# PRELIMINARY DRAFT

# NATIONAL BUILDING CODE OF INDIA

## PART 8 BUILDING SERVICES

## Section 1 Lighting and Natural Ventilation

BUREAU OF INDIAN STANDARDS

C O N T E N T S

National Building Code Sectional Committee, CED 46

FOREWORD

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 8 'Building Services', Section 2 'Electrical and Allied Installations' of the Code, adequately covers the illumination levels required and methods of achieving the same.

Ventilation requirements to maintain air quality and control body odours 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 are covered in this Section. The provisions on mechanical ventilation are covered in Part 8 'Building Services', Section 3 'Air conditioning, Heating and Mechanical Ventilation' of the Code.

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. The first revision of the Section was brought out in 1983. In the second revision, 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 last 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, was 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 taken care of in the last revision of the Code. Accordingly, the relevant requirements for energy efficient system for lighting and natural ventilation were duly included in the concerned provisions under the Section.

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, supporting the relevant provisions; inclusion of provisions on sky component calculation procedure along with examples in Annex B supporting the relevant clauses; inclusion of reference to SP 41:1987 for obtaining coefficient utilization for determination of luminous flux; provisions relating to efficient artificial light source and luminaires were updated; inclusion of modern lighting techniques such as LED and induction light *vis-à-vis* their energy consumption; provisions relating to photocontrols for artificial lights were updated; inclusion of definitions and enabling provision for lighting shelves and light pipes; elaboration of the provisions related to thermal comfort clause including therein 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; inclusion of provision on colour rendering in line with that in SP 72 : 2010 'National Lighting Code 2010'.

As a result of experience gained since the implementation of the 2016 version of the Code and feedback received as well as revisions of Indian Standards on which this Section was based, a need was felt to revise this Section.

This revision has therefore, been prepared to take care of these. The significant changes incorporated in the 2024 revision include the following:

a) Provisions for spatial and environmental consideration in building design; and operable windows and UV Exposure have been added.
b) Clause for aims of good lighting has been updated and modified.
c) Table 5 for illuminance and lighting performance parameters has been modified and updated.
d) Provisions for Planning and Design Guidelines for Circadian Lighting and outdoor lighting has been added.
e) Detailed provisions on Design Charts for Natural Ventilation and Acceptable Air Temperature with the Increase in the Air Speed have been added.
f) Various other existing provisions have been updated based on the latest technical developments in the field.
g) Orientation of building clause has been renamed to site planning and building placement.
h) Clause for aspects of daylighting has been updated.
j) Terminology clause has been updated with new terms and definitions.

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) : 1992 | Code of practice for interior illumination : Part 1 General requirements and recommendations for working interiors (*first revision*) |
| IS 7662 (Part 1) : 1974 | Recommendations for orientation of buildings : Part 1 Non-industrial 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, 'SP 72 : 2010' may also be referred.

Assistance has been made from the following documents in formulating this Section:

Report on energy conservation in buildings, submitted to Department of Power, Ministry of Energy by CSIR-Central Building Research Institute, Roorkee.

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

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.

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.

**Members are requested to share their inputs/comments on the draft particularly w.r.t the changes listed above in the foreword; and specially on those text highlighted in yellow in this draft.**

**Important Explanatory Note for Users of the Code**

In any Part/Section of this Code, 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 [8-1(1)] refers to the Indian Standard(s) give at serial number (1) of the list of standards given at the end of this Part/Section, that is, 7662 (Part 1) : 1974 'Recommendations for orientation of buildings : Part 1 Non-industrial buildings'

# PRELIMINARY DRAFT
# NATIONAL BUILDING CODE OF INDIA
## PART 8 BUILDING SERVICES
### Section 1 Lighting and Natural Ventilation

**1 SCOPE**

**1.1** This Code (Part 8/Section 1) covers requirements and methods for lighting and natural ventilation of buildings.

**1.2** The provisions in respect of lighting and ventilation in sustainable buildings are covered in Part 11 'Approach to Sustainability' of the Code which shall be used in conjunction with this Section.

**1.3** 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 ventilation for barrier free access and movement within and around buildings by ~~for~~ elderly and persons with disability ~~and of different age groups,~~ shall be ensured in accordance with Part 3 'Development Control Rules and General Building Requirements' of the Code.

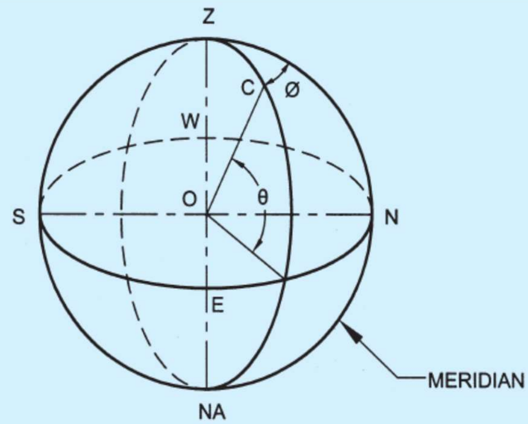
**2 TERMINOLOGY**

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

**2.1 Lighting**

**2.1.1** *Altitude* ($\theta$) – 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* ($\Phi$) – 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.

**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 2º 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 is brighter than the zenith, 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:

$$L_\theta = L_z \operatorname{cosec} \theta \text{ (for } 15^\circ < \theta \leq 90^\circ)$$
$$L_\theta = L_z \operatorname{cosec} 15^\circ \text{ (for } 0^\circ \leq \theta \leq 15^\circ) = 3.8637\, L_z$$

**2.1.7** *Circadian lighting* – It is a lighting design that mimics natural daylight patterns to align with the body's internal clock, supporting alertness during the day and relaxation at night, promoting overall well-being and better sleep.

**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 use of natural optical radiation from the sun and sky to illuminate interior spaces, providing both visual comfort and contributing to the regulation of the human circadian cycle. In this context, daylight refers to the portion of solar radiation that falls within the visible spectrum, specifically between 380 nm and 780 nm. Daylighting is designed to optimize the use of natural light to reduce artificial lighting needs while enhancing occupant well-being.

**2.1.11** *Daylight Area* – The surface area on a working plane that receives natural light with an illuminance level not less than a specified daylight factor or sufficient illuminance level. This area is defined by the relevant daylight factor contour, indicating the portion of the space effectively lit by daylight under specified conditions. ~~The superficial surface area on the working plane illuminated to not less than a specified daylight factor specified daylight factor or sufficient illuminance level, that is, the area within the relevant contour.~~

**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 a clear sky, excluding direct sunlight. 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. ~~The measure of total daylight illuminance at a point on a given plane expressed as the ratio (or percentage) which the illuminance at the point on the given plane bears to the simultaneous illuminance on a horizontal plane due to clear design sky at an exterior point open to the whole sky vault, direct sunlight being excluded~~

**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)* – The ratio (or percentage) of that part of the daylight illuminance at a point on a given plane which is received by direct reflection from external surfaces as compared to the simultaneous exterior illuminance on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

**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 ~~and time~~.

**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 $m^2$.

**2.1.18** *Indoor Artificial Lighting* – Artificial lighting designed to enhance visual comfort, performance, and well-being within indoor spaces. Its effectiveness is evaluated using several factors:

a) *Spectral Power Density (SPD)* – A measure of the light spectrum distribution, indicating how different wavelengths contribute to the overall lighting and its effects on human perception and biological responses.
b) *Colour Tuning* – The adjustment of light's color temperature and spectral composition to suit visual tasks or mood, influencing both visual and non-visual responses like circadian regulation.
c) *Flicker Rate* – The frequency of light fluctuations, with high rates potentially causing discomfort, strain, or reduced efficiency, even if imperceptible to the human eye.
d) *Unified Glare Rating (UGR)* – A metric used to quantify the level of discomfort caused by glare in indoor environments, helping to ensure visual comfort without compromising the ability to perform tasks effectively.

**2.1.19** *Internal Reflected Component (IRC)* – The ratio (or percentage) of that part of the daylight illuminance at a point in a given plane which is received by direct reflection or inter-reflection from the internal surfaces as compared to the simultaneous exterior illuminance on a horizontal plane due to the entire hemisphere of an unobstructed clear design sky.

**2.1.20** *Low Energy Cooling and Ventilation for Indian Residences (LECaVIR)* – This is a project focusing on developing low-energy cooling and ventilation designs for Indian homes, incorporating smart, self-learning control algorithms. It identifies periods for Natural Ventilation (NV) across India's climatic zones, and for other conditions, introduces Mixed Mode (MM) solutions that combine NV, low-energy cooling, and AC systems. LECaVIR promotes energy-efficient technologies. The project also develops building energy management systems to optimize energy use by switching between modes and controlling key variables with self-learning algorithms for continuous improvement.

**2.1.21** *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.

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

**2.1.23** *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.

**2.1.24** *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.

**2.1.25** *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 ($cd/m^2$).

**2.1.26** *Luminous Flux ($\Phi$)* – 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 ($\Phi_n$)* – Total luminous flux which reaches the working plane.
b) *Nominal Luminous Flux ($\Phi_o$)* – Total luminous flux of the light sources in the interior.

**2.1.27** *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.

**2.1.28** *Melanopic Equivalent Daylight Illuminance* (*lx*) – It represents the illuminance of a D65 daylight reference light that matches melanopic irradiance. It measures the impact of light on melanopsin receptors, which influence circadian rhythms like sleep and alertness. MEDI is the globally recognized metric for evaluating light's biological effects, sometimes referred to as melanopic EDI.

NOTE – D65 is a standard reference illuminant defined by the **International Commission on Illumination (CIE)** that represents average daylight, including both direct sunlight and skylight. It is commonly used in visual assessments and lighting standards to provide a consistent basis for evaluating how light interacts with objects and materials under typical daylight conditions.

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

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

**2.1.31** *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.

**2.1.32** *Outdoor Artificial Lighting* – Lighting systems designed for outdoor environments, aiming to provide visibility and safety while minimizing environmental impact. Key aspects include:

a) *Fully Shielded* – Fixtures designed to direct all light downward, preventing upward light emissions and reducing glare or light pollution.
b) *Full Cut-Off* – A lighting design where no light is emitted above the horizontal plane of the fixture, reducing sky glow and improving lighting efficiency.
c) *Light Trespass* – The unwanted or excessive spillover of light into areas where it is not needed, such as neighbouring properties, which can cause discomfort and reduce privacy.
d) *Sky Glow* – The brightening of the night sky caused by artificial lighting, which diminishes the visibility of stars and natural darkness, often exacerbated by poorly designed outdoor lighting.

**2.1.33** *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.

**2.1.34** *Photopic Lux* – Photopic lux measures light intensity as perceived by the human eye under well-lit conditions. It focuses on visual responses, mainly through cone receptors. This is the standard metric for assessing visible light.

**2.1.35** *Reflected Glare* – ~~The variety of ill effects on visual efficiency and comfort produced by unwanted reflections in and around the task area.~~ 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.

**2.1.36** ~~*Reflection*~~ *Surface Reflectance (Reflectance)* – The ratio of the luminous flux reflected by a body (with or without diffusion) to the flux it receives. Some symbols used for reflection factor 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.

**2.1.37** *Reveal* – The side of an opening for a window.

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

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

where $L$ and $W$ are the length and width respectively of the interior, and $H_m$ is the 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 reflection factor of the upper stretch of the walls is less than half the reflection factor 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.

**2.1.39** *Sky Component (SC)* – The ratio (or percentage) of that part of the daylight illuminance at a point on a given plane which is received directly from the sky as compared to the simultaneous exterior illuminance on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

**2.1.40** *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.

**2.1.41** *Utilization Factor (Coefficient of Utilization) (μ)* – The ratio of the total luminous flux which reaches the working plane (effective luminous flux, $\Phi_h$) to the total luminous flux of the light sources in the interior (nominal luminous flux, $\Phi_o$).

**2.1.42** *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.

**2.1.43** *Working Plane* – A horizontal plane at a level at which work will normally be done (*see* **4.1.4.3** and **4.1.4.4**).

**2.1.44** *UV-A* – Ultraviolet radiation with wavelengths between 315 and 400 nanometers. It penetrates the skin more deeply and plays a role in skin aging and DNA damage, but is less effective for germicidal purposes. It is also essential in the synthesis of pre-vitamin D3.

**2.1.45** *UV-B* – Ultraviolet radiation with wavelengths between 280 and 315 nanometers. It is highly effective in promoting the synthesis of pre-vitamin D3 in the skin and plays a significant role in germicidal activities, capable of causing DNA damage in microorganisms.

**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.

**Table 1 Maximum Allowable Contaminant Concentrations for Ventilation Air**
(*Clause* 2.2.9)

| **Sl No.** | **Contaminants** | **Annual Average (Arithmetic Mean)** µg/m$^3$ | **Short Term Level (Not to Exceed More than Once a Year)** µg/m$^3$ | **Averaging Period** h |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| 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 |

**2.2.10** *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.

**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.

**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 ~~ORIENTATION OF BUILDING~~ SITE PLANNING AND BUILDING PLACEMENT

**3.1** The chief aim of orientation of buildings 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.

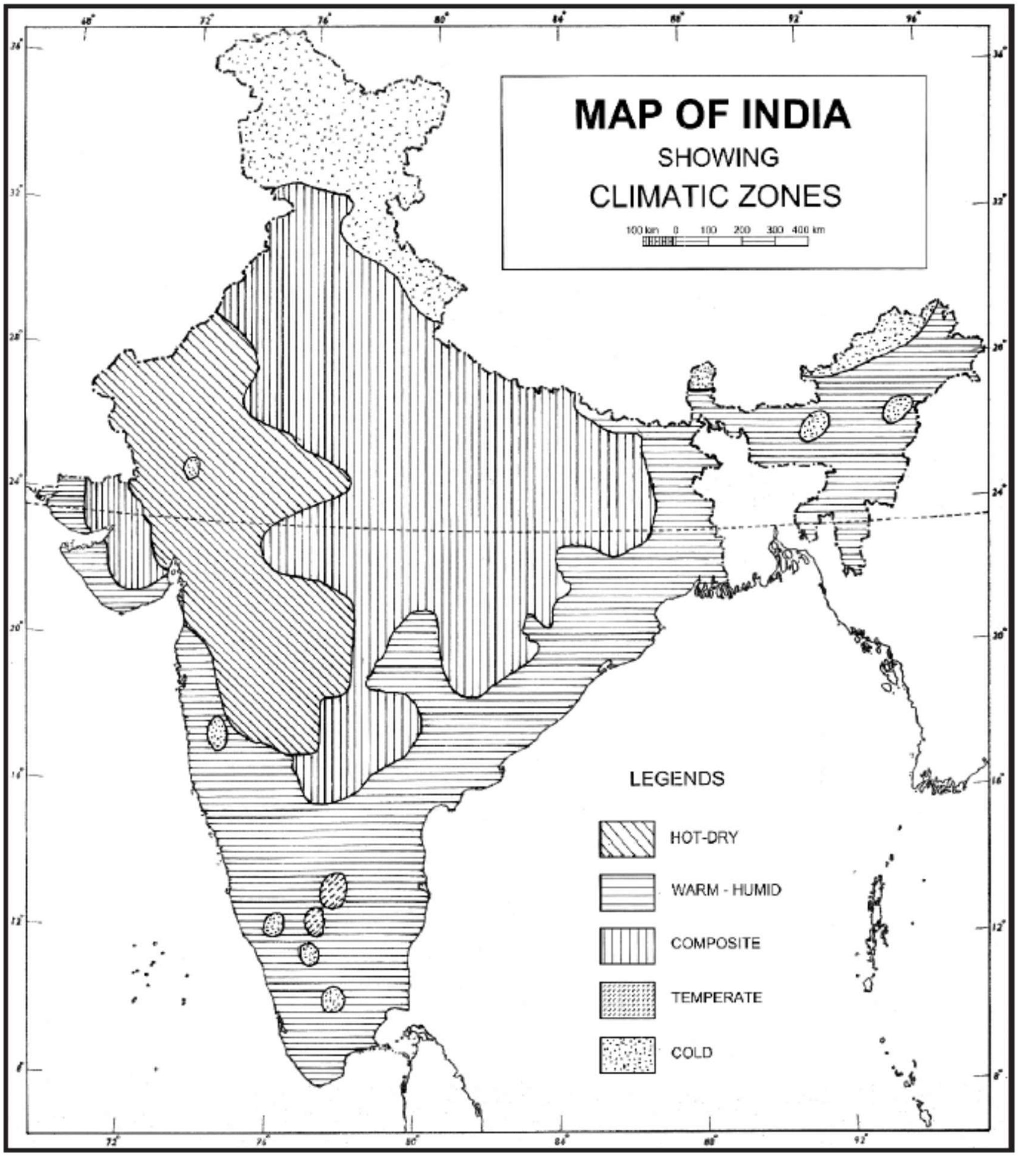
### 3.2 Basic Climate Zones

**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 | 25-30 | below 75 |
| iv) | Cold | below 25 | all values |
| v) | Composite | *see* **3.2.2** | |

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




Based upon Survey of India Outline Map printed in 1993. © Government of India Copyright, 2005

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhatisgarh & Madhya Pradesh have not been verified by Governments concerned.

FIG. 2 MAP OF INDIA SHOWING CLIMATIC ZONE

**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 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 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 orientation can be calculated as per the method given in Annex A.

**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. Design considerations should ensure that, during the winter period, each facade receives a minimum of 1 hour of sun exposure daily. Additionally, a maximum limit of 250 hours of sun exposure per window per year should be maintained to prevent overheating, in accordance with recommended daylight availability protocols, which should be tested and adapted for local Indian conditions.

**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)

| Sl No. | Orientation | | 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 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.

**3.6 Aspects of Daylighting**

In daylighting design, 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. Daylighting 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.

~~Since the clear design sky concept for daylighting takes care of the worst possible situation, orientation is not a major problem for daylighting in buildings, except that direct sunshine and glare should be avoided. However, due allowance should be given to the mutual shading effects of opposite facades and significant vegetation elements.~~

**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 shall guide the integration of these elements into building design:

a) Vegetation that matches or exceeds the building height shall be incorporated into the site design to enhance both aesthetic and environmental impacts. This vegetation should provide visual harmony with the surrounding landscape and offer ecological benefits, such as shading, improved air quality, and reduced heat islands.

b) Adequate spacing between a building and neighbouring structures is essential for ensuring access to natural light, ventilation, and privacy. The distance between buildings shall 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 shall 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.

d) Tree planting in open spaces and streets shall be carefully planned to provide shade and allow sunlight, without obstructing natural winds or 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 (e.g., Asoka, Aso Palav) shall be placed at a distance proportional to their mature height to avoid obstructing light and airflow. Less dense or deciduous trees (e.g., Gulmohar, Amaltas, Neem) may be planted with considerations beyond daylight access, including aesthetic and ecological benefits.

**3.8 Operable Windows and UV Exposure**

Operable windows shall be provided in habitable spaces to allow for natural ventilation and daylighting. To optimize UV exposure for health benefits while minimizing potential harm and ensure that operable windows are accessible to all occupants, including those with special ability following criteria shall be met:

a) *Direct Sun Access* – Windows shall be oriented to receive direct sunlight for a minimum of 1200 hours (as per DIN 5034-1) per year. This exposure shall be evenly distributed throughout the year to ensure adequate UV-B radiation for vitamin D synthesis.
b) *UV-A and UV-B Balance* – While UV-B is crucial for vitamin D production, excessive exposure can lead to skin damage. Operable windows shall be designed or equipped with shading devices (e.g., blinds, awnings) to allow for controlled modulation of both UV-A and UV-B radiation. This will enable occupants to balance the benefits of sunlight exposure with the need for protection against excessive UV radiation.

**3.9** For detailed information regarding orientation of buildings and recommendations for various climatic zones of country, reference may be made to good practice [8-1(1)].

## 4 LIGHTING

### 4.1 Principles of Lighting

**4.1.1** *Aims of Good Lighting*

Good lighting is essential for all buildings and serves multiple purposes. Its primary aims are to create a comfortable, functional, and visually pleasing environment that supports human well-being. It should promote work and other activities within the building, ensure the safety of occupants, and, in harmony with the structure and decoration, foster a pleasant and engaging atmosphere. In addition, good lighting should consider human development, such as supporting eye growth and maintaining healthy circadian rhythms. Glare control is also critical, as excessive glare can cause discomfort, eye strain, and headaches. By managing glare effectively, lighting systems can enhance visual comfort, improve productivity, and contribute to an overall better quality of life for the occupants.

Good lighting is necessary for all buildings and has three primary aims. The first aim is to promote work and other activities carried out within the building; the second aim is to promote the safety of the people using the building; and the third aim is to create, in conjunction with the structure and decoration, a pleasing environment conducive to interest of the occupants and a sense of their well-being.

**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 **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code, 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 ensured that the visual performance exceeds the specified minimum. Illuminance for working areas within a building should be at least 150 lux, or as per the average illuminance values recommended in Table 5, whichever is higher.

**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** When the task brightness appropriate to an occupation has been determined, the brightness of the other parts of the room should be planned to give a proper emphasis to visual comfort and interest.

A general guide for the brightness relationship within the normal field of vision should be as follows:

a) For high task brightness (above 100 cd/m$^2$) : — Maximum

| | | |
|---|---|---|
| 1) Between the visual task and the adjacent areas like table tops | : | 3 to 1 |
| 2) Between the visual task and the remote areas of the room | : | 10 to 1 |

b) For low and medium task brightness (below 100 cd/m$^2$) – The task should be brighter than both the background and the surroundings; the lower the task brightness, the less critical is the relationship.

**4.1.2.4** 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 13 and Annex B of Part 3 ‘Development Control Rules and General Building Requirements’ of the Code 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:

| *Lamp Luminance* kcd/m$^2$ | *Minimum Shielding Angle* Degrees |
|---|---|
| 1 to 20 | 10 |
| 20 to 50 | 15 |
| 50 to 500 | 20 |
| ≥ 500 | 30 |

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 5 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 [8–1(2)].

**4.1.4** *Recommended Values of Illuminance*

Table 5 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 task.

The illuminance shall comply with the requirements given in Part 3 'Development Control Rules and General Building Requirements' of the Code for persons with disabilities, in addition to the requirements specified in Table 5.

**4.1.4.1** Composition of The Tables

For the application of the Table 5 in **4.1.4** (*see* **4.1.4.1**, **4.1.4.2** and **4.1.6**).

a) Column 1 lists the reference number for each task area or activity area.
b) Column 2 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, e.g. a corridor or resting room.

c) Column 3 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 2 is performed.

d) Column 4 gives the minimum illuminance uniformity $U_o$ on the reference surface for the maintained average illuminance $\bar{E}_m$ chosen according to 5.

j) Column 5 gives the minimum colour rendering indices ($R_a$) (*see* 4.1.8) for the situation listed in Column 2.

m) Column 6 gives the UGR limits (Unified Glare Rating limit, $R_{UGL}$) that are applicable to the situation listed in Column 2 (*see* 4.1.3).

n) Column 7 gives the maintained cylindrical illuminance $\bar{E}_{m,z}$ for the recognition of object and people .

o) Column 8 gives the maintained average illuminance on walls $\bar{E}_m$, wall.

p) Column 9 gives the maintained average illuminance on ceilings $\bar{E}_m$, ceiling.

**4.1.4.2** The different locations and tasks are grouped within the following sections:

1) Traffic zones inside buildings;
2) General areas inside buildings – Rest, sanitation and first aid rooms;
3) General areas inside buildings – Control rooms
4) General areas inside buildings – Store rooms, cold stores
5) Logistics and warehouses
6) Industrial activities and crafts – Agriculture;
7) Industrial activities and crafts – Bakeries
8) Industrial activities and crafts – Cement, cement goods, concrete, bricks
9) Industrial activities and crafts – Ceramics, tiles, glass, glassware
10) Industrial activities and crafts – Chemical, plastics and rubber industry
11) Industrial activities and crafts – Electrical and electronic industry
12) Industrial activities and crafts – Food stuffs and luxury food industry
13) Industrial activities and crafts – Foundries and metal casting
14) Industrial activities and crafts – Hairdressers
15) Industrial activities and crafts – Jewellery manufacturing
16) Industrial activities and crafts – Laundries and dry cleaning
17) Industrial activities and crafts – Leather and leather goods
18) Industrial activities and crafts – Metal working and processing
19) Industrial activities and crafts – Paper and paper goods
20) Industrial activities and crafts – Power stations
21) Industrial activities and crafts – Printers
22) Industrial activities and crafts – Rolling mills, iron and steel works
23) Industrial activities and crafts – Textile manufacture and processing
24) Industrial activities and crafts – Vehicle construction and repair
25) Industrial activities and crafts – Wood working and processing
26) Offices
27) Retail premises
28) Places of public assembly – General areas
29) Places of public assembly – Restaurants and hotels
30) Places of public assembly – Theatres, concert halls, cinemas, places for entertainment
31) Places of public assembly – Trade fairs, exhibition halls

32) Places of public assembly – Museums
33) Places of public assembly – Libraries
34) Places of public assembly – Car parks (indoor)
35) Educational premises – Nursery school, play school
36) Educational premises – Educational buildings
37) Health care premises – Rooms for general use
38) Health care premises – Staff rooms
39) Health care premises – Wards, maternity wards
40) Health care premises – Examination rooms (general)
41) Health care premises – Eye Examination rooms
42) Health care premises – Ear Examination rooms
43) Health care premises – Scanner rooms
44) Health care premises – Delivery rooms
45) Health care premises – Treatment rooms (general)
46) Health care premises – Operating areas
47) Health care premises – Intensive care unit
48) Health care premises – Dentists
49) Health care premises – Laboratories and pharmacies
50) Health care premises – Decontamination rooms
51) Health care premises – Autopsy rooms and mortuaries
52) Transportation areas – Airports
53) Transportation areas – Railway installations

**4.1.4.3** The illumination levels recommended in Table 5 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 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 13 and Annex B of Part 3 'Development Control Rules and General Building Requirements' of the Code 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 ~~should~~ 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 **13** and **Annex B** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

**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 ($U_o$), color 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 4 shows the assignment of columns to requirements, as informed 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 Ēm, Uo, Ra and RUGL. The requirements for the space in which the task(s) or activities are carried out are given by Ēm,z for the perception of objects and people within this space and Ēm,wall and Ēm,ceiling for room brightness. The latter are used for designing the room and the space including RUGL. Glare (by RUGL) 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 4 Assignment of Columns to Requirements**

| **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)

$\bar{E}_{m,ceiling}$ – Average Illuminance level at ceiling

In all enclosed places the maintained illuminances on the major surfaces shall have the following values, unless specified in the table.

**Table 5 Illuminance and Lighting Performance Parameters**
(*Clauses* 4.1.3.1, 4.1.4, 4.1.4.1, 4.1.4.2, 4.1.4.3, 4.3.2 *and* 4.3.2.1)

| Sl. No. | Ref. No. | Type of task/activity area | $\bar{E}_m$ $(l_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 1) | **1** | **Areas Inside Buildings** | | | | | | | |
| 2) | 1.1 | Corridors and circulation areas | 75-100-150 | 0.40 | 70 | 28 | | | |
| 3) | 1.2 | Stairs, escalators, travelators | 75-100-150 | 0.40 | 70 | 25 | | | |
| 4) | 1.3 | Elevators, lifts | 75-100-150 | 0.40 | 70 | 25 | | | |
| 5) | 1.4 | Area in front of lifts, elevators and escalators | 150-200-300 | 0.40 | 70 | 25 | | | |
| 6) | 1.5 | Loading ramps/bays | 100-150-200 | 0.40 | 70 | 25 | | | |
| 7) | 1.6 | Building entrance with canopy | 20-30-50 | 0.40 | - | - | | | |
| 8) | 1.7 | Gangways: manned | 100-150-200 | 0.40 | 70 | 25 | | | |
| 9) | **2** | **General Areas Inside Buildings-Rest, Sanitation and First Aid Rooms** | | | | | | | |
| 10) | 2.1 | Canteens and break areas | 150-200-300 | 0.40 | 80 | 22 | | | |
| 11) | 2.2 | Resting rooms | 75-100-150 | 0.40 | 80 | 22 | | | |
| 12) | 2.3 | Rooms for physical exercise | 200-300-500 | 0.40 | 80 | 22 | | | |
| 13) | 2.4 | Cloakroom (area), washrooms, bathrooms, dressing-, lockers-, shower, sink and toilet areas | 150-200-300 | 0.40 | 80 | 25 | | | |
| 14) | 2.5 | Facial lighting in front of mirrors | 150-200-300 | 0.40 | 80 | - | | | |
| 15) | 2.6 | Sick bay | 300-500-750 | 0.60 | 80 | 19 | | | |
| 16) | 2.7 | Rooms for medical attention | 300- 500-750 | 0.60 | 90 | 19 | | | |
| 17) | 2.8 | General cleaning | 75-100-150 | 0.40 | - | - | | | |
| 18) | **3** | **General Areas Inside Buildings-Control Rooms** | | | | | | | |
| 19) | 3.1 | Plant rooms, switch gear rooms | 150-200-300 | 0.40 | 80 | 25 | 50 | 50 | |
| 20) | 3.2 | Post sorting, switchboard | 300-500-750 | 0.60 | 80 | 19 | 150 | 150 | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 21) | 3.3 | Surveillance station | 200-300-500 | 0.60 | 80 | 19 | 100 | 100 | |
| 22) | **4** | **General Areas Inside Buildings-Store Rooms, Cold Stores** | | | | | | | |
| 23) | 4.1 | Store and stockrooms | 75 -100-150 | 0.40 | 80 | 25 | | | |
| 24) | 4.2 | Dispatch packing handling areas | 200-300-500 | 0.60 | 80 | 25 | | | |
| 25) | 4.3 | Larder | 150-200-300 | 0.40 | 80 | 25 | | | |
| 26) | **5** | **Logistics and Warehouses** | | | | | | | |
| 27) | **5.1** | Unloading/ loading area | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 28) | 5.2 | Packing/ grouping area | 200-300-500 | 0.50 | 80 | 25 | 100 | | |
| 29) | 5.3 | Configuration and rehandling | 500-750-1000 | 0.60 | 80 | 22 | 150 | | |
| 30) | 5.4 | Open goods storage | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 31) | 5.5 | Rack storage floor | 100-150-200 | 0.50 | 80 | 25 | | | |
| 32) | 5.6 | Rack storage rack face | 50-75-100 | 0.40 | 80 | - | - | | |
| 33) | 5.7 | Central logistics corridor (heavy traffic) | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 34) | 5.8 | Automated zones (unmanned) | 50-75-100 | 0.40 | 80 | 25 | | | |
| 35) | **6** | **Industrial Activities and Crafts-Agriculture** | | | | | | | |
| 36) | 6.1 | Loading and operating of goods, handling equipment and machinery | 150-200-300 | 0.40 | 80 | 25 | | | |
| 37) | 6.2 | Buildings for livestock | 30-50-75 | 0.40 | 70 | - | | | |
| 38) | 6.3 | Sick animal pens; calving stalls | 150-200-300 | 0.60 | 80 | 25 | | | |
| 39) | 6.4 | Feed preparation; dairy; utensil washing | 150-200-300 | 0.60 | 80 | 25 | | | |
| 40) | **7** | **Industrial Activities and Crafts – Bakeries** | | | | | | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 41) | 7.1 | Preparation and baking | 200-300-500 | 0.60 | 80 | 22 | 75 | | |
| 42) | 7.2 | Finishing, glazing, decorating | 300-500 - 750 | 0.70 | 80 | 22 | 100 | | |
| 43) | **8** | **Industrial Activities and Crafts-Cement, Cement Goods, Concrete, Bricks** | | | | | | | |
| 44) | 8.1 | Drying | 30-50 -75 | 0.40 | 70 | 28 | - | | |
| 45) | 8.2 | Preparation of materials; work on kilns and mixers | 150 -200-300 | 0.40 | 70 | 28 | 50 | | |
| 46) | 8.3 | General machine work | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 47) | 8.4 | Rough forms | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 48) | **9** | **Industrial Activities and Crafts-Ceramics, Tiles, Glass, Glassware** | | | | | | | |
| 49) | 9.1 | Drying | 30 -50- 75 | 0.40 | 70 | 28 | - | | |
| 50) | 9.2 | Preparation, general machine work | 200 -300-500 | 0.60 | 80 | 25 | 100 | | |
| 51) | 9.3 | Enamelling, rolling, pressing, shaping simple parts, glazing, glass blowing | 200 -300-500 | 0.60 | 80 | 25 | 100 | | |
| 52) | 9.4 | Grinding, engraving, glass polishing, shaping precision parts, manufacture of glass instruments | 500-750-1000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 53) | 9.5 | Grinding of optical glass, crystal, hand grinding and engraving | 500-750-1000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 54) | 9.6 | Precision work, e.g. decorative grinding, hand painting | 750-1000-1000 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 55) | 9.7 | Manufacture of synthetic precious stones | 1000-1500-2000 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 56) | **10** | **Industrial Activities and Crafts-Chemical, Plastics and Rubber Industry** | | | | | | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 57) | 10.1 | Remote- operated processing installations | 30 -50-75 | 0.40 | 70 | - | - | | |
| 58) | 10.2 | Processing installations with limited manual intervention | 100-150-200 | 0.40 | 70 | 28 | 50 | | |
| 59) | 10.3 | Constantly manned work stations in processing installations | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 60) | 10.4 | Precision measuring rooms, laboratories | 300-500 -750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 61) | 10.5 | Precision measuring rooms, laboratories | 300-500 -750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 62) | 10.6 | Pharmaceuti cal production | 300-500 -750 | 0.60 | 80 | 22 | 150 | | |
| 63) | 10.7 | Tyre production | 300-500 -750 | 0.60 | 80 | 22 | 150 | | |
| 64) | 10.8 | Colour inspection | 750-1000-1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 65) | 10.9 | Cutting, finishing, inspection | 500-750-1000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 66) | **11** | **Industrial Activities and Crafts-Electrical and Electronic Industry** | | | | | | | |
| 67) | 11.1 | Cable and wire manufacture | 200 -300-500 | 0.60 | 80 | 25 | 100 | | |
| 68) | 11.2 | Winding-large coils | 200 -300-500 | 0.60 | 80 | 25 | 100 | | |
| 69) | 11.3 | Winding-medium-sized coils | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 70) | 11.4 | Winding-small coils | 500-750-1000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 71) | 11.5 | Coil impregnating | 200 -300-500 | 0.60 | 80 | 25 | 100 | | |
| 72) | 11.6 | Galvanising | 200 -300-500 | 0.60 | 80 | 25 | 100 | | |
| 73) | 11.7 | Assembly work:-rough, e.g. large transformers | 200 -300-500 | 0.60 | 80 | 25 | 100 | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 74) | 11.8 | Assembly work:- medium, e.g. switchboards | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 75) | 11.9 | Assembly work:- fine, e.g. telephones, radios, IT equipment (computers) | 500-750-1000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 76) | 11.10 | Assembly work:- precision, e.g. measuring equipment, printed circuit boards | 750-1000-1500 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 77) | 11.11 | Electronic workshops, testing, adjusting | 1000-1500-2000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 78) | **12** | **Industrial Activities and Crafts-Food Stuffs and Luxury Food Industry** | | | | | | | |
| 79) | 12.1 | Work stations | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 80) | 12.2 | Sorting and washing of products, milling, mixing, packing | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 81) | 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 | | |
| 82) | 12.4 | Cutting and sorting of fruit and vegetables | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 83) | 12.5 | Manufacture of delicatessen foods, | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 84) | 12.6 | Inspection of glasses and bottles, product control, trimming, sorting, decoration | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 85) | 12.7 | Laboratories | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 86) | 12.8 | Colour inspection | 750-1000-1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 87) | **13** | **Industrial Activities and Crafts-Foundries and Metal Casting** | | | | | | | |
| 88) | 13.1 | Man-size underfloor tunnels, cellars, etc. | 30 -50- 75 | 0.40 | 70 | - | - | | |
| 89) | 13.2 | Platforms | 75-100-150 | 0.40 | 70 | 25 | 50 | | |
| 90) | 13.3 | Sand preparation | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 91) | 13.4 | Dressing | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 92) | 13.5 | Work stations at cupola and mixer | 150 -200-300 | 0.40 | 80 | 25 | 50 | | |
| 93) | 13.6 | Casting bay | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 94) | 13.7 | Shake out areas | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 95) | 13.8 | Machine moulding | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 96) | 13.9 | Hand and core moulding | 200- 300-500 | 0.60 | 80 | 25 | 100 | | |
| 97) | 13.10 | Die casting | 200- 300-500 | 0.60 | 80 | 25 | 100 | | |
| 98) | 13.11 | Model building | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 99) | **14** | **Industrial Activities and Crafts-Hairdressers** | | | | | | | |
| 100) | 14.1 | Hairdressing | 300-500-750 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 101) | **15** | **Industrial Activities and Crafts – Jewellery Manufacturing** | | | | | | | |
| 102) | 15.1 | Working with precious stones | 1000 -1500-2000 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 103) | 15.2 | Manufacture of jewellery | 750-1000-1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 104) | 15.3 | Watch making (manual) | 1000-1500-2000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 105) | 15.4 | Watch making (automatic) | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 106) | **16** | **Industrial Activities and Crafts-Laundries and Dry Cleaning** | | | | | | | |
| 107) | 16.1 | Goods in, marking and sorting | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 108) | 16.2 | Washing and dry cleaning | | 0.60 | 80 | 25 | 100 | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| | | | 200-300-500 | | | | | | |
| 109) | 16.3 | Ironing, pressing | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 110) | 16.4 | Inspection and repairs | 500-750 – 1000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 111) | **17** | **Industrial Activities and Crafts-Leather and Leather Goods** | | | | | | | |
| 112) | 17.1 | Work on vats, barrels, pits | 150-200-300 | 0.40 | 80 | 25 | 75 | | |
| 113) | 17.2 | Fleshing, skiving, rubbing, tumbling of skins | 200-300-500 | 0.40 | 80 | 25 | 100 | | |
| 114) | 17.3 | Saddlery work, shoe manufacture: stitching, sewing, polishing, shaping, cutting, punching | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 115) | 17.4 | Sorting | 300-500-750 | 0.60 | 90 | 22 | 150 | | |
| 116) | 17.5 | Leather dyeing (machine) | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 117) | 17.6 | Quality control | 750-1000-1500 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 118) | 17.7 | Colour inspection | 750-1000-1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 119) | 17.8 | Shoe making | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 120) | 17.9 | Glove making | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 121) | **18** | **Industrial Activities and Crafts-Metal Working and Processing** | | | | | | | |
| 122) | 18.1 | Open die forging | 150-200-300 | 0.60 | 80 | 25 | 50 | | |
| 123) | 18.2 | Drop forging | 200-300-500 | 0.60 | 80 | 25 | 75 | | |
| 124) | 18.3 | Welding | 200-300-500 | 0.60 | 80 | 25 | 75 | | |
| 125) | 18.4 | Rough and average machining: tolerances ≥ 0,1 mm | 200-300-500 | 0.60 | 80 | 22 | 75 | | |

| Sl. No. | Ref. No. | Type of task/activity area | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 126) | 18.5 | Precision machining; grinding: tolerances < 0,1 mm | 300-500-750 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 127) | 18.6 | Scribing; inspection | 500-750-1000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 128) | 18.7 | Wire and pipe drawing shops; cold forming | 200-300-500 | 0.60 | 80 | 25 | 75 | | |
| 129) | 18.8 | Plate machining: thickness ≥ 5 mm | 150-200-300 | 0.60 | 80 | 25 | 50 | | |
| 130) | 18.9 | Sheet metalwork: thickness < 5 mm | 200-300-500 | 0.60 | 80 | 22 | 75 | | |
| 131) | 18.10 | Tool making; cutting equipment manufacture | 500-750-1000 | 0.70 | 80 | 19 | 150 | | |
| 132) | 18.11 | Assembly: | | | | | | | |
| 133) | | - rough | 150-200-300 | 0.60 | 60 | 25 | 50 | | |
| 134) | | - medium | 200-300-500 | 0.60 | 80 | 25 | 75 | | |
| 135) | | - fine | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 136) | | - precision | 500-750-1000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 137) | | Galvanizing | 200-300-500 | 0.60 | 80 | 25 | 75 | | |
| 138) | 18.12 | Surface preparation and painting | 500-750-1000 | 0.70 | 80 | 25 | 150 | | |
| 139) | 18.13 | Tool, template and jig making, precision mechanics, micro-mechanics | 750-1000-1500 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 140) | **19** | **Industrial Activities and Crafts-Paper and Paper Goods** | | | | | | | |
| 141) | 19.1 | Edge runners, pulp mills | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 142) | 19.2 | Paper manufacture and processing, paper and corrugating machines, | 200-300-500 | 0.60 | 80 | 25 | 75 | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| | | cardboard manufacture | | | | | | | |
| 143) | 19.3 | Standard bookbinding work, e.g. folding, sorting, gluing, cutting, embossing, sewing | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 144) | **20** | **Industrial Activities and Crafts-Power Stations** | | | | | | | |
| 145) | 20.1 | Fuel supply plant | 30-50-75 | 0.40 | 70 | - | - | - | - |
| 146) | 20.2 | Boiler house | 75-100-150 | 0.40 | 70 | 28 | 50 | | |
| 147) | 20.3 | Machine halls | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 148) | 20.4 | Side rooms, e.g. pump rooms, condenser rooms, etc.; switchboards (inside buildings) | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 149) | 20.5 | Control rooms | 300-500-750 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 150) | **21** | **Industrial Activities and Crafts-Printers** | | | | | | | |
| 151) | 21.1 | Cutting, gilding, embossing, block engraving, work on | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 152) | 21.2 | Paper sorting and hand printing | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 153) | 21.3 | Type setting, retouching, lithography | 750-1000 -1500 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 154) | 21.4 | Colour inspection in multicoloured printing | 1000 -1500 -2000 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 155) | 21.5 | Steel and copper engraving | 1500- 2000-3000 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 156) | **22** | **Industrial Activities and Crafts-Rolling Mills, Iron and Steel Works** | | | | | | | |
| 157) | 22.1 | Production plants without manual operation | 30-50-75 | 0.40 | 70 | - | - | | |
| 158) | 22.2 | Production plants with occasional manual operation | 100-150 -200 | 0.40 | 70 | 28 | 50 | | |

| Sl. No. | Ref. No. | Type of task/activity area | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 159) | 22.3 | Production plants with continuous manual operation | 150-200-300 | 0.60 | 80 | 25 | 50 | | |
| 160) | 22.4 | Slab Store | 30-50-75 | 0.40 | 70 | - | - | | |
| 161) | 22.8 | Furnaces | 150-200-300 | 0.40 | 70 | 25 | 50 | | |
| 162) | 22.9 | Mill train; coiler; shear line | 200-300-500 | 0.60 | 70 | 25 | 75 | | |
| 163) | 22.10 | Control platforms; control panels | 200-300-500 | 0.60 | 80 | 22 | 75 | | |
| 164) | 22.11 | Test, measurement and inspection | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 165) | 22.12 | Underfloor man-sized tunnels; belt sections, cellars, etc. | 30-50-75 | 0.40 | 70 | - | | | |
| 166) | **23** | **Industrial Activities and Crafts-Textile Manufacture and Processing** | | | | | | | |
| 167) | 23.1 | Work stations and zones in baths, bale opening | 150-200-300 | 0.60 | 70 | 25 | 50 | | |
| 168) | 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 | | |
| 169) | 23.3 | Spinning, plying, reeling, winding | 300-500-750 | 0.60 | 70 | 22 | 150 | | |
| 170) | 23.4 | Warping, weaving, braiding, knitting | 300-500-750 | 0.60 | 70 | 22 | 150 | | |
| 171) | 23.5 | Sewing, fine knitting, taking up stitches | 500-750-1000 | 0.70 | 80 | 22 | 150 | | |
| 172) | 23.6 | Manual design, drawing patterns | 500-750-1000 | 0.70 | 90 | 22 | 150 | | |
| 173) | 23.7 | Finishing, dyeing | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 174) | 23.8 | Drying room | 75-100-150 | 0.40 | 60 | 28 | 50 | | |
| 175) | 23.9 | Automatic fabric printing | 300-500-750 | 0.60 | 90 | 25 | 100 | | |

| Sl. No. | Ref. No. | Type of task/activity area | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 176) | 23.10 | Burling, picking, trimming | 750-1000 - 1500 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 177) | 23.11 | Colour inspection; fabric control | 750-1000 - 1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 178) | 23.12 | Invisible mending | 1250-1500 - 2000 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 179) | 23.13 | Hat manufacturing | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 180) | **24** | **Industrial Activities and Crafts-Vehicle Construction and Repair** | | | | | | | |
| 181) | 24.1 | Press shop - large parts | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 182) | 24.2 | Press shop - visual inspection | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 183) | 24.3 | Body work and assembly-automatic line | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 184) | 24.4 | Body work and assembly-manual welding | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 185) | 24.5 | Painting, spraying chamber, polishing chamber | 500-750-1000 | 0.70 | 80 | 22 | 150 | | |
| 186) | 24.6 | Painting, inspection, touch-up and polishing | 750-1000 - 1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 187) | 24.7 | Upholstery manufacture (manual) | 750-1000 - 1500 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 188) | 24.8 | Detailing: Subparts assembly (doors, dashboard, upholstery) Underchassis assembly Motor and mechanical assembly Final assembly conveyor line | 500-750-1000 | 0.70 | 80 | 22 | 150 | | |
| 189) | 24.9 | Detailing :- work with electronics | 500-750-1000 | 0.60 | 90 | 22 | 150 | | |
| 190) | 24.10 | Final inspection | 750-1000 - 1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |

| Sl. No. | Ref. No. | Type of task/activity area | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 191) | 24.11 | General vehicle services, repair and testing | 300-500-750 | 0.60 | 80 | 22 | 100 | | |
| 192) | **25** | **Industrial Activities and Crafts-Wood Working and Processing** | | | | | | | |
| 193) | 25.1 | Automatic processing, e.g. drying, plywood manufacturing | 30-50-75 | 0.40 | 70 | 28 | - | | |
| 194) | 25.2 | Steam pits | 100-150 - 200 | 0,40 | 70 | 28 | 50 | | |
| 195) | 25.3 | Saw frame | 200 -300-500 | 0.60 | 70 | 25 | 100 | | |
| 196) | 25.4 | Work at joiner's bench, gluing, assembly | 200-300-500 | 0.60 | 80 | 25 | 100 | | |
| 197) | 25.5 | Polishing, painting, fancy joinery | 500-750-1000 | 0.70 | 80 | 22 | 150 | | |
| 198) | 25.6 | Work on wood working machines, e.g. turning, fluting, dressing, rebating, grooving, cutting, sawing, sinking | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 199) | 25.7 | Selection of veneer woods | 500-750-1000 | 0.90 | 70 | 22 | 150 | | |
| 200) | 25.8 | Marquetry, inlay work | 500-750-1000 | 0.90 | 70 | 22 | 150 | | |
| 201) | 25.9 | Quality control, inspection | 750-1000-1500 | 0.90 | 70 | 19 | 150 | 75 | 50 |
| 202) | **26** | **Offices** | | | | | | | |
| 203) | 26.1 | Filing, copying, etc. | 200-300-500 | 0.40 | 80 | 19 | 100 | 75 | 50 |
| 204) | 26.2 | General office Area - Writing, typing, reading, data processing | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 205) | 26.3 | Private Cabins | 300-500-750 | 0.70 | 80 | 19 | 150 | 75 | 50 |
| 206) | 26.4 | CAD work stations | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 207) | 26.5 | Huddle / Breakout Area | 200-300-500 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 208) | 26.6 | Conference and meeting rooms | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 209) | 26.7 | Light On Presenter | 150-200-300 | | 80 | 19 | | | |
| 210) | 26.8 | Reception desk | 200-300 - 500 | 0.60 | 80 | 22 | 100 | 75 | 50 |
| 211) | 26.9 | Archiving | 150-200-300 | 0.40 | 80 | 25 | 75 | - | - |
| 212) | 26.10 | Canteens and Break out areas | 150-200-300 | 0.60 | 80 | 22 | | | |
| 213) | 26.11 | Resting rooms | 75-100-200 | 0.40 | 80 | 22 | | | |
| 214) | 26.12 | Rooms for Physical exercise | 200-300-500 | 0.40 | 80 | 22 | | | |
| 215) | 26.13 | Cloakroom (area), wash room | 150- 200-300 | 0.40 | 80 | 25 | 100 | 75 | 50 |
| 216) | 26.14 | Facial Lighting in front of mirrors | 200-300-500 | 0.40 | 80 | | | | |
| 217) | 26.15 | Sick bay | 300-500-750 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 218) | 26.16 | Rooms for medical attention | 300-500-750 | 0.40 | 90 | 19 | 100 | 75 | 50 |
| 219) | 26.17 | General cleaning | 75-100-150 | 0.40 | 80 | | | | |
| 220) | 26.18 | Corridors and circulation areas | 75 -100-150 | 0.40 | 70 | 28 | | | |
| 221) | 26.19 | Stairs, escalators, travolators | 75-100-150 | 0.40 | 70 | 25 | | | |
| 222) | 26.20 | Elevators, lifts | 75-100-150 | 0.40 | 70 | 25 | | | |
| 223) | 26.21 | Area in front of lifts, elevators and escalators | 150-200-300 | 0.40 | 70 | 25 | | 75 | 50 |
| 224) | 26.22 | Auditorium, training hall, town hall, amphitheater | 300-500-750 | 0.60 | 80 | 19 | 75 | 50 | |
| 225) | **27** | **Retail Premises** | | | | | | | |
| 226) | 27.1 | General sales area | 200-300-500 | 0.40 | 80 | 22 | 75 | | |
| 227) | 27.2 | Till area | 300-500 - 750 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 228) | 27.3 | Wrapper table | 300-500-750 | 0.60 | 80 | 22 | 100 | | |
| 229) | 27.4 | Storage area | 200-300-500 | 0.40 | 80 | 25 | 50 | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 230) | 27.5 | Dressing/fitting room | 200-300-500 | 0.4 | 90 | - | - | | |
| 231) | **28** | **Places of Public Assembly General Areas** | | | | | | | |
| 232) | 28.1 | Entrance halls | 75-100-150 | 0.40 | 80 | 22 | 50 | | |
| 233) | 28.2 | Cloakrooms | 150-200-300 | 0.40 | 80 | 25 | 75 | | |
| 234) | 28.3 | Lounges | 150-200-300 | 0.40 | 80 | 22 | 75 | | |
| 235) | 28.4 | Ticket offices | 200-300-500 | 0.60 | 80 | 22 | 75 | | |
| 236) | **29** | **Places of Public Assembly- Restaurants and Hotels** | | | | | | | |
| 237) | 29.1 | Reception/cashier desk, porters desk | 200-300-500 | 0.60 | 80 | 22 | 100 | | |
| 238) | 29.2 | Kitchen | 300-500-750 | 0.60 | 80 | 22 | 100 | | |
| 239) | 29.3 | Restaurant, dining room, function room | - | - | 80 | - | - | | |
| 240) | 29.4 | Self-service restaurant | 150-200-300 | 0.40 | 80 | 22 | 75 | | |
| 241) | 29.5 | Buffet | 200-300-500 | 0.60 | 80 | 22 | 75 | | |
| 242) | 29.6 | Conference rooms | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 243) | 29.7 | Corridors | 75-100-150 | 0.40 | 80 | 25 | 50 | | |
| 244) | **30** | **Places of Public Assembly-Theatres, Concert Halls, Cinemas, Places for Entertainment** | | | | | | | |
| 245) | 30.1 | Practice rooms | 200-300-500 | 0.60 | 80 | 22 | 100 | | |
| 246) | 30.2 | Dressing rooms | 200-300-500 | 0.60 | 90 | 22 | 100 | | |
| 247) | 30.3 | Seating areas-maintenance, cleaning | 150-200-300 | 0.40 | 80 | 22 | 50 | | |
| 248) | 30.4 | Stage area rigging | 200-300-500 | 0.40 | 80 | 25 | 75 | | |
| 249) | **31** | **Places of Public Assembly-Trade Fairs, Exhibition Halls** | | | | | | | |
| 250) | 31.1 | General lighting | 200-300-500 | 0.40 | 80 | 22 | 50 | | |
| 251) | **32** | **Places of Public Assembly-Museums** | | | | | | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$**,wall** $l_x$ | $\bar{E}_m$**,ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 252) | 32.1 | Exhibits, insensitive to light | - | - | 80 | - | - | - | - |
| 253) | 32.2 | Exhibits sensitive to light | - | - | 80 | - | - | - | - |
| 254) | **33** | **Places of Public Assembly-Libraries** | | | | | | | |
| 255) | 33.1 | Bookshelves | 150 -200-300 | 0.40 | 80 | 19 | - | - | - |
| 256) | 33.2 | Reading area | 300-500-750 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 257) | 33.3 | Counters | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 258) | 33.4 | General lighting | 200-300-500 | 0.40 | 80 | 22 | 75 | | |
| 259) | **34** | **Places of Public Assembly-Car Parks (Indoor)** | | | | | | | |
| 260) | 34.1 | Entry/exit ramps (during daylight hours) | 200-300-500 | 0.40 | 70 | 25 | 75 | | |
| 261) | 34.2 | Entry/exit ramps (at night) | 50-75-100 | 0.40 | 70 | 25 | 50 | | |
| 262) | 34.3 | Traffic lanes, internal ramps and pedestrian paths | 50-75-100 | 0.40 | 70 | 25 | 50 | | |
| 263) | 34.4 | Parking areas - not open to public | 50-75-100 | 0.25 | 70 | - | 50 | | |
| 264) | 34.5 | Parking areas - open to public with a large number of users e.g shopping centers, arenas. | 100-150-200 | 0.40 | 70 | - | 50 | | |
| 265) | 34.6 | Ticket office | 200-300-500 | 0.60 | 80 | 19 | 75 | 75 | 50 |
| 266) | **35** | **Educational Premises-Nursery School, Play School** | | | | | | | |
| 267) | 35.1 | Play room | 200-300-500 | 0.40 | 80 | 22 | 100 | 75 | 50 |
| 268) | 35.2 | Nursery | 200-300-500 | 0.40 | 80 | 22 | 100 | 75 | 50 |
| 269) | 35.3 | Handicraft room | 200-300-500 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 270) | **36** | **Educational Premises-Educational Buildings** | | | | | | | |
| 271) | 36.1 | Classroom-General activities | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 272) | 36.2 | Auditorium, lecture halls | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 273) | 36.3 | Attending lecture in seating areas in auditoriums and lecture halls | 150-200-300 | 0.60 | 80 | 19 | 75 | 75 | 50 |
| 274) | 36.4 | Black, green and white boards | 300-500-750 | 0.70 | 80 | 19 | - | | |
| 275) | 36.5 | Black, green and white boards in auditorium and lecture halls | 300-500-750 | 0.60 | 80 | 19 | - | | |
| 276) | 36.6 | Projector and smartboard presentation | - | - | - | - | - | | |
| 277) | 36.7 | Display board | 150-200-300 | 0.60 | 80 | 19 | - | | |
| 278) | 36.8 | Demonstration table in auditoriums and lecture halls | 500-750-1000 | 0.70 | 80 | 19 | - | | |
| 279) | 36.9 | Light on teacher / presenter | - | - | 80 | - | 150 | | |
| 280) | 36.10 | Light on podium area | 200-300-500 | 0.70 | 80 | - | - | | |
| 281) | 36.11 | Computer work only | 200-300-500 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 282) | 36.12 | Art rooms in art schools | 500-750-1000 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 283) | 36.13 | Technical drawing rooms | 500-750-1000 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 284) | 36.14 | Practical rooms and laboratories | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 285) | 36.15 | Handcraft rooms | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 286) | 36.16 | Teaching workshop | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 287) | 36.17 | Preparation rooms and workshops | 300-500-750 | 0.60 | 80 | 22 | 150 | | |
| 288) | 36.18 | Entrance halls | 150-200-300 | 0.40 | 80 | 22 | 75 | | |
| 289) | 36.19 | Circulation areas, corridors | 75-100-150 | 0.40 | 80 | 25 | 50 | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 290) | 36.20 | Stairs | 100-150-200 | 0.40 | 80 | 25 | 50 | | |
| 291) | 36.21 | Student common rooms and assembly halls | 150-200-300 | 0.40 | 80 | 22 | 75 | | |
| 292) | 36.22 | Teachers rooms | 200-300-500 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 293) | 36.23 | Library: bookshelves | 150-200-300 | 0.60 | 80 | 19 | 75 | 75 | 50 |
| 294) | 36.24 | Library: reading areas | 300-500-750 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 295) | 36.25 | Stock rooms for teaching materials | 75 – 100-150 | 0.40 | 80 | 25 | 50 | | |
| 296) | 36.26 | Sports halls, gymnasiums, swimming pools | 200 – 300 – 500 | 0.60 | 80 | 22 | 100 | | |
| 297) | 36.27 | School canteens | 150-200-300 | 0.40 | 80 | 22 | 75 | | |
| 298) | 36.28 | Kitchen | 300 – 500-750 | 0.60 | 80 | 22 | 100 | | |
| 299) | **37** | **Health Care Premises-Rooms for General Use** | | | | | | | |
| 300) | 37.1 | Waiting rooms | 150-200-300 | 0.40 | 80 | 22 | 75 | 75 | 30 |
| 301) | 37.2 | Corridors: during the day | 75-100-150 | 0.40 | 80 | 22 | 50 | 50 | 30 |
| 302) | 37.3 | Corridors: cleaning | 75-100-150 | 0.40 | 80 | 22 | 50 | 50 | 30 |
| 303) | 37.4 | Corridors: during the night | 30-50-75 | 0.40 | 80 | 22 | - | - | - |
| 304) | 37.5 | Corridors with multi- purpose use (e.g. preexamination of patients) | 150-200-300 | 0.60 | 80 | 22 | 75 | 75 | 50 |
| 305) | 37.6 | Day rooms | 200-300-500 | 0.60 | 80 | 22 | 75 | 75 | 50 |
| 306) | 37.7 | Elevators, lifts for persons and visitors | 75- 100-150 | 0.60 | 80 | 22 | 50 | 50 | 30 |
| 307) | 37.8 | Service lifts | 150-200-300 | 0.60 | 80 | 22 | 75 | 75 | 50 |
| 308) | **38** | **Health Care Premises-Staff Rooms** | | | | | | | |
| 309) | 38.1 | Staff office | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 310) | 38.2 | Staff rooms | 200-300-500 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 311) | **39** | **Health Care Premises-Wards, Maternity Wards** | | | | | | | |
| 312) | 39.1 | General lighting | 75-100-150 | 0.70 | 80 | 19 | 50 | 50 | 30 |
| 313) | 39.2 | Reading lighting | 200-300-500 | 0.70 | 80 | 19 | 100 | 75 | 50 |
| 314) | 39.3 | Wards-Simple examinations | 200-300-500 | 0.70 | 80 | 19 | 100 | 75 | 50 |
| 315) | 39.4 | Examination and treatment | 750-1000 -1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 316) | 39.5 | Night lighting, observation lighting | 5 | - | 80 | - | - | - | - |
| 317) | 39.6 | Bathrooms and toilets for patients | 150-200-300 | 0.70 | 90 | 22 | 75 | 75 | 50 |
| 318) | **40** | **Health Care Premises-Examination Rooms (General)** | | | | | | | |
| 319) | 40.1 | General lighting | 300-500-750 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 320) | 40.2 | Examination and treatment | 750-1000-1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 321) | **41** | **Health Care Premises-Eye Examination Rooms** | | | | | | | |
| 322) | 41.1 | General lighting | 300-500-750 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 323) | 41.2 | Examination of the outer eye | 750-1000-1500 | - | 90 | - | 150 | 75 | 50 |
| 324) | 41.3 | Reading and colour vision tests with vision charts | 300-500-750 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 325) | **42** | **Health Care Premises-Ear Examination Rooms** | | | | | | | |
| 326) | 42.1 | General lighting | 300-500-750 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 327) | 42.2 | Ear examination | 750-1000-1500 | - | 90 | - | 150 | 75 | 50 |
| 328) | **43** | **Health Care Premises-Scanner Rooms** | | | | | | | |
| 329) | 43.1 | General lighting | 200-300-500 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 330) | 43.2 | Scanners with image enhancers and television systems | 30-50-75 | - | 80 | 19 | - | - | - |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 331) | **44** | **Health Care Premises-Delivery Rooms** | | | | | | | |
| 332) | 44.1 | General lighting | 200-300-500 | 0.60 | 90 | 19 | 100 | 75 | 50 |
| 333) | 44.2 | Examination and treatment | 750-1000-1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 334) | **45** | **Health Care Premises-Treatment Rooms (General)** | | | | | | | |
| 335) | 45.1 | Dialysis | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 336) | 45.2 | Dermatology | 300-500-750 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 337) | 45.3 | Endoscopy | 200-300-500 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 338) | 45.4 | Plastering | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 339) | 45.5 | Medical baths | 200-300-500 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 340) | 45.6 | Massage and radiotherapy | 200-300-500 | 0.60 | 80 | 19 | 100 | 75 | 50 |
| 341) | **46** | **Health Care Premises-Operating Areas** | | | | | | | |
| 342) | 46.1 | Pre-op and recovery rooms | 500-750-1000 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 343) | 46.2 | Operating cavity surround | 750- 1000-1500 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 344) | 46.3 | Operating theatre | 750-100 -1500 | 0.60 | 90 | 19 | - | - | - |
| 345) | 46.4 | Operating cavity | - | - | 90 | - | - | - | - |
| 346) | **47** | **Health Care Premises-Intensive Care Unit** | | | | | | | |
| 347) | 47.1 | General lighting | 200-300-500 | 0.60 | 90 | 19 | 50 | 50 | 30 |
| 348) | 47.2 | Simple examinations | 300-500-750 | 0.60 | 90 | 19 | 100 | 75 | 50 |
| 349) | 47.3 | Examination and treatment | 1000-1250 -1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 350) | 47.4 | Night watch | 20 | - | 90 | 19 | - | - | - |
| 351) | **48** | **Health Care Premises-Dentists** | | | | | | | |
| 352) | 48.1 | General lighting | 300-500-750 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 353) | 48.2 | At the patient | 750-1000-1500 | 0.70 | 90 | - | 150 | 75 | 50 |
| 354) | 48.3 | Operating cavity | - | - | - | - | - | - | - |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 355) | 48.4 | White teeth matching | - | - | - | - | - | - | - |
| 356) | **49** | **Health Care Premises-Laboratories and Pharmacies** | | | | | | | |
| 357) | 49.1 | General lighting | 300-500-750 | 0.60 | 80 | 19 | 150 | 75 | 50 |
| 358) | 49.2 | Colour inspection | 750-1000-1500 | 0.70 | 90 | 19 | 150 | 75 | 50 |
| 359) | **50** | **Health Care Premises-Decontamination Rooms** | | | | | | | |
| 360) | 50.1 | Sterilization | 300-500-750 | 0.60 | 80 | 22 | 100 | 75 | 50 |
| 361) | 50.2 | Disinfection | 300-500-750 | 0.60 | 80 | 22 | 100 | 75 | 50 |
| 362) | **51** | **Health Care Premises-Autopsy Rooms and Mortuaries** | | | | | | | |
| 363) | 51.1 | General lighting | 300-500-750 | 0.60 | 90 | 19 | 150 | 75 | 50 |
| 364) | 51.2 | Autopsy table and dissecting table | 500 -7500 | 0.70 | 90 | - | 150 | 75 | 50 |
| 365) | **52** | **Transportation Areas-Airports** | | | | | | | |
| 366) | 52.1 | Arrival and departure halls, baggage claim areas | 150-200-300 | 0.40 | 80 | 22 | 75 | | |
| 367) | 52.2 | Connecting areas | 100-150-200 | 0.40 | 80 | 22 | 50 | | |
| 368) | 52.3 | Information desks, check-in desks | 300-500-750 | 0.70 | 80 | 19 | 150 | | |
| 369) | 52.4 | Customs and passport control desks | 300-500-750 | 0.70 | 80 | 19 | 150 | | |
| 370) | 52.5 | Waiting areas | 150-200-300 | 0.40 | 80 | 22 | 50 | | |
| 371) | 52.6 | Luggage storage rooms | 150-200-300 | 0.40 | 80 | 25 | 50 | | |
| 372) | 52.7 | Security check areas | 200-300-500 | 0.60 | 80 | 19 | 100 | | |
| 373) | 52.8 | Air traffic control tower | 300-500-750 | 0.60 | 80 | 19 | 50 | 75 | 50 |
| 374) | 52.9 | Tasks in hangars: Testing and repair areas Engine test areas Measuring areas | 300-500-750 | 0.60 | 80 | 22 | 50 | | |

| **Sl. No.** | **Ref. No.** | **Type of task/activity area** | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,**wall** $l_x$ | $\bar{E}_m$,**ceiling** $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** | **(10)** |
| 375) | **53** | **Transportation Areas-Railway Installations** | | | | | | | |
| 376) | 53.1 | Fully enclosed platforms, small number of passengers | 30-50-75 | 0.30 | 80 | - | - | - | - |
| 377) | 53.2 | Fully enclosed platforms, medium number of passengers | 75-100-150 | 0.40 | 80 | - | - | - | - |
| 378) | 53.3 | Fully enclosed platforms, large number of passengers | 150-200-300 | 0.50 | 80 | - | - | - | - |
| 379) | 53.4 | Fully enclosed passenger subways (underpasses), small number of passengers | 30-50-75 | 0.30 | 80 | - | - | - | - |
| 380) | 53.5 | Fully enclosed passenger subways (underpasses), medium number of passengers | 75-100-150 | 0.40 | 80 | - | - | - | - |
| 381) | 53.6 | Fully enclosed passenger subways (underpasses), large number of passengers | 150-200-300 | 0.50 | 80 | - | - | - | - |
| 382) | 53.7 | Stairs, ecalators, small number of passengers | 30-50-75 | 0.30 | 80 | - | - | - | - |
| 383) | 53.8 | Stairs, ecalators, medium number of passengers | 75-100-150 | 0.40 | 80 | - | - | - | - |
| 384) | 53.9 | Stairs, ecalators, large number of passengers | 150-200-300 | 0.50 | 80 | - | - | - | - |
| 385) | 53.10 | Ticket hall and concourse | 150-200-300 | 0.50 | 80 | 28 | 75 | | |

| Sl. No. | Ref. No. | Type of task/activity area | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| 386) | 53.11 | Ticket counters and luggage offices | 200-300-500 | 0.50 | 80 | 19 | 100 | 75 | 50 |
| 387) | 53.12 | Waiting rooms | 150-200-300 | 0.40 | 80 | 22 | 75 | | |
| 388) | 53.13 | Entrance halls, station halls | 150-200-300 | 0.40 | 80 | - | 75 | | |
| 389) | 53.14 | Switch and plant rooms | 150-200-300 | 0.50 | 80 | 28 | 50 | | |
| 390) | 53.15 | Railway control centre (area of dispatcher) | 150-200-300 | 0.50 | 80 | 19 | - | - | - |
| 391) | 53.16 | Access tunnels | 30-50-75 | 0.40 | 20 | - | - | - | - |
| 392) | 53.17 | Assembly work in maintenance sheds - rough | 150-200-300 | 0.40 | 80 | - | - | - | - |
| 393) | 53.18 | Assembly work in maintenance sheds - medium | 200-300-500 | 0.50 | 80 | - | - | - | - |
| 394) | 53.19 | Assembly work in maintenance sheds - fine | 300-500 -750 | 0.60 | 80 | - | - | - | - |
| 395) | 53.20 | Assembly work in maintenance sheds precision | 500-750-1000 | 0.70 | 80 | - | - | - | - |
| 396) | 53.21 | Circulation areas for maintenance halls for railway vehicles (without additional vehicular traffic) | 75-100-150 | 0.25 | 80 | - | - | - | - |
| 397) | 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 here is vertical at bookshelves.
2 For 36.4, 36.7 and 36.23, Vertical Illuminance.
3 For 40.1 & 40.2, Preferred Color temperature should be 4000K to 5000K.
4 For 41.1, preferred Color temperature should be 4000K to 5000K.

| Sl. No. | Ref. No. | Type of task/activity area | $\bar{E}_m$ $(L_x)$ | $U_o$ | $R_a$ | $R_{UGL}$ | $\bar{E}_{m,z}$ $l_x$ | $\bar{E}_m$,wall $l_x$ | $\bar{E}_m$,ceiling $l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| | | 5 For 41.2 and 41.3, preferred Color temperature should be 4000K to 6500K.<br>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. | | | | | | | |

**4.1.5.1** *Corridors, passages and stairways*

Accidents may result if people leave a well-lighted working area and pass immediately into corridors or on to stairways where the lighting is inadequate, as the time needed for adaptation to the lower level may be too long to permit obstacles or the treads of stairs to be seen sufficiently quickly. For the same reason, it is desirable that the illumination level of rooms which open off a working area should be fairly high even though the rooms may be used only occasionally.

It is important, when lighting stairways, to prevent disability from glare caused by direct sight of bright sources to emphasize the edges of the treads and to avoid confusing shadows. The same precautions should be taken in the lighting of catwalks and stairways on outdoor industrial plants.

**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.
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.

**4.1.8** *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 National Lighting Code 2010. 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 (Ra) is obtained by the average value for eight samples (*see* Fig. 8 of Part 2 'Physics of Light Section 3 'Colour' of National Lighting Code 2010). For perfect agreement of colour, the R1 value should be 100. In general:

$$Ra = 1/ (R1 + R2 + R3 + R4 + ......+ R8)$$

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

$$Ri = 100 - 4.6\Delta Ei,$$

where,

$\Delta Ei$ = Chromaticity shift on the CIE chromaticity diagram for each sample.

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

| *Colour Rendering Evaluated* | *Ra (General Colour Rendering Index)* |
|---|---|
| True | 90 - 100 |
| Good | 70 - 90 |
| Moderate | 50 - 70 |

**4.1.9** For detailed information regarding principles of good lighting, reference may be made to good practice [8-1(2)].

**4.2 Daylighting**

The primary source of lighting for daylighting is the sun. The light received by the earth from the sun consists of two parts, namely, direct solar illuminance and sky illuminance. For effective daylighting design, direct solar illuminance shall not be considered due to the risk of glare and overheating. Instead, only sky illuminance shall be accounted for in contributing to the natural illumination of building interiors during daylight hours. This approach ensures a more balanced, diffused light that enhances occupant comfort and minimizes energy consumption. ~~For the purposes of daylighting design, direct solar illuminance shall not be considered and only sky illuminance shall be taken as contributing to illumination of the building interiors during the day~~.

**4.2.1** The relative amount of sky illuminance 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 6.

**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, 9 000 lux for warm humid climate, 9 000 lux for temperate climate and 10 500 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 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 of Annex B.

a) The recommended sky component level should be ensured generally on the working plane at the following positions:
    1) At a distance of 3 m to 3.75 m from the window along the central line perpendicular to the window,
    2) At the centre of the room if more appropriate, and
    3) At fixed locations, such as school desks, black-boards and office tables.
b) 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.

**Table 6 Solar Altitudes (to the Nearest Degree) for Indian Latitudes**
(*Clause* 4.2.1)

| **Period of Year** | **22 June** | | | | | | **21 March and 23 September** | | | | | | **22 December** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hours of Day (Sun or Solar) | 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 |
| Latitude | 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) |
| 10°N | 18 | 31 | 45 | 58 | 70 | 77 | 15 | 30 | 44 | 59 | 72 | 80 | 9 | 23 | 35 | 46 | 53 | 57 |
| 13°N | 19 | 32 | 46 | 60 | 72 | 80 | 15 | 29 | 44 | 58 | 70 | 77 | 8 | 21 | 33 | 43 | 51 | 54 |
| 16°N | 20 | 33 | 47 | 61 | 74 | 83 | 14 | 29 | 43 | 56 | 68 | 74 | 7 | 19 | 31 | 41 | 48 | 51 |
| 19°N | 21 | 34 | 48 | 62 | 75 | 86 | 14 | 28 | 42 | 55 | 66 | 71 | 5 | 18 | 29 | 48 | 45 | 48 |
| 22°N | 22 | 35 | 49 | 62 | 75 | 89 | 14 | 28 | 41 | 53 | 64 | 68 | 4 | 16 | 27 | 36 | 42 | 45 |
| 25°N | 23 | 36 | 49 | 63 | 76 | 88 | 13 | 27 | 40 | 52 | 61 | 65 | 3 | 14 | 25 | 34 | 39 | 42 |
| 28°N | 23 | 36 | 49 | 63 | 76 | 86 | 13 | 26 | 39 | 50 | 59 | 62 | 1 | 13 | 23 | 31 | 37 | 39 |
| 31°N | 24 | 37 | 50 | 62 | 75 | 82 | 13 | 25 | 37 | 48 | 56 | 56 | - | 11 | 21 | 28 | 34 | 36 |
| 34°N | 25 | 37 | 49 | 62 | 73 | 79 | 12 | 25 | 36 | 46 | 53 | 56 | - | 9 | 18 | 26 | 31 | 33 |

**4.2.5.3** *Correction for glazing*

Where windows are glazed, the sky components obtained from Annex A shall be reduced by 10 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 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 [8-1(3)].

These values when multiplied by the correction factors, corresponding to the mean elevation of obstruction from the point in question as given in Table 7, can be taken as the external reflected components for that point.

**Table 7 Correction Factor for ERC**
(*Clause* 4.2.6)

| **Sl No.** | **Mean Angle of Elevation** (1) | **Correction Factor** (2) |
|---|---|---|
| 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 |

**4.2.6.1**-For method of calculating ERC, reference may be made to accepted standard {*see* Examples 10 and 11 given in Annex B of good practice [8-1(3)]}.

**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 [8-1(3)].

**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.

**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 8.

**Table 8 Relative Availability of Daylight on the Window Plane at Ground Level in a Four-Storeyed Building Blocks (Clear Design-Sky as Basis, Daylight Availability Taken as Unity on an Unobstructed Façade, 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 x Height)** | **Parallel Blocks facing Gaps Between Opposite Blocks (Length = 2 x 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 |

**4.2.10** For specified requirements for daylighting of special occupancies and areas, reference may be made to good practice [8-1(4)].

**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 5 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 5, 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 ($\Phi$) 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
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, taking into account the influence of the windows without curtains, shelves, almirahs and doors with different colours, etc, should be estimated.

c) *Calculation for Determining the Luminous Flux [see Table 22 of SP: 41 (S&T) – 1987 'Handbook on functional requirements of buildings other than industrial buildings']*

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

or, $$\phi = \frac{E_{\text{av}}.A}{\mu}$$ , for new condition, and

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

where

$\Phi$ = Total luminous flux of the light sources installed in the room, in lumens;

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

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

$\mu$ = utilization factor in new conditions; and

$d$ = maintenance factor.

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

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

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

where

$\Phi_{lamp}$ = luminous flux of each lamp, in lumens

$\Phi_{luminaires}$ = luminous flux of each luminaire, in lumens

$N_{lamp}$ = total number of lamps

$N_{luminaires}$ = total number of luminaires.

**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 SP : 41 (S&T) – 1987 'Handbook on functional requirements of buildings other than industrial buildings'].
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,

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

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.

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.

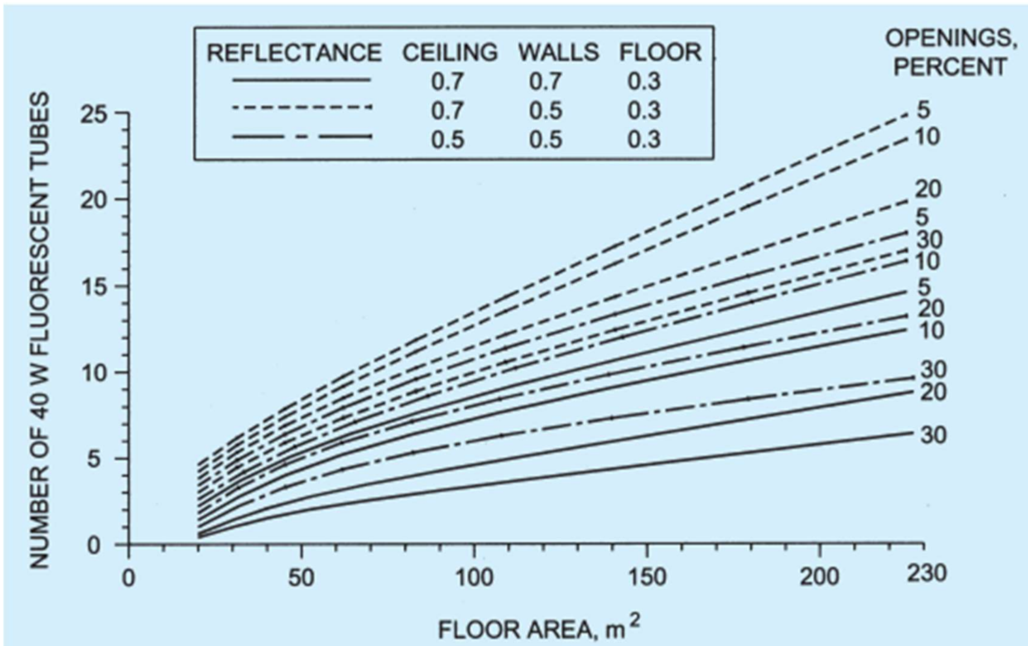



FIG. 3 SUPPLEMENTARY ARTIFICIAL LIGHTING FOR 40W FLUORESCENT TUBES

**4.3.4** For detailed information on the design aspects and principles of artificial lighting, reference may be made to good practice [8-1(2)].

**4.3.5** For specific requirements for lighting of special occupancies and areas, reference may be made to good practice [8-1(5)].

**4.3.6** Electrical installation aspect for artificial lighting shall be in accordance with Part 8 ‘Building Services', Section 2 'Electrical and Allied Installations’ of the Code.

**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 façade are not significant and a window facing such an obstruction may be regarded as a case of unobstructed window.

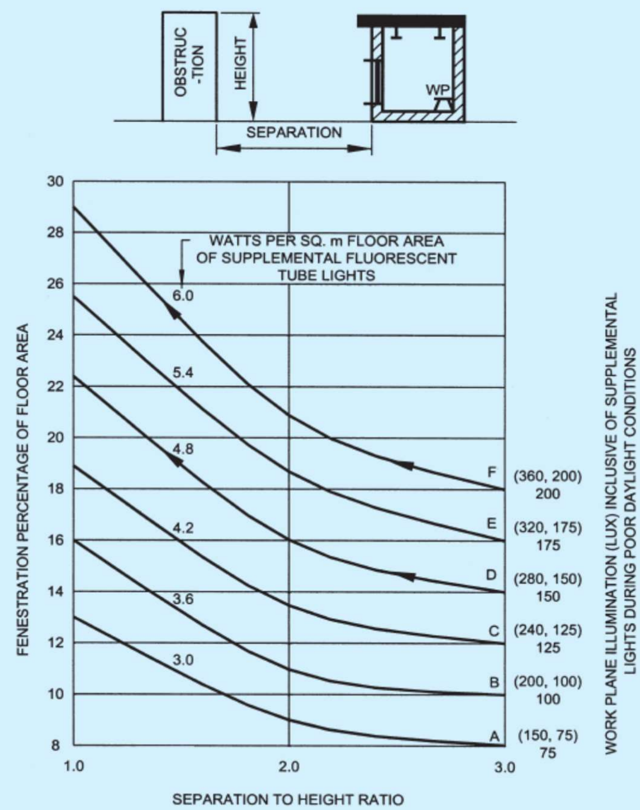



FIG. 4 NOMOGRAPH FOR DAYLIGHTING AND SUPPLEMENTAL LIGHTING DESIGN OF BUILDING

**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 center 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 3m, 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 per $m^2$ 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.

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.

**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 watts 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.

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 watts per $m^2$ 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.
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.
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. For example, high pressure sodium vapour lamps, which have very high luminous efficacy, are not suitable for commercial interiors because of poor colour rendering index and colour appearance, but are highly desirable in heavy industries. Also, the choice of light sources depends on the mounting height in the interiors. For example, fluorescent lamps are not preferred for mounting beyond 7 m height, when high pressure gas discharge lamps are preferred because of better optical control due to their compact size.

**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 9 along with average life in burning hours, Colour Rendering Index and Colour Temperature.

Following recommendations may be followed in the choice of light sources for different locations:

a) For supplementary artificial lighting of work area in office building care should be taken to use fluorescent lamps, which match with colour temperature of the daylight.
b) For residential buildings fluorescent lamps and/or CFLs of proper CRI and CCT are recommended to match with the colours and interior design of the room.
c) For commercial interiors, depending on the mounting heights and interior design, fluorescent lamps, CFLs and low wattage metal halide lamps are recommended. For highlighting the displays in show windows, hotels, etc, low wattage tubular or dichroic reflector type halogen lamps can be used.
d) For industrial lighting, depending on the mounting height and colour consideration fluorescent lamps, high pressure mercury vapour lamps or high pressure sodium vapour lamps are recommended.

**Table 9 Luminous Efficacy, Life, Lumen Maintenance and Colour Rendition of Light Sources**

(*Clause* 4.4.6.1)

| **Sl No.** | **Light Source** | **Wattage Range** W | **Efficacy** lm/W | **Average Life** h | **Lumen Maintenance** | **Colour Rendition** |
|---|---|---|---|---|---|---|
| (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) | Standard fluorescent lamps | 20 to 80 | 55 to 65 | 5 000 | Fair to good | Good |
| iv) | Compact fluorescent lamps (CFL) | 5 to 40 | 60 to 70 | 7 500 | Good | Good to very good |
| v) | Slim line fluorescent | 18 to 58 | 57 to 67 | 5 000 | Fair to good | Good |
| v) | High pressure mercury vapour lamps | 60 to 1 000 | 50 to 65 | 5 000 | Very low to fair | Federate |
| vi) | Blended - light lamps | 160 to 250 | 20 to 30 | 5 000 | Low to fair | Federate |
| vii) | High pressure sodium vapour lamps | 50 to 1 000 | 90 to 125 | 10 000 to 15 000 | Fair to good | Low to good |
| viii) | Metal halide lamps | 35 to 2 000 | 80 to 95 | 4 000 to 10 000 | Very low | Very good |
| ix) | Low pressure sodium | 10 to 180 | 100 to 200 | 10 000 to 20 000 | Good to very good | Poor |
| x) | LED | 0.5 to 2.0 | 60 to 100 | 10 000 | Very good | Good for white LED |

NOTES

**1** The table 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 to 70 percent energy if CFL lamps are replaced with Induction Lighting, and 40 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 for 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.
c) In residential buildings, bare fluorescent tubes are recommended. Wherever the incandescent lamps are employed, they should be provided with white enameled conical reflectors at an inclination of about 45° from vertical.

**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. This will tend to reduce the duration over which artificial lights will be used and minimize the wastage of energy. Depending upon the location of the building a minimum of three to six months interval for periodic cleaning of luminaries and window panes is recommended for maximum utilization of daylight and artificial lights. Ideal cleaning period of windows should be 3 months, during the dry season or if façade having extensive shading.

**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 photo controls 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 5.
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.

**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 nongrid 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 Planning and Design Guidelines for Circadian Lighting**

Circadian lighting, designed to align with human biological rhythms, is gaining importance in building environments to enhance occupant well-being and productivity. The primary aim of circadian lighting is to support the human circadian cycle by adjusting both light intensity and color temperature throughout the day. Morning light should provide higher intensity and cooler (blue-enriched) lighting to stimulate alertness, while evening lighting should transition to warmer tones, reducing intensity to aid relaxation and prepare for rest. The following guidelines have been developed to ensure effective implementation of circadian lighting in buildings:

a) Circadian lighting should be incorporated in key areas where occupants spend extended periods, such as residential spaces, offices, healthcare facilities, and educational institutions.
b) Special emphasis should be placed on bedrooms, workspaces, and recovery areas to ensure the lighting supports appropriate activities and physiological needs.
c) The lighting system must include dynamic controls that enable gradual changes in light intensity and color temperature to mimic natural daylight cycles. This enhances the synchrony of internal biological clocks with environmental light cues.
d) Systems should allow for customization based on the specific needs of the building occupants, particularly in environments where night shifts or extended work hours are common.
e) Where feasible, circadian lighting should be designed to complement natural daylight. Automatic sensors can be installed to measure daylight levels and adjust artificial lighting accordingly, ensuring smooth transitions between natural and artificial light sources.
f) Architectural design should consider window placement, daylight access, and the use of shading devices to maximize exposure to natural light during daytime hours, supporting the body's natural rhythms.
g) The lighting system should provide the appropriate spectral composition, especially in the blue-light range during the morning hours to promote alertness and productivity.
h) Specific lux levels for various periods of the day should be maintained to ensure sufficient light exposure during daylight hours and reduced exposure in the evening, following best practices for circadian lighting design.
j) The lighting system should use energy-efficient solutions, such as LEDs, which allow for variable intensity and color temperature settings without increasing power consumption significantly.
k) The integration of circadian lighting with broader energy management systems is recommended to maintain sustainability while ensuring user comfort and health.
m) Circadian lighting has proven benefits in improving sleep patterns, mood, and overall well-being. It should be prioritized in environments such as healthcare facilities, elder care homes, and educational institutions where the impact of lighting on health is critical.
n) Personalized settings can be incorporated for users who may need specific lighting conditions, such as individuals with sleep disorders or irregular work schedules, to help regulate their internal clocks.

o) Regular maintenance, testing, and recalibration of circadian lighting systems are crucial to ensuring they perform as intended. Automated monitoring systems can be used to track and adjust light levels in real-time based on changing environmental conditions or specific building requirements.
p) These guidelines aim to promote the health, comfort, and efficiency of building occupants by incorporating scientifically-backed principles of circadian lighting into modern building design. By adjusting lighting according to the natural rhythms of daylight, buildings can better support the physiological needs of their users, improving both their well-being and productivity.

**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 shall be designed and managed in accordance with ECBC guidelines, focusing on energy efficiency and minimizing light pollution.

**4.6.1** *Lighting Design and Light Zones*

Outdoor lighting designs shall adhere to energy efficiency measures and address the requirements of different light zones, as per ECBC recommendations:

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.
c) Rural Zones – Lighting shall be kept minimal, ensuring safety while limiting light pollution. Energy-efficient, low-intensity lighting should be implemented.

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

**4.6.2** *Energy Efficiency and Light Pollution Mitigation*

To comply with ECBC and reduce light pollution, outdoor lighting systems shall incorporate the following:

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 shall be implemented to prevent upward light emission and sky glow, focusing light where needed to minimize spillover and improve energy use.
c) *Lighting Controls* – ECBC-compliant controls, such as timers, dimmers, and motion sensors, should be employed to reduce lighting during periods of low activity, contributing to energy savings.

d) *Luminaire Efficacy* – All outdoor lighting luminaires shall meet the minimum efficacy requirements as specified in the ECBC 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 behaviors, such as feeding and mating, due to poorly managed artificial lighting. ECBC-compliant lighting should minimize impact on ecosystems.
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 ECBC lighting recommendations.

## 5 VENTILATION

### 5.1 General

Ventilation of buildings is required to supply fresh air for respiration of occupants, to dilute inside air to prevent vitiation by body odours and to remove any products of combustion or other contaminants in 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 health of the occupants.

### 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.

**5.2.1.1** 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.

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) |
| 1) | Assembly rooms | 4-8 |
| 2) | Bakeries | 20-30 |
| 3) | Banks/building societies | 4-8 |
| 4) | Bathrooms | 6-10 |
| 5) | Bedrooms | 2-4 |
| 6) | Billiard rooms | 6-8 |
| 7) | Boiler rooms | *see* Note 2 |
| 8) | Cafes and coffee bars | 10-12 |
| 9) | Canteens | 8-12 |
| 10) | Cellars | 3-10 |
| 11) | Changing rooms | 6-10 |
| 12) | Churches | 1-3 |
| 13) | Cinemas and theatres | 10-15 |
| 14) | Club rooms | 12,*Min* |
| 15) | Compressor rooms | 10-12 |
| 16) | Conference rooms | 8-12 |
| 17) | Corridors | 5-10 |
| 18) | Dairies | 8-12 |
| 19) | Dance halls | 12, *Min* |
| 20) | Dye works | 20-30 |
| 21) | Electroplating shops | 10-12 |
| 22) | Engine rooms/DG Rooms/GG Rooms | *see* Note 2 |
| 23) | Entrance halls | 3-5 |
| 24) | Factories and work shops | 8-10 |
| 25) | Foundries | 15-30 |

| *Sl No.* | *Application* | *Air Change per Hour* |
|---|---|---|
| (1) | (2) | (3) |
| 26) | Garages | 6-8 |
| 27) | Glass houses | 25-60 |
| 28) | Gymnasium | 6, *Min* |
| 29) | Hair dressing saloon | 10-15 |
| 30) | Hospitals sterilising | 15-25 |
| 31) | Hospital wards | 6-8 |
| 32) | Hospital domestic | 15-20 |
| 33) | Laboratories | 6-15 |
| 34) | Launderettes | 10-15 |
| 35) | Laundries | 10-30 |
| 36) | Lavatories | 6-15 |
| 37) | Lecture theatres | 5-8 |
| 38) | Libraries | 3-5 |
| 39) | Lift cars | 20, *Min* |
| 40) | Living rooms | 3-6 |
| 41) | Mushroom houses | 6-10 |
| 42) | Offices | 6-10 |
| 43) | Paint shops(not cellulose) | 10-20 |
| 44) | Photo and X-ray dark room | 10-15 |
| 45) | Public house bars | 12, *Min* |
| 46) | Recording control rooms | 15-25 |
| 47) | Recording studios | 10-12 |
| 48) | Restaurants | 8-12 |
| 49) | Schoolrooms | 5-7 |
| 50) | Shops and supermarkets | 8-15 |
| 51) | Shower baths | 15-20 |
| 52) | Stores and warehouses | 3-6 |
| 53) | STP rooms | 30, *Min* |
| 54) | Squash courts | 4, *Min* |
| 55) | Swimming baths | 10-15 |
| 56) | Toilets | 6-10 |
| 57) | Underground vehicle parking | 6, *Min* |
| 58) | Utility rooms | 15-30 |
| 59) | Welding shops | 15-30 |

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 **11.2.2** of Part 8 ‘Building Services’, Section 3 ‘Air Conditioning, Heating and Mechanical Ventilation’ of the Code.

**5.2.3** *Heat Balance of Body*

Specially in hot weather, when thermal environment inside the room is worsened by heat given off by machinery, occupants and other sources, the prime need for ventilation is to provide such thermal environment 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 (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 age of persons, 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 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 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) 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.

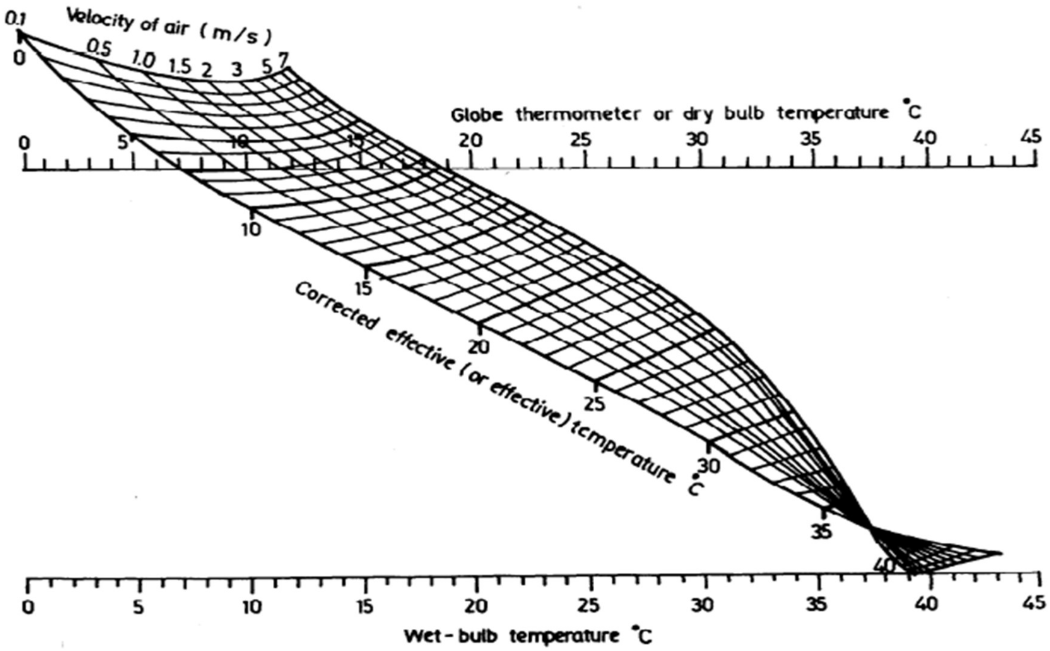



FIG. 5 CORRECTED EFFECTIVE TEMPERATURE NOMOGRAM

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.

**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:

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

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 humidities. Such wind speeds are given in Table 10. 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 11. For obtaining values of indoor wind speed above 2.0 m/s, mechanical means of ventilation may have to be adopted (*see also* Part 8 'Building services', Section 3 'Air Conditioning, Heating and Mechanical Ventilation' of the Code).

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.

**Table 10 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] |

[1] None
[2] Higher than those acceptable in practice.

**Table 11 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] |

[1] None
[2] Higher than those acceptable in practice.

**5.2.3.1.3** *Adaptive Thermal Comfort*

For details on adaptive thermal comfort, reference shall be made to Part 8 'Building Services', Section 3 'Air Conditioning, Heating and Mechanical Ventilation' of this Code.

**5.2.3.2** 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 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 12.

**Table 12 Maximum Permissible Wet Bulb Temperatures for Given Dry Bulb Temperatures**

(*Clause* 5.2.3.2)

| **Sl No.** | **Dry Bulb Temperature** °C (1) | **Maximum Wet-Bulb Temperature** °C (2) |
|---|---|---|
| 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 1h 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 rise in the dry bulb temperature as well, as much as possible. Long exposures to temperature 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.

**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:

$$Q_1 = \frac{2.9768\, K_s}{t}$$

where

$Q_1$ = quantity of air, in $m^3/h$;
$K_s$ = sensible heat gained, in W; and
$t$ = allowable temperature rise, in °C.

**5.3.2.2** Temperature rise refers mainly to the difference between the air temperatures at the outlet (roof exit) and at the inl et 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 13 related to industrial buildings may be used for general guidance.

**Table 13 Allowable Temperature Rise Values**
(*Clause* 5.3.2.2)

| **Sl No.** | **Height of Outlet Opening** m | **Temperature Rise** °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 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:

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

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 in most cases 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 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.

**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*

1) 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.
2) 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.
3) 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:

    i) For sitting on chair 0.75 m
    ii) For sitting on bed 0.60 m
    iii) For sitting on floor 0.40 m.

4) Inlet openings should not as far as possible is obstructed by adjoining buildings, trees, sign boards or other obstructions or by partitions inside in the path of air flow.
5) 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 1.1m. 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.
6) Greatest flow per unit area of openings is obtained by using inlet and outlet openings of nearby equal areas at the same level.
7) 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.

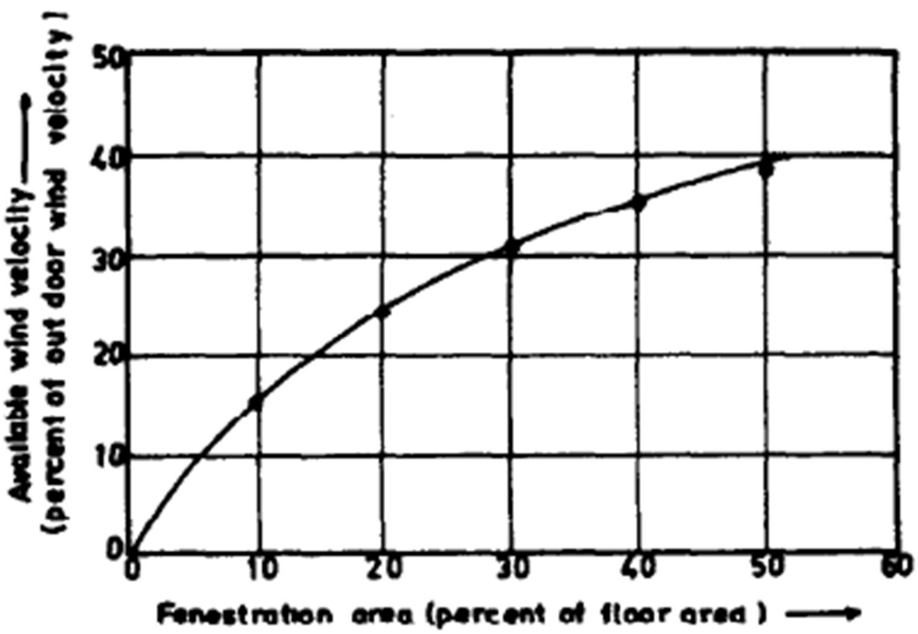



FIG. 6 EFFECT OF AREA OF OPENING ON AVERAGE INDOOR WIND VELOCITY

8) Where the direction of wind is quite constant and dependable, the size of the inlet should be kept within 30 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.
9) 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.
10) 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.

11) 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.
12) 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).
13) 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.
14) 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).

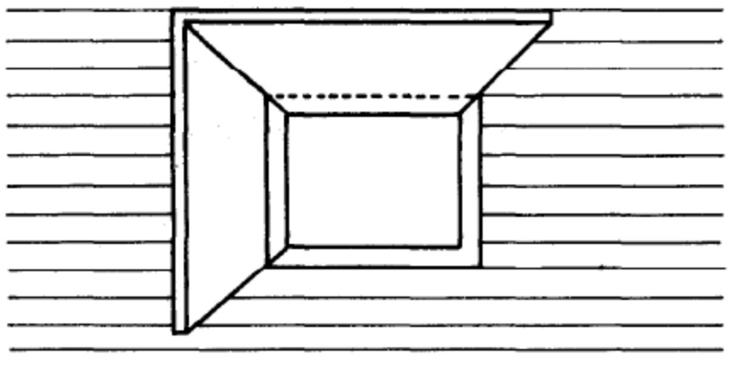


FIG. 7 L-TYPE LOUVER

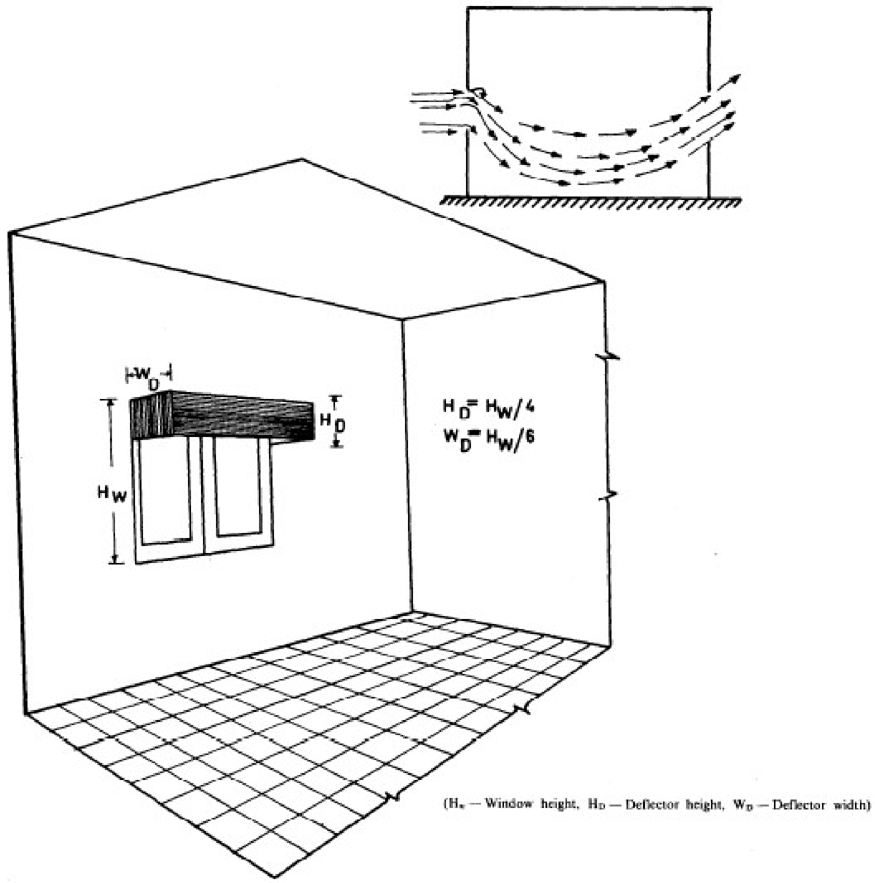



FIG. 8 SKETCH OF A PELMET TYPE WIND DEFLECTOR

15) Roof overhangs help promoting air motion in the working zone inside buildings.
16) 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.
17) 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.
18) *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.
19) 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.

20) 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 (*see* Fig. 9).

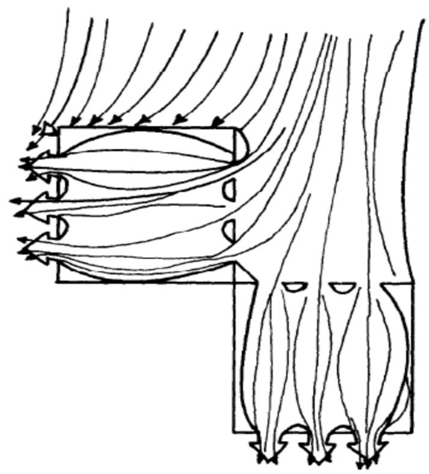


FIG. 9 TWO UNITS LOCATED AT THE END-ON POSITION

21) Air motion in two wings oriented parallel to the prevailing breeze is promoted by connecting them with a block on downstream side.
22) 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.
23) 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.
24) Hedges and shrubs defect 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.
25) 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,
26) Ventilation conditions indoors can be ameliorated by constructing buildings on earth mound having a slant surface with a slope of 10° on upstream side.
27) 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.
28) Height of industrial buildings, although determined by the requirements of industrial processes involved, 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.
29) 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 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**

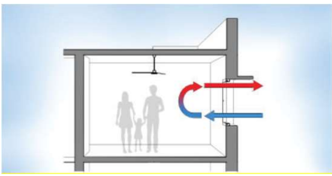
Openings for natural ventilation can be sized without the need for complex and expensive computer simulation methods using analytical techniques. This section presents four design charts (DCs) which can be used to assist in the sizing of ventilation openings to deliver natural ventilation.

The design charts are derived from analytical techniques (CIBSE, 2005, and CIBSE,2010). The design charts 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 (ΔCp), 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)
d) DC-04: wind-driven flow; cross-ventilation with multiple openings (Fig. 10D and Fig. 14)



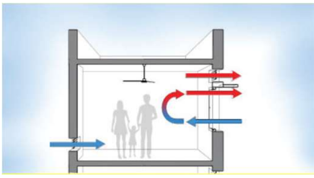


Fig. 10A DC-01

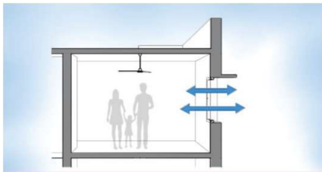


Fig. 10B DC-02

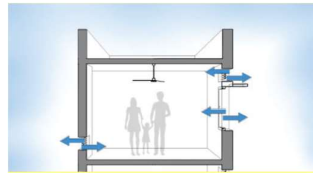


Fig. 10C DC-03

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*

DC-01 buoyancy-driven flow; single-sided ventilation with one opening

The DC-01 is derived from Equation 3 (CIBSE, 2005). For single openings the value for Cd adopted is 0.25.

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

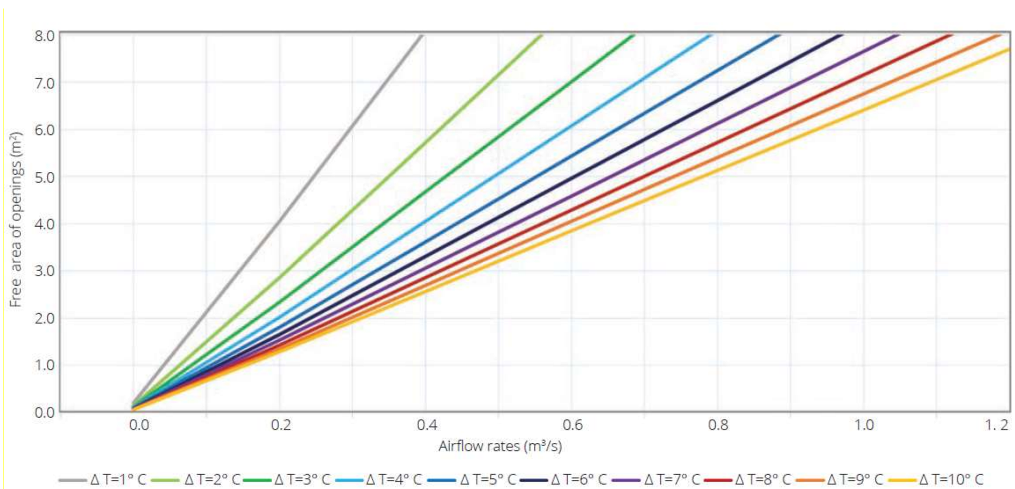



FIG. 11 DESIGN CHART DC-01 FOR SINGLE-SIDED SINGLE OPENING BUOYANCY DRIVEN FLOW

DC-02: buoyancy-driven flow; cross-ventilation

The DC-02 is also derived from Equation 3 (CIBSE, 2005). Conversely, for multiple openings, the value for Cd adopted is 0.61

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

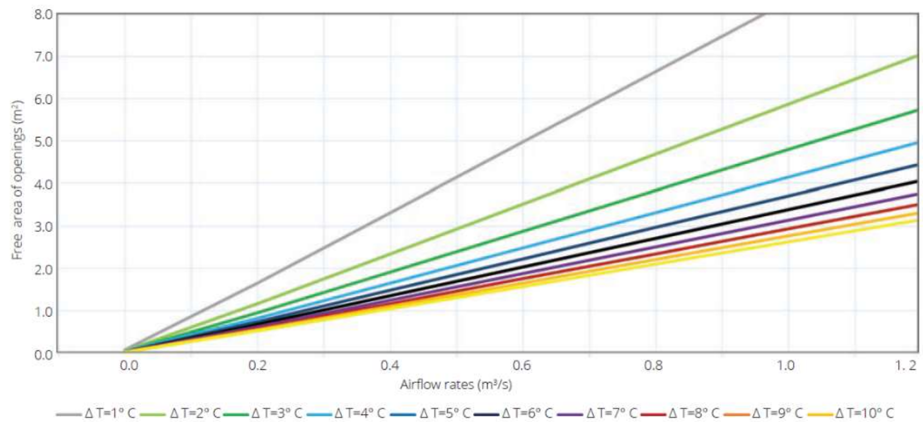



FIG. 12 DESIGN CHART DC-02 FOR MULTIPLE OPENINGS AND BUOYANCY-DRIVEN FLOW

**5.4.4.2** *Design Charts for Natural Ventilation – By Wind Effect*

DC-03: wind-driven flow; single-sided ventilation with one opening

The DC-03 is derived from Equation 4 (CIBSE, 2005).

$$A_f = q_{rec} / C\, V_z$$

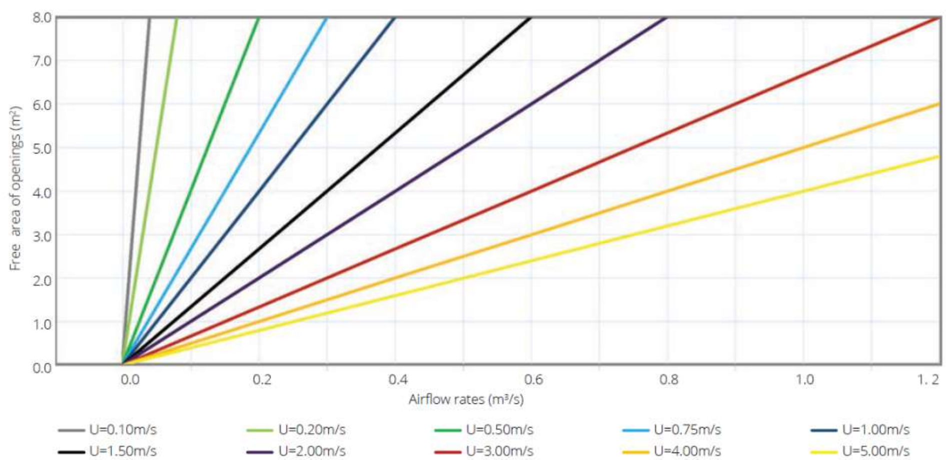



FIG. 13 DESIGN CHART DC-03 FOR SINGLE-SIDED SINGLE OPENINGS AND WIND-DRIVEN FLOW

DC-04: wind-driven flow; cross-ventilation with multiple openings

The DC-4 is derived from Equation 6 (CIBSE, 2005). Pressure coefficients for orthogonal and oblique wind directions for the building shape used are from CIBSE Guide A (CIBSE, 2010).

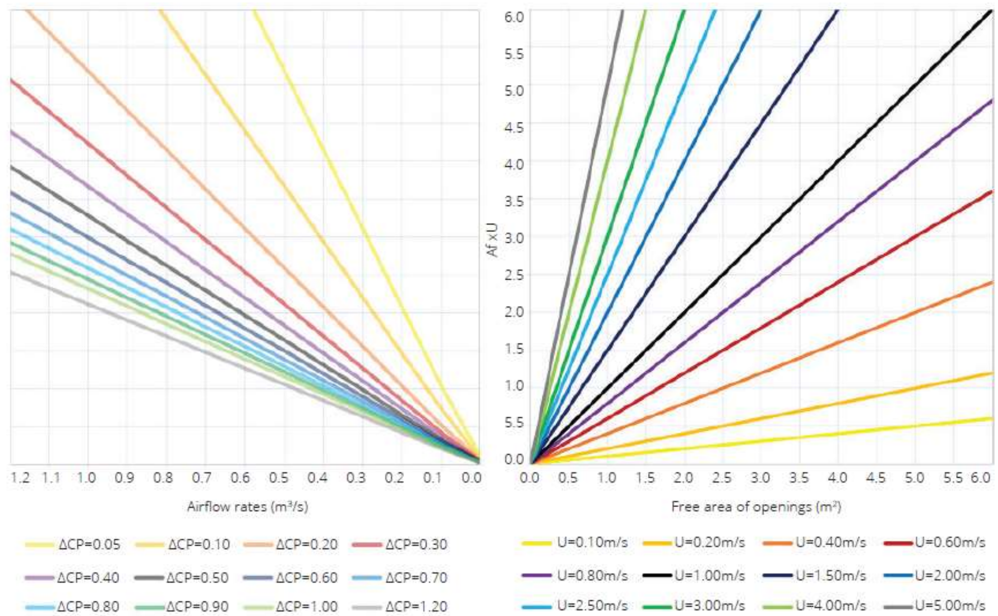



FIG. 14 DESIGN CHART DC-04 FOR MULTIPLE OPENINGS AND WIND-DRIVEN FLOW

## 5.5 Mechanical Ventilation

The requirements of mechanical ventilation shall be in accordance with Part 8 'Building services', Section 3 'Air Conditioning, Heating and Mechanical Ventilation' of the Code.

## 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:

$$Q_w = K.A.V$$

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.

**5.6.1.2** *Stack effect (thermal action)*

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

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

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:

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

**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).

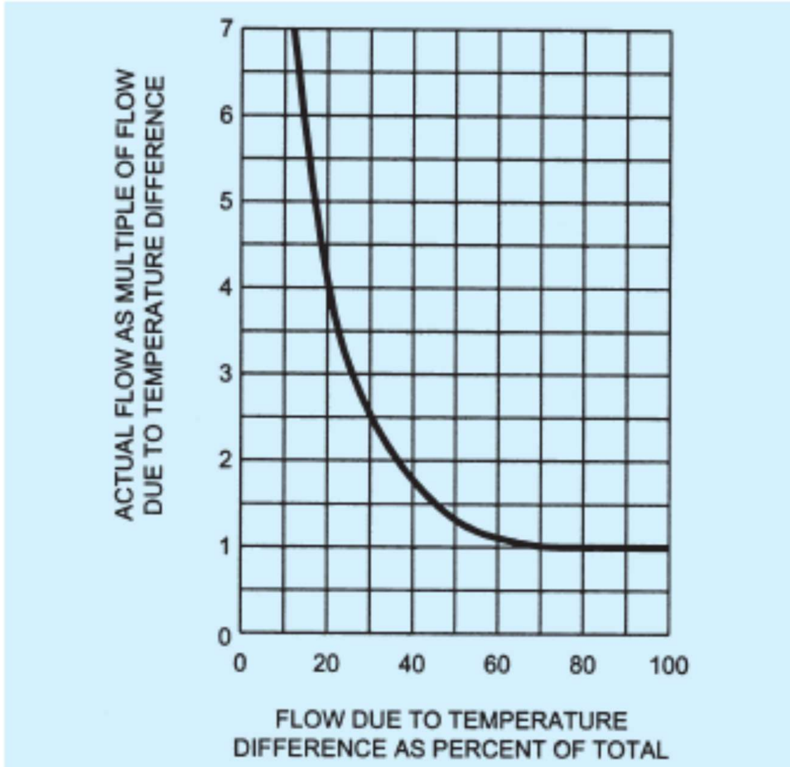



FIG. 15 DETERMINATION OF FLOW CAUSED BY COMBINED FORCES OF WIND AND TEMPERATURE DIFFERENCE

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 [8-1(6)].

**5.6.2** *Mechanical Ventilation*

The determination of rate of ventilation in case of mechanical ventilation shall be done in accordance with Part 8 'Building Services', Section 3 'Air Conditioning, Heating and Mechanical Ventilation' of the Code.

**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 55D $m^3$/min.

**5.7.1.1.2** The height of fan blades above the floor should be $(3H + W)/4$, 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.

**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 14.

**Table 14 Optimum Size/Number of Fans for Rooms of Different Sizes**
(*Clause* 5.7.4)

| **Sl. No.** | **Room Width** m | **Optimum Size, mm/Number of Fans** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 |

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

Potential to extend hours of NV using the LECaVIR solutions

The LECaVIR 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 LECaVIR 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 IMAC-MM, and estimated with the LECaVIR 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 15 for the scenario with Tradiant = Tair (ASHRAE, 2010) and applies to clothing insulation values ranging from 0.50 clo to 0.70 clo and to metabolic rates ranging from 1.00 met to 1.30 met. 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 (i.e. a radiant cooling panel). This scenario yields more conservative values than the scenario for when occupants have some control over the local environment (ASHRAE, 2017). Hours with mechanical cooling.

**Table 15 Corresponding Rise in the Acceptable Air Temperature with the Increase in the Air Speed [Sources: Figure 5.2.3.1 (ASHRAE-55, 2010) and Figure 5.3.3A (ASHRAE-55, 2017)]**

| **Sl. No.** | **Fan Speed Mode** | **Air Speed** m/s | **Corresponding Rise in Temperature** ˚C | | |
|---|---|---|---|---|---|
| | | | **As Per ASHRAE 55-2010 Applying: 0.50 clo to 0.70 clo; 1.00 met to 1.30 met** | | **As Per ASHRAE 55-2017 Applying:** |
| | | | **Tr-Ta=-10** | **Tr-Ta=0** | **0.50 clo to 1.00 clo; 1.10 met** |
| (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 |


FIG. 16 NUMBER OF HOURS IN A YEAR USING 'NATURAL VENTILATION, MECHANICAL COOLING AND OTHER MM', FROM THE IMAC-MM, AND USING 'NATURAL VENTILATION, ENHANCED NATURAL VENTILATION (NV+), MECHANICAL COOLING AND OTHER MM', FROM LECaVIR SOLUTIONS FOR NV+ FOR EIGHT INDIAN CITIES

**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 systems include naturally ventilated buildings that are designed using one of the following approaches as defined by CBE (2007):

a) Concurrent mixed-mode (Figure 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 (Figure 17b) 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 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.

c) Zoned mixed-mode (Figure 17c) 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.

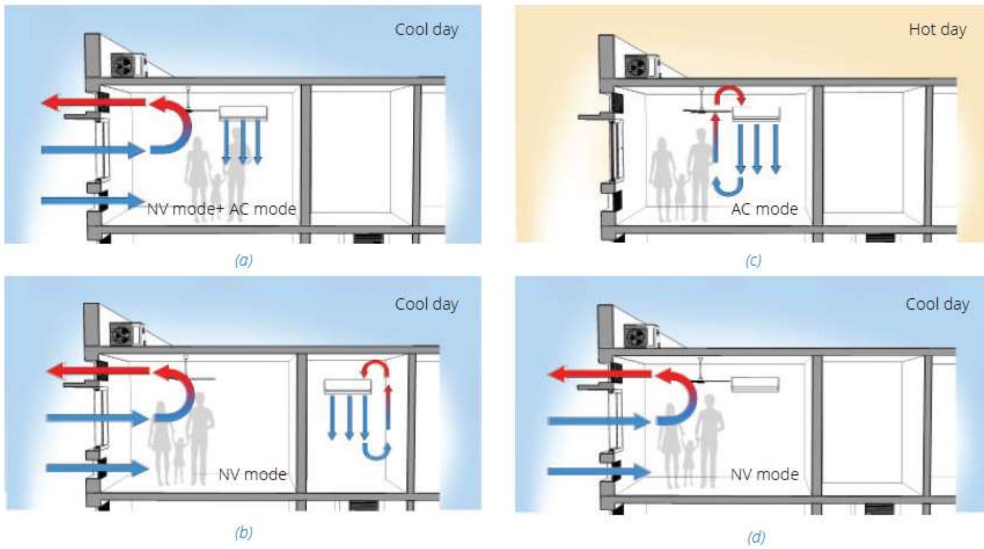



FIG. 17 CLASSIFICATION OF MIXED-MODE SYSTEMS. CONCURRENT MIXED-MODE SYSTEM (A); CHANGE-OVER MIXED-MODE SYSTEM (B); AND ZONED MIXED-MODE SYSTEM FOR COOL DAY (C) AND FOR HOT DAY (D)

## ANNEX A
(*Clause* 3.4.1)

## 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. Figure 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

$\beta$ = solar altitude,
$\phi$ = angle tilt of the surface from the vertical (*see* Fig.12), and
$\alpha$ = wall solar azimuth angle.

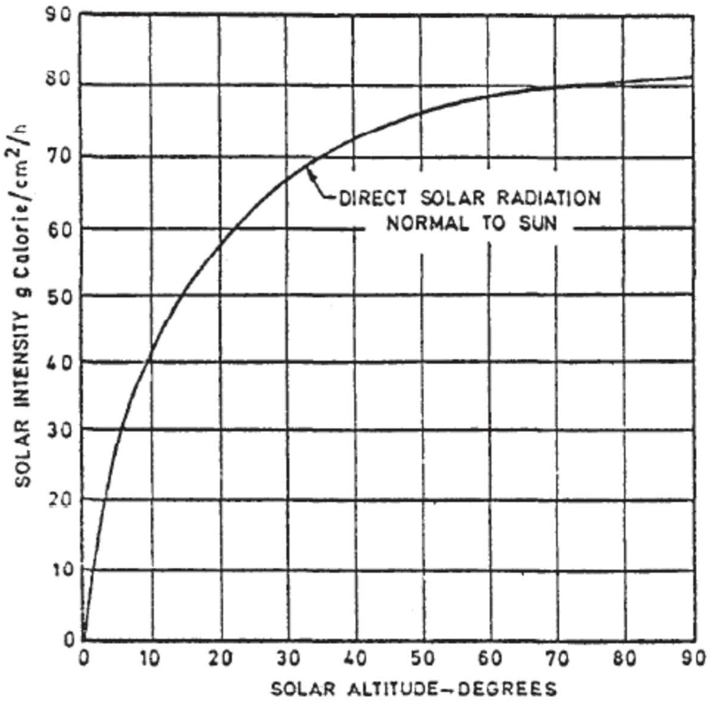



FIG. 18 DIRECT SOLAR INTENSITIES NORMAL TO SUN AT SEA LEVEL FOR STANDARD CONDITION (COMPUTED)

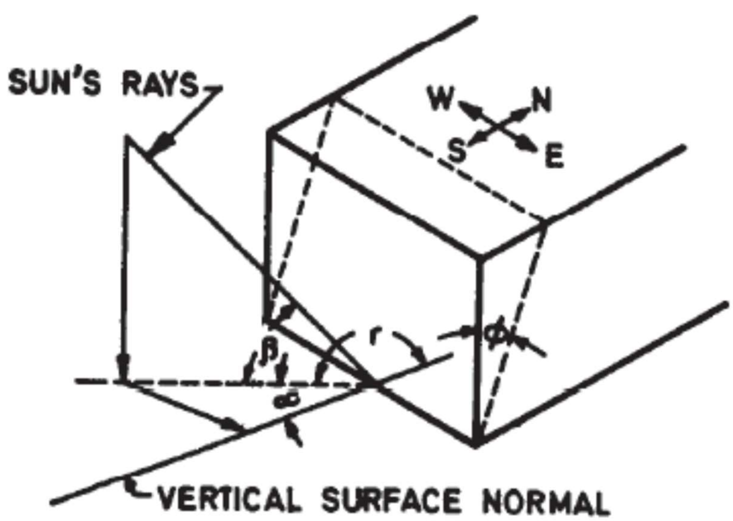



FIG. 19 DEFINITION OF SOLAR ANGLES

## 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 x 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 x 10 m = *A* (say) and 4 m x 20 m = 2*A*. Since, the external wall surface 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 16.

**A-2.1.4** From Table 16, 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 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.

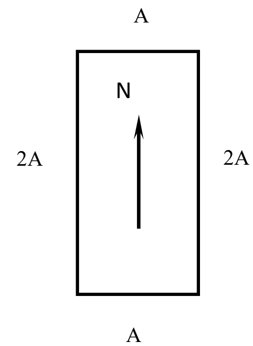
**A-2.1.6** At hill stations, winter season cause more discomfort and so sole criterion for optimum orientation should be based on receiving maximum solar energy on building in winter.

**Table 16 Solar Heat Gained Due to Orientation of Buildings**
(*Clause* A-2.1.3)

| | | 8º N THIRUVANANTHAPURAM | | 13º N CHENNAI | |
|---|---|---|---|---|---|
| | | May 16 | Dec 22 | May 16 | Dec 22 |
| 1. | North | 2 177 X A = 2 177A | – | 1 625 X A = 1 625A | – |
| | East | 2 618 X 2A = 5 236A | 2 177 X 2A = 4 354A | 2 697 X 2A = 5 394A | 2 019 X 2A = 4 038A |
| | South | – | 4 164 X A = 4 164A | – | 4 385 X A = 4 385A |
| | West | 2 618 X 2A = 5 236A | 2 177 X 2A = 4 354A | 2 697 X 2A = 5 394A | 2 019 X 2A = 4 038A |
| | **Total** | 12 649A | 12 872A | 12 413A | 12 461A |
| 2. | NE | 2 650 X A = 2 650A | 410 X A = 410A | 2 492 X A = 2 492A | 315 X A = 315A |
| | SE | 1 167 X 2A = 2 334A | 3 391 X 2A = 6 782A | 1 341 X 2A = 2 682A | 3 423 X 2A = 6 846A |
| | SW | 1 167 X 2A = 2 334A | 3 391 X A = 3 391A | 1 341 X A = 1 341A | 3 423 X A = 3 423A |
| | NW | 2 650 X 2A = 5 300A | 410 X 2A = 820A | 2 492 X A = 4 984A | 315 X 2A = 630A |
| | **Total** | 12 618A | 11 403A | 11 499A | 11 214A |
| 3. | North | 2 177 X 2A = 4 354A | – | 1 625 X 2A = 3 250A | – |
| | East | 2 618 X A = 2 618A | 2 177 X A = 2 177A | 2 697 X A = 2 697A | 2 019 X A = 2 019A |
| | South | – | 4 164 X 2A = 8 328A | – | 4 385 X 2A = 8 770A |
| | West | 2 618 X A = 2 618A | 2 177 X A = 2 177A | 2 697 X A = 2 697A | 2 019 X A = 2 019A |
| | **Total** | 9 590A | 12 602A | 8 644A | 12 808A |
| 4. | NE | 2 650 X 2A = 5 300A | – | 2 492 X A = 4 984A | 315 X 2A = 630A |
| | SE | 1 167 X A = 1 167A | 2 177 X A = 2 177A | 1 341 X A = 1 341A | 3 423 X A = 3 423A |
| | SW | 1 167 X 2A = 2 334A | 4 164 X 2A = 8 328A | 1 341 X 2A = 2 682A | 3 423 X 2A = 6 846A |
| | NW | 2 650 X A = 2 650A | 2 177 X A = 2 177A | 2 492 X A = 2 492A | 315 X A = 315A |
| | **Total** | 11 451A | 12 682A | 11 499A | 11 214A |

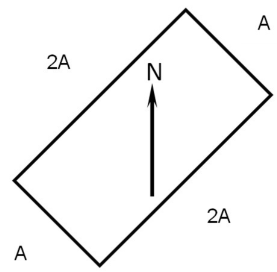
| | | 19º N MUMBAI | | 23º N KOLKATA | |
|---|---|---|---|---|---|
| | | May 16 | Dec 22 | May 16 | Dec 22 |
| 1. | North | 962 X A = 962A | – | 741 X A = 741A | – |
| | East | 2 795 X 2A = 5 590A | 1 830 X 2A = 3 660A | 2 871 X 2A = 5 742A | 1 703 X 2A = 3 406A |
| | South | – | 4 574 X A = 4 574A | 205 X A = 205A | 4 637 X A = 4 637A |
| | West | 2 795 X 2A = 5 590A | 1 830 X 2A = 3 660A | 2 871 X 2A = 5 742A | 1 703 X 2A = 3 406A |
| | **Total** | 12 142A | 11 894A | 12 430A | 11 449A |
| 2. | NE | 2 255 X A = 2 255A | 237 X A = 237A | 2 192 X A = 2 192A | 173 X A = 173A |
| | SE | 1 640 X 2A = 3 280A | 3 438 X 2A = 6 876A | 1 845 X 2A = 3 690A | 3 454 X 2A = 6 908A |
| | SW | 1 640 X A = 1 640A | 3 438 X A = 3 438A | 1 845 X A = 1 845A | 3 454 X A = 3 454A |
| | NW | 2 255 X 2A = 4 510A | 237 X 2A = 474A | 2 192 X 2A = 4 384A | 173 X 2A = 346A |
| | **Total** | 11 685A | 11 025A | 12 111A | 10 881A |
| 3. | North | 962 X 2A = 1 924A | – | 741 X 2A = 1 482A | – |
| | East | 2 795 X A = 2 795A | 1 830 X A = 1 830A | 2 871 X A = 2 871A | 1 703 X A = 1 703A |
| | South | – | 4 574 X 2A = 9 148A | 205 X 2A = 410A | 4 637 X 2A = 9 274A |
| | West | 2 795 X A = 2 795A | 1 830 X A = 1 830A | 2 871 X A = 2 871A | 1 703 X A = 1 703A |
| | **Total** | 7 514A | 12 808A | 7 634A | 12 680A |
| 4. | NE | 2 255 X 2A = 4 510A | 237 X 2A = 474A | 2 192 X 2A = 4 384A | 173 X 2A = 346A |
| | SE | 1 640 X A = 1 640A | 3 438 X A = 3 438A | 1 845 X A = 1 845A | 3 454 X A = 3 454A |
| | SW | 1 640 X 2A = 3 280A | 3 438 X 2A = 6 876A | 1 845 X 2A = 3 690A | 3 454 X 2A = 6 908A |
| | NW | 2 255 X A = 2 255A | 237 X A = 237A | 2 192 X A = 2 192A | 173 X A = 173A |
| | **Total** | 11 685A | 11 025A | 12 111A | 10 881A |

| | | 29º N DELHI | |
|---|---|---|---|
| | | May 16 | Dec 22 |
| 1. | North | 536 X A = 536A | – |
| | East | 2 950 X 2A = 5 900A | 1 467 X 2A = 2 934A |
| | South | 741 X A = 741A | 4 543 X A = 4 543A |
| | West | 2 950 X 2A = 5 900A | 1 467 X 2A = 2 934A |
| | **Total** | 13 077A | 10 411A |



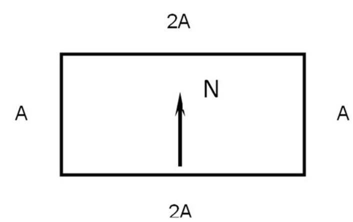

TYPE I

| | | | |
|---|---|---|---|
| 2. | NE | 2 098 X A = 2 098A | 110 X A = 110A |
| | SE | 2 192 X 2A = 4 384A | 3 265 X 2A = 6 530A |
| | SW | 2 192 X A = 2 192A | 3 265 X A = 3 265A |
| | NW | 2 098 X 2A = 4 196A | 110 X 2A = 220A |
| | **Total** | 12 870A | 10 125A |



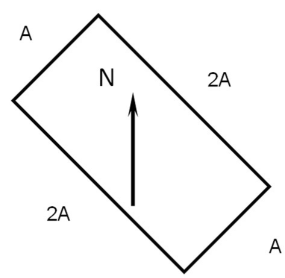

TYPE II

| | | | |
|---|---|---|---|
| 3. | North | 536 X 2A = 1 072A | – |
| | East | 2 950 X A = 2 950A | 1 467 X A = 1 467A |
| | South | 741 X 2A = 1 482A | 4 543 X 2A = 9 086A |
| | West | 2 950 X A = 2 950A | 1 467 X A = 1 467A |
| | **Total** | 8 454A | 12 020A |




TYPE III

| | | | |
|---|---|---|---|
| 4. | NE | 2 098 X 2A = 4 196A | 110 X 2A = 220A |
| | SE | 2 192 X A = 2 192A | 3 265 X A = 3 265A |
| | SW | 2 192 X 2A = 4 384A | 3 265 X 2A = 6 530A |
| | NW | 2 098 X A = 4 196A | 110 X A = 110A |
| | **Total** | 12 870A | 10 125A |




TYPE IV

# ANNEX B

(*Clauses* 4.2.5, 4.2.5.2, 4.2.5.4 *and* 4.2.6.1)

## SKY COMPONENT TABLES

### B-1 Description of Tables

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

a) Table 17 – Percentage sky components on the horizontal plane due to a vertical rectangular opening for the clear design sky

b) Table 18 – Percentage sky components on the vertical plane perpendicular to a vertical rectangular opening for the clear design sky

c) Table 19 – Percentage sky components on the vertical plane parallel to a vertical rectangular opening for the clear design sky

**B-1.2** All the tables 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).

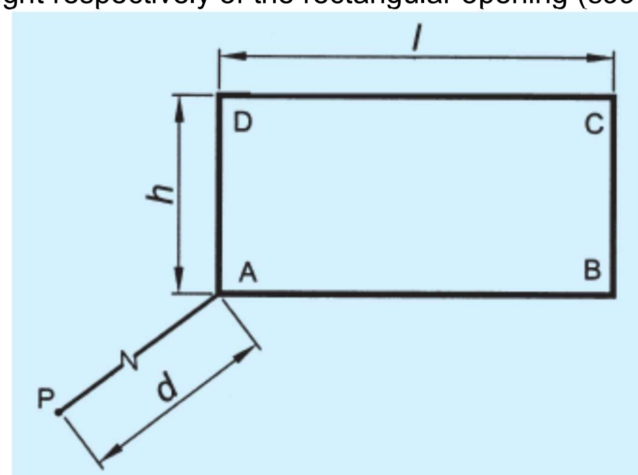



FIG. 20 DEPICTION OF OBSERVATION POINT 'P' W.R.T. WINDOW OPENING

**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 three tables, 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 Tables to get the sky component at given point is explained with help of the following example.

**B-1.6.2** *Example*

It is desired to calculate the sky component 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.

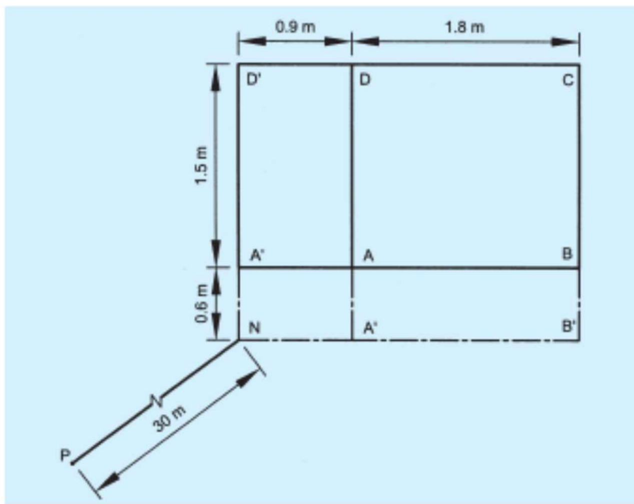



FIG. 21

Consider ABCD extended to NB'CD'

1) 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 per cent (from Table 16)

2) For NA'DD'

$l/d$ = 0.9/3 = 0.3
$h/d$ = (1.5+0.6)/3 = 0.7
$F_2$= 2.441 per cent (from Table 16)

3) For NB'BA'

$l/d$ = (1.8+0.9)/3 = 0.9
$h/d$ = 0.6/3 = 0.2
$F_3$= 0.878 per cent (from Table 16)

4) For NA'AA'

$l/d$ = 0.9/3 = 0.3
$h/d$ = 0.6/3 = 0.2

$F_4$= 0.40 3 per cent (from Table 16)

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** For extremely irregular obstruction or obstructions not in a plane parallel to the window, diagrammatic methods, such as Waldrams diagrams may have to be employed.

**B-2.3** For bay windows, dormer windows or corner windows the effective dimensions of window opening computed should be taken when using the tables to find the sky components.

**B-3 CALCULATION OF IRC**

**B-3.1** The internal reflected component 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:

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

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.

**Values of C for Different Angle of Obstruction**
(*Clause* B-3.1)

| *Angle of Obstruction,* Degree (1) | *Sky + External Obstruction,* C (2) |
|---|---|
| 5 | 68.9 |
| 15 | 50.6 |
| 25 | 36.2 |
| 35 | 26.7 |
| 45 | 20.1 |
| 55 | 15.8 |
| 65 | 12.9 |
| 75 | 11.1 |
| 85 | 10.36 |

**B-3.2 Example**

Consider two rooms of dimensions:

Room $X = 6\ \text{m}\ (l) \times 5\ \text{m}\ (w) \times 3\ \text{m}\ (ht)$

Room $Y = 3.7\ \text{m} \times 3\ \text{m} \times 3\ \text{m}$

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

Window size in room $X = 2.5\ \text{m} \times 1.8\ \text{m}$

Window size in room $3.7\ \text{m} \times 3\ \text{m}$

The window are on the $Y = 6\ \text{m} \times 3\ \text{m}$ side in room *X* and $3.7\ \text{m} \times 3\ \text{m}$ side in room *Y,* and the sill heights are $0.9\ \text{m}$ from floor level.

Reflection coefficients of:

walls and ceiling = 70 percent

floor = 20 percent

glazing = 15 percent

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

a) Total interior area, $A = 2(30 + 18 + 15) = 126\ \text{m}^2$

b) Average reflection factor of interior:

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

c) 1 – *R* = 0.44

d) Mid-height of window is $1.83\ \text{m}$ from floor, average reflection factor of room below $1.83\ \text{m}$ level excluding the wall containing the window:

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

e) Average reflection factor of room above $1.83\ \text{m}$ level excluding the wall containing the window:

$$R_{\text{ew}} = \frac{18.72 \times 0.7 + 30 \times 0.7}{18.72 + 30} = 0.7$$

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

Value of IRC in room Y:

a) Total interior area:

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

b) Average reflection factor:

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

c) Mid-height of window from floor = $1.46\ \text{m}$

d) Average reflection factor below $1.46\ \text{m}$ level

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

e) Average reflection factor above $1.46\ \text{m}$ level

$$R_{\text{ew}} = \frac{3.7 \times 3 \times 0.7 + 1.54 \times 9.7 \times 0.7}{11.1 + 14.94} = 0.7$$

f) 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.

**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.

**Table 17 Percentage Sky Components on the Horizontal Plane Due to a Vertical Rectangular Opening for the Clear Design Sky**
(*Clauses* B-1.1 and B-1.6.2)

| **l/d**<br><br>**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) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |

| l/d<br>h/d<br>(1) | 1.3<br>(14) | 1.4<br>(15) | 1.5<br>(16) | 1.6<br>(17) | 1.7<br>(18) | 1.8<br>(19) | 1.9<br>(20) | 2.0<br>(21) | 3.0<br>(22) | 4.0<br>(23) | 5.0<br>(24) | 10.0<br>(25) | INF<br>(26) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |

**Table 18 Percentage Sky Components on the Vertical Plane Perpendicular to a Vertical Rectangular Opening for the Clear Design Sky**
(*Clause* B-1.1)

| l/d<br><br>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) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |

| l/d<br>h/d<br>(1) | 1.3<br>(14) | 1.4<br>(15) | 1.5<br>(16) | 1.6<br>(17) | 1.7<br>(18) | 1.8<br>(19) | 1.9<br>(20) | 2.0<br>(21) | 3.0<br>(22) | 4.0<br>(23) | 5.0<br>(24) | 10.0<br>(25) | INF<br>(26) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |

**Table 19 Percentage Sky Components on the Vertical Plane Parallel to a Vertical Rectangular Opening for the Clear Design Sky**
(*Clause* B-1.1)

| 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 | 1.3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| h/d | | | | | | | | | | | | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |

| l/d | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 3.0 | 4.0 | 5.0 | 10.0 | INF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| h/d | | | | | | | | | | | | |
| (1) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) | (25) | (26) |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |
| 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 |

## 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 the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

| | *IS No.* | *Title* |
|---|---|---|
| (1) | 7662 (Part 1) : 1974 | Recommendations for orientation of buildings : Part 1 Non-industrial buildings |
| (2) | 3646 (Part 1) : 1992 | Code of practice for interior illumination : Part 1 General requirements and recommendations for building interiors (*first revision*) |
| (3) | 2440 : 1975 | Guide for daylighting of buildings (*second revision*) |
| (4) | 6060 : 1971 | Code of practice for daylighting of factory buildings |
| | 7942 : 1976 | Code of practice for daylighting of educational buildings |
| (5) | 1944 | Code of practice for lighting of public thoroughfares: |
| | (Part 1 & 2) : 1970 | Parts 1 and 2 For main and secondary roads (Group A and B) (*first revision*) |
| | Part 6 : 1981 | Lighting for town and city centres and areas of civic importance (Group E) |
| | 2672 : 1966 | Code of practice for library lighting |
| | 4347 : 1967 | Code of practice for hospital lighting |
| | 6074 : 1971 | Functional requirements of hotels, restaurants and other food service establishments |
| | 6665 : 1972 | Code of practice for industrial lighting |
| | 10894 : 1984 | Code of practice for lighting of educational institutions |
| | 10947 : 1984 | Code of practice for lighting for ports and harbours |
| (6) | 3362 : 1977 | Code of practice for natural ventilation of residential buildings (*first revision*) |