	f) One layer of compressed straw building slabs :						
	1) Without finish	50	–	–	–	–	–
	2) With not less than 5 mm gypsum plaster finish	–	50	–	–	–	–
	g) Aerated concrete blocks	50	50	63	63	75	100
	h) Bricks of clay:						
	1) Without finish	75	75	90	90	100	100
	2) With not less than 13 mm lightweight aggregate gypsum plaster	–	–	75	75	90	90

Table 19 Framed External Walls Non-Load Bearing [(Required to Resist Fire from Inside the Building (B)]

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection to Provide Sufficient Insulation to Achieve a Modified Fire Resistance of Up to 240 min
(1)	(2)	(3)
i)	Steel frame with an external cladding of sheet steel fully lapped, steel bolted and fixed to steel sheeting rails, with timber or steel supporting framework and internal lining of:	
	a) Metal lath and plaster, thickness of plaster:	
	1) Sanded gypsum plaster (metal lathing grade)	13
	2) Lightweight aggregate gypsum plaster	10

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Table 19 (*Concluded*)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection to Provide Sufficient Insulation to Achieve a Modified Fire Resistance of Up to 240 min
(1)	(2)	(3)
	b) One layer of plasterboard with joints taped and filled	12.7
	c) Plasterboard of thickness with not less than 5 mm gypsum plaster finish	9.5
	d) One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9
	e) One layer of wood/wool slabs	25
	f) One layer of compressed straw building slabs	50
	g) One layer of chipboard or of plywood	18
	h) Aerated concrete blocks	50
	j) Bricks of clay	75
	k) Any internal decorative lining with a cavity fill independently supported and retained in position of mineral fibre insulating material (excluding glass) at a density of 48 kg/m3	50

Table 20 Framed Walls Non-Load Bearing [Required to Resist Fire from Inside the Building (C)]

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of 90 min
(1)	(2)	(3)
i)	Timber frame with external cladding of weather boarding or external plywood, 9.5 mm with an internal lining of :	
	a) Plasterboard not less than 9.5 mm thick, finished with:	
	1) Gypsum plaster	13
	2) Lightweight aggregate gypsum plaster	10
	b) Plasterboard not less than 12.7 mm thick, finished with:	
	1) Gypsum plaster	10

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Table 20 (*Concluded*)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of 90 min
(1)	(2)	(3)
	2) Lightweight aggregate gypsum plaster	10
	c) One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9 12

Table 21 Reinforced Concrete Columns

(*Clause* C-1)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance (min) of					
			30	60	90	120	180	240
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Fully exposed	a) Width	150	200	250	300	400	450
		b) Cover	40	40	40	40	40	40
ii)	50 percent exposed	a) Width	125	160	200	200	300	350
		b) Cover	40	40	40	40	40	40
iii)	One face exposed	a) Thickness	100	120	140	160	200	240
		b) Cover	40	40	40	40	40	40

Table 22 Concrete Beams

(*Clause* C-1)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance (min) of					
			30	60	90	120	180	240
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	a) Width	200	200	200	200	240	280
		b) Cover	20	20	20	40	60[1)]	70[1)]
ii)	Reinforced concrete (continuous)	a) Width	200	200	200	200	240	280
		b) Cover	20	20	20	30	40	50[1)]
iii)	Prestressed concrete (simply supported	a) Width	100	120	150	200	240	280
		b) Cover	25	40	55[1)]	70[1)]	80[1)]	90[1)]

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Table 22 (*Concluded*)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance (min) of					
			30	60	90	120	180	240
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
iv)	Prestressed concrete (continuous)	a) Width	80	100	120	150	200	240
		b) Cover	20	30	40	55[1)]	70[1)]	80[1)]

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

Table 23 Concrete Floors

(*Clause* C-1)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance (min) of					
			30	60	90	120	180	240
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	a) Thickness	75	95	110	125	150	170
		b) Cover	20	20	25	35	45[1)]	55[1)]
ii)	Reinforced concrete (continuous)	a) Thickness	75	95	110	125	150	170
		b) Cover	20	20	20	25	35	45[1)]

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

Table 24 Concrete Floors: Ribbed Open Soffit

(*Clause* C-1)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance (min) of					
			30	60	90	120	180	240
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	a) Thickness of floor	75	95	110	125	150	170
		b) Rib width	125	125	125	125	150	175
		c) Cover	20	20	35	45[1)]	55[1)]	65[1)]
ii)	Reinforced concrete (continuous)	a) Thickness	75	95	110	125	150	170
		b) Width	125	125	125	125	150	175
		c) Cover	20	20	20	35	45[1)]	55[1)]

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

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Table 25 Encased Steel Columns, 203 mm × 203 mm

(*Clause* 3.4.3 *and* C-1)

Sl No.	Nature of Construction and Materials	Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance (min) of				
		60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Hollow protection (without an air cavity over the flanges):					
	a) Metal lathing with trowelled lightweight aggregate gypsum plaster[1)]	13	15	20	32	–
	b) Plasterboard with 1.6 mm wire binding at 100 mm pitch, finished with lightweight aggregate gypsum plaster not less than the thickness specified:					
	1) 9.5 mm plaster board	10	15	–	–	–
	2) 19 mm plaster board	10	13	20	–	–
	c) Asbestos insulating boards, thickness of board:					
	1) Single thickness of board, with 6 mm cover fillets at transverse joints	–	19	25	–	–
	2) Two layers of total thickness	–	–	–	38	50
	d) Solid bricks of clay, composition, or sand lime, reinforced in every horizontal joint, ulastered	50	50	50	75	100
	e) Aerated concrete blocks	60	60	60	–	–
	f) Solid blocks of lightweight concrete Hollow protection (with an air cavity over the flanges)	50	50	50	60	75
ii)	Asbestos insulating board screwed to 25 mm asbestos battens	12	19	–	–	–
iii)	Solid protections					
	a) Concrete, not leaner than 1 : 2 : 4 mix (unplastered):					
	1) Concrete not assumed to be load bearing, reinforced [2)]	25	25	25	50	75
	2) Concrete assumed to be load bearing	50	50	50	75	75
	b) Lightweight concrete, not leaner than 1 : 2 : 4 mix (unplastered): concrete not assumed to be load bearing, reinforced[2)]	25	25	25	40	60

[1)] So fixed or designed, as to allow full penetration for mechanical bond.

[2)] Reinforcement should consist of steel binding wire not less than 2.3 mm in thickness, or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement should not exceed 200 mm in any direction.

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Table 26 Encased Steel Beams, 406 mm × 176 mm

(Protection Applied on Three Sides)

(*Clause* 3.4.3 *and* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance (min) of					
		30	60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Hollow protection (without an air cavity beneath the lower flange):						
	a) Metal lathing with trowelled lightweight aggregate gypsum plaster[1)]	13	13	15	20	25	–
	b) Plasterboard with 1.6 mm wire binding[2)] at 100 mm pitch, finished with lightweight aggregate gypsum plaster not less than the thickness specified:						
	1) 9.5 mm plaster board	10	10	15	–	–	–
	2) 19 mm plaster board	10	10	13	20	–	–
	c) Asbestos insulating boards, thickness of board :						
	1) Single thickness of board, with 6 mm cover	–	–	19	25	–	–
	2) Two layers of total thickness	–	–	–	–	38	50
ii)	Hollow protection (with an air cavity below the lower flange):						
	a) Asbestos insulating board screwed to 25 mm asbestos battens	9	12	–	–	–	–
iii)	Solid protection :						
	a) Concrete, not leaner than 1 : 2 : 4 mix (unplastered):	25	25	25	25	50	75
	1) Concrete not assumed to be load bearing, reinforced[3)]	50	50	50	50	75	75
	2) Concrete assumed to be load bearing						
	b) Lightweight concrete[4)], not leaner than 1 : 2 : 4 (mix) unplastered	25	25	25	25	40	60

[1)] So fixed or designed, as to allow full penetration for mechanical bond.

[2)] Where wire binding cannot be used, expert advice should be sought regarding alternative methods of support to enable the lower edges of the plasterboard to be fixed together and to the lower flange, and for the top edge of the plasterboard to be held in position.

[3)] Reinforcement should consist of steel binding wire not less than 2.3 mm in thickness or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement should not exceed 200 mm in any direction.

[4)] Concrete not assumed to be load bearing, reinforced.

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Table 27 Timber Floors — Tongued and Grooved Boarding, or Sheets of Tongued and Grooved Plywood or Wood Chipboard, of not Less than 21 mm Finished Thickness

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance (min) of		
		30	60	120
(1)	(2)	(3)	(4)	(5)
i)	37 mm (minimum) timber joists with a ceiling of:			
	a) Timber lathing and plaster, plaster of thickness	15	–	–
	b) Metal lathing and plaster, thickness of plaster:			
	1) Sanded gypsum plaster (metal lathing grade)	15	–	–
	2) Lightweight aggregate gypsum plaster	13	13	25
	c) One layer of plasterboard with taped and filled joints	12.7	–	–
	d) Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	19	31	–
	e) One layer of plasterboard not less than 9.5 mm thick, finished with:			
	1) Gypsum plaster	5	–	–
	2) Sanded gypsum plaster	13	–	–
	3) Lightweight aggregate gypsum plaster	13	–	–
	f) One layer of plasterboard not less than 12.7 mm thick, finished with:			
	1) Gypsum plaster	5	–	–
	2) Lightweight aggregate gypsum plaster	10	–	–
	g) One layer of asbestos insulating board with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	9	12	–

Table 28 Timber Floors — Tongued and Grooved Boarding, or Sheets of Tongued and Grooved Plywood or Wood Chipboard, of not Less than 15 mm Finished Thickness

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance (min) of		
		30	60	120
(1)	(2)	(3)	(4)	(5)
i)	37 mm (minimum) timber joists with a ceiling of:			
	a) Timber lathing and plaster, plaster of thickness	15	–	–

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Table 28 (*Concluded*)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance (min) of		
		30	60	120
(1)	(2)	(3)	(4)	(5)
	b) Metal lathing and plaster, thickness of plaster for:			
	1) Sanded gypsum plaster (metal lathing grade)	15	–	–
	2) Lightweight aggregate gypsum plaster	13	13	25
	c) One layer of plasterboard with taped and filled joints	12.7	–	–
	d) Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	22	31	–
	e) One layer of plasterboard not less than 9.5 mm thick, finish with:			
	1) Gypsum plaster	5	–	–
	2) Sanded gypsum plaster	15	–	–
	3) Lightweight aggregate gypsum plaster	13	–	–
	f) One layer of plasterboard not less than 12.7 mm thick, finished with:			
	1) Gypsum plaster	5	–	–
	2) Lightweight aggregate gypsum plaster	10	–	–
	g) One layer of asbestos insulating board, with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	9	12 [1)]	–

[1)] Finished on top with 25 mm minimum thick glass fibre or mineral wool laid between joints.

Table 29 Timber Floors — Any Structurally Suitable Flooring of Timber or Lignocelluloses Boards

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance (min) of	
		30	60
(1)	(2)	(3)	(4)
i)	37 mm (minimum) timber joists with a ceiling of:		
	a) Timber lathing and plaster, plaster of thickness	15	–

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Table 29 (*Concluded*)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance (min) of	
		30	60
(1)	(2)	(3)	(4)
	b) Metal lathing and plaster, thickness of plaster for :		
	1) Sanded gypsum plaster (metal lathing grade)	15	–
	2) Lightweight aggregate gypsum plaster	13	19
	c) One layer of plasterboard with joints taped and filled and backed by timber	12.7	–
	d) Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	25	–
	e) Two layers of plasterboard, each not less than 9.5 mm thick, joints between boards staggered and outer layer finished with gypsum plaster	5	–
	f) One layer of plasterboard not less than 9.5 mm thick, finish with :		
	1) Sanded gypsum plaster	13	–
	2) Lightweight aggregate gypsum plaster	15	–
	g) One layer of plasterboard not less than 12.7 mm thick, finished with :		
	1) Sanded gypsum plaster	15	–
	2) Lightweight aggregate gypsum plaster	13	–
	h) One layer of asbestos insulating board with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	12	–

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ANNEX D

(*Clauses* 5.1.4 *and* 6)

ADDITIONAL REQUIREMENTS FOR HIGH RISE BUILDINGS

D-1 GENERAL

High rise buildings should receive special attention with respect to fire and life safety particularly with regard to planning, design, execution, maintenance and training so that the intended provisions of this NBCS are well implemented. These get further accentuated as the buildings go taller; some of the key aspects are as follows:

a) Staging and evacuation requirements of occupants;

b) Stack effect posing challenges towards pressurization and smoke exhaust;

c) Zoning of firefighting system to meet functional requirements of hydraulic pressure and flow; and

d) Challenges experienced by fire personnel in reaching the place of fire and towards evacuation.

Aspects to mitigate these challenges require innovative approach, interaction with local fire authorities and meaningful strategic planning towards maintenance and fire drills.

D-2 EGRESS AND EVACUATION STRATEGY

One firefighting shaft should be planned for each residential building/tower, in an educational building/block, and for each compartment of institutional, assembly, business and mercantile occupancy types. In buildings/floors having three or more compartments, there should be at least two firefighting shafts to serve the compartments.

For other occupancy types, requirement of firefighting shaft should be ascertained in consultation with the local fire authority. The firefighting shaft should necessarily have connectivity directly to exit discharge or through exit passageway (having 120 min fire resistance walls) to exit discharge.

Staircase and fire lift lobby of a firefighting shaft should be smoke controlled as per **4.4.2.5** and Table 5.

It is recommended that the pressurization requirement for staircase in firefighting shaft and for other fire exit staircases in buildings greater than 60 m in height be evaluated to limit the force required to operate the door assembly (in the direction of door opening) to not more than 133 N to set the door leaf in motion. The aspect of pressurization, door area/width and door closure should be planned in consideration to the above.

D-3 FIRE SAFETY REQUIREMENTS FOR LIFTS

The provisions as given in **7.1** to **7.2.4** under fire safety requirements of lifts in high rise buildings in Part D 'Building Services, Section 5 Installation of Lifts, Escalators, Moving Walks and Power-Driven Parking Systems, Subsection 5A Lifts' of this NBCS should be applicable.

D-4 HORIZONTAL EXITS AND REFUGE AREA

D-4.1 Horizontal Exit

A horizontal exit should be through a fire door of 120 min rating in a fire resistant wall. Horizontal exit require separation with the adjoining compartment through 120 min fire barrier. The adjoining compartment of the horizontal exit should allow unlocked and ease of egress and exits for the occupants using defend in place strategy.

Requirements of horizontal exits are as under:

a) Width of horizontal exit doorway should be suitable to meet the occupant load factor for egress;

b) Doors in horizontal exits should be openable at all times from both sides; and

c) All doors should swing in the direction of exit travel. For horizontal exits, if a double leaf door is used, the right hand door leaf should swing in the direction of exit travel.

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D-4.2 Refuge Space/Area

a) Refuge spaces and refuge areas are provided for occupants staging requirements and also enabling assisted evacuation. The aspect of staging and refuge requirements should be planned in the building for people with disabilities and ailments, including specific assistance required for certain section of occupants based on their age and other challenges for self-evacuation.

b) Refuge spaces should be achieved by adequate planning and consideration of space provided in the lift lobby of firefighting shaft, enabling the staging for such occupants and further assisted evacuation through fireman lift in the firefighting shaft. This should enable these occupants to be assisted evacuated by the lift and further to be brought to exit discharge through the well-planned evacuation strategy through exit passageway on the ground or level of exit discharge. Provision for such staging of the occupants should be minimum 12 m^2 or 5 percent of calculated occupants of the floor (served by that firefighting shaft) with a refuge area space of 0.45 m^2 per person in the firefighting shaft lift lobby, whichever is higher.

c) Alternate to refuge spaces, refuge areas should be provided in buildings of height more than 24 m. Refuge area provided should be planned to accommodate the occupants of two consecutive floors (this should consider occupants of the floor where refuge is provided and occupants of floor above) by considering area of 0.3 m^2 per person for the calculated number of occupants and should include additionally to accommodate one wheelchair space of an area of 0.9 m^2 for every 200 occupants and portion thereof, based on the occupant load served by the area of refuge or a minimum of 15 m^2, whichever is higher, should be provided as under:

1) The refuge area should be provided on the periphery of the floor and open to air at least on one side protected with suitable railings.

2) Refuge area(s) should be provided at/or immediately above 24 m and thereafter at every 15 m or so.

   The above refuge area requirement for mall-like (mix of assembly, mercantile, cinema screen and restaurant) occupancy requirement should however be in accordance with **6.4.2.2**.

3) A prominent sign bearing the words 'REFUGE AREA' should be installed at the entry of the refuge area, having height of letters of minimum 75 mm, and also containing information about the location of refuge areas on the floors above and below this floor. The same signage should also be conspicuously located within the refuge area.

4) Each refuge area should be ventilated and provided with first aid box, fire extinguishers, public address speaker, fire man talk back, and adequate emergency lighting as well as drinking water facility.

5) Refuge areas should be approachable from the space they serve by an accessible means of egress.

6) Refuge areas should connect to firefighting shaft (comprising fireman's lift, lobby and staircase) without having the occupants requiring to return to the building spaces through which travel to the area of refuge occurred.

7) The refuge area should always be kept clear. No storage of combustible products and materials, electrical and mechanical equipment, etc should be allowed in such areas.

8) Refuge area should be provided with adequate drainage facility to maintain efficient storm water disposal.

9) Entire refuge area should be provided with sprinklers.

10) Where there is a difference in level between connected areas for horizontal exits, ramps of slope not steeper than 1 in 12 should be provided (and steps should be avoided).

NOTE — Refuge area provided in excess of the requirements should be counted towards FAR.

High rise apartment buildings with apartments having balcony, need not be provided with refuge area; however, apartment buildings without balcony should provide refuge spaces or refuge areas as given above. When refuge areas are preferred over refuge spaces in apartment buildings of height above 60 m (and having balconies), the same should be provided around 60 m level and thereafter at levels around every 30 m. The refuge area should be an area equivalent to 0.3 m^2 per person for accommodating occupants of two consecutive floors, where occupant load should be derived on basis of 12.5 m^2 of gross floor area and additionally 0.9 m^2 for accommodating wheelchair requirement or should be 15 m^2, whichever is higher.

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D-5 ELECTRICAL SERVICES

The specific requirements for electrical installations in multi-storeyed buildings given in Part D 'Building Services, Section 2 Electrical and Allied Installations' of this NBCS and Section 7 of National Electrical Code of India 2023 should be followed.

Wherever transformers are planned at higher floors, the HT cables should be routed through a separate shaft having its own fire resistance rating of 120 min. Wherever HT generators are planned centrally at ground or first basement level, redundant transformers and HT cables should be planned for buildings above 60 m in height.

D-6 FIRE PROTECTION

D-6.1 For residential occupancies above 120 m in height and other occupancies above 60 m in height, the sprinklers should be fed from the main and an alternate/standby riser with suitable isolation valves. The entire sprinkler system should be designed in accordance with good practice [F(20)].

D-6.2 Where the height of the building exceeds 150 m to 175 m, fire water static storage and pumps should be required to be provided at 160 m to 180 m and thereafter at intermediate floors at higher levels enabling efficient and functional firefighting installations. The static fire water storage tanks located at such levels should have capacity at minimum half of the storage of underground static water storage tank as in. Such tanks should be supplemented with water supplies through one working and one standby pump of capacity 2 850 litre/min with two risers at alternate locations feeding to such fire water static storage tanks. The fire pump's requirement and capacity should also be derived for occupancy type as per Table 7A and Table 7J substituting the diesel pump with electrical pump. The fire pump room at such level should have dedicated connectivity through passageway (with 120 min integrity) from the firefighting shaft. Such fire pump room should have 120 min fire resisting wall and provided with adequate ventilation with talk-back connectivity to the main fire pump room and Fire Command Centre.

D-6.3 As an alternative to bottom-fed and standpipe and sprinkler that rely on pumps, in high rise buildings, water can be fed by gravity based tanks located at such levels along the height of the building designed to cater to the stories located 55 m to 60 m below. *See* Fig. 20 and Fig. 21 for guidance/details regarding sizing of pipes and achieving the desired pressure and capacity/volume {as suggested in [F(29)]} to cater respectively to the hydrants and the sprinklers. It is recommended to have the top-most tank having dual risers each connecting to different tank. A cross connection with isolation valve at the top and bottom of the dual risers is recommended.

Repeater tanks provided at higher stories can also be designed to fill the tank below, should the need arise. The top-most tank should have additional capacity (50 percent) to cater to the tank below. Overflow pipes can feed the tank below and designed accordingly. This system is particularly preferred in the case of single tower high rise building. *See* Fig. 20 and Fig. 21 for details.

D-6.4 For high rise buildings, seismic bracings should be considered for firefighting installations depending on seismic vulnerability of the region and the type of occupancy.

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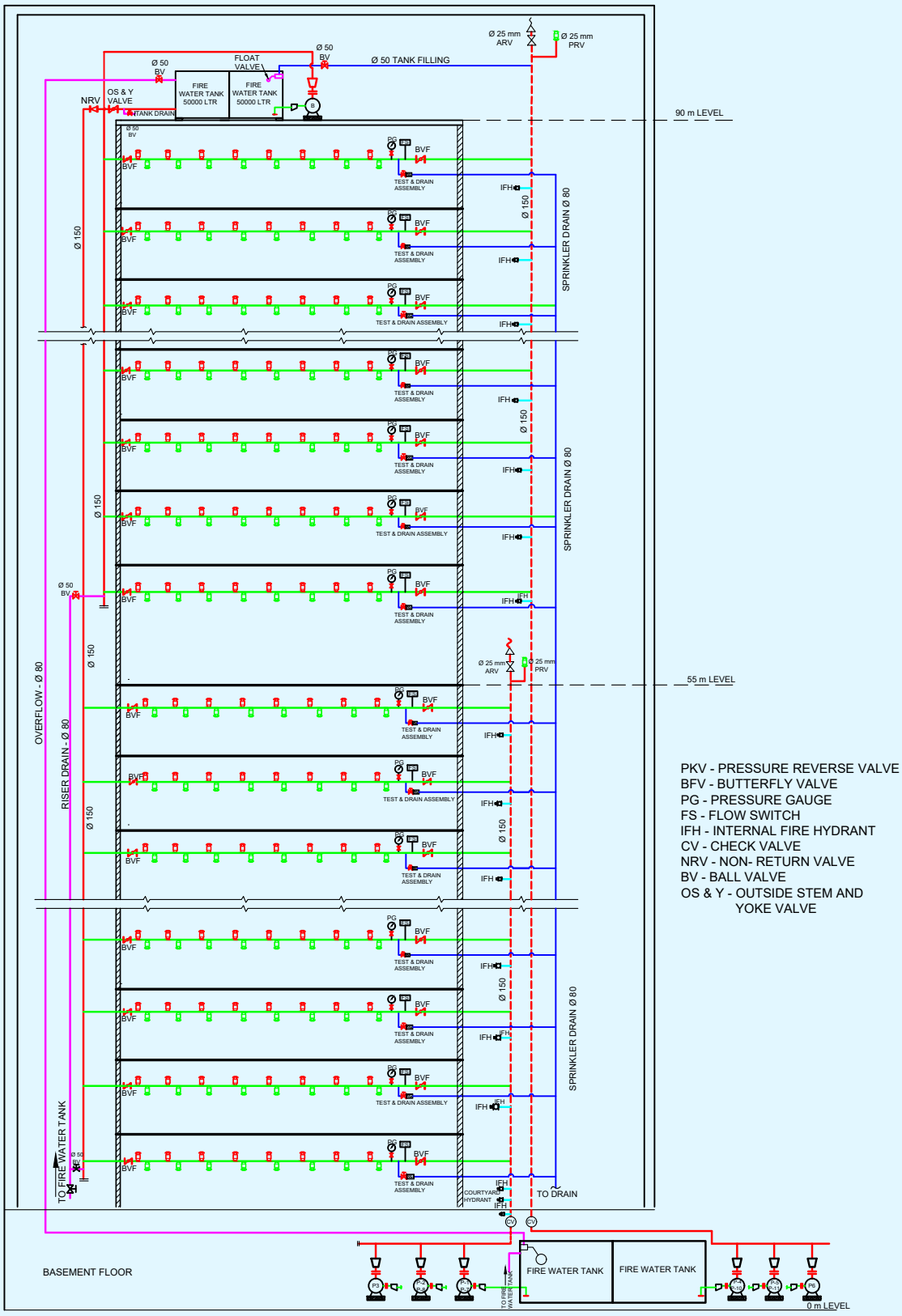

FIG. 20 SCHEMATIC OF GRAVITY BASED FEED FOR 55 M TO 90 M (CONTINUED)

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EQUIPMENT DATA:

PUMP	P-1	P-2	P-3
DESIGNATION	COMMON STANDBY PUMB	COMMON MAIN PUMP	COMMON JOCEKY PUMP
CAPACITY	2 850 lpm	2 850 lpm	180 lpm
HEAD	10 bar	10 bar	10 bar
MODE OF OPERATION	AUTO START and MANUAL START/STOP	AUTO START and MANUAL START/STOP	AUTO START/STOP
DS	DIESEL STAND BY		
SE	STAND BY ELECTRICAL PUMP		
ME	MAIN ELECTRICAL PUMP		
JE	JOCKEY ELECTRICAL		
B	BOOSTER PUMP		

PUMP	P-4	P-5	P-6
DESIGNATION	COMMON STANDBY PUMB	COMMON MAIN PUMP	COMMON JOCEKY PUMP
CAPACITY	2 850 lpm	2 850 lpm	180 lpm
HEAD	15 bar	15 bar	15 bar
MODE OF OPERATION	AUTO START and MANUAL START/STOP	AUTO START and MANUAL START/STOP	AUTO START/STOP
DS	DIESEL STAND BY		
SE	STAND BY ELECTRICAL PUMP		
ME	MAIN ELECTRICAL PUMP		
JE	JOCKEY ELECTRICAL		
B	BOOSTER PUMP		

PUMP	B
DESIGNATION	BOOSTER PUMP
CAPACITY	900 LPM
HEAD	4.5 BAR

FIG. 20 DETAILS OF EQUIPMENT FOR FIGURE 55 M TO 90 M ABOVE

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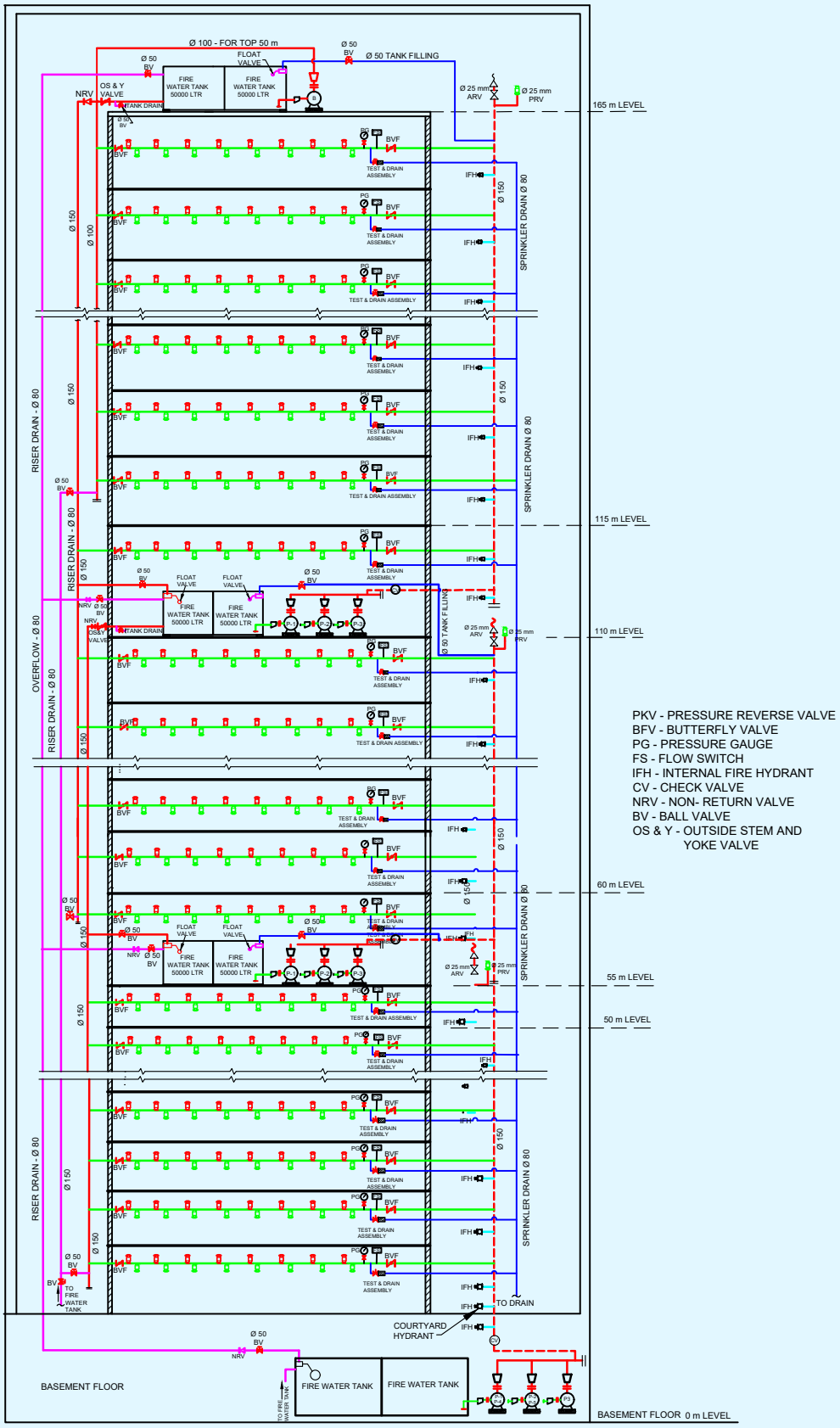

FIG. 21 SCHEMATIC OF GRAVITY BASED FEED FOR 90 M AND ABOVE HIGH RISES (CONTINUED)

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EQUIPMENT DATA:

PUMP	P-1	P-2	P-3
DESIGNATION	COMMON STANDBY PUMB	COMMON MAIN PUMP	COMMON JOCEKY PUMP
CAPACITY	2 850 lpm	2 850 lpm	180 lpm
DUTY HEAD	10 bar	10 bar	10 bar
SHUT OF HEAD	12 bar	12 bar	12 bar
MODE OF OPERATION	AUTO START and MANUAL START/STOP	AUTO START and MANUAL START/STOP	AUTO START/STOP

PUMP	B
DESIGNATION	BOOSTER PUMP
CAPACITY	900 LPM
HEAD	4.5 BAR

FIG. 21 SCHEMATIC OF GRAVITY BASED FEED FOR 90 M AND ABOVE HIGH RISES

D-7 FIRE AND LIFE SAFETY AUDIT

D-7.1 The following should be applicable:

a) Fire and life safety audit should be carried out for all high rise buildings;

b) Such audits should preferably be conducted by a third party auditor having requisite experience in fire and life safety inspections;

c) Frequency of such audits should be once in two years.

DI-7.2 Good practices towards fire and life safety audit should be as given below:

a) Objective is to ensure that a building's fire prevention, fire protection and life safety measures are evaluated against established Indian Standards;

b) Methodology includes: Audit planning, on-site audit execution, documentation and reporting;

c) Audit objectives to cover: compliance verification, risk identification, performance evaluation, corrective recommendations, documentation and process review;

d) Fundamental principles should be: objectivity, consistency, risk-based approach, comprehensive coverage, continuous improvement, transparency and documentation, and stakeholder involvement;

e) In the audit methodology and process the following should be adhered: planning and preparation (Pre-audit data collection, Risk assessment and prioritization techniques, Audit team composition and qualifications), Audit execution (On-site inspection procedure, documentation review and interview, checklist and performance indicators), and Audit reporting (structure and content of the report, documentation of non-compliances and recommendations, methods for risk communication);

f) Audit criteria for fire safety should be well established; covering respectively for fire prevention namely:

1) Building design and construction features

i) Structural fire resistance

ii) Fire compartmentation and separation

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iii) Material selection and non-combustibility

iv) Means of egress and access routes

v) Integration of fire safety systems

vi) Compliance with regulatory requirements

vii) Documentation and verification

2) Maintenance of fire prevention systems and housekeeping practices

i) Regular maintenance and servicing

ii) Housekeeping practices

iii) Documentation and verification

iv) Training and accountability;

g) Audit criteria for fire safety should be well established; covering respectively for fire protection systems namely:

1) Assessment of fire detection and alarm systems

i) Design and installation compliance

ii) Function performance and testing

iii) Maintenance and calibration

iv) Integration with emergency systems

v) Documentation and compliance verification

2) Inspection of fire suppression systems

i) Design and installation compliance

ii) Operational testing and performance

iii) Maintenance and inspection records

iv) Integration with fire safety systems

v) Physical condition and accessibility

vi) Compliance with regulatory and manufacturer specifications

3) Evaluation of emergency lighting signage

i) Design and installation compliance

ii) Visibility and illumination levels

iii) Operational performance

iv) Maintenance and inspection

v) Integration with overall safety systems

vi) Documentation and compliance verification

4) Evaluation of life safety components

i) Assessment of exit routes, corridors and stairways

- Design and layout
- Unobstructed passage
- Dimensions and capacity
- Signage and emergency lighting
- Physical condition and maintenance

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- Special provisions
- Documentation and verification

ii) Verification of occupant load, exit capacities and travel distances

- Occupant load verification
- Assessment of exit capacities
- Measurement of travel distances
- Integration and documentation
- Assessment of portable and wheeled fire extinguisher;

h) Audit criteria for life safety should be well established to cover:

1) Structural and environment safety

i) Evaluation of structural fire resistance and compartmentation

ii) Assessment of emergency communication systems and evacuation aids

2) Accessibility and special needs

i) Consideration for persons with disabilities

ii) Audit of assisted evacuation procedures;

j) Performance indicators and compliance assessment – To address:

1) Scoring and rating methodologies for audit findings

2) Risk evaluation and prioritization of deficiencies

3) Criteria for Compliance/Partial Compliance/Non-Compliance;

k) Corrective actions and follow-up are essential so as to provide opportunity to the building owner/resident to address the shortfall so as to make the premises safe; and

m) Reporting and record keeping – To have standard formats/templates to record observations, measurements including photographs stored in compatible formats, all with a view to enable suitable reviewing for consistency.

D-8 HELIPAD

For high rise buildings above 200 m in height, provision for helipad is recommended for specific requirements like landing of fire equipment, and support facilities or other emergencies.

Suitable fire protection is required for the helipad areas to enable their safe usage at all times. The firefighting facilities for rooftop helipad includes fire detection, fixed or portable firefighting foam system (oscillating foam monitor, deck integrated foam nozzles or portable foam units), fire hydrants and trained response team.

Low expansion aqueous film forming foam (AFFF) can be applied to the helideck from either fixed nozzles or an oscillating nozzle, particularly on the landing pad, at the rate of 10 lpm per square foot for a duration of 10 min.

Without the requirement for any additional water, buildings having helipad should use the water available for wet riser, sprinkler system, etc for foam based fire protection. This can be achieved by a suitable tee connection in the standpipe by attaching a 100 mm or 150 mm deluge valve (to control the flow of water) and extending a 100 mm or 150 mm water line from that valve, to the foam producing equipment located near (outside) the helipad area.

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ANNEX E

(*Clauses* 4.5.3.4, 6 *and Table* 6)

ATRIUM

E-1 ATRIUM REQUIREMENTS

a) In order for an atrium to be permitted in buildings, the following should be complied with:

   1) Atrium should be permitted in buildings of Type 1 and Type 2 construction only.

   2) The use of combustible furnishings and decorations on the floor of the atrium should be limited and sparsely distributed.

b) Smoke detectors (preferably beam type or aspirating type) should be provided on the underside of each floor protruding into the atrium, at the atrium roof and adjacent to each return air intake from the atrium. Within atrium space, beam type or aspirating type smoke detectors should be used to ensure detection of smoke, considering factors such as stratification of smoke.

c) Where the ceiling of the atrium is more than 17 m above the floor, water based protection (automatic sprinklers) at the ceiling of atrium is not required. In such case, travel distance allowance should be as applicable for sprinkler spaces.

d) Hydrants should be available at the floor of the atrium and also at the adjoining upper spaces/floors of the atrium. Sprinklers are required to be installed for coverage of glass areas of retail, tenant and other areas adjoining the exit access corridor and atrium. Sprinklers should be at a distance of 450 mm to 600 mm enabling cooling of such glass and limiting the extent of fire and smoke to the atrium (*see* Fig. 22). This provision does not allow similar sprinkler installation arrangement to offset fire compartmentation requirements, in which case fire barrier is required as per relevant provisions of this Part.

e) Atrium in business occupancy should be planned with 6 air changes per hour (ACPH) while atrium in hotels and assembly occupancy should be planned with 8 ACPH smoke extraction system.

f) Such air changes should be planned in atrium for a height of 15 m from the top.

g) Smoke exhaust fans should be capable of operating effectively at 250 °C for 120 min.

h) Makeup air supply points should be located beneath the smoke layer and on the lower levels connected by the atrium.

j) Makeup air should be provided by fans, openings to outside to allow infiltration, or the combination thereof.

k) It is recommended that makeup air be designed at 85 percent to 95 percent of the exhaust flow rate, not including the leakage through these small paths.

m) The makeup air should not cause door-opening force to exceed allowable limits.

n) The makeup air velocity should not exceed 1.02 m/s is where the makeup air could come into contact with the plume unless a higher makeup air velocity is supported by engineering analysis;

p) Atrium smoke management system fans should be provided with emergency power.

q) If so, required by the Authority, an engineering analysis should be performed which demonstrates that the smoke system for the atrium is designed to keep the smoke layer interface 1 800 mm above the highest occupied floor level of exit access, open to the atrium, for a period equal to 1.5 times the calculated egress time or 20 min, whichever is greater.

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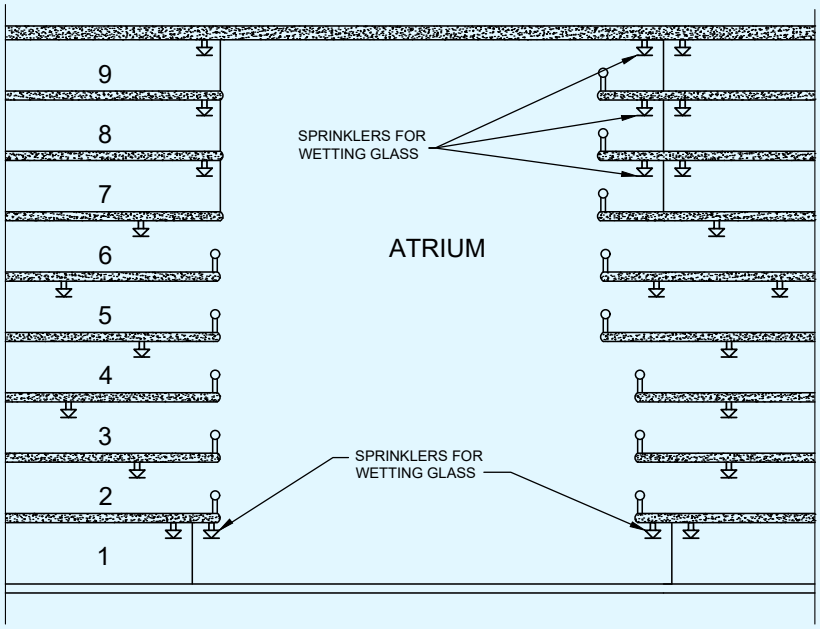

FIG. 22 SPRINKLER PROTECTION OF GLASS FOR FLOOR OPEN TO ATRIUM

ANNEX F

(*Clause* 6)

REQUIREMENTS FOR DATA CENTRES

F-1 GENERAL

Data centres are classified under Group E Business occupancy and in particular as E-II sub-occupancy considering its primary use, scale, and presence of process equipment. A comprehensive fire risk assessment should be conducted at the planning stage and periodically during operation. Assessments must include ignition sources, fire load, electrical risks, HVAC systems, etc. For guidance on the facilities and infrastructure of datacentres, refer to the following good practices.

IS/ISO/IEC 22237-1 : 2021	Information technology – Data centre facilities and infrastructures: Part 1 General concepts
IS/ISO/IEC 22237-3 : 2021	Information technology – Data centre facilities and infrastructures: Part 3 Power distribution
IS/ISO/IEC 22237-4 : 2021	Information technology – Data centre facilities and infrastructures: Part 4 Environmental control

F-2 BUILDING DESIGN AND CONSTRUCTION

F-2.1 The fire resistance rating for the structural and non-structural elements should be based on guidelines as per approved and accepted standards. The fire rating should be validated and certified with a view to meeting the requirements of Table 1. In the absence of any validated/certified rating, guidance may be obtained from the information available in Annex C.

F-2.2 An anti-static floor system is highly recommended to prevent electrostatic discharge and support cable management. The data centre must be completely isolated from dust, water, vibration, and humidity. All external openings should be sealed, and no water sources or pipelines should be routed through or above the data centre,

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UPS room, or communications room to eliminate risks of leakage or moisture intrusion. However, any location of chillers at higher heights be opted considering the operational efficiency and the same should be adequately considered in the structural design; Authorities may consider exempting the increased building height in such a case. Considering the sensitivity and fire hazards, such floors should have no other occupancy or else this should be considered in the calculation of floor area ratio and height.

F-2.3 Server rooms, battery banks, fuel storage, and other high-risk areas should be physically separated using fire-rated assemblies. Cable trays and ducts openings for cable trays and ducts should be sealed with materials having fire resistance rating of the compartment.

F-2.4 The number of basements should be kept as minimum and it should not be more than 2. The basement(s) should be within the building line and their total area should not exceed the area of ground floor.

F-2.5 The parking requirement should be arrived at considering the requirement for administrative building (at 1 ECS per 100 m^2). The parking requirement for the data centre/utility building should be based on the actual required number and area (of trucks) for which additional considerations of loading and unloading spaces for services, including rack placement/replacement as advised by the OEMs, DG set, utilities, etc should be made. In addition, consideration for the fire truck and its movement should be ensured in consultation with the local Fire Authority.

F-2.6 Lifts, when planned, consider respectively for administrative building as passenger lift as per Part D/ Section 5A of this NBCS should, and for the datacentre building as special goods lifts and special service lifts, for which OEMs should be consulted considering the size, speed and weight of payload; and any required special requirement.

F-2.7 Heights of stories should be arrived at based on the size of racks opted and the associated services (like cooling/ducting) and the same is effectively addressed in the structural design. The total height of the datacentre building should be arrived based on the FAR and only Type 1 construction. Ground-coverage should ideally not exceed 60 percent considering the peculiar requirements and the essential nature of these buildings which are required in the society in the current times, and the associated moment of heavy vehicles to install/maintain/repair the racks/occupant.

NOTE — Authorities to consider also the possible change of occupancy from data centre to other permitted business as well; and the ground-coverage.

F-3 FIRE DETECTION SYSTEMS

F-3.1 Use of aspirating smoke detection system in server areas is recommended for very early detection.

F-3.2 The system should incorporate heat sensitivity and high-sensitivity smoke detectors (HSSD) to enable early fire detection and prompt activation of suppression mechanisms.

F-3.3 For other requirements on fire detection and alarm system **4.9** be referred.

F-4 FIRE SUPPRESSION SYSTEMS

F-4.1 The fire suppression system in data centres should be designed to ensure both operational continuity and protection of sensitive equipment. The preferred suppression technologies and clean agent extinguishers (such as heptafluoro propane, fluorinated ketone based system or equivalent) should be available throughout data hall areas. These systems should be effective in suppressing fires without leaving any residue, making them safe for electronic and electrical installations.

F-4.2 All critical areas within the data centre, including server rooms, network rooms, UPS and battery areas, and under-floor and overhead spaces, must be covered comprehensively by the fire suppression system.

F-4.3 The suppression agents should be ozone-friendly and compliant with international environmental norms. The recharge process must be easy, with minimal downtime, and the equipment should be easy to test periodically.

F-4.4 An early warning fire detection and suppression system should be integrated with the fire alarm and building management system (BMS) for real-time monitoring and response. The system should be engineered to offer reliable and quick suppression to minimize damage and downtime.

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F-5 ELECTRICAL AND HVAC FIRE SAFETY (*See also* Part D/Sec 2 and Part D/Sec 3 of this NBCS)

F-5.1 UPS, transformer, and generator rooms should be separated with fire-rated partitions/doors and have independent suppression systems. Should the need arise, the generators can be placed one over the other/stacked (suggested upto 5 numbers) parallel to the data centre building, but adequate fire safety should be ensured for which OEM's advice and specialist literature should be referred.

F-5.2 Wherever batteries are provided, the same should be segregated by 120 min fire rated construction. Ventilation to the room should be provided as per manufacturer's instructions.

F-5.3 Air conditioning and ventilating systems should be so installed and maintained as to minimize the danger of spread of fire, smoke or fumes from one floor to other or from outside to any occupied building or structure.

F-5.4 Supply air ducts, fresh air and return air ducts/passages must include fire dampers and smoke detectors (*see* **3.5.7.4**).

F-5.5 Insufficient power capacity design for a data centre can result in various issues such as system downtime, data loss, increased cost, reduced performance, regulatory non-compliance, etc. Ensuring a robust power capacity design is crucial for the reliable and efficient operation of data centres.

F-6 MEANS OF EGRESS

F-6.1 Exit Access

Exits should be provided on each floor or compartment in accordance with **4.4.2**. All exits should be unobstructed, illuminated, and clearly marked.

F-6.2 Staircases and Corridors

Staircases must be enclosed, fire-rated, and positively pressurized to prevent smoke ingress. Staircases should be of minimum 1.5 m in width, and 2 numbers of it will be required in the datacentre building. Staircase for administrative building should be arrived at using **4**; in any case, minimum 2 staircases are required.

F-6.3 Emergency Lighting and Signage

Emergency lighting consistent with emergency system for the building should be provided. Addressable emergency exit lighting system is recommended, adaptive type exit signages can also be used.

F-7 MEP, FIREFIGHTING AND SEISMIC SUPPORT REQUIREMENT

F-7.1 Earthquakes can cause downtime, data loss, service disruptions, fire, etc. Seismic bracing is essential to secure MEP equipment and systems, safeguarding them against the threats posed by earthquakes.

F-7.2 Non-structural measures focus on protecting operational components. These include seismic-rated mounting systems for equipment racks, secure cable pathways, MEP and firefighting services to avoid disconnections, and reinforced architectural features like ceilings and raised floors. These elements must meet seismic standards to ensure systems stay operational during and after an earthquake.

F-7.3 Seismic analysis/calculations should be carried out based on Part C 'Structural Design, Section 1 Loads and Load Effects' of this NBCS and good practice [F(32)]. Each non-structural component's seismic interactions with all other connected components and with the supporting structure should be accounted for in the design. The component should accommodate drifts, deflections, and relative displacements determined in accordance with the applicable seismic requirements of standards.

F-7.4 Each straight pipe/duct/cable containment run with two or more supports requires a minimum of two transverse braces (perpendicular to the run) and one longitudinal brace (parallel to the run).

F-7.5 Wire rope angular bracing should be seismic certified/tested by third party accredited lab as per method of testing for rating seismic and wind restraints. Rigid angular bracing and modular support system should be

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analyzed for both tensile and compressive loads for strength and serviceability for the maximum length of element being used in worst case condition as per load combination as mentioned in standards.

F-7.6 Calculate the static and dynamic loading due to wind forces that is required to select/design vibration isolators, bases and seismic and wind restraints for outdoor and roof top equipment's/services. The calculation of wind load should be as per Part C 'Structural Design, Section 1 Loads and Load Effects' of thi NBCS. Worst case between seismic loads and wind loads should be considered for supporting and vibration isolation.

F-8 SECURITY

F-8.1 It is recommended that all doors should be access controlled or should be as per best suitable secure design requirement.

F-8.2 Doors should send an alarm if left open.

F-8.3 In line with safety requirements, access should be open for the fire affected area.

F-9 OPTIONAL PERFORMANCE INDICATORS

For guidance on the performance indicators of datacentres, the following good practices may be referred.

IS/ISO/IEC 30134-1 : 2016	Information technology — Data centres — Key performance indicators: Part 1 Overview and general requirements
IS/ISO/IEC 30134-2 : 2016	Information technology — Data centres — Key performance indicators: Part 2 Power usage effectiveness (PUE)
IS/ISO/IEC 30134-3 : 2016	Information technology — Data centres — Key performance indicators: Part 3 Renewable energy factor (REF)
IS/ISO/IEC 30134-4 : 2017	Information technology — Data centres — Key performance indicators: Part 4 IT equipment energy efficiency for servers (ITEEsv)
IS/ISO/IEC 30134-5 : 2017	Information technology — Data centres — Key performance indicators: Part 5 IT equipment utilization for servers (ITEUsv)
IS/ISO/IEC 30134-6 : 2021	Information technology — Data centres — Key performance indicators: Part 6 Energy reuse factor (ERF)
IS/ISO/IEC 30134-8 : 2022	Information technology — Data centres — Key performance indicators: Part 8 Carbon usage effectiveness (CUE)
IS/ISO/IEC 30134-9 : 2022	Information technology — Data centres — Key performance indicators: Part 9 Water usage effectiveness (WUE)

ANNEX G

[*Clauses* 6.4.2.2(e) *and* 6.8.1.5]

CAR PARKING FACILITIES

G-1 The provisions given in **G-2** to **G-5** should apply to parking structures of the closed or open type, within buildings above or below grade.

G-2 GENERAL

a) Where both parking and repair operations are conducted in the same building, the entire building should comply with the requirements for Group G occupancies, unless the parking and repair sections are effectively separated by separation walls of 120 min fire rating.

b) Floor surfaces should be non-combustible, sloping towards drains to remove accumulation of water.

c) Those parts of parking structures located within, immediately above or below, attached to, or less than

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3 m away from a building used for any other purpose should be separated by fire resistant walls and floors having fire resistance rating of not less than 120 min. This should exclude those incidental spaces which are occupied by cashier, attendant booth or those spaces used for toilets, with a total area not exceeding 200 m^2.

d) Vehicle ramps should not be considered as exits unless pedestrian facilities are provided.

e) Other occupancies like fuel dispensing, should not be allowed in the building. Car repair facilities, if provided, should be separated by 120 min fire resistant construction.

f) In addition to fire protection requirements as per Table 7A to Table 7J, appropriate fire detection and suppressions systems should be provided for the protection of hydraulic oil tank and pumps located below ground level for operation of car lifts.

g) Means of egress should meet the requirements specified in **4**.

G-3 OPEN PARKING STRUCTURES (INCLUDING MULTI-LEVEL PARKING AND STILT PARKING)

a) The term open parking structure specifies the degree to which the structure's exterior walls must have openings. Parking structures that meet the definition of the term open parking structure provide sufficient area in exterior walls to vent the products of combustion to a greater degree than an enclosed parking structure.

b) A parking structure having each parking level wall openings open to the atmosphere, for an area of not less than 0.4 m^2 for each linear metre of its exterior perimeter should be construed as open parking structure. Such openings should be distributed over 40 percent of the building perimeter or uniformly over two opposing sides. Interior wall lines should be at least 20 percent open, with openings distributed to provide ventilation, else, the structure should be deemed as enclosed parking structures.

NOTE — A car park located at the stilt level of a building (not open to sky) can be considered an open or an unenclosed car park if any part of the car park is within 30 m of a permanent natural ventilation opening and any one of the following is complied with towards the permanent natural ventilation requirement:

1) 50 percent of the car park perimeter should be open to permanent natural ventilation.

2) At least 75 percent of the car park perimeter is having the 50 percent natural ventilation opening.

c) All stilt parking is required to be provided with sprinkler system where such buildings are required to be sprinklered.

d) Open parking structures are not required to be provided with compartmentation.

e) Open car parking (open to sky) within building complex having fire hydrant system should also need to be protected with yard hydrant installation system in accordance with good practice [F(29)].

G-4 ENCLOSED PARKING STRUCTURES

a) Those car parking structures which are enclosed on all sides and on top, not falling within the definition of open car parking [*see* G-3(b)] and also those situated in the basements should be known as enclosed car parking structures.

b) All sprinklers in car parking should be standard response type with minimum K-factor of 80, area coverage of 9 m^2 and designed as per good practice [F(20)].

c) For smoke ventilation requirement of car parking, *see* **4.6**.

d) All fire exit doors from the car parking to exits should be painted green and should display exit signage.

G-5 AUTOMATED CAR PARKING UTILIZING MECHANICAL OR COMPUTERIZED/ ROBOTIC MEANS

a) Automated car parking structure can be of open parking type or enclosed types.

b) Automated car parking facilities pose more hazard compared to manual parking due to following reasons:

1) High density of cars due to close stacking one over another.

2) Lack of provision on fire separation/compartmentation horizontal or vertical leading to rapid fire spread.

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3) Non-availability of any person to notice/control the fire in initial stages.

4) Limited access to firefighting personnel.

5) Extensive height and depth involved with highly combustible load.

c) All basements should deploy sprinkler system with not less than K 115 quick response sprinklers, with a minimum of 2 sprinkler for each vehicle with not more than 7.2 m^2 coverage per sprinkler. The area of operation for basement sprinkler should not be less than 230 m^2. This should be applicable to both internal combustion engines (ICE) and electric battery operated or hybrid vehicles. All the sprinklers installed should be protected with a sprinkler guard.

d) All basements that deploy stack parking with one car above the other, where 2 sprinklers cannot be installed for the car below, a quick response extended coverage horizontal side wall of K 115 should be deployed. The pressure rating for this sprinkler should be based on original equipment manufacturers (OEM) recommendation based on the length and width covered. This sprinkler coverage should be within the OEM listing and approvals. Electric or hybrid car should not be parked on stack parking at any level. All the sprinklers installed should be protected with a sprinkler guard.

e) All buildings with automated puzzle parking without human interface should deploy sprinklers as applicable for normal parking. However, the riser should be limited to 24 m height, and additional risers with isolation valves should be added for each riser of 15 m thereon. This is to facilitate maintenance and isolation in case of false activation of sprinklers. All the sprinklers installed should be protected with a sprinkler guard.

f) Fire escape staircases, at least 1 250 mm wide should be provided at appropriate locations so that no place is more than 45 m from the nearest staircase. Horizontal walkways, at least 1 000 mm wide for access to all the areas should be provided at every parking level.

g) Travel distance and means of egress should be governed by the respective sections of this NBCS.

h) The hazardous areas like DG sets, transformers, HT/LT panels for the parking lot should be suitably segregated from other areas as per requirements given in this NBCS and all such areas should be protected by suitable automatic fire suppressions systems.

G-6 REQUIREMENTS FOR ELECTRIC VEHICLES (EV) CAR PARKING

See also **10.7** of Part D 'Building Services, Section 2 Electrical and Allied Installation' of this NBCS, including regarding electrical safety and location.

EV car parking are best planned in outdoors in well ventilated condition or in separate parking building at/above ground level having naturally cross-ventilated sides. Wherever EVs are designated in the regular car parking they should be segregated from other vehicles using both passive means and active measures of fire protection. The preferred locations are in the ground level and in no case below the first basement. Charging points for EVs may not be permitted below the ground level; and when permitted the same should be restricted to first basement. To enable immediate attention, the EV charging points for the EVs should be available at the entrance/first opportunity of the basement. Isolation cut-off switches (and fireman's emergency switch) should preferably be of the automated type or when manually operated should be located at the ground level also.

Active protection measure includes one or more of: water mist sprinkler system, and smart detection/monitoring system that enables early detection of thermal runaway issues that can flare up the fire should it happen. Fire suppressing materials using vermiculite/clay/mica based encapsulating agents that provide satisfactory performance may also be used.

The passive protection measures include fire rated walls (preferred over fire curtains/smoke curtains), fire doors, etc and additional protection measures to protect the structural elements from possible rising heat due to fire/hot gases. In the case of basements, maximum sizes of such a compartment for the EV parking (and charging) stations should be 1 000 m^2.

NOTE — The above provisions may be modified based on the availability of more suitable/better extinguishing media that proves effective against such fires.

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ANNEX H

(*Clause* 6.4.4)

FIRE AND LIFE SAFETY REQUIREMENTS FOR METRO STATIONS

H-1 APPLICATION AND SCOPE

The provisions of this Annex relate to the buildings constructed as part of the metro stations/metro rail systems.

H-2 TERMINOLOGY — *See* 2.46.

H-3 GENERAL

H-3.1 Classification

Metro stations can be classified under 'Assembly occupancies'. These include any station building or part thereof, permanent or temporary, through which people transit for the duration of time required to enter the building and board the train to depart the station platform or to alight from the train and depart from the station building.

H-3.2 Sub-classification

Metro rail system buildings can be further classified under the following headings:

a) Elevated and enclosed stations,

b) Elevated and open stations,

c) Underground (enclosed) stations, and

d) Train depots.

NOTE – The above includes all open and enclosed metro stations along with their associated ancillary structures and train depots. Elevated should mean to include 'at-grade' stations as well.

H-3.3 Fire Zones

Metro stations, that is, mass rapid transit, may be constructed in any Fire Zone No. 1, 2 or 3, as per the transportation requirement/policy.

H-3.4 Type of Construction

Metro stations should conform to Type 1 or Type 2 or combinations of Types 1 and 2 non-combustible constructions, as defined in 3.4.

H-4 LIFE SAFETY REQUIREMENTS

H-4.1 Occupant Load

a) Main occupant load in a transit station is the platform occupant load, on which basis the life safety provisions of transit stations are designed. Occupant loads in transit stations are mainly a function of the train carrying capacities rather than the areas of a station.

b) For calculating platform occupant loads for a multiline, multilevel or multiplatform station, maximum occupant load for each platform should be considered separately for determining the egress capacity from that platform.

c) At levels where egress routes from separate platforms converge, occupant loads of all platforms should be considered to calculate egress capacity from that level. Simultaneous loads should be considered for all egress routes passing through each level of that station.

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d) Platform occupant load should be based on the greater of the AM or PM 'peak hour loads' generated by the system and train loads.

e) Peak hour load should be converted to peak minute loads by dividing by 60 and multiplying further by a system surge factor varying from 1.3 to 1.5, as defined by the transit system authority. Surge factor may require to be further enhanced where increased footfalls are anticipated, like stations catering to sports complex, transit oriented development, and stations serving two or more lines.

NOTE — Surge factors should be based on actual calculations by transit system authority and in no case it should be less than 1.3.

f) Platform occupant load should be determined by factoring in the peak hour entraining loads at platform edges and train loads, in emergency evacuation scenario, as defined here:

1) *Train on Fire* – It is assumed that a train loaded to crush capacity/link load as may be decided by the transit system authority, travelling in peak direction at peak hour has caught fire, and as per the operating procedure it is brought to the next station, whereupon it should require to be evacuated.

2) The train in this case being called the 'incident train' and the platform on which it is arriving being called 'incident platform' of the 'incident station'.

3) Passengers waiting on all the platforms of the 'incident station' should require to be evacuated as well.

4) Number of passengers should be determined as defined in (g) below.

5) Only one source of fire, that is, train fire should be assumed at a time.

6) It is assumed that the train on non-incident platform should not stop at the incident station and should stop only at previous/next station.

g) Platform occupant load for emergency evacuation scenario, should be the addition of two headway entraining loads for peak direction platform, one headway entraining load for off-peak direction platforms and one crush train load/link load.

NOTE — *See* also **H-4.1**(b) and **H-4.1**(c).

h) *Occupancy in Non-public Areas*:

1) Use of designated non-public areas by station staff whose work assignments require their presence in the station structures should be permitted.

2) Unmanned plant rooms and any other areas where usual occupancy is less than 10 persons at any given time should be treated as unoccupied areas.

j) *Segregation with Non-transit Occupancy*:

Non-transit (and incidental) occupancies, of area up to 300 m^2 (total area of all floors), should be permitted to be accommodated within the station building. Occupant load of areas under non-transit occupancies should be in accordance with Table 2.

H-5 EGRESS PROVISIONS

H-5.1 Evacuation Time

a) *Means of Egress–public Areas* — Egress from metro station should be designed to facilitate the evacuation of a pre-defined platform occupant load to a designated point of safety in pre-defined emergency scenario(s), as defined by the transit system authority.

b) *Evacuation Time from Platform* — Enough egress capacity should be provided to evacuate the platform occupant load within 4 min from enclosed stations and within 5.5 min from open stations.

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c) *Evacuation Time to Point of Safety* — Further, station design should permit evacuation of the remotest person on platform to a point of safety within 6 min in case of enclosed stations and within 8 min in case of open stations.

NOTE – Evacuation time specified in (b) and (c) may be modified based on actual engineering analysis by evaluating material heat release rates, station geometry and emergency ventilation systems.

d) For open stations where the concourse is below or protected from the platform by distance or materials as determined by an appropriate engineering analysis, that concourse should be permitted to be defined as a point of safety.

e) For enclosed stations equipped with an emergency ventilation system and where the emergency ventilation system provides protection for the concourse from exposure to the effects of a train fire at the platform as confirmed by engineering analysis, that concourse is permitted to be defined as a point of safety.

H-5.2 General Arrangement

a) Means of egress from each station platform should be provided so that they are equally distributed as far as possible, in capacity and placement, throughout the length of platform.

b) There should be at least two means of egress remote from each other.

c) Means of egress may however, be allowed to converge at concourse or subsequent levels with sufficient capacity to achieve the required evacuation time.

d) As far as possible, all the egress capacity required for emergency evacuation should be provided with the unenclosed stairs and escalators which are used for normal circulation.

H-5.3 Travel Distance

The maximum travel distance on the platform to a point at which a means of egress route leaves the platform should not be more than 100 m. This should, however be subject to fulfilling the egress requirements specified in **H-5.2**.

H-5.4 Means of Egress

H-5.4.1 *Non-public Areas*

Means of egress from unoccupied non-public areas should be permitted to be merged into public means of egress.

H-5.4.2 *Non-transit Occupancies*

Separate means of egress should be provided for such non-transit occupancies which are segregated from the station's public area to ensure independent evacuation from either occupancy. Such means of egress may be allowed to converge beyond station concourse area with the approval of the competent authority. Travel distance and other egress provisions of such non-transit occupancies should be in accordance with **4.4**.

H-5.4.3 *Platform*, *Corridors*, *Ramps*

Platforms, corridors and ramps serving as means of egress should be designed as per the following criteria:

a) A minimum clear width of 1 200 mm should be provided along all platforms, corridors, and ramps serving as means of egress

b) In computing the means of egress capacity available on platforms, corridors, and ramps, 300 mm should be deducted at each side wall and 450 mm should be deducted at platform edges that are open to the trainway.

c) The maximum means of egress capacity of platforms, corridors, and ramps should be computed at 0.0820 people/mm-min.

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d) The maximum means of egress travel speed along platforms, corridors, and ramps should be computed at 38.0 m/min.

e) The means of egress travel speed for concourses and other areas where a lesser pedestrian density is anticipated should be computed at 60.0 m/min.

H-5.4.4 *Stairways*

a) Unenclosed stairs and escalators should be permitted to be counted as contributing to the means of egress capacity in stations.

b) Minimum widths of such unenclosed staircases should be 1 800 mm for unidirectional stairs, and 2 400 mm for bidirectional stairs.

c) Wall or floor-mounted railings on both sides should be permitted on stairs without affecting the widths stated in (b) above by more than 300 mm.

d) Enclosed stairs in the means of egress should be minimum 1 200 mm wide.

e) Capacity and travel speed for stairs should be computed at 0.0555 people/mm-min and 14.6 m/min, respectively.

H-5.4.5 *Escalators*

a) Escalators should not account for more than one-half of the means of egress capacity at any one level.

b) In calculating the egress capacity of escalators,

1) one escalator at each level should be considered as being out of service, and

2) the escalator chosen should be the one having the most adverse effect upon egress capacity.

c) Where escalators are permitted as a means of egress in stations, the following criteria should be complied with:

1) The escalators should be constructed of non-combustible materials (exceptions like rollers and handrails should be permitted with intimation to the Competent Authority).

2) Escalators running in the direction of egress should be permitted to remain operating.

3) Escalators running in reverse to the direction of egress should be capable of being stopped either locally by a manual stopping device at the escalator or remotely by a manual stopping device at a remote location or remotely as part of a pre-planned evacuation response. A stopped escalator should be counted as equivalent to 1 m wide staircase.

d) Where provision is made for remote stopping of escalators counted as means of egress, one of the following should apply:

The stop should be delayed until it is preceded by a minimum 15 s audible signal or warning message sounded at the escalator; wherein (1) the signal or message should have a sound intensity that is at least 15 dBA above the average ambient sound level for the entire length of the escalator, (2) the signal should be distinct from the fire alarm signal, and (3) the warning message should meet audibility and intelligibility requirements.

OR

Where escalators are equipped with the necessary controls to decelerate in a controlled manner under the full rated load, the stop should be delayed for at least 5 s before beginning deceleration, and the deceleration rate should be no greater than 0.052 m/s^2.

e) Escalators with or without intermediate landings should be acceptable as a means of egress, regardless of vertical rise.

f) Escalators exposed to the outdoor environment should be provided with slip-resistant landing and floor plates.

g) Stopped escalators should be permitted to be started in the direction of egress in accordance with the requirements for stopping of escalators described in **H-5.4.5**(c)(3) and **H-5.4.5**(d).

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h) Capacity and travel speed for escalators should be computed at 120 people/min and 18.5 m/min (vertical component of travel speed), respectively.

H-5.4.6 *Lifts*

Lifts meeting the following requirements should be counted as one of the means of egress in stations.

H-5.4.6.1 *Capacity of lifts*

Where lifts are counted as contributing to the means of egress capacity;

a) lifts should have a minimum of 60 min fire resistance rating;

b) they should account for no more than 50 percent of the required egress capacity;

c) at least one lift should be considered out of service, and one lift should be reserved for fire service; and

d) the capacity of each lift should be the carrying capacity of the lifts within 30 min.

H-5.4.6.2 *Holding area for lifts*

Lifts counted as one of the means of egress from any level of a station should be accessed through holding areas or lobbies at that level, which should be designed as follows:

a) The holding areas or lobbies should be separated from the platform by a smoke-tight fire separation having a fire resistance rating of at least 60 min but not less than the time required to evacuate the holding area occupant load.

b) At least one stair should be accessible from the holding area.

c) The holding area should be sized to accommodate one person per 0.2 m^2.

d) If the holding area includes portions of the platform, the area within 600 mm of the trainway should not be considered in the calculation;

e) Upon activation of smoke control in the platform or adjacent trainway areas, the holding area should be pressurized to a minimum of 25 Pa.

f) The holding area should be provided with emergency voice alarm devices with two-way communication to the system operations control centre.

H-5.4.6.3 *Design features of lifts*

Lifts counted as one of the means of egress should be designed as follows:

a) Shaft enclosures should be constructed as fire separations having a 120 min fire resistance rating.

b) The design should limit water flow into the shaft.

c) No more than two lifts used for means of egress or fire department access should share the same machine room or lift pit.

d) Machine rooms should be separated from each other by fire separation having a minimum fire resistance rating of 120 min.

e) The lifts should be connected to back-up power supply.

f) During emergency evacuation, the lifts should travel only between the incident level and a point of safety.

H-5.4.7 *Doors and Gates*

The egress capacity for doors and gates in a means of egress serving public areas should be computed as,

a) 60 people per minute (p/min) for single leaf doors and gates;

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b) 0.082 people/mm-min for bi-parting multi-leaf doors and gates measured for the clear width dimension; and

c) gates in a means of egress should be designed in accordance with the requirements for doors serving as a means of egress.

H-5.4.8 *Fare Barriers*

a) Fare barriers complying with the following provisions should be permitted in the means of egress serving the stations. Such barriers should be designed to release, permitting unimpeded travel in the direction of egress under all the following conditions:

   1) Power failure or ground fault condition;

   2) Activation of the station fire alarm signal; and

   3) Manual activation from a switch in a constantly attended location in the station or operations control centre.

b) Fare barriers that do not comply with the requirements of **H-5.4.8**(a) should be permitted in the means of egress where barriers in the equipment are designed to provide egress when a horizontal force not exceeding 66 N is applied in the egress direction.

c) Gate-type fare barriers in the means of egress should meet the following criteria:

   1) Each unit should provide a minimum of 450 mm clear width at and below a height of 1 000 mm and 530 mm clear width above that height.

   2) Each unit should be credited with a capacity of 50 p/min for egress calculations.

   3) Fare barriers should be designed so that their failure to operate properly will not prohibit the movement of passengers in the direction of emergency egress.

H-5.4.9 *Horizontal Exits*

Horizontal exits should be permitted for up to 100 percent of the number of horizontal exits and required egress capacity, provided that not more than 50 percent of the number and required capacity is into a single building and provided they comply with the following provisions:

a) Width of the horizontal exit should at least be the same as that of the exit doorways.

b) A horizontal exit should be equipped with at least one fire/smoke door of a minimum 60 min fire resistance, of self-closing type. Further, it should have direct connectivity to the egress staircase for evacuation.

c) Where there is a difference in level between connected areas for horizontal exits or ramps, slope not more than 1 in 12 should be provided.

d) Doors in horizontal exits should be able to open at all times from both sides.

H-5.4.10 *Platform Screen and Edge Door*

Horizontal sliding platform screen or platform edge doors should be permitted to separate the platform from the trainway in stations, provided that the doors permit emergency egress from the train to the platform regardless of the stopping position of the train; and the doors provide egress when a force not exceeding 220 N is applied from the train side of the doors. The doors should be designed to withstand positive and negative pressures caused by passing trains.

H-5.4.11 *Access for Fire Brigade Personnel*

A dedicated access staircase for firemen should be provided in each underground station. This access should be arranged so as to provide uninterrupted access from ground level to station concourse and platform levels. If continuous access is not feasible, smoke sealed lobbies should be provided at concourse or other intermediate

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levels and such lobbies should be protected with fire doors of adequate rating. Firemen staircases should be maintained under positive pressure at all times.

H-5.4.12 Emergency and escape lighting and illumination of means of all exits should comply with the various provisions under **3.5.6** and **H-9**.

H-6 FIRE SEPARATION AND COMPARTMENTATION

H-6.1 Fire compartments should be provided in transit stations in accordance with the provisions of this section. Fire ratings of various occupancies within open stations and enclosed stations should be as indicated in Table 30.

H-6.2 Further transit station should be divided into fire compartments by means of compartment walls and compartment floors by a fire separation of at least 120 min between the following occupancies:

a) Public areas and non-public areas,

b) Transit and non-transit areas, and

c) Ancillary areas located beneath and within 3 m of the trainway in open stations.

H-6.3 No fire separation should be required for occupancies like ticketing offices, toilets, other offices and the like.

H-6.4 Incidental kiosks inside stations for other purposes like commercial use, etc should be provided with detection and a suitable automatic suppression system, if areas occupied by such occupancies exceed 10 m^2.

H-6.5 Fire Doors

Fire doors should comply with the following requirements:

a) Fire doors should be constructed of non-combustible material having appropriate fire resistance, and two fire doors may be fitted in an opening if each door by itself is capable of closing the opening and the two doors together achieve the required level of fire resistance.

b) All fire doors should be fitted with an automatic self-closing device, of same fire rating as the door, which is capable of closing the door from any angle and against any latch fitted to the door.

c) Any fire door fitted within an opening which is provided as a means of escape should be capable of being opened manually or by an electromagnetic or electro-mechanical device which can be activated by the presence of smoke and/or the fire alarm system, including the case of fire doors opening into pressurised exit staircases.

H-6.6 Smoke Compartmentation

a) Smoke compartments should be created to ensure that in case of a fire scenario, the escape routes are not full of smoke and a safe passage is provided to firefighters to reach the fire location.

b) Smoke barriers should be provided within the ceiling at platform and concourse levels at locations and spacing as determined by the engineering analysis and should be designed to withstand temperatures up to 250 °C for 60 min.

c) Smoke barriers should also be provided around all openings containing staircases, escalators and lifts in public areas connecting platform to levels above or below them.

d) Multiple smoke compartments catered by a combined ductwork should be provided with fire dampers for a fire barrier.

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Table 30 Fire Ratings for Mass Rapid Transit Station Occupancies

(*Clause* H-6.1)

Sl No.	Occupancies	Fire Rating of Enclosures h		Fire Rating of Doors h	
		Open Station	Enclosed Station	Open Station	Enclosed Station
(1)	(2)	(3)	(4)	(5)	(6)
i)	Auxiliary substation, electrical UPS/battery room	2	2	2	2
ii)	Signalling equipment room, telecom equipment room, S&T (signalling and train control) UPS/battery room, electrical cable shafts, S&T cable shafts	2	2	1.5	1.5
iii)	Environmental control system (ECS) plant room, tunnel ventilation room, firemen's staircase, emergency equipment store, CDMA room, GSM room, sewage ejector room, sump pump room, chiller plant room, pump room, DG panel room	2	2	1.5	1.5
iv)	Station manager room, security room, stores, cleaners room, refuse storage, plumbing shafts, staff mess rooms, distribution board room and the like.	1	2	0.5	1.5

H-7 OTHER SPECIFICS REGARDING SAFETY REQUIREMENTS

a) Materials used as interior wall and ceiling and other decorative features in enclosed stations should be non-combustible.

b) For protection against intrusion of flammable and combustible liquids and flooding of underground transit systems, any structure including emergency egress or access stairs or vent or fan shaft structure utilized for ventilation of underground system should be permitted to be terminated at grade, provided that the level at which it is terminated is at least 450 mm above the surrounding ground level/footpath level.

c) Emergency ventilation fans, their motors, and all related components exposed to the exhaust airflow should be rated for 250 °C for a minimum of 120 min. Emergency ventilation fans should be connected to a secondary power supply.

d) Operation of the emergency ventilation system components should be initiated from the central supervising station.

e) All types of kiosks like ticketing booth, information counter, commercial, if any, etc, should be constructed with non-combustible materials.

f) Stations should be provided with power supply as per **H-8**.

g) Emergency lighting should be provided throughout the station as per **3.5.6.1** and **H-9**.

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h) Voice evacuation/public address system should be provided throughout the station, and ancillary buildings as per requirements.

j) Equipment rooms should be protected by fire suppression systems as per relevant standards.

k) Emergency command centres and emergency response procedures should be in place.

m) Evacuation should take place under the guidance and control of authorized, trained system employees or other authorized personnel as warranted under an emergency situation.

n) Adequate warning signs, directional signs, exit signs should be provided throughout the facility.

H-8 POWER SUPPLY SYSTEM

H-8.1 General

The auxiliary substation at metro stations can be provided at any location, for example, ground level, concourse level, platform level, etc. The access for dismantling and replacement in future and ease of operation and maintenance of the equipment are to be ensured.

H-8.2 Uninterrupted Power Supply (UPS) System

The UPS should be an online parallel redundant system with battery backup for emergency power supply. The batteries should provide backup for a minimum 90 min. If, DG set power backup to UPS is provided, the battery backup time should be suitably selected.

H-8.3 Back-up or Emergency Power Supply

a) The back-up/emergency power supply should have a capacity to cater all critical loads such as emergency lighting, protective signalling system, communication system, station control room/fire command centre, lifts providing required egress capacity, etc.

b) Power supply to these systems and equipment should be from normal and emergency (standby generator power sources with changeover facility).

c) If the power supply is taken from HT source and HT generation, the transformer should be selected with standby capacity to ensure continuity of power supply to such systems. Where parallel HV/LV supply from a separate independent source is provided with appropriate transformer for emergency, the provision of diesel generator for emergency supply may be waived off at the discretion of metro Authority. In such a scenario, in case of failure of mains power, the transfer to emergency power supply should be automatic and within 10 s for ensuring uninterrupted supply to emergency systems.

H-8.4 Cables

a) Fire resistant/survival, low smoke zero halogen, copper conductor, armoured, cross linked polyethylene (XLPE) insulated cables should be used at enclosed stations for fire and life safety equipment like fire alarm system (FAS), tunnel ventilation fans, smoke extraction fans, staircase pressurization fans, fire pumps, emergency lighting, etc.

b) All cables and wiring used for fire and life safety equipment should have a 3 h fire survival capability at 950 °C.

c) For all other essential services at enclosed stations like chillers, AHU, normal lighting, chilled water pumps etc. flame retardant, low smoke zero-halogen (LSZH), armoured, XLPE insulated aluminium/copper conductor cables should be used.

d) At open stations, flame retardant, low smoke halogen free (FRLSH), armoured, XLPE insulated aluminium/copper conductor cables should be used for power supply.

H-9 EMERGENCY LIGHTING SYSTEM

a) LED lighting fixtures should be used for lighting at metro stations.

b) Emergency illumination should include illumination of means of egress, illuminated exit signs, and all other luminaires specified as necessary to provide required illumination. Emergency lighting systems should be designed and installed so that the failure of any illumination source cannot leave in total

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darkness any space that requires emergency illumination. Emergency lighting should not provide less than average of 10 lux. Minimum illumination of 10 lux should be maintained on egress route.

c) Fire resistant, low smoke and zero halogen (FS) copper conductor wires should be used for wiring of emergency lighting system at underground stations. Emergency lighting system circuit should have 3 h fire survival capability at 950 °C.

d) Out of total light fixtures installed at any station, at least 30 percent of the total lights, all uniformly distributed should be connected to emergency power source, that is, UPS.

e) Emergency lighting should be powered from a source independent of that supplying the normal lighting.

H-10 FIRE PROTECTION FACILITIES

The following requirement should apply to all open (elevated and at-grade), and enclosed metro stations and depots.

H-10.1 The details of the protection and facilities required for open (elevated and at-grade) stations and depots are given hereunder.

H-10.1.1 *Pumping Arrangements*

Each station should be provided with two pumps having a minimum discharge capacity of 1 620 litre/min with different prime movers. It is possible to provide two electrically driven pumps, if assured back-up power is available for driving the pumps. Jockey pumps having a capacity of 180 litre/min should also be provided to take care of minor system leakages, (*Also refer* to **H-10.1.9**).

H-10.1.2 *Fire Extinguishers*

a) Water CO_2 type, CO_2/ABC type fire extinguisher(s) should be provided in each platform and distributed in such a way that an the extinguisher is available within a travel distance of 30 m from any point;

b) Water CO_2 type, CO_2/ABC type fire extinguisher(s) should be provided in each concourse for every 300 m^2 floor area and distributed in such a way that an extinguishers are available within a travel distance of 30 m from any point; and

c) At least one extinguisher should be provided for each equipment room and other enclosure for every 300 m^2 floor area.

H-10.1.3 *Small Bore Hose Reels*

a) One hose reel should be provided for every 1 000 m^2 floor area of station platform or part thereof, subject to a travel distance of 30 m to the nearest hose reel.

b) One hose reel should be provided for every 1 000 m^2 floor area, concourse or part thereof subject to a travel distance of 30 m to the nearest hose reel.

c) Where equipment rooms not covered by hose reel's reach from FHCs located at concourse and platform locations, additional hose reel points should be provided to ensure its coverage.

H-10.1.4 *Fire Alarm System*

a) Fire detection system should be of the addressable type. Detectors are required to be provided only in areas where there is false ceiling(s)/ false floor(s) and areas for equipment rooms. Wherever there are false ceilings/false floors with perforation less than 70 percent, the detectors should be provided both above and below false ceiling/false floor, giving due consideration to the depth of false ceiling/flooring. In open stations, in areas having high heights and cross-ventilation, detectors will not be effective and hence it can be dispensed. Detector(s) should be provided in lift shaft(s) and escalator pit(s) also.

b) Spacing of detectors and devices should be as per [4(26)].

c) Manual call stations(s) should be provided at central location(s) on each platform (near emergency stop plunger) and at least two on the concourse, on each sidewall. When the concourse is in two halves, at least one manual call station should be provided on each side.

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H-10.1.5 Inert Gas/CO_2/ *based fire Suppression System*

AIS HT, Main LT and panel supplying power to UPS, DG change-over, fire pump panel and transformers at the stations should be protected with the inert gas/ CO_2 based fire suppression system in accordance with IS 15506/ IS 15525/IS 15501/IS 15528. A suitable detection mechanism should be provided for triggering the suppression system automatically.

H-10.1.6 *Provision of Hydrants and Wet Risers*

a) Minimum two hydrants should be provided at each platform with a hose box containing two lengths of hose pipes (15 m each with a nozzle) subject to a travel distance of 30 m to reach the nearest hydrant. Location of hydrants should be staggered for better coverage. The hydrants should cover the entire length of the platform when two hose pipes are coupled to the landing valves and used. If not fully covered, additional hydrant(s) should be provided.

b) Minimum two hydrants should be provided for each concourse, including commercial area, if any, with a hose box containing two lengths of hose pipes (15 m each with a nozzle), subject to a travel distance of 30 m to reach the nearest hydrant.

c) Hydrants should be provided at each entry to the station at ground and upper levels near the staircase. At least two hydrants for parking area should be provided subject to a travel distance of 30 m to the nearest hydrant.

d) In depots, fire piping should be provided along the depot boundary as ring main. The ring main should be provided with a yard hydrant every 60 m. The building should be provided with a yard hydrant, preferably at its entry, through a branch from the ring main. The inside of the building should be provided with a number of FHCs required for coverage and maintaining a maximum travel distance of 30 m to the nearest FHC. Yard hydrant in the depot should be provided as per Table 31 through branches from ring main. Other provision(s) of fire detection and suppression in the depot should be as per Table 31.

H-10.1.7 *Automatic Sprinkler System*

Sprinklers are required to be provided only in the commercial areas and any combustible storage area within the station (also refer **H-10.1.9**). Alternatively, automatic fire suppression system instead of water-based sprinkler system, as per application, is also acceptable.

H-10.1.8 *Water Requirement*

a) For stand-alone open metro stations, exclusive water requirement for the fire protection system for the installed pumping capacity, as stated in **H-10.1.1** should be at least 50 000 litre.

b) However, when commercial areas are present within open metro stations, firefighting facilities should need augmentation as in **H-10.1.9**.

H-10.1.9 In case of other types of occupancy like commercial areas inside metro stations and combustible storage areas, if any, within open stations, the pumping/water requirement should be as per Table 32.

The volume of water stated in Table 32 should be stored in more than one interconnected compartments/tanks. Wherever existing structures are upgraded to include a commercial area and additional water requirement as per Table 32 if any, may be met by additional tank or overhead tanks as permissible by structure. Size of the main header should not be less than 150 mm diameter in all cases. Entire fire protection system should be designed and installed as per the relevant Indian Standards.

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Table 31 Requirement of Firefighting Installations in Depot Building

(*Clause* H-10.1.6)

Sl No.	Name/Part of the Building	Occupancy	Fire Extinguisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System Installation	Manually Operated Electronic Fire Alarm System	Automatic Detection and Alarm System	Underground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace tank over Respective Tower Terrace	Pump near Underground Static Water Storage Tank (Fire Pump) with minimum pressure of 3.5 Kg/cm^2 at Remotest Location	Pump at the Terrace Tank level with minimum pressure of 3.5 Kg/cm^2	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
i)	Live OHE areas/third rail areas (like inspection bay, workshop bay, stabling lines, auto coach washing plant, covered electrical substation, etc)	Assembly	R	R	R	NR	R	NR	R	NR	2 00 000 litre	NR	2 850 lpm main and standby electric pumps, and 180 lpm jockey pump	NR	
ii)	Areas having engineering workshops and offices [Inspection offices, workshop offices, (ETU) workshop, P-way offices, depot control centre, PPIO, other administrative offices, etc]		R	R	R	NR	R	NR	R	R		NR		NR	
iii)	Storage areas (DCOS, Store rooms, scrap yards within buildings, lubricant and any other combustible storage areas)		R	R	R	R	R	R	R	R		R (10 000 litre) For main store building		NR	

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Table 31 (*Concluded*)

Sl No.	Name/Part of the Building	Occupancy	Fire Extinguisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System Installation	Manually Operated Electronic Fire Alarm System	Automatic Detection and Alarm System	Underground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace tank over Respective Tower Terrace	Pump near Underground Static Water Storage Tank (Fire Pump) with minimum pressure of 3.5 Kg/cm^2 at Remotest Location	Pump at the Terrace Tank level with minimum pressure of 3.5 Kg/cm^2	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
iv)	Miscellaneous areas (canteen, time office, security rooms, open scrap yards, sewage treatment plants, contractor rooms, training establishments, commercial areas, etc)		(*See* Note 2)				R	(*See* Note 2)							

R – Required NR – Not Required

NOTES

1 Automatic sprinkler system is required in every storage areas and scrap yard inside the buildings. The same wet riser pumps can be used for feeding sprinkler system, if any.

2 Miscellaneous areas or any other building structure within the depot premise (separated from other depot establishments) can be considered an individual occupancy and minimum requirements for firefighting provisions for these occupancies should be adopted as given in Table 7A to Table 7J.

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Table 32 Water Capacity

(*Clause* H-10.1.9)

Sl No.	Area Occupied by Commercial Occupancies	Hydrant Pump Capacity (Minimum Pressure of 3.5 kg/cm^2 at the Remotest Location)	Sprinkler Pump Capacity	Jockey Pump	Common Standby Pumps	Water Capacity
	m^2	litre/min	litre/min	litre/min	litre/min	litre
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Up to and including 300	2 280	Common pump	180	2 280	75 000
ii)	More than 300 and up to 1 000	2 850	Common pump	180	2 850	1 00 000
iii)	More than 1 000	2 850	2 850	180 each	2 850	2 00 000

H-10.2 Details of Protection and Facilities Required for Enclosed Metro Stations

H-10.2.1 *Hydrant System*

a) *Pumping Arrangements* — Each station should be provided with two pumps having a minimum discharge flow rate of 2 850 litre/min with different prime movers. It is possible to provide two electrically driven pumps, if assured back-up power is available for driving the pumps. Jockey pump having a capacity of 180 litre/min should also be provided to take care of minor system leakages.

b) *Flow of Hydrant Pump* — For hydrant system, having three or more hydrants on any floor, the minimum flow rate for the most demanding horizontal hydrant should be 2 850 litre/min.

c) *Requirement of Residual Pressure at Remotest Hydrant* — Hydraulically designed hydrant system should be designed to provide the water flow rate required at a minimum residual pressure of 7 bar at the remotest located hydrant.

d) *Flow of each Hydrant* — A hydraulically designed hydrant system supplying three or more hydrants on any floor, hydraulic calculations and pipe sizes should be calculated by providing 946 litre/min at the three most remote hydrants and at the minimum residual pressure of 7 bar.

e) *Water Requirement for Hydrant System* — The minimum water supply should be capable of providing the system demand for at least 60 min.

f) *Orifice plate* — Required to be installed when the static pressure at the hydrant exceeds 12.1 kg/cm^2.

g) *Distance of Fire Hydrant* (*FHC*) — FHC should be provided with hose box containing two lengths of hose pipes (15 m each with a nozzle). The travel distance to any hydrant should not exceed 30 m.

H-10.2.2 *Manual Medium Velocity Spray Nozzle Systems*

a) *Design Density* — A general range of water spray application rates that should apply to most ordinary combustible solids or liquids should be from 6.1 lpm/m^2 to 20.4 lpm/m^2 of protected surface.

b) The horizontal distance between spray nozzles/open head sprinklers should not exceed 2.5 m.

c) *Water Requirement for Spray System* — The water supply duration for an exposure protection sprinkler system should be for a minimum of 60 min.

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H-10.2.3 *Water Requirement*

The enclosed station should be provided with water storage of 2 00 000 litre capacity. The underground fire water storage tanks should not be more than 7 m in depth from the level having fire brigade draw-out connection, while the draw-out connection should not be more than 5 m away from tank wall. In case any of the above criteria could not be met, one additional booster pump of suitable rating should be provided to support fire brigade vehicle for proper suction of water from the tank.

H-10.2.4 *Fire Extinguishers — See* **H-10.1.2**

H-10.2.5 *Inert Gas/CO_2 based Fire Suppression System — See* **H-10.1.5**

H-10.2.6 *Automatic Sprinkler System — See* **H-10.1.7**

H-10.2.7 *Station Control Room/Fire Command Centre*

a) The station control room should have the main fire alarm panel with communication system (suitable public address system) to aid floors and facilities for receiving the message from different floors.

b) Fire command centre (FCC)/station control room (SCR) should be provided with emergency lighting. All controls and monitoring of fire alarm systems, pressurization systems, smoke management systems should be done from FCC/SCR. Monitoring of integrated building management systems, CCTVs or any other critical parameters in building may also be from the FCC/SCR.

c) Details of all floor plans along with the details of firefighting equipment and installations (2 sets laminated and bound) should be maintained in fire command centre.

H-10.2.8 *Fire Alarm System*

An addressable fire detection and alarm system should be provided. Major components of fire alarm system should be as per IS 2189 and as specified herein :

a) *FACP Battery Backup*

FACP should have provision of battery for power backup in case of power failure.

The secondary power supply should have sufficient capacity to operate the system under quiescent load (system operating in a non-alarm condition) for a minimum of 24 h and, at the end of that period, should be capable of operating all alarm notification appliances used for evacuation or to direct aid to the location of an emergency for 5 min.

Battery calculations should include a minimum 20 percent safety margin above the calculated required amp-hour capacity.

In case of availability of emergency generator or two reliable sources of power supply from two separate transformers, 4 h of power backup may be taken in place of 24 h.

b) *Response Indicator*

Generally, response indicators are provided to identify the location of detectors which are installed at unapproachable/concealed locations. Response indicator should not be provided with addressable type fire alarm system.

H-11 STATION SMOKE MANAGEMENT SYSTEM

H-11.1 The subsequent clauses give the requirement of smoke extraction and smoke purging system required in enclosed metro stations. Smoke management system is not required for open (elevated and at-grade) stations.

H-11.2 Station Public Area Smoke Extraction Systems

Station public area should be provided with active smoke extraction system to maintain tenable environment for the time required for safe evacuation of passenger(s).

The smoke extraction system should be an engineered smoke control system and its design should be based on the following:

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a) *Fire size*

The capacity of the engineered smoke extraction system should be calculated based on the incidence of a likely minimum baggage fire size of 1 MW.

b) *Smoke clear height*

The design smoke clear height should be above the heads of people escaping beneath it. The minimum height should be 2.0 m.

c) *Perforated ceiling*

For cases where the smoke reservoir is above the false ceiling, the ceiling should be of perforated type with at least 70 percent opening.

d) *Makeup air*

Makeup air should be drawn directly from the external space/air shaft, through inlet air ventilators or door-ways.

e) *Mode of activation*

1) *Automatic activation*

The engineered smoke extraction system should have provision of automatic activation by smoke detectors located in the fire zone. Use of smoke detectors for activation should be carefully designed, so that accidental or premature activation of smoke detectors in a non-fire zone (due to smoke spills or spread from other areas) are avoided.

2) *Manual activation*

A remote manual activation and control switches, as well as visual indication of the operation status of the smoke ventilation system, should also be provided at the station control room (SCR).

f) *Interlocking with other systems*

1) Except for smoke extraction system, all other air conditioning and mechanical ventilation systems within the areas served should be shut down automatically upon activation of the smoke extraction system.

g) *Standby fans/multiple fans*

Either a standby fan or multiple fans with excess capacity should be provided for each mechanical smoke extraction system, such that in the event the duty fan or the largest capacity fan fails, the required smoke extraction rate will still be met. The standby fan should be automatically activated in the event the duty fan fails.

h) Emergency ventilation fans, their motors, and all related components exposed to the exhaust airflow should be rated for 250 °C for a minimum of 120 min. Emergency ventilation fans should be connected to a secondary power supply.

H-11.3 Smoke Purging System

a) For extraction of cold smoke after the extinguishing of fire, smoke purging system should be provided.

b) Smoke purging system should be provided in the following areas of underground station:

1) Station control room;

2) S and T rooms;

3) Fire pump rooms;

4) UPS rooms; and

5) Auxiliary sub-station.

For other back of house rooms, normal ventilation system may be utilized to remove the cold smoke.

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c) *Design of smoke purging system*

Smoke purging system, where provided in station and ancillary building, should comply with all the following requirements:

1) The smoke purging system need not be a dedicated system.
2) The purging system should have purge rate of not less than 9 air changes per hour (ACPH) or room ventilation ACPH, whichever is higher.
3) Makeup air should be drawn from adjacent area or corridor free from smoke or can be supplied by a separate mechanical system.
4) Smoke purging fans, their motors, and all related components exposed to the exhaust airflow should be fire rated and designed to operate in smoke of 250°C for a minimum of 120 min. Smoke purging fans should be connected to a secondary power supply.
5) In case of smoke/fire in entries subway, it should be rendered out of use and evacuation should be dealt procedurally.

H-11.4 Tenability Criteria

A tenable environment should be maintained in the path of egress. The tenability criteria considerations are given hereunder:

a) Smoke obstruction:
   1) Internally illuminated signage (80 lux) discernible at 30 m.
   2) Walls and doors or externally illuminated signage discernible at 10 m.

b) Heat effects:
   1) Exposure temperature (occupied zone) ≤ 60 °C for 10 min.
   2) Radiant heat exposure ≤ 2.5 kW/m^2

c) Carbon monoxide – The smoke extraction system to be designed to maintain fractional effective dose (FED) of less than 0.3. The permissible exposure to carbon monoxide should be as per following table:

Sl No.	*Time* min	*Maximum Carbon Monoxide Exposure* ppm
(1)	(2)	(3)
i)	4	1 706
ii)	6	1 138
iii)	10	683
iv)	15	455
v)	30	228
vi)	60	114
vii)	240	28

d) Velocity – Air velocity should be greater than or equal to 0.75 m/s and less than or equal to 11 m/s along the path of egress.

e) Noise – Noise level along the path of egress should not exceed 85 dBA at any point 1.5 m above walking surface.

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ANNEX J

(*Clause* 6.4.4)

FIRE AND LIFE SAFETY REQUIREMENTS FOR METRO TRAINWAYS

J-1 APPLICATION

Provisions of this Annex should apply to all portions of underground, elevated and at-grade metro trainway including tail buffer tracks and sidings not intended to be occupied by the passengers. These provisions may be amended, if required, as per the approval of the Competent Authority.

J-2 USE AND OCCUPANCY

J-2.1 Passengers should be allowed to enter the trainway only in the case it becomes necessary to evacuate a train.

J-2.2 Passenger evacuation from train onto the trainway should take place only under the guidance and control of authorized, trained system employee or other authorized personnel as warranted under an emergency situation.

J-2.3 Warning signs in accordance with **J-4.4.1** should be posted at locations where unauthorized personnel might trespass.

J-3 CONSTRUCTION

J-3.1 Construction Type

J-3.1.1 *Cut and Cover*

Where trainways are to be constructed by cut and cover method, perimeter walls, base and roof slabs and other related constructions should be of not less than Type 1 or Type 2 or combination of Types 1 and 2 non-combustible constructions as defined in this Part. The type of construction should be further determined by an engineering analysis of potential fire exposure hazards to the structure.

J-3.1.2 *Bored Tunnels*

Where trainway sections are to be constructed by a tunnelling method through earth, unprotected steel liners, reinforced concrete, shotcrete, or equivalent should be permitted to be used.

J-3.1.3 *Rock Tunnels*

Where trainway sections are to be constructed by a tunneling method through rock, steel bents with concrete liner, if lining is required, should be permitted to be used.

J-3.1.4 *Underwater Tunnels*

Underwater tunnels should be not less than Type 2 construction.

J-3.1.5 *Mid Tunnel Ventilation Shaft and Trainway Exit structures*

Mid tunnel ventilation shafts and trainway emergency egress or access stairs should not be less than Type 1 construction.

J-3.1.6 *At-Grade Construction*

Materials used for at-grade construction should not be less than Type 2 materials. The type of construction should be further determined by an engineering analysis of potential fire exposure hazards to the structure.

J-3.1.7 *Elevated Viaduct or Portals*

All elevated structures necessary for trainway support and all structures and enclosures on or under the trainway should be of not less than Type 1 or Type 2 or combination of Type 1 and Type 2 construction. The type of construction should be further determined by an engineering analysis of potential fire exposure hazards to the structure.

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J-3.2 Protection against Intrusion of Flammable and Combustible Liquids and Flooding of Enclosed Trainway

Any structure including emergency egress or access stairs or vent or fan shaft structure utilized for ventilation of underground system should be permitted to be terminated at grade, provided that the level at which it is terminated is at least 450 mm above the surrounding ground level/footpath level.

J-3.3 Compartmentation

J-3.3.1 Ancillary areas should be separated from trainway areas within underwater trainway sections by construction having a minimum 180 min fire resistance rating.

J-3.3.2 Ancillary areas should be separated from trainway areas within enclosed trainway sections by construction having a minimum 120 min fire resistance rating.

J-3.4 Combustible Components

Where combustible components not specifically mentioned here are installed in a trainway, a fire hazard analysis should be conducted to determine that the level of occupant fire safety is not adversely affected by the contents.

J-3.5 Walking Surfaces

Walking surfaces designated for evacuation of passengers should be constructed of non-combustible materials.

J-4 EMERGENCY EGRESS

J-4.1 Location of Egress Routes

J-4.1.1 The system should incorporate a walking surface or other approved means for passengers to evacuate a train at any point along the trainway so that they can proceed to the nearest station or other point of safety.

J-4.1.2 Walkway continuity should be maintained at special track sections like cross over or pocket tracks. Walkway continuity should be provided by cross walks at track level.

J-4.1.3 Within enclosed trainways, the maximum distance between emergency exits/exit stairways should not exceed 750 m.

J-4.1.4 For trainways in twin bore tunnels or trainways in a tunnel divided by a minimum 120 min fire rated wall separation, cross-passageways should be permitted to be used in-lieu of emergency exit stairways.

J-4.1.5 Where cross passageways are utilized in-lieu of emergency exit stairways, the following requirements should apply:

a) First cross-passageway should be provided not farther than 500 m from the end of platform of an enclosed station or from the tunnel portal or from a mid-tunnel exit way.

b) Distance between any two cross-passageways should not be more than 250 m.

c) The crossover in an enclosed trainway should be considered as cross-passageway. The distance between crossover and subsequent cross-passageway should not be more than 250 m.

d) Cross-passageways should be separated from each trainway with separate self-closing fire door assemblies having a fire protection rating of minimum 90 min.

e) A tenable environment should be maintained in the portion of the trainway that is not involved in an emergency and that is being used for evacuation.

f) A ventilation system for the incident trainway should be designed to control smoke in the vicinity of the passengers.

g) Provisions should be made for evacuating passengers via the non-incident trainway to a nearby station or other emergency exit.

h) The provisions should include measures to protect passengers evacuating from non-incident tunnel from oncoming traffic and from other hazards.

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j) Where cross-passageways are used in-lieu of emergency exit stairways, the interior of the cross-passage should not be used for any purpose other than as an area of refuge or for access/egress to the opposite tunnel, except for installation of non-combustible equipment inside the cross passageways, provided that such equipment does not infringe the required clear space of the cross-passage.

J-4.1.6 *Level of Cross Passage*

The level of cross-passage inside the tunnel should be designed in accordance to the following requirements:

a) In trainways where passengers have to walk on the track bed during evacuation, the floor of the cross-passages in such trainways should be kept close to the level of the track bed. The maximum permitted level difference between the level of track bed and the floor of the cross-passage should be 250 mm. Further, a smooth surface for transition of level difference should be provided at such cross-passages.

b) In trainways where passengers have to walk on a walkway mounted at the level of the train floor during evacuation, the floor of the cross-passages in such trainways should be kept in level with the walkway. Further, such walkways should always be provided on the cross-passageway side of the trainway for unobstructed access to the cross-passageway.

J-4.1.7 For open-cut trainways, an engineering analysis should be conducted to evaluate the impact of the trainway configuration on safe egress from a train fire to a point of safety.

J-4.1.8 Where the engineering analysis indicates that the configuration will impact tenability beyond the immediate vicinity of the fire, egress routes should be provided such that the maximum distance from any point within the open-cut section to a point of egress from the trainway should not be more than 380 m.

J-4.1.9 All the distances mentioned in J-4.1.3, J-4.1.5 and J-4.1.8 should be permitted with a maximum variation of $^{+10}_{-0}$percent.

J-4.2 Size of Egress Routes

J-4.2.1 Cross-passageways should be a minimum of 1 200 mm in clear width and 2 100 mm in height.

J-4.2.2 The width of exit stairs should not be required to exceed 1 200 mm for enclosed trainways.

J-4.2.3 If double leaf doors wider than 1 200 mm are provided in egress routes serving trainways, then size of active leaf should not be less than 810 mm.

J-4.3 Egress Components

J-4.3.1 Walking surfaces serving as egress routes within guide ways should have a uniform, slip-resistant design except as permitted herein:

a) Where the trainway track bed serves as the emergency egress pathway, it should be nominally level and free of obstructions.

b) Walkways that are more than 750 mm above the floor or grade below should be provided witha continuous handrail along the side opposite the trainway.

c) Raised walkways that are greater than 1 200 mm wide and located between two trainways should not be required to have a handrail.

d) Doors in the means of egress, except cross-passageway doors, should open in the direction of exit travel.

e) Doors in the means of egress should,

1) open fully when a force not exceeding 220 N is applied to the latch side of the door, and

2) be adequate to withstand positive and negative pressures caused by passing trains and the emergency ventilation system.

J-4.3.2 Horizontal sliding doors should be permitted in cross-passageways.

J-4.4 Signage, Illumination and Emergency Lighting

J-4.4.1 Warning signs posted on entrances to the trainway and on fences or barriers adjacent to the trainway

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should clearly state the hazard (for example, DANGER: HIGH VOLTAGE, 25 000 V) with letter sizes and colours in conformance with requirements of *Metro Railway Rules*.

J-4.4.2 System egress points should be illuminated.

J-4.4.3 Points of exit from elevated and enclosed trainways should be marked with internally or externally illuminated signs.

J-4.4.4 Tunnel lighting should be 100 percent on emergency power source, that is, UPS. Minimum illumination of 10 lux should be maintained on tunnel egress routes. Emergency lighting should be powered from a source independent of that supplying the normal lighting.

J-4.4.4 *Identification*

Emergency exit facilities should be identified and maintained to allow for their intended use.

J-4.4.5 Enclosed trainways greater in length than the minimum length of one train should be provided with directional signs as appropriate for the emergency procedures developed for the metro system.

J-4.4.6 Directional signs indicating station or portal directions should be installed at maximum 25 m intervals on either side of the enclosed trainways.

J-4.4.7 Directional signs should be readily visible by passengers for emergency evacuation.

J-5 FIRE PROTECTION AND LIFE SAFETY SYSTEMS

J-5.1 Emergency Access

J-5.1 Except as described herein, points of egress and exits from the guide way should serve as emergency access routes.

J-5.2 If security fences are used along the trainway, access gates should be provided in security fences.

J-5.3 Access gates should be a minimum 1 200 mm wide and should be of the hinged or sliding type.

J-5.4 Access gates should be placed as close as practicable to the portals to permit easy access to tunnels.

J-5.5 Information that clearly identifies the route and location of each gate should be provided on the gates or adjacent thereto.

J-5.6 Access to the elevated trainway should be from stations or by mobile ladder equipment from roadways adjacent to the track way.

J-5.7 If no adjacent or crossing roadways exist for the elevated trainway, access roads at a maximum of 750 m intervals should be required.

J-5.8 Where the configuration of an open-cut trainway prevents or impedes access for firefighting, provisions should be made to permit fire fighter access to that section of trainway at intervals not exceeding 750 m.

J-5.9 All the distances mentioned in J-5.7 and J-5.8 above should be permitted with a maximum variation of $^{+10}_{0}$ percent.

J-5.10 Distance between Tunnel Hydrants

Double headed type hydrants should be provided inside tunnels.

a) The travel distance to tunnel hydrant should not be more than 30 m.

b) Tunnel hydrant should be installed on a pipe having diameter of not less than 100 mm.

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J-6 EMERGENCY VENTILATION SYSTEM FOR TRAINWAY

J-6.1 General

J-6.1.1 The following defines the requirements for the mechanical ventilation systems used in passenger trainway area.

J-6.1.2 Mechanical emergency ventilation should be provided in underground or enclosed trainways exceeding 300 m.

J-6.1.3 *Exemption*

a) A mechanical emergency ventilation system is not required for underground or enclosed trainways at most 60 m in length.

b) An engineering analysis is required for underground or enclosed trainways more than 60 m in length but less than 300 m to determine if a mechanical emergency ventilation is required; and

c) Emergency ventilation meeting the tenability criteria for occupied areas should not be required in storage track area like stabling line, depot line, Y-siding, etc where the storage track has no openings along its length to passenger trainway areas and where a fire hazard analysis indicates that a fire on a train in the storage track area will not impact passengers or passenger areas.

J-6.1.4 *Engineering Analysis*

The analysis should take into consideration all the factors that affect fire safety. A report of the analysis should be submitted. If the engineering analysis is not carried out, then a mechanical ventilation system should be provided.

J-6.2 The engineering analysis of the emergency ventilation system should include the following:

a) A validated trainway analytical simulation program that provides a quantitative analysis of airflow dynamics produced in the fire scenario, a validated computational fluid dynamic (CFD) technique, or both, as approved; and

b) The no-fire (or cold) air velocities that can be measured during commissioning to confirm that a mechanical ventilation system as built meets the requirements determined by the analysis.

J-6.2.1 Where required by J-6.1.2, the mechanical ventilation system should make provision for the protection of passengers, employees, and emergency personnel from fire and smoke during a fire emergency.

J-6.3 Design

J-6.3.1 The emergency ventilation system should be designed to cater the following:

a) Provide a tenable environment along the path of egress from a fire incident in enclosed station and enclosed trainways;

b) Produce sufficient airflow rates within enclosed trainways to meet critical velocity;

c) Be capable of reaching full operational mode within 180 s;

d) Address the maximum number of trains that could be between ventilation shafts during an emergency; and

e) Maintain the required airflow rates for a minimum of 2 h.

J-6.3.1.1 Where the airflow rates required to accomplish J-6.3.1 (a), J-6.3.1 (b), or approved alternative performance criteria are dependent upon the unimpaired function of the air distribution system, that system should be designed to continue operation when exposed to the conditions generated during the design incident for the duration of 2 h.

J-6.3.1.2 Where the airflow rates required to accomplish J-6.3.1(a), J-6.3.1(b), or approved alternative performance criteria are dependent upon the continued integrity of structural and architectural features, those features should be designed to remain intact when exposed to the conditions generated during the design incident for the duration determined as per J-6.3.1(e).

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J-6.3.2 *Additional Design Requirements*

The design should encompass the following:

a) The heat release rate from a vehicle and any other combustible materials (if permitted) in the trainways that could contribute to the fire load at the incident site, subject to the approval of the Metro Rail Administration;

b) The rate of fire growth

c) Fire scenarios and fire profiles.

d) Station and trainway geometries.

e) The effects of elevation, elevation differences, ambient temperature differences and ambient wind.

f) A system of fans, shaft and devices for directing airflow in stations and trainways.

g) Predetermined procedures for initiating quick response from the OCC/SCR during fire.

h) A ventilation system reliability engineering analysis that, as a minimum considers the following subsystems:

   1) Electrical;

   2) Mechanical; and

   3) Supervisory control.

j) Criteria for the system reliability analysis in **6.3.2** (h) should be established and approved.

k) The analysis should consider as a minimum of the following events:

   1) Fire in the trainway or station;

   2) Local incident within the electrical utility that interrupts power to the emergency ventilation system;

   3) Derailment; and

   4) The loss of a fan that results in the most adverse effect on the ventilation system performance.

J-6.3.3 The design and operation of the signalling system, and ventilation system should be coordinated to match the total number of trains that could be between ventilation shafts during an emergency.

J-6.3.4 Emergency ventilation air distribution system should be permitted to serve more than one trainway.

J-6.4 Emergency Ventilation Fans

a) The emergency ventilation system fans that are designated for use in fire and similar emergency should be capable of satisfying the emergency ventilation requirements to move train-way air in directions to provide the needed ventilation response as per engineering analysis.

b) Individual emergency ventilation fan motors should be designed to achieve their full operating speed in no more than 30 s from a stopped position when started across the line and in no more than 60 s for variable speed motors.

c) Emergency ventilation fans, their motors, and all related components exposed to the exhaust airflow should be designed to operate at 250 °C for a minimum of 2 h.

d) Local fan motor starter and related operating control device should be located away from the direct airstream of the fans to the greatest extent practical.

e) Thermal overload protective devices in fan motors, damper motors, or on motor controls used for emergency ventilation should not be permitted.

f) Non-emergency ventilation airflows that do not impact the emergency ventilation airflows should be permitted to be left operational where identified in the engineering analysis.

g) The ventilation system designated for use in emergencies should be capable of operating at full capacity in either the supply mode or exhaust mode to provide to provide the needed ventilation response where dilution of noxious products is to be maximized.

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h) The ventilation system designated for use in emergencies should be capable of being turned off and dampers closed to provide the needed ventilation response where dispersion of noxious products is to be minimized.

j) Fan should be rated in accordance with the ANSI/AMCA 300, AMCA 250/ISO 13350, ASHRAE Handbook-Fundamentals, ISO 5801, and ASHRAE 149.

k) Fans that are associated only with the passengers or employee comfort and that are not designed to function as a part of emergency ventilation system should shut down automatically on identification and initiation of a fire emergency ventilation program so as not to jeopardize or conflict with emergency airflows.

J-6.5 Airflow Control Devices

a) Devices that are interrelated with the emergency ventilation system and that are required to meet the emergency ventilation system airflow should be structurally capable of withstanding both maximum repetitive and additive piston pressure of moving trains and emergency airflow velocities.

b) Devices in the emergency ventilation system that are exposed to the exhaust airflow and are critical to the system's effective functioning in the event of an emergency should be constructed of materials suitable for operation in an ambient atmosphere at the design condition of 250 °C for 2 h.

c) Finishes applied to non-combustible devices should not be required to meet the provisions of **J-6.5(b)**.

d) Other devices should be designed to operate throughout the anticipated temperature range. Over current elements in devices or on device controls required to support the emergency ventilation should not be permitted where such over current elements are subject to false operation due to exposure to elevated temperatures during a fire emergency.

K-6.6 Testing

a) Equipment used for emergency ventilation (including fans, dampers and airflow control devices and associated electrical equipment) should be approved in accordance with the requirements of a recognized standard for the type of equipment to be installed and should be factory acceptance tested.

b) The non-fire (or cold) airflows provided by the installed mechanical ventilation system should be measured during commissioning to confirm that the airflow meets the requirement determined by the engineering analysis.

L-6.7 Emergency Ventilation Openings

a) Emergency ventilation openings should be positioned or designed to minimize recirculation of smoke into the station or enclosed trainway through any openings, such that a tenable environment is maintained along the path of egress for the time of tenability and as required for designated points of safety.

b) Adjacent structures and property uses should also be considered.

M-6.8 Emergency Ventilation System

a) Operation of the emergency ventilation system should be initiated from the operations control centre.

b) The operations control centre should receive verification of proper response by emergency ventilation fan(s) and an interrelated device(s).

c) Local controls should be permitted to override the operations control centre becomes inoperative or where the operation of the emergency ventilation system is specifically redirected to another site.

N-6.9 Power Supply for Emergency Ventilation System

a) The design of the power for the emergency ventilation system should comply with the requirements of **H-8** of this Part.

b) Overcurrent elements that are designed to protect conductors serving motors for both emergency fans and related emergency devices should not be permitted where such overcurrent elements are subject to false operation due to exposure to elevated temperatures during a fire emergency. All other motor and

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fan protection device should be bypassed during a fire emergency, except for motor overcurrent and excessive vibration.

c) The emergency ventilation circuits routed through the station public areas and trainway should be protected from physical damage by fixed guideway transit or passenger rail vehicles or other normal operations and from fire.

J-6.10 Critical Velocity

a) The minimum steady-state velocity of the ventilation airflow moving toward the fire within an enclosed trainway or enclosed passageway that is required to control back layering at the fire site, such that a tenable environment is maintained along the path of egress upstream of the fire, and as required for designated points of safety.

b) The equation for critical velocity is as follows:

$$V_c = K_1 K_g \left(\frac{gHQ}{\rho C_\rho A T_I}\right)^{\frac{1}{3}}$$

$$T_\mathrm{f} = \left(\frac{Q}{\rho C_\rho A V_c}\right) + T$$

$$K_\mathrm{g} = \{1 + 0.0374\,(G)^{0.8}, 1, \begin{matrix} G < 0 \\ G \geq 0 \end{matrix}$$

where

V_c = critical velocity (m/s or fpm)

A = the annulus area (not including the area of blockages, such as vehicles) perpendicular to the flow (m^2 or ft^2)

C_p = the specific heat of the air (kJ/kg/K or Btu/lb/R)

g = acceleration due to gravity (m/s^2 or ft/s^2)

G = absolute value of tunnel grade, as a percent

K_g = grade factor

H = height from the base of the fire to the tunnel ceiling at the fire site (not tunnel height) (m or ft)

K_1 = Critical Froude number factor with a constant value of 0.606 (critical Froude number of the negative one-third power)

ρ = average density of the approach (upstream) air (kg/m^3 or lb/ft^3)

Q = convective heat the fire adds directly to the air at the fire site (kW or Btu/s)

T = temperature of the approach air (K or R)

T_f = Average temperature of the fire site gases (K or R)

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ANNEX K

(*Clause* 6.7.3)

FIRE PROTECTION CONSIDERATIONS FOR VENTING IN INDUSTRIAL BUILDINGS

K-1 APPLICATION

K-1.1 The provisions given below are applicable only to single storey industrial buildings (factories and storage buildings) covering large floor areas without sub-dividing/separating walls which are usually designed to meet modern production methods.

K-1.2 The requirements of fire and explosion venting of industrial buildings, as dealt with in this section, fall under two categories:

a) Smoke and fire venting; and

b) Explosion relief vents.

K-2 SMOKE AND FIRE VENTING

K-2.1 The basic considerations for formulating the design and other requirements for smoke and fire vents are as given in **K-2.1.1** to **K-2.1.20**.

K-2.1.1 The smoke and hot combustion products from a fire, being lighter than the surrounding air, tend to rise, and on reaching the roof or ceiling spread out (mushroom) on all sides and form a layer which floats on top of the cold air beneath. In the absence of vents, this layer becomes progressively deeper until the whole building is filled with hot smoky gases. The time consumed for this to happen may be only a few minutes, depending on variables like, type of materials on fire, process/storage conditions involved, etc.

K-2.1.2 The hot gases at the roof level moved by convection currents contribute to rapid lateral spread of fire.

K-2.1.3 The provision of properly designed and suitably located vents in adequate number helps the speedy removal of smoke and hot gases, thereby preventing spread of fire, besides reducing risks of explosion of unburnt gases, and reducing damage to the contents and structure of the building by heat and smoke. In addition, they facilitate firefighting operations, and minimize personal hazards to the firemen.

K-2.1.4 The time taken for accumulation of smoke and hot gases within a building on fire being very short, the venting devices installed should be designed to operate in the early stage of the fire and must be automatic so as to ensure speed and efficiency in their operation.

K-2.1.5 The smoke and fire venting system should be designed in such a manner as to keep the temperature of the combustion products from the fire as low as possible, preferably below approximately 150 °C.

K-2.1.6 Automatic venting systems are complementary to the fire extinguishing systems, and automatic sprinklers, where provided, should operate before the operation of the vents; otherwise, venting may delay sprinkler operation.

K-2.1.7 It is easier to vent a building of smoke than clear it of smoke once it has been filled.

K-2.1.8 Venting is particularly desirable in large area industrial buildings or warehouses, windowless buildings, underground structures or in areas housing hazardous operations. Automatic fire vents should be provided for all industrial occupancies (including storage buildings) classified as medium hazard or above having floor areas exceeding 750 m^2, irrespective of whether they are compartmentalized or not.

K-2.1.9 These provisions do not cover other aspects, of ventilation (or lighting) designed for regulation of temperature within a building for personal comfort or meeting process needs.

K-2.1.10 Similarly, fire and smoke venting requirements as given here under are also not applicable to multi-storeyed buildings, as their requirements are different and more complex.

K-2.1.11 It is difficult to determine precise venting requirements on account of the many variables involved. For instance, the rate of combustion varies appreciably according to the nature, shape, size, and packaging of the combustible materials as well as the size, height, and disposition of the stacks of materials.

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K-2.1.12 In industrial buildings of floor area less than 750 m^2 and used as low fire hazard occupancies, conventional ventilators fitted high up near the eaves of the external walls may serve as vents for smoke and hot gases, provided care is taken to ensure that they are kept open at all times or are designed to open automatically in case of fire.

K-2.1.13 Extinction of fires by closing the doors and windows is not likely in the case of industrial buildings because of their large size, where sufficient air to sustain the fire at least in the initial stages can be expected to be present.

K-2.1.14 Of the two types of building ventilation, namely, vertical, and horizontal, vertical ventilation is the one commonly adopted in the case of single storey industrial buildings.

K-2.1.15 Since 70 percent to 80 percent of heat produced in a fire is convective heat, the ventilation system has to be suitably designed to ensure early outflow of the heat and thereby minimize fire spread.

K-2.1.16 Combustible roof linings should be avoided, as they themselves will contribute to the spread of fire, thereby multiplying the venting problems.

K-2.1.17 A wind blowing across a flat roof or a roof with a pitch under 40° produces a negative pressure, that is, it tends to draw gases out of the building and so aids venting of hot gases. Wind blowing across a roof of pitch greater than 40° will draw gases out on the leeward side, but oppose outward flow on the windward side of the roof.

K-2.1.18 For vents to work at full efficiency, the area of the inlets for cold air entering the compartment must equal at least the total area of the vents. Ideally, the inlets should be as close to the ground as possible.

K-2.1.19 Where roof vents are installed in a single-storey building any neighbouring buildings, particularly those of more than one storey, will be subject to some degree of exposure hazard either from flying birds or radiation, or both, as a result.

K-2.1.20 If vents are to be installed, the size, design, number and disposition of the vents and the associated roof screens/curtain boards have to be assessed after careful analysis of the various factors stated under **K-2.1.11**, as well as other related factors like type of building construction, nature and height of roof, process hazards, exposure hazard, etc.

K-2.2 Venting Area

K-2.2.1 The estimated requirements for ventilation are largely based on the assumed build-up of the fire from the time of initial outbreak to the time of effective firefighting action by fire brigade.

K-2.2.2 The vent area required to be provided should be approximately proportional to the perimeter of the fire area, because the entrained air forms the bulk of the vented gases.

K-2.2.3 The effective area should be the minimum cross-sectional area through which the hot gases must flow out to the atmosphere.

K-2.2.4 No consideration should be given to the increased air movement obtained by power operated fans, since it must be assumed that in the event of fire, power will be interrupted, or fans damaged by heat.

K-2.2.5 The total vent areas to be provided should be as per the following ratios of effective area of vent openings to floor area for various occupancy classifications indicated:

a) Low heat release content (Sub-division G-1) — 1 : 150

b) Moderate heat release content (Sub-division G-2) — 1 : 100

c) High heat release content (Sub-division G-3) — 1 : 30 to 1 : 50

K-2.3 Types of Vents

K-2.3.1 Venting should be accomplished by any of the types such as monitors, continuous gravity vents, until type vents or sawtooth roof skylights.

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K-2.3.2 Where monitor type vents are installed, wire glass or metal panels should be used only if the sash is arranged to open automatically.

K-2.3.3 The use of plain thin glass for venting should be avoided on account of its unpredictable behaviour during fire. However, if glass or other suitable plastic sheet materials with early disintegration characteristics are used, they should be designed for automatic operation.

K-2.3.4 Where monitors or unit type vents are used, the panels should be hinged at the bottom and designed to open automatically. Both sides of the vents should be designed to vent simultaneously to ensure that their effectiveness at the time of fire is not in any way impeded by wind direction.

K-2.3.5 Where movable shutters are provided for continuous gravity vents, these should open automatically in the event of fire.

K-2.3.6 Unit type vents should be of relatively small area, ranging between 1 m^2 and 9 m^2, having light weight metal frames and housing with hinged dampers which should be designed for both manual and automatic operation.

K-2.3.7 Sawtooth roof skylight should be considered as satisfactory for venting purposes only when designed for automatic operation.

K-2.3.8 Likewise, exterior wall windows should not be reckoned as satisfactory means for venting of fire gases and smoke in industrial buildings. However, they may be reckoned as additional means of venting when, they are located close to the eaves and are provided with ordinary glass or movable sash arranged for both manual and automatic operation.

K-2.3.9 Baffles should not be installed inside vents, as they greatly reduce the effective area for venting.

K-2.4 Vent Operation

K-2.4.1 The vents should be automatic in operation, unless where specified in these provisions that they should be designed for both manual and automatic operation.

K-2.4.2 The release mechanism should be simple for operation and independent of electrical power since electrical services may be interrupted by fire.

K-2.4.3 The automatic operation of vents should be achieved by actuation of fusible links or other types of heat and smoke detectors, or by interlocking with operation of sprinkler system or any other automatic fire extinguishing system covering the area. Following their release, the vents should be designed to open by a system of counterweights and associated equipment utilizing the force of gravity or spring loaded levers.

K-2.4.4 Automatic fire alarm system, where installed, should be coupled to the automatic vents to ensure simultaneous operation.

K-2.4.5 Automatic sprinklers, where installed, should operate before the vents open in order to avoid any likely delay in sprinkler operation. However, heat actuated devices used for vent release should be suitably shielded from sprinkler discharge so that water does not delay their action. Further, provision of operating the vents manually may also be provided.

K-2.4.6 Premises where height of roof apex is 10 m or more or where the materials handled or stored have high smoke producing characteristics, in addition to fusible links, the vent release mechanism should be interlinked to smoke actuated automatic fire detectors to ensure early operation of vents.

K-2.4.7 Non-corrosive materials should be used for hinges, hatches and other related parts to ensure long fail-safe operation of the vents.

K-2.4.8 In case of any doubts regarding the types of vents required to be installed for any particular occupancy, authorities having jurisdiction should be consulted.

K-2.5 Size, Spacing and Disposition of Vents

K-2.5.1 Vents should be correctly sited to ensure their functional efficiency. Ideally, they should be sited at the highest point in each area to be covered.

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K-2.5.2 They should, as far as possible, be located immediately above the risk to be protected so as to allow free and speedy removal of smoke and other combustion products in the event of fire.

K-2.5.3 The minimum dimension for an effective vent opening should be not less than 1.25 m in any direction.

K-2.5.4 The spacing of the individual vent should be based on the principle that more number of well distributed smaller vents are more effective than fewer number of badly located larger vents.

K-2.5.5 The maximum spacing between vents for the three occupancy classifications should be as follows:

a) Low heat release content : 45 m between content centres

b) Moderate heat release content : 36 m to 37 m between release content centres

c) High heat release content : 22.5 m to 30 m between content centres, depending on the severity of fire potential.

K-2.5.6 Vents should be placed in a sheltered situation where advantage can be taken of the prevailing wind. The design of the vent should be such as to produce a suction effect. A wind blowing across a flat roof or one with a pitch of 40° produces a negative pressure, that is, it tends to draw gases out of the building and so aids venting of hot gases. Wind blowing across a roof of pitch greater than 40° will draw gases out of the leeward side, but oppose outward flow on the windward side of the roof.

K-2.5.7 Low level inlets, with total area not less than the total area of vents, should be provided to permit outside air to be drawn in to aid automatic venting. These inlets, which may be in the form of doors, windows, or such other openings, should be designed for manual operation when desired.

K-2.6 Roof Screens or Curtain Boards

K-2.6.1 Industrial buildings with large areas and having no subdivision/separating walls limiting the area of individual compartments to 750 m^2 or less, should be provided with roof screens or curtain boards.

These screens which extend from the roof downwards at specific intervals not only prevent lateral spread of heat and smoke in the event of fire below, but substantially assist in early operation of automatic sprinklers and vents.

K-2.6.2 They should be of sheet metal or any other substantially non-combustible material strong enough to withstand damage by heat or impact.

K-2.6.3 They should be reasonably gas-tight, although small openings for passage of pipes, conduits, etc, should be permitted.

K-2.6.4 They should extend down from the roof/ceiling for a minimum depth of 2.2 m. Around specific hazards, the depth should be 4 m. Where roof/ceiling height exceeds 15 m they should extend down to within 3 m of the floor. For pitched sawtoothed roofs, they should extend down to truss level dividing the roof into compartments.

K-2.6.5 In moderate hazard occupancies, the distance between the screens/curtain boards should not exceed 75 m and the curtained areas should be limited to a maximum of 4 500 m^2.

K-2.6.6 In high hazard occupancies, the distance between screens should not exceed 30 m and the curtained area should be limited to 750 m^2.

K-2.6.7 The curtained roof area should be so arranged that they effectively aid in the venting of smoke and hot gases through the automatic vents provided in each area.

K-2.6.8 In sprinklered buildings, the screens should preferably be so located as to coincide with the individual sprinkler system areas.

K-3 EXPLOSION RELIEF VENTS

K-3.1 Industrial premises where combustible dusts can accumulate or where flammable gases, vapours or mists in explosive concentrations may be present are constantly exposed to explosion hazards. Pressures developed by such explosions may be of the order of 7×10^5 Pa and ordinary buildings will not be able to withstand the shock of such pressures. Hence, such buildings require explosion relief vents for preventing structural damage.

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K-3.2 Basic Principle/Considerations

K-3.2.1 Most ordinary building walls will not withstand a sustained internal pressure as great as 6.9×10^3 Pa. Hence, explosion relief vents for buildings must be designed to operate at pressures well below those at which the building walls will fail.

K-3.2.2 There is a rise in pressure during an explosion within an enclosure even with open, unobstructed vents, and any delay in opening the venting devices increases that pressure.

K-3.2.3 Structural damage can be minimized by locating hazardous operations or equipment outside buildings and cut-off from other operations by a pressure resisting wall. Such isolated processes or equipment should be housed in single-storey buildings properly vented and a device provided at the inlet of the collector which will prevent an explosion from blowing back through the duct work and into the building.

K-3.2.4 Where highly hazardous operations cannot be located outside of main buildings, they should be segregated by pressure resisting walls and each such unit should be ventilated outdoors. External walls may be of heavy construction, if equipped with suitable vents or high weight panels which blow out easily.

K-3.2.5 Operations or equipment involving explosion hazards should not be permitted in basements or areas partially below grade.

K-3.2.6 Fire can be expected to follow an explosion in most occupancies, so that any fixed fire extinguishing equipment, like sprinklers, if installed, should be such that only the minimum damage is caused to it.

K-3.2.7 For a given material, the finer the particle size of the dust, the more violent is the explosion. Some materials, such as aluminium powder, hydrogen, and acetylene, are difficult to vent effectively due to the rapid rate of pressure rise. Some slow burning materials, such as coal dust in a confined space, may do much damage because of the longer duration of their presence. Some dusts, such as magnesium, titanium and zirconium and several metal hydrides may react with and ignite in some common inert gases, such as nitrogen and carbon dioxide.

K-3.2.8 The maximum explosion pressure in a vented structure decreases as the size of the vent increases but is independent of the rupturing pressure of a diaphragm.

K-3.2.9 The most effective vent for the release of explosion pressures is an unobstructed vent opening.

K-3.2.10 Pressure required to rupture diaphragms of the same area and material directly varies with the thickness of the material.

K-3.2.11 The slower the rate of pressure rise, the more easily can the explosion be vented.

K-3.2.12 The degree of venting required is directly proportional to the degree of explosion hazard.

K-3.2.13 Experience has shown that most explosions of dusts, vapours and gases do not involve a large part of the total volume of the enclosure, and frequently occur near the upper or lower limits of the explosive range. Consequently, such explosions are relatively weak compared with the optimum.

K-3.2.14 Rectangular unrestricted vents are as effective as square vents of equal area.

K-3.3 Types of Explosion Relief Vents

K-3.3.1 The explosion relief vents should be any one or more of the following types, depending on individual requirements as assessed by the Authority. Open or unobstructed vents, louvres, open roof vents, hanger type doors, building doors, windows, roof or wall panels or movable fixed sash.

K-3.3.2 The effect or external wind pressure or suction on these devices should be taken into consideration while designing and selecting the type of vents, since wind pressures may reach over 2×10^5 Pa in severe windstorms.

K-3.3.3 The type of vent for explosion relief for any occupancy should be selected with life safety as the primary aim followed by minimum damage to property.

K-3.3.4 Where large hanger type doors of metal curtain doors inside walls are used as vents, care should be taken to ensure that they are kept wide open during operations.

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K-3.3.5 Where weather hoods are used to cover roof vents, they should be as light as possible and lightly attached so as to enable them to be blown off quickly when an explosion occurs.

K-3.3.6 Doors and windows when used as explosion vents should be installed to swing outwards. Doors should have friction, spring or magnetic latches that will function automatically to permit the door to open under slight internal pressure.

K-3.3.7 Movable sash should be of the top or bottom hinged or protected type. These should be equipped with a latch or friction device to prevent accidental opening due to wind action or intrusion. Such latches or locks should be well maintained.

K-3.3.8 Fixed sash should be set in place with very light wall anchorages, or, if tight, should be securely fitted and glazed with plastic panes in plastic putty.

K-3.3.9 Where the process is such that the whole of a building or a room may be desirable to arrange for a lightly constructed wall or roof to collapse and thus avert the worst effects of an explosion.

K-3.4 Design, Size and Disposition of Vents

K-3.4.1 The required area of explosion vents should ordinarily depend on the expected maximum intensity of an explosion in the occupancy, the strength of the structure, the type of vent closure and other factors.

K-3.4.2 Venting should be planned in such a manner as to prevent injury to personnel and damage to exposure. In congested locations, substantial ducts or diverters should be provided to direct the blast.

K-3.4.3 When ductwork is used, the ducts should be of sufficient strength to withstand the maximum expected explosion pressure.

K-3.4.4 Where explosions are likely within duct and piping systems, they should be vented by the use of suitable diaphragms designed to blow out at a predetermined pressure. There should be no physical connection between ductwork system for more than one collector.

K-3.4.5 In large structures, the position of vents should be relative to the point of origin of explosion, when it can be determined.

K-3.4.6 Where relatively slow explosions involving coal dust, chlorinated solvents, etc are involved, light, hinged swinging panels may be preferred to diaphragm type of vents.

K-3.4.7 Obstructions of any kind blocking the vents from the risk covered should be avoided, particularly where risks of rapid violent explosions are present.

K-3.4.8 Counterweights add to the inertia of the vents and so should be avoided.

K-3.4.9 Various relieving devices, including devices actuated by detonators, should start to open at as low a pressure as possible. They should be of light construction, so that full opening can be quickly attained.

K-3.4.10 Vents should be of such size and design as to prevent rupture of the protected device or apparatus.

K-3.4.11 Skylights or monitors with movable sash that will open outwards, or fixed sash containing panes of glass or plastic that will blow out readily under pressure from within, can be used to supplement wall vents or windows, provided resistance to their displacement or opening is kept as low as consistent with the requirements for structural strength.

K-3.4.12 Flexible plastic sheets when used for vent closures should be installed in slotted frames in such a way that pressure from within bulges the sheets and releases them from the holding frame.

K-3.4.13 Fragile sheets made of plastic, when used for vent closures, should be thin sheets that will crack or rupture under less pressure, than single strength glass. For this reason, use of transparent or translucent plastic sheets is more advantageous than use of glass in window sash.

K-3.4.14 If closed vents are used, they should be larger in area than unenclosed vents to provide equivalent explosion pressure relief.

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K-3.4.15 Small enclosures, such as machines, should be vented more generously than buildings, because if an explosion occurs in a machine, its entire volume may be involved.

K-3.4.16 Vents for the protection of buildings and equipment should be installed on the following basis:

a) Small enclosures of less than 30 m^3, machines and ovens of light construction: 1 000 cm^2 for each 0.3 m^3 to 0.9 m^3.

b) For small enclosures of more substantial construction having reasonably high bursting strength: 1 000 cm^2 for each 0.9 m^3.

c) Fairly large enclosures of 30 m^3 to 700 m^3, such as bins, silos, rooms, storage tanks, etc: 1 000 cm^2 for each 0.9 m^3 to 1.5 m^3. In these cases, attempt should be made to the extent possible to predict the likely point of origin of the explosion in relation to the vent.

d) Large rooms and buildings over 700 m^3 containing hazardous equipment comprising a small fraction of the entire volume:

   1) For heavy reinforced concrete, walls: 100 cm^2 for each 2.25 m^3.

   2) For light reinforced concrete, brick, or wood construction: 1 000 cm^2 for each 1.65 m^3 to 2.25 m^3.

   3) For lightweight construction such as prefabricated panels: 1 000 cm^2 for each 1.5 m^3 to 1.65 m^3.

e) Large rooms or building over 700 m^3 containing hazardous equipment comprising a large part of the entire volume of a room or building should be vented as generously as possible: 1 000 cm^2 for each 0.3 m^3 to 1.05 m^3.

f) In order to obtain these ratios, the size of the building or room must be limited. For some hazardous materials, such as hydrogen, acetylene, carbon disulphide, etc, these limits are extremely low.

g) Emphasis should always be placed on segregating hazardous areas by means of firewalls or separating walls to prevent spread of fire.

h) Interior walls of light construction, such as tile, should be avoided in hazardous locations since they can cause injuries to personnel in the event of an explosion.

ANNEX M

(*Clause* 1.4)

PERFORMANCE BASED DESIGN

M-1 GENERAL

M-1.1 Performance based design may be applicable under following conditions to any occupancy, subject to:

a) Approval from state/local authority, where they have resource (local/shared/outsourced) to evaluate a performance-based design for any building;

b) The performance-based design should meet the goals and objectives of this Annex and should be carried out by a registered professional;

c) The local authority having jurisdiction should make the final determination whether the performance objectives have been met; and

d) All necessary documentation as per this annex pre- and post-construction should be part of the submission and should be retained during the entire life of the building.

M-1.2 The provisions of this Annex provides performance based design (PBD) which is applicable only to validate the fire safety aspects for heritage buildings (constructed well before the first version of NBC) that are either made available to public or are converted to other building occupancy (and constrained to add additional staircase/refuge that damages it heritage nature).

The Authority may exempt compliance (of such heritage buildings as above constructed before the publication of the first NBC) with the relevant requirements in this NBCS, if the alternate design(s) proposed based on performance-based solutions duly validated by engineering calculations/computational fluid dynamics (CFD)

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modelling, achieve the objectives.

PBD is an engineering approach to fire protection design based on (1) agreed upon fire safety goals and objectives, (2) deterministic and/or probabilistic analysis of fire scenarios, and (3) quantitative assessment of design alternatives against the fire safety goals and objectives using accepted engineering tools, methodologies, and performance criteria.

M-1.3 The application of performance-based fire engineering is highly individualized, excluding its universal adoption across different structures. Due to its reliance on custom-built environmental and occupancy variables, any implementation should undergo a unique validation process by the relevant jurisdiction.

Implementing a performance-based approach necessitates a rigorous assessment of site-specific data to ensure all fire dynamics calculations reflect the unique hazards of the structure. The proponent is responsible for establishing safety parity with prescriptive standards through quantitative evidence. Due to the sophisticated nature of computational fluid dynamics (CFD) modelling, an independent technical audit is recommended to validate the integrity of the design's assumptions and outcomes.

The implementation of PBD requires a multilateral agreement on risk thresholds involving all key stakeholders, including the authority having jurisdiction (AHJ). Due to the sophisticated nature of these designs, specialized fire science expertise is mandatory to ensure that the transition from a theoretical model to a specific environment is technically sound.

NOTE — Computational models, particularly CFD simulations, should be recalculated to reflect the unique spatial geometry and airflow dynamics of the site. Also, the analysis must incorporate local emergency response variables, ensuring the design aligns with the actual equipment and arrival times of the area's fire services.

M-2 MINIMUM CRITERIA

M-2.1 The minimum criteria to accept the PBD solutions should be the compliance to the following:

a) Safe egress (ASET > RSET) through validated evacuation modelling.

b) Controlled fire and smoke spread, maintaining tenable conditions; and

c) Reliable fire suppression and detection exceeding the minimum requirements of this Part.

NOTE — ASET = Available Safe Egress Time; and RSET = Required Safe Egress Time

M-2.2 Tenability refers to the conditions within a space that allow occupants to survive and potentially evacuate safely during a fire. Various factors contribute to tenability, and recommendations suggested is limiting the exposure to the most life-threatening hazards. Thus, to ensure occupant safety in fire scenarios, maintaining tenability criteria at a height of 1.8 m from the floor level is a crucial consideration.

Where possible, the toxicity effects (life threatening hazard) is arrived by obtaining the amount of fractional effective dose (FED) of asphyxiant gases (like, carbon monoxide, hydrogen cyanide); and fractional effective concentration (FEC) of the irritant gases (like, HCl, NO, SO_2). The requirements are:

a) Maintaining FED < 0.3 (recommended to prevent incapacitation of sensitive individuals); and

b) Maintaining FEC < 0.3 (recommended).

FEC is used to assess the combined effect of multiple irritant gases (present in the fire effluent) expressed as:

$$FEC = \sum(Ci/Fi)$$

where

Ci = the concentration of each individual irritant gas (i).

Fi = the concentration of that specific irritant gas (i) that is expected to cause a significant reduction in the possibility of escape and survivability. These Fi values are typically based on experimental data and toxicological studies.

NOTE — Specialist literature be referred to obtain the values of Fi.

M-2.3 In addition, the following thermal exposure limits are recommended:

a) *Convective Heat Exposure* — Air temperature should not exceed 60 °C to prevent heat stress; and

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b) *Radiant Heat Exposure* — Maintain below 2.5 kW/m² to avoid skin burns and incapacitation.

M-2.4 Also, the visibility through smoke criteria is essential and the same is suggested as minimum visibility of 5 m to 10 m should be maintained for safe evacuation and wayfinding.

M-2.5 The PBD involves iterative process in arriving at the desired outcome. *See* Fig. 23 for the typically accepted flowchart.

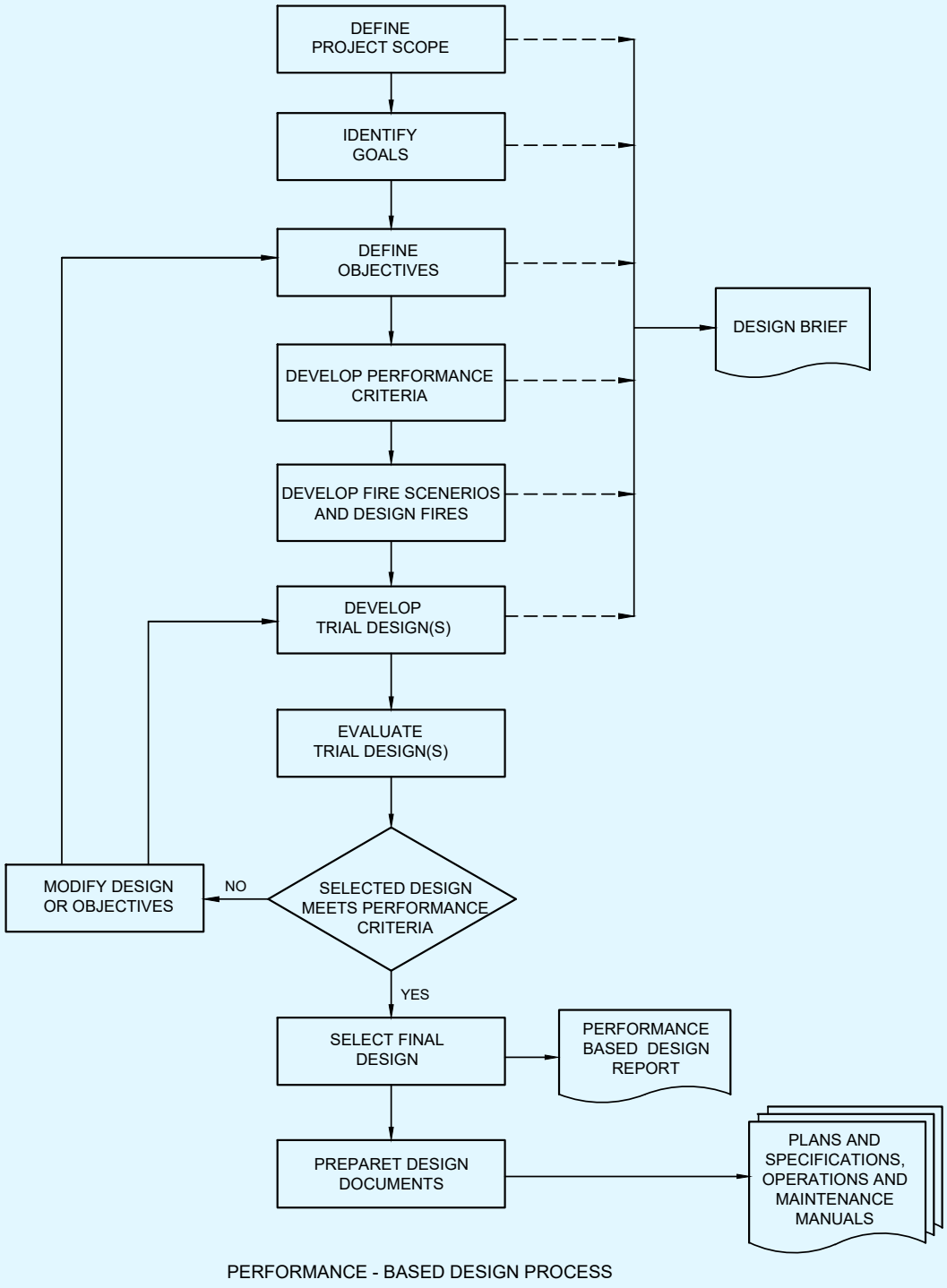

FIG. 23 FLOWCHART DEPICTING THE PROCESS IN PERFORMANCE BASED DESIGN

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ANNEX N

(*Table* 7G)

(*Informative*)

SUGGESTED REQUIREMENTS OF FIRE PROTECTION FOR SPECIFIC INDUSTRIES
(Supplementary to Table 7G)

Sl No.	Type of Factory	Type of Installation								Recommended Water Supply litre		Recommended Pump Capacity litre per minute
		Extinguisher	Small Bore Hose Reels	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manual Fire Alarm System	Automatic Fire Detection & Alarm System	Static Tank at Ground Level	Overhead / Terrace Tank	Fire Pump Ground Level
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Minimum Firefighting Requirements for Factories/Industries – LOW HAZARD (Notes 1, 2a, 3, 4, 5 and 13)												
i)	Artisans workshops, village and cottage industries, tiny sector industries (duly licensed by the Govt. of India)	R	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
ii)	Aggregate built-up area less than 500 m^2	R	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
iii)	Aggregate built-up area from 500 m^2 to less than 1 500 m^2	R	R	NR	NR	NR	NR	NR	NR	15 000	5 000 (Note 12)	R (Note 7a)
iv)	Aggregate built-up area from 1 500 m^2 to less than 2 500 m^2	R	R	NR	NR	NR	NR	NR	NR	25 000	5 000 (Note 12)	R (Note 7a)

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Sl No.	Type of Factory	Type of Installation								Recommended Water Supply litre		Recommended Pump Capacity litre per minute
		Extinguisher	Small Bore Hose Reels	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manual Fire Alarm System	Automatic Fire Detection & Alarm System	Static Tank at Ground Level	Overhead / Terrace Tank	Fire Pump Ground Level
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
v)	Aggregate built-up area more than 2 500 m^2	Pl. see Appendix "1" and also Notes 8, 9, 10 and 11										
Minimum Firefighting requirements for Factories/Industries – ORDINARY HAZARD (Notes 1, 2b, 3, 5 and 13)												
vi)	Aggregate Built-up area less than 500 m^2	R	R	NR	NR	NR	NR	NR	NR	20 000	5 000 (Note 12)	R (Note 7a)
vii)	Aggregate Built-up area from 500 m^2 to less than 1 500 m^2	R	R	NR	NR	R	NR	NR	NR	40000	10 000 (Note 12)	R (Note 7b)
viii)	Aggregate Built-up area from 1 500 m^2 to less than 2 500 m^2	R	R	R	R	R	NR	R	R	60 000	15000 (Note 12)	R (Note 7c)
ix)	Aggregate Built-up area more than 2 500 m^2	Pl. see Appendix "2" and also Notes 8, 9, 10 and 11										
Minimum Firefighting requirements for Factories/Industries – High Hazard 'A' (Notes 2c, 5 and 13)												
x)	Aggregate built-up area less than 1 000 m^2	R	R	R	R	R	R	R	R	75 000	10 000 (Note 12)	R (Note 7d)

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Sl No.	Type of Factory	Type of Installation								Recommended Water Supply litre		Recommended Pump Capacity litre per minute
		Extinguisher	Small Bore Hose Reels	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manual Fire Alarm System	Automatic Fire Detection & Alarm System	Static Tank at Ground Level	Overhead / Terrace Tank	Fire Pump Ground Level
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
xi)	Aggregate built-up area from 1 000 m^2 to less than 2 500 m^2	R	R	R	R	R	R	R	R	1 00 000	15 000 (Note 12)	R (Note 7d)
xii)	Aggregate built-up area more than 2 500 m^2	Pl. *see* Appendix '3' and also Notes 8, 9, 10 and 11										
Minimum Firefighting requirements for Factories/Industries – High Hazard "B" (Notes 2c and 6)												
Please *see* Appendix '4' and also Notes 8, 9, 10 and 11												
Firefighting provisions should comply with various provisions contained in Note 8. In addition, all factories/industries should be protected as per the applicable standards like oil industry safety directorate (OISD) or others as specified in Note 6.												
R - Required. NR - Not Required.												

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NOTES

1 The aggregate built up area of all floors of the facility could be a process building or a storage, a utility building or open storage and any other facilities as the case may be.

2a Buildings above 9 m are not permitted for factories/industries mentioned in Sl No. 1, 2 and 3 of low hazard of Annex 'A' Table.

2b Buildings/Plants above 18 m in height are not permitted for factories/industries mentioned in Sl No. 1 to 4 of ordinary hazard of Annex 'A' Table. However, where nature of process within the Plants demand heights beyond 18 m (for example, where there are tall machinery, vessels, columns, reactors, etc are involved) and occupant load is less (for example, power plants, boiler installations, etc), increase in heights can be allowed. Non-industrial occupancies within the complex but beyond operational area such as offices, residential and the like should comply with respective provisions in this NBCS according to the occupancy.

2c Buildings/plants above 15 m in height are not permitted for high hazard factories/industries. However, where there are vessels, columns, reactors, etc, are involved and specifically related to the process requirements, the heights can be more than 15 m. However, where nature of process within the building/plants demand heights beyond 15 m (for example, where there are tall machinery, vessels, columns, reactors, etc are involved) and occupant load is less (for example, power plants, boiler installations, etc), increase in heights can be allowed. Non-industrial occupancies within the complex but beyond operational area such as offices, residential and the like should comply with respective provisions in this NBCS according to the occupancy.

3 In case, the factories/industries complex consists of building(s) with occupancies having mixed hazards, fire protection systems should be governed by the highest hazard.

4 Those factories/industries which were defined or licensed as "Artisans workshops, Village and Cottage Industries, Tiny sector industries" by the Government of India should need to provide only extinguishers and buckets, their quantity and distribution should comply with IS 2190.

5 Multiple occupancy industrial estates (all in one building) should be protected according to the requirements for 'Ordinary' hazard industries. No high hazard occupancies should be allowed in such buildings.

6 In case of high hazard industries-A (where applicable) and high hazard industries-B like Petrochemical industries, Refineries and the like, compliance with the requirements of other agencies like Oil Industry Safety Directorate (OISD), Petroleum and Explosives Safety Organisation (PESO), Petroleum and Natural Gas Regulatory Board (PNGRB), Oil Mines Regulations (OMR), Central Electricity Authority (CEA) should be necessary in addition to those from Annex 'A' Table.

7a Entire occupancy should be protected by one electric driven main pump of at least 450 lpm discharge capacity at 50 m head, one standby pump of similar capacity (with reliable back-up power supply like DG Set).

7b Entire occupancy should be protected by one electric driven main pump of at least 900 lpm discharge capacity at 50 m head, one standby pump of similar capacity (with reliable back-up power supply like DG Set).

7c Entire occupancy should be protected by one electric driven main pump of at least 1 620 lpm discharge capacity at 70 m head, one standby diesel engine driven pump of similar capacity and one jockey pump of capacity of at least 180 lpm.

7d Entire occupancy should be protected by one electric driven main pump of at least 2 280 lpm discharge capacity at 70 m head, one standby diesel engine driven pump of similar capacity and one jockey pump of capacity of at least 180 lpm.

8 Entire occupancy should be protected by hydrant, sprinkler, water spray, water mist, clean agent, foam, fire alarm systems, etc as applicable in accordance with the current versions of IS 13039, IS 15105, IS 15325, IS 15519, IS 12385, IS 15693, IS 2189, IS 15908, etc in all respects that include design and installation of pumps, pipelines, etc.

9 Certain occupancies may also be protected by automatic water mist systems with appropriate (pressure) applications. Installation and design of such systems should comply to IS 15519.

10 For all occupancies, pumping capacities and water requirements should need to be provided wherever indicated in respective columns in Annex 'N' Table. However, where pumping capacities and water requirements are not indicated in the respective columns, reference should be made to the concerned Indian Standard codes of practices for hydrant/sprinkler/water spray, etc, for details. In either case, design and installation of systems like hydrant, sprinkler, spray systems, etc, should strictly be carried out as per provisions in respective Indian Standards stated in Note 8 above.

11 Where application of water as extinguishing medium is not appropriate due to the presence of water-reactive materials or other valid acceptable reasons, a suitable alternative extinguishing system and method should be provided in accordance with relevant Indian Standards.

12 Overhead fire water tank should be connected to hose reels and also sprinkler system (where applicable).

13 Classifications of various occupancies shown in Annex 'B' is only indicative for ready reference and understanding. While designing hydrant and sprinkler systems, classifications for the purpose of design and installation should strictly adhere to those available in IS 13039 and IS 15105 respectively.

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Appendix '1' to Annex N

Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Abrasive manufacturing premises	R	R	R	NR	Required for packing material/other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
ii)	Aerated water factories, mineral water factories	R	R	R	NR	Required for packing material/ bottles and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
iii)	Agarbatti manufacturing	R	R	R	NR	Required for packing material/Finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
iv)	Analytical and/or quality control laboratories (without pilot plant)	R	R	R	Required if the combined floor area of the building is more than 5 000 m^2	NR	Suitable detection system backed up by manual call stations should be provided for the entire factory where combined area of the process/Storage blocks	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
							exceeds 5 000 m^2	
v)	Areca nut slicing and/or betel nut factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
vi)	Asbestos steam packing and lagging manufac-turers	R	R	R	NR	NR	Suitable detection system backed up by manual call stations should be provided for the entire factory where combined area of the process/storage blocks exceeds 5 000 m^2	
vii)	Battery charging/battery service station	R	R	R	R	R	Suitable detection system backed up by manual call stations should be provided for the entire factory where combined area of the process/storage blocks exceeds 5 000 m^2	Water mist systems as per IS 15519

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
viii)	Battery manufacturing	R	R	R	R	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Suitable detection system backed up by manual call stations should be provided for the entire factory where combined area of the process/storage blocks exceeds 5 000 m^2	Water mist systems in battery charging stations as per IS 15519
ix)	Breweries	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
x)	Brick works	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xi)	Canning factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xii)	Cardamom factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xiii)	Cement factories and/or asbestos or concrete products manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	Clean agent-inert gas systems (CO_2, Nitrogen) for bag filters, mill house, coal bins
xiv)	Ceramic factories and crockery and stoneware pipe manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xv)	Clay works	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xvi)	Clock and watch manufacturing	R	R	R	NR	Raw Material godowns should be sprinklered if the value of plastic/rubber and other similar commodities in the storage area exceeds 20 percent of the total	Manual fire alarm system should be provided throughout, operations like spray painting, wood working, solvent cleaning etc, should need to be spot-protected if combined area	

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Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
						value of the storage building	occupied by such operations exceed 10 percent of the total manufacturing area	
xvii)	Coffee curing, roasting and grinding premises	R	R	R	Required if the area occupied by process building exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	If combined area of the entire factory is more than 2 000 m^2, manual fire alarm system should be required, Suitable detection system backed up by Manual call stations should be provided for the entire factory where combined area of the process/storage blocks exceeds 5 000 m^2	If combined area of process and storage blocks in the same building exceeds 2 000 m^2, sprinkler installation will be required in the entire area
xviii)	Condensed milk factories, milk pasteurising plant and dairies	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xix)	Confectionery manufacturing	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Appendix '1' to Annex N

Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xx)	Crockery and stoneware pipe manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxi)	Electric generating houses (Hydro electric)	R	R	R	NR	Sprinkler protection for storage areas not forming part of main occupancy if area exceeds 2 000 m^2	Auto fire alarm system for all areas except detached storage buildings and utility blocks where manual alarm systems should be provided	Water spray system for transformers, FDS/NIFPS system, cable galleries, conveyors including transfer towers, etc as per IS 3034 and IS 15325
xxii)	Electric Lamps (Incandescent and Fluorescent) and TV Picture Tube Manufacturing	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxiii)	Electric Sub-Station/ Distribution Station	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	Water spray system for transformers if capacity thereof is more than 10 MVA or oil capacity exceeds 2 000 litre.

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Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
								(As per CEA Regulations and IS 3034, IS 15325)
xxiv)	Electro Plating Works	R	R	R	NR	NR	NR	
xxv)	Electronic and/or Computer equipments Assemble and Manufactures	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxvi)	Engineering workshops heavy (Structural Steel Fabricators, Sheet Metal Fabricators (Tin Printing excluded), Hot or Cold Rolling, Pipe Extruding, Stamping, Pressing, Drawing (other than wire Drawing) or Forging Mills, Ore Crushing Mills, Ferrous and non Ferrous Metal Smelting or Extraction Works and Foundries (allowing storage of Wooden	R	R	R	NR	Raw material godowns should be sprinklered if the value of plastic/rubber and other similar commodities in the storage area exceeds 20 percent of the total value of the storage building.	Manual fire alarm system should be provided throughout, operations like manufacture of plastic/rubber components, powder coating/spray painting, drying of painted goods, use or storage of flammable liquids having flash point of 23 °C and below, wood working, upholstering, engine testing and flammable gas plant should need to be spot-protected by appropriate means if combined area	

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Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Patterns only) and galvanizing works and the like)						occupied by such operations exceed 10 percent of the total manufacturing area. Else such areas should be fire separated from the main operations	
xxvii)	Engineering workshops Light (Blacksmiths, Electroplating, Anodizing or Lead, Zinc or other Metal Coating Works, Machine Shops, Heat Treatment shops, Electro Magnets manufacturing, Electrical and Mechnical Machinery Assemblers/Manufacturers, General Engineering Goods and Merchandise Manufacturers, Maintenance and Repair Workshops, Mfrs. of Welding Electrodes and Wire drawing, Automobile factories and the like)							

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Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxviii)	Fruits and vegetables dehydrating/drying factories	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxix)	Fruit products and condiment factories	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxx)	Glass and glass Fibre manufacturing	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxi)	Gold thread factories/ gilding factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxii)	Granite manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	If inflammable liquids having a flash point of less than 65° are used, manual foam spray

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Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
								system should be used in the areas concerned
xxxiii)	Gum and/or Glue and Gelatine Manufacturing	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxiv)	Ice Candy and Ice-cream Manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxv)	Ice Factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxvi)	Ink (excluding Printing Ink) Factories	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxxvii)	Laundries	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxviii)	Mica products manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxix)	Pottery works	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xl)	Poultry farms	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xli)	Salt Crushing Factories and Refineries	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Low Hazard Factories/Industries with Aggregate Built-up area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xlii)	Sugar Candy Manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xliii)	Sugar Factories and Refineries	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xliv)	Tanneries/Leather Goods Manufacturers	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xlv)	Tea Blending and Tea Packing Factories	R	R	R	Required if the area occupied by process building exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	If combined area of the entire factory is more than 2 000 m^2, manual fire alarm system should be required, suitable detection system backed up by manual call stations should be provided for the entire factory where combined area of the process/ storage blocks exceeds 5 000 m^2	If combined area of process and storage blocks in the same building exceeds 2 000 m^2, sprinkler installation will be required in the entire area

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xlvi)	Umbrella Assembling Factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xlvii)	Vermicelli Factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xlviii)	Water Treatment/Water Filtration Plants and Water Pump House	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xlix)	Zinc/Copper/Aluminium Factories	R	R	R	NR	NR	Suitable detection system backed up by manual call stations should be provided for the entire factory where combined area of the process/storage blocks exceeds 5 000 m^2	
	R – Required. NR – Not Required.							

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Appendix '2' to Annex N

Ordinary Hazard Factories/Industries with Aggregate Built-up Area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Airport and other transportation terminal building	R	R	R	To be fully sprinklered	To be fully sprinklered (cargo)	To be fully protected by automatic intelligent fire alarm system	Kitchen hoods and ducts should be protected with wet chemical systems as per this NBCS. Also, systems as per ICAO standards.
ii)	Aluminium factories	R	R	R	NR	NR	NR	
iii)	Bakeries	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
iv)	Beedi factories	R	R	R	NR	NR	NR	
v)	Biscuit factories	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
vi)	Bobbin factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Appendix '2' to Annex N

Ordinary Hazard Factories/Industries with Aggregate Built-up Area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
vii)	Bookbinders, envelopes and paper bag manufacturers	R	R	R	Required when a single un-compartmented area is more than 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
viii)	Cable manufacturing	R	R	R	Required when a single un-compartmented area is more than 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
ix)	Carbon paper/typewriter ribbon manufacturers	R	R	R	Required when a single un-compartmented area is more than 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
x)	Cardboard box manufacturing	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xi)	Carpenters, wood wool and furniture manufac-turers. Basket weavers, cane furniture manufactuirng	R	R	R	Required when a single un-compartmented area is more than 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Appendix '2' to Annex N

Ordinary Hazard Factories/Industries with Aggregate Built-up Area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xii)	Carpet and drugget factories	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xiii)	Chemical manufacturing involving chemicals, dyes, intermediates, pigments, acids, medicinal/ pharma-ceuticals formulation and toilet preparation including soap manufac-turing, chemical mixing and blending factories using no chemicals/ solvents having flash point below 23 °C	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	If the quantity of chemicals/ solvents having flash point below 23 °C is less than 200 litre in process and there is no storage of such solvents/chemicals more than 200 litre then such industries can be considered under this table. Else, *see* High hazard
xiv)	Cigar and cigarette factories	R	R	R	Required in full	Required in full	Automatic fire alarm system should be provided for godown buildings, manual system for process blocks	

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Ordinary Hazard Factories/Industries with Aggregate Built-up Area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xv)	Coffee grinding premises	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xvi)	Coir, carpets, rugs and tobacco, hides and skin presses	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xvii)	Cork products manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xviii)	Dry cleaning, dyeing, laundries	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xix)	Electric generating stations (other than hydel)	R	R	R	NR	Sprinkler protection for storage areas not forming part of main occupancy if area exceeds 2 000 m^2	Automatic fire alarm system for all areas except detached storage buildings and utility blocks where manual alarm systems should be provided	Water spray system for transformers, FDS/NIFPS system, cable galleries, conveyors including transfer towers, etc as per IS 3034 and IS 15325

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xx)	Enamelware factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxi)	Filter and wax paper manufacturing	R	R	R	Required when a single un-compartmented area is more than 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxii)	Flour mills	R	R	R	Required if combined floor plate area exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxiii)	Garment makers	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxiv)	Ghee factories (other than vegetable)	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxv)	Grain and/or seeds disintegrating and/or crushing factories	R	R	R	Required if combined floor plate area exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxvi)	Grease manufacturing	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxvii)	Hat and topee factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxviii	Hosiery, lace, embroidery and thread factories	R	R	R	Required if combined floor plate area exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxix)	Incandescent gas mantle manufacturers	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxx)	Industrial gas manufacturing Including halogenated hydrocarbon gases	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2000 m^2	
xxxi)	Linoleum factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxii)	Man-made yarn/fibre manufacturing (except acrylic)	R	R	R	Required if combined floor plate area exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Automatic fire alarm system should be provided when combined floor plate exceeds 5 000 m^2, else manual systems should be provided	
xxxiii)	Manure and fertiliser works. (blending, mixing and granulating only)	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxiv)	Mineral oil blending and processing	R	R	R	Required when a single un-compartmented area is more than 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding	Manual fire alarm system for entire unit if area of single largest building	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
						2 000 m^2 in area	exceeds 2 000 m^2	
xxxv)	Oil and leather cloth factories	R	R	R	Required when a single un-compartmented area is more than 2 000 m^2	Required for Packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxvi)	Oxygen plants	R	R	R	Required for manufacturing blocks	Required for storage blocks	Automatic fire alarm system should be provided throughout	
xxxvii)	Plywood manufacturing/wood veneering factories	R	R	R	Required when a single un-compartmented area is more than 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xxxviii)	Paper and cardboard mills	R	R	R	NR	Raw material and Finished goods storage should be provided with sprinklers	Automatic fire alarm system should be provided throughout	
xxxix)	Plastic goods manufacturing polytetra fluoroethylene, flourinated ethylene-	R	R	R	Required if combined floor plate area exceeds 2 000 m^2	Raw material and finished goods storage should be provided with sprinklers if area exceeds	Manual fire alarm system for entire unit if area of single largest building	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	propylene, poly-chlorotrifluroethylene, polyvinyl chloride, polyvinyl acetate, polyvinylidene chloride, vinyl chloride-vinylidene, chloride copolymer, polyvinylidene flouride, polycarbonate, phenylene oxide polymer, polysulfone, chlorinated polyether, phenolics, melamine formaldehyde, urea formaldehyde, silicones, phenol furfural, phenol formaldehyde, tetraflouro ehtylene, polyvinyl fluoride, cresol formaldehyde, ploy amide (nylon). rope works, assembling of plastic goods such as toys and the like					2 000 m^2	exceeds 2 000 m^2	
xl)	Plastic goods manufacturing polyethylene,	R	R	R	Required if combined floor plate area exceeds	Raw material and finished goods storage should be provided with	Manual fire alarm system for entire unit if area of bulding(s) exceeds	Many chemicals are water reactive with water and alternative systems

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	polypropylene, polybutylene, ethylenemethacrylic acid ionomer, polyvinyl alcohol, polyvinyl butyrate, polyvinyl formaldehyde, polystyrene, styrene-acrylonitrile copolymer, acrylonitrile- butadiene-styrene, polymethyl methacrylate, cellulose acetate, cellulose acetate butyrate, cellulose propionate, Cellulose triacetate, ethyl cellulose, acetal, epoxy, polyesters, polyurethanes, acid monomer, acrylate, allyl, methyl methacrylate, polythene				2 000 m^2	sprinklers	2 000 m^2	(not involving water) should be used
xli)	Plastic goods manufacturing foamed plastics	R	R	R	R	Raw material and finished goods storage should be provided with sprinklers	Manual fire alarm system for entire unit	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xlii)	Printing press premises	R	R	R	Required if area of building(s) exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system required if area of building(s) exceeds 2 000 m^2	
xliii)	Pulverising and crushing mills of metal and metallic ores (excluding aluminium and magnesium metals)	R	R	R	NR	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system is required if the floor area exceeds 2 000 m^2	
xliv)	Pulverising and crushing mills of metallic ores of aluminum and magnesium and coal	R	R	R	Required if area of building(s) exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Automatic fire alarm systems if the floor area exceeds 2 000 m^2	Depending on the circumstances like water reacting chemicals, open-sided structure, etc, sprinklers may be replaced with water mist systems
xlv)	Rice mills	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
xlvi)	Rope works (other than plastic)	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xlvii)	Rubber tyres and tubes manufacturing	R	R	R	Required if area of building(s) exceeds 2 000 m^2	Required for packing material/finished goods godowns	Automatic fire alarm systems if the floor area exceeds 2 000 m^2	
xlviii)	Shellac factories	R	R	R	NR	NR	Manual fire alarm system required	Only local protection, that is, where chemicals used, have a flash point below 23 °C, with medium velocity water spray for manufacturing blocks, similar protection for the area where materials are stored (raw material as well as finished goods)
xlix)	Silk filatures and cocoon stores	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
l)	Spray painting	R	R	R	R	NR	NR	If area of the building exceeds 500 m^2, protection systems like sprrinklers, inert gas agents should be installed

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
li)	Soaps and glycerine factories	R	R	R	NR	Raw material and finished goods godowns should be sprinklered if the storage area is more than 2 000 m^2	Automatic fire alarm systems if the floor area exceeds 2 000 m^2	
lii)	Starch factories	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
liii)	Steel plants	R	R	R	NR	NR	Automatic fire alarm systems if the floor area exceeds 2 000 m^2	
liv)	Tanneries/leather goods manufac- turers	R	R	R	Required if area of building(s) exceeds 2 000 m^2	Required for packing material/finished goods and other raw materials godowns if exceeding 2 000 m^2 in area	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
lv)	Tank farms other than those categorised under high hazard 'A'	R	R	R	Water spray/foam system as applicable should be provided for all tanks			

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
lvi)	Textile mills	R	R	R	Required for all process blocks from mixing operations till weaving shed	Required for raw material and finished goods godowns	Automatic fire alarm systems should be provided for raw materials and finished goods godowns	Hazardous areas like singeing, raising, polymerizing, etc should be fire separated (2 h) from adjoining blocks. Concealed spaces/return air ducts/plenum in all process blocks upto weaving should be provided with quick response sprinklers. Diversion systems should be provided where the chute feed machines are installed between blow and carding sections
lvii)	Tea factories	R	R	R	Required if area of building(s) exceeds 2 000 m^2	Required if area exceeds 2 000 m^2	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
lviii)	Tobacco (chewing) and pan-masala making	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
lix)	Tobacco grinding and crushing	R	R	R	NR	Required if the area of building exceeds 2 000 m^2	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
lx)	Tobacco redrying factories	R	R	R	Required if the area of building exceeds 2 000 m^2	Required if the area of building exceeds 2 000 m^2	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	
lxi)	Woollen mills	R	R	R	Required for all processing areas	Required for raw material/finished goods godowns	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	

R – Required. NR – Not Required.

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High Hazard "A" Factories/Industries with Aggregate Built-up Area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Aircraft hangers	R	R	R	Required in full	Required in full	Automatic intelligent fire alarm system with flame detectors	High expansion foam systems should need to be installed. Also, systems as per ICAO standards
ii)	Aluminium/magnesium powder plants	R	R	R	NR	NR	Manual fire alarm system for entire unit if area of single largest building exceeds 2 000 m^2	Special dry powder systems
iii)	Bituminized paper and/or hessian cloth manufacturing including tar felt manufacturing	R	R	R	Required if area of the building exceeds 2 000 m^2	Raw material and finished goods godowns should be sprinklered	Manual fire alarm system for entire unit	
iv)	Chemical manufacturing involving chemicals, dyes, intermediates, pigments, acids, medicinal/ pharma-ceuticals formulation and toilet preparation including soap manufacturing, chemical mixing and blending factories using chemicals/ solvents having flash point below 23 °C and metallic	R	R	R	MV spray systems and/or foam system should be provided locally as applicable for vessels, pumps, compressors, reactors, columns, etc where chemicals having flash point below 23 °C are in process. (Suitable care should taken to check whether chemicals are water reacting)	MV spray systems and gaseous protection systems as applicable for godowns storing materials with flash points below 23 °C. (Suitable care should taken to check whether chemicals are water reacting)	Manual fire alarm systems should be provided for entire unit	All tanks having a diameter of 9 m or more, storing Class A or B chemicals should be provided with medium velocity spray systems and foam systems as applicable backed up with suitable detection systems

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	nitrates, coal tar and wood distillation plant							
v)	Cotton waste factories	R	R	R	Entire area should be sprinklered if the combined area of all buildings exceed 2 000 m^2		Manual fire alarm systems should be provided for entire unit	
vi)	Coal and/or coke and/or charcoal ball briquettes manufacturing	R	R	R	NR	Raw materials and finished goods godown should be sprinklered when area is more than 2 000 m^2	Manual fire alarm systems should be provided for entire unit	
vii)	Celluloid goods manufacturing	R	R	R	NR	NR	Manual fire alarm systems should be provided for entire unit	Alcohol resistant foam, carbon dioxide (CO_2), dry chemicals where applicable for all process areas and godowns
viii)	Cigarette filter manufacturing	R	R	R	Required for all process areas	Raw materials and Finished goods godown should be sprinklered when area is more than 2 000 m^2	Manual fire alarm systems should be provided for entire unit	
ix)	Cinema films and t.v. production studios	R	R	R	Required for all process areas	Godowns should be sprinklered if area is more than 2 000 m^2	Automatic fire alarm system should be provided	
x)	Cotton seed cleaning or de-linting factories, cotton ginning and pressing units	R	R	R	Required for all process areas	Godowns should be sprinklered if area is more than 2000 m^2	Manual fire alarm systems should be provided for entire unit	

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xi)	Distilleries	R	R	R	Local protection with medium velocity spray/foam systems as applicable should be provided for process areas	NR	Automatic fire alarm system should be provided	
xii)	Duplicating and stencil paper manufacturing	R	R	R	Required for all process areas	Godowns should be sprinklered if area is more than 2 000 m^2	Manual fire alarm systems should be provided for entire unit	
xiii)	Fire-works manufacturing	R	R	R	Required for all process areas	Required for all raw material and finished goods godowns	Manual fire alarm systems should be provided for entire unit	
xiv)	Foamed plastics manufacturing and/or converting plants	R	R	R	Required for all process areas	Required for all raw material and finished goods godowns	Manual fire alarm systems should be provided for entire unit	
xv)	Jute mills and jute presses	R	R	R	Required for all process areas	Required for all raw material and finished goods godowns	Manual fire alarm systems should be provided for entire unit	
xvi)	LPG bottling plants	R	R	R	Required for all process areas	Required for all storage and decantation, truck loading areas	Manual fire alarm systems should be provided for entire unit	LPG storage tankage like bullets and spheres should be protected with medium velocity water spray systems backed up with suitable detection systems as per IS 15325.

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
								Also, systems as per OISD- STD-144 and other applicable OISD standards
xvii)	Match factories	R	R	R	Required for all process areas	Required for all raw material and finished goods godowns	Manual fire alarm systems should be provided for entire unit	
xviii)	Man made fibres (acrylic fibres/yarn making)	R	R	R	Required for all process areas	Required for all raw material and finished goods godowns	Automatic fire alarm systems should be provided for entire unit	
xix)	Mattress and pillow making	R	R	R	Required for all process areas if area of the building is more than 2 000 m^2	Required for all raw material and finished goods godowns having area more than 2 000 m^2	Manual fire alarm systems should be provided for entire unit	
xx)	Metal or tin printers	R	R	R	Required for all process areas if area of the building is more than 2 000 m^2	Required for all raw material and finished goods godowns having area more than 2 000 m^2	Manual fire alarm systems should be provided for entire unit	
xxi)	Oil mills	R	R	R	Required for all process areas if area of the building is more than 2 000 m^2	Required for all raw material and finished goods godowns having area more than 2 000 m^2	Automatic fire alarm systems should be provided for entire unit	Local protections such as medium velocity spray or foam systems as applicable should be provided in process and storage areas

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Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxii)	Oil extraction plants (other than those forming part of ghee factories and oil refining factories)	R	R	R	Required for all process areas if area of the building is more than 2 000 m^2	Required for all raw material and finished goods godowns having area more than 2 000 m^2	Automatic fire alarm systems should be provided for entire unit	Local protections such as medium velocity spray or foam systems as applicable should be provided in process and storage areas
xxiii)	Oil terminals/depots handling flammable liquids having flash point of 23 °C and below	R	R	R	Automatic medium velocity water spray and /or foam systems should be provided as applicable for all tanks backed up with suitable automatic detection systems. Also, systems as per OISD-STD-117 and other applicable OISD standards			
xxiv)	Paints and varnish factories	R	R	R	Required for all process areas if area of the building is more than 2 000 m^2	Required for all raw material and finished goods godowns having area more than 2 000 m^2	Automatic fire alarm systems should be provided for entire unit	Local protections such as medium velocity spray or foam systems as applicable should be provided in process and storage areas
xxv)	Printing ink manufacturing	R	R	R	Required for all process areas if area of the building is more than 2 000 m^2	Required for all raw material and finished goods godowns having area more than 2 000 m^2	Automatic fire alarm systems should be provided for entire unit	Local protections such as medium velocity medium velocity spray or foam systems as applicable should be provided in process and storage areas
xxvi)	Saw mills	R	R	R	NR	NR	Manual fire alarm system should be provided for entire unit	

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Appendix '3' to Annex N

High Hazard "A" Factories/Industries with Aggregate Built-up Area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxvii)	Solvent extraction plants	R	R	R	NR	NR	Automatic fire alarm systems should be provided for entire unit	Entire factory and storage tanks to be protected by medium velocity water spray system and/or foam system
xxviii)	Surgical cotton manufacturers	R	R	R	Required for all process areas	Required for all raw material and finished goods godowns	Automatic fire alarm systems should be provided for entire unit	
xxix)	Tank farms storing flammable liquids having flash point of 23 °C and below	R	R	R	Automatic medium velocity water spray and /or Foam systems should be provided as applicable for all tanks backed up with suitable automatic detection systems. Also, systems as per OISD-STD-116 and other applicable OISD standards			
xxx)	Tarpaulin and canvas proofing factories	R	R	R	Required for all process areas where building area is more than 2 000 m^2	Required for all raw material and finished goods godowns where the building area is more than 2 000 m^2	Automatic fire alarm systems should be provided for entire unit	
xxxi)	Turpentine and rosin distilleries	R	R	R	NR	NR	Automatic fire alarm systems should be provided for entire unit	Local protections such as medium velocity water spray or foam systems as applicable should be provided in process and storage areas

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Appendix '3' to Annex N

High Hazard "A" Factories/Industries with Aggregate Built-up Area more than 2 500 m^2

Sl No.	Description	Extinguisher	Hose Reel	Hydrant System	Sprinkler System		Fire Alarm System	Special Protection
					Process Blocks	Storage Blocks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
xxxii)	Tyre retreading and resoling factories	S	R	R	Required for all process areas where building area is more than 2 000 m^2	Required for all Raw material and finished goods godowns where the building area is more than 2 000 m^2	Automatic fire alarm systems should be provided for entire unit	
	R – Required. NR – Not Required. S – Suitable							

Appendix '4' to Annex N

High Hazard 'B' Factories/Industries (All Chemicals, Petroleum, Gas Processing, Petrochemicals, Fertilizer Plants, Thermal Power Plants, etc)

Sl No.	Description	Fire Extinguishers, Firefighting Equipment	Hydrant System, Fire Monitors, Hose Reels	Fire Alarm System	Sprinkler System	High Volume Long Range (HVLR) Monitors	Gas/HC/Fire/Heat Detection System	Automatic Heat/Fire Detection and Suppression System	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Process units (columns, boilers, furnaces, reactors, vessels, drums, etc)	R	R (Note 1)	R	R (Note 2)	Refer Note 3	R (Note 4)	NR	
ii)	Tank farm areas (storage of liquid/gas flammable	R	R	R	R	R	R	R	High volume long range monitors of capacity 500 to

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Appendix '4' to Annex N									
High Hazard 'B' Factories/Industries (All Chemicals, Petroleum, Gas Processing, Petrochemicals, Fertilizer Plants, Thermal Power Plants, etc)									
Sl No.	**Description**	**Fire Extinguishers, Firefighting Equipment**	**Hydrant System, Fire Monitors, Hose Reels**	**Fire Alarm System**	**Sprinkler System**	**High Volume Long Range (HVLR) Monitors**	**Gas/HC/Fire/Heat Detection System**	**Automatic Heat/Fire Detection and Suppression System**	**Remarks**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	products Class A and cluster of Class A and B products)				(Note 5, 6)	(Note 7, 8)		(Note 9)	4 000 gpm (variable flow) as required as per Standards; HVLR monitors of 10 500 gpm should be considered to fight fire in large dia tanks. Fire water monitors around the tank farm area as per IS/OISD standards
iii)	Pump house area (Pumps and Compressors - rotary equipment)	R	R	R	R	NR	R (Note 4)	NR	
iv)	Loading/unloading gantry (tank wagon and tank truck loading/unloading)	R	R	R	R	R	R (Note 4)	NR	Water sprinkler throughout the length of Gantry. Hydrocarbon (HC) detectors at drains
v)	LPG filling stations	R	R	R	R	NR	R	NR	LPG storage – Mounded storage, Horton spheres, Bullets should have water sprinklers with medium velocity spray

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Appendix '4' to Annex N

High Hazard 'B' Factories/Industries (All Chemicals, Petroleum, Gas Processing, Petrochemicals, Fertilizer Plants, Thermal Power Plants, etc)

Sl No.	Description	Fire Extinguishers, Firefighting Equipment	Hydrant System, Fire Monitors, Hose Reels	Fire Alarm System	Sprinkler System	High Volume Long Range (HVLR) Monitors	Gas/HC/Fire/Heat Detection System	Automatic Heat/Fire Detection and Suppression System	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
vi)	Conveyor belt areas	R	R	R	R	NR	NR	R (Note 10)	Handling flammable dusts like coal / lignite dust, etc
vii)	Sub-station and electrical panels	R	NR	R	NR	NR	NR	R (Note 11, 12)	Substation to be air pressurized
viii)	Chlorination plant	R	NR	NR	R	NR	R (Note 13)	NR	
ix)	Transformers	R	R	R	R	NR	NR	R (Note 14)	
x)	Cable trenches, racks and cable galleries	R	NR	R	NR	NR	R	R (Note 11 and 12)	Adequate ventilation and sealing in cable gallery housing
xi)	Quality control lab	R	R	R (Note 15)	R	NR	R	NR	

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Appendix '4' to Annex N

High Hazard 'B' Factories/Industries (All Chemicals, Petroleum, Gas Processing, Petrochemicals, Fertilizer Plants, Thermal Power Plants, etc)

Sl No.	Description	Fire Extinguishers, Firefighting Equipment	Hydrant System, Fire Monitors, Hose Reels	Fire Alarm System	Sprinkler System	High Volume Long Range (HVLR) Monitors	Gas/HC/Fire/Heat Detection System	Automatic Heat/Fire Detection and Suppression System	Remarks
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
xii)	Admin. building	R	R	R (Note 15)	R	NR	NR	NR	
xiii)	Control room	R	NR	R	R	NR	NR	R (Note 16)	
xiv)	Firefighting pumps and fire water system	Electric and diesel/HSD driven pumps of similar capacity and same head. Jockey pump with 3 percent to 5 percent capacity of main pumps. Overhead fire water tanks and reservoir with adequate capacity to fight two simultaneous fires.							
xv)	Fire tenders	Independent fire station equipped with water, foam, dry chemical power tenders and rescue vehicles - response time on fire call must be within 05 min.							

R – Required. NR – Not Required.

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NOTES

1 Fire water network with fire hydrants, monitors all around the process unit and tank farm areas should be provided in accordance with relevant Indian Standards, OISD. Fire hydrants should be at different platforms/levels in TPH/boilers/furnaces/columns/reactors.

2 Water sprinklers in technological platforms for all static equipment normally reflux drums, air-fin fan coolers, etc should be provided in accordance with relevant Indian Standards, OISD.

3 Elevated fire water monitors (variable flow) to fight fires at tall columns / boiler house / reactors / technological platforms, etc should be provided in accordance with relevant Indian Standards, OISD.

4 Hydrocarbon detectors, gas detectors, heat sensors at strategic / critical locations normally drain points of vessels, columns, pump drain, tank drain points, etc should be provided in accordance with relevant Indian Standards, OISD.

5 Fixed foam pourer system for Class-A products storage tanks should be provided in accordance with relevant Indian Standards, OISD.

6 Water Sprinklers ring at top and middle of tanks for water cooling in all storage tanks should be provided in accordance with relevant Indian Standards, OISD.

7 HVLR - Remote/manual operated variable flow monitors having discharge of 500 gpm to 4 000 gpm capacity should be provided as per requirement. HVLR Monitor of 10 500 gpm should be considered for large dia tanks (for > 60 M and above). Fire robot may be considered for fighting multiple tank/area fires as per the relevant Indian Standards.

8 Medium expansion foam generators (MEFG) may be provided to fight fire due to accidental spillage of flammable materials in tank dykes/spill fires.

9 Automatic site configurable linear heat detection and foam suppression system should be provided for EFR tanks (rim seal areas) Class A products.

10 Linear heat detection system, site configurable type with water mist/spray system should be provided in all conveyor belts for early detection of rise in temperature.

11 Linear heat detection system, site configurable type should be provided in all cable cellars, trenches, for early detection.

12 All electrical panels should be provided with linear heat detection and inert gas suppression system (environment friendly halon free).

13 Chlorine leakage kit, chlorine protective suit, sensors, neutraliser, etc should be provided.

14 Water mist /deluge system and nitrogen injection fire prevention system (NIFPS) with site configurable linear heat sensing detector should be provided for oil filled transformers.

15 Wireless heat and smoke detection with alarm and notification to concerned should be provided.

16 Clean agent inert gas fire suppression system (environment friendly halon free) should be provided in all control rooms.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of this Part. The latest version of a standard should be adopted at the time of enforcement of this Part. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in this Part.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part.

	IS No.	*Title*
(1)	IS 3808 : 1979	Method of test for non-combustibility of building materials (*first revision*)
(2)	IS/ISO 834-1 : 1999	Fire resistance tests — Elements of building construction: Part 1 General requirements
	IS/ISO 834-4 : 2000	Fire Resistance tests — Elements of building construction: Part 4 Specific requirements for load bearing vertical separating elements
	IS/ISO 834-5 : 2000	Fire resistance tests — Elements of building construction: Part 5 Specific requirements for load bearing horizontal separating elements
	IS/ISO 834-7 : 2000	Fire-resistance tests — Elements of building construction: Part 7 Specific requirements for columns
	IS/ISO 834-8 : 2003	Fire-Resistance tests — Elements of building construction: Part 8 Specific requirements for non-load bearing vertical separating elements
	IS/ISO 834-9 : 2003	Fire-resistance tests — Elements of building construction: Part 9 Specific requirements for non-load bearing ceiling elements
(3)	IS 8757 : 2021	Glossary of terms associated with fire safety (*second revision*)
	IS 7673 : 2004	Glossary of terms for fire fighting equipment (*first revision*)
(4)	IS 8758 : 2013	Recommendations for fire precautionary measures in the construction of temporary structures and pandals (*second revision*)
(5)	IS 9668 : 1990	Code of practice for provision and maintenance of water supplies and fire fighting
	IS 3844 : 1989	Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (*first revision*)
(6)	IS 1646 : 2015	Fire safety of buildings (General): Electrical installations — Code of practice(*third revision*)
(7)	IS 9457 : 2025	Safety colours, safety signs and accident prevention tags — Code of practice (*second revision*)
	IS 12349 : 1988	Fire protection — Safety sign
	IS 12407 : 1988	Graphic symbols for fire protection plan
(8)	IS/ISO 7240-7 : 2023	Fire detection and alarm systems Part 7: Point-type smoke detectors using scattered light, transmitted light, or Ionization (*first revision*)

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	IS No.	*Title*
	IS/ISO 7240-12 : 2022	Fire detection and alarm systems: Part 12 Line type smoke detectors using a transmitted optical beam (*first revision*)
(9)	IS 655 : 2006	Specification for air ducts (*third revision*)
(10)	IS 1649 : 1962	Code of practice for design and construction of flues and chimneys for domestic heating appliances (*first revision*)
	IS 1642 : 2013	Code of practice for safety of buildings (general): Details of construction (*second revision*)
(11)	IS 12777 : 1989	Fire safety — Flame spread of products — Method for classification
(12)	IS 1642 : 2013	Code of practice for safety of buildings (general): Details of construction (*second revision*)
(13)	IS 16246 : 2015	Elastomer insulated cables with limited circuit integrity when affected by fire — Specification
(14)	IS 6044 (Part 1) : 2018	Liquefied petroleum gas storage installations — Code of practice: Part 1 Residential commercial and industrial cylinder installations (*third revision*)
	IS 6044 (Part 2) : 2021	Code of practice for liquefied petroleum gas storage installations: Part 2 Commercial, industrial and domestic bulk storage installations (*second revision*)
(15)	IS 2175 : 1988	Specification for heat sensitive fire detectors for use in automatic fire alarm system (*second revision*)
	IS/ISO 7240-5 : 2018	Fire detection and alarm systems: Part 5 Point-type heat detectors (*second revision*)
	IS/ISO 7240-7 : 2023	Fire detection and alarm systems: Part 7 Point-type smoke detectors using scattered light, transmitted light, or Ionization (*first revision*)
	IS/ISO 7240-11 : 2011	Fire detection and alarm systems: Part 11 Manual call points
	IS/ISO 7240-15 : 2014	Fire detection and alarm systems: Part 15 Point-type fire detectors using scattered light, transmitted light, or ionization sensor in combination with a heat sensor (*first revision*)
	IS/ISO 7240-12 : 2022	Fire detection and alarm systems: Part 12 Line type smoke detectors using a transmitted optical beam (*first revision*)
(16)	IS 2189 : 2026	Selection, installation and maintenance of automatic fire detection and alarm system — Code of practice (*third revision*)
(17)	IS 636 : 2018	Non-percolating flexible fire fighting delivery hose *(fourth revision)*
	IS 884 : 2025	First-aid hose-reel for fire fighting — Specification (*second revision*)

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IS No.	*Title*
IS 901 : 1988	Specification for couplings, double male, and double female instantaneous pattern for fire fighting (*third revision*)
IS 902 : 1992	Specification for suction hose couplings for fire fighting purposes (*third revision*)
IS 903 : 2025	Fire hose delivery couplings, branch pipe, nozzles and nozzle spanner — Specification (*fifth revision*)
IS 904 : 1983	Specification for two-way and three-way suction collecting heads for fire fighting purposes (*second revision*)
IS 905 : 1980	Specification for delivery breechings, dividing and collecting, instantaneous pattern for fire fighting purposes (*second revision*)
IS 906 : 2024	Specification for revolving branch pipe for fire fighting (*fourth revision*)
IS 907 : 1984	Specification for suction strainers, cylindrical type for fire fighting purpose (*second revision*)
IS 908 : 1975	Specification for fire hydrant, stand post type (*second revision*)
IS 909 : 1992	Specification for underground fire hydrant: Sluice valve type (*third revision*)
IS 910 : 1980	Specification for combined key for hydrant, hydrant cover and lower valve (*second revision*)
IS 926 : 1985	Specification for fireman's axe (*second revision*)
IS 927 : 1981	Specification for fire hooks (*second revision*)
IS 928 : 1984	Specification for fire bells (*second revision*)
IS 937 : 1981	Specification for washers for water fittings for fire fighting purposes (*second revision*)
IS 939 : 1977	Specification for snatch block for use with fibre rope for fire brigade use (*first revision*)
IS 941 : 1985	Specification for blowers and exhauster for fire fighting (*second revision*)
IS 942 : 1982	Functional requirements for 275-l/min portable pump set for fire fighting (*second revision*)
IS 943 : 1979	Functional requirement for 680-l/min trailer pump for fire brigade use (*second revision*)
IS 944 : 1979	Functional requirement for 1800-l/min trailer pump for fire brigade use (*second revision*)
IS 947 : 1985	Functional requirement for towing tender for trailer fire pump for fire brigade use (*first revision*)

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IS No.	*Title*
IS 948 : 1983	Functional requirement for water tender, Type A, for fire brigade use (*second revision*)
IS 949 : 2012	Functional requirement for emergency (rescue) tender for fire brigade use (*second revision*)
IS 950 : 2012	Functional requirements for water tender, Type B for fire brigade use (*third revision*)
IS 952 : 1986	Specification for fog nozzle for fire brigade use (*second revision*)
IS 955 : 1980	Functional requirements for dry power tender for fire-brigade use (150 kg capacity) (*first revision*)
IS 957 : 1967	Specification for control van for fire brigade
IS 1941 (Part 1) : 1976	Functional requirements for electric motor sirens: Part 1 AC, 3-phase 50 Hz, 415 Volts type (*second revision*)
IS 2097 : 2024	Specification for foam making branch pipe (*third revision*)
IS 2175 : 1988	Specification for heat sensitive fire detectors for use in automatic detectors for use in automatic fire alarm system (*second revision*)
IS 2546 : 1974	Specification for galvanized mild steel fire bucket (*first revision*)
IS 2696 : 1974	Functional requirements for 1125 l/min light fire engine (*first revision*)
IS 2745 : 1983	Specification for non-metal helmet for firemen and civil defence personnel (*second revision*)
IS 2871 : 2012	Specification for branch pipe, universal for fire fighting purposes (*second revision*)
IS 2930 : 1980	Functional requirements for hose laying tender for fire brigade use (*first revision*)
IS 3582 : 1984	Specification for basket strainers for fire fighting purposes (cylindrical type) (*first revision*)
IS 4308 : 2019	Specification for dry powder for fire fighting (*third revision*)
IS 4571 : 1977	Specification for aluminium extension ladders for fire brigade use (*first revision*)
IS 4643 : 1984	Specification for suction wrenches for fire brigade use (*first revision*)
IS 4927 : 1992	Specification for unlined flax canvas hose for fire fighting (*first revision*)
IS 4928 : 1986	Specification for delivery valve for centrifugal pump outlets (*first revision*)
IS 4947 : 2006	Specification for gas cartridges for use in fire extinguishers (*third revision*)

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IS No.	*Title*
IS 4989 : 2018	Foam concentrate for producing mechanical foam for fire fighting — Specification (*fourth revision*)
IS 4989 (Part 4) : 2003	Multipurpose aqueous film forming foam liquid concentrate for extinguishing hydrocarbon and solvent fires
IS 5131 : 2002	Specification for dividing breeching with control, for fire brigade use (*second revision*)
IS 5290 : 2025	Specification for landing valve (*fourth revision*)
IS 5486 : 1985	Specification for quick release knife (*first revision*)
IS 5505 : 1985	Specification for multi-edged rescue axe (non-wedging) (*first revision*)
IS 5612	Specification for hose-clamps and hose-bandages for fire brigade use
(Part 1) : 1977	Hose clamps (*first revision*)
(Part 2) : 1977	Hose bandages (*first revision*)
IS 5714 : 1981	Specification for hydrant, stand-pipe for fire fighting (*first revision*)
IS 6026 : 1985	Specification for hand operated sirens (*first revision*)
IS 6067 : 1983	Functional requirements for water tender, Type `X' for fire brigade use (*first revision*)
IS/ISO 7240-5 : 2018	Fire detection and alarm systems: Part 5 Point-type heat detectors (*second revision*)
IS/ISO 7240-7 : 2023	Fire detection and alarm systems: Part 7 Point-type smoke detectors using scattered light, transmitted light, or ionization (*first revision*)
IS/ISO 7240-11 : 2011	Fire detection and alarm systems Part 11 Manual call points
IS 8090 : 1976	Specification for couplings, branch pipe, nozzle, used in hose reel tubing for fire fighting (*first revision*)
IS 8096 : 2005	Rubber or plastics coated fabrics for water resistant clothing — Specification (*second revision*)
IS 8423 : 1994	Specification for controlled percolating hose for fire fighting (*first revision*)
IS 8442 : 2024	Specification for stand post type water monitor for fire fighting (*second revision*)
IS 9972 : 2023	Specification for automatic sprinkler heads (*second revision*)
IS 10460 : 1983	Functional requirements for small foam tender for fire brigade use

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IS No.	*Title*
IS 10993 : 1984	Functional requirements for 2 000 kg dry powder tender for fire brigade use
IS 11101 : 1984	Specification for extended branch pipe for fire brigade use
IS 11108 : 1984	Specification for portable fire extinguisher halon —1211 type
IS 11833 : 1986	Specification for dry powder fire extinguisher for metal fires
IS 12717 : 1989	Functional requirements of fire fighting equipment — High capacity portable pumpset (1 100-1 600 L/min)
IS 12796 : 1989	Specification for fire rake
IS 13039 : 2014	Code of practice for provision and maintenance of external hydrant system (*first revision*)
IS 14933 : 2001	Specification for high pressure fire fighting hose
IS 14951 : 2001	Specification for fire extinguisher, 135 l capacity mechanical foam type
IS 15051 : 2001	Specification for high pressure fire hose delivery couplings
IS 15105 : 2021	Design and installation of fixed automatic sprinkler fire extinguishing system (*first revision*)
IS 15220 : 2002/ ISO 7201-1	Specification for halon 1211 and halon 1301 — Fire extinguishing media for fire protection
IS 15683 : 2018	Portable fire extinguishers — Performance and construction — Specification (*first revision*)
IS 15493 : 2021	Gaseous fire extinguishing systems — General requirements *(first revision)*
IS 15505 : 2004/ ISO 14520-6	Gaseous fire extinguishing systems: HCFC Blend A extinguishing systems
IS 15506 : 2004/ ISO 14520-14	Gaseous fire extinguishing systems — IG 55 extinguishing systems
IS 15525 : 2004/ ISO 14520-13	Gaseous fire extinguishing systems — IG 100 extinguishing systems
IS 15501 : 2004/ ISO 14520-15	Gaseous fire extinguishing systems — IG 541 extinguishing systems
IS 15497 : 2004/ ISO 14520-12	Gaseous fire extinguishing systems — IG 01 extinguishing systems
IS 15519 : 2020	Code of practice for water mist fire protection systems — System design, installation, and commissioning (*first revision*)
IS 15528 : 2004	Gaseous fire extinguishing systems — Carbon dioxide, total flooding and

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IS No.	*Title*
	local application including in cabinet subfloors systems
IS 15517 : 2004/ ISO 14520-9	Gaseous fire extinguishing systems — HFC 227ea (Hepta Fluoro Propane) extinguishing system
IS 16018 : 2012	Wheeled fire extinguisher — Performance and construction — Specification
(18) IS 2190 : 2024	Code of practice for selection, installation, and maintenance of portable first-aid fire (*fifth revision*)
(19) IS 884 : 2025	Specification for first aid hose reel for fire fighting *(second revision)*
(20) IS 15105 : 2021	Design and installation of fixed automatic sprinkler fire extinguishing system — Code of practice (*first revision*)
(21) IS 15325 : 2020	Design and installation of fixed automatic high and medium velocity water spray system — Code of practice (*first revision*)
(22) IS 12835 (Part 1) : 2021	Design and installation of fixed foam fire extinguishing system — Code of practice Part 1 Low expansion foam (*first revision*)
(23) IS 15517 : 2004	Gaseous fire extinguishing systems — Carbon dioxide, total flooding and local application including in cabinet subfloors systems
(24) IS 15519 : 2020	Water mist fire protection systems — System design, installation, and commissioning — Code of Practice (*first revision*)
(25) IS 15493 : 2021	Gaseous fire extinguishing systems — General requirements
IS 15505 : 2004	Gaseous fire extinguishing systems — HCFC blend A
IS 15506 : 2004	Gaseous fire extinguishing systems — IG 55 extinguishing systems
IS 15525 : 2004	Gaseous fire extinguishing systems — IG 100 extinguishing systems
IS 15501 : 2004	Gaseous fire extinguishing systems — IG 541 extinguishing systems
IS 15497 : 2004	Gaseous fire extinguishing systems — IG 01 extinguishing systems
IS 15517 : 2004	Gaseous fire extinguishing systems — Carbon dioxide, total flooding and local application including in cabinet subfloors systems
IS 9668 : 1990	Code of practice for provision and maintenance of water supplies and fire fighting
IS 3844 : 1989	Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (*first revision*)
(26) IS 2189 : 2026	Selection, installation and maintenance of automatic fire detection and alarm system — Code of practice (*second revision*)

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	IS No.	*Title*
	IS 2190 : 2024	Selection, installation, and maintenance of portable first-aid fire extinguishers — Code of practice (*fifth revision*)
	IS 13039 : 2014	External hydrant systems — Provision and maintenance — Code of practice (*first revision*)
(27)	IS 4878 : 1986	Byelaws for construction of cinema buildings (*first revision*)
(28)	IS 2726 : 1988	Code of practice for fire safety of industrial buildings: Cotton ginning and pressing (including cotton seed delintering) factories (*first revision*)
	IS 3034 : 1993	Code of practice for fire safety of industrial buildings: Electrical generating and distributing stations (*second revision*)
	IS 3058 : 1990	Code of practice for fire safety of industrial buildings: Viscose rayon yarn and/or staple fibre plants (*first revision*)
	IS 3079 : 1990	Code of practice for fire safety of industrial buildings: Cotton textile mills (*first revision*)
	IS 3594 : 2024	Code of practice for fire safety of industrial buildings: General storage and warehousing including cold storage (*second revision*)
	IS 3595 : 2002	Code of practice for fire safety of industrial buildings: Coal pulverizers and associated equipment (*second revision*)
	IS 3836 : 2000	Code of practice for fire safety of industrial buildings: Jute mills (*second revision*)
	IS 4209 : 2013	Code of safety in chemical laboratories (*second revision*)
	IS 4226 : 1988	Code of practice for fire safety of industrial buildings: Aluminium/ Magnesium powder factories (*first revision*)
	IS 4886 : 1991	Code of practice for fire safety of industrial buildings: Tea factories (*first revision*)
	IS 6329 : 2000	Code of practice for fire safety of industrial buildings: Saw mills and wood works (*first revision*)
	IS 9109 : 2000	Code of practice for fire safety of industrial buildings: Paint and varnish factories
	IS 11457 (Part 1) : 1985	Code of practice for fire safety of chemical industries: Part 1 Rubber and plastic
(29)	IS 13039 : 2014	External hydrant systems — Provision and maintenance — Code of practice (*first revision*)
(30)	IS 18271 : 2023	Fire safety in commercial kitchen — Guidelines
(31)	IS 4963 : 2025	Accessibility in built environment for older adults and persons with disabilities — Requirements (*second revision*)

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IS No.	*Title*
(32) IS 16700 : 2023	Criteria for structural safety of tall concrete buildings (*first revision*)
(33) IS 3614 : 2021	Fire doors and doorsets — Specification (*first revision*)
(34) IS 12458 : 2019	Fire resistance of through penetration firestops — Method of test (*first revision*)
(35) IS 18190 : 2023	Fire resistance of perimeter fire barrier joint system — Method of tests

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INDEX OF TERMS

(Lists the terms appearing in the Part/Section of the NBCS)

A

*A*95 — Part D/Section 5A

Acceleration — Part D/Section 5A, Part D/ Section 5B

Access Panel — Part E/Section 1

Access Point — Part D/Section 6

Accessibility — Part D/Section 5A, Part F

Accessory — Part D/Section 2

Accidental Loads — Part C/Section 6A, Part C/ Section 6B

*Accompanying Lo*ad — Part C/Section 6A, Part C/ Section 6B

Action — Part C/Section 6A, Part C/Section 6B

Action Effect or Load Effect — Part C/Section 6A, Part C/Section 6B

Actual Length — Part C/Section 6A

Admixtures (*Including Superplasticizer and Accelerator*) — Part C/Section 7

Air Admittance Valve — Part E/Section 2

*Air Brea*k — Part E/Section 2

Air Change per Hour (*ACPH*) — Part D/Section 1, Part F

Air Circuit Breaker (*ACB*) — Part D/Section 2

Air Conditioning — Part D/Section 3

Air Gap, Drainage — Part E/Section 2

Air Gap, Water Distribution — Part E/Section 1

Air System Balancing — Part D/Section 3

Air Valve — Part E/Section 1

Aisle — Part F

Allowable Load — Part C/Section 2

Alteration — Part A, Part F

Alternating Current Variable Voltage (*ACVV*) *Control* — Part D/Section 5A

Alternating Current Variable Voltage Variable Frequency (*ACVVVF*) *Control* — Part D/Section 5A

Altitude — Part D/Section 1

Ambient Noise — Part D/Section 4

*Anaerobic Diges*tion — Part E/Section 3

Anchor Pile — Part C/Section 2

Angle of Attack — Part C/Section 1

Angle of Inclination — Part D/Section 5B

Angular Distortion — Part C/Section 2

Annealed Fire Resistant Glass — Part C/Section 8

Annealed Glass (*see Glass*) — Part C/Section 8

Antenna — Part D/Section 6

Anti-siphon — Part E/Section 1

Apparatus — Part D/Section 2

Appliance — Part D/Section 2

Appliance Valve — Part E/Section 4

Approved — Part A

Approved Agency — Part E/Section 4

Appurtenance — Part E/Section 1

Apron — Part D/Section 5A

Area of Parking — Part D/Section 5C

As-Cut Finished Sizes — Part C/Section 8

Aspect Ratio — Part C/Section 8

Aspirator — Part E/Section 1

Assembly Buildings — Part C/Section 1

Assisted Evacuation — Part F

Atmospheric Pressure — Part D/Section 3

Atrium — Part F

Attenuation — Part D/Section 6

Audible Frequency Range — Part D/Section 4

Authorities Concerned — Part F

Authority Having Jurisdiction — Part C/Section 7, Part E/Section 1, Part E/Section 4

Authorization — Part E/Section 3

Authorized Person — Part D/Section 5A

Automatic Fire Detection and Alarm System — Part F

Automatic Operation — Part D/Section 5A

Automatic Parking System — Part D/Section 5C

Automatic Rescue Device — Part D/Section 5A

Automatic Sprinkler System — Part F

Automatic Water Spray Systems — Part F

Automobile Lift — Part D/Section 5A

Auxiliary or Emergency or Safety Brake — Part D/Section 5B

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Available Head — Part E/Section 1

Available Car Area — Part D/Section 5A

A-Weighted Sound Pressure — Part D/Section 4

A-Weighted Sound Pressure Level — Part D/Section 4

Axial Flow Fan — Part D/Section 1

Axis of Measurement — Part D/Section 5A

Azimuth — Part D/Section 1

B

Backbone — Part D/Section 6

Backbone Cabling Media Distribution and Building Pathway — Part D/Section 6

Back Fill — Part C/Section 2

Back Pressure Backflow — Part E/Section 1

Back Siphonage — Part E/Section 1

Back Up — Part E/Section 2

Back-up Protection — Part D/Section 2

Back Water Valve — Part E/Section 2

Backflow — Part E/Section 1

Backflow Prevention Device — Part E/Section 1

Background Noise — Part D/Section 4

Balancing Weight — Part D/Section 5A

Balustrade — Part C/Section 8, Part D/Section 5B

Balustrade Decking — Part D/Section 5B

Bamboo — Part C/Section 3B

Bamboo Bore/GHOON Hole — Part C/Section 3B

Bamboo Clump — Part C/Section 3B

Bamboo Culm — Part C/Section 3B

Bamboo Mat Board — Part C/Section 3B

Bamboo Mat Corrugated Sheets — Part C/ Section 3B

Bamboo Mat Corrugated Sheet — Part C/Section 3B

Bamboo Mat Ridge Cap (*BMRC*) — Part C/Section 3B

Bamboo Mat Veneer Composite — Part C/Section 3B

Barrel — Part E/Section 1

Barrier — Part D/Section 2

Base — Part C/Section 1, Part E/Section 1

Base Layer — Part C/Section 7

Basic Protection — Part D/Section 2

Basic Module — Part C/Section 7

Bath Room Group — Part E/Section 1, Part E/ Section 2

Bather Load — Part E/Section 1

Batter Pile (*Raker Pile*) — Part C/Section 2

Battery Charging Stations — Part D/Section 2

Battery Energy Storage System (*BESS*) — Part D/ Section 2

Battery of Fixtures — Part E/Sction 2

Beads or Glazing Beads — Part C/Section 8

Beam — Part C/Section 3B, Part C/Section 6A

Beam, Built-Up-Laminated — Part C/Section 3A

Beam, Glued-Laminated — Part C/Section 3A

Bearing Capacity, Safe — Part C/Section 2

Bearing Capacity, Ultimate — Part C/Section 2

Bearing Pressure, Allowable (*Gross or Net*) — Part C/Section 2

Bearing Type Connection — Part C/Section 6A

Bed Block — Part C/Section 4

Bed Pan Washer — Part E/Section 2

Bedding — Part E/Section 1

Benching — Part E/Section 2

Binder Jetting-based 3D *Printing* — Part C/Section 7

Bite — Part C/Section 8

Biodegradable Substance — Part E/Section 3

Biomethanation — Part E/Section 3

Black Water — Part E/Section 2

Block (*Setting Block*) — Part C/Section 8

Bond — Part C/Section 4 Section 7

Bonding Conductor — Part D/Section 2

Bonding Ring Conductor (*BRC*) — Part D/Section 2

Bored Cast In-situ Pile — Part C/Section 2

Bored Compaction Pile — Part C/Section 2

Bored Pile — Part C/Section 2

Bottom Car Clearance — Part D/Section 5A

Bottom Car Run-by — Part D/Section 5A

Bottom Counterweight Run-by — Part D/Section 5A

Bottom Refuge Space — Part D/Section 5A

Box System — Part C/Section 4

Braced Member — Part C/Section 6A

Brake Load — Part D/Section 5B

Branch — Part E/Section 2

Branch Soil Pipe (*BSP*) — Part E/Section 2

Branch Soil Waste Pipe (*BSWP*) — Part E/Section 2

Branch Switch — Part D/Section 2

Branch Vent Pipe (*BVP*) — Part E/Section 2

Branch Waste Pipe (*BWP*) — Part E/Section 2

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Breadth — Part C/Section 1
Break-In — Part D/Section 4
Breaking Strength — Part C/Section 3B
Break-Out — Part D/Section 4
Bressummer — Part C/Section 3A
Brightness Ratio or Contrast — Part D/Section 1
Brittle Cladding — Part C/Section 6A
Broad Band Noise — Part D/Section 4
Buckling Load — Part C/Section 6A
Buckling Strength or Resistance — Part C/Section 6A
Buffer — Part D/Section 5A
Building — Part A, Part F
Building, Height of — Part A, Part F
Building Drain-Combined — Part E/Section 2
Building Drain-Sanitary — Part E/Section 2
Building Drain-Storm — Part E/Section 2
Building Trap — Part E/Section 2
Building Energy Simulation (*BES*) — Part F, Part D/Section 3
Buildability — Part C/Section 7
Building Height — Part C/Section 5
Building Integrated Renewable Energy — Part D/Section 3
Building Line — Part A
Building Official — Part A
Building Permit — Part A
Building Sewer — Part E/Section 2
Building Sub-drain — Part E/Section 2
Building Management System (*BMS*) — Part D/Section 3, Part D/Section 6, Part F
Building Related Illnesses — Part D, Section 3, Part F
Built-up Section — Part C/Section 6A, Part C/ Section 6B
Bunched — Part D/Section 2
Bundle-Column — Part C/Section 3B
Burried Direct — Part D/Section 2
Bus Bar — Part D/Section 6
Busbar Trunking System — Part D/Section 2
Business Buildings — Part C/Section 1
Buttress — Part C/Section 4
Bypass Equipotential Bonding Conductor — Part D/Section 2

C

C_{TR} — Part D/Section 4
Cable — Part D/Section 2
Cable, Fire Survival — Part D/Section 2
Cable, Flame Retardant (*FR*) — Part D/Section 2
Cable, Flame Retardant Low Smoke Halogen Free (*FR-LSH*) — Part D/Section 2
Cable, Flexible — Part D/Section 2
Cable, Metal-Sheathed — Part D/Section 2
Cable, PVC Sheathed-insulated — Part D/Section 2
Cable, Weatherproof — Part D/Section 2
Cable, XLPE — Part D/Section 2
Cable Armoured — Part D/Section 2
Cable Bracket — Part D/Section 2
Cable Channel — Part D/Section 2
Cable Cleat — Part D/Section 2
Cable Coupler — Part D/Section 2
Cable Ducting — Part D/Section 2
Cable Ladder — Part D/Section 2
Cable Raceways – Part D/Section 2
Cable Support and Fixing Materials (*Fire Survival*) — Part D/Section 2
Cable Tray — Part D/Section 2
Cable Trunking — Part D/Section 2
Cable Tunnel — Part D/Section 2
Call Indicator — Part D/Section 5A
Camber — Part C/Section 6A and 6B
Candela (*cd*) — Part D/Section 1
Capacity Factor — Part F
Capacity of Means of Egress — Part F
Car Bodywork — Part D/Section 5A
Car Door Electric Contact — Part D/Section 5A
Car Frame — Part D/Section 5A
Car Platform — Part D/Section 5A
Cartridge Fuse Link — Part D/Section 2
Category 1 *circuit* — Part D/Section 2
Category 2 *circuit* — Part D/Section 2
Category 3 *circuit* — Part D/Section 2
Catwalk — Part F
Ceiling Rose — Part D/Section 2
Cell — Part C/Section 3B
Cellular Concrete — Part C/Section 7

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Cellulose — Part C/Section 3B
Central Field – Part D/Section 1
Centre Internode — Part C/Section 3B
Centrifugal Fan — Part D/Section 1
Cesspool — Part E/Section 2
Chair — Part E/Section 1
Chair Rail — Part C/Section 8
*Channe*l — Part E/Section 1
Characteristic Load — Part C/Section 6A, Part C/Section 3B, Part C/Section 6B
Characteristic Strength — Part C/Section 3B
Characteristic Yield/Ultimate Stress — Part C/ Section 6A
Check — Part C/Section 3A
Circadian Lightning — Part D/Section 1
Circuit — Part D/Section 2
Circuit, Final Sub — Part D/Section 2
Circuit Breaker — Part D/Section 2
Circuit Breaker, Linked — Part D/Section 2
Circulating Hot Water System — Part E/Section 1
Clay — Part C/Section 2
Clay, Firm — Part C/Section 2
Clay, Soft — Part C/Section 2
Clay, Stiff — Part C/Section 2
Cleaning Eye — Part E/Section 2
Clear Design Sky — Part D/Section 1
Clear Glass — Part C/Section 8
Clear Waste Water — Part E/Section 2
Cleavability — Part C/Section 3B
Closely-spaced Modules — Part C/Section 1
Coaxial Cable — Part D/Section 6
Coefficient of Linear Expansion — Part C/Section 8
Coefficient of Performance, Compressor, Heat Pump — Part D/Section 3
Coefficient of Performance, Compressor, Refrigerating — Part D/Section 3
Coefficient of Performance (*Heat Pump*) — Part D/Section 3
Coefficient of Performance (*Refrigerating*) — Part D/Section 3
Collapse — Part C/Section 3B
Collection — Part E/Section 3
Collection Chamber — Part E/Section 2
Colour Rendering Index (*CRI*) — Part D/Section 1
Column — Part C/Section 1, Part C/Section 3B, Part C/Section 6A, Part C/Section 4
Comb — Part D/Section 5B
Comb Lighting — Part D/Section 5B
Comb Plate — Part D/Section 5B
Comb Plate Switch — Part D/Section 5B
Comb Teeth — Part D/Section 5B
Combined Piled Raft Foundation — Part C/Section 2
Combined System — Part E/Section 2
Combustible Material — Part F, Part C/Section 8
Common Path of Travel — Part F
Common Rafter — Part C/Section 3B
Communication Pipe — Part E/Section 1
Compact Section — Part C/Section 6A
Compact Substation or Prefabricated Substation — Part D/Section 2
Compensation Means — Part D/Section 5A
Competent Authority — Part E/Section 4
Competent Maintenance Person — Part D/ Section 5A, Part D/Section 5B
Competent Official — Part A
Component — Part C/Section 7
Composite Action — Part C/Sec 6 B
Composite Station — Part F
Composite Members — Part C/Section 7
Composting — Part E/Section 3
Compression Wood — Part C/Section 3A
Concrete buildings — Part C/Section 1
Concourse — Part F
Conductor of a Cable or Core — Part D/Section 2
Conductor, Aerial — Part D/Section 2
Conductor, Bare — Part D/Section 2
Conductor, Earthed — Part D/Section 2
Conductor, Insulated — Part D/Section 2
Conduit — Part D/Section 2
Connection — Part E/Section 2
Connecting Structure — Part C/Section 5
Connector — Part D/Section 2
Connector Box or Joint Box — Part D/Section 2
Connector for Portable Appliances — Part D/ Section 2
Consolidation Point (*CP*) — Part D/Section 6

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Constant Stress Range — Part C/Section 6A

Construction and Demolition Waste — Part E/ Section 3

Consumer — Part E/Section 1, Part E/Section 2

Consumer's Pipe — Part E/Section 1

Consumer's Terminals — Part D/Section 2

Contaminants — Part D/Section 1

Continuous Operating Voltage (U_c) — Part D/Section 2

Continuous pressure operation — Part D/ Section 5A

Control — Part D/Section 5A

Conversion — Part A

Concrete for 3D Printing — Part C/Section 7

Cooling Load — Part D/Section 3

Cooling Tower — Part D/Section 3

Cord, Flexible — Part D/Section 2

Core of a Cable — Part D/Section 2

Core — Part C/Section 5

Core and Outrigger Structural System — Part C/Section 5

Core, Outrigger and Belt Wall System — Part C/Section 5

Correlated Colour Temperature (*CCT*) — Part D/Section 1

Corridor — Part C/Section 8

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Counterweight — Part D/Section 5A

Cover — Part E/Section 1

Components — Part C/Section 7A

Covered Area — Part F

Coupled Structural Wall Building — Part C/Section 5

Coupled Glazing (*Secondary Glazing*) — Part C/Section 8

Crack Mouth Opening Displacement (*CMOD*) — Part C/Section 5

Crack Opening Displacement (*COD*) — Part C/Section 5

Crane Load — Part C/Section 6A

Crookedness — Part C/Section 3B

Cross Wall — Part C/Section 3B

Cross-connect — Part D/Section 6

Cross-Connection — Part E/Section 1

Cross-Sectional Area of Masonry Unit — Part C/Section 4

Cross-Talk — Part D/Section 4

Crown of Trap — Part E/Section 2

Crumple Section — Part C/Section 4

Crush Train Load — Part F

Cumulative Fatigue — Part C/Section 6A

Current Carrying Capacity of a Conductor — Part D/Section 2

Current using Equipment — Part D/Section 2

Curtain Wall — Part C/Section 4, Part C/Section 8

Curtain Wall Assembly — Part C/Section 8

Curvature — Part C/Section 3B

Customer's/Consumer's Connection — Part E/ Section 4

Cut-Out — Part D/Section 2

Cut-Off Level — Part C/Section 2

Cut-Off Limit — Part C/Section 6A

D

Damp Situation — Part D/Section 2

Danger — Part D/Section 2

Datacentre — Part D/Section 2

Daylight Area — Part D/Section 1

Daylight Factor — Part D/Section 1

Daylighting — Part D/Section 1

Daylight Penetration — Part D/Section 1

Deconstruction — Part C/Section 6A

Deconstruction (*or Disassembly, or Demounting*) — Part C/Section 6A

Design for Deconstruction (*DfD*) — Part C/Section 6A

De-structured Bamboo — Part C/Section 3B — Part D/ Section 2

Dead -end — Part F

Dead -end Travel — Part F

Dead Knot — Part C/Section 3A

Dead Zone Length — Part C/Section 7

Dead Loads — Part C/Section 6A

Decay or Rot — Part C/Section 3A

Decayed Knot — Part C/Section 3A

Decibel — Part D/Section 4

Dedicated Outdoor Air System (*DOAS*) — Part D/Section 3

Deep Area — Part E/Section 1

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Deep Manhole – Part E/Section 2
Deflection — Part C/Section 6A
Deflector Sheave — Part D/Section 5A
Delamination — Part C/Section 3B
Demand Based Ventilation — Part D/Section 3
Demand Recirculation Water System — Part E/Section 1
Demolition Permit — Part A
Depth — Part C/Section 1
Depth of Manhole — Part E/Section 2
Design Acceleration — Part C/Section 1, Part D/ Section 5A
Design Acceleration Spectrum — Part C/Section 1
Design Current (*of a Circuit*) — Part D/Section 2
Design Food Elevation — Part E/Section 1
Design Life — Part C/Section 6A
Design Service Life — Part C/Section 6B
Design Load — Part C/Section 2
Design Load/Factored Load — Part C/Section 6A, Part C/Section 6B
Design Pressure Difference — Part D/Section 3
Design Spectrum — Part C/Section 6A
Design Stress — Part C/Section 2
Design Horizontal Force — Part C/Section 1
Detail Category — Part C/Section 6A, Part C/ Section 6B
Developed Height — Part C/Section 1
Developed Length — Part E/Section 2
Development — Part A
Development Permit — Part A
Dew Point Temperature — Part D/Section 3
Diameter — Part E/Section 2
Diameter of Knot — Part C/Section 3A
Diaphragm — Part C/Section 1, Part C/Section 7
Diaphragm, Structural — Part C/Section 3A
Differential Settlement of CPRF (*Spr, Diff*) — Part C/Section 2
Differential Shrinkages — Part C/Section 6B
Dilution Ventilation — Part D/Section 1
Direct Acting Lift — Part D/Section 5A
Direct Contact — Part D/Section 2
Distributed Antenna System (*DAS*) — Part D/ *Section* 6
Direct to Home (*DTH*) — Part D/Section 6
Directions in the Printed Specimens — Part C/Section 7
Direct Solar Illuminance — Part D/Section 1
Direct Tap — Part E/Section 1
Discolouration — Part C/Section 3A, Part C/Section 3B
Disconnector — Part D/Section 2
Discontinuity — Part C/Section 6A
Discrimination (*Selectively-Over-Current Discrimination*) — Part D/Section 2
Disposal — Part E/Section 3
Distance Piece — Part C/Section 8
Distance Area or Resistance Area (*for an Earth Electrode only*) — Part D/Section 2
Distribution/Distributing Company — Part E/ Section 4
Diversity Factor — Part D/Section 2
Diving Pool — Part E/Section 1
Door Pre-opening Time/Advanced Door Opening Time — Part D/Section 5A
Door-to-Door Time — Part D/Section 5A
Door or Shutter Assembly Door-Set — Part C/Section 8
Door Closer — Part D/Section 5A
Door Closing Time — Part D/Section 5A
Door Closing Delay Time — Part D/Section 5A
Door Opening Time — Part D/Section 5A
Door Operator — Part D/Section 5A
Door (*Lift Landing Door and Lift Car Door*) — Part D/Section 5A
Door, Centre Opening Sliding — Part D/Section 5A
Door, Mid-Bar Collapsible — Part D/Section 5A
Door, Multi-Panel — Part D/Section 5A
Door, Single Slide — Part D/Section 5A
Door, Swing — Part D/Section 5A
Door, Two Speed Siding — Part D/Section 5A
Door, Vertical Bi-parting — Part D/Section 5A
Door, Vertical Lifting — Part D/Section 5A
Double Glazed Fire Resistant Glass — Part C/ Section 8
Double Glazing — Part C/Section 8
Down-Comer — Part F
Down-Direction Valve — Part D/Section 5A
Down Take Tap — Part E/Section 1
Drain — Part A, Part E/Section 2

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Drain Vent Pipe (*DVP*) — Part E/Section 2
Drainage — Part A, Part E/Section 2
Drainage Fixture Unit (*DFU*) — Part E/Section 2
Drainage Work — Part E/Section 2
Drinking Water Fountain — Part E/Section 1
Drive Way — Part D/Section 5C
Drive Control System — Part D/Section 5A
Driven Cast in-situ Pile — Part C/Section 2
Drop Connection — Part E/Section 2
Drop Manhole — Part E/Section 2
Dry Riser — Part F
Dry Bulb Temperature — Part D/Section 1, Part D/ Section 3
Duct — Part D/Section 2
Ducting — Part D/Section 2
Duct System — Part D/Section 3
Ductility — Part C/Section 6A
Dumb Waiter — Part D/Section 5A
Durability — Part C/Section 6A
Duration of Load — Part C/Section 3A
Dwellings — Part C/Section 1

E

Earth — Part D/Section 2
Earth Continuity Conductor — Part D/Section 2
Earthed Concentric Wiring — Part D/Section 2
Earth Electrode — Part D/Section 2
Earth Electrode Network — Part D/Section 2
Earth Electrode Resistance — Part D/Section 2
Earth Fault — Part D/Section 2
Earth Fault Current — Part D/Section 2
Earth Fault Loop Impedance (Z_s) — Part D/Section 2
Earthing — Part D/Section 2
Earthing Conductor — Part D/Section 2
Earthing Lead — Part D/Section 2
Earth Leakage Current — Part D/Section 2
Earthing Resistance, Total — Part D/Section 2
Earthquake Effects — Part C/Section 6A
Earthquake Loads — Part C/Section 6A
Economizer, Air — Part D/Section 3
Economizer, Water — Part D/Section 3
Eco-Toilet (*or Bio Toilet*) — Part E/Section 2
Edge Distance — Part C/Section 3A, Part C/ Section 6A
Edge Deterioration — Part C/Section 8
Edge Faults — Part C/Section 8
Edge Polished — Part C/Section 8
Edging — Part C/Section 8
Educational Buildings — Part C/Section 1
Effective Frontal Area — Part C/Section 1
Effective Height — Part C/Section 4
Effective Lateral Restraint – Part C/Section 6A
Effective Length — Part C/Section 4, Part C/ Section 6A
Effective Opening — Part E/Section 1
Effective Perceived Noise Level in Decibel (*EPN dB*) — Part D/Section 4
Effective Temperature (*ET*) — Part D/Section 1, Part D/Section 3
Effective Thickness — Part C/Section 4
Efficiency of a Pile Group — Part C/Section 2
Egress Lighting — Part F
Elastic Cladding — Part C/Section 6A
Elastic Critical Moment — Part C/Section 6A
Elastic Design — Part C/Section 6A
Elastic Force Reduction Factor — Part C/Section 1
Elastic Limit — Part C/Section 6A
Electric Safety Chain — Part D/Section 5A
Electric Shock — Part D/Section 2
Electric Vehicle (*EV*) — Part D/Section 2
EV Connector — Part D/Section 2
Electric Vehicle Supply Equipment (*EVSE*) — Part D/Section 2
Electrical Anti-Creep System — Part D/Section 5A
Electrical and Mechanical Interlock — Part D/ Section 5A
Electrical Equipment (*abb: Equipment*) — Part D/Section 2
Electrically Independent Earth Electrodes — Part D/Section 2
Electrical Safety Devices — Part D/Section 5B
Electrical Safety System — Part D/Section 5B
Electrical Supply System for Life and Safety Services — Part D/Section 2
Electro-mechanical Lock — Part D/Section 5A
Electronic Control — Part D/Section 5A
Electronic Devices — Part D/Section 5A

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Electromechanical Parking Systems — Part D/ Section 5C
Element of Surface Area — Part C/Section 1
Embodied Carbon — Part C/Section 6A
Emergency Floor Drain — Part E/Section 2
Emergency Lighting — Part F
Emergency Lighting System — Part F
*Emergency Stop S*witch — Part D/Section 5B
Emergency Switching — Part D/Section 2
Emulative Detailing System — Part C/Section 7
Enclosed Station — Part F
Enclosed Distribution Board — Part D/Section 2
Enclosure — Part D/Section 2
*End Dist*ance — Part C/Section 3A, Part C/ Section 3B, Part C/Section 6A
End Splitting — Part C/Section 3B
Energy Accumulation Type — Part D/Section 5A
Energy Dissipation Type — Part D/Section 5A
Energy Efficiency Ratio (*EER*) — Part D/Section 3
Energy Recovery Unit — Part D/Section 3
Entraining Load — Part F
Entrance Bias — Part D/Section 5A
Entrance Floor — Part D/Section 5A
Environmental Product Declaration (*EPD*) — Part C/Section 6A
Equipotential Bonding — Part D/Section 2
Equivalent Continuous A-Weighted Sound Pressure Level, $L_{Aeq.T}$ — Part D/Section 4
Equivalent Sound Absorption Area of a Room, *A* — Part D/Section 4
Equivalent Sound Pressure Level (L_{Aeq}) — Part D/Section 5A, Part D/Section 5B
Erection Loads — Part C/Section 6A
Erection Tolerance — Part C/Section 6A
Escalator — Part D/Section 5B
Escape Lighting — Part F
Evacuation Lift — Part F, Part D/Section 5A
Evacuation Exit Lobby (*EEL*) — Part D/Section 5A
Evacuation Time — Part F
Evaporative Cooling — Part D/Section 3
Exhaust of Air — Part D/Section 1
Existing Lift — Part D/Section 5A
Exit — Part F
Exit Access — Part F
Exit Access Corridor — Part F
Exit Discharge — Part F
Exit Door, Height — Part F
Exit Handling Capacity — Part F
Exit Signages — Part F
Exit Stairway, External — Part F
Exit Stairway, Internal — Part F
Exit Width, Clear — Part F
Exit Width, Maximum — Part F
Exit Width, Minimum — Part F
Exit, Doorway — Part F
Exit, External Ramp — Part F
Exit, Half a Unit Width – Part F
Exit, Horizontal — Part F
Exit, Passageway — Part F
Exit, Ramp — Part F
Extracted Specimen — Part C/Section 7
Exit, Roof — Part F
Exit, Separation — Part F
Exit, Stairway — Part F
Exit, Tunnel — Part F
Exit, Unit Width — Part F
Extrudability — Part C/Section 7
Exit, Width — Part F
Exothermic Welding — Part D/Section 2
Exposed Conductive Part — Part D/Section 2
Exposed Edge — Part C/Section 8
Exposed Metal — Part D/Section 2
Exposed Surface Area to Mass Ratio — Part C/ Section 6A
Express Zone — Part D/Section 5A
Exterior Panel — Part D/Section 5B
External (*Exterior*) *Exit Stairway* — Part F
External Influence — Part D/Section 2
External Reflected Component (*ERC*) — Part D/Section 1
Extraneous Conductive Part — Part D/Section 2
Extrusion-based Concrete 3D Printing — Part C/Section 7

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F

Fabrication Tolerance — Part C/Section 6A
Facade — Part C/Section 8
Facade Level — Part D/Section 4
Faced Wall — Part C/Section 4
Faceted Glazing — Part C/Section 8
Factor of Safety — Part C/Section 6A
Factor of Safety (*With Respect to Bearing Capacity*) — Part C/Section 2
Fatigue — Part C/Section 6A, Part C/Section 6B
Fatigue Limit State — Part C/Section 6B
Fatigue Loading — Part C/Section 6A,
Fatigue Strength — Part C/Section 6A, Part C/ Section 6B
Fault — Part D/Section 2
Fault Current — Part D/Section 2
Fault Protection — Part D/Section 2
Feed Cistern — Part E/Section 1
Fenestration — Part C/Section 8
Fetch Length — Part C/Section 1
Fin — Part C/Section 8
Filament — Part C/Section 7
Final Circuit — Part D/Section 2
Finger Joint — Part C/Section 3A
Finger Jointed Timber — Part C/Section 3A
Fire Barrier (*or Fire Resisting Barrier*) — Part F
Fire Compartment — Part F
Fire Command Centre (*FCC*) — Part F
Fire Damper — Part D/Section 3
Fire or Fire/Smoke Damper — Part F
Fire Door and Fire Door Assembly — Part F
Fire Door Assembly, Fire Resistance Rating — Part F
Fire Enclosure — Part F
Fire Exit — Part F
Fire Exit Hardware — Part F
Fire Exposure Condition — Part C/Section 6A and 6B
Firefighting shaft (*Fire Tower*) — Part F
Firefighter Access Panel — Part F
Fireman's Lift — Part F
Fire Load — Part F
Fire Load Density — Part F
Fire Prevention — Part F
Fire Protection System — Part C/Section 6A
Fire Resistance — Part F, Part C/Section 6A
Fire Resistance Level — Part C/Section 6A
Fire Resistance Rating — Part F
Fire Resistant Wall — Part F
Fire Separation — Part F, Part C/Section 8
Fire Stop — Part F
Fire Stop Assembly for Joints — Part F
Fire Stop Assembly for Penetrations — Part F
Fire Suppression Systems — Part F
Fire Survival Distribution Board — Part D/Section 2
Fire Tower — Part F
Fire Wall or Fire Separating Wall — Part F
Fish Wire — Part D/Section 2
Fitting, Lighting — Part D/Section 2
Fittings — Part E/Section 1, Part E/Section 2
Fixed Equipment — Part D/Section 2
Fixture Unit — Part E/Section 1, Part E/Section 2
Flameproof Enclosure — Part D/Section 2
Flattened Bamboo — Part C/Section 3B
Flight Time — Part D/Section 5A
Flexible Shear Connector — Part C/Section 6 B
Flexural Stiffness — Part C/Section 6A
Float Glass — Part C/Section 8
Float Operated Valve — Part E/Section 1
Flood Level Rim — Part E/Section 1, Part E/Section 2
Floor Area (*Gross*) — Part F
Floor Area Ratio (*FAR*) — Part F
Floor Area (*Net*) — Part F
Floor Levelling Switch — Part D/Section 5A
Floor Stopping Switch — Part D/Section 5A
Flow Pressure — Part E/Section 1
Flush Over Panel — Part C/Section 8
Flushing Cistern — Part E/Section 1
Flushometer Tank — Part E/Section 1
Foam Protection System — Part F
Footing — Part C/Section 2
Foyer — Part F
Force Coefficient — Part C/Section 1
Formation — Part E/Section 1, Part E/Section 2
Foundation — Part C/Section 2

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Foundation, Raft — Part C/Section 2
Frame — Part C/Section 8
Frame Building — Part C/Section 5
Framed-Tube System — Part C/Section 5
Frameless Glazing — Part C/Section 8
Free-Field Level — Part D/Section 4
French Drain or Rubble Drain — Part E/Section 2
Frequency — Part D/Section 4, Part D/Section 6
Fresh Air or Outside Air — Part D/Section 1
Friction Type Connection — Part C/Section 6A
Front Putty — Part C/Section 8
Frost Line — Part E/Section 1, Part E/Section 2
Full Culm — Part C/Section 3B
Full Load Pressure — Part D/Section 5A
Fully Framed Glazing — Part C/Section 8
Functional Earthing — Part D/Section 2
Fundamental or Ultimate Stress — Part C/Section 3A, Part C/Section 3B

G

Gap — Part C/Section 8
Gas Fitter — Part E/Section 4
Gas-Based Suppression Systems — Part F
Gauge — Part C/Section 6A
Geared Machine — Part D/Section 5A
Gearless Machine — Part D/Section 5A
General Ventilation — Part D/Section 1
General Washing Place — Part E/Section 1
Generator of Wastes — Part E/Section 3
Geothermal Heat Pump — Part D/Section 3
Geyser — Part E/Section 1
Glare — Part D/Section 1
Glass — Part C/Section 8
Glass Appearance Faults — Part C/Section 8
Glazing — Part C/Section 8
Glazing-bite — Part C/Section 8
Glide — Part D/Section 3
Global Warming Potential (*GWP*) — Part D/Section 3
Globe Temperature — Part D/Section 1
Glue — Part C/Section 3A
Glued Laminated (*Glulam*) — Part C/Section 3A
Glued Laminated, Horizontally — Part C/Section 3A
Glued Laminated, Vertically — Part C/Section 3A
Goods Lift — Part D/Section 5A
Gradient Height — Part C/Section 1
Gravel — Part C/Section 2
Gravity Columns — *Part C/Section* 5
Gravity Load — Part C/Section 6A
Grease Interceptor (*or Grease Trap*) — Part E/Section 2
Grey water — Part E/Section 2
Grid — Part D/Section 5C
Gridded Water Distribution System — Part E/Section 1
Ground Improvement — Part C/Section 2
Ground Roughness — Part C/Section 1
Ground-Borne Noise — Part D/Section 4
Group Automatic Operation — Part D/Section 5A
Grout — Part C/Section 4
Grouted Cavity Reinforced Masonry — Part C/Section 4
Grouted Hollow-unit Masonry — Part C/Section 4
Grouted Masonry — Part C/Section 4
Grouted Multi-Wythe Masonry — Part C/Section 4
Guard Rail — Part C/Section 8
Guide Rails — Part D/Section 5A
Guide Rails Fixing — Part D/Section 5A
Guide Shoe — Part D/Section 5A
Gully Chamber — Part E/Section 2
Gully Trap — Part E/Section 2
Gusset Plate — Part C/Section 6A
Gust — Part C/Section 1

H

Hairline Scratch — Part C/Section 8
Halo — Part C/Section 8
Hand-Held Equipment — Part D/Section 2
Handling Capacity (*HC*) — Part D/Section 5A
Handrail — Part D/Section 5B, Part F
Hardening Behaviour – Part C/Section 5
Harmonics (*Current and Voltage*) — Part D/Section 2
Haunching — Part E/Section 1
Hazardous Live-Part — Part D/Section 2
Hazardous Material — Part F
Headway — Part F

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Heat Pump — Part D/Section 3
Heat Recovery — Part D/Section 3
Heat Soaking — Part C/Section 8
Heat Strengthened Glass — Part C/Section 8
Heating Load — Part D/Section 3
Headroom/Overhead — Part D/Section 5A
Heel Rest Bend or Duck-foot Bend — Part E/Section 1
Hemi Cellulose — Part C/Section 3B
Hermetic Seal — Part C/Section 8
High Activity Area — Part C/Section 8
High Altitudes — Part E/Section 1, Part E/Section 2
High Rise Building — Part F
High Risk Area — Part C/Section 8
High Shear — Part C/Section 6A
Highway Authority — Part E/Section 1, Part E/Section 2
Hoisting Beam — Part D/Section 5A
Hollow Unit — Part C/Section 4
Home Lift — Part D/Section 5A
Horizontal Cabling — Part D/Section 6
Horizontal Cabling Media Distribution and Building Pathway — Part D/Section 6
Horizontal Cross-connect (*HC*) — Part D/Section 6
Horizontal Exit — Part F
Horizontal Movements — Part D/Section 5C
Horizontal Pipe — Part E/Section 1, Part E/Section 2
Hospital Lift — Part D/Section 5A
Hot Water Tank — Part E/Section 1
Humidification — Part D/Section 1
Humidity, Absolute — Part D/Section 1
Humidity, Relative — Part D/Section 1
Hybrid Building — Part D/Section 3
Hydrant System — Part F
Hydraulic Lift — Part D/Section 5A
Hydraulic Parking System — Part D/Section 5C
Hydro-pneumatic Systems — Part E/Section 1
Hydronic Systems — Part D/Section 3
Hydronic System Balancing — Part D/Section 3

I

Illuminance — Part D/Section 1
Impact Sound Pressure Level, L_i — Part D/Section 4
Imposed Load (*Live Load*) — Part C/Section 1, Part C/Section 6A
Impulse Current — Part D/Section 2
Impulse Withstand Voltage — Part D/Section 2
In Building Solution (*IBS*) — Part D/Section 6
Increments — Part C/Section 7
Incidental Occupancy within Station — Part F
Incoming Traffic — Part D/Section 5A
Indirect Acting Lift — Part D/Section 5A
Indirect Contact — Part D/Section 2
Indirect-Direct Cooling — Part D/Section 3
Indirect Waste Pipe — Part E/Section 2
Indoor Air Quality (*IAQ*) — Part D/Section 3
Indoor Ambient Noise — Part D/Section 4
Indoor Artificial Lighting — Part D/Section 1
Industrial Buildings — Part C/Section 1
Industrial Plugs and Sockets — Part D/Section 2
Infill Balustrades — Part C/Section 8
Infiltration/Exfiltration — Part D/Section 3
Inflammable Material — Part D/Section 2
Initial Dead Load — Part C/Section 6B
Initial Load Test — Part C/Section 5B
Injection — Part C/Section 2
Inlet — Part E/Section 1
Inlet Fittings — Part E/Section 2
Inlet Hopper — Part E/Section 2
Inner Diameter — Part C/Section 3B
Insanitary — Part E/Section 2
Insertion Loss — Part D/Section 4
Inside Location — Part C/Section 3A, Part C/Section 3B
Inside Plant (*ISP*) — Part D/Section 6
Inspection Chamber — Part E/Section 2
Inspection Door — Part D/Section 5B
Inspector — Part D/Section 5A
Instability — Part C/Section 6A
Installation — Part D/Section 5A, Part E/Section 4, Part D/Section 5B
Installation (*Electrical*) — Part D/Section 2
Installer — Part D/Section 5A, Part D/Section 5B
Instantaneous Safety Gear — Part D/Section 5A

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Integrated Fire Safety System — Part F
Institutional Buildings — Part C/Section 1
Insulated — Part D/Section 2
Insulating Glass Unit (*IGU*) — Part C/Section 8
Insulation — Part D/Section 2
Insertion Loss (*LIL*) — Part D/ Section 4
Insulation, Basic — Part D/Section 2
Insulation, Double — Part D/Section 2
Insulation, Reinforced — Part D/Section 2
Insulation, Supplementary — Part D/Section 2
Interceptor — Part E/Section 2
Interceptor Manhole or Interceptor Chamber — Part E/Section 2
Inter Floor Traffic — Part D/Section 5A
Interior Panel — Part D/Section 5B
Interlayer — Part C/Section 8
Intermediate Cross-Connect — Part D/Section 6
Internal (*Interior*) *Exit Stairway* — Part F
Internal Partition — Part C/Section 8
Internal Reflected Component (*IRC*) — Part D/ Section 1
Interval — Part D/Section 5A
Invert — Part E/Section 2
Inverter — Part D/Section 2
Internet of Things — Part D/Section 6
Isolation — Part D/Section 2
Isolator — Part D/Section 2
Isoptera — Part C/Section 3A

J

Jack — Part D/Section 5A
Jerk — Part D/Section 5A
Joint — Part C/Section 1, Part C/Section 3B, Part C/Section 4
Joist — Part C/Section 3B
Jointed Detailing System — Part C/Section 7
Joint Reinforcement — Part C/Section 4
Junction Box — Part D/Section 2
Junction Pipe — Part E/Section 1, Part E/Section 2

K

Key Elements — Part C/Section 5
Knot — Part C/Section 3A
Knot Hole — Part C/Section 3A

L

Lagging — Part E/Section 1, Part E/Section 2
Lamella Roof — Part C/Section 3A
Laminated Glass — Part D/Section 5A
Layer — Part C/Section 7
Laminated Safety Glass — Part C/Section 8
Laminated Veneer Lumber — Part C/Section 3A
Laminations — Part C/Section 3A
Landfilling — Part E/Section 3
Landing Call Push — Part D/Section 5A
Landing Door — Part D/Section 5A
Landing Zone — Part D/Section 5A
Large CPRF — Part C/Section 2
Large Lobby — Part D
Large Lobby at the Level of Exit Discharge — Part F
Latent Heat — Part D/Section 3
Latent Heat Load — Part D/Section 3
Lateral Force-Resisting System (*LFRS*) — Part C/ Section 1
Lateral Restraint for a Beam — Part C/Section 6A
Lateral Support — Part C/Section 4
Latewood — Part C/Section 3A
Leachate — Part E/Section 3
Leading Imposed Load — Part C/Section 6A
Leaf — Part C/Section 4
Leakage Current — Part D/Section 2
Length of Internode — Part C/Section 3B
Levelling — Part D/Section 5A
Levelling Accuracy — Part D/Section 5A
Levelling Zone — Part D/Section 5A
Levelling Device, Lift Car — Part D/Section 5A
Levelling Device, One Way Automatic — Part D/Section 5A
Levelling Devices — Part D/Section 5A
Levelling Device, Two-Way Automatic Maintaining — Part D/Section 5A
Levelling Device, Two-way Automatic Non-maintaining — Part D/Section 5A
Levelling Zone — Part D/Section 5A
LEMP Protection Measures (*SPM*) — Part D/ Section 2

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License — Part D/Section 5A
Licensed (*or Registered*) *Plumber* — Part E/Section 1, Part E/Section 2
Lift — Part D/Section 5A
Lift Car — Part D/Section 5A
Lift Landing — Part D/Section 5A
Lift Lobby — Part F
Lift Machine — Part D/Section 5A
Lift Pit — Part D/Section 5A
Lift Ride Quality — Part D/Section 5A
Lift Well — Part D/Section 5A
Lift Well Enclosure — Part D/Section 5A
Light Output Ratio (*LOR*) *or Efficiency* — Part D/ Section 1
Light Pipe — Part D/Section 1
Light Shelf — Part D/Section 1
Light Transmission — Part C/Section 8
Light Transmittance — Part C/Section 8
Light-Weight Concrete — Part C/Section 7
Lighting — Part D/Section 1
Lightning Electromagnetic Impulse — Part D/ Section 2
Lightning Protection — Part D/Section 2
Lightning Protection Level (*LPL*) — Part D/Section 2
Lightning Protection Zone — Part D/Section 2
Lightning Protection System (*LPS*) — Part D/Section 2
Lightning Protection System, External — Part D/Section 2
Lightning Protection System, Internal — Part D/Section 2
Lignin — Part C/Section 3B
Limit State — Part C/Section 6A & 6B
Limiting Capacity — Part C/Section 2
Line Conductor — Part D/Section 2
Linear Defects — Part C/Section 8
Linking Beams (*Also called Coupling Beams*) — Part C/Section 5
Link Load — Part F
Liquefaction — Part C/Section 1 and 2
Live Knot — Part C/Section 3A
Live or Alive — Part D/Section 2
Live Load — Part C/Section 6A
Live Part — Part D/Section 2
Loads — Part C/Section 6A and 6B
Load Bearing Member — Part D/Section 5A
Load Bearing Wall — Part C/Section 4
Load Eccentricity (*eL or eB*) — Part C/Section 2
Loaded Edge Distance — Part C/Section 3A
Loaded End or Compression End Distance — Part C/Section 3B
Local Area Network (*LAN*) — Part D/Section 6
Local Exhaust Ventilation — Part D/Section 1
Local Multipoint Distribution System (*LMDS*) — Part D/Section 6
Location — Part C/Section 3A
Locations, Industrial — Part D/Section 2
Locations, Non-Industrial — Part D/Section 2
Locking Devices — Part D/Section 5C
Loose Grain (*Loosened Grain*) — Part C/Section 3A
Loose Knot — Part C/Section 3A
Lower Inner Decking — Part D/Section 5B
Lower Outer Decking — Part D/Section 5B
Low Rise Building — Part C/Section 1
Low-Voltage Switchgear and Controlgear Assembly — Part D/Section 2
Lumen — Part D/Section 1
Luminaire — Part D/Section 2
Luminance (*At a point of a Surface in a Given Direction*) (*Brightness*) — Part D/Section 1
Luminous Flux — Part D/Section 1

M

m-k Factor — Part C/Section 6 B
Machette — Part C/Section 3B
Machine Room — Part D/Section 5A
Machine Room Less Lift — Part D/Section 5A and 5B
Machine to Machine (*M2M*) *Communication* — Part D/Section 6
Machinery — Part D/Section 5A and 5B
Material Efficiency — Part C/Section 6
Machinery Spaces — Part D/Section 5A and 5B
Maximum Capacity — Part D/Section 5B
Maximum CPRF Settlement (*Spr,Max*) — Part C/Section 2
Made-Up Ground — Part C/Section 2
Main Cross-connect — Part D/Section 6

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Main Distribution Frame (*MDF*) — Part D/Section 6
Main Drain — Part E/Section 1
Main Earthing Terminal — Part D/Section 2
Main Member — Part C/Section 6A
Main Soil Pipe (*MSP*) — Part E/Section 2
Main Soil and Waste Pipe (*MSWP*) — Part E/ Section 2
Main Vent Pipe (*MVP*) — Part E/Section 2
Main Waste Pipe (*MWP*) – Part E/Section 2
Maintenance — Part D/Section 5A, Part D/Section 5B
Maintenance Factor — Part D/Section 1
Maintenance Organization — Part D/Section 5A and 5B
Make-Up Air — Part D/Section 1
Make-Up Water — Part E/Section 1
Manhole — Part E/Section 2
Manhole Chamber — Part E/Section 2
Manifestation — Part C/Section 8
Manifold — Part E/Section 4
Manufacturer — Part D/Section 5A, Part D/ Section 5B
Masonry — Part C/Section 4
Masonry Buildings — Part C/Section 1
Masonry Unit — Part C/Section 4
Mass Rapid Transit — Part F
Mast — Part D/Section 5A
Mast Section — Part D/Section 5A
Mast Tie — Part D/Section 5A
Mat — Part C/Section 3B
Material Efficiency — Part C/Section 6A
Maximum Thickness — Part C/Section 8
Mean Ground Level — Part C/Section 1
Mean Outer Diameter — Part C/Section 3B
Mean Radiant Temperature — Part D/Section 3
Mean Wall Thickness — Part C/Section 3B
Means of Egress — Part F
Means of Escape — Part F
Mechanical Ventilation — Part D/Section 1
Mechanically Laminated — Part C/Section 3A
Mercantile Buildings — Part C/Section 1
Meridian — Part D/Section 1
Meshed Bonding Network (*MESH-BN*) — Part D/Section 2
Metropolitan Area Network (*MAN*) — Part D/Section 6
Mill Tolerance — Part C/Section 6A
Miniature Circuit Breaker (*MCB*) — Part D/Section 2
Minimum Breaking Load — Part D/Section 5A
Minimum Thickness — Part C/Section 8
Mixed Mode Building — Part D/Section 3
*Mixed Occupa*ncy — Part F
Mixed Building or Hybrid Building — Part C/ Section 5
Mobile Equipment — Part D/Section 2
Modular Coordination — Part C/Section 7
Modular Grid — Part C/Section 7
Module — Part C/Section 7
Modulus of Elasticity (*Young's Modulus*) — Part C/Section 8
Moment Frame System — Part C/Section 5
Moment Frame-Structural Wall System — Part C/Section 5
Monitoring — Part D/Section 2
Monolithic Glass — Part C/Section 8
Mortise and Tenon — Part C/Section 3B
Mould — Part C/Section 3A
Moulded Case Circuit Breaker (*MCCB*) — Part D/ Section 2
Moving Walk — Part D/Section 5B
Mullion — Part C/Section 8
Multichannel Multipoint Distribution System (*MMDS*) — Part D/Section 6
Multimodule — Part C/Section 7
Multiple-Tube System — Part C/Section 5
Multi-Tower Structures Linked by Podium — Part C/Section 5
Multiple Earthed Neutral System — Part D/Section 2
*Multiple Occupa*ncy — Part F
Multi-User Telecommunications Outlet Assembly (*MUTOA*) — Part D/Section 6
Municipal Authority — Part E/Section 3
Municipal Solid Waste — Part E/Section 3

N

Natural Ventilation — Part D/Section 1
Natural Period — Part C/Section 5

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Naturally Conditioned Building — Part D/Section 3

Negative Skin Friction — Part C/Section 2

Net Section — Part C/Section 3B

Neutral Conductor — Part D/Section 2

Newel — Part D/Section 5B

Node — Part C/Section 3B

Noise — Part D/Section 4

Noise Exposure Forecast (*NEF*) — Part D/Section 4

Noise Criteria — Part D/Section 4

Noise Rating (NR) — Part D/Section 4

Noise Reduction Co-efficient (*NRC*) — Part D/ Section 4

Nominal Speed — Part D/Section 5B

Nominal Thickness — Part C/Section 8

Nominal Travel Time/Theoretical Time of Travel — Part D/Section 5A

Non-Combustible Material — Part C/Section 8

Non-Return Valve — Part D/Section 5A

Non-Selective Collective Automatic Operation — Part D/Section 5A

Non-transit Occupancy — Part F

Normal Operation — Part D/Section 5A

Normal Stress — Part C/Section 6A

Normalized Impact Sound Pressure Level — Part D/Section 4

North and South Points — Part D/Section 1

Notice of Completion — Part A

O

Occupancy or Use Group — Part A, Part F, Part C/Section 1

Occupant Load — Part F

Occupant Load Factor (*OLF*) — Part F

Occupier — Part A

Occupational Exposure Limit (*OEL*) — Part D/ Section 3

Octave Band — Part D/Section 4

Offset — Part C/Section 2, Part E/Section 1, Part E/Section 2

Oil Buffer Stroke — Part D/Section 5A

One Pipe-Partially Ventilated System — Part E/ Section 2

One Pipe-Fully Ventilated System — Part E/Section 2

One-Way Restrictor — Part D/Section 5A

Open time — Part C/Section 7

Open Station — Part F

Operating Device — Part D/Section 5A

Operation — Part D/Section 5A

*Operational Construction/Installatio*n — Part A

Operational or Services Brake — Part D/Section 5B

Operating Panel — Part D/Section 5C

Operative Temperature — Part D/Section 3

Operator of a Facility — Part E/Section 3

Optical Distribution Frame — Part D/Section 6

Optical Fibre — Part D/Section 6

Ordinary moment resisting frame (*OMRF*) — Part C/Section 1

Orientation of Buildings — Part D/Section 1

Organic Coated Glass — Part C/Section 8

Origin of an Electrical Installation — Part D/ Section 2

Outdoor Artificial Lighting — Part D/Section 1

Outer Diameter — Part C/Section 3B

Out-of-Plane Deformation — Part C/Section 7

Outgoing Traffic — Part D/Section 5A

Outside Location – Part C/Section 3A, Part C/ Section 3B

Outside Plant (OSP) — Part D/Section 6

Overcurrent — Part D/Section 2

Overload Current (*of a Circuit*) — Part D/Section 2

Over Speed Governor — Part D/Section 5A

Overhead Beams — Part D/Section 5A

Owner of the Installation — Part D/Section 5A and 5B

Ozone Depletion Potential (*ODP*) — Part D/Section 3

P

Pane — Part C/Section 8

Panel — Part C/Section 8

Panel Wall — Part C/Section 4

Parking Equipment Attendant — Part D/Section 5C

Parking Unit — Part D/Section 5C

Partial Safety Factor — Part C/Section 6A and 6B

Partial Safety Factor for Loads — Part C/Section 6A and 6B

Partially Separate System — Part E/Section 2

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Partition — Part C/Section 8

Partly Framed or Unframed Glazing — Part C/ Section 8

Passenger — Part D/Section 5A

Passenger Arrival Rate — Part D/Section 5A

Passenger Average Waiting Time (*AWT*) — Part D/Section 5A

Passenger Lift — Part D/Section 5A

Passive Cooling — Part D/Section 3

Passive Fire Protection — Part F

Passive Heating — Part D/Section 3

Passive Solar Gain — Part C/Section 8

Patterned Glass — Part C/Section 8

Pawl Device — Part D/Section 5A

Peak Ground Acceleration — Part C/Section 1

Peak Gust — Part C/Section 1

Peak to Peak Vibration Levels — Part D/Section 5A

Peat — Part C/Section 2

Plenum — Part F

Pelletization — Part E/Section 3

Percentile Level — Part D/Section 4

Performance Based Design — Part F

Performance Time/Door-to-Door Time — Part D/Section 5A

Perimeter Fire Barrier — Part C/Section 8

Period of Structural Adequacy under Fire — Part C/Section 6A

Period of Supply — Part E/Section 1

Peripheral Field — Part D/Section 1

Permanent Load — Part C/Section 2

Permissible Stress — Part C/Section 3A, Part C/Section 3B, Part C/Section 6A

Pessral — Part D/Section 5A

PEN Conductor — Part D/Section 2

Phase Conductor — Part D/Section 2

Pier — Part C/Section 4

Pile-Enhanced Raft — Part C/Section 2

Pile Foundation — Part C/Section 2

Pile-Pile Interaction — Part C/Section 2

Pile-Raft Interaction — Part C/Section 2

Pile-Raft Coefficient or Load Sharing Ratio (α_{CPRF}) — Part C/Section 2

Pile Spacing — Part C/Section 2

Partition Wall — Part C/Section 4

Pilot — Part E/Section 4

Pink Noise — Part D/Section 4

Pipe System — Part E/Section 2

Pipe Work — Part E/Section 1

Pit — Part D/Section 5B

Pitch — Part C/Section 6A and 6B

Pitch Pocket — Part C/Section 3A

Place of Comparative Safety — Part F

Plastic Collapse — Part C/Section 6A

Plastic Design — Part C/Section 6A

Plastic Hinge — Part C/Section 6A

Plastic Moment — Part C/Section 6A

Plastic Section — Part C/Section 6A

Plenum — Part D/Section 3

Plug — Part D/Section 2

Plumbing — Part E/Section 1, Part E/Section 2

Plumbing System — Part E/Section 1, Part E/ Section 2

Pocket Type Reinforced Masonry — Part C/Section 4

Podium — Part F

Point of Safety — Part F

Point (*in Wiring*) — Part D/Section 2

Poisson's Ratio — Part C/Section 6A

Pool — Part E/Section 1

Pool Depth — Part E/Section 1

Population — Part D/Section 5A

Portable Equipment — Part D/Section 2

Position and/or Direction Indicator — Part D/ Section 5A

Positive Drive Lift — Part D/Section 5A

Positive Ventilation — Part D/Section 1, Part D/Section 3

Potable Water — Part E/Section 1

Precast Concrete Piles in Prebored Holes — Part C/ Section 2

Precast Driven Pile — Part C/Section 2

Printable Concrete — Part C/Section 7

Prefabricate — Part C/Section 7

Prefabricated Building — Part C/Section 7

Preliminary Operation — Part D/Section 5A

Preloading — Part C/Section 2

Premises — Part E/Section 1, Part E/Section 2

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Pressure Coefficient — Part C/Section 1
Pressure Balancing Valve — Part E/Section 1
Pressure Regulator — Part E/Section 4
Pressure Relief Valve — Part D/Section 5A
Pressurization — Part F
Pressurization Level — Part F
Pressurization System — Part F
Principal Rafter — Part C/Section 3B
Principal Occupancy or Use Group — Part F
Printability — Part C/Section 7
Print Plane — Part C/Section 7
Prism — Part C/Section 4
Processing — Part E/Section 3
Programmable Electronic System in Safety Related Applications for Lifts (*PESSRAL*) — Part D/ Section 5A
Progressive Safety Gear — Part D/Section 5A
Progressive Horizontal Evacuation — Part F
Proof Checking/Peer Reviewing — Part A
Proof Stress — Part C/Section 6A
Proof Testing — Part C/Section 6A
Propagation Delay — Part D/Section 6
Propeller Fan — Part D/Section 1
Prospective Fault Current (I_{pf}) — Part D/Section 2
Protection, Ingress — Part D/Section 2
Protection, Mechanical Impact — Part D/Section 2
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