राष्ट्रीय प्रकाश संहिता 2010

National Lighting Code 2010

(SP 72 : 2010)

भारतीय मानक ब्यूरो

मानक : पथप्रदर्शक

BUREAU OF INDIAN STANDARDS

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NATIONAL LIGHTING CODE

INTRODUCTION

The NATIONAL LIGHTING CODE (NLC) covers the following:

a) Guidance on illuminating engineering practices to be followed by various types of occupancies;

b) Guidance on good engineering practices to be followed in the design, selection, installation and maintenance of lighting systems for indoor and outdoor areas;

c) Matters related to the science of illumination such as physics of light, electric light sources, luminaires and photometry;

d) Coordination aspects to be considered while designing the lighting systems such as daylighting; and

e) Aspects relating to energy management and energy conservation in lighting installations including guidelines for design and good practices to be adopted for effective and efficient use of light sources.

This code has been formulated for the purpose of setting out in a convenient form the requirements for responsible social, commercial and engineering conduct as designers, manufacturers and suppliers of lighting. Lighting technology plays a significant role in achieving basic social safety and environmental objectives.

The intent of this code is to encourage good lighting practices and systems which would minimize light pollution, glare, light tresspass and conserve energy while maintaining safety, security, utility and productivity.

The lighting industry is highly fragmented and has relatively low technical barriers to entry. Despite its fundamental importance to many basic safety operations it is subject to comparatively low levels of regulation. Consequently end users and consumers do not always have access to accurate and reliable information on what represents a safe, reliable and efficient lighting system. This code aims to build up a trust between the industry and its customers through integration of commerce and technology.

This code, however, does not specify the additional requirements to be considered while designing lighting systems for certain areas such as marine, railway rolling stock, theatre, television and photography, etc.

This code does not cover the requirements and methods of tests applicable to light sources and luminaires for which separate Indian Standards exist. However, this code covers the measurement aspects of luminaires in a photometric laboratory.

Economic development over the last few years has shown a major boost in the demand of lighting equipment. With an estimated 17 percent of the energy consumption in India due to lighting, there are many opportunities to save energy and thus resources. Moreover, lighting has, until the recent past, been taken for granted as a matter of aesthetics without putting any serious thought on energy conservation, safety, reliability, etc. Putting in place the best available technology, proper design, planning and selection of equipment for the lighting in industrial, commercial, public and utility areas and residential applications with special emphasis on energy conservation, there is ample scope in overall improvement of the lighting system to cater to the need of the individual, society and the country as a whole.

The National Lighting Code is a single document in which, like a network, the information contained in various Indian Standards is compiled into a pattern of continuity and cogency with the interdependent requirements of Sections carefully analyzed and fitted in. This makes the whole code a cogent continuous volume.

This code contains good practices and regulations which can be immediately adopted or enacted for use by various departments and public bodies. It lays down a set of minimum provisions necessary to protect the interest of the public with regard to lighting levels and quantity, and safety parameters. For the choice of lighting products and method of lighting design for the lighting professional, detailed guidelines have been provided in this code, still leaving enough scope for the integrity of the users, designers, architects and consultants.

This National Lighting Code is applicable to the lighting systems in large varieties of interior and exterior installations including special areas like hospitals, utilities, sports complexes, metro railway, etc, under the control of qualified persons.

The keywords of NLC are:

Physics of light, Electric light sources and their accessories, Luminaires, Interior illumination, Exterior illumination, Lighting for hazardous areas, Road lighting, Energy-effective lighting systems, Installation aspects for. lighting, Daylighting for buildings, Emergency lighting, Lighting maintenance, etc.

This NLC is divided into 13 parts some of which are having sections making a total of 29 parts and sections as given below:

Part 1 Lighting vocabulary;

Part 2 Physics of light in 3 sections;

Part 3 Electric light sources and their accessories in 2 sections;

Part 4 Luminaires in 2 sections;

Part 5 Interior illumination in 5 sections;

Part 6 Exterior illumination in 7 sections;

Part 7 Lighting for hazardous areas;

Part 8 Road lighting;

Part 9 Energy-effective lighting systems;

Part 10 Installation aspects for lighting in 3 sections;

Part 11 Daylighting for buildings;

Part 12 Emergency lighting; and

Part 13 Lighting maintenance.

Numerical values in this code are in the metric (SI) systems.

The NLC as written is based on the present stage of knowledge on the various aspects of lighting systems. In this NLC many of the problems have been answered fully and some partially. Therefore, a continuous programme will go on, by which additional knowledge that is gained through technological evolutions, users' views over a period of time pinpointing areas of classification, and coverage and results of research in the field would be incorporated into the code from time to time to make it a living document. It is therefore proposed to bring out changes to the code periodically. In the meantime, all or some parts of the code may be adopted with or without changes by delegated legislative authorities in their regulations, administrative orders or similar documents.

The revision cycle of NLC is generally five years. Changes, proposals and comments may be Submitted to, Electrotechnical Department, Bureau of Indian Standards (BIS), Manak Bhavan, New Delhi 110002 or online *via* the internet to eetd@bis.org.in.

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NATIONAL LIGHTING CODE

PARTI LIGHTING VOCABULARY

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

The principal objective of this terminology is to provide definitions which are sufficiently clear so that each term can be understood with the same meaning in the lighting field. Only those terms have been given in this part which have been considered relevant keeping in view the contents of National Lighting Code.

The definitions given in this part are in line with the IEC Pub 60050(845): 1987 'Lighting Vocabulary Chapter 845: Lighting', issued by International Electrotechnical Commission (IEC).

The following Indian Standards are necessary adjuncts to this part.

IS No.	*Title*
9206:1979	Dimensions of caps for tungsten filament general service electric lamps
2418(Part3):1977	Tubular fluorescent lamps for general lighting service: Part 3 Dimensions of G-5 and G-13 bi-pin caps (First Revision)
10322(Part 1):1982	Luminaires: Part 1 General requirements

NATIONAL LIGHTING CODE

PARTI LIGHTING VOCABULARY

1 SCOPE

This part of the code covers definitions and terms used in the field of lighting, which have been considered relevant keeping in view the contents of the code.

2 TERMINOLOGY

In addition to the definitions given in this part for more detailed vocabulary on lighting, reference may be made to the following Indian Standards.

1885(Part 16/Sec 1):1968 Electrotechnical Vocabulary: Part 16 Lighting, Section 1 General aspects

1885(Part 16/Sec 2): 1968 Electrotechnical Vocabulary: Part 16 Lighting, Section 2 General illumination lighting fittings and lighting for traffic and signaling

1885(Part 16/Sec 3): 1967 Electrotechnical Vocabulary: Part 16 Lighting, Section 3 Lamps and auxiliary apparatus.

3 RADIATION, QUANTITIES AND UNITS

3.1 General Terms

3.1.1 *Electromagnetic Radiation*

a) Emission or transfer of energy in the form of electromagnetic waves with the associated photons; and

b) These electromagnetic waves or these photons.

NOTE — The French term 'radiation' applies preferably to a single element of any radiation, characterized by one wavelength or one frequency.

3.1.2 *Optical Radiation* — Electromagnetic radiation at wavelengths between the region of transition to X-rays (λ=l nm) and the region of transition to radio waves (λ=l mm).

3.1.3 *Visible Radiation*—Any optical radiation capable of causing a visual sensation directly.

NOTE —There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant power reaching the retina and the responsivity of the observer. The lower limit is generally taken between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

3.1.4 *Infrared Radiation* — Optical radiation for which the wavelengths are longer than those for visible radiation.

NOTE — For infrared radiation, the range between 780 nm and 1mm is commonly subdivided into:
lR-A : 780 nm -1400 nm
lR-B . 1.4 nm - 3 nm
IR-C : 3 nm -1 mm

3.1.5 *Ultraviolet Radiation*—Optical radiation for which the wavelengths are shorter than those for visible radiation.

NOTE — For ultraviolet radiation, the range between 100 nm and 400 nm is commonly subdivided into :
UV-A : 315 nm - 400 nm
UV-B : 280 nm - 315 nm
UV-C : 100 nm - 280 nm

3.1.6 *Light*

a) Perceived light (*see* **4.2.1**); and

b) Visible radiation (*see* **3.1.3**).

NOTE — The word light is sometimes used in sense (b) for optical radiation extending outside the visible range, but this usage is not recommended.

3.1.7 *Monochromatic Radiation* — Radiation characterized by a single frequency. In practice, radiation of a very small range of frequencies which can be described by stating a single frequency.

NOTE — The wavelength in air or in vacuum is also used to characterize a monochromatic radiation.

3.1.8 *Spectrum (of a Radiation)* — Display or specification of the monochromatic components of the radiation considered.

NOTES

1 There are line spectra, continuous spectra, and spectra exhibiting both these characteristics.

2 This term is also used for spectral efficiencies (excitation spectrum, action spectrum).

3.1.9 *Spectral Line*

a) Monochromatic radiation emitted or absorbed in a transition between two energy levels.

b) Its manifestation in a spectrum.

3.1.10 *Polarized Radiation* — Radiation whose electromagnetic field, which is transversal, is oriented in defined directions.

NOTE — The polarization may be linear, elliptic or circular.

3.1.11 *Diffraction* — Deviation of the direction of propagation of a radiation, determined by the wave nature of radiation, and occurring when the radiation passes the edge of an obstacle.

3.1.12 *Wavelength (X)* — Distance in the direction of propagation of a periodic wave between two successive points at which the phase is the same.

Unit : m

NOTES

1 The wavelength in a medium is equal to the wavelength in vacuum divided by the refractive index

of the medium. Unless otherwise stated, values of wavelength are generally those in air. The refractive index of standard air (for spectroscopy: t = 15°C, p = 101 325 Pa) lies between 1.000 27 and 1.000 29 for visible radiations.

2 $\lambda = \frac{V}{\nu}$, where λ is the wave length (m), V is the phase velocity (m/s) in that medium, and ν the frequency (Hz).

3.1.13 *Wave Number* (σ) — The reciprocal of the wavelength.

Unit: m^{-1}

3.1.14 *Point Source* — Source of radiation the dimensions of which are small enough, compared with the distance between the source and the irradiated surface, for them to be neglected in calculations and measurements.

NOTE — A point source which emits uniformly in all directions is called an isotropic point source or uniform point source.

3.1.15 *Steradian* (sr) — SI unit of solid angle. Solid angle that, having its vertex at the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

3.2 Radiant, Luminous and Photon Quantities and their Units

3.2.1 *Light Stimulus* — Visible radiation entering the eye and producing a sensation of light.

3.2.2 *CIE Standard Photometric Observer* — Ideal observer having a relative spectral responsivity curve that conforms to the $V(\lambda)$ function for photopic vision or $V'(\lambda)$ function for scotopic vision, and that complies with the summation law implied in the definition of luminous flux.

3.2.3 *Radiant Flux*; *Radiant Power* (Φ_e; Φ; P) — Power emitted, transmitted or received in the form of radiation.

Unit : W

3.2.4 *Luminous Flux* (Φ_v; Φ) — Quantity derived from radiant flux (Φ_e) by evaluating the radiation according to its action upon the CIE standard photometric observer. For photopic vision:

$$\Phi_v = K_m \int_0^{\infty} \frac{d\Phi_e(\lambda)}{d\lambda} V(\lambda) d\lambda$$

where,

$\frac{d\Phi_e(\lambda)}{d\lambda}$ = the spectral distribution of the radiant flux; and

$V(\lambda)$ = the spectral luminous efficiency.

Unit : lm

NOTE — For the values of K_m (photopic vision) and K'_m (scotopic vision), *see* **3.2.18**.

3.2.5 *Photon Flux* (Φ_p; Φ) — Quotient of the number of photons dN_p emitted, transmitted, or received in an element of time dt, by that element.

$$\Phi_p = \frac{dN_p}{dt}$$

Unit: s^{-1}

NOTE — For a beam of radiation whose spectral distribution is $\frac{d\Phi_e(\lambda)}{d\lambda}$ or $\frac{d\Phi_e(\nu)}{d\nu}$, the photon flux Φ_p is

$$\Phi_p = \int_0^{\infty} \frac{d\Phi_e(\lambda)}{d\lambda} \frac{\lambda}{hc_0} d\lambda = \int_0^{\infty} \frac{d\Phi_e(\nu)}{d\nu} \frac{1}{h\nu} d\nu$$

where h, Planck's constant
= (6.626 0755 ± 0.000 004 0) × 10^{-34} J.s
c_0, speed of light in vacuum = 299 792 458 $m.s^{-1}$

3.2.6 *Radiant Energy* (Q_e; Q) — Time integral of the radiant flux Φ_e over a given duration Δt.

$$Q_e = \int_{\Delta t} \Phi_e dt$$

Unit : J = W.s

3.2.7 *Quantity of Light* (Q_v; Q) — Time integral of the luminous flux Φ_v over a given duration Δt.

$$Q_v = \int_{\Delta t} \Phi_v dt$$

Unit: lm.s

Other unit: lumen-hour (lm·h).

3.2.8 *Radiant Intensity (of a source, in a given direction)* (I_e; I) — Quotient of the radiant flux $d\Phi_e$ leaving the source and propagated in the element of solid angle $d\Omega$ containing the given direction by the element of solid angle.

$$I_e = \frac{d\Phi_e}{d\Omega}$$

Unit: $W \cdot sr^{-1}$

3.2.9 *Luminous Intensity (of a source, in a given direction)* (I_v; I) — Quotient of the luminous flux $d\Phi_v$ leaving the source and propagated in the element of solid angle $d\Omega$ containing the given direction, by the element of solid angle.

$$I_v = \frac{d\Phi_v}{d\Omega}$$

Unit: cd = $lm \cdot sr^{-1}$

3.2.10 *Luminance (in a given direction, at a given point of real or imaginary surface* (L_v; L) — Quantity defined by the formula:

$$L_v = \frac{d\Phi_v}{dA.\cos\theta.d\Omega}$$

where $d\Phi_v$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle $d\Omega$ containing the given direction; dA is the area of a section of that beam containing the given point, θ is the angle between the normal to that section and the direction of the beam.

Unit: $cd \cdot m^{-2} = lm \cdot m^{-2} \cdot sr^{-1}$

3.2.11 *Illuminance (at a point of a surface) (E_v ; E)* — Quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element.

Equivalent Definition: Integral, taken over the hemisphere visible from the given point, of the expression $L_v.\cos\theta.d\Omega$, where L_v is the luminance at the given point in the various directions of the incident elementary beams of solid angle $d\Omega$, and θ is the angle between any of these beams and the normal to the surface at the given point.

$$E_v = \frac{d\Phi_v}{dA} = \int_{2\pi sr} L_v.\cos\theta.d\Omega$$

Unit: $lx = 1 m.m.^{-2}$

3.2.12 *Candela* (cd) — SI unit of luminous intensity : The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

$$1 \text{ cd} = 1 \text{ lm} \cdot sr^{-1}$$

3.2.13 *Lumen* (lm) — SI unit of luminous flux : Luminous flux emitted in unit solid angle (steradian) by a uniform point source having a luminous intensity of 1 candela.

Equivalent Definition — Luminous flux of a beam of monochromatic radiation whose frequency is 540×10^{12} hertz and whose radiant flux is 1/683 W.

3.2.14 *Lux* (lx) — SI unit of illuminance : Illuminance produced on a surface of area 1 square metre by a luminous flux of 1 lumen uniformly distributed over that surface.

$$1 \text{ lx} = 1 \text{ lm} \cdot m^{-2}$$

NOTE — Non metric unit : lumen per square foot ($lm.ft^{-2}$) or foot-candle (fc) (USA) = 10.764 lx.

3.2.15 *Candela per square metre* (cd. m^2) — SI unit of luminance.

NOTE — This unit has sometimes been called the nit (nt) (name discouraged). Other units of luminance:

Metric, non SI: lambert (L) = $\frac{10^4}{\pi} cd.m^{-2}$

Non metric: footlambert (fL) = 3.426 $cd.m^{-2}$

3.2.16 *Radiant Efficiency (of a source of radiation) (η_e ; η)* — Ratio of the radiant flux of the emitted radiation to the power consumed by the source.

Unit : 1

NOTE — It must be specified whether or not the power dissipated by auxiliary equipment such as ballasts, etc, if any, is included in the power consumed by the source.

3.2.17 *Luminous Efficacy of a source (η_v ; η)* — Quotient of the luminous flux emitted by the power consumed by the source.

Unit: $lm \cdot W^{-1}$

NOTE — See note under **3.2.16**.

3.2.18 *Luminous Efficacy of Radiation (K)* — Quotient of the luminous flux Φ_v by the corresponding radiant flux Φ_e.

$$K = \frac{\Phi_v}{\Phi_e}$$

Unit : $lm.W^{-1}$

NOTE — When applied to monochromatic radiations, the maximum value of $K(\lambda)$ is denoted by the symbol K_m K_m = 683 $lm \cdot W^{-1}$ for $\nu_m = 540 \times 10^{12}$ Hz ($\lambda_m \approx 555$ nm) for photopic vision.
K'_m = 1 700 $lm \cdot W^{-1}$ for λ'_m = 507 nm for scotopic vision. For other wavelengths, $K(\lambda) = K_m V(\lambda)$ and $K'(\lambda) = K'_m V'(\lambda)$.

4 VISION, COLOUR RENDERING

4.1. The Eye

4.1.1 *Retina* — Membrane situated inside the back of the eye that is sensitive to light stimuli; it contains photoreceptors, the cones and the rods and nerve cells that transmit to the optic nerve the signals resulting from stimulation of the photoreceptors.

4.1.2 *Cones* — Photoreceptors in the retina containing light sensitive pigments capable of initiating the process of photopic vision.

4.1.3 *Rods* — Photoreceptors in the retina containing a light sensitive pigment capable of initiating the process of scotopic vision.

4.1.4 *Yellow Spot*; *Macula Lutea* — Layer of photostable pigment covering parts of the retina in the foveal region.

4.1.5 *Fovea*; *Fovea Centralis* — Central part of the retina, thin and depressed, which contains almost exclusively cones and forming the site of most distinct vision.

NOTE — The fovea subtends an angle of about 0.026 radian (1.5°) in the visual field.

4.1.6 *Foveola* — Central region of the fovea which contains only cones.

NOTE — The foveola subtends an angle of about 0.017 radian (1°) in the visual field.

4.1.7 *Adaptation* — The process by which the state of the visual system is modified by previous and present exposure to stimuli that may have various luminances, spectral distributions and angular subtenses.

NOTES

1 The terms light adaptation and dark adaptation are also used, the former when the luminances of the

stimuli are of at least several candelas per square metre, and the latter when the luminances are of less than some hundredths of a candela per square metre.

2 Adaptation to specific spatial frequencies, orientations, sizes, etc, are recognized as being included in this definition.

4.1.8 *Chromatic Adaptation* — Adaptation by stimuli in which the dominant effect is that of different relative spectral distributions.

4.1.9 *Photopic Vision* — Vision by the normal eye when it is adapted to levels of luminance of at least several candelas per square metre.

NOTE — The cones are the principal active photoreceptors in photopic vision.

4.1.10 *Scotopic Vision* — Vision by the normal eye when it is adapted to levels of luminance less than some hundredths of a candela per square metre.

NOTE — The rods are the principal active photoreceptors in scotopic vision.

4.1.11 *Mesopic Vision* — Vision intermediate between photopic and scotopic vision.

NOTE — In mesopic vision, both the cones and the rods are active.

4.1.12 *Hemeralopia; Night Blindness* — Anomaly of vision in which there is a pronounced inadequacy or complete absence of scotopic vision.

4.1.13 *Defective Colour Vision* —Anomaly of vision in which there is a reduced ability to discriminate between some or all colours.

4.2 Light and Colour

4.2.1 *(Perceived) Light* — Universal and essential attribute of all perceptions and sensations that are peculiar tp the visual system.

NOTES

1 Light is normally, but not always, perceived as a result of the action of a light stimulus on the visual system.

2 *See* 3.1.6,

4.2.2 *(Perceived) Colour*—Attribute of visual perception consisting of any combination of chromatic and achromatic content. This attribute may be described by chromatic colour names such as yellow, orange, brown, red, pink, green, blue, purple etc, or by achromatic colour names such as white, grey, black, etc, and qualified by bright, dim, light, dark, etc, or by combinations of such names.

NOTES

1 Perceived colour depends on the spectral distribution of the colour stimulus, on the size, shape structure and surround of the stimulus area, on the state of adaptation of the observer's visual system, and on the observer's experience of the prevailing and similar situations of observation.

2 Perceived colour may appear in several modes of colour appearance. The names for various modes of appearance are intended to distinguish among qualitative and geometric differences of colour perceptions. Some of the more important terms of the modes of colour appearance are given in 4.2.3, 4.2.4 and 4.2.5.

Other modes of colour appearance include film colour, volume colour, illuminant colour, body colour, and Ganzfeld colour. Each of these modes of colour appearance may be further qualified by adjectives to describe combinations of colour or their spatial and temporal relationships. Other terms that relate to qualitative differences among colours perceived in various modes of colour appearance are given in 4.2.6, 4.2.7, 4.2.8 and 4.2.9.

4.2.3 *Object Colour* — Colour perceived as belonging to an object.

4.2.4 *Surface Colour* — Colour perceived as belonging to a surface from which the light appears to be diffusely reflected or radiated.

4.2.5 *Aperture Colour* — Perceived colour for which there is no definite spatial localization in depth, such as that perceived as filling a hole in a screen.

4.2.6 *Luminous (Perceived) Colour* — Colour perceived to belong to an area that appears to be emitting light as a primary light source, or that appears to be specularly reflecting such light.

NOTE — Primary light sources seen in their natural surroundings normally exhibit the appearance of luminous colours in this sense.

4.2.7 *Non-Luminous (Perceived) Colour* — Colour perceived to belong to an area that appears to be transmitting or diffusely reflecting light as a secondary light source.

NOTE — Secondary iight sources seen in their natural surroundings normally exhibit the appearance of non-luminous colours in this sense.

4.2.8 *Related (Perceived) Colour* — Colour perceived to belong to an area seen in relation to other colours.

4.2.9 *Unrelated (Perceived) Colour*—Colour perceived to belong to an area seen in isolation from other colours.

4.2.10 *Achromatic (Perceived) Colour*

a) In the perceptual sense — Perceived colour devoid of hue. The colour names white, grey and black are commonly used or, for transmitting objects, colourless and neutral; and

b) In the psychophysical sense — *See* 5.2.4.

4.2.11 *Chromatic (Perceived) Colour*

a) *In the perceptual sense* — Perceived colour possessing hue. In everyday speech, the word colour is often used in this sense in contradistinction to white, grey or black. The adjective coloured usually refers to chromatic colour; and

b) *In the psychophysical sense* — *See* 5.2.5.

4.2.12 *Brightness; Luminosity (Obsolete)* —Attribute of a visual sensation according to which an area appears to emit more or less light.

4.2.13 *Bright*—Adjective used to describe high levels of brightness.

4.2.14 *Dim* — Adjective used to describe low levels of brightness.

4.2.15 *Lightness (of a Related Colour)* — The brightness of an area judged relative to the brightness of a similarly illuminated area that appears to be white or highly transmitting.

NOTE — Only related colours exhibit lightness.

4.2.16 *Light* — Adjective used to describe high levels of lightness.

4.2.17 *Dark* — Adjective used to describe low levels of lightness.

4.2.18 *Hue* — Attribute of a visual sensation according to which an area appears to be similar to one of the perceived colours, red, yellow, green, and blue, or to a combination of two of them.

NOTE — Formerly 'Farbton' in German.

4.2.19 *Unitary Hue; Unique Hue* — Perceived hue that cannot be further described by the use of hue names other than its own.

NOTE — There are four unitary hues; red, green, yellow and blue.

4.2.20 *Binary Hue* — Perceived hue that may be described as a combination of two unitary hues. For example, orange is a yellowish red or reddish yellow; violet is reddish blue, etc.

4.2.21 *Chroma* — Chromaticness, colourfulness, of an area judged as a proportion of the brightness of a similarly illuminated area that appears white or highly transmitting.

NOTE — For given viewing conditions and at luminance levels within the range of photopic vision, a colour stimulus perceived as a related colourv of a given chromaticity and from a surface having a given luminance factor, exhibits approximately constant chrome for all levels of illuminance except when the brightness is very high. In the same circumstances, at a given level of illuminance, if the luminance factor is increased, the chroma usually increases.

4.3 Visual Phenomena

4.3.1 *Visual Acuity, Visual Resolution*

a) *Qualitatively* — Capacity for seeing distinctly fine details that have very small angular separation; and

b) *Quantitatively* — Any of a number of measures of spatial discrimination such as the reciprocal of the value of the angular separation in minutes are of two neighbouring objects (points or lines or other specified stimuli) which the observer can just perceive to be separate.

4.3.2 *Accommodation* — Adjustment of the dioptric power of the crystalline lens by which the image of an object, at a given distance, is focused on the retina.

4.3.3 *Luminance Threshold* — Lowest luminance of a stimulus which enables it to be perceived.

NOTE — The value depends on field size, surround, state of adaptation, and other viewing conditions.

4.3.4 *Flicker* — Impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time.

4.3.5 *Glare* — Condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or to extreme contrasts.

NOTE — In Russian, the terms 4.3.5 to 4.3.10 relate to the properties of the light sources and other luminous surfaces which disturb the condition of vision, and not to the changed condition of vision caused by an unsuitable distribution of luminance in the visual field.

4.3.6 *Direct Glare* — Glare caused by self luminous objects situated in the visual field, especially near the line of sight.

4.3.7 *Glare by Reflections* — Glare produced by reflections, particularly when the reflected images appear in the same or nearly the same direction as the object viewed.

NOTE — Formerly reflected glare.

4.3.8 *Veiling Reflections* — Specular reflections that appear on the object viewed and that partially or wholly obscure the details by reducing contrast.

4.3.9 *Discomfort Glare* — Glare that causes discomfort without necessarily impairing the vision of objects.

4.3.10 *Disability Glare* — Glare that impairs the vision of objects without necessarily causing discomfort.

4.3.11 *Equivalent Veiling Luminance (for Disability Glare or Veiling Reflections)* — The luminance that, when added by superposition to the luminance of both the adapting backgrounds and the object, makes the luminance threshold or the luminance difference threshold the same under the two following conditions: a) Glare present, but no additional luminance; and b) Additional luminance present, but no glare.

4.4 Colour Rendering

4.4.1 *Colour Rendering*— Effect of an illuminant on the colour appearance of objects by conscious or subconscious comparison with their colour appearance under a reference illuminant.

4.4.2 *Reference Illuminant* — An illuminant with which other illuminants are compared.

NOTE — A more particular meaning may be needed in the case of illuminants for colour reproduction.

4.4.3 *Colour Rendering Index (R)* — 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.

4.4.4 *CIE 1974 Special Colour Rendering Index (Ri)* — Measure of the degree to which the psychophysical colour of a CIE test colour sample illuminated by the test illuminant conforms to that of the same sample illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

4.4.5 *CIE 1974 General Colour Rendering Index* (R_a) — Mean of the CIE 1974 special colour rendering indices for a specified set of eight test colour samples.

5 COLORIMETRY

5.1 Colour

a) (Perceived) Colour — *See* 4.2.2; and

b) (Psychophysical) Colour.

A specification of a colour stimulus in terms of operationally defined values, such as three tristimulus values.

NOTE — When the meaning is clear from the context the term colour may be used alone.

5.2 Stimuli

5.2.1 *Colour Stimulus* — Visible radiation entering the eye and producing a sensation of colour, either chromatic or achromatic.

5.2.2 *Colour Stimulus Function* — Description of a colour stimulus by the spectral concentration of a radiometric quantity, such as radiance or radiant power, as a function of wavelength.

5.2.3 *Metameric Colour Stimuli, Metamers* — Spectrally different colour stimuli that have the same tristimulus values.

5.2.4 *Achromatic Stimulus* — A stimulus that, under the prevailing conditions of adaptation, gives rise to an achromatic perceived colour.

NOTE — In the colorimetry of object colours, the colour of the perfect reflecting or transmitting diffuser is usually considered to be an achromatic stimulus for all illuminants, except those whose light sources appear tc be highly chromatic.

5.2.5 *Chromatic Stimulus* — A stimulus that, under the prevailing conditions of adaptation, gives rise to a chromatic perceived colour.

NOTE — In the colorimetry or object colours, stimuli having purities greater than zero are usually considered to be chromatic stimuli.

5.3 Illuminants

5.3.1 *Illuminant* — Radiation with a relative spectral power distribution defined over the wavelength range that influences object colour perception.

NOTE — In everyday English this term is not restricted to this sense, but is also used for any kind of light falling on a body or scene.

5.3.2 *Daylight Illuminant*—Illuminant having the same or nearly the same relative spectral power distribution as a phase of daylight.

5.3.3 *CIE Standard Illuminants*—The illuminants A, B, C, D_{gs}, and other illuminants D, defined by the CIE in terms of relative spectral power distributions.

NOTE — These illuminants are intended to represent; A, Planckian radiation at a temperature of about 2 856 K; B, Direct solar radiation (obsolete); C, average daylight; and D_{65}, daylight including the ultraviolet region.

5.3.4 *CIE Standard Sources* — Artificial sources specified by the CIE whose radiations approximate CIE standard illuminants A, B, and C.

5.4 Trichromatic Systems

5.4.1 *Colour Matching* — Action of making a colour stimulus appear the same in colour as a given colour stimulus.

NOTE — The French and Russian terms apply mainly to the adjustment of equality of the fields of a visual colorimeter, whereas the English and German terms apply equally well to the selection of two material specimens having the same colour under a given illuminant.

5.4.2 *Reference Colour Stimuli*—The set of three colour stimuli on which a trichromatic system is based.

NOTES

1 These stimuli are either real colour stimuli or theoretical stimuli which are defined by linear combinations of real colour stimuli; the magnitude of each of these three reference colour stimuli is expressed in terms of either photometric or radiometric units, or more commonly by specifying the ratios of their magnitudes or by stating that a specified additive mixture of these three stimuli matches a specified achromatic stimulus.

2 In the CIE standard colorimetric systems, the reference colour stimuli are represented by the symbols [X], [Y], [Z] and $[X_{10}]$, $[Y_{10}]$, and $[Z_{10}]$.

5.4.3 *Tristimulus Values (of a Colour Stimulus)* — Amounts of the three reference colouf stimuli, in a given trichromatic system, required to match the colour of the stimulus considered.

NOTE — In the CIE standard colorimetric systems, the tristimulus values are represented by the symbols X, Y, Z, and X_{10}, Y_{10}, and Z_{10}.

5.4.4 *Colour Space* — Geometric representation of colours in space, usually of three dimensions.

5.4.5 *Colour Solid* — That part of a colour space which contains surface colours.

5.4.6 *CIE 1931 Standard Colorimetric System* (XYZ) — A system for determining the tristimulus values of any spectral power distribution using the set of reference colour stimuli [X], [Y], [Z] and the three CIE colour matching functions $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$ adopted by CIE in 1931.

NOTES

1 $\bar{y}\lambda \equiv V(\lambda)$ and hence the tristimulus values *Y* are proportional to luminances.

2 This standard colorimetric system is applicable to centrally viewed fields of angular size between about 1° and about 4° (0.017 and 0.07 rad).

5.5 Chromaticity

5.5.1 *Chromaticity Coordinates* — Ratio of each of a set of three tristimulus values to their sum.

NOTES

1 As the sum of the three chromaticity coordinates equals 1, two of them are sufficient to define a chromaticity.

2 In the CIE standard colorimetric systems, the chromaticity coordinates are represented by the symbols *x, y, z* and x_{10}, y_{10}, and z_{10}.

5.5.2 *Chromaticity* — Property of a colour stimulus defined by its chromaticity coordinates, or by its dominant or complementary wavelength and purity taken together.

5.5.3 *Chromaticity Diagram* —A plane diagram in which a point specified by chromaticity coordinates represents the chromaticities of colour stimuli.

NOTE — In CIE standard colorimeter system *y* is normally plotted as ordinate and *x* as abscissa, to obtain an *x, y* chromaticity diagram.

5.5.4 *Planckian Locus* — The locus of points in a chromaticity diagram that represents chromaticities of the radiation of Planckian radiators at different temperatures.

5.5.5 *Daylight Locus* — The locus of points in a chromaticity diagram that represents chromaticities of phases of daylight with different correlated colour temperatures.

5.5.6 *Colour Temperature* (T_{cp} — The temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus.

Unit: K

NOTE — The reciprocal colour temperature is also used, unit K^{-1}

5.5.7 *Correlated Colour Temperature* (T_{cp} — 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.

Unit: K

NOTES

1 The recommended method of calculating the correlated colour temperature of a stimulus is to determine on a chromaticity diagram the temperature corresponding to the point on the Planckian locus that is intersected by the agreed isotemperature line containing the point representing the stimulus.

2 Reciprocal correlated colour temperature is used rather than reciprocal colour temperature whenever correlated colour temperature is appropriate.

6 EMISSION, OPTICAL PROPERTIES OF MATERIALS

6.1 Emission

6.1.1 *Emission (of Radiation)* — Release of radiant energy.

6.1.2 *Incandescence* — Emission of optical radiation by the process of thermal radiation.

NOTE — In USA, incandescence is restricted to visible radiation.

6.1.3 *Energy Level* — Discrete quantum state of energy of an atom, a molecule or an ion.

6.1.4 *Excitation* — Elevation of the energy levels of atoms, molecules or ions to higher energy levels.

6.1.5 *Luminescence* — Emission, by atoms, molecules or ions in a material, of optical radiation which for certain wavelengths or regions of the spectrum is in excess of the radiation due to thermal emission from that material at the same temperature, as a result of these particles being excited by energy other than thermal agitation.

NOTE — In the USA this term sometimes applies to emitted radiation.

6.1.6 *Photoluminescence* Luminescence caused by absorption of optical radiation.

6.1.7 *Fluorescence* — Photoluminescence in which the emitted optical radiation results from direct transitions from the photo-excited energy level to a lower level, these transitions taking place generally within 10 nano seconds after the excitation.

6.1.8 *Phosphorescence* — Photoluminescence delayed by storage of energy in an intermediate energy level.

NOTES

1 For organic substances, the term phosphorescence applies generally to triplet singlet transitions.

2 This term is sometimes used as a loose expression to designate other types of luminescence.

6.1.9 *Thermally Activated Luminescence; Thermoluminescence* — Luminescence occurring when a previously excited luminescent material is heated.

6.1.10 *(Luminescence) Emission Spectrum* — Spectral distribution of the radiation emitted by a luminescent material for a specified excitation.

6.1.11 *Stimulated Emission* — Process of emission by quantum transition from an excited energy level to a lower level, triggered by incident radiation having the frequency of that transition.

6.1.12 *LASER* — Source emitting coherent optical radiation produced by simulated emission.

6.1.13 *Light Emitting Diode; LED (Abbreviation)* — Solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current.

6.2 Optical Properties of Materials

6.2.1 *Reflection* — Process by which radiation is returned by a surface or a medium, without change of frequency of its monochromatic components.

NOTES

1 Part of the radiation falling on a medium is reflected at the surface of the medium (surface reflection); another part may be scattered back from the interior of the medium (volume reflection).

2 The frequency is unchanged only if there is no Doppler effect due to the motion of the materials from which the radiation is returned.

6.2.2 *Transmission* — Passage of radiation through a medium without change of frequency of its monochromatic components.

6.2.3 *Diffusion Scattering* — Process by which the spatial distribution of a beam of radiation is changed when it is deviated in many directions by a surface or by a medium, without change of frequency of its monochromatic components.

NOTES

1 A distinction is made between selective diffusion and non-selective diffusion according to whether or not the diffusing properties vary with the wavelength of the incident radiation.

2 *See* 6.2.1.

6.2.4 *Regular Reflection; Specular Reflection* — Reflection in accordance with the laws of geometrical optics, without diffusion.

6.2.5 *Regular Transmission; Direct Transmission* — Transmission in accordance with the laws of geometrical optics, without diffusion.

6.2.6 *Diffuse Reflection* — Diffusion by reflection in which, on the macroscopic scale, there is no regular reflection.

6.2.7 *Diffuse Transmission* — Diffusion by transmission in which, on the macroscopic scale, there is no regular transmission.

6.2.8 *Mixed Reflection* — Partly regular and partly diffuse reflection.

6.2.9 *Isotropic Diffuse Reflection* — Diffuse reflection in which the spatial distribution of the reflected radiation is such that the radiance or luminance is the same in all directions in the hemisphere into which the radiation is reflected.

6.2.10 *Isotropic Diffuse Transmission* — Diffuse transmission in which the spatial distribution of the transmitted radiation is such that the radiance or luminance is the same in all directions in the hemisphere into which the radiation is transmitted.

6.2.11 *Diffuser* — Device used to alter the spatial distribution of radiation and depending essentially on the phenomenon of diffusion.

NOTE — If all the radiation reflected or transmitted by the diffuser is diffused with no regular reflection or transmission, the diffuser is said to be completely diffusing; independently of whether or not the reflection or transmission is isotropic.

6.2.12 *Perfect Reflecting Diffuser* — Ideal isotropic diffuser with a reflectance equal to 1.

6.2.13 *Perfect Transmitting Diffuser* — Ideal isotropic diffuser with a transmittance equal to 1.

6.2.14 *Lambert's (Cosine) Law* — For a surface element whose radiance or luminance is the same in all directions of the hemisphere above the surface:

$$I(\theta) = I_n \cos\theta$$

where, $I(\theta)$ and I_n are the radiant or luminous intensities of the surface element in a direction at an angle 0from the normal to the surface and in the direction of that normal, respectively.

6.2.15 *Reflectance (for Incident Radiation of Given Spectral Composition, Polarization and Geometrical Distribution)(p)* — Ratio of the reflected radiant or luminous flux to the incident flux in the given conditions

Unit: 1

6.2.16 *Gloss (of a surface)* — The mode of appearance by which reflected highlights of objects are perceived as superimposed on the surface due to the directionally selective properties of that surface.

6.2.17 *Absorption* — Process by which radiant energy is converted to a different form of energy by interaction with matter.

6.2.18 *Reflectivity (of a Material)(p)* — Reflectance of a layer of the material of such a thickness that there is no change of reflectance with increase in thickness.

Unit: 1

6.2.19 *Diffusion Factor (of a Diffusing Surface, by Reflection or by Transmission) (σ)* — Ratio of the mean of the values of luminance measured at 20° and 70° (0.35 and 1.22 radian) to the luminance measured at 5° (0.09 radian) from the normal, when the surface considered is illuminated normally.

$$\sigma = \frac{L(20°) + L(70°)}{2L(5°)}$$

NOTES

1 The diffusion factor is intended to give an indication of the spatial distribution of the diffused flux. It is equal to 1 for every isotropic diffuser, whatever the value of the diffuse reflectance or transmittance.

2 This way of defining the diffusion factor may be applied only to materials for which the indicatrix of

diffusion does not differ appreciably from that of ordinary opal glass.

6.2.20 *Liquid Crystal Display; LCD* — A display device which uses certain liquid crystals whose reflectance or transmittance may be changed by applying an electric field.

6.2.21 *Refractive Index (of a Medium, for a Monochromatic Radiation of Wavelength X in vacuum); $n(\lambda)$* — Ratio of the velocity of the electromagnetic waves in vacuum to the phase velocity or tne waves or the monochromatic radiation in the medium.

Unit: 1

NOTE — For isotropic media, this index is equal to the ratio of the sines of the angles of incidence (θ_1) and refraction (θ_2) af a ray passing through the surface separating vacuum and medium:

$$n(\lambda) = \frac{\sin \theta_1}{\sin \theta_2}$$

6.2.22 *Dispersion*

a) Phenomenon of change in the velocity of propagation of monochromatic radiations in a medium as a function of the frequency of these radiations;

b) Property of a medium giving rise to this phenomenon; and

c) Property of an optical system resulting in the separation of the monochromatic components of a radiation, obtained for example by means of prisms or gratings.

6.2.23 *Transparent Medium* — Medium in which the transmission is mainly regular and which usually has a high regular transmittance in the spectral range of interest.

NOTE — Objects may be seen distinctly through a medium which is transparent in the visible region, if the geometric form of the medium is suitable.

6.2.24 *Translucent Medium* — Medium which transmits visible radiation largely by diffuse transmission, so that objects are not seen distinctly through it.

7 RADIOMETRIC, PHOTOMETRIC AND COLORIMETRIC MEASUREMENTS, PHYSICAL DETECTORS

7.1 General Terms and Instruments

7.1.1 *Comparison Lamp* — Light source having a constant but not necessarily known luminous intensity, luminous flux, or luminance, with which a standard lamp and the light source under test are successively compared.

7.1.2 *Colorimetry* — Measurement of colours based on a set of conventions.

7.1.3 *Illuminance Meter* — Instrument for measuring illuminance.

7.1.4 *Luminance Meter* — Instrument for measuring luminance.

7.1.5 *Colorimeter* — Instrument for measuring colorimetric quantities, such as the tristimulus values of a colour stimulus.

7.1.6 *Flicker Photometer*—Visual photometer in which the observer sees either an undivided field illuminated successively, or two adjacent fields illuminated alternately, by two sources to be compared, the frequency of alternation being conveniently chosen so that it is above the fusion frequency for colours but below the fusion frequency for brightnesses.

7.1.7 *Goniophotometer* — Photometer for measuring the directional light distribution characteristics of sources, luminaires, media or surfaces.

7.1.8 *Integrating Sphere; Ulbricht Sphere* — Hollow sphere whose internal surface is a diffuse reflector, as non-selective as possible.

NOTE — An integrating sphere is used frequently with a radiometer or photometer.

7.1.9 *Integrating Photometer* — Photometer for measuring luminous flux, generally incorporating an integrating sphere.

7.1.10 *Reflectometer* — Instrument for measuring quantities pertaining to reflection.

7.2 Physical Detectors of Optical Radiation

7.2.1 *Photoelectric Detector* — Detector of optical radiation which utilizes the interaction between radiation and matter resulting in absorption of photons and the consequent liberation of electrons from their equilibrium state thereby generating an electric potential or current or a change in electric resistance excluding electrical phenomenon caused by temperature changes.

7.2.2 *Photoemissive Cell; Phototube* — Photoelectric detector that utilizes emission of electrons caused by optical radiation.

7.2.3 *Photoelement; Photovoltaic Cell* — Photoelectric detector that utilizes the electromotive force produced by the absorption of optical radiation.

7.2.4 *Dark Current (I_Q)* — Output current of a photoelectric detector or of its cathode in the absence of incident radiation.

8 LIGHT SOURCES

8.1 General Terms

8.1.1 *Primary Light Source* — Surface or object emitting light produced by a transformation of energy.

8.1.2 *Secondary Light Source* — Surface or object which is not self emitting but receives light and redirects it, at least in part, by reflection or transmission.

8.1.3 *Lamp*—Source made in order to produce an optical radiation usually visible.

NOTE — This term is also used for certain types of luminaires.

8.2 Incandescent Lamps

8.2.1 *Incandescent (Electric) Lamp* — Lamp in which light is produced by means of an element heated to incandescence by the passage of an electric current.

8.2.2 *Carbon Filament Lamp* — Incandescent lamp whose luminous element is a filament of carbon. For the shapes of filament, *see* **9.3, 9.4** and **9.5.**

8.2.3 *Metal Filament Lamp* — Incandescent lamp whose luminous element is a filament of metal. For the shapes of filament, *see* **9.3,9.4** and **9.5.**

8.2.4 *Tungsten Filament Lamp* — Incandescent lamp whose luminous element is a filament of tungsten. For the shapes of filament, *see* **9.3, 9.4** and **9.5.**

8.2.5 *Vacuum (Incandescent) Lamp* — Incandescent lamp in which the luminous element operates in an evacuated bulb.

8.2.6 *Gas Filled (Incandescent) Lamp* — Incandescent lamp in which the luminous element operates in a bulb filled with an inert gas.

8.2.7 *Tungsten Halogen Lamp* — Gas filled lamp containing halogens or halogen compounds, the filament being of tungsten.

NOTE — Iodine lamps belong to this category.

8.3 Discharge Lamps and Arc Lamps

8.3.1 *Electric Discharge (in a Gas)* — The passage of an electric current through gases and vapours by the production and movements of charge carriers under the influence of an electric field.

NOTE — The phenomenon results in the emission of electromagnetic radiation which plays an essential part in all its applications in lighting.

8.3.2 *Glow Discharge* — Electric discharge in which the secondary emission from the cathode is much greater than the thermionic emission.

NOTE — This discharge is characterized by a considerable cathode fall (typically 70 V or more) and by low current density at the cathode (say 10 A-nr^{2}).

8.3.3 *Arc Discharge; Electric Arc (in a Gas or in a Vapour)* — Electric discharge characterized by a cathode fall which is small compared with that in a glow discharge.

NOTE — The emission of the cathode results from various causes (thermionic emission, field emission, etc.) acting simultaneously or separately, but secondary emission plays only a small part.

8.3.4 *Discharge Lamp* — Lamp in which the light is produced, directly or indirectly, by an electric discharge through a gas, a metal vapour or a mixture of several gases and vapours.

NOTE — As the light is mainly produced in a gas or in a metal vapour, one distinguishes between gaseous discharge lamps, for example xenon, neon, helium, nitrogen, carbon dioxide lamp, and metal vapour lamps, such as the mercury vapour lamp and the sodium vapour lamp.

8.3.5 *High Intensity Discharge Lamp; HID Lamp* — An electric discharge lamp in which the light producing arc is stabilized by wall temperature and the arc has a bulb wall loading in excess of 3 watts per square centimeter.

NOTE — HID lamps include groups of lamps known as high pressure mercury, metal halide and high pressure sodium lamps.

8.3.6 *High Pressure Mercury (Vapour) Lamp* — A high intensity discharge lamp in which the major portion of the light is produced, directly or indirectly, by radiation from mercury operating at a partial pressure in excess of 100 kPa.

NOTE — This term covers clear, phosphor coated (mercury fluorescent) and blended lamps. In a fluorescent mercury discharge lamp, the light is produced partly by the mercury vapour and partly by a layer of phosphors excited by the ultraviolet radiation of the discharge.

8.3.7 *Blended Lamp; Self Ballasted Mercury Lamp* — Lamp containing in the same bulb a mercury vapour lamp and an incandescent lamp filament connected in series.

NOTE — The bulb may be diffusing or coated with phosphors.

8.3.8 *Low Pressure Mercury (Vapour) Lamp* — A discharge lamp of the mercury vapour type, with or v/ithout a coating of phosphors, in which during operation the partial pressure of the vapour does not exceed 100 Pa.

8.3.9 *High Pressure Sodium (Vapour) Lamp* — A high intensity discharge lamp in which the light is produced mainly by radiation from sodium vapour operating at a partial pressure of the order of 10 kPa.

NOTE — The term covers lamps with a clear or diffusing bulb.

8.3.10low *Pressure Sodium (Vapour) Lamp* — A discharge lamp in which the light is produced by radiation from sodium vapour operating at a partial pressure of 0.1 to 1.5 Pa.

8.3.11 *Metal Halide Lamp* — A high intensity discharge lamp in which the major portion of the light is produced from a mixture of a metallic vapour and the products of the dissociation of halides.

NOTE — The term covers clear and phosphor coated lamps.

8.3.12 *Fluorescent Lamp* —A discharge lamp of the low pressure mercury type in which most of the light is emitted by one or several layers of phosphors excited by the ultraviolet radiation from the discharge.

NOTE — These lamps are frequently tubular and, in the UK, are then usually called fluorescent tubes.

8.3.13 *Cold Cathode Lamp* **—** A discharge lamp in which the light is produced by the positive column of a glow discharge.

NOTE — Such a lamp is generally fed from a device providing sufficient voltage to initiate starting without special means.

8.3.14 *Hot Cathode Lamp* **—** A discharge lamp in which the light is produced by the positive column of an arc discharge.

NOTE — Such a lamp generally requires a special starting device or circuit.

8.3.15 *Cold-start Lamp; Instant-start Lamp* — A discharge lamp designed to start without preheating of the electrodes.

8.3.16 *Preheat Lamp; Hot-start Lamp* — A hot cathode lamp which requires preheating of the electrodes for starting.

8.3.17 *Switch-start Fluorescent Lamp* — A fluorescent lamp designed to operate in a circuit requiring a starter for the preheating of the electrodes.

8.3.18 *Starterless Fluorescent Lamp* — A fluorescent lamp of cold or hot start type designed to operate with an auxiliary equipment which enables it, when switched on, to start rather quickly without the intervention of a starter.

8.3.19 *Arc Lamp*—A discharge lamp in which the light is emitted by an arc discharge and/or by its electrodes.

NOTE — The electrodes may be either of carbon (operating in air) or of metal.

8.3.20 *Short-arc Lamp; Compact-source Arc Discharge Lamp*—An arc lamp, generally of very high pressure, in which the distance between the electrodes is of the order of 1 to 10 mm.

NOTE — Certain mercury vapour or xenon lamps belong to this type.

8.3.21 *Long-arc Lamp* **—** An arc lamp, generally of high pressure, in which the distance between the electrodes is large, the arc filling the discharge tube and being therefore, stabilized.

8.4 Lamps of Special Types or for Special Purposes

8.4.1 *Prefocus Lamp* — Incandescent lamp in which, during manufacture, the luminous element is accurately adjusted to a specified position with respect to locating devices that form part of the cap.

8.4.2 *Reflector Lamp* **—** Incandescent or discharge lamp in which part of the bulb, of suitable shape, is coated with a reflecting material so as to control the light.

8.4.3 *Pressed Glass Lamp* — A reflector lamp, the bulb of which consists of two glass parts fused together, namely a metallized reflecting bowl and a patterned cover forming an optical system.

8.4.4 *Sealed Beam Lamp*—A pressed glass lamp designed to give a closely controlled beam of light.

8.4.5 *Projector Lamp* — Lamp in which the luminous element is so mounted that the lamp may be used with an optical system projecting the light in chosen directions.

NOTE — This term includes various types of lamp such as floodlight lamps, spotlight lamps, studio lamps, etc.

8.4.6 *Projection Lamp* — Lamp in which the luminous element is of relatively concentrated form and is so mounted that the lamp may be used with an optical system for the projection of either still or motion pictures on a screen.

8.4.7 *Photoflood Lamp* — Incandescent lamp of especially high colour temperature, often of the reflector type, for lighting objects to be photographed.

8.4.8 *Photoflash Lamp*—Lamp emitting, by combustion within a bulb, a large quantity of light in a single flash of very short duration, for lighting objects to be photographed.

8.4.9 *Flash Tube: Electronic Flash Lamp* — Discharge lamp to be operated with an electronic equipment in order to give a high light output for a very brief period, capable of repetition.

NOTE —This type of lamp may be used for lighting objects to be photographed, for stroboscopic observation or for signaling purposes.

8.4.10 *Daylight Lamp* **—** Lamp giving light with a spectral energy distribution approximating that of a specified daylight.

8.4.11 *Tungsten Ribbon Lamp; Strip Lamp* — Incandescent lamp in which the luminous element is a tungsten ribbon.

NOTE — This type of lamp is particularly used as a standard in pyrometry and spectral radiometry.

8.4.12 *Infrared Lamp* **—** Lamp which radiates especially strongly in the infrared, the visible radiation produced, if any, not being of direct interest.

8.4.13 *Ultraviolet Lamp* — Lamp which radiates especially strongly in the ultraviolet, the visible radiation produced, if any, not being of direct interest.

NOTE — There flre several types of such lamps used for photobiological, photochemical and biomedical purposes.

8.4.14 *Bactericidal Lamp; Germicidal Lamp* — Low pressure mercury vapour lamp with a bulb which transmits the bactericidal ultraviolet-C radiation.

8.4.15 *Spectroscopic Lamp* — Discharge lamp which gives a well defined line spectrum and which, in combination with filters, may be used to obtain monochromatic radiation.

8.4.16 *Reference Lamp* — A discharge lamp selected for the purpose of testing ballasts and which, when associated with a reference ballast under specified condition, has electrical values which are close to the objective values given in a relevant specification.

8.4.17 *Secondary Standard Lamp* — Lamp intended to be used as a secondary photometric standard.

8.4.18 *Working Standard Lamp* — Lamp intended to be used as a working photometric standard.

8.5 Operational Conditions and Characteristics of Lamps

8.5.1 *Rated Luminous Flux (of a Type of Lamp)* — The value of the initial luminous flux of a given type of lamp declared by the manufacturer or the responsible vendor, the lamp being operated under specified conditions.

Unit: lm

NOTES

1 The initial luminous flux is the luminous flux of a lamp after a short ageing period as specified in the relevant lamp standard.

2 The rated luminous flux is sometimes marked on the lamp.

8.5.2 *Rated Power (of a Type of Lamp)* — The value of the power of a given type of lamp 'declared by the manufacturer or the responsible vendor, the lamp being operated under specified conditions.

Unit: W

NOTE — The rated power is usually marked on the lamp

8.5.3 *Life (of a Lamp)* — The total time for which a lamp has been operated before it becomes useless, or is considered to be so according to specified criteria.

NOTE — Lamp life is usually expressed in hours.

8.5.4 *Life Test*—Test in which lamps are operated under specified conditions for a specified time or to the end of life and during which photometric and electrical measurements may be made at specified intervals.

8.5.5 *Life to X Percent Failures* — The length of time during which X percent of the lamps subjected to a life test reach the end of their lives, the lamps being operated under specified conditions and the end of life judged according to specified criteria.

8.5.6 *Average Life* — The average of the individual lives of the lamps subjected to a life test, the lamps being operated under specified conditions and the end of life judged according to specified criteria.

8.5.7 *Luminous Flux Maintenance Factor; Lumen Maintenance (of a Lamp)* — Ratio of the luminous flux of a lamp at a given time in its life to its initial luminous flux, the lamp being operated under specified conditions.

NOTE — This ratio is generally expressed in percent.

8.5.8 *Amplitude of Fluctuation of the Luminous Flux (of a Source run on Alternating Current)* — Relative amplitude of the periodic fluctuation of the luminous flux as measured by the ratio of the difference between the maximum and the minimum luminous flux to the sum of both these values:

$$\frac{\Phi_{max} - \Phi_{min}}{\Phi_{max} + \Phi_{min}}$$

NOTES

1 This ratio is usually expressed in percent and is then known under the expression peri.cent flicker which, however, should be depreciated.

2 Another means sometimes used by the lighting industry to characterize the fluctuation in light output is, flicker index, which is defined by the ratio of two areas deduced from the diagram representing the variation of the instantaneous flux over a period of time; the area of the diagram above the average value is divided by the total area under the curve (this total area is the product of the average value and the given period of time).

8.5.9 *Lamp Voltage (of a Discharge Lamp)* — The voltage between the electrodes of the lamp during stable operating conditions (the root mean square value in the case of an alternating current).

8.5.10 *Starting Time (of an Arc Discharge Lamp)* — The time required for an arc discharge lamp to develop an electrically stable arc discharge, the lamp being operated under specified conditions and the time being measured from the moment its circuit is energized.

NOTE — There is a time delay in the starting device between the time when power is applied to this device and the time when power is applied to the lamp electrodes. The starting time is measured from the latter moment.

8.5.11 *Series Cathode Heating (of a Discharge Lamp)* — Type of heating of the electrodes of a discharge lamp in Which the heating current flows through the electrodes in series.

8.5.12 *Series Cathode Pre-heating (of a Discharge Lamp)* — Type of pre-heating of the electrodes of a discharge lamp in which the pre-heating current flows through the electrodes in series.

8.5.13 *Parallel Cathode Heating (of a Discharge Lamp)* —Type of heating of the electrodes of a discharge lamp in which these electrodes are fed by separate circuits.

NOTE — Each electrode is usually connected across a low voltage winding which may be part of the ballast and provides the heating current. In certain circuits, this low voltage is automatically decreased after the arc has struck.

8.5.14 *Parallel Cathode Pre-heating (of a Discharge Lamp)* — Type of pre-heating of the electrodes of a discharge lamp in which these electrodes are fed by separate circuits.

NOTE — Each electrode is usually connected across a low voltage winding which may be part of the ballast and provides the preheating current. In certain circuits, this low voltage is automatically decreased after the arc has struck.

9 COMPONENTS OF LAMPS AND AUXILIARY APPARATUS

9.1 Luminous Element — The part of a lamp which emits light.

9.2 Filament — Threadlike conductor, usually of tungsten, which is heated to incandescence by the passage of an electric current.

9.3 Straight Filament — Filament which is uncoiled and straight or which consists of uncoiled straight portions.

9.4 Single Coil Filament — Filament wound in the form of a helix.

9.5 Coiled Coil Filament — Helical filament wound into a larger helix.

9.6 Bulb — Transparent or translucent gas tight envelope enclosing the luminous element(s).

9.7 Clear Bulb — Bulb which is transparent to visible radiation.

9.8 Frosted bulb — Bulb which is made diffusing by roughening its inner or outer surface.

9.9 Opal Bulb — Bulb in which all, or a layer, of the material diffuses the light.

9.10 Coated Bulb — Bulb coated internally or externally with a thin diffusing layer.

9.11 Reflectorized bulb — Bulb having part of its interior or exterior surface coated to form a reflecting surface to enhance the light in particular directions.

NOTE — Such surfaces may remain transparent to certain radiations, in particular to the infrared.

9.12 Enamelled Bulb — Bulb coated with a layer of translucent enamel.

9.13 Coloured Bulb — Bulb made of glass coloured in the mass, or of clear glass coated internally or externally with a coloured layer which may be transparent or diffusing.

9.14 Hard Glass Bulb — Bulb made of glass with a high softening temperature and resistant to thermal shock.

9.15 Cap; Base — That part of a lamp which provides connection to the electrical supply by means of a lamp holder or lamp connector and, in most cases, also serves to retain the lamp in the lamp holder.

NOTE — The cap of a lamp and its corresponding holder are generally identified by one or more letters followed by a number which indicates approximately the principal dimension (generally the diameter) of the cap in millimeters. The standard code is to be found in IS 2418(Part 3) and 9206.

9.16 Screw Cap — Cap (international designation E) having its shell in the form of a screw thread which engages the lamp holder.

9.17 Bayonet Cap — Cap (international designation B) with bayonet pins on its shell which engage in slots in a lamp holder.

9.18 Shell Cap — Cap (international designation S) having a smooth cylindrical shell.

9.19 Pin Cap — Cap (international designation F for a single pin, G for two or more pins) which has one or more pins.

9.20 Pre-focus Cap — Cap (international designation P) which enables the luminous element to be brought into a specified position relative to the cap during manufacture of the lamp so that reproducible positioning may be assured when the lamp is inserted in a suitable lamp holder.

9.21 Bayonet Pin — Small piece of metal which projects from the shell of a cap, particularly a bayonet cap, and which engages in a slot in a lamp holder to fix the cap.

9.22 Contact Plate — Piece of metal, insulated from the shell of the cap, which is connected to one of the lead in wires and provides connection to the electric supply.

9.23 Pin; Post — Piece of metal, usually of cylindrical shape, fixed at the end of the cap so as to engage in the corresponding hole in a lamp holder for fixing the cap and/or for making contact.

NOTE — The pin and post generally indicate a difference in size, a pin being smaller than a post.

9.24 Lamp holder — A device which holds the lamp in position, usually by having the cap inserted in it, in which case it also provides the means of connecting the lamp to the electric supply.

NOTE — The term socket or, when the context is clear, the abbreviation holder are commonly used instead of lamp holder.

9.25 Main Electrode (of a Discharge Lamp) — Electrode through which the discharge current passes after the discharge has been stabilized.

9.26 Starting Electrode (of a Discharge Lamp) — Auxiliary electrode for starting the discharge in a lamp.

9.27 Arc Tube — The enclosure in which the arc of the lamp is confined.

9.28 Emissive Material — Material deposited on a metal electrode to promote the emission of electrons.

9.29 Starting Strip — Narrow conducting strip placed longitudinally on the internal or external wall of a tubular discharge lamp for assisting in starting.

NOTE — The strip may be connected to one or both of the shells of the caps or, possibly, to an electrode.

9.30 Starting Device — Apparatus which provides, by itself or in combination with other components in the circuit, the appropriate electrical conditions needed to start a discharge lamp.

9.31 Starter — A starting device, usually for fluorescent lamps, which provides for the necessary preheating of the electrodes and, in combination with the series impedance of the ballast, causes a surge in the voltage applied to the lamp.

9.32 Ignitor — A device intended, either by itself or in combination with other components, to generate voltage pulses to start a discharge lamp without providing for the pre-heating the electrodes.

9.33 Ballast — A device connected between the supply and one or more discharge lamps which serves mainly to limit the current of the lamp(s) to the required value.

NOTE — A ballast may also include means for transforming the supply voltage, correcting the power factor and, either alone or in combination with a starting device, provide the necessary conditions for starting the lamp(s).

9.34 Semiconductor Ballast — A unit comprising semiconductor devices and stabilizing elements for the operation under ac power of one or more discharge lamps and energized by a dc or an ac source.

9.35 Reference Ballast — A special inductive type ballast designed for the purpose of providing comparison standards for use in testing ballasts, for the selection of reference lamps and for testing regular production lamps under standardized conditions.

9.36 Dimmer — A device in the electric circuit for varying the luminous flux from lamps in a lighting installation.

10 LIGHTING TECHNOLOGY, DAYLIGHTING

10.1 General Terms

10.1.1 *Lighting*; *Illumination* — Application of light to a scene, objects or their surroundings so that they may be seen.

NOTE — This term is also used colloquially with the meaning 'lighting system' or 'lighting installation'.

10.1.2 *Lighting Technology*; *Illuminating Engineering* — Applications of lighting considered under their various aspects.

10.1.3 *Luminous Environment* — Lighting considered in relation to its physiological and psychological effects.

10.1.4 *Visual Performance* — Performance of the visual system as measured for instance by the speed and accuracy with which a visual task is performed.

10.1.5 *Equivalent Contrast (of a Task)* — Luminance contrast of a visibility reference task having equal visibility at the same luminance level as that of the task considered.

10.2 Types of Lighting

10.2.1 *General Lighting* — Substantially uniform lighting of an area without provision for special local requirements.

10.2.2 *Local Lighting* — Lighting for a specific visual task, additional to and controlled separately from the general lighting.

10.2.3 *Localized Lighting* — Lighting designed to illuminate an area with a higher illuminance at certain specified positions, for instance those at which work is carried out.

10.2.4 *Permanent Supplementary Artificial Lighting (in Interiors)* — Permanent artificial lighting intended to supplement the natural lighting of premises, when the natural lighting is insufficient or objectionable, if used alone.

NOTE — This type of lighting is generally denoted in brief by the initial letters PSALI of the words of the English term.

10.2.5 *Emergency Lighting* — Lighting provided for use when the supply to the normal lighting fails.

10.2.6 *Escape Lighting* — That part of emergency lighting provided to ensure that an escape route may be effectively identified and used.

10.2.7 *Safety Lighting* — That part of emergency lighting provided to ensure the safety of people involved in a potentially hazardous process.

10.2.8 *Stand-by Lighting* — That part of emergency lighting provided to enable normal activities to continue substantially unchanged.

10.2.9 *Direct Lighting* — Lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 90 percent to 100 percent.

10.2.10 *Semi Direct Lighting* — Lighting of means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 60 percent to 90 percent.

10.2.11 *General Diffused Lighting* — Lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 40 percent to 60 percent.

10.2.12 *Semi Indirect Lighting* — Lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 10 percent to 40 percent.

10.2.13 *Indirect Lighting* — Lighting by means of luminaires having a distribution of luminous intensity such that the fraction of the emitted luminous flux directly reaching the working plane, assumed to be unbounded, is 0 percent to 10 percent.

10.2.14 *Directional Lighting* — Lighting in which the light on the working plane or on an object is incident predominantly from a particular direction.

10.2.15 *Diffused Lighting* — Lighting in which the light on the working plane or on an object is not incident predominantly from a particular direction.

10.2.16 *Floodlighting* — Lighting of a scene or object, usually by projectors, in order to increase considerably its illuminance relative to its surroundings.

10.2.17 *Spotlighting* — Lighting designed to increase considerably the illuminance of a limited area or of an object relative to the surroundings, with minimum diffused lighting.

10.3 Terms Used in Lighting Calculations

10.3.1 *Illuminance Vector (at a Point)* — Vector quantity equal to the maximum difference between the illuminances on opposite sides of an element of surface through the point considered, that vector being normal to and away from the side with the greater illuminance.

10.3.2 *Distribution of Luminous Intensity (Spatial) (of a Source)* — Display, by means of curves or tables, of the value of the luminous intensity of the source as a function of direction in space.

10.3.3 *Symmetrical Luminous Intensity Distribution (of a Source)* — Distribution of luminous intensity having an axis of symmetry or at least one plane of symmetry.

NOTE — Sometimes this term is used in the sense of the term **10.3.4**. This usage is to be discouraged.

10.3.4 *Rotationally Symmetrical Luminous Intensity Distribution (of a Source)* — Distribution of luminous intensity which may be represented by rotating around an axis of a polar luminous intensity distribution curve in a plane containing that axis.

10.3.5 *Mean Spherical Luminous Intensity (of a Source)* — Average value of the luminous intensity of the source in all directions, equal to the quotient of its luminous flux by the solid angle 4π sr.

10.3.6 *Iso-intensity Curve; Iso-intensity Line; Isocandela Curve or Line (Deprecated) (of a Source)* — Curve traced on a sphere that has its centre at the light centre of the source, joining all the points corresponding to those directions in which the luminous intensity is the same, or a plane projection of that curve.

10.3.7 *Iso-intensity Diagram*; *Isocandela Diagram (Deprecated)* — Array of iso-intensity curves.

10.3.8 *Half-Peak Divergence*; *One-Half-Peak Spread (of a Projector, in a Specified Plane)* — Angular extent of all the radius vectors of the polar curve of luminous intensity in the specified plane having lengths greater than 50 percent of the maximum.

NOTE — In British practice beam spread relates to the total angle within which the illuminance on a plane normal to the axis of the beam exceeds 10 percent of the maximum.

10.3.9 *Cumulative Flux (of a Source, for a Solid Angle)* — Luminous flux emitted by the source under operating conditions, within a cone having a vertically downward axis and enclosing to the solid angle.

10.3.10 *Zonal Flux (of a Source, for a Zone)* — Difference of the cumulative fluxes of the source for the solid angles subtended by the upper and lower boundaries of the zone.

10.3.11 *Total Flux (of a Source)* — Cumulative flux of the source for the solid angle 4π sr.

10.3.12 *Downward Flux (of a Source)* — Cumulative flux of the source for the solid angle 2π sr, below the horizontal plane passing through the source.

10.3.13 *Upward Flux (of a Source)* — Difference of total and downward fluxes.

10.3.14 *Optical Light Output Ratio (of a Luminaire)* — Ratio of the total flux of the luminaire, measured under specified conditions, to the sum of the individual luminous fluxes of the lamps when inside the luminaire.

NOTE — For luminaires using incandescent lamps only, the optical light output ratio and the light output ratio are the same in practice.

10.3.15 *Light Output Ratio (of a Luminaire)*; *Luminaire Efficiency* — Ratio of the total flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment, under specified conditions.

10.3.16 *Downward Light Output Ratio (of a Luminaire)* — Ratio of the downward flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment, under specified conditions.

10.3.17 *Direct Flux (on a Surface)* — Luminous flux received by the surface directly from a lighting installation.

10.3.18 *Indirect Flux (on a Surface)* — Luminous flux received by the surface from a lighting installation, after reflection from other surfaces.

10.3.19 *Installation Flux Density (for an Interior Lighting)* — Quotient of the sum of the individual total fluxes of the luminaires of an installation, by the floor area.

Unit: $lm.m^{-2}$

10.3.20 *Reference Surface* — Surface on which illuminance is measured or specified.

10.3.21 *Work Plane*; *Working Plane* — Reference surface defined as the plane at which work is usually done.

NOTE — In interior lighting and unless otherwise indicated, this plane is assumed to be a horizontal plane 0.85 m above the floor and limited by the walls of the room.

10.3.22 *Utilization Factor* — (*Coefficient of Utilization of an Installation, for a Reference Surface*) — Ratio of the luminous flux received by the reference surface to the sum of the individual fluxes of the lamps of the installation.

10.3.23 *Utilance (of an Installation, for a Reference Surface) (U)* -- Ratio of the luminous flux received by the reference surface to the sum of the individual total fluxes of the luminaires of the installation.

10.3.24 *Room Index*; *Installation Index (K)* — Number representative of the geometry of the room between the working plane and the plane of the luminaires, used in calculation of utilization factor or utilance.

NOTES

1 Unless otherwise indicated, the room index (*K*) is given by the formula:

$$K = \frac{ab}{h(a+b)}$$

in which a and b are the dimensions of the sides of the room and h the mounting height, that is the distance between the working place and the plane of the luminaires.

2 In British practice, the ceiling cavity index is calculated from the same formula except that *h* is the distance from ceiling to luminaires.

3 In the USA, the term room cavity ratio is currently used. This is equal to five times the reciprocal of the room index defined by the formula in Note 1. Two supplementary terms are used, ceiling cavity ratio and floor cavity ratio which are derived in the same way as the room cavity ratio except that h is respectively the distance from the ceiling to the luminaires and from the floor to the working plane.

10.3.25 *Iso-luminance Curve* — Locus of points on a surface at which the luminance is the same, for given positions of the observer and of the source or the sources in relation to the surface.

10.3.26 *Iso-illuminance Curve*; *Iso-illuminance Line*; *Iso-lux Curve or Line (Deprecated)* — Locus of points on a surface where the illuminance has the same value.

10.3.27 *Uniformity Ratio of Illuminance (on a Given Plane)* — Ratio of the minimum illuminance to the average illuminance on the plane.

NOTE — Use is made also of a) the ratio of the minimum to the maximum illuminance and b) the inverse of either of these two ratios.

10.3.28 *Light Loss Factor*; *Maintenance Factor (Obsolete)* — Ratio of the average illuminance on the working place after a certain period of use of a lighting installation to the average illuminance obtained under the same conditions of the installation considered conventionally as new.

NOTES

1 The term depreciation factor has been formerly used to designate the reciprocal of the above ratio.

2 The light losses take into account dirt accumulation on luminaire and room surfaces and lamp depreciation.

10.3.29 *Service Illuminance (of an Area)* — Mean illuminance during one maintenance cycle of an installation averaged over the relevant area.

NOTE — The area may be either the whole area of the working plane in an interior or the working areas.

10.3.30 *Ballast Lumen Factor* — Ratio of the luminous flux emitted by a reference lamp when operated with a particular production ballast to the luminous flux emitted by the same lamp when operated with its reference ballast.

10.4 Terms Relating to Distance Measurements

10.4.1 *Light Centre (of a Source)* — Point used as origin for photometric measurements and calculations.

10.4.2 *Test Distance (for Photometric Measurements)* — Distance from the light centre to the surface of the detector.

10.4.3 *Spacing (in an Installation)* — Distance between the light centres of adjacent luminaires of the installation.

10.4.4 *Suspension Length (of a Luminaire in an Interior)* — Distance between the ceiling and the light centre of the luminaire.

10.5 Terms Relating to Interreflection

10.5.1 *Interreflection* — General effect of the reflections of radiation between several reflecting surfaces.

10.5.2 *Configuration Factor (Between Two Surfaces S_i and S_j) (c_{ij})* — Ratio of irradiance or illuminance (E_i) at a point on surface S_i due to the flux received from the surface S_j, to the radiant or luminous exitance (M_j) of surface S_j.

$$c_{ij} = \frac{E_i}{M_j}$$

Unit : 1

10.5.3 *Form Factor (Between Two Surfaces S_i and S_j) (f_{ij})* — Ratio of the average radiant or luminous flux density (Φ_i) received over surface S_i of area A_i from surface S_j to the radiant or luminous exitance (M_j) of surface S_j.

$$f_{ij} = \frac{\Phi_i}{A_i . M_j}$$

10.6 Daylighting

10.6.1 *Solar Radiation* — Electromagnetic radiation from the sun.

10.6.2 *Extraterrestrial Solar Radiation* — Solar radiation incident on the outer limit of the earth's atmosphere.

10.6.3 *Solar Constant ($E_{e,o}$)* — Irradiance produced by extraterrestrial solar radiation on a surface perpendicular to the sun's rays at mean sun-earth distance.

NOTE — $E_{e,o}$ = (1 367 ± 7)W·m^{-2}. Final report No. 590 of CIMO VIII [Commission for instruments and methods of observation] of the World Meteorological Organization, Mexico City, October 1981.

10.6.4 *Direct Solar Radiation* — That part of extraterrestrial solar radiation which as a collimated beam reaches the earth's surface after selective attenuation by the atmosphere.

10.6.5 *Diffuse Sky Radiation* — That part of solar radiation which reaches the earth as a result of being scattered by the air molecules, aerosol particles, cloud particles or other particles.

10.6.6 *Global Solar Radiation* — Combined direct solar radiation and diffuse sky radiation.

10.6.7 *Sunlight* — Visible part of direct solar radiation.

10.6.8 *Skylight* — Visible part of diffuse sky radiation.

10.6.9 *Daylight* — Visible part of global solar radiation.

10.6.10 *Reflected (Global) Solar Radiation* — Radiation that results from reflection of global solar radiation by the surface of the earth and by any surface intercepting that radiation.

10.6.11 *Optical Thickness of the Atmosphere [$\delta(\varepsilon)$]* — Quantity defined by the formula:

$$\delta(\varepsilon) = -\ln(\Phi'_e / \Phi_e)$$

where Φ_e is the radiant flux of a collimated beam entering the upper limit layers of the atmosphere at an angle ε to the vertical, and Φ'_e the attenuated radiant flux of that beam reaching the surface of the earth.

NOTES

1 *See* **10.6.5**.

2 In English, the term Optical Depth is sometimes used instead of Optical Thickness.

10.6.12 *Total Turbidity Factor (according to Linke) (T)* — Ratio of the vertical optical thickness of a turbid atmosphere to the vertical optical thickness of the pure and dry atmosphere (Rayleigh atmosphere), related to the whole solar spectrum.

$$T = \frac{\delta_R + \delta_A + \delta_Z + \delta_W}{\delta_R}$$

where δ_R is the optical thickness with respect to Rayleigh scattering at the air molecules, δ_A, δ_Z, δ_W are the optical thickness with respect to Mie scattering and absorption at the aerosol particles, to the ozone absorption, and to water vapour absorption respectively.

10.6.13 *Relative Optical Air Mass (m)* — Ratio of the slant optical thickness, $\delta(\varepsilon)$, to the vertical optical thickness, $\delta(0)$, of the atmosphere.

$$m = \delta(\varepsilon) / \delta(0)$$

Unit: 1

NOTE — When the curvature of the atmosphere and atmospheric refraction are neglected, then m = 1/cosε.

10.6.14 *Global Illuminance (E_g)* — Illuminance produced by daylight on a horizontal surface on the earth.

10.6.15 *CIE Standard Overcast Sky* — Completely overcast sky for which the ratio of its luminance L_γ in the direction at the angle γ above the horizon to its luminance L_z at the zenith is given by the relation

$$L_\gamma = L_z (1 + 2 \sin\gamma) / 3.$$

10.6.16 *CIE Standard Clear Sky* — Cloudless sky for which the relative luminance distribution is described in CIE publication No. 22 (1973).

10.6.17 *Sunshine Duration (S)* — Sum of time intervals within a given time period (hour, day, month, year) during which the irradiance from direct solar radiation on a plane normal to the sun direction is equal to or greater than 200 watts per square meter.

10.6.18 *Daylight Factor (D)* — Ratio of the illuminance at a point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. The contribution of direct sunlight to both illuminances is excluded.

NOTES

1 Glazing, dirt effects, etc. are included.

2 When calculating the lighting of interiors, the contribution of direct sunlight shall be considered separately.

10.6.19 *Sky Component of Daylight Factor (D_s)* — Ratio of that part of the illuminance at a point of a given plane which is received directly (or through clear glass) from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. The contribution of direct sunlight to both illuminances is excluded.

NOTE — *See* Note 2 of **10.6.18**.

10.6.20 *Externally Reflected Component of Daylight Factor (D_e)* — Ratio of the part of the illuminance at a point on a given plane in an interior which is received directly from external reflecting surfaces illuminated directly or indirectly by a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. The contribution of direct sunlight to both illuminances is excluded.

10.6.21 *Internally Reflected Component of Daylight Factor (D_i)* — Ratio of the part of the illuminance at a point on a given plane in an interior which is received directly from internal reflecting surfaces illuminated directly or indirectly by a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky. The contribution of direct sunlight to both illuminances is excluded.

10.6.22 *Obstruction* — Anything outside a building which prevents the direct view of part of the sky.

10.6.23 *Daylight Opening* — Area, glazed or unglazed, that is capable of admitting daylight to an interior.

10.6.24 *Window* — Daylight opening on a vertical or nearly vertical area of a room envelope.

10.6.25 *Rooflight*; *Skylight* — Daylight opening on the roof or on a horizontal surface of a building.

10.6.26 *Shading* — Device designed to obstruct, reduce or diffuse solar radiation.

11 LUMINAIRES AND THEIR COMPONENTS

11.1 Luminaire — Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply.

NOTE — The term lighting fittings is deprecated.

11.2 Symmetrical (Asymmetrical) Luminaire — Luminaire with a symmetrical (asymmetrical) luminous intensity distribution.

11.3 Wide Angle Luminaire — Luminaire which distributes the light over a comparatively wide solid angle.

11.4 Ordinary Luminaire — Luminaire without special protection against dust or moisture.

11.5 Protected Luminaire — Luminaire with special protection against ingress of dust, moisture or water.

NOTE — IS 10322(Part 1):1982, considers among others the following types of protected luminaires:

a) Dust-Proof luminaire;
b) Dust-tight luminaire;
c) Drip-proof luminaire;
d) Splash-proof luminaire;
e) Rainproof luminaire;
f) Jet-proof luminaire; and
g) Watertight luminaire.

11.6 Flameproof Luminaire; Explosion-Proof Luminaire — Luminaire which satisfies the appropriate regulation applicable to equipment with explosion proof enclosure, for use in situations where there is a risk of explosion.

11.7 Adjustable Luminaire — Luminaire of which the main part may be turned or moved by means of appropriate devices.

NOTE — An adjustable luminaire may be fixed or portable.

11.8 Portable Luminaire — Luminaire which can easily be moved from one place to another even while connected to the electric supply.

11.9 Pendant Luminaire; Suspended Luminaire — Luminaire provided with a cord, chain, tube, etc, which permits it to be suspended from a ceiling or a wall support.

11.10 Recessed Luminaire — Luminaire suitable to be fully or partly recessed into a mounting surface.

11.11 Troffer — Long recessed luminaire usually installed with the opening flush with the ceiling.

11.12 Coffer — Recessed panel or dome in the ceiling.

11.13 Downlight — Small luminaire concentrating the light, usually recessed in the ceiling.

11.14 Cornice Lighting — Lighting system comprising light sources shielded by a panel parallel to the wall and attached to the ceiling, and distributing light over the wall.

11.15 Valance Lighting; Pelmet Lighting — Lighting system comprising light sources shielded by a panel parallel to the wall at the top of a window.

11.16 Cove Lighting — Lighting system comprising light sources shielded by a ledge or recess, and distributing light over the ceiling and upper wall.

11.17 Standard Lamp; Floor Lamp — Portable luminaire on a high stand suitable for standing on the floor.

11.18 Bulkhead Luminaire — Protected luminaire of compact design intended to be fixed directly on a vertical or horizontal surface.

11.19 Table Lamp — Portable luminaire intended for standing on furniture.

11.20 Hand Lamp — Portable luminaire with a handle and a flexible cord for its supply.

11.21 Torch; Flashlight — Portable luminaire fed by a built in source, usually a dry battery or an accumulator, sometimes a manual generator.

11.22 Lighting Chain — Set of lamps arranged along a cable and connected in series or parallel.

11.23 Projector — Luminaire using reflection and/or refraction to increase the luminous intensity within a limited solid angle.

11.24 Searchlight — A high intensity projector having an aperture usually greater than 0.2 m and giving an approximately parallel beam of light.

11.25 Spotlight — A projector having an aperture usually smaller than 0.2 m and giving a concentrated beam of light of usually not more than 0.35 radian (20°) divergence.

11.26 Floodlight — Projector designed for floodlighting, usually capable of being pointed in any direction.

11.27 Cut-off — Technical device used for concealing lamps and surfaces of high luminance from direct view in order to reduce glare.

NOTE — In public lighting, distinction is made between full cut-off luminaires, semi cut-off luminaires and non cut-off luminaires.

11.28 Cut-off Angle (of a Luminaire) — Angle, measured up from nadir, between the vertical axis and the first line of sight at which the lamps and the surfaces of high luminance are not visible.

11.29 Shielding Angle — The complementary angle of the cut-off angle.

11.30 Refractor — Device used to alter the spatial distribution of the luminous flux from a source and depending essentially on the phenomenon of refraction.

11.31 Reflector — Device used to alter the spatial distribution of the luminous flux from a source and depending essentially on the phenomenon of reflection.

11.32 Diffuser — Device used to alter the spatial distribution of the luminous flux from a source and depending essentially on the phenomenon of diffusion.

11.33 Bowl — Diffuser, refractor or reflector in the form of a bowl, intended to be placed below the lamp.

11.34 Globe — Envelope of transparent or diffusing material, intended to protect the lamp, to diffuse the light, or to change the colour of the light.

11.35 Shade — Screen which may be made of opaque or diffusing material and which is designed to prevent a lamp from being directly visible.

11.36 Louvre — Screen made of translucent or opaque components and geometrically disposed to prevent lamps from being directly visible over a given angle.

11.37 Protective Glass — Transparent or translucent part of an open or closed luminaire designed to protect the lamp(s) from dust or dirt, or to prevent their contact with liquids, vapours or gases and to render them inaccessible.

11.38 Luminaire Guard — Device, shaped as a grid, used to shield the protective glass of the luminaire against mechanical shocks.

11.39 Studio Floodlight — Lighting device with a half peak divergence exceeding 1.74 radian (100°) and with a total divergence not less than 3.14 radians (180°).

11.40 Special Studio Floodlight — Lighting device with a specified half peak divergence, less than 1.74° radian (100°) and a specified total divergence.

11.41 Reflector Spotlight — Projector with simple reflector and sometimes capable of adjustment of divergence by relative movement of lamp and mirror.

11.42 Lens Spotlight — Projector with simple lens, with or without reflector, sometimes capable of adjustment of divergence by relative movement of lamp and lens.

11.43 Fresnel spotlight — Lens spotlight but with a stepped lens.

11.44 Profile Spotlight — Projector giving a hard edged beam of light which may be varied in outline by diaphragms, shutters or silhouette cut-off masks.

11.45 Effects Projector — Projection apparatus with optics designed to give even field illumination of slides and, with a suitable objective lens, well defined projection of detail.

NOTE — Slide can be of stationary or moving-effects type.

11.46 Soft light — Lighting device of sufficient size to produce diffused lighting with indefinite shadow boundaries.

11.47 Miner's (Personal) Lamp — Mine luminaire with integral energy sources, required for each person entering an underground mine.

11.48 Cap Lamp — Miner's personal lamp designed to be attached to a miner's helmet.

11.49 Portable Mine Luminaire — Mine luminaire with integral or mains operated power source, which may supply light while being moved.

11.50 Mine Rescue Luminaire — Portable mine luminaire with integral power source designed for rescue operations.

11.51 Intrinsically Safe Luminaire — Mine luminaire whose safety results from the use of intrinsically safe electrical circuits.

SP 72 : 2010

NATIONAL LIGHTING CODE

PART 2 PHYSICS OF LIGHT
Section 1 General Principles

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

It took scientists a very long time to formulate a tenable theory relating to the nature of light, even when its properties and behaviour were fairly well understood. Its interaction with matter leads to transformation into thermal, electrical or chemical energy.

This section is devoted to properties and behavior of light, especially the laws of propagation in various media, the energy content and various colour aspects to the extent of understanding of physical characteristics of light which is indispensable for those involved in lighting practice.

NATIONAL LIGHTING CODE

PART 2 PHYSICS OF LIGHT
Section 1 General Principles

1 SCOPE

This section covers general principles about the physics of light related to illumination.

2 TERMINOLOGY

The terminology used in this section is given in Part 1 of this code.

3 GENERAL PRINCIPLES

3.1 Theories of Light

In 1678, Christian Huygens postulated that light was propagated through an omnipresent, very thin medium called 'ether'. He believed that light waves were longitudinal.

This theory could explain the following:

a) Reflection of light;

b) Refraction of light; and

c) Double refraction.

The major contribution was the formulation of the wave principle.

In 1704 Isaac Newton published the light theory discarding Greek thoughts that vision was the result of an 'imago' dissociation from the object being viewed that enters the eye and the conviction that the eye transmitted 'visual rays', which scanned the object being viewed. Newton regarded light consisting of an endless stream of high speed particles.

This theory could explain the following:

a) Rectilinear propagation of light;

b) Reflection of light; and

c) Refraction of light.

In 1768, Euler brought strong arguments in favour of continuous waves rather than pulses. He was the first to suggest the concept of wavelength.

Following the ideas of Hooke and Thomas Young, Augustin Fresnel accepted that light was a transverse movement, instead of a longitudinal one to explain double refraction and polarization.

In 1873, Maxwell published his opinion that light was electromagnetic waves and that light waves are carried by an electromagnetic field, rather than by material ether as postulated by Huygens. Subsequently, Heinrich Hertz experimentally generated electromagnetic waves supporting Maxwell's theory.

Maxwell's theory could not satisfactorily explain spectral energy distribution in relation to the temperature of an incandescent body. In 1900, Max Plank suggested that light is not emitted continuously but in small indivisible quantities. In 1905, Albert Einstein used the quantum theory to successfully explain that photoemission (the emission of electrons by certain metals under the influence of light) took place only if the wavelength of the light was shorter than a certain maximum value as determined by the metal. This could not be explained with the wave theory. The quantum theory also explained spectral lines.

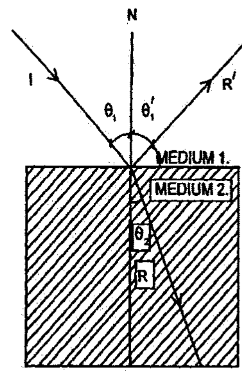
Louis de Broglie and Werner Heisenberg in 1927 constructed a mathematical model to explain the theory that on an atomic scale there is a fundamental uncertainty between the determination of the position and the velocity of a photon. It was shown by Heisenberg, however, that for particles of atomic magnitude, it is in principle impossible to determine both position and momentum simultaneously with perfect accuracy.

The corpuscular and the wave descriptions are merely complementary ways of describing the same principle. The concepts of photons and waves are equally justified and each is applicable in its own sphere.

3.2 Lighting Phenomena

3.2.1 *Laws of Reflection and Refraction*

When a ray of light strikes any boundary between two transparent substances, in which the velocity of light is appreciably different, it is in general divided into a reflected ray and a refracted ray. This is explained by Fig. 1.



I— Incident ray
R' — Reflected ray
R— Refracted ray
N— Normal to the surface

Fig. 1 Laws of Reflection and Refraction

Mathematical representation of the laws of reflection and refraction are:

a) Law of reflection

$$\theta_1 = \theta_1'$$

where

θ_1 is the angle of incidence and θ_1' is the angle of reflection.

The incident ray (I) and the reflected ray (R') and the normal (N) are in one plane; and

b) Law of refraction (Snell's Law):

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{\mu_1}{\mu_2}$$

where

θ_2 = angle of refraction;

μ_1 = refractive index of medium 1; and

μ_2 = refractive index of medium 2.

The incident ray (I) and the refracted ray (R) and the normal (N) at the point of incidence are in one plane.

NATIONAL LIGHTING CODE

PART 2 PHYSICS OF LIGHT

Section 2 Vision

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Light has an effect on the physiology and psychology of the human being, and it enables him to perceive what is going on around him. There exists a close relationship between the way the visual scene is presented to us and the ability of the eye to fulfill its task properly.

NATIONAL LIGHTING CODE

PART 2 PHYSICS OF LIGHTS
Section 2 Vision

1 SCOPE

This section covers lighting and vision and its effect on the physiology and psychology of human beings.

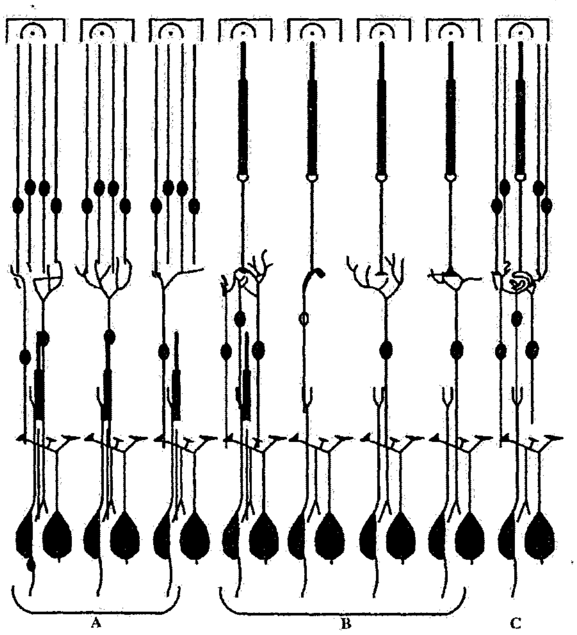
2 TERMINOLOGY

For the purpose of definitions, Part 1 of this code shall apply.

3 THE VISUAL PROCESS AND THE EYE

3.1 The unique properties of the eye, a tremendous sensitivity range, in the order of 1:10, combined with a high resolving power and the ability to distinguish between up to 100 000 colour shades, provided the lighting is good, are mainly attributable to the fact that the eye combines two seeing functions in one organ.

These functions are attributed to the rods and cones. The rods are highly light sensitive and principally responsible for detection of shape and movement, but cannot distinguish colours. Cones, on the other hand, are less sensitive to light, but can distinguish colours. They also enable us to see fine detail.



A. Several rods connected to the same nerve fibre
B. Cones in the fovea, each with a single line connection to the brain
C. Rods and cones sharing the same nerve fibre

Fig. 1 Schematic Section through the Retina, Showing the Various Types of Connection from the Rods and Cones to the Nerve Fibre

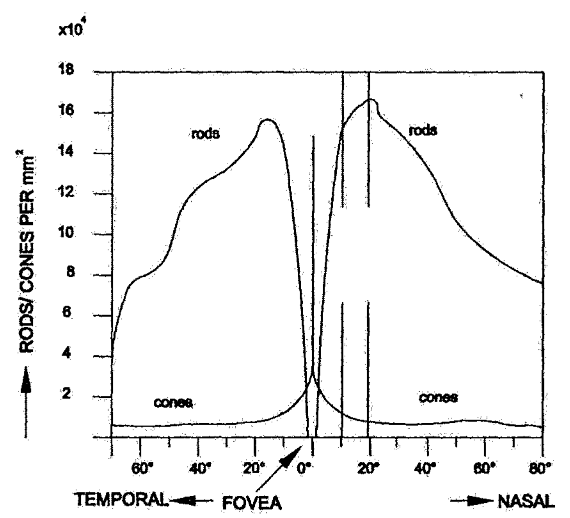


Fig. 2 Distribution of Density of Rods and Cones over a Horizontal Section through the Retina

The process of seeing is essentially an electrochemical one. When in the retina a rod or cone is stimulated, the chemical composition of a pigment changes temporarily. This results in a minute electric current, which passes to the brain through nerve fibre. In the case of the rods, about one hundred at a time are connected to one and the same nerve fibre (*see* Fig.1). The result is that these clusters of rods are highly sensitive to light as the stimulus of more rods is summed. On the other hand, definition is poor as the brain cannot distinguish between individual rods in a cluster. Under conditions of rod seeing only, one obtains therefore a rather blurred picture. With rods no colours can be distinguished, but the sensitivity of the rod pigment varies for the various spectral colours. The maximum sensitivity is found at a wavelength of 507 nm (green) and steeply decreases toward both ends of the spectrum.

Sparsely distributed, cones occur over the entire retina, but in the fovea they are densely packed (*see* Fig. 2). Unlike with rods, at least in the foveal area, each cone is individually connected to the brain, resulting in a very high resolving power. On the other hand, sensitivity to light for cones is far less than for rods. Therefore, at luminance levels of 3.5 cd/m^2 and less, cones gradually cease to function. The overall spectral sensitivity curve for cones is different from that for rods. The point of maximum sensitivity lies at 555 nm (bright yellow), and the fall off toward the red side of the spectrum is less pronounced. The result is that at very low lighting levels, when the cones no longer function and the rods take over, blue colours seem to become brighter with respect to red colours [*see* Fig. 3 a)].

The cones enable us to distinguish colours. Until a few decades ago the underlying processes were hardly understood, but now we know that there are in fact three types of cones, with pigments sensitive to the red, green and blue parts of the spectrum, respectively. Persons who miss one type of cone present in the eye are fully colour blind (like those whose eyes have only rods, but such people have other visual deficiencies as well).

The division in rods and cones explains much of the characteristics and properties of the human eye. At normal visual conditions (sufficient light available), the image of the object we are studying is brought to focus on the foveal region, which is so small that it is just covered by the image of the full moon. Larger scenes are scanned by continually revolving movements of the eyes. This can be clearly seen when somebody is reading a book. The spot of focal attention is sharply pictured in full colour by the cones of the fovea. The periphery of vision, covering a horizontal angle of more than 200° when seeing with both eyes without moving one's head, produces no detailed image, but permits general perception. Toward the edge of the scene, colour perception falls off through lack of cones. The state of vision, which always occurs if sufficient light is available, is called 'photopic vision'.

At very low luminance levels (less than 0.035 cd/m^2), the cones do not function. Vision is then by rods only, resulting in a general picture of low definition and no colours. Therefore, the proverb: 'In the dark all cats are grey' literally makes sense. Although it will be impossible to focus on an object, movements are comparatively easily detected. Because of the Purkinje shift, blue objects remain visible longer than do red ones with decreasing luminance. This situation is called 'scotopic vision'.

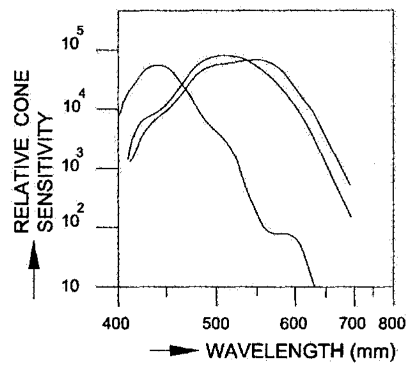


Fig. 3 a) Approximate Spectral Sensitivity Curves of the Three Colour Receptors in the Cones

Between photopic and scotopic vision there is a transitional state (between 0.035 and 3.5 cd/m^2) where the cones still partly function. This situation is called 'mesopic vision'.

4 SPECTRAL EYE SENSITIVITY CURVE

4.1 Light forms a part and only a very small part of the total spectrum of electromagnetic radiation. For practical visual conditions the range between 380 nm and 780 nm is normally adopted.

Within the visible range, the eye sensitivity varies strongly with different wavelengths of the same energy content. For example, under conditions of photopic vision, the eye is about twenty times more sensitive to light with a wavelength of 550 nm (yellow) than to wavelengths of 700 nm (deep red) or 450 nm (violet blue). As has already been explained before, the peak sensitivity for scotopic vision lies about 50 nm nearer to the blue end of the spectrum than the maximum sensitivity for photopic vision, the so called Purkinje shift.

The spectral eye sensitivity curve has been assessed in a great many cases, under photopic as well as scotopic visual conditions, and found to be remarkably consistent between subjects. As early as 1924, the International Commission on Illumination (CIE) laid down a standard spectral eye sensitivity curve for photopic vision, based upon the work of six scientific teams, together testing some 250 subjects. In 1951 a similar curve for scotopic vision was defined. The curves give the relative photopic eye sensitivity V(λ) or scotopic eye sensitivity V'(λ) as a function of the wavelength (λ) and are therefore generally called the V(λ) or V'(λ) curves [*see* Fig. 3 b)].

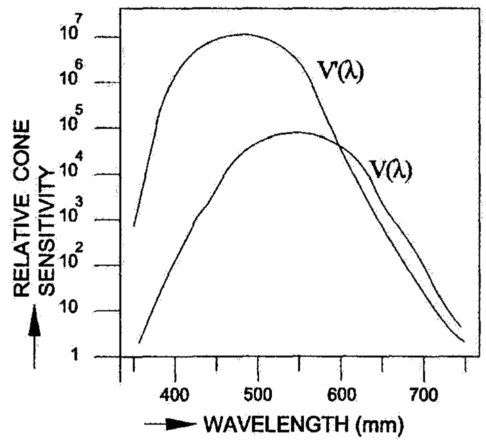


Fig. 3 b) Spectral Sensitivity Curves of the Cones V (λ) and Rods V'(λ) also Showing the Difference in Absolute Sensitivity

NOTE

V(λ) - Relative Photopic Eye Sensitivity
V'(λ) - Relative Scotopic Eye Sensitivity
λ - Wave Length

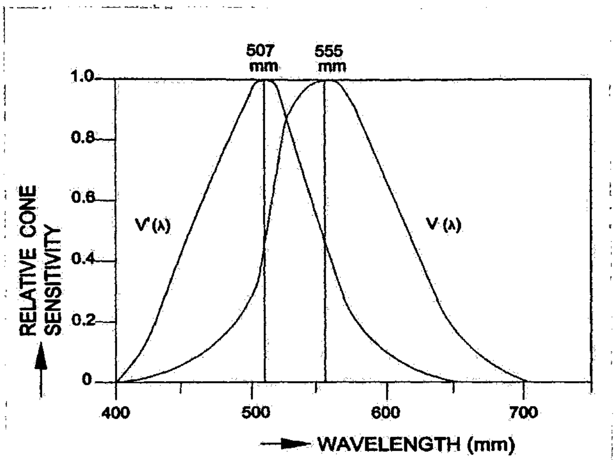


Fig. 4 Standard Spectral Eye-Sensitivity Curves for Photopic V(λ) and Scotopic V'(λ) Vision

The peak sensitivities for photopic and scotopic vision occur at 555 nm and 507 nm respectively (*see* Fig. 4).

5 THE VISUAL PROCESS AND THE BRAIN

5.1 The way the retina of both eyes are connected to the visual cortex in the two brain halves is not as straightforward as might be expected. The optic nerves of both eyes unite immediately after entering the cranial cavity, forming the so called 'optic chiasma' and then divide again into two branches, the 'optic tracts', which lead to the two halves of the visual cortex. The optic chiasma forms a cross over point, where the optic nerve from each eye splices into two strands, in such a way that each optic tract contains nerve fibres coming from both eyes. The arrangement is in fact such that the left half of the visual cortex takes care of the right side of each retina. A person who has one of his optic tracts severed will therefore be half blind in both eyes. (*see* Fig. 5).

Each nerve fibre forms an uninterrupted link between its ending in the retina and a well defined part of the visual cortex. It is therefore possible to 'map' the retinal area on the cortex. Remarkable, but not illogical, is the observation that the foveal area occupies a proportionally much larger region of the visual cortex than the peripheral areas of the retina.

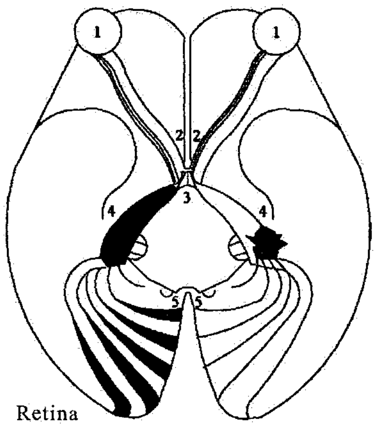
6 VISUAL ABILITY

6.1 Visual ability provides different visual information like the ability to differentiate between closely spaced visual stimuli, luminous variations in the field of view and three dimensional vision.

7 VISUAL ACUITY

7.1 Qualitatively, visual acuity helps in distinguishing fine detail and quantitatively it provides details on angular separation of two neighbouring objects that the eye can just perceive as being separated. Visual acuity depends on the quality of the visual organ and varies with background luminance and observation time.

What is generally assessed as 'visual' in the consulting room of the ophthalmologist is not so much the pure visual acuity of the eye, but the recognition acuity. For scientific research, the study of resolution acuity is essential. Age has a marked negative effect on visual acuity. Visual acuity is expressed as the reciprocal of the minimum visual angle (in minutes of arc), being detected. Visual acuity depends on the average luminance level in the field of view to which the eye is momentarily adapted (adaptation luminance); (*see* Fig. 6).



1. Retina
2. Optic nerve
3. Optic chiasma
4. Optic tracts
5. Visual cortex

Fig. 5 Schematic Diagram of the Visual Pathway, Showing How the Retinas of Both Eyes are Connected to the Two Halves of the Visual Cortex

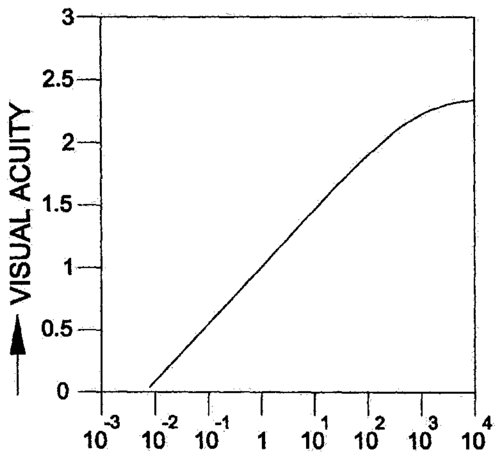


Fig. 6 Relative Visual Acuity Plotted against Adaptation Luminance (L_a)

NOTE — Measurements have been taken under conditions of optimum contrast using test persons with normal eyesight and not older than 50 years.

8 CONTRAST DETECTION

8.1 Contrast can take two forms which mostly occur together, contrast in colour and contrast in luminance. Contrast in luminance can be expressed as contrast value or contrast ratio. Contrast value has more importance under conditions of artificial lighting. The mathematical expressions are as given below:

$$C = (L_o - L_b)/L_b = \text{Contrast value}$$

$$C = L_h/L_l = \text{Contrast ratio}$$

where

- C = Contrast value or Contrast ratio;
- L_o = Object luminance;
- L_b = Background luminance;
- L_h = Higher luminance; and
- L_l = Lower luminance.

Contrast in colour can be distinguished better, under an overall luminance level sufficient to permit full adaptation for cone vision, without excessive brightness contrasts in the field of view and under a light source having a spectral energy distribution curve approximately similar to the spectral eye sensitivity curve for photopic vision. The eye will not appraise luminance values the same way under all circumstances. A white surface placed against a black background will make the white seem 'whiter'. A dark object against a very bright background will appear darker (*see* Fig. 7).

Metamerism takes place when two colour shades are observed under sources having line spectrum, separately.

Successive and simultaneous contrast takes place when looking away from a surface of strongly saturated colour and when looking at adjacent coloured surfaces respectively.

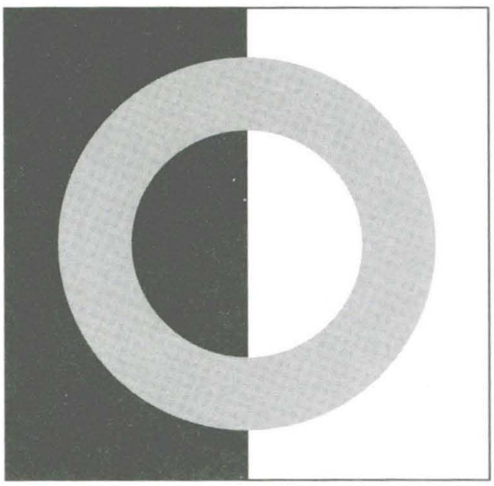


Fig. 7 Contract Effects (Simultaneous Contrast)

NOTE — The part of the grey ring seen against the background seems somewhat lighter than the part seen against the white. This effect is enhanced by placing a pencil along the black-white junction.

9 THREE DIMENSIONAL VISION

9.1 Three dimensional vision is possible with the help of both eyes. Good three dimensional vision depends on coordination between two eyes and binocular vision. It is found that a difference in distance over a range of more than one kilometer is possible to judge by three dimensional vision.

Eyesight deteriorates first slowly, but then at a rapidly increasing rate with age. From about 45 years of age, nearby seeing, (reading for example) becomes increasingly difficult, whereas distant objects give no problems, a condition that is known as 'presbyopia'. From about 50 years of age human beings will suffer from overall eye sensitivity, visual acuity, contrast sensitivity and colour sensitivity. Old people need as much as 15 times more light for a specific task than do the young. [*see* Fig. 8 a) and Fig 8 b)].

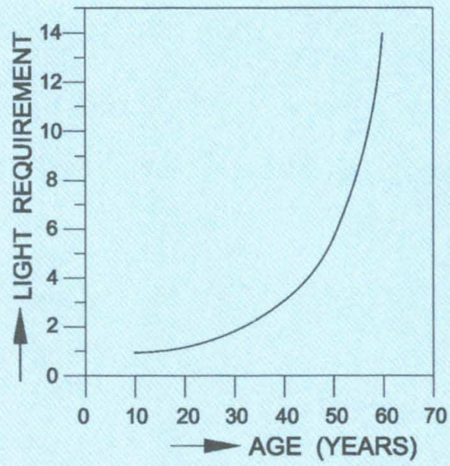


Fig. 8 a) Light Requirement for a Specific Reading Task Plotted against Age

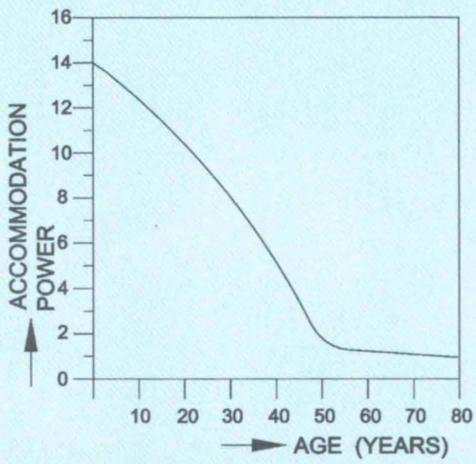


Fig. 8 b) Accommodation Powers, in Diopters Plotted against Age

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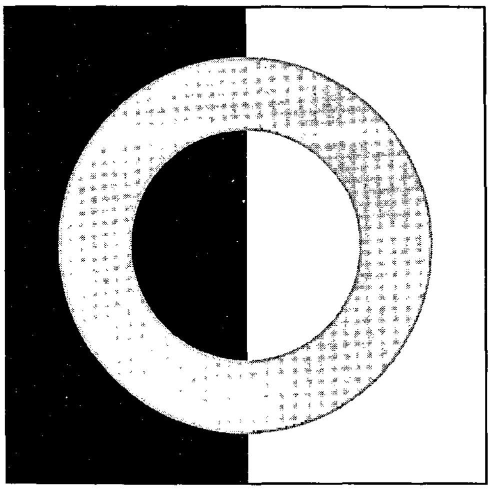

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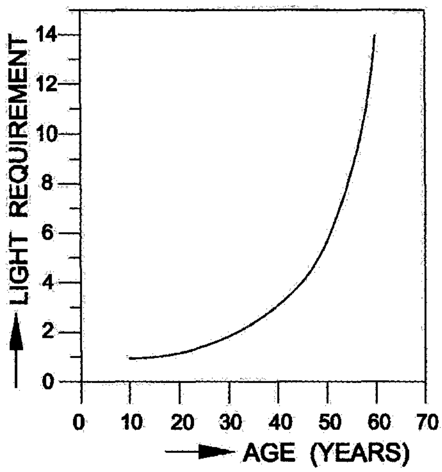

Fig. 8 a) Light Requirement for a Specific Reading Task Plotted against Age

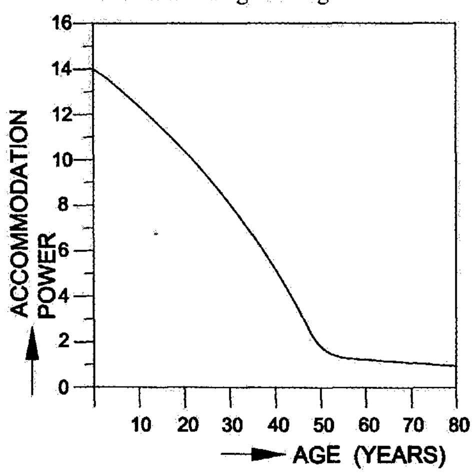

Fig. 8 b) Accommodation Powers, in Diopters Plotted against Age

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Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Colour has been of great interest to human beings right from the stone age. From the drawings in different caves of the world it is evident that man came to know the usage of colour from very early days. But proper understanding of the scientific basis of colour is rather recent in the history of science.

The perception of light and colour is achieved by direct association of things around us and there are many human factors, involved in this connection. Due to these factors, varying from person to person various methods of assessment and standardization are suggested.

In the 17th century Sir Isaac Newton laid the foundation of colour science or colorimetry. He found that sunlight, called 'white' light when passed through a glass prism is dispersed into a 'spectrum' of seven colours. Their wavelength range is given in Table 1 and he concluded through experiments that these seven colours are constituents of white light.

Maxwell (1831-79) established the colour matching principle, that is, matching of colours of different wavelengths from the primaries of Red, Green and Blue lights. By mixing these three primaries, that is, R, G and B almost all colours can be matched.

Table 1 Spectral Range of Colours

Sl. No. (1)	Colour (2)	Wave Length Range(nm) (3)
i)	Violet	380-420
ii)	Indigo	420-440
iii)	Blue	440-490
iv)	Green	490-560
v)	Yellow	560-590
vi)	Orange	590-630
vii)	Red	630-780

NATIONAL LIGHTING CODE

PART 2 PHYSICS OF LIGHT
Section 3 Colour

1 SCOPE

This section of the code covers the broad aspect of colours in the field of Illumination Engineering.

2 TERMINOLOGY

The definitions given in Part 1 of this code shall apply.

3 ADDITIVE COLOUR MIXING OF LIGHT

3.1 The mixing of coloured lights is called additive colour mixing process. This can be explained by considering three basic colours, termed as Primaries. These are Red (R), Green (G) and Blue (B). By mixing two primary colours secondary colours or complementary colours are produced. If three primary colours are mixed in the right intensities a white light will be produced. This mixing process may be represented as:

R+G	=	Yellow;
G+B	=	Cyan;
B+R	=	Magenta; and
R+G+B	=	White (*see* Fig. 1).

Here, the symbol "=" is used to represent matched equivalent. This trichromatic mixing however, follows algebraic law, that is, any colour stimuli 'C' can be matched by adding R, G and B and expressed as,

$$C(C) = R(R) + G(G) + B(B) \qquad (1)$$

The symbols within brackets represent corresponding stimuli including the colour C to be matched. R, G, B and C are quantities or amounts of the stimuli. Now, as the stimuli is due to various quantities of reference lights only, we must have

$$C = R + G + B \qquad (2)$$

Instead of using actual values of the quantities, a ratio of the matching stimuli can be used. Thus, dividing both sides of the equation (1) above by (R + G + B), we may write

$$1 = r + g + b \qquad (3)$$

where

$$r = R/(R+G+B);\ g = G/(R+G+B);\ b = B/(R+G+B)$$

Thus the equation (1) can be written as

$$1.0(C) = r(R) + g(G) + b(B) \qquad (4)$$

The r, g and b are uniform. A white light is matched by equal amount of R(700 nm), G(546.1 nm) and B(435.8 nm).

It can be seen that it is possible to match all colours of the spectrum by means of the additive mixture of three stimuli. This can be represented by curves as shown in Fig. 2 and are known as colour matching functions. It is to be noted that all three curves have negative portions but these are very small for blue and green.

4 INTERNATIONAL STANDARD COLOUR MATCHING FUNCTION

4.1 To avoid negative loops of the colour matching functions as explained above, it was decided, for

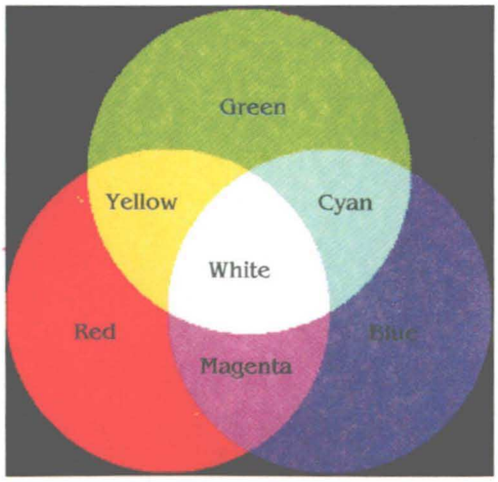


Fig. 1 Additive Colour Process

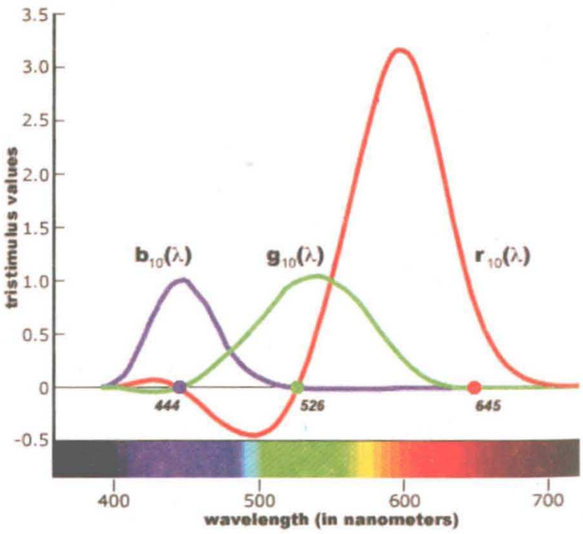


Fig. 2 Colour Matching Functions

convenience, to transform the colour axes in such a way that these functions can never become negative. This can be done by converting R, G and B functions into three imaginary primaries. Furthermore, one of the functions is made to coincide with the V(λ) standard observer curve and another function is made nearly equal to zero value.

CIE has defined these stimuli X, Y and Z which can be derived from the amounts of R, G and B necessarily for a colour match by the method of transformation.

So we have:

$$C(C) = X(X) + Y(Y) + Z(Z) \quad (5)$$

Following the arguments given in **3.1**, we can have,

$$1.0\,(C) = x(X) + y(Y) + z\,(Z) \quad (6)$$

where

$x = X/(X + Y + Z)$;

$y = Y/(X + Y + Z)$; and

$z = Z/(X + Y + Z)$.

$$x + y + z = 1. \quad (7)$$

The tristimulus functions in terms of imaginary primaries may be represented by x(λ), y(λ) and z(λ) and the resulting curves may be as shown in Fig 3.

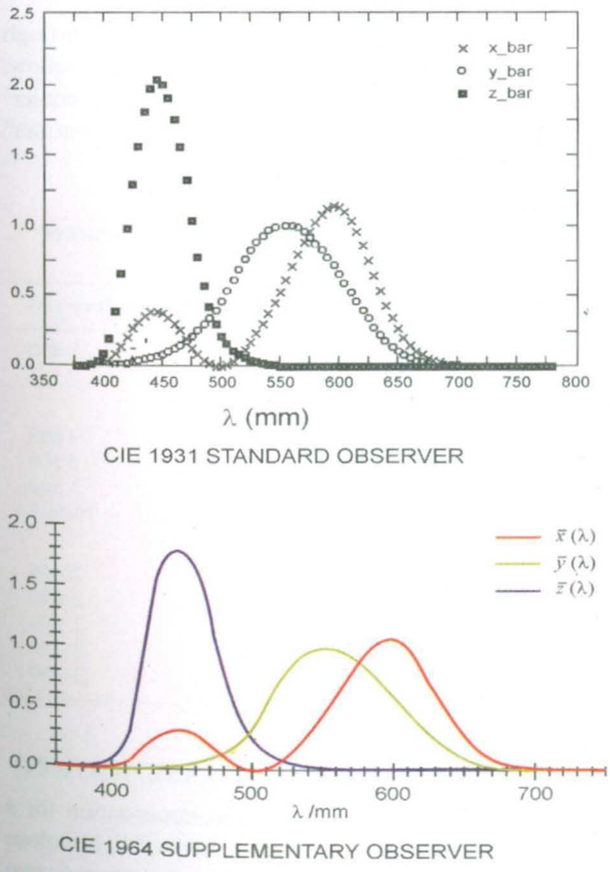


Fig. 3 CIE Tristimulus Function

5 SUBTRACTIVE COLOUR MATCHING

5.1 There is a fundamental difference between mixing of coloured lights and mixing of dyes and paints. If the coloured paints are mixed the result will be always darker than any of the paints mixed. If the right colours of dyes and paints are mixed in the right proportions the effect will be black. This form of mixing of dyes and pigments is known as subtractive colour mixing.

The colour of an object is due to selective reflection and/or transmission. Due to this property, therefore, a coloured object subtracts out certain spectrum of incident light.

Like additive primaries, three colours are chosen as subtractive primaries, which will absorb only red, green and blue light respectively. For example, a colourant absorbing Red will not absorb the Blue and Green spectra of the incident light. The object, therefore, will appear as bluish green, that is, Cyan (C) and Cyan will be one of the subtractive primaries. Similarly, Magenta (M) and Yellow (Y) will be other two subtractive primaries, like additive mixing.

We may write

Y + C = Green;

C + M = Blue;

M + Y = Red; and

Y + C + M = Black (*see* Fig.4).

6 COLOUR OF LIGHT SOURCES

6.1 There are two aspects of colour of light sources:

(a) Colour appearance of light, which can be

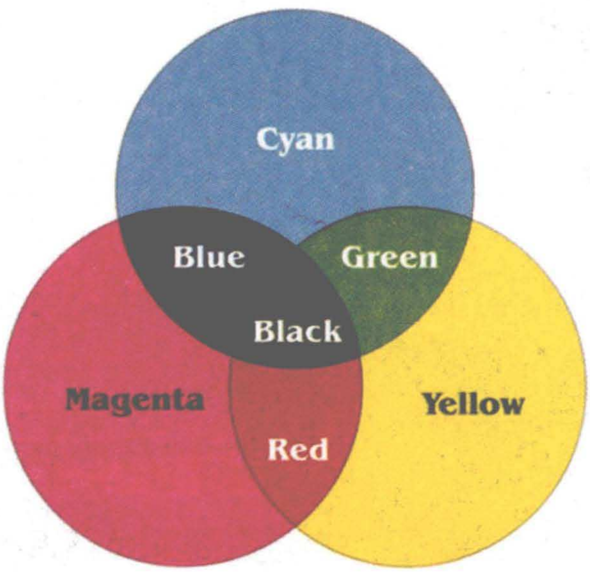


Fig. 4 Subtractive Colour Process

described by colour temperature or correlated colour temperature; and

(b) Colour rendering characteristics of light which is related with the spectral power distribution (SPD) of light, that is, it depends on the content of the radiant power at different wavelengths throughout the visible spectrum. It is to be noted that different spectral power distribution of light sources can produce, identical colour appearances.

7 COLOUR TEMPERATURE

7.1 In order to compare the colour characteristics of radiation from a light source with that of a blackbody, the temperature of the blackbody is selected as the basis of comparison. The radiation characteristic of a blackbody is directly related with its temperature. The colour temperature (T_c) is the temperature of the blackbody at which it has the same chromaticity as the source. An exact match is only possible if the source is also a thermal radiator.

8 CORRELATED COLOUR TEMPERATURE

8.1 For a source which is not a thermal radiator, like fluorescent and other gas discharge lamps, the colour appearance cannot exactly be matched with a blackbody in terms of colour temperature, but may closely resemble it at a particular temperature. Therefore, it can be defined as the colour temperature of a blackbody that resembles closely that of the source and is termed as Correlated Colour Temperature.

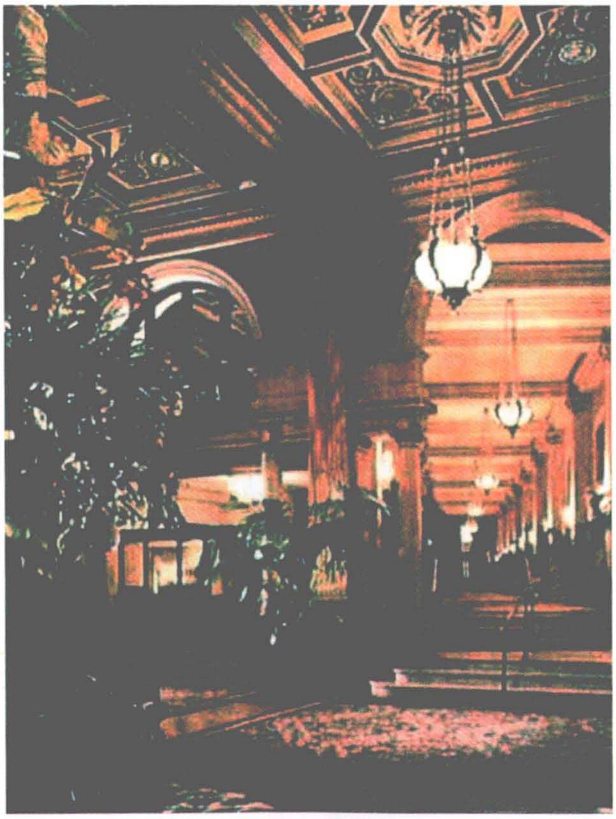


Fig. 5 Light Source with Colour Temperature of 2 700 K Gives a Very Warm Appearance

Fig. 6 Fluorescent Light Sources of 4 100 K Create a Cool Appearance

The colour appearance of a lamp is expressed in terms of colour temperature (T_c) measured in Kelvin (K).

When a blackbody is slowly heated, it passes through graduations of colour from dark red, red, orange, yellow, white to light blue. Higher temperature indicates 'cooler' colour, while lower colour temperature denotes 'warmer' colour as given in Table 2, Fig. 5 and Fig. 6.

Table 2 Colour Temperature of Various Sources
(*Clause* 8.1)

Light Source	Colour Temperature (K)
Candle light	1 800
Daylight(colour temperature of daylight changes throughout the day)	
- Sunrise and sunset	3 000
- Noon sun and sky	5 500
- Cloudy sky	7 500
- North sky only (no sun)	10 000
Incandescent lamps	
- Edison era carbon filament	2 400
- Modern tungsten filament	2 800
- Tungsten halogen lamp	3 100
- Theatrical halogen lamp	3 200
- Photoflood lamp	3 400

9 CIE SYSTEM OF COLOUR CLASSIFICATION

9.1 In 1931, CIE published a recommendation for a system of classification or measurement of light colour based on additive colour mixing. From equation 6, two chromaticity coordinates may be used with a two dimensional plot or a map of all colours represented in it. All colours are bounded by two sides of a triangle with its apex region as Red, Green and Blue. The boundary line represents the locus of spectral colours. The line joining red and blue contains various shades of purple which do not occur in the electromagnetic spectrum.

A typical shape of the CIE colour triangle is shown is Fig. 7.

Any colour can now be identified and defined by two coordinates x and y values, which are called chromaticity coordinates.

For a blackbody or thermal radiator its colour can be denoted by a colour temperature and the corresponding colour can be represented in the CIE triangle. Therefore, the blackbody colour temperature can be suitably scaled and plotted on the CIE colour triangle and this forms a curve, known as blackbody or Planckian locus. This curve is shown in Fig. 7.

10 COLOUR RENDERING INDEX

10.1 In **6.1**, it has been indicated that 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 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 (8) are tested under a standard or reference light source and the chromaticity coordinates are plotted on the CIE triangle. The same test is repeated under the source under test and corresponding chromaticity coordinates are plotted on the same plot. The difference between the positions 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

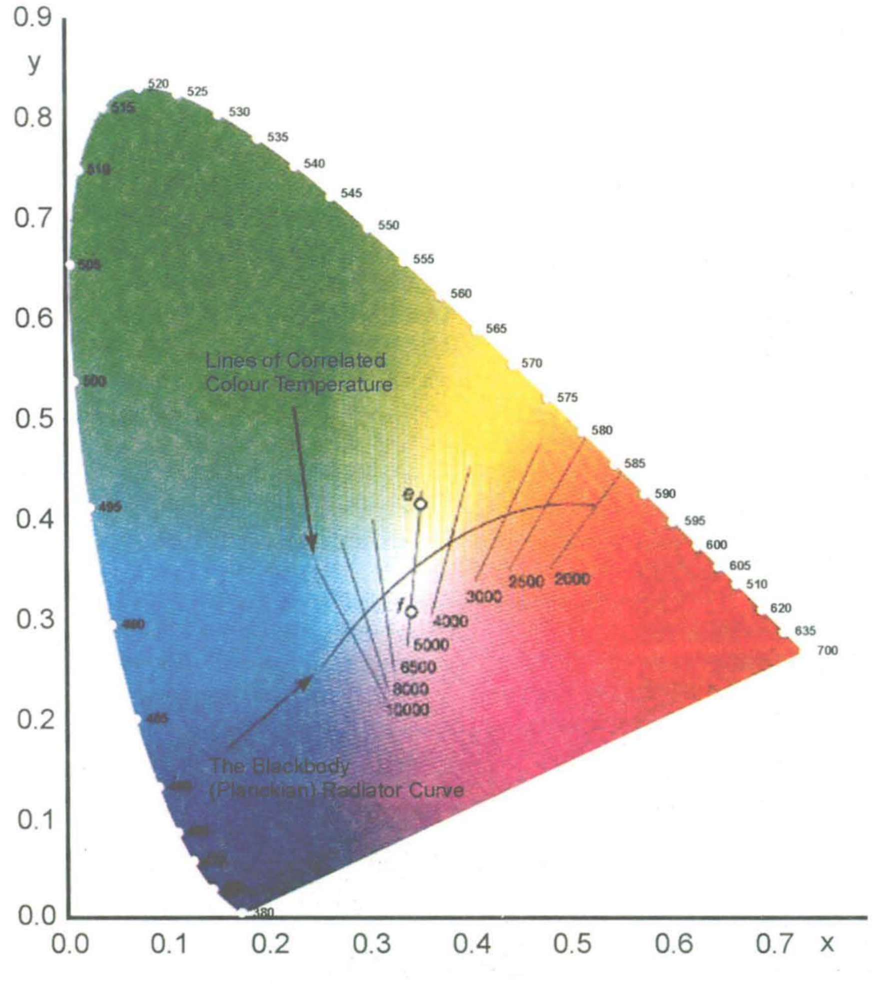


Fig. 7 Locus of Spectrum Colours Plotted on the 1931 CIE Chromaticity Diagram

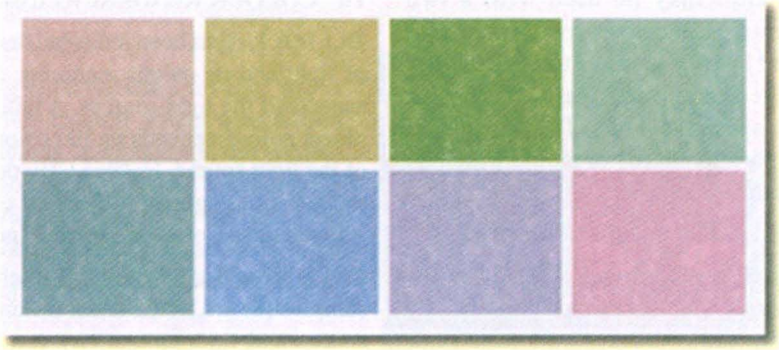


Fig. 8 General Colour Rendering Index by the Average Value of Eight Samples

samples (*see* Fig. 8). For perfect agreement of colour, the CRI value should be 100. In general:

$$Ra = 1/8(R1 + R2 + R3 + R4 + ... + R8) \quad (8)$$

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

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

where

DEi = Chromaticity shift on the CIE chromaticity diagram for each sample.

NOTE —

Colour Rendering Evaluated	Ra (General colour rendering index)
True	90 100
Good	70 – 90
Moderate	50 – 70

11 REFERENCE ILLUMINANTS

11.1 The appraisal of colour rendering properties of light sources shall always be referred to a Reference Illuminant, which must have the same or nearly the same colour as

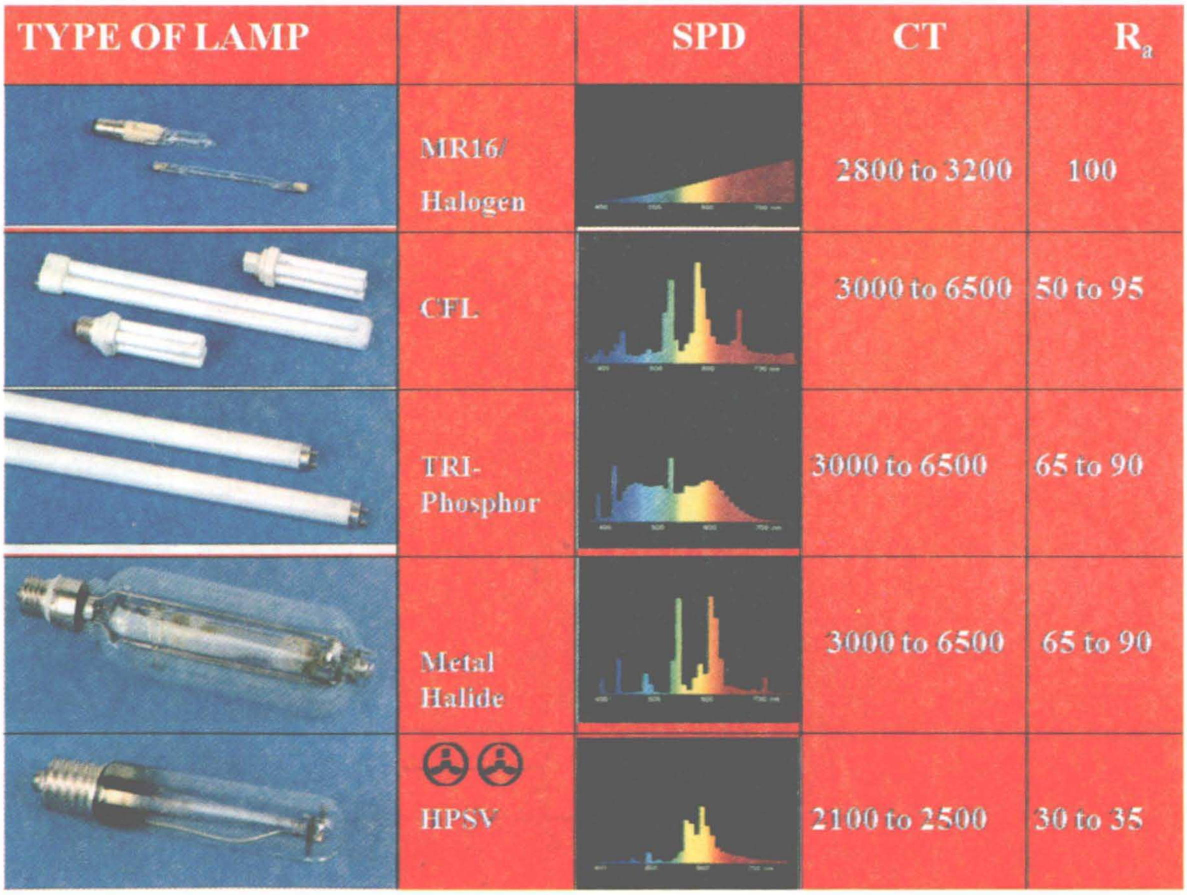


Fig. 9 Colour Characteristics of Different Light Sources

the lamp to be tested. It should be so selected that chromaticity difference is smaller than 15 mired.

NOTE — mired = Micro-reciprocal-degree = 10^{-6} K^{-1}

Types of Reference Illuminants are given below:

Illuminant A — This illuminant represents light from a blackbody radiator at an absolute temperature of 2 856 K (approximately). The SPD (spectral power distribution) values from 380 to 830 nm in 1 nm intervals are given in CIE 15.2. In practice, this illuminant is realized by operating a gas filled tungsten lamp at an operating temperature of 2 790 K to attain a colour temperature of 2 856 K.

Illuminant B — This illuminant is not in practice now. This represents direct sunlight with a correlated colour temperature of 4 900 K. This is realized by a source A with a specified filter.

Illuminant C — This represents average daylight with a correlated colour temperature of about 6 800 K. CIE 15.2 gives the SPD values.

Illuminant D65 — This illuminant represents a phase of daylight with a correlated colour temperature of 6 500 K. This is the best and widely used light source described by CIE standard daylight illuminant.

At present no artificial light source is recommended to realize illuminant D65; usually 'North' light is used for visual colour matching purposes. CIE has published a method for assessing how closely a daylight source simulates a particular reference illuminant.

12 METAMERIC LIGHT AND CONDITIONAL MATCHING

12.1 If two light sources have the same SPD (spectral power distribution), they are in perfect match or 'non metameric'. But it is often possible that two lights having different SPD may produce an identical visual effect. Such a colour match is called metameric lights namely, light from incandescent filament and warm white fluorescent lamps.

SP 72 : 2010

NATIONAL LIGHTING CODE

PART 3 ELECTRIC LIGHT SOURCES AND THEIR ACCESSORIES
Section 1 Electric Light Sources

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

The development of new and improved light sources for lighting has proceeded at a rapid and accelerating pace. There is a wide choice of sources, luminaires, and controls, and it is possible that any one of several basic choices could be used for a given lighting application. While the general characteristics can be provided, a definitive guide with absolute values for all types and manufacturers would be too extensive for this code.

In this section, various lamp types typically used in India (that may or may not be locally manufactured) have been dealt with. Since Section 2 of this part on control gears for light sources would take care of all the accessories required for operation of different types of lamps, they have not been covered in this section of the code.

In case of any contradiction in the technical particulars given in this code with that specified in the relevant Indian Standards, the latter shall prevail.

The following Indian Standards are a necessary adjunct to this section.

IS No.	*Title*
418:2004	Tungsten filament lamp for domestic and similar general lighting purposes (Fourth Revision)
2418(Part 1):1977	Specification for tubular fluorescent lamps for general lighting service: Part 1 Requirements and tests (First Revision)
9900(Part 1):1981	High pressure mercury vapour lamps: Part 1 Requirements and tests
9974(Part 1):1981	High pressure sodium vapour lamps: Part 1 General requirements and tests
12948:1990	Tungsten halogen lamps (non-vehicle)
15111(Part 2):2002	Self ballasted lamps for general lighting services: Part 2 Performance requirements

NATIONAL LIGHTING CODE

PART 3 ELECTRIC LIGHT SOURCES AND THEIR ACCESSORIES
Section 1 Electric Light Sources

1 SCOPE

This code is an introduction to most of the light sources used for general lighting. It provides essential information to understand typical characteristics of each source. Although there are brief constructional details and performance characteristics of various types of electric light sources, the designer should also consult the individual manufacturer's catalogue on light sources and associated equipment for detailed information.

2 TERMINOLOGY

The definitions of the terms used in this chapter are given in Part 1 of this code.

3 CLASSIFICATION OF LAMPS

3.1 General

Electric light sources can be subdivided by their main principle of operation (*see* Fig. 1):

a) Incandescent lamps: In these the light comes from a heated metal wire. The halogen lamp contains a special gas to improve the efficacy. These types are widely used, but will be phased out in the coming years due to their low efficacy;

b) Gas Discharge lamps: The light from these lamps, comes from a discharge between two electrodes in a gas filled glass or ceramic tube. There are two ranges depending on the most important gas, mercury or sodium. Both these ranges can be subdivided by the pressure in the glass tube: high or low pressure; and

c) Solid State Lighting or LED lamps: An LED is a semiconductor device. When a current is passed through an LED, electrons move through the semiconductor material and some of them fall into a lower energy state. In the process, the 'spare' energy is emitted as light. The wavelength (and hence colour) of the light can be tuned as required by using different semiconductor materials and manufacturing processes. Furthermore, the wavelength spread of the emitted light is relatively narrow, giving pure (or saturated) colours.

3.2 Development of Electrical Light Sources

Starting with the invention of the incandescent lamp in 1879, the development of all other major groups of light sources can be seen in Fig. 2.

4 INCANDESCENT FILAMENT LAMP

4.1 The first incandescent lamp was invented by Thomas Alva Edison in 1879 and comprised carbon filaments instead of tungsten filaments. These lamps had an efficacy of 2.54 lm/W. The incandescent lamp family can be subdivided into 2 groups:

a) GLS; and

b) Tungsten Halogen lamps.

4.2 General Lighting Service

GLS (general lighting service) lamps consist of a tungsten wire filament on a suitable mount structure enclosed in a glass bulb containing an inert gas or vacuum. The base of the GLS incandescent lamp is either bayonet cap or screw cap type; the outer envelope can be clear, inside frosted, white diffuse coated, and specially shaped for decorative purpose. Although, GLS lamps are the simplest in terms of technology and usability, they are already on

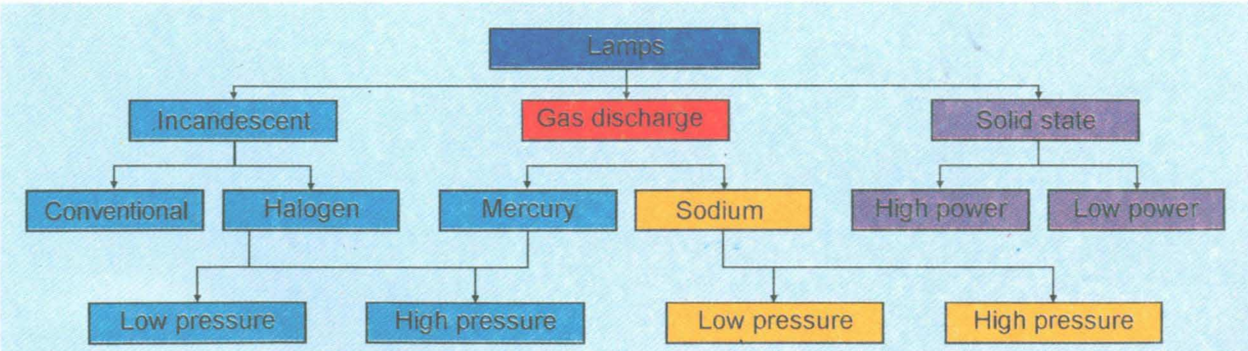


Fig. 1 Broad Classification of Lamps

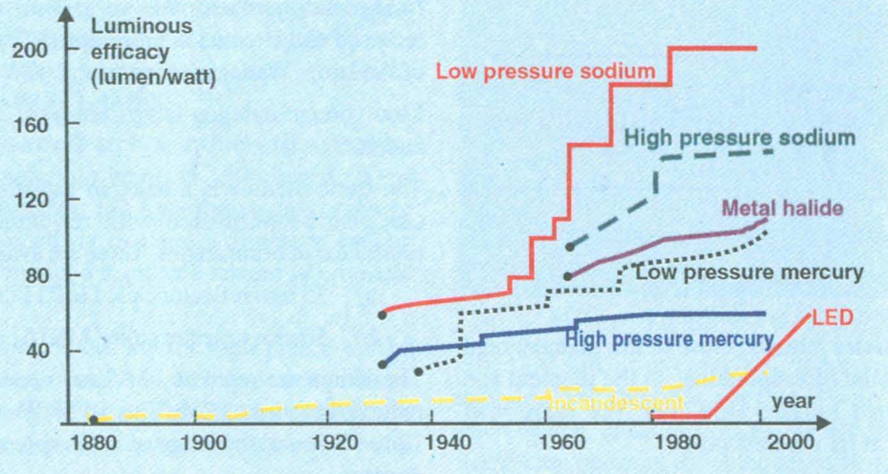


Fig. 2 Development of Various Light Sources

their way out, and many countries have banned (or are in the process of banning) them as they are extremely energy inefficient.

Tungsten has many desirable properties for use as an incandescent light source. Its low vapour pressure and high melting point (3 655 K) permit high operating temperatures.

Evaporation of the filament is reduced by filling the bulb with an inert gas. The operating temperature of the filament can then be correspondingly higher. Nitrogen and argon are the gases most commonly used. The bulb may be of clear, coloured or white translucent glass and, a wide variety of shapes. The cap provides the means of connecting the lamp to the socket. These caps are identified by the letters E (Edison) and B (Bayonet) in the type reference followed by a figure indicating the diameter of the cap in millimeters. The most common types of caps used in India for general lighting service lamps are bayonet (B22d), medium screw (E27) and large screw (E 40) type caps. For some of the decorative lamps smaller bayonet (for example, B15) or screw (E14, E17) caps are also used.

A wide variety of tungsten filament lamps are being produced by different manufacturers for various applications.

NOTE — The requirements and tests of GLS lamps are specified in IS 418.

4.3 Halogen Lamps

A halogen lamp works on the principle of the incandescent lamp. The light output in a halogen lamp is more consistent than a standard incandescent lamp and the life is much longer. The size is smaller for the halogen cycle to have a high bulb wall temperature, which requires quartz or hard glass to be used. Better beam control is possible because of the small source size.

The light is produced by a coiled filament of tungsten. The filament is protected by a quartz or hard glass bulb which is deliberately small to ensure the correct bulb wall temperature. The bulb is filled with a halogen gas rather than nitrogen and argon. The halogen gas is either iodine or bromine, or in some cases a mixture of both. The bulb shape is tubular and its surface is closer to the hot filament (*see* Fig. 3).

When a tungsten filament is hot, minute particles of tungsten evaporate. These tungsten particles combine with the halogen gas and are prevented from condensing on the bulb, provided the bulb is above 200°C. The combined tungsten and halogen remains as a gas which circulates within the bulb, and when it approaches the filament where the temperature is much higher, the combination becomes unstable and reverts to the two separate constituents of tungsten and halogen. The tungsten condenses on the coolest local point, usually around the end of the filament (*see* Fig. 4). This process is called the halogen regenerative cycle.

As the inside surface of the bulb remains clean the lumen maintenance remains high throughout the lamp life.

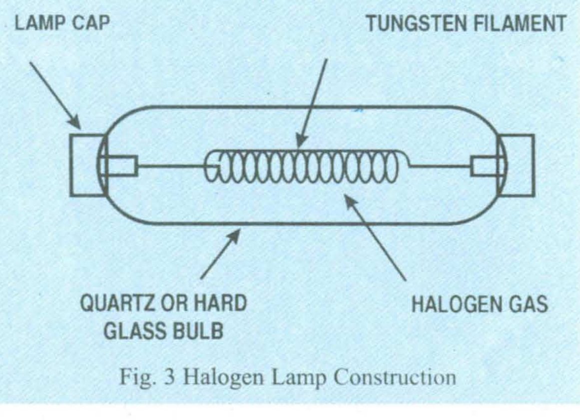


Fig. 3 Halogen Lamp Construction

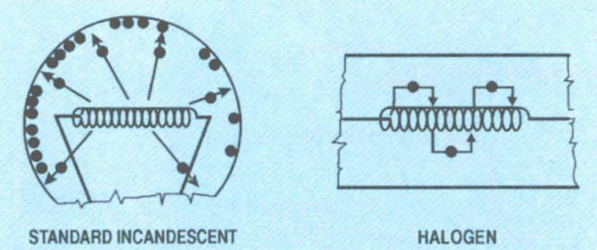


Fig.4 Operating Principle

The tungsten particles released close to the filament tend to reduce the amount of evaporation, so the filament and thus the lamp last longer. However, the lamp will eventually break at its weakest point.

Halogen lamps last longer than standard incandescent lamps. The halogen lamp has a higher lamp efficacy than GLS lamps.

Halogen lamps are smaller in size and lighter in weight as compared to incandescent lamps (*see* Fig. 5). This allows the design and use of smaller lightweight luminaires. It provides greater mounting flexibility when using single ended lamps. Luminaires can be designed to provide better control of light; more light can be directed where it is needed.

NOTE — The requirements and tests of tungsten halogen lamps are specified in IS 12948.

4.2.1 *Basic Halogen Lamp Types*

Halogen lamps can be operated on mains voltage (MV halogen lamps) or on low voltage (LV halogen lamps). The common types of halogen lamps are:

a) Linear (sometimes called double ended) (*see* Fig 6);
b) Single ended ;
c) Capsule (single ended but no outer bulb); and
d) PAR (capsule contained in PAR shape bulb).

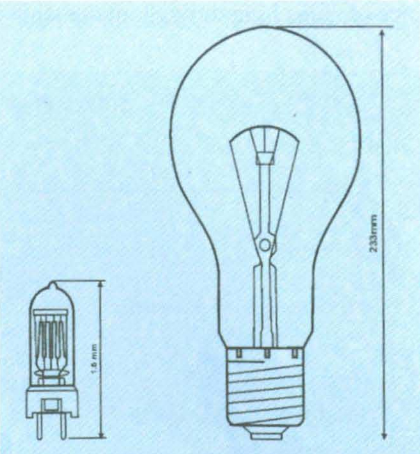


Fig. 5 Incandescent and Halogen Lamps

Linear halogen lamps have a slim tubular bulb and recessed single contact lamp caps (R7s), one at each end of the lamp. Wattages range from 100W to 2 000W.

Low voltage halogen lamps are most commonly single ended.

The basic module is a halogen capsule. These capsules can also be permitted with reflectors, with precise pre-focussed beam angles. These are available in two sizes:

a) 35 mm reflector called MR11 (*see* Fig. 7a); and
b) 50 mm reflector called MR16 (*see* Fig. 7b).

The lamps are rated at 12 V and need a transformer to reduce the normal 240 V to 12 V. Wattages range from 12 to 75 W and the range of beam spreads is from 7 to 55 degrees.

The lamp caps are all 2 pin (GU4 for MR11 and GU5.3 for MR16). In India MR16, is the most common lamp used. They are available as open reflectors or with a front glass cover.

The reflectors usually have a special dichroic coating, (which is why these lamps are often referred to as dichroic lamps) which absorbs radiated infrared waves from the capsule and transmits light waves. However, halogen

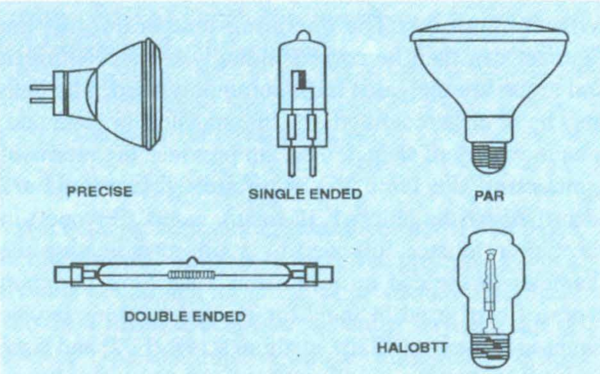


Fig. 6 Types of Halogen Lamps

Fig. 7 (a) (MR11) Fig. 7 (b) (MR16)

Fig. 7 Low Voltage Halogen Lamps (Dichroic Lamps)

lamps also radiate UV rays, which is why a front glass cover is always recommended.

5 GAS DISCHARGE LAMPS

As a result of intensive research, an entirely new category of light sources came into being in 1906 based on the principle of gas discharge. The light from a gas discharge lamp is not produced by heating a filament but by excitation of gas contained in either a tubular or elliptical shaped outer bulb.

Gas discharge can be under low or high pressure. The most common metals used are mercury and sodium. However, new generation lamps also have other additives in addition to the basic metals, for improved lamp performance.

5.1 Low Pressure Mercury Vapour Lamp

In low pressure mercury vapour lamps, commonly called fluorescent lamps, light is produced predominantly by fluorescent powder activated by UV energy generated by a mercury arc. The lamp, usually in the form of a long tubular shape with an electrode sealed into each end contains mercury vapour at low pressure with a small amount of inert gas for starting. The inner wall of the bulb is coated with fluorescent powders commonly known as phosphors.

Fluorescent lamps have a limited range of shapes. The most common is the straight tube in various diameters (*see* Table 1 and Fig.8). The diameter may be quoted in mm, but the universal term is 'T' for tube followed by the diameter in eighths of an inch. Most T12 (12/8") lamps are now being replaced by more energy-effective T8 lamps of the same length but reduced power. The latest T5 lamps with 16 mm dia are most energy-effective lamps.

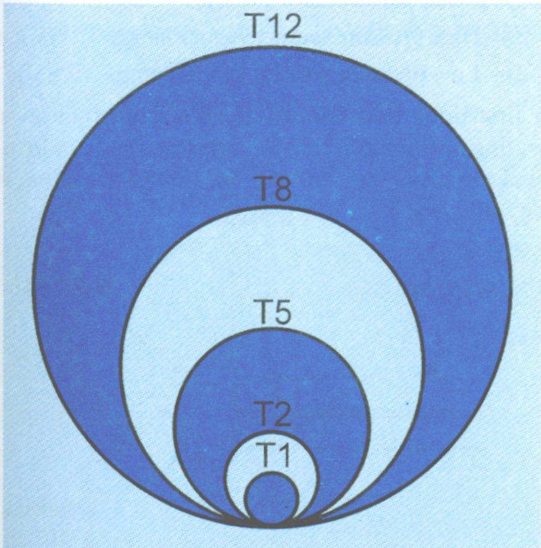


Fig. 8 Types of Fluorescent Lamp Diameters

Table 1 Various Tube Types and Their Diameters
(*Clause* 5.1)

Tube type	Modular size	Diameter
T12	$12^1/_8$ inch	38 mm
T8	$8^1/_8$ inch	26 mm
T5	$5^1/_8$ inch	16 mm
T2	$2^1/_8$ inch	6 mm
T1	$1^1/_8$ inch	2.8 mm

NOTE — T 1.5 lamp has 4.6 mm dia

When the circuit is energized, the current preheats the cathodes. The cathodes are coated with material which, when heated, emits electrons. The electrons establish an electric arc between the cathodes at opposite ends of the tube. The electrons collide with the mercury atoms, causing mercury to emit invisible ultraviolet radiation. The ultraviolet radiation is absorbed by the phosphor coating on the tube and is re-radiated as visible light (*see* Fig. 9).

To provide the initial warm up there is a device called a starter, which first connects the cathodes in series to allow preheating, and then switches the voltage across the two electrodes (*see* Fig. 10). The most common form of starter is a small cylindrical component containing a glow switch. All hot cathode lamps have bi-pin caps. Instant start circuits used to be a popular way to give quicker starting with no initial flickering. However, electronic starting

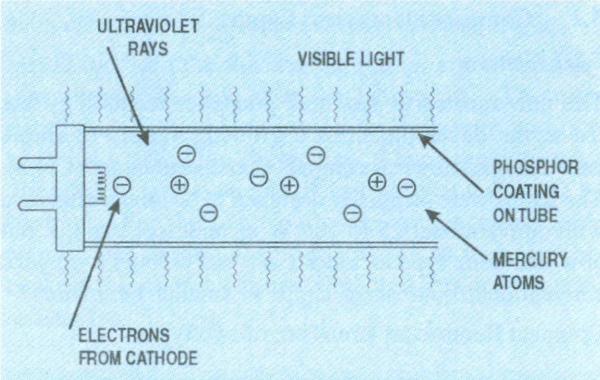


Fig. 9 Fluorescent Lamp Operation

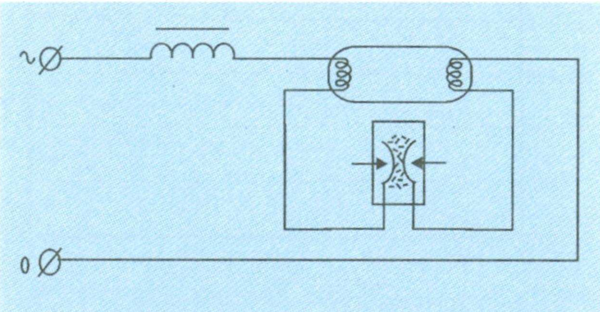


Fig. 10 Fluorescent Lamp Operation with a Bimetallic Starter

methods are now replacing such control gear because they are more efficient and incorporate additional safety features.

Fluorescent lamp performance is dependent upon the type of fluorescent powder used, length, diameter and ambient temperature.

Luminous efficacy and colour properties are primarily determined by the type of flupowder used. T12 lamps used standard halophosphate phosphors. New generation T8 and T5 lamps also use triband and multiline phosphors which results in higher lamp performance (efficacy, colour quality and lifetime performance). Lamp output is affected by extremes in ambient temperature. Fluorescent lamps are relatively sensitive to ambient temperature because they are low pressure lamps.

5.1.1 *High Frequency Operation*

With frequencies from 15 to 30 kHz light output improves up to 10 percent (*see* Fig. 11). This is why the use of high frequency electronic ballasts is becoming popular. Additional benefits of high frequency lamps are the elimination of any irritating flicker, better starting, and the lighter ballasts. Different size and shape configurations are easy to arrange with the electronic components. The preheating time of electrodes can be controlled by suitable design of the circuits.

NOTE — The requirements and tests of low pressure mercury vapour lamps (tubular fluorescent lamps) are given in IS 2418(Part 1).

5.2 Compact Fluorescent Lamps

5.2.1 *General*

The new rare earth activated phosphor technology has led to the development of a growing variety of single ended lamps known as compact fluorescent lamps (CFLs). The lamps were originally designed to be interchangeable with conventional 25 to 100 W incandescent lamps, but now this lamp type includes sizes and colours to replace conventional fluorescent lamps in smaller luminaires.

Compact fluorescent lamps are of two types:

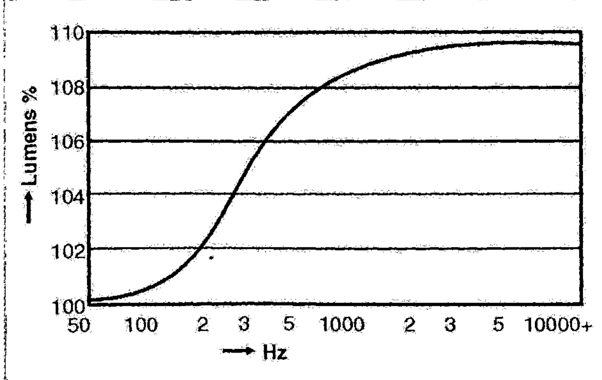


Fig. 11 High Frequency Operation

a) Integrated (where control gears are integrated in the lamp construction)
b) Non Integrated (separate external control gears are to be used)

The CFL Integrated lamp has a similar lamp base to GLS lamps (B22 /E27) and is best suited for residential and semicommercial applications; GLS lamps can be directly replaced by a lower wattage CFL-I lamp with potential energy saving upto 75 percent (check manufacturers' specifications). Most manufacturers now offer wide options in this category in terms of diameter of tube, shapes (straight, helix etc.), and also with external decorative covers.

The CFL-NI (non-integrated) versions also have options of various bases (2 pin, 4 pin) and number of interconnected tubes. The two pin versions have an internal starter built into the cap and are not dimmable (*see* Fig.12). The four pin versions require external starting and are suitable for use with high frequency electronic ballast systems (with or without dimming options) and emergency lighting. Compact fluorescent lamps have triphosphors amd so have excellent colour rendering. Lamps in the colour temperature range from 2 700 K to 6 500 K are available.

The CFL-NI are also now available in multiple bends to further reduce sizes, offering more design flexibility to luminaire manufacturers.

NOTE — The requirements and tests of CFL lamps are given in IS 15111(Part 1 and Part 2).

5.3 High Intensity Discharge (HID) Lamps

5.3.1 *Types of HID Lamps*

There are four main ranges of HID lamps:

a) High pressure mercury vapour lamps (HPMV);
b) Metal halide lamps (MH);
c) High pressure sodium vapour lamps (HPSV); and
d) Low pressure sodium vapour lamps (LPSV).

The first three have similar general construction and operating principles. LPSV lamps are more close to fluorescent tubes only without the phosphor coating and using sodium in place of mercury.

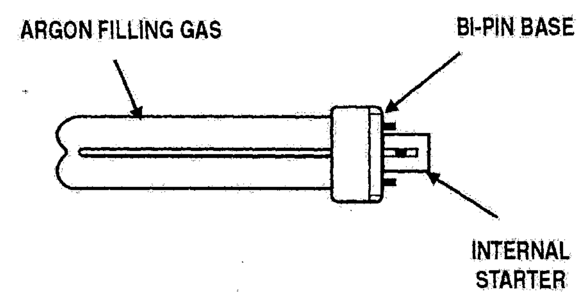


Fig. 12 Two Pin Lamps

5.3.2 *Operating Principles*

High intensity discharge is often shortened to HID. HID lamps give out light from an intense electrical arc or discharge between two electrodes (*see* Fig. 13).

The process is similar to the fluorescent lamp, except that the light comes from the arc itself, and not from the phosphor coating on the tube wall. Some discharge lamps do have phosphor coated bulbs but this is only to provide supplementary colour and/or increase the apparent size of the source to reduce glare.

Principal parts in a HID lamp are as follows:

a) Discharge tube;
b) Outer glass;
c) Electrodes;
d) Fill gas;
e) Bulb coating; and
f) Lamp caps.

Properties of discharge depend on the type and pressure of gas, electrode material, temperature of electrodes, shape and surface structure of electrodes, distance between electrodes, geometry of discharge vessel and current density.

Most discharge lamps do not start instantly. Composition of gas in cold lamps differ from hot lamps. This leads to change in luminous flux and colour characteristics and change in electrical characteristics. There is also a reignition time as the arc temperature and pressure is very high, it has high resistance. In general the arc must cool down to reignite again or a very high ignition voltage must be applied to start immediately.

In summary, discharge lamp characteristics are:

a) Type of metal (sodium or mercury) and pressure (high or low) decides the type of light (quantity and quality);
b) Need a higher voltage to start;
c) Additional gas (fill gas) to help in starting and operations;
d) All lamps will need a starter to start. They can be built-in or external ignitor;
e) All lamps will need a ballast to operate. They can also be built-in or external;
f). Ra < 100; and
g). Long service life.

5.3.3 *High Pressure Mercury Vapour (HPMV) Lamps*

The high pressure mercury vapour lamp was one of the first HID lamp types to appear on the market in 1930s. The outer bulb stabilizes and maintains the necessary high temperature around the arc tube and also absorbs the potentially hazardous UV radiation coming from the arc. Nitrogen gas within the outer bulb protects the metal parts from oxidation.

The bulb is phosphor coated to generate some red light that is added to the light from the arc tube, improving the colour rendering and appearance of the lamp. The light direct from the arc is mainly blue and green.

Starting and operating principles of an HPMV lamp are shown in Fig 14. When the circuit is energized, a small arc is formed between the starting electrode and adjacent main electrode. The arc ionizes the fill gas and metallic vapour. When enough ions are present in the arc tube, the main arc strikes between the two main electrodes (resistance drops sufficiently). The current to the starting electrode stops as the resistance is higher than that between the main electrodes. The main arc radiates intense light.

Inside the arc tube the starting gas is argon. Mercury ions support the arc after the lamp starts. The main electrodes are double layers of tungsten wire with rare earth oxides for long life and good lumen maintenance. The starting resistor limits the current to a low value for starting. After the lamp starts the current bypasses the resistor and starting electrode as soon as the resistance between the main electrodes falls below that of the starting resistor (*see* fig. 15).

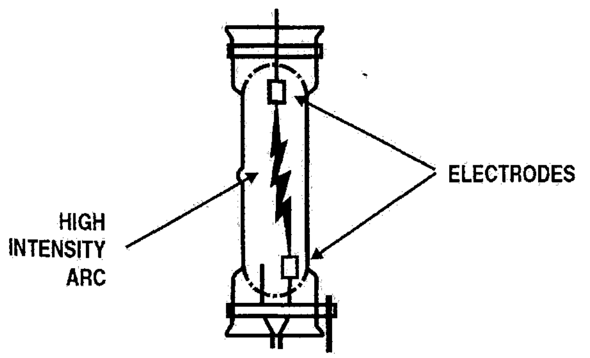


Fig. 13 Operating Principle of HID Lamps

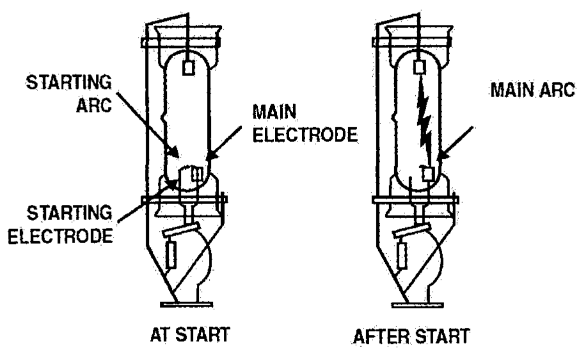


Fig. 14 HPMV Lamp Operation

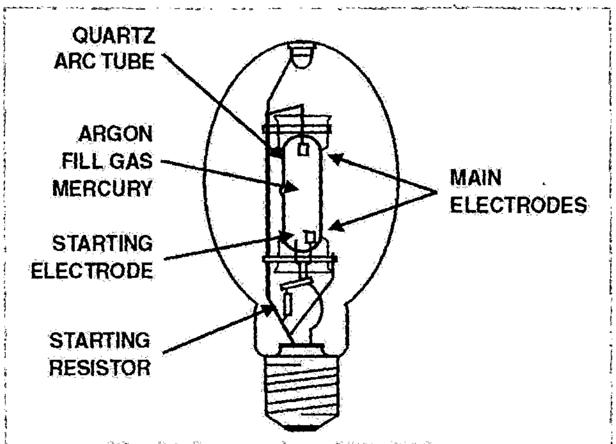


Fig. 15 Construction of HPMV Lamps

NOTE — The requirements and tests of HPMV lamps are specified in IS 9900 (Part 1).

Mercury vapour lamps were widely used for lighting residential streets, industrial interior and exterior situations and amenity lighting.

These lamps are also on their way out because of their lower efficacy as compared to new generation high pressure metal halide lamps.

5.3.4 *Blended Lamps*

These lamps have a mercury arc tube in series with an incandescent tungsten filament. This filament acts as the ballast for the mercury arc tube, so no separate ballasts are required for the starting and operation of a blended lamp. This characteristic makes the blended lamp suitable for direct replacement of high wattage GLS lamps with the advantages of longer life and higher efficacy of the mercury lamp.

5.3.5 *Metal Halide (MH) Lamps*

Rapid technological changes have now made this group of lamps the most popular lamp both for indoor and outdoor applications. Its compact size and excellent colour properties make it suitable for a wide range of applications from sports to industry, cities and shops.

Metal halide lamps can broadly be grouped into 2 types, depending on the discharge tube material:

a) Quartz metal halides; and

b) Ceramic discharge metal halides.

Further these lamps can be single ended or double ended.

Fig. 16 shows how metal halide lamps are similar to mercury lamps. The main difference is that the arc tube contains metal halides in addition to mercury. There are three main groups:

a) Tricolour radiators, employing sodium (Na), thallium (Tl) and indium (In);

b) Multi-line radiators, employing rare earths and associated elements, chiefly scandium (Sc), dysprosium (Dy), thulium (Tm) and holmium (Ho); and

c) Molecular radiators, which display a quasi-continuous spectrum. These employ tin iodide (SnI_2) and tin chloride ($SnCl_2$).

The outer bulb is of the same materials and functions as in the mercury lamp. Both clear and phosphor coated versions are available. Phosphor coated lamps help further modify the colour and generally to lower the colour temperature of the lamp. The arc tubes are usually smaller for equivalent wattage. The main electrodes are similar to those of mercury lamps except there is no emission coating and they are larger.

The starting electrode is the same except there is a bimetallic switch that shorts the starter circuit to the main electrode after the lamp starts. The arc tube is slightly smaller than in the mercury lamp. The ends have a white reflective coating to control the arc temperature and metal vaporization. Also the ends are moulded to a precise parabolic shape.

Most multivapour lamps require special metal halide ballasts, and compatibility between lamp and control gear should always be checked.

MH lamps operate on the same general principles as mercury lamps. The addition of metal halides into the arc tube affects the light output and improves the colour characteristics. The metal halides vaporize into halogen and metal in the central core of the arc (the hottest area).

The additional metals radiate more light than mercury and at desirable wavelengths. It is the combination of several metals that produces white light and the number and proportion of the metallic constituents can vary this colour. As the metals and halogen move out of the central arc towards the tube walls they recombine at the cooler temperature. This halogen cycle repeats.

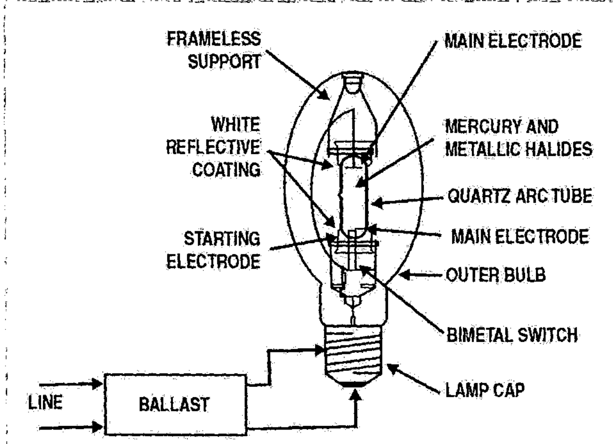


Fig. 16 Metal Halide Lamps Construction

Metal Halide lamps offer greater light output than comparable mercury lamps. Consequently less wattage is required for a given lighting level and less power is consumed.

Metal halide lamps provide good colour uniformity from lamp to lamp and better colour rendering than mercury vapour lamps. Metal halide elliptical lamps are sensitive to burning position with vertical (± 15°) preferred for most. Metal halide tubular lamps have a horizontal burning position (± 15°).

Special types are also available where the arc is automatically extinguished if the outer envelope is broken or punctured. They may be required in locations where exposure to UV radiation is to be avoided.

Low wattage metal halide lamps come in varieties for different applications, such as displays, recessed lighting and track lighting. They produce brilliant white light in a small arc capsule, enclosed in a small outer jacket. Current lamps include the following variations:

a) Single ended with medium base;

b) Single ended with bi-pin base; and

c) Double ended with recessed single contact base.

Some single ended lamps have a transparent sleeve surrounding the arc capsule, which serves as a heat shield to achieve uniform capsule temperature, thereby improving colour uniformity and stability over life.

5.3.6 *Low Pressure Sodium Vapour (LPSV)Lamps*

All the light produced from sodium lamps comes from vaporized sodium contained in an arc tube. If the sodium pressure in the arc tube is very low then all the radiation from the discharge appears as yellow light. To obtain the low pressure, a large arc tube is required which is similar to a compact fluorescent tube but made of a special ply glass with a sodium resistant internal skin.

The U shaped arc tube is contained in a glass outer vacuum jacket, with a clear coating which reflects internal infrared energy, to maintain the correct operating temperature (*see* Fig. 17). Low pressure sodium lamp wattages range from 18 W to 180 W.

The larger versions achieve an efficacy of almost 200 lm/W and are the most efficient light sources available. However, the yellow colour makes it unsuitable for general interior lighting and their main use is for lighting trunk roads, tunnels, underpasses and for security lighting.

LPSV lamps require their own control gear with a ballast and ignitor or special ballast only. Because of the quantity of sodium contained in these lamps, transportation and disposal must be in an approved manner.

Also LPSV lamps cannot be used in or above hazardous zones in case fire results from an accidental lamp breakage.

5.3.7 *High Pressure Sodium Vapour (HPSV) Lamps*

High pressure sodium lamps (HPSV) are so called to distinguish them from low pressure sodium lamps, but the difference is relative and the actual arc tube pressure is not much above atmospheric pressure. This means there is no violent failure should an arc tube rupture. Also, there is no significant UV radiation from the lamp and consequently HPSV lamps can be used safely in open luminaires. When running in a stable condition after a few minutes, the yellow light from the sodium discharge is absorbed and reradiated as blue, green and red light and colours become visible.

These lamps are different in construction, operation and light radiation to the other HID lamps. However, there are some similarities as shown in Fig 18. The HPSV lamps have fewer internal parts than MV or MH lamps.

The arc tube is a special translucent aluminium oxide ceramic material designed to withstand temperatures up to 1 300°C and to transmit 92 percent of the visible wavelength. The arc tube should be free of pores that can leak or weaken the tube and not deteriorate in the presence of hot sodium.

The outer bulb contains a vacuum. The arc tube fill gas is xenon. The amalgam reservoir at one end of tube holds a liquid sodium and mercury mixture.

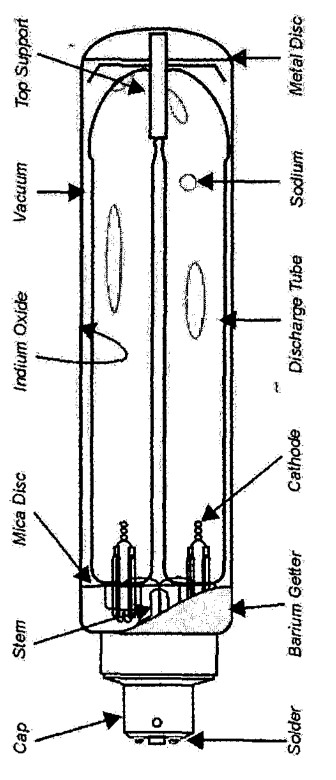


Fig. 17 Construction of LPSV Lamps

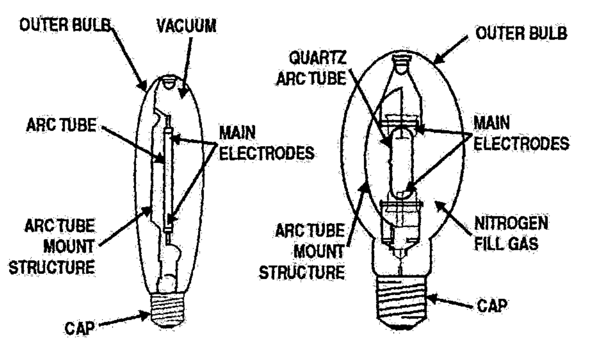


Fig. 18 Construction of HPSV Lamps

The reservoir is the coolest part of the arc tube. Excess sodium-mercury condenses and collects at this point (*see* Fig. 19).

The electrodes are double layer tungsten coils with rare earth oxides like in other HID lamps. HPSV lamps have no starting electrode. The external control gear includes an ignitor that provides a high voltage pulse to start the arc. The starting pulse for a 400 W lamp is 2 500 to 4 500 V and lasts for less than 1 microsecond. The short duration means little energy is used but is sufficient to ionize the xenon gas. Once the current flows through the ionized gas the heat from the arc evaporates the amalgam mixture. The warm up period of high pressure sodium lamps is longer than for most metal halide lamps, around 5 minutes, but conversely the hot restrike period is shorter, typically less than one minute (*see* Fig. 20).

As the sodium vaporizes during warm up, the colour shifts from blue to orange to golden white as the pressure rises. Colour changes very little throughout lamp life. HPSV lamps offer several advantages over mercury and metal halide lamps. High pressure sodium lamps have good lumen maintenance.

Most high pressure sodium lamps can operate in any position. The burning position has no significant effect on light output. Lamp types are also available with diffuse coating on the inside of the outer bulb to increase source luminous size or reduce source luminance, if required.

Because of the small diameter of a high pressure sodium lamp arc tube, no starting electrode is built into the arc tube as in the mercury lamp. A high voltage high frequency pulse is required to start these lamps.

HPSV lamps are mostly used in urban lighting where a warm and appealing colour of light combined with high light output and low energy consumption are required, for example, squares, parks, city centres, residential areas. It is also used for decorative outdoor lighting where lighting can create an image and life in the cities, for example, monuments, facades, historical buildings.

Another area where HPSV lamps have better preference is for industrial lighting for a relatively high lighting level with good rendering of colour at low cost namely,/ industrial halls, light industry, etc.

NOTE — The requirements and tests of HPSV lamps are specified in IS 9974(Part 1).

5.3.8 *Compact Arc Lamps*

High pressure gas discharge lamps having an arc length which is small compared with the size of the electrodes are called short arc or compact arc lamps. Depending on rated wattage and intended application, the arc length of these lamps may vary from about a third of a millimeter to about a centimeter. These lamps have the highest luminance and radiance of any continuously operating light source and are the closest approach to a point source.

The envelope is made from optically clear quartz material of various grades and has a spherical or ellipsoidal shape. The grade of the quartz will determine the amount of ozone generated. The most widely used material for the electrodes is tungsten.

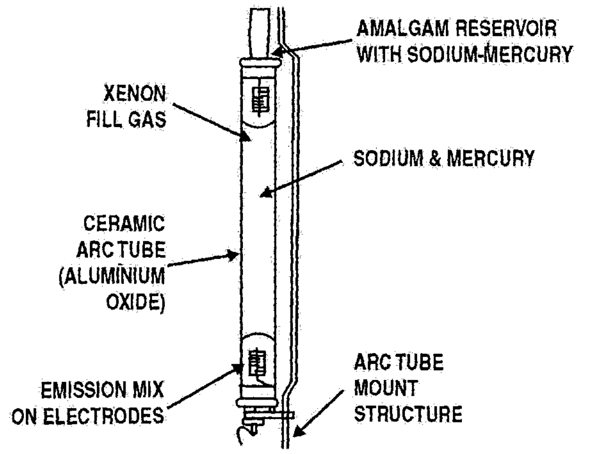


Fig. 19 Arc Tube Components

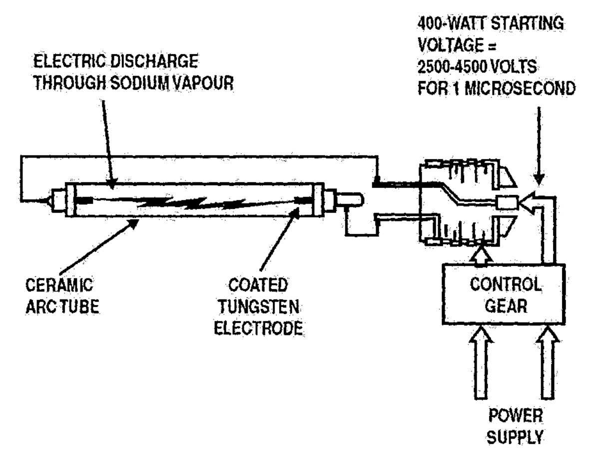


Fig. 20 HPSV Lamp Operation

Most compact arc lamps are designed for DC operation. This results in better arc stability and substantially longer life. DC systems consist of an ignitor and a regulated power supply. High voltage pulses (up to 50 000 V) break down the gap between the electrodes, ionize the gas and heat the cathode tip to thermionic emitting temperatures.

Note that higher wattage lamps do not necessarily yield more light intensity. When higher illumination intensity is needed, lamps with greater brightness must be selected and this does not always increase with lamp wattage.

5.3.8.1 *Xenon lamps*

Xenon compact arc lamps are filled at several atmospheres of xenon gas. They reach 80 percent of final output within 10 minutes or less of starting. The arc colour is very close to daylight (6 000 K). The spectrum is continuous in the visible range and extends far into the ultraviolet. A xenon lamp exhibits strong lines in the near infrared between 800 nm and 1 000 nm and some weak lines in the blue portion of the spectrum.

Xenon compact arc lamps are made with rated wattages from 75 to 30 000 watts and are available for operation in either a vertical or horizontal position. The breakdown voltage between the electrodes will run from 10 kV for a small lamp up to 60 kV or more for lamps rated 30 kW. The luminous efficacy of xenon compact arc lamps is approximately 30 lm/W at 1 000 W, 45 lm/W at 5 000 W, and over 150 lm/W at 20 kW.

5.3.8.2 *Mercury-xenon lamps*

A mercury-xenon lamp contains a specific amount of mercury and a small amount of xenon added at a pressure exceeding one atmosphere. The xenon is necessary to facilitate starting and to sustain the arc until the mercury is fully vaporized; it also reduces the warm up period. Normal warm up time is 10 to 15 minutes.

Mercury lamps are sensitive to cooling because the bulb temperature determines the vapour pressure. The lamp can be overcooled to the point that full output in the mercury spectrum is never achieved. The cooling water should be ordinary tap water. Chilled water may decrease the operating voltage and interfere with the proper evaporation of mercury. In some cases, the mercury may not evaporate at all, causing unsuitable performance and shortened lamp life.

Typical steady state voltage of a mercury-xenon lamp is higher than that of a xenon lamp. The output in the visible range consists mainly of four mercury lines and some continuum, due to the high operating pressure. A properly warmed lamp will show no significant trace of the xenon gas spectrum. Mercury-xenon lamps are available in wattages from 200 to 7 000 W. The luminous efficacy is approximately 50 lm/W at 1 000 W and about 55 lm/W at 5 000 W.

5.3.8.3 *Lamp handling*

Compact arc lamps contain highly pressurized gas, and present an explosion hazard even when cold. It is necessary to wear face protection, such as a welder's helmet, whenever handling lamps.

Special storage cases are provided to eliminate possible hazards during shipping and handling. Safety goggles and soft cotton gloves should be worn when removing and installing lamps. The quartz envelope should never be touched with bare hands; such handling may lead to deterioration and premature failure. If accidentally handled, the lamp surface should be cleaned with an alcohol swab to remove any residue. One should never look directly at an operating arc lamp which may result in severe eye injury. UV protective lenses, such as a welder's helmet, should be worn, when working around operating arc lamps.

5.3.8.4 *Polarization*

Some lamps can only be mounted one way in the power arc housing since the anode (+) and cathode (-) have different diameters, thus making accidental polarization reversal nearly impossible. However, some lamps have the same diameter anode and cathode, allowing room for error. Reference should be made to the lamp manufacturer's data sheet for proper identification of the anode and cathode.

It may be noted that reversed polarization will result in immediate and permanent damage to the lamp electrodes. A lamp that has been fired with reversed polarization will have obvious physical damage to the electrodes. A damaged lamp will fire, but it will exhibit unstable performance and a severely shortened operating life.

5.3.8.5 *Lamp stability*

Short term stability is measured over seconds, while long term stability is measured over minutes, hours, or even days. Short term stability is affected by arc 'wander,' 'flare' and 'flutter.' Arc wander is the movement of the attachment point of the arc on the cathode surface. Typically the arc moves around the conical cathode tip in a circular fashion, taking several seconds to move a full circle.

Arc flare refers to the momentary change in brightness as the arc moves to an area on the cathode having a preferential emissive quality over the previous attachment point. Arc flutter is the rapid side-to-side displacement of the arc column as it is buffeted by convection currents in the xenon gas which are caused as the gas is heated by the arc and cooled by the envelope walls.

Arc wander and flare can be reduced by a slight decrease in the operating current. For example, a 75 W xenon lamp rated at 5.4 A may be operated at 4.5 A for the first one or two minutes of operation, after which the current should be brought up to the specified normal operating level.

5.3.8.6 *Lamp life*

The useful life of compact arc lamps is determined primarily by the decrease of luminous flux caused by the deposit of evaporated electrode material on the inner wall of the envelope. Frequent ignition accelerates electrode wear and hastens the blackening of the envelope. Average lamp life is based on approximately 20 minutes of operation for each ignition. The end of the lamp life is the point at which the UV output has decreased by approximately 25 percent, the arc instability has increased beyond 10 percent, or the lamp has ceased to operate under specified conditions. Lamps should be replaced when the average lamp life has been exceeded by 25 percent.

As the lamp ages, the operating voltage will increase. Lamp current should be decreased to maintain output until the minimum operating current is reached. At this time the lamp should be replaced. Lamp life varies with different types. The manufacturer's specifications give the rated lamp life.

6 INDUCTION LAMPS

The induction lamp introduces a totally new concept in light generation. Light generation is on the same principle as a low pressure mercury vapour lamp. It is the changing magnetic field within the lamp that generates the current flow through the ionized mercury vapour.

The fundamental difference is that there are no electrodes or wire connections into the lamp. Induction lamps are sometimes called 'electrodeless' lamps because of this feature. The glass bulb has a hollow centre and in this there is an induction coil, which is connected to a high frequency supply generated by control gear mounted in the lamp cap. This lamp has a sealed glass bulb, which contains krypton gas, a small amount of mercury (6 mg), and an internal phosphor coating (*see* Fig. 21). An electrical current passing through a low pressure of mercury vapour produces UV radiation. This is absorbed by the phosphor coating and emitted as light.

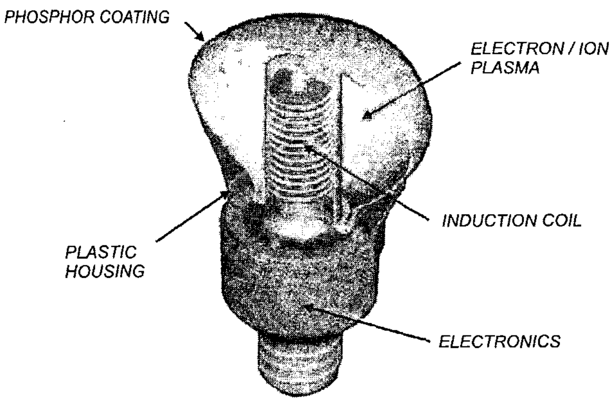


Fig. 21 Components of Typical Induction Lamp

The principal advantage offered by this lamp is a long life, as there are practically no failure points. However, electrodes absorb energy and so reduce the lamp efficacy. They also cause local blackening on the lamp wall which reduces light output.

7 LIGHT EMITTING DIODES (LEDS)

LEDs are semiconductor diodes,which are electronic devices that permit current to flow in only one direction. The diode is formed by bringing two slightly different materials together to form p-n junction. In a p-n junction, the 'p' type contains excess positive charge (holes, indicating the absence of electrons) while the 'n' type contains excess negative charge (electrons).

When a forward voltage is applied to the semiconducting element forming the p-n junction (hereafter referred to as the junction), electrons move from the 'n' area toward the 'p' area and holes move toward the 'n' area. Near the junction, the electrons and holes combine. As this occurs, energy is released in the form of light that is emitted by the LED (*see* Fig. 22). Manufacturers' specifications provide the maximum reverse voltages acceptable for LED devices; 5 V is a typical maximum rating.

A typical voltage-current relationship for an illumination-grade LED is shown in Figure 23. As seen in this figure, a slight change in voltage can result in very large changes in current. Since the light output of an LED is proportional to its current, this can result in unacceptable variation in light output. If the resulting current exceeds the limits recommended by the manufacturer, the long-term performance of the LED can be affected, resulting in shorter useful life. The solid line in Fig. 23 is for normal operating parameters; the dotted lines are extrapolated.

An LED driver performs a function similar to the ballast for discharge lamps. It controls the current flowing through the LED. Most LED drivers are designed to provide current to a specific device or array. Since LED packages and arrays are not presently standardized, it is very important that a driver is selected that is matched to the specific device or array to be illuminated.

Several material technologies are available to make an LED. The LED materials are specific materials known as III-V (three-five) materials, either having a vacant place for an electron, a hole, or a single electron at the outer shell of the atom. The material used in the semiconducting element of an LED determines its colour. Older technologies are GaP and AlGaAs. With these technologies it was possible to make wavelengths from red to yellowish green and are mostly used as indicators in the automotive industry and keypad and instrument cluster illumination in the computer industry. The disadvantage of these technologies is that the lifetime of the LEDs shortens

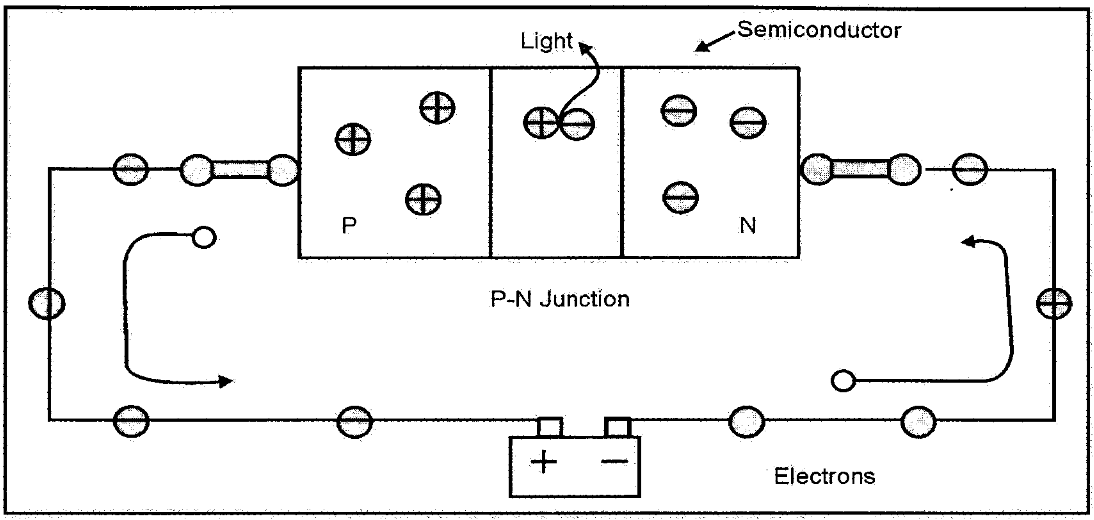


Fig. 22 LED Operation

significantly at higher temperatures and higher currents. The positive point is that the production of those LEDs is very cost effective.

These disadvantages were overcome with the introduction of AlInGaP (Aluminum indium gallium phosphide), a material system able to handle high currents and high humidity. This technology is the basis for the high-brightness red and amber LEDs.

In the early 90's, the InGaN technology development started (Mr. Nakamura at Nichia was first to introduce it). This technology brought the first blue, green and cyan LEDs. Later white LEDs appeared on the market. Suddenly the whole spectrum was filled, except true yellow.

This opened the road for many applications: traffic signals, including green, large screens based on red, green and blue, general illumination tasks based on white light like torches and colour screens on cell phones with a white backlight.

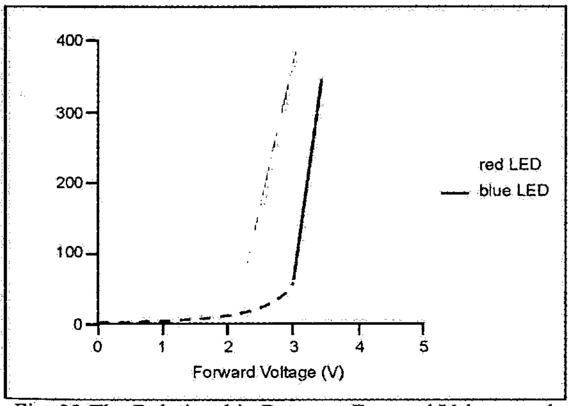


Fig. 23 The Relationship Between Forward Voltage and Current for Illuminator LEDs

At this moment two technologies are leading in the field of high-brightness LEDs: AlInGaP and InGaN.

Various types of LEDs are available and performance characteristics can differ widely.

Through hole LEDs are seen as the classic LEDs. They are called through hole, because the leads of the package have to go though a hole in the printed circuit board (PCB). These are available with diameters of 3.4 and 5 mm and are used in a variety of applications. The product is basically a lead frame with an epoxy housing, forming the primary lens. Typical currents range from 20-50 mA. The thermally improved version is known as the Superflux LED, that can handle up to 70 mA. This product is widely used in the automotive and signage industry producing up to 10 lumens. Automatic placement with high yields of these LEDs is difficult, therefore surface mount devices (SMD) were developed. Surface mount LEDs also called SMD LEDs, are being used in instrument clusters in cars, car radios, backlights for mobile phone screens, keypad illumination and all kind of indicators in for example, computers. These can be placed and soldered on a printed circuit board (PCB) with standard automatic placing equipment and in-line soldering equipment. The LEDs are placed on a PCB and then moved through a high temperature oven that melts the solder, or transported through a wave of melted solder. Typical currents range from a few mAs up to 150 mA, producing less than 1 lm up to 10 lm. These types of LEDs are suited for high volume production.

High Power LEDs have bridged the gap between the semiconductor industry and general lighting. Designed with the best optical and thermal properties, these LEDs have become suitable for general lighting. A thermal and

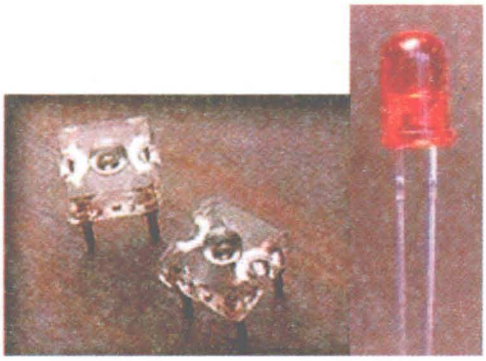


Fig. 24 Through Hole LEDs

optical design is needed to make use of the high potential of these LEDs. The current ranges from 350 mA upto 1 500 mA, producing more than 200 lm.

LED characteristics can be divided in optical performance, thermal and electrical performance and different ways to drive the LED.

As with other light source technologies, such as fluorescent and high intensity discharge, lighting systems using LEDs can be thought of as having a light source

Fig. 25 LED Arrays

(typically, the individual LED source), a ballast (for LEDs, often called a driver), and a luminaire (the surrounding materials for optical control of the emitted light and thermal control of the overall system). Unlike traditional lighting systems with few (typically, one to four) light sources, LED systems will likely contain arrays of many individual light sources in the near future. Fig. 25 shows several arrays that are commercially available.

8 CHARACTERISTICS OF LIGHT SOURCES

8.1 Typical examples of electrical, photometric, colour characteristics and life of the most commonly available light sources are given in the following table.

Light Source	*Wattage Range (W)*	*Efficacy (lm/W)*	*Life(h)*	*Lumen. Maintenance*	*Starting Time(s)*	*Colour Rendition*	*Dimming Capability*	*Optical Control*
Incandescent	15 to 200	12 to 20	500 to 1 000	Fair to good	Instant	Very Good	Very Good	Good
Tungsten-Halogen	300 to 1 500	20 to 27	200 to 2 000	Good to Very Good	Instant	Very Good	Good	Very Good
Standard Fluorescent	20 to 80	55 to 65	5 000	Fair to Good	3 to 10	Good	Fair	Poor
Slim line Fluorescent	18 to 58	57 to 67	5 000	Fair to Good	3 to 10	Good	Low	Poor
Compact Fluorescent	5 to 40	60 to 70	7 500	Good	2 to 5	Good to Very Good	Very Low	Fair
High Pressure Mercury	60 to 1 000	50 to 65	5 000	Very low to fair	2 to 4	Federate	Fair	Poor
Blended Light	160 to 250	20 to 30	5 000	Low to Fair	Instant	Federate	Very Low	Poor
Metal Halide	35 to 2 000 W	80 to 95	4 000 to 8 000	Very Low	240 to 360	Very good	Low	Good
High Pressure Sodium	50 to 1 000 W	90 to 125	10 000 to 15 000	Fair to good	120 to 240	Low to good	Low	Good
Low Pressure Sodium	10 to 180 W	100 to 200	10 000 to 20 000	Good to Very good	240 to 600	Poor	Very Low	Poor
LED	0.5 to 2.0	60 to 100	10 000	Very Good	Instant	Good for white LED	No	Good

NATIONAL LIGHTING CODE

PART 3 ELECTRIC LIGHT SOURCES AND THEIR ACCESSORIES
Section 2 Control Gears for Light Sources

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Arc discharge lamps like fluorescent, high pressure sodium, mercury and metal halide lamps have negative volt-ampere characteristics and hence require an auxiliary device to limit the current. This device is known as the ballast which regulates the current and voltage across the lamp and also provides voltage sufficient to ensure ignition of the arc discharge lamps.

In addition to the ballast, a starting device known as starter is used to strike fluorescent lamps and an electronic device known as an ignitor is used to strike high pressure sodium vapour lamps and metal halide lamps.

Since the ballast is an inductive circuit, the power factor of the system comprising the ballast and lamp is very low, to the extent of 0.5 lagging. For the improvement of the power factor a capacitor is connected across the mains which compensates the inductive load arising out of the ballast.

All these components are the essential accessories for the operation of discharge lamps and are known as control gears.

NATIONAL LIGHTING CODE

PART 3 ELECTRIC LIGHT SOURCES AND THEIR ACCESSORIES
Section 2 Control Gears for Light Sources

1 SCOPE

This section covers the details about the control gear for use with various light sources.

2 TERMINOLOGY

The definitions of the terms used in this section are given in Part 1 of this code.

3 BALLAST

3.1 General

The ballast is an inductive device which provides sufficient voltage for lamp ignition and regulates the voltage and current across the lamp for its optimum operation. The life and light output ratings of discharge lamps are based on their use with a ballast providing proper characteristics. A ballast that does not provide proper electrical values may reduce lamp life or light output or both. The ballast consumes power and hence the luminaire efficacy, that is, lumens per watt consumed is lower than the lamp efficacy.

3.2 Electromagnetic Ballast

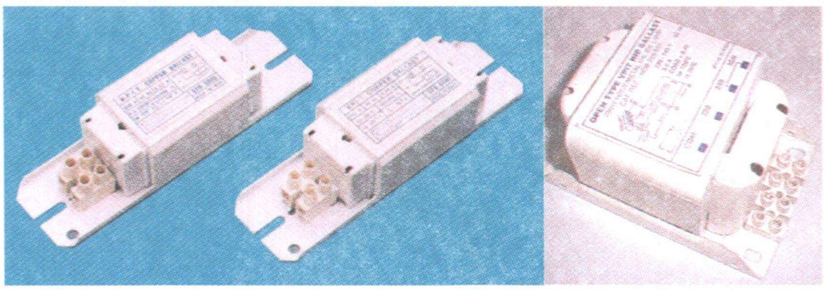
3.2.1 *Construction and Operation*

The construction of a ballast is similar to a transformer with a core and coil. The core is made up of laminated steel sheet of 0.2 to 0.5 mm thickness, stacked together and is wound with the coil made of copper or aluminium wire. The assembly is impregnated with a non-electrically conducting material that provides electrical insulation while aiding in heat dissipation, and with leads attached, is placed into a case. The case is filled with a potting material (polyester compound, for example, containing filler such as silica). This compound completely fills the case encapsulating the core and coil. The base is then attached and the leads are terminated to the connector block. This is the most economic and common type of fluorescent lamp ballast. The core is generally made of J type or L type lamination and is surrounded by coil.

In the case of fluorescent lamps the laminations are mainly of J, L or U and T type. Whereas in the case of HID ballasts the lamination is E and I type. In order to reduce watt loss or power consumption of the ballast, various qualities or grades of silicon laminations are used namely, M45, M43, M22, etc. The coil comprises wound aluminium or copper wire to achieve proper inductance. In the case of canister type ballasts the core is bolted around the coil and the entire mass of the core-coil is potted in polyester resin inside a canister. The new technology ballast is the open type VPIT ballast. Here the ballast core along with coil is crimped with the base plate. The mass is vacuum pressure impregnated in a white unsaturated polyester resin. This type of ballast is superior to the canister type in terms of watt loss, temperature rise, ballast lumen factor and life.

Because of the magnetic elements in the ballast, vibrations are set up in the luminaire based on the input power frequency. This may produce an audible hum which is undesirable. This sound level produced will depend upon the ballast and luminaire construction and mounting. Therefore the shell type of ballast which is made of E and I or T and U or T and E type of laminations are clamped or bolted together. The amount of copper or aluminium conductor contained in this type of ballast is less than the core type of ballast and thus there are less overall losses. In the shell type ballast the coil is surrounded by the lamination core. These types of reactor ballasts are used for HID lamps alongwith a capacitor.

The lead-lag ballast design approach is commonly used to operate twin lamps namely, 36/40 W fluorescent lamps in two independent circuits. A current limiting reactor operates one lamp and a combination reactor and capacitor connected in series operates the second. The lamps operate independently so that a failure of one has no effect on the other. The input current of the combination of the capacitors and reactors is lower than the sum of the two individual operating currents. These elements provide a high power factor and reduce the stroboscopic effect.



Rapid start and instant start ballasts are designed to start the lamp rapidly or instantly. The design of this ballast is essentially the combination of the two parts. One is the normal core and coil ballast and the other one is the filament heating transformer which helps in starting the lamp instantly whereas the ballast performs the usual function of operating the lamps by controlling the running current. The filament heating transformer helps in starting the lamp rapidly or instantly.

Where the line voltage is below or above the specified lamp starting voltage range, a transformer is used in conjunction with the reactor to provide proper starting voltage. This is normally accomplished with the combination of primary and secondary coils forming a one piece single high reactance autotransformer. These autotransformer type ballasts are commonly used for low pressure sodium vapour lamps.

The power factor of this circuit is about 50 percent lagging. High power factor versions are available in which a capacitor is installed in the circuit to increase the power factor of the system to better than 90 percent. These ballasts are also known as booster ballasts and are of two types namely, combination of autotransformer and reactor or center tapped ballast combined with capacitor in order to boost the voltage.

3.2.2 *Selection of Electromagnetic Ballast*

While selecting the luminaire the following electrical parameters are to be considered:

a) Starting current;
b) Running current;
c) Lamp wattage;
d) Ballast losses;
e) Winding temperature (t_w) — t_w is the maximum winding temperature which can be withstood by the ballast continuously for 10 years; and
f) Temperature rise (Δt) — Δt means temperature rise of the winding of the ballast above the ambient temperature.

$t_w = \Delta t + t_a$ where t_a is the ambient temperature.

Thus the objective should be to select a ballast having a low value of Δt and a higher value of t_w.

3.2.3 *General Guidelines on Watt Loss of Ballast*

Sl. No.	*Lamp*	*Watt Loss*
i)	36/40W FTL	9W
ii)	80W HPMV	14W
iii)	125W HPMV	17W
iv)	250W HPMV	23W
v)	400W HPMV	30W
vi)	70W HPSV/MH	15W
vii)	150W HPSV/MH	22W
viii)	250W HPSV/MH	32W
ix)	400W HPSV/MH	42W

NOTE — MH = Metal Halide lamp

3.3 Electronic Ballast

3.3.1 *Construction and Operation*

It consists of electronic components and operates the lamp at 20 to 60 kHz frequency. The electronic ballast has approximately half the power loss of the magnetic ballast. The lamp efficacy also increases by 10 to15 percent when the lamp operates at a frequency above 20 kHz. Hence a 36 W fluorescent lamp operating at 32 W can deliver its desired lumen output.

The electronic ballast is available in instant start or warm start version. The instant start ballast was developed to start the lamp without any delay or flashing. Instead of heating the electrodes prior to starting, the instant start ballast provides a high initial voltage to strike the lamp.

The high voltage is required to initiate the discharge between the unheated electrodes. Since there is no heating operation of electrodes, power loss is lower than the rapid start ballast system. The warm start ballast heats the electrodes to approximately 1 470°F (800°C) before applying the voltage. Electrode heating reduces the amount of voltage required to start the lamp.

The harmonic distortion of the electronic ballast is generally below 30 percent but better designs are available with total harmonic distortion (THD) of less than 10 percent. The power factor of a luminaire with electronic ballast varies from 0.75 to 0.99 lag based on the design and the application. Another important parameter of the electronic ballast is the current crest factor and this is usually less than 1.7.

The lamp current crest factor (CCF) directly impacts lamp life. It is defined as peak current divided by average current as delivered by the ballast to the lamp. It is recommended to have a crest factor less than 1.7. It may be noted that with a perfect current sine wave having a crest factor of 1.414 maximum lamp life can be obtained.

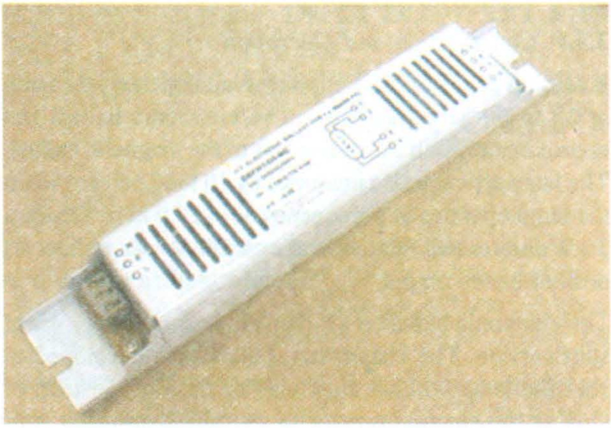
The electronic ballast is also available in a constant wattage version. This ballast is an integrated circuit (IC) based design which delivers constant lamp wattage and hence constant illumination level irrespective of supply voltage variation.

The power factor of this ballast is usually 0.99. Another feature of the electronic ballast is its low striking voltage and wide range of operating voltage. It strikes the lamp at 100 V and its operating voltage varies from 100 to 300 V.

Since the watt loss or power consumption of the electronic ballast is very low, the ballast lumen factor in the case of the electronic ballast is very high (0.98 to 1.5).

Ballast Factor (BF):

$$BF = \frac{\text{Light output of lamp with the Test Ballast (lumen)}}{\text{Light output of the lamp with a Reference Ballast (lumen)}}$$



With the improvement in solid state devices and the availability of sophisticated integrated circuit functions, there are now commercially available electronic ballasts that provide 50 Hz ac input to the ballast and operate the lamps at 20 to 50 kHz, with resulting improvements in ballast efficiency and lamp efficacy. Designs are available for rapid start and instant start of lamps. In order to offset the higher costs of electronic ballasts, some are designed for use with multiple lamps.

The better designs have circuits which keep the line current harmonic distortion below 20 percent and provide a power factor in excess of 90 percent.

Electronic ballasts can also be designed to operate off DC and low voltage systems for application in buses, airplanes, trailers and battery operated emergency systems. These ballasts utilize transistors for inverting the voltage and operate at frequencies ranging from 400 Hz to 25 kHz. These ballasts are known as transistor ballasts and are normally used for emergency lighting.

3.3.2 *Selection Criteria of Electronic Ballasts*

a) Total power consumption;

b) Instant start or warm start;

c) Standard or constant wattage;

d) Total harmonic distortion (THD);

e) Current crest factor;

f) Ballast lumen factor;

g) Power factor; and

h) Filter circuit and deactivation circuit as safety feature.

3.4 Hybrid Ballast

This is generally a combination of an electronic control circuit with a reactor ballast. The electronic control circuit helps in starting the lamp whereas the reactor ballast which is usually a lead type ballast controls the normal operation. These types of ballasts are commonly used for lower wattage low pressure sodium vapour lamps.

4 CAPACITOR

The capacitor is an essential component of the control gear. It is a passive element and generally used for improvement of power factor of the discharge lamp circuit. In special operations it is also being used as a part of the starting device as stated above.

A metalized polypropylene capacitor is commonly used for lighting equipment. The capacitor can also be the oil filled paper type in an aluminium can. A discharge resistor of suitable rating is permanently connected across the terminals for safety.

Power factor improvement is done by connecting the capacitors either in parallel across the mains or in series with the ballast. Parallel capacitors are designed for 250 V rating whereas the series capacitors are suitable for 400 V ac supply. Depending on the circuit impedance and the power factor improvement required, the capacitance values are chosen.

The series capacitors with core coil ballasts are quite useful for having a lead lag circuit, for avoiding a stroboscopic effect and achieving a total power factor near unity. The capacitor also helps in filtering voltage spikes travelling on the input line.

It is generally used to improve the power factor of a discharge lamp used with an inductive type electromagnetic ballast. It is made up of zinc and aluminium alloy metalized on 6 micron thick dielectric material of polypropylene film. The film is wrapped around a bobbin and resin inside aluminium or reinforced polypropylene plastic can. An inbuilt discharge resistance of suitable rating is provided across the capacitor terminals for safety. Normally the capacitor is connected across the mains and is designed for 250 V rating.

4.1 General Guidelines of Capacitors for Various Lamps:

Sl.No.	*Lamp*	*Power Factor*	*Capacitor in Parallel*
i)	36/40W FTL	> 0.9	4 µfd
ii)	2x36/40W FTL	> 0.8 / 0.9	6.5/8 µfd
iii)	80W HPMV	> 0.85	8 µfd
iv)	125W HPMV	> 0.85	10 µfd
v)	250W HPMV	> 0.85	15 µfd
vi)	400W HPMV	> 0.85	20 µfd
vii)	70W HPSV	> 0.85	10 µfd
viii)	150W HPSV	> 0.85	15 µfd
ix)	250W HPSV	> 0.85	33 µfd
x)	400W HPSV	> 0.85	42 µfd

5 STARTER

A number of different means of lamp starting have been developed since the advent of the fluorescent lamp. The first was preheated starting, which required an automatic or manual starting switch. The operation of a preheat circuit requires heating of the electrodes prior to application of voltage across the lamp.

It is a device to strike the discharge lamps. The most common type of starter is the glow switch starter. The bulb is filled with an inert gas chosen for the voltage characteristics desired. When the supply voltage is applied to the luminaire, the gas inside the starter produces a glow discharge between the starter contacts. The heat generated from the glow distorts the bimetallic strip, the contact closes and electrode preheating begins.

Since the contacts are closed, the discharge stops and the bimetal cools down. Immediately the bimetal opens up which creates a inductive spike across the lamp. If the lamp fails to strike, the same process will repeat till the lamp ignites. During the 'on' condition of the lamp, the starter contacts disconnect and it consumes no power.

The starter on-off emits radiations which may be picked up by nearby radios, causing an audible sound. Therefore, the starters for preheat circuits have capacitors for reduction of radio interference.

6 IGNITOR

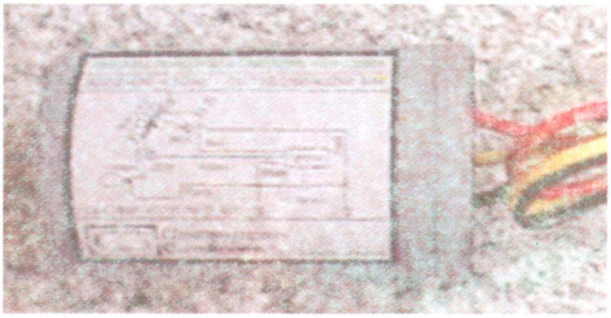
The ignitor is an electronic device and is used for striking high pressure sodium vapour and metal halide lamps. In the case of these lamps, high voltage usually higher than supply voltage is required to ionize the discharge path of the lamp filament. The crucial points in the successful ignition of a lamp are the peak voltage, number of pulse and phase positions of the ignition pulse. There are two types of ignitors as stated in **6.1** and **6.2**.

Ignitors are used in the ballast circuit for most high pressure sodium vapour lamps, some metal halide lamps and some speciality arc lamps. The ignitor starts cold lamps by first providing a high enough voltage for ionization of the gas to produce a glow discharge. To complete the starting process, enough power must then be provided by the starting pulses to sustain an arc through a glow-to-arc transition. The range of pulse voltage to start cold lamps is 1 to 5 kV, usually provided by an electronic resonant circuit which applies multiple pulses to the lamp when the circuit is energized. The circuit turns itself off after the lamp starts by sensing the reduction in open circuit voltage or, with some ignitors, after a fixed period of time.

Instant restarting of hot lamps is accomplished by increased ignition voltage. Voltage pulses of 10 to70 kV are required by the range of available HID lamps, and these are again provided by resonant circuits. To reduce the voltage to ground to half these values, ignitor circuits are available to apply opposing pulses simultaneously to the ends of the lamp. Most instant restart lamps are of double ended construction. It minimizes arc-over between lead wires, internal supports or base contacts. These high voltage starting pulses are normally applied in one or several short bursts, using the open circuit voltage reduction upon restart to turn off the ignitor.

6.1 Impulse Type

In the case of an impulse type ignitor the ballast is used as an autotransformer to generate a peak voltage of 3 to 5 kV across the lamp. Once the lamp is switched on, the lamp reaches its maximum lumen output within 10 to 15 minutes. The ignitor stops providing pulses after the lamp



starts operating. In the case of non integrated luminaires where the lamp is located away from the control gear, the width of the pulse voltage generated by ignitor and ballast is high so as to achieve reliable striking of lamp. The maximum permissible distance of the lamp compartment from control gear is 30 m.

6.2 Superimposed Type

Superimposed ignitors are available for striking sodium vapour and metal halide lamps. This ignitor consists of a core and coil assembly in addition to the electronic components. The ignitor generates a peak voltage of 3 to 5 kV across the lamp terminals and since the ballast is not used as an autotransformer to amplify voltage, the ballast is free from the detrimental effect of pulse voltage in case of malfunctioning of the lamp during the end of its life. Another important characteristic of metal halide lamps is the hot restriking time. If the supply voltage is switched off and immediately switched on, the lamp will have to cool down for 10 to 15 minutes before it reignites.

Instant restriking of a hot metal halide lamp is accomplished by applying a pulse voltage of 25 to 70 kV across the lamp terminals. Most instant hot restriking lamps are of double ended construction to minimize the arc-over voltage between the terminals.

NATIONAL LIGHTING CODE

PART 4 LUMINAIRES

Section 1 Classification and Selection of Luminaires

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

An electrical light source is a device which converts electrical energy into light energy. However, we can seldom use a bare light source for any lighting application. One of the prerequisites of the effective use of light is to redistribute the light from the bare lamp in the required pattern, depending upon the lighting need. This is achieved by the use of an apparatus known as a luminaire.

A luminaire is technically defined as an apparatus which distributes, filters or transforms the light given by the lamp or lamps and which includes all the items necessary for fixing and protecting these lamps and for connecting them to the electrical circuit.

The following Indian Standard is a necessary adjunct to this section.

IS No.	*Title*
10322(Part 1):1982	Luminaires: Part 1 General requirements

NATIONAL LIGHTING CODE

PART 4 LUMINAIRES

Section 1 Classification and Selection of Luminaires

1 SCOPE

This section covers the general aspects of luminaires, selection criteria and different classifications of luminaires.

2 TERMINOLOGY

The definitions of the terms used in this section are given in Part 1 of this code.

3 CLASSIFICATION OF LUMINAIRES

Classification of luminaires is commonly organized on the basis of application areas usually distinguished as commercial, industrial, domestic etc. Another form of classification employs the luminous intensity or flux distribution of the luminaires (*see* Fig. 1).

3.1 Purpose of Classification

A variety of luminaires and luminaire systems are available for different lighting applications catering from the simplest to the most sophisticated and specialized visual requirement. The success of any lighting design depends largely on how intelligently a lamp and luminaire combination has been selected. There are various technical parameters which are to be evaluated and weighed for a judicious choice of a luminaire for a particular application.

Luminaire classification helps specifiers and manufacturers describe, organize, catalogue, and retrieve luminaire information. The nature of luminaire classification has undergone a change with the advancement of computer and information technology.

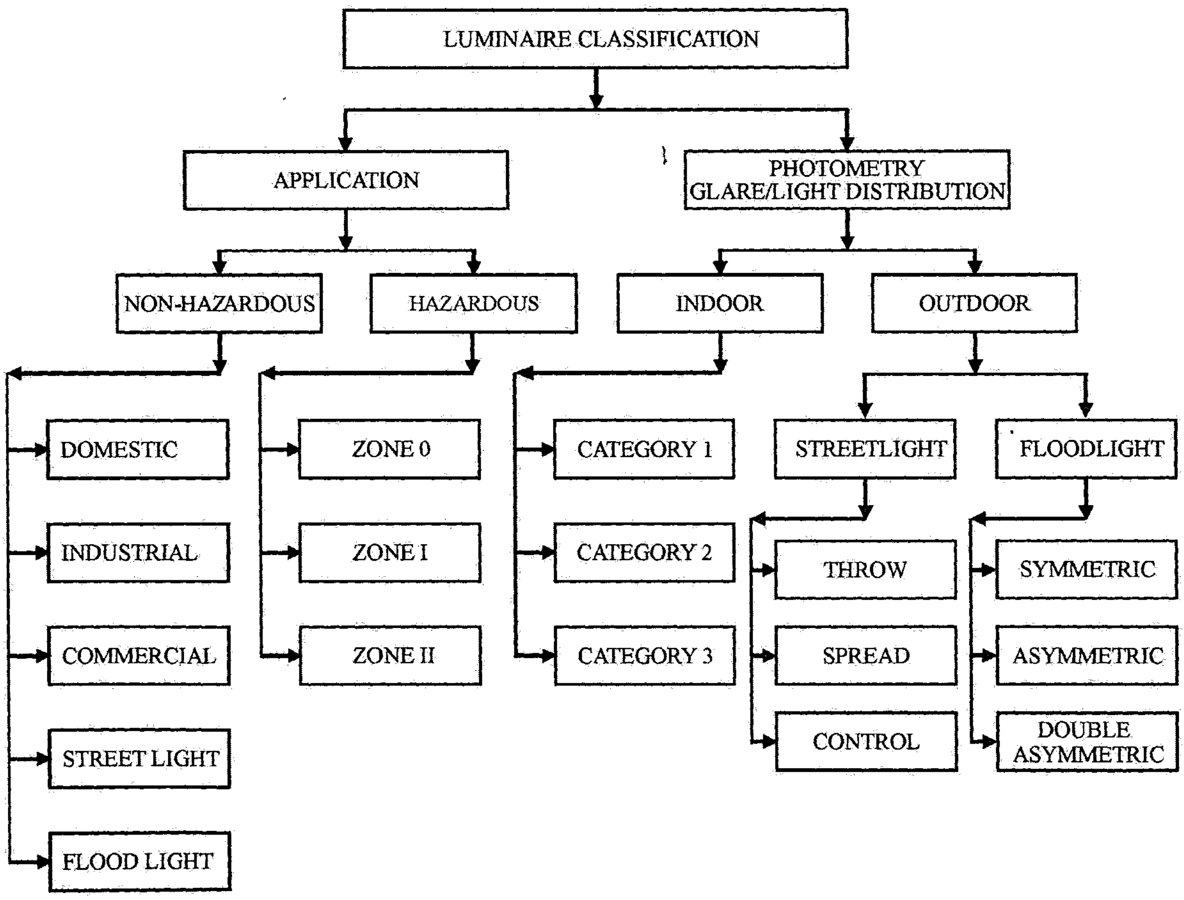


Fig. 1 Luminaire Classification

Modern lighting design and specification practice relies on computerised luminaire databases which can be stored and accessed on CDs or on the internet giving us freedom to update luminaire data frequently and easily. In such systems, a luminaire can be known by all of its characteristics, with any one of these being the path by which a search finds the luminaire in a database.

3.2 Classification Based on Application

In general luminaires are classified in two major categories; from the safety point of view:

a) Non-hazardous application; and

b) Hazardous application.

3.2.1 *Non-hazardous Application*

Further application based classifications are given below.

3.2.1.1 *Indoor luminaire*

a) Domestic;

b) Commercial; and

c) Industrial.

3.2.1.2 *Semi-indoor and semi-outdoor luminaire*

Areas covered from the top but open from the sides such as boiler platforms, electrostatic precipitators (ESP), conveyors, preheater towers in cement plants, etc.

3.2.1.3 *Outdoor luminaire*

a) Road lighting;

b) Flood lighting; and

c) Landscape lighting.

NOTE — Generally luminaire manufacturers publish their product literature classified as above. This is the first stage of luminaire selection.

3.2.2 *Hazardous Area Application*

This can be classified into three parts:

a) Zone 0, where no luminaire or more precisely no electrical apparatus is allowed;

b) Zone I, which calls for flame proof luminaires; and

c) Zone II, where increased safety luminaires can be used.

3.3 Classification Based on Light Distribution

Interior luminaires have been classified by CIE depending on the percentage of total light output in the upper hemisphere (90° to 180°) and lower hemisphere (0° to 90°).

3.4 Classification Based on Method of Mounting

3.4.1 *Indoor Type*

Luminaires are classified as wall mounted, pendant, surface mounted, recessed, etc. Depending on the ceiling, luminaires with appropriate mounting arrangement are to be selected.

3.4.2 *Outdoor Type*

This can be pole mounted, bracket mounted, post top mounted or buried.

4 SELECTION OF LUMINAIRES

4.1 The basic selection criteria of the luminaire depends on:

a) Optical characteristics;

b) Electrical parameters;

c) Environmental protection;

d) Safety requirements; and

e) Appearance and architectural integration.

4.2 Optical Characteristics

The heart of the luminaire is its optical system which is the basic means of distributing and utilizing the light from the bare lamp. There are commonly four methods of light control.

4.2.1 *Reflection*

This is the most effective and efficient method of light control and commonly used for most of the luminaires.

Reflectors direct light where it is needed and may be used to shield the brightness of the lamp. Reflecting materials can be matt or specular, metallic or white, hammered or ridged, or a combination of these. It is the job of the reflector to capture some or most of the light emitted from the lamp and redirect it to more useful zones. Each type of reflector material produces a different light distribution, as described below.

4.2.1.1 *Specular reflection*

This type of reflection follows the laws of reflection that is, the angle of incidence is equal to the angle of reflection. This method of light control is used for those applications where precise light control is required. Some examples are given below (*see* Fig. 2):

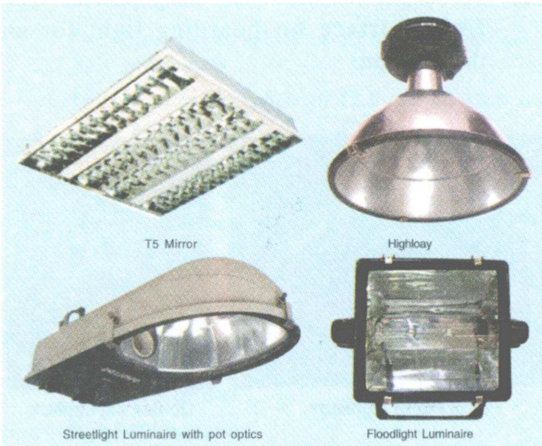


Fig. 2 Specular Reflection

a) Mirror optics luminaires for commercial applications;

b) High bay luminaires with anodized aluminum reflectors for industrial applications;

c) Street lighting luminaires using precision optics technology with HID light sources; and

d) Floodlighting luminaires.

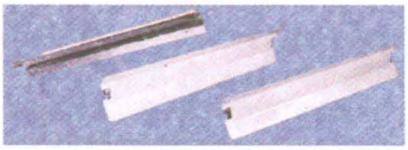
4.2.1.2 *Diffused reflection*

In this type of reflection, reflected light is independent of the angle of incidence and reflection does not follow the law of reflection. This method has limited capability of light control but has the advantage of reducing the brightness of the light source. Some examples are given below (*see* Fig. 3):

a) White painted reflector for tubular fluorescent lamps; and

b) Highbay luminaires with vitreous enamelled reflectors.

T5 Luminaire



Vitreous Enamelled

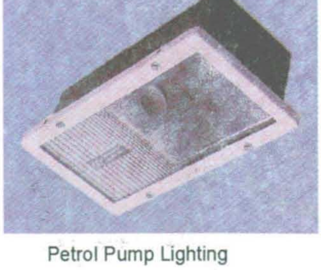
Fig. 3 Diffused Reflection

4.2.1.3 *Spread reflection*

This type of reflection is a combination of diffused and specular reflection. This is achieved by giving an unsmooth finish to the specular reflector's surface. This finds application for some specific areas. Some examples are given below (*see* Fig. 4):

a) Petrol station canopy lighting luminaire with hammer finish specular reflector; and

b) Floodlight with wide beam using specular hammer finish surface for hoarding light for wide distribution.



Petrol Pump Lighting

Double asymmetric Floodlight

Fig. 4 Spread Reflection

4.2.2 *Diffusion*

A perfectly diffusing surface is one which has the same brightness whatever the angle of view. This method is exclusively used for decorative luminaires where aesthetic need prevails over functional requirement. Some examples are given below (*see* Fig. 5):

a) Any fluorescent luminaire with diffuser for commercial application; and

b) Post top luminaire.

Post Top

Fig. 5 Diffusion

4.2.3 *Refraction*

Nowadays refraction is used for light control. As a result we see the emergence of refractors using prismatic light controllers made of acrylic or polycarbonate. They collect light from the light source and refract it into more useful zones, controlling glare in the process. The great advantage of this system is that, it gives light not only on working plane but illuminates the complete interior, thereby significantly improving space ambience. Fig. 6 gives a typical example of this type of luminaire.

Refractor Optics Using Polycarbonate Prismatic Light Controller

Fig. 6 Refraction

4.3 Electrical Characteristics

4.3.1 The electrical parameters of a luminaire depend on the kind of electrical control gear and its features for safe fault free operation of the lamps. Features of components such as capacitors, ignitors, etc, have been covered in Part 3, Section 2 of this code.

4.3.2 *Other Components*

There are other components which are part and parcel of the luminaire such as the lampholder, starterholder, connector, internal wiring, etc. They are also equally important and proper care should be taken while selecting the luminaire.

4.4 Protection against Environmental Conditions

4.4.1 Dampness, rain, hurricanes, winds, hot sun, vibration, dust and vandalism are just some of the conditions that a luminaire may be expected to withstand. It is necessary that the luminaire should have the requisite environmental protection to withstand these adverse conditions depending on the atmosphere.

The degree of ingress protection (IP) against dust and liquid is generally represented by an IP number. The first numeral refers to protection against solid particles while the second numeral stands for protection against liquids. Table 1 shows how IP values influence the performance of luminaires.The symbols to be used for various degrees of protection are shown in Table 2 and Table 3.

4.5 Safety Requirements

Safety requirements are given in IS 10322 (Part1).

4.6 Appearance and Architectural Integration

The luminaire is an integral part of the space. In addition to producing light, the outward appearance of a luminaire may contribute to the ambience, and thus may be an important criterion in selecting the lighting system. The lighting specifier should work with other design team members to understand whether the luminaires should be:

a) Integrated into the architecture, for example, concealed behind architectural features such as beams, coves, slots, etc;

b) Unobtrusive, for example, recessed into ceilings,

Table 1 IP Values and Performance of Luminaires
(*Clause* 4.4.1)

Application Area	Required IP Rating	Performance
Coal Handling Plant	IP 65	Dust-tight luminaire ensures protection against ingress of dust and water jets.
Road lighting	IP 66	Luminaire shall have sealed lamp compartment ensuring protection against entry of insects, not to mention dust and powerful water jets
AC offices/General purpose lighting	IP 20	Luminaire construction ensures protection against accidental contact with live parts by any solid object of 12.5 mm dia or greater, but no protection against entry of liquid.

NOTE — For road lighting applications IP-43, IP-54 and IP-65 can also be used depending on the category of road.However, for 'fit and forget' maintenance the concept of IP-66 is the better option.

Table 2 Ingress Protection – First Numerals
(*Clause* 4.4.1)

First characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non-protected	–
1	Protected against solid foreign objects of 50 mm dia and greater	The object probe, sphere of 50 mm dia shall not fully penetrate[1])
2	Protected against solid foreign objects of 12.5 mm dia and greater	The object probe, sphere of 12.5 mm dia shall not fully penetrate[1])
3	Protected against solid foreign objects of 2.5 mm dia and greater	The object probe, sphere of 2.5 mm dia shall not penetrate at all[1])
4	Protected against solid foreign objects of 1.0 mm dia and greater	The object probe of 1.0 mm dia shall not penetrate at all[1])
5	Dust-protected	Ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the apparatus or to impair safety
6	Dust-tight	No ingress of dust

[1]) The full diameter of the object probe shall not pass through an opening of the enclosure.

wall furnishing or landscaping so that the luminaire 'disappears';

c) Visible but minimal in appearance so that attention is not drawn to the luminaires, for example, luminaires simple in style, usually with clean geometric shapes and basic finishes, that are suspended, surface mounted or pole mounted; or

d) Noticeable and responsive to the style of the space, for example, the luminaire style supports the design intent of the space by mimicking finishes, contributing rhythm or scale, or suggesting a formal or casual feeling or historical period.

Table 3 Ingress Protection – Second Numerals

(*Clause* 4.4.1)

Second characteristic numeral	Degree of protection	
	Brief description	Definition
0	Non-protected	–
1	Protected against vertically falling water drops	Vertically falling drops shall have no harmful effects
2	Protected against vertically falling water drops when	Vertically falling drops shall have no harmful effects enclosure tilted up to 15° when the enclosure is tilted at any angle up to 15° on either side of the vertical
3	Protected against spraying water	Water sprayed at an angle up to 60° on either side of the vertical shall have no harmful effects
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effects
5	Protected against water jets	Water projected in jets against the enclosure from any direction shall have no harmful effects
6	Protected against powerful water jets	Water projected in powerful jets against the enclosure from any direction shall have no harmful effects
7	Protected against the effects of temporary immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is temporarily immersed in water under standardized conditions of pressure and time
8	Protected against the effects of continuous immersion in water	Ingress of water in quantities causing harmful effects shall not be possible when the enclosure is continuously immersed in water under conditions which shall be agreed between manufacturer and user but which are more severe than for numeral 7

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NATIONAL LIGHTING CODE

PART 4 LUMINAIRES
Section 2 Photometry

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

This section sets out to provide specifications for the standard conditions under which photometric tests should be carried out and to recommend testing procedures, which will give sufficiently accurate and reproducible results when determining and reporting the photometric characteristics of luminaires. These specifications are intended to provide a basis for uniform national standards and to give guidance to photometric laboratories in the conduct of tests and in the presentation of luminaire performance data. The section also gives specifications for the measurement of correction factors applicable to luminaires operated under practical test conditions different from the standard test conditions.

Detailed descriptions of photometric methods are primarily of value to laboratory personnel and engineers, but are also important to users of the data. Proper interpretation of data often depends on a full knowledge of the testing procedures involved and this section also sets out to provide the user with the information needed to understand photometric testing procedures and data presentation.

NATIONAL LIGHTING CODE

PART 4 LUMINAIRES
Section 2 Photometry

1 SCOPE

This section of the code covers general requirements for the photometry of luminaires, which are considered to be applicable to most types of luminaires.

2 TERMINOLOGY

The following definitions of terms used in this section shall apply in addition to those given in Part 1 of this code.

2.1 Luminaire — Apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for supporting, fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electricity supply.

2.2 Design Attitude (of a Luminaire) — The attitude in which a luminaire is designed to operate as determined by reference to the manufacturer's instructions or to common practice.

2.3 Measurement Attitude (of a Luminaire) — The attitude in which a luminaire is measured.

NOTE — If not otherwise indicated, assumed to coincide with the design attitude.

2.4 Light Centre (of a Source) — Point used as origin for photometric measurements and calculations.

2.5 Photometric Centre — The point in a luminaire or lamp from which the photometric distance law operates most closely in the direction of maximum intensity.

2.6 First Axis (of a Luminaire) (also Reference Axis) — An axis containing the photometric centre, used in photometric measurements as a reference direction to correlate the photometric measurements with the attitude of the luminaire.

2.7 Second Axis (of a Luminaire) (also Auxiliary Axis) — An axis containing the photometric centre, perpendicular to the first (reference) axis, linked to the luminaire and used together with the first axis for defining the attitude of the luminaire.

2.8 Practical Ballast — A ballast, which is representative of the range of production ballasts appropriate to the luminaire and lamp(s) under test.

2.9 Terms Related to Measured Quantities for Luminaires

2.9.1 *Luminaire Data per 1 000 lm (of Lamp Flux)* — Photometric data of a luminaire relative to a total theoretical luminous flux of 1 000 lm from all the lamps of the luminaire, when these are operated outside the luminaire under reference conditions but with the same ballast(s).

2.9.2 *Luminous Intensity Distribution (of a Luminaire)* — The distribution of luminous intensity with direction. The luminous intensity distribution may be represented by numerical tables or by graphics and is usually expressed in units of candelas per 1 000 lm of lamp flux.

2.9.3 *Ballast Lumen Factor (BLF)* — Ratio of the luminous flux emitted by a reference lamp when operated with a practical ballast at the rated voltage of the ballast to the luminous flux emitted by the same lamp when operated with its reference ballast.

2.9.4 *Light Output Ratio (of a Luminaire) (LOR)* — The ratio of the luminous flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment under specified conditions.

2.9.5 *Light Output Ratio Working (of a Luminaire) (LORW)* — The ratio of the luminous flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire under reference conditions and with a reference ballast.

2.9.6 *Average Luminance* — The luminous intensity per unit projected luminous area in a given direction of a luminaire.

2.10 Terms Related to Measurements

2.10.1 *Absolute Measurement* — A measurement scale in the appropriate SI units.

2.10.2 *Relative Measurement* — A measurement obtained as a ratio of two quantities of the same type expressed in arbitrary units or a measurement in SI units relative to specified bare lamp flux.

2.10.3 *Bare Lamp Measurement* — A measurement in which a lamp is photometered separately from a luminaire in order to determine the light output ratio of luminaire data per 1 000 lm of lamp flux.

2.10.4 *Reference Conditions (Luminaire)* — The conditions under which photometric measurements on luminaires are performed.

2.10.5 *Reference Conditions (Lamp)* — The conditions under which lamp flux is measured.

2.10.6 *Reference Ballast* — Special inductive type ballast designed for the purpose of providing a comparison standard for use in testing ballasts, for selection of reference lamps and for testing regular production lamps under standardized conditions.

2.11 Terms Related to Measuring Instruments

2.11.1 *Photometer* — An instrument for measuring photometric quantities.

2.11.2 *Goniophotometer* — Photometer for measuring the directional light distribution characteristics of sources, luminaires, media or surfaces.

2.11.3 *Photometer Head* — The part of the goniophotometer comprising the photometer itself (normally a silicon photodiode with colour filters for the spectral correction of the detector responsivity). It may also contain means for the directional evaluation of the light (for example, diffusing windows, lenses, apertures). The photometer converts the incident light into an electrical quantity.

2.11.4 *Illuminance Meter* — Photometer for the measurement of illuminance.

3 PHOTOMETRIC CHARACTERISTICS

Photometric characteristics can be divided into measured characteristics, that is, those directly measured with laboratory instruments, and derived characteristics, that is, characteristics, which can be calculated from the measured ones. The derived characteristics are more closely related to lighting applications.

4 CO-ORDINATE SYSTEMS FOR THE PHOTOMETRY OF LUMINAIRES

4.1 General Aspects

The basic photometric data of a luminaire consists of a set of values of the luminous intensity in different directions, produced by direct photometric measurements.

Measurements of intensity distribution involve photometric and angular measurements (the goniophotometer), under controlled working conditions of the luminaire (electrical and temperature measurements). For such photometric measurements involving direction, it is necessary to define a spatial framework around the luminaire (the co-ordinate system).

4.2 Basic Goniophotometers

For the measurements of the luminous intensity in different directions, the luminaires are mounted in a goniophotometer to facilitate the positioning at definite angles. A goniophotometer usually consists of a mechanical device for the support and positioning of the luminaire or lamp and the photometer head, together with associated devices for acquiring and processing data.

Basically three types of goniophotometer can be distinguished:

a) A goniophotometer, which rotates the luminaire around two mutually perpendicular axes, the intersection of which is the photometric centre of the goniophotometer. This type of goniophotometer is normally used with a single photometer head positioned at an adequate distance from the centre;

b) A goniophotometer which rotates the luminaire around one axis only, the second rotation being given by a relative movement between the luminaire and the photometer head around a second axis at right angles to the first and crossing it at the photometric centre of the goniophotometer; and

c) A goniophotometer in which the luminaire does not move at all. The photometer head rotates around two mutually perpendicular axes, the crossing of which is the photometric centre of the goniophotometer.

NOTES

1. In the first type, the burning position of the lamp changes continuously during measurements, which restrict the use of this type of goniophotometer.
2. In the second type, the burning position of the lamp is the burning position considering the normal use of the luminaire even if the luminaire moves in space or rotates during measurements.
3. The three basic types of goniophotometer listed above can be used in a variety of configurations, each one fitting a particular purpose. Differences lie in the mounting position of the goniophotometer with respect to the ground, in the orientation of the reference axis with respect to the goniophotometer, and in the way in which the luminaire is mounted in the goniophotometer.

4.3 The Co-ordinate System

The determination of the intensity distribution of a luminaire in space involves the use of a co-ordinate system to define the direction in which the intensity measurements are made. The system used is a spherical co-ordinate system with the centre coincident with the photometric centre of the luminaire.

From a general point of view the co-ordinate system consists of a set of planes with a single axis of intersection.

A direction in space is characterized by two angles:

a) The angle between one half-plane, taken as an origin, and the half-plane containing the direction considered; and

b) The angle between the axis of intersection and the direction considered or the complement of this angle.

The orientation of this system with respect to the first axis and the second axis of the luminaire is chosen with particular regard to the type of luminaire, the type of lamp, the mounting attitude of the luminaire and its application, in order to perform more accurate measurements or to simplify the consequent lighting calculations.

4.4 Systems of Measurement Planes

In general, the luminous intensity of a luminaire is measured in a number of planes. From the variety of possible measurement planes, three systems of planes have proven especially useful (*See* Fig. 1 to Fig. 3).

5 STANDARD TEST CONDITIONS

5.1 Test Room

5.1.1 *Measurement Location*

The luminaire shall be measured in surroundings so arranged that the photometer head receives only light from the luminaire direct or with intended reflection.

5.1.2 *Air Movement, Ambient Temperature*

Measurements shall be made in still air free from smoke, dust and mist. The air temperature around the luminaire or the bare lamp should be 25 ± 2°C unless otherwise specified. For lamps, which are not thermally sensitive,

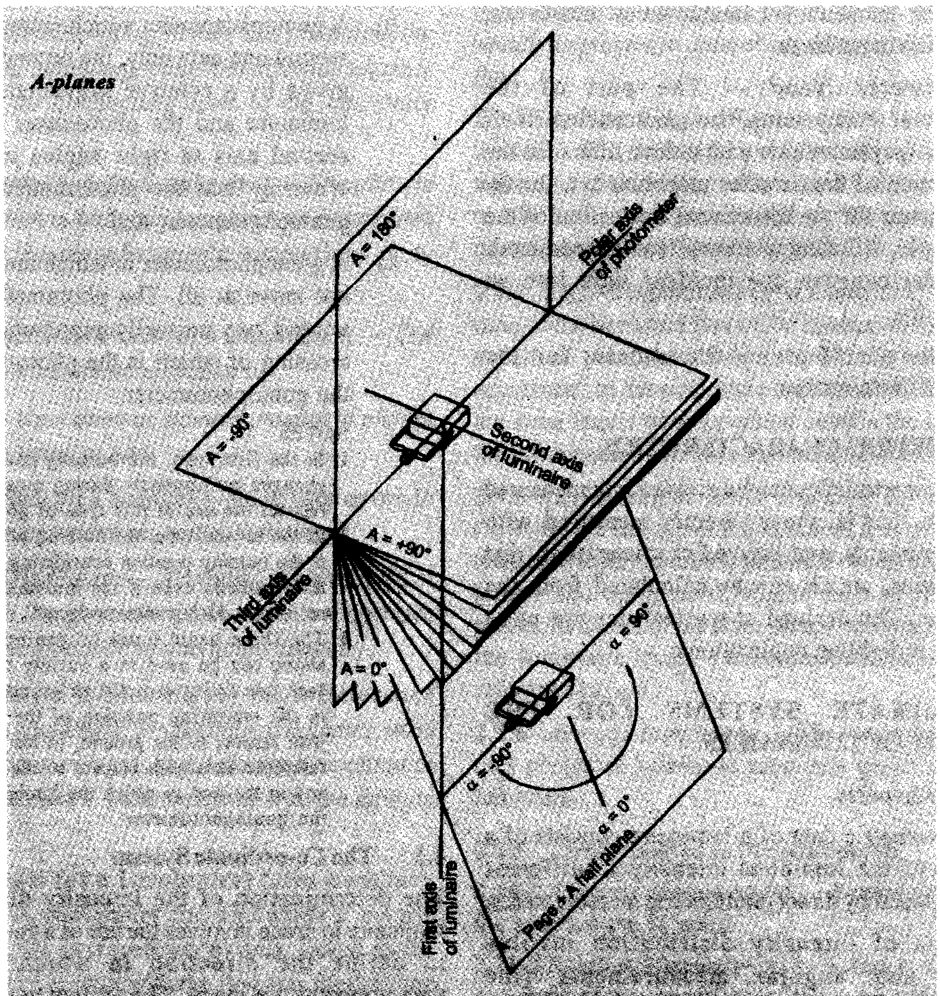


Fig. 1 Luminaire Orientation for A, Alpha Goniophotometry

The system of A-planes is a group of planes for which the line of intersection (polar axis) goes through the photometric centre and is perpendicular to the plane containing the first and the second axes of the luminaire.

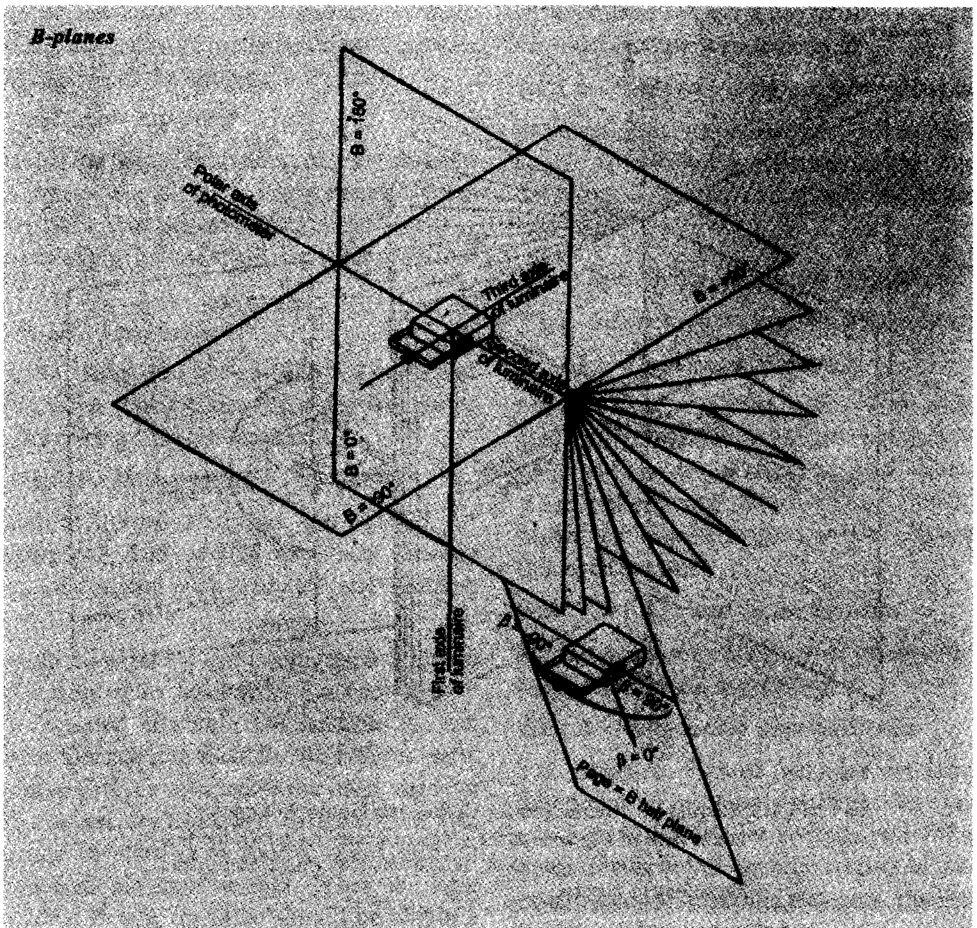


Fig. 2 Luminaire Orientation for B, Beta Goniophotometry

The system of B-planes is the group of planes for which the line of intersection (polar axis) goes through the photometric centre and is parallel to the second axis of the luminaire.

larger temperature tolerances of ± 5°C may be acceptable.

5.1.3 *Test Lamps*

The lamps should comply with and be measured according to the relevant Indian standards. If relevant standards do not exist, the lamps should comply as closely as possible with the nominal specifications of the lamp manufacturer.

If the lamp is of a type for which the luminous flux published in the lamp manufacture's catalogue relates to an operating ambient temperature other than 25 ± 2°C, measurements of the bare lamps are done at 25 ± 2°C, but a temperature correction factor, supplied by the lamp manufacturer or determined by the laboratory, shall be applied to these measurements so as to relate bare lamp measurements more closely to the lamp catalogue data.

5.1.4 *Test Ballast*

The built-in ballast should be used for testing the luminaire and the bare lamps. If the ballast is not built-in, the ballast should be of a type approved by the luminaire manufacturer and the same ballast should be used for testing the luminaire and the bare lamps.

5.1.5 *Test Luminaires*

The luminaire should be representative of the manufacturer's regular product.

The luminaire shall normally be mounted in the position in which it is designed to operate in service. However, the measurement attitude, provided that it is declared, may differ slightly from this. With public lighting luminaires, for example, it is common practice to measure the luminaire with the exit plane of the canopy in a horizontal plane.

5.1.6 *Test Voltage*

The test voltage at the supply terminals shall be the rated lamp voltage or the rated circuit voltage appropriate to the ballast in use, if any.

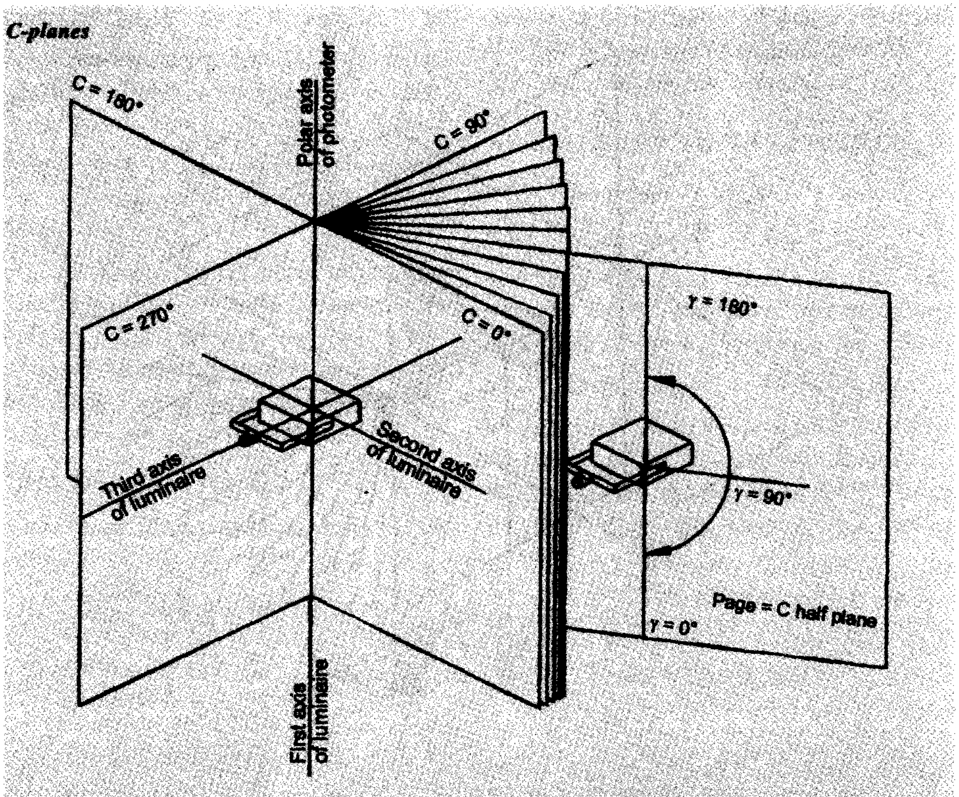


Fig. 3 Luminaire Orientation for C, Gamma Goniophotometry

The system of C-planes is the group of planes for which the line of intersection (polar axis) is the vertical line through the photometric centre.

6 PRACTICAL TEST CONDITIONS

6.1 General

As it is virtually impossible to carry out photometry on a lamp or luminaire without some variation in ambient temperature and some movement of air within its vicinity, tests should be made to ensure that the laboratory conditions are satisfactory.

6.2 Ambient Temperature

The mean ambient temperature should equal 25 ± 2°C throughout the test of the lamp or luminaire.

6.3 Air Movement

The movement of air around the bare lamp or luminaire under test may reduce the operating temperature, thereby altering the light output of some types of lamp. Draughts, air conditioning or the motion of the luminaire in the measuring equipment may cause such movement of air. Air movement in the vicinity of the luminaire should not exceed 0.2 m/s.

For lamps for which larger tolerances for ambient temperature are allowed, a faster air movement may be acceptable.

To ensure that the laboratory conditions are satisfactory, the tests given in **6.4** shall be made. The tests are primarily made for the measurement of low pressure mercury fluorescent lamps.

6.4 Draughts and Air Conditioning

A bare lamp mounted on the photometer should be stabilized in the proposed laboratory conditions and the luminous intensity in a specified direction measured at a known ambient temperature. The air conditioning plant should then be switched off, any remaining draughts reduced as far as practicable, and the lamp restabilized.

The luminous intensity should then again be measured at the same ambient temperature. The difference between the two readings should not exceed 2 percent. A similar test should be carried out on the luminaire.

These tests should be repeated for a number of different positions of the lamp or luminaire in the goniophotometer.

7 PREPARATION OF LAMPS, BALLASTS AND LUMINAIRES FOR TESTS

7.1 Lamps

7.1.1 *General Requirements for All Types of Lamp*

The lamps selected for type testing of luminaires should comply with the relevant Indian Standard. If such recommendations do not exist, the lamps should comply with the specifications of the lamp manufacturer.

7.1.1.1 *Physical characteristics*

The dimensions of the lamps, in so far as they are relevant to the measurements, should be as close as possible to the nominal values. Lamp caps and lamp bulbs should be assembled as closely as possible on their nominal alignments.

7.1.1.2 *Electrical characteristics*

The wattage of the lamp should be within ± 5 percent of the rated value when tested under reference conditions according to the relevant Indian Standards.

7.1.1.3 *Photometric characteristics*

Lamps of stable luminous output are needed for photometric purposes. They should be almost constant in light output for constant supply voltage and repeated operation.

All lamps should be aged by cyclic operation until the light output is shown to be stable. Lamps may be provisionally regarded as stable and suitable for test purposes if, after thermal stabilization, the differences in light output between three successive readings, made at intervals of 15 minutes, are less than 1 percent. After this, test lamps should be allowed to cool to room ambient temperature, and should then be relit. When the light output has become steady, its value should be within 2 percent of the last of the three former readings. Such lamps may then be taken as test lamps. Repeat checks should be made regularly.

Lamps for multiple lamp luminaires, if intended to be of the same type and wattage, should be matched for light output within a spread of 3 percent when operated under the same reference conditions.

7.1.1.4 *Operation and handling*

During successive bare lamp measurements, a test lamp should be operated in a consistent position and with consistent electrical connections. To facilitate this, lamps should be suitably marked. As far as possible, lamps should be inserted in luminaires with consistency of electrical connection. The bare lamp should operate in the attitude in which it is run for the measurement of rated flux, according to the relevant lamp data sheets given in the relevant Indian Standard, while the lamp(s) in the luminaire should operate in the design attitude for the luminaire.

7.1.1.5 *Alignment of lamp in the luminaire*

The light distribution of a luminaire is frequently dependent upon the alignment of the lamp in relation to the position of a filament gap, arc tube support, cap and socket tolerances, etc. Care must be taken to comply with the manufacturer's specification.

7.1.1.6 *Photometric light centre of the lamp*

For measurements on bare lamps, the position of the light centre (photometric centre) of the lamp should be determined in accordance with the following criteria. (*see* Fig. 4).

7.2 Specific Requirements of Different Types of Lamp

7.2.1 *Incandescent Tungsten Filament Lamps*

7.2.1.1 *Physical characteristics*

For lamps with a diffuse coating of the bulb, the diffusing quality of the lamp bulb should correspond to the average of the production. When lamps with clear bulbs are used in luminaires equipped with mirrors, the filaments must be centered within the limits specified if any by the relevant Indian Standards.

7.2.1.2 *Electrical characteristics*

During measurements the voltage should be held within 0.2 percent of the test voltage.

7.2.1.3 *Photometric characteristics*

The luminous flux of incandescent lamps is strongly dependent on the supply voltage. Care must be taken to avoid variable resistive contacts and voltage drop in the leads. If proper current with respect to the test voltage is established for a specific test lamp, the current control of the lamp is recommended.

It should be noted, however, that since luminous flux is more sensitive to changes in current than to changes in voltage, the permissible tolerance for current control is only half that for voltage control.

The repeatability of successive luminous flux measurements should be within ± 1 percent.

Ageing of lamps shall be one percent of the rated life (or 1 hour if the rated life is shorter than 100 hours) at the rated voltage.

The burning position shall be vertical, cap up unless otherwise specified by the lamp manufacturer.

7.2.1.4 *Operation and handling*

Bare lamps should be operated only in positions allowed by the manufacturer. The ambient temperature should be within the range 25 ± 2°C. During measurements, it should not vary by more than 3°C.

Tungsten halogen lamps should not be moved while hot. After accidental finger contact, even when cold, these lamps must be cleaned carefully with alcohol to eliminate all grease deposits.

7.2.2 *Tubular and Self-Ballasted Lamps (CFLs) (including Amalgam Lamps)*

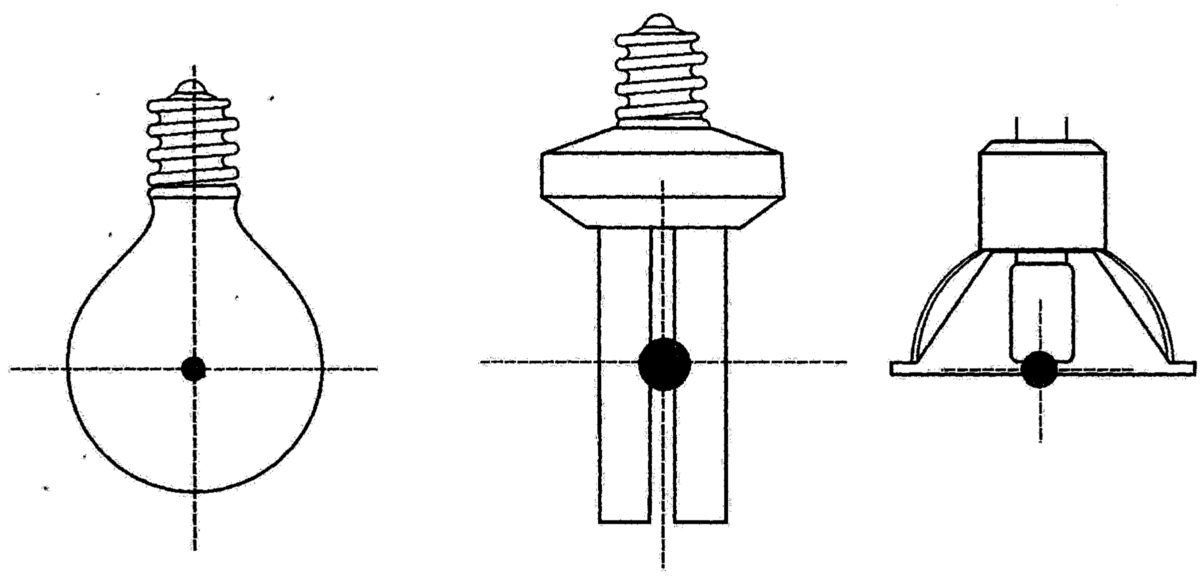


Fig. 4 The Photometric Centre of Incandescent, Compact Fluorescent and Reflector Lamps

7.2.2.1 *Physical characteristics*

The diffusing quality of the lamp should correspond to the average of the production.

The lamps should have no apparent end blackening and in the central plane normal to the axis, the intensity in any direction should not differ by more than 3 percent from the mean intensity.

7.2.2.2 *Electrical characteristics*

The test voltage should be the rated circuit voltage of the luminaire. During measurements the applied voltage should be within ± 0.5 percent of that specified.

7.2.2.3 *Photometric characteristics*

The luminous flux of tubular fluorescent lamps is strongly dependent on ambient air temperature, air movement and lamp position.

Ageing of the lamps shall be for at least 100 hours on a ballast complying with the requirements of the relevant Indian Standards, at rated voltage, with an off period of 10 minutes a minimum of 8 times every 24 hours. The ageing position of the lamp shall be horizontal.

7.2.2.4 *Operation and handling*

Bare lamps should be operated in the burning position as defined by the lamp manufacturer.

The lamps in the luminaire should be operated in the design attitude for the luminaire. Lamp circuit pins and ballast connections should be marked so that the pin and ballast connections remain unchanged throughout the test.

The ambient temperature should be 25 ± 2°C. The air around a lamp should be kept as free as possible from draughts.

Single capped compact fluorescent lamps: Experience shows that during normal handling of the lamps an excess amount of mercury may be distributed in small droplets within the discharge tube. Stabilization of such lamps may require up to 15 hours in order to move the excess mercury to the coldest spot in the tube. Once it has passed through this burn-in period, the lamp will normally need only 15 minutes for reestablishing each time it is relit, provided that it has been kept in the same position and not subjected to shocks and vibration.

For self-ballasted lamps (CFLs), the stabilization may require up to 15 hours.

7.2.3 *High Pressure Mercury Vapour Lamps*

7.2.3.1 *Physical characteristics*

For lamps with a phosphor or diffuse coating, the quality of the lamp bulb should correspond to the average of the production.

7.2.3.2 *Electrical characteristics*

The test voltage should be the rated circuit voltage appropriate to the ballast in use. During measurements the voltage should be within ± 0.2 percent of that specified.

7.2.3.3 *Photometric characteristics*

The luminous flux of high pressure mercury vapour lamps is dependent on the lamp position. The light distribution of clear bulb lamps can vary with position, as a result of a displacement of the discharge within the arc tube.

Ageing shall be for at least 100 hours on a ballast complying with the relevant Indian Standard, at the rated circuit voltage, with off periods of 30 minutes every 6 hours. The ageing position of the lamp shall be vertical, cap up unless otherwise specified by the manufacturer.

7.2.3.4 *Operation and handling*

Bare lamps will normally be operated in a vertical position, cap up. The lamps in the luminaire should operate in the design attitude for the luminaire. In other operating conditions, measurement correction factors must be introduced.

The ambient temperature should be within the range 25 ± 2°C. During measurement, it should not vary by more than 3°C.

7.2.4 *Metal Halide Lamps*

7.2.4.1 *Physical characteristics*

For lamps with a phosphor coating the quality of the lamp bulb should correspond to the average of the production.

7.2.4.2 *Electrical characteristics*

The test voltage should be the rated circuit voltage appropriate to the ballast in use. During measurements the voltage should be within ± 0.2 percent of that specified.

7.2.4.3 *Photometric characteristics*

The luminous flux and colour properties of metal halide lamps are strongly dependent on the operating position, the immediate prior history of operation and the geometry, that is, the shape and dimensions of the lamp.

The ageing period shall be for 100 hours at the rated circuit voltage, with off periods of 30 minutes every 6 hours in the position to be used for the test on a ballast complying with the relevant Indian Standards if any, or complying with the manufacturer's specifications.

If lamps are required for more than one burning position, a different lamp should be prepared for each burning position.

If a lamp is used in a burning position other than the one in which it was aged, a reorientation burn-in period is required until stable output is again achieved.

7.2.4.4 *Operation and handling*

The bare lamps should only be operated in a position in which they were burnt-in. The lamps in the luminaire should normally be operated in the design attitude for the luminaire. This may require the ageing of a different lamp for each of the different burning positions involved.

The ambient temperature should be within the range 25 ± 2°C. During measurement, it should not vary by more than 3°C.

This type of lamp should not be moved while hot as this can affect the distribution of metal in the lamp and so change its characteristics. After switch-off the lamp must cool down for at least 5 minutes.

Lamps should be stored in a position in which they will be operated. Lamps should be marked on the cap to indicate the operating position.

7.2.5 *Low Pressure Sodium Vapour Lamps*

7.2.5.1 *Physical characteristics*

Low pressure sodium lamps should have an even distribution of sodium globules.

7.2.5.2 *Electrical characteristics*

The test voltage should be the rated circuit voltage appropriate to the ballast in use. During measurements the voltage should be within 0.2 percent of that specified.

7.2.5.3 *Photometric characteristics*

The ageing period shall be for at least 100 hours on a ballast complying with the relevant Indian Standard if any, at the rated voltage, with off periods of 30 minutes every 6 hours.

The ageing position of the lamp shall be horizontal, axes of the U-tube usually in a vertical plane.

7.2.5.4 *Operation and handling*

Bare lamps should be operated in a horizontal position. The lamp in the luminaire should be operated in the design attitude for the luminaire.

The movement of sodium limits the permitted orientation of the lamps in operation. Lamps with no sodium retaining facilities are limited to horizontal burning within 5° cap down and 15° cap up.

Other lamps can be operated within 20° of the horizontal unless otherwise specified by the manufacturer.

The ambient temperature should be within the range 25 ± 2°C. During measurement, it should not vary by more than 3°C.

Special care is needed in handling low pressure sodium lamps. They should not be moved while hot as this can affect the distribution of metal in the lamps and so change their characteristics. They should still be handled gently, even when cold.

7.2.6 *High Pressure Sodium Vapour Lamps*

7.2.6.1 *Physical characteristics*

For lamps with a diffuse coating of the bulb the diffusing quality of the lamp bulb should correspond to the average of the production. For lamps with a clear bulb, the axis of the discharge tube should not deviate by more than 3° from that of the cap.

7.2.6.2 *Electrical characteristics*

The test voltage should be the rated circuit voltage appropriate to the ballast in use. During measurements the voltage should be within ± 0.2 percent of that specified. Lamp voltage should comply with the requirements of the relevant Indian Standards if any.

7.2.6.3 *Photometric characteristics*

Ambient temperature affects lamp operation to a small extent, but more serious effects may occur in an enclosed luminaire due to infrared reflections. Measurements on lamps in the luminaires should only be carried out after arc voltage stabilization.

The ageing period shall be at least 100 hours on a ballast complying with the relevant Indian Standards, if any, or with the specifications of the lamp manufacturer, at rated circuit voltage with off periods of 30 minutes every 6 hours. The ageing position of the lamp shall be horizontal.

7.2.6.4 *Operation and handling*

Bare lamps should normally be operated in a horizontal position. The lamp in the luminaire should be operated in the design attitude for the luminaire.

The ambient temperature should be within the range 25 ± 2°C. During measurement, it should not vary by more than 3°C.

7.3 Test Ballast

The test ballast for the luminaire test should be the ballast incorporated in the luminaire or supplied with it for external operation. The ballast should comply with the electrical requirements of the relevant Indian Standards if any, or with the specification of the lamp manufacturer. The ballast setting (lamp power delivered under reference conditions) should be within ± 5 percent of the corresponding reference ballast and should be representative of the production ballast in setting and in power loss. If the ballast setting is outside these limits, then a ballast lumen factor should be introduced.

NOTE — For the measurement of light output ratio working (LORW) the ballast for the bare lamp measurement should be a reference ballast. The electrical characteristics of reference ballasts are given in the relevant Indian Standards if any.

7.4 Luminaires for Test

7.4.1 *Selection and Handling of the Luminaire*

The luminaire selected should be representative of the manufacturer's regular product. Its dimensions should be checked for compliance with the manufacturer's data.

Attention should be paid to all features which may affect photometric performance. Optical parts should be clean, and all components rigidly located in their designed positions. Adjustable lampholders should be correctly set according to the manufacturer's instructions.

The luminaire should be mounted according to the manufacturer's instructions so that its alignment is mechanically true. If specific instructions are not provided, then the plane containing the lower edge of the luminaire canopy (or the plane containing the reflector opening if this is lower) should be taken as one reference and the longitudinal axis, determined from the outer edges of the luminaire when viewed in plan, should be taken as the second reference.

7.4.2 *Photometric Center of the Luminaire*

The position of the photometric centre of a luminaire should be determined in accordance with the following (*see* fig. 5).

a) Luminaires with substantially opaque sides shall be at the centre of the main luminaire opening.
b) Luminaires with diffusing or prismatic sides shall be at the centre of the solid figure bounded in outline by the luminous surfaces, but at the light centre of the lamp if it is outside this solid figure.
c) Luminaires with transparent sides or without side members shall be at the light centre of the lamp.

For special types of luminaires, however, other criteria may be specified.

8 PHOTOMETRIC METHODS AND PRACTICAL TEST PROCEDURES

8.1 General

8.1.1 *Absolute Measurements*

Absolute measurements involve measurements by instruments calibrated in the appropriate SI units. The goniophotometer itself must, therefore be calibrated. In the case of a measurement of luminous intensity distribution this can be done either by using a calibrated luminous intensity standard lamp or by using a previously calibrated photometer head to measure illuminance and converting it to intensity using the photometric distance law.

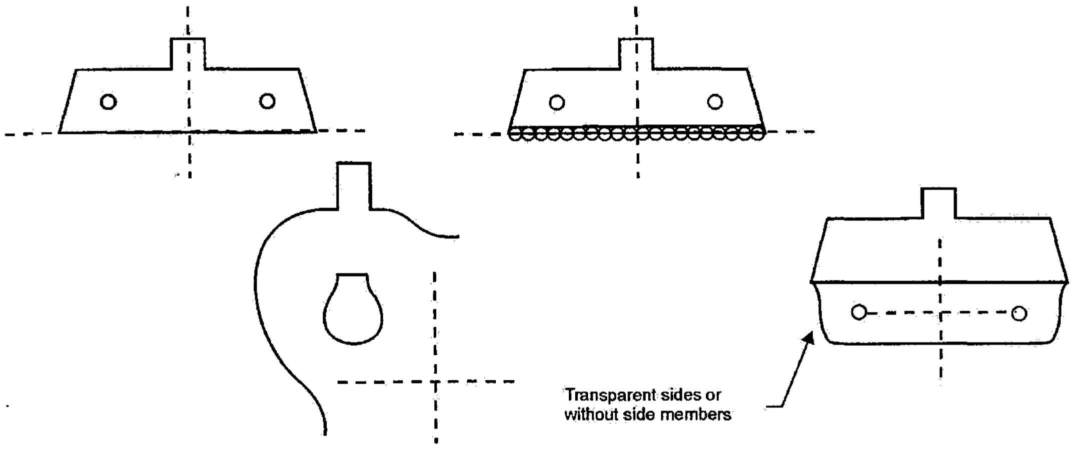
8.1.2 *Relative Measurements*

Absolute photometric measurements on luminaires are often unnecessary. Luminaire output is often specified relative to that of the lamp, both being measured in arbitrary units on the same goniophotometer with the lamp operated on the luminaire ballast, if any.

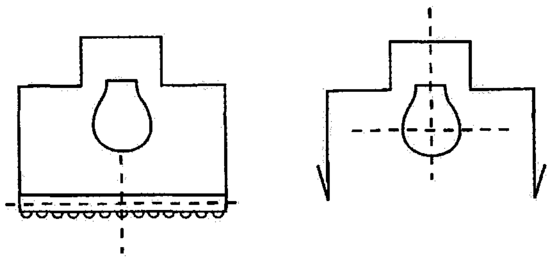
The results of the measurements can then be expressed per 1 000 lm of lamp flux.

This method of expressing results as ratios allows all photometric measurements from which they are derived

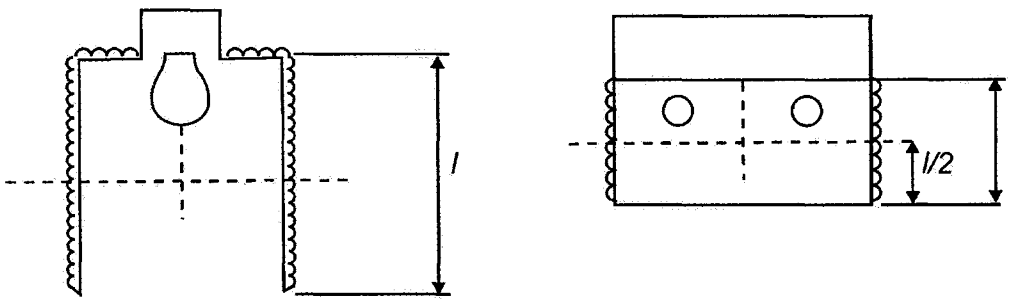
Luminaires with opaque sides, lamp compartment substantially white



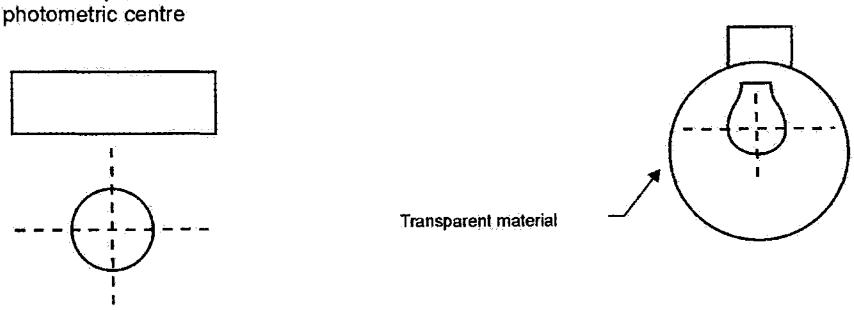
Luminaires with opaque side,
lamp compartment substantially black



Luminaires with diffusing/prismatic sides



Luminaires with transparent sides or without side members:
all at lamp photometric centre



to be made in arbitrary units. Provided that the same measuring instrument is used to measure the output of both the luminaire and the bare lamp, the scale factor of the instrument will cancel out, as will many of the measuring errors.

8.2 Photometric Measurements on Luminaires

8.2.1 *Principal Photometric Measurements*

8.2.1.1 *Light output ratio (LOR)*

This requires measurements of the luminous flux of the luminaire and of the bare lamp and may be determined in a photometric integrator or may be derived from measurements of intensity distribution made on a goniophotometer.

8.2.1.2 *Intensity distribution (relative)*

Measurement shall be on a goniophotometer and does not require measurement of the bare lamp.

8.2.1.3 *Intensity distribution (in cd)*

This shall be as given in **8.2.1.2**, but requires a calibrated goniophotometer. Results are expressed in candelas.

8.2.1.4 *Intensity distribution (in cd per 1 000 lm of lamp flux)*

This shall be measured on a goniophotometer (not necessarily calibrated), but also requires measurement of the bare lamp(s).

8.2.1.5 *Luminaire luminance (in cd per meter square or cd per meter square per 1 000 lm of lamp flux)*

Luminance may be measured or may be calculated from intensity and projected luminous area in the specified direction.

8.2.1.6 *Illuminance distribution (in lx or lx per 1 000 lm of lamp flux)*

The measurement of illuminance distribution is taken on a plane or a series of planes.

8.2.2 *Subsidiary Measurements*

8.2.2.1 *Measurement correction factors*

Factors for correcting measurements made in non-standard conditions in order to relate the measurements to the standard test conditions.

8.2.2.2 *Service correction factors*

Factors for modifying standard data to non-standard service conditions.

8.2.2.3 *Ballast lumen factor*

This factor is usually required to take into account the influence of the specific ballasts supplied with luminaires. It may be determined with any of the apparatus used for the principal photometric measurements.

8.3 Derived Values

Other photometric characteristics of luminaires may be derived from the principal and subsidiary measurements. In particular, zonal flux values may be derived from either absolute or relative intensity distributions.

Isocandela data or isolux data in standard configurations are derived values which are also widely used.

9 GENERAL MEASUREMENT REQUIREMENTS

Luminaires and lamps should be photometered under the standard measurement conditions. Measurements should not begin until the luminaire or lamp has stabilized photometrically. The measuring instruments should also have stabilized before use. Check measurements (for example, of intensity) should be made at regular intervals (for example, every 5 minutes). The criterion for photometric stabilization is that the change of intensity over a 15 minute period is less than 1 percent.

Before readings are taken, checks should be made for stray light and the zero reading checked with the photometer head covered. During a measurement and for any preceding period that may affect results, supply voltage and ambient temperature should be closely controlled. If reactive circuits are being operated on an ac supply, a check should also be made of the supply frequency. During an extended measurement (for example, with a goniophotometer), regular checks should be made that stabilization is maintained.

At the end of the measurements (and regularly during a long series of measurements) a return should be made to the initial position to check that the initial photometric reading is maintained within ± 1 percent. This kind of check is extremely important.

10 LUMINOUS INTENSITY DISTRIBUTION MEASUREMENTS

In the photometry of luminaires, a goniophotometer is principally used to measure the intensity of a luminaire in selected directions. The measurements may be used to derive photometric characteristics or may be transformed for publication in graphical form, such as polar curves. Curves may be relative (that is, scaled in arbitrary units) or may be expressed in cd per 1 000 lm of lamp flux.

A goniophotometer may also be used to measure the light output ratio of a luminaire. This requires measurement of both the bare lamp and the luminaire in the same units.

A goniophotometer may also be used to determine photometric correction factors and to measure luminaire luminance.

11 CONSTRUCTION

In the design of a goniophotometer, the principal objectives are to achieve an adequate optical path length in the space available and to maintain luminaires in their designed attitudes.

A goniophotometer should be capable of supporting the luminaire rigidly and the largest luminaire that the goniophotometer is designed to measure should be completely visible from every point of the sensitive surface of the photometer head at all directions of measurements. In many goniophotometers, part of the luminaire support structure may cause obstruction to the light path. This obstruction should be minimized.

The construction must provide an accurate angular measurement of the luminaire position relative to the photometer head. The measured position should be correct within ± 0.5 percent. More severe requirements may apply depending on the light intensity distribution of the luminaires for example, for floodlights. Any mirror used in the construction of the goniophotometer should be rigidly supported and remain flat in all normal positions of rotation.

12 SCREENING AGAINST STRAY LIGHT

Stray light is any light that reaches the photometer head other than directly from the source to be measured, due to reflections or to the presence of other light sources. The following steps should be taken to keep it to a minimum.

The photometer head should be screened so that as far as possible it sees only the luminaire and, where appropriate, the lower surface of the mounting board. Where a mirror is used, the photometer head should be screened so that it can see only the image of the luminaire and does not receive light directly from any part of the luminaire itself.

All surfaces that the photometer head sees should be finished matt black, including the bevelled edges of mirrors. It should be noted that many so-called matt black paints have a luminance factor, which can be as high as 4 percent near the normal to the surface and even higher at glancing angles of incidence. Screens should be arranged so that stray light from the luminaire can reach the photometer head only after two or more reflections. Where this is not possible, surfaces should be covered with black velvet, black carpet, etc. Any surface such as the edges of screens, which are parallel with the photometer head and luminaire axis, should be grooved, angled or chamfered to a sharp edge to minimize reflections onto the photometer head.

All that part of the background to the luminaire, which might be viewed by the photometer head, should be matt black. This includes the floor and the ceiling. The remainder of the room can be of a lighter colour, provided that precautions have been taken to eliminate the stray light.

Stray light that cannot be eliminated should be subtracted from the readings taking into account the variation of stray light with the luminaire position.

13 TEST DISTANCE (FOR MEASUREMENTS BASED ON THE PHOTOMETRIC DISTANCE LAW)

The photometric test distance is the distance from the photometric center of the luminaire to the surface of the photometer head.

Measurements of intensity should be made at a distance such that the inverse square law applies within practical limits. In general, the test distance should not be less than 15 times the maximum dimension of the light emitting area of the luminaire. However, for luminaires with an approximately cosine distribution in planes passing through the long axis of the luminaire, the minimum test distance can be determined as 15 times the dimension of the light emitting area normal to the lamp axis or 5 times the dimension of the light emitting area parallel to the lamp axis. The minimum test distance to be used should be the greater of these two distances.

It should be noted that in certain cases, for example, luminaires with a very narrow beam, even a test distance ratio of fifteen might not be sufficient.

14 MEASUREMENT OF LUMINAIRES

14.1 Mounting

The luminaire should be mounted on the goniophotometer in its design attitude. Its photometric centre should be coincident with the effective centre of rotation of the goniophotometer. Its orientation should be correct with respect to the azimuth scale of the goniophotometer and to the azimuth reference of the luminaire.

14.2 Measurement

Unless otherwise specified, the C, Gamma co-ordinate system (*see* **4.4** and Fig. 3) shall apply. The number of readings of intensity in various vertical planes and the angular spacing between measurement points should be such as to permit interpolating intensity values during light calculations with an acceptable accuracy. The number of planes should be determined by the nature of the distribution having regard to symmetry or irregularity and to the end results desired from the test, notably the required accuracy of subsequent lighting calculations.

The luminaire should move smoothly, without rocking, and, in the case of luminaires using thermally sensitive lamps, sufficiently slowly to minimize disturbance to the thermal equilibrium of the luminaire. The velocity of the ambient air of the rotating fluorescent lamps in an open luminaire should not exceed 0.2 m/s.

Light output characteristics of lamps, in particular discharge lamps, may change significantly when the lamps are operated in other than normal operating position. Measurement correction factors should be applied.

Due to minor variations in optical components, luminaires designed to provide symmetrical distribution should always be measured in the two half-planes of symmetry.

15 MEASUREMENT OF BARE LAMPS

15.1 Mounting

The bare lamp should be mounted in the orientation for which it was designed and to which the lamp photometric data relate.

Lamps of the type designed for universal mounting can be mounted in any position provided that the lamp photometric data available relates to the position chosen, which should, preferably, be the same position as the operating position in the luminaire. In such cases the orientation of the lamp during measurement should be specified in the test report.

The light centre (photometric centre) of the lamp should be at the effective centre of rotation of the goniophotometer.

The lamp should be correctly aligned. Some lamps, for example, lamps fitted with bayonet caps, may require a modified lampholder to provide a sufficiently rigid support.

15.2 Intensity Measurement

Intensity measurements of bare lamps are made to calibrate the photometer head or to calculate the luminous flux of the bare lamp.

Intensity measurements of the bare lamp should preferably be made just prior to, or immediately after those measurements of the luminaire. Measurements of intensity should be made in the same units as for those of the luminaire.

16 MULTILAMP LUMINAIRES

In case of a multilamp luminaire, it will be necessary to repeat the measurement for each lamp separately (where relevant, each on its appropriate ballast). All lamps that operate from a single ballast should be operating during measurement in the same ambient temperature conditions.

17 SOURCES OF ERROR

There can be two types of error; error arising from a systemic effect and random error. Systemic errors are inherent in the test methods used or caused by imperfection in the instruments. Random errors are due to variations in test conditions outside the photometrist's control. It is the random errors, which affect repeatability.

Repeatability and thus the effect of random errors can be checked by simply repeating measurements on the same luminaire. Systemic errors, on the other hand are much less easily quantified. If they could be quantified, they would be eliminated, since the results would be corrected for them. The only kind of check available on systemic errors is likely to be a comparison with similar measurements made on the same luminaire elsewhere.

17.1 Possible Systemic Errors

17.1.1 Possible systemic errors may be due to any one or more of the following reasons:

a) Room:
   i) Measurement of temperature;
   ii) Stray light; and
   iii) Obstruction of light.
b) Goniophotometer:
   i) Mechanical alignment and mechanical deformation;
   ii) Stray light and obstruction of light;
   iii) Measurement of angles;
   iv) Burning position of luminaire and movement;
   v) Mirror defects; general nonflatness (for example, due to sag), local nonflatness (for example, due to ripples in the glass), light scattering due to scratches, variation of reflectance with wavelength, variation of reflectance over the surface, polarization; and
   vi) Variation of reflection properties of mirror due to dust.
c) Photometer head and associated equipment:
   i) Calibration;
   ii) Nonlinearity and fatigue;
   iii) Spectral responsibility;
   iv) Variation of responsibility over the measuring surface;
   v) Angular aperture of collimated photometer heads;
   vi) Misalignment and measurement of distance;
   vii) Distance too short;
   viii) Time response and integration time; and
   ix) Vignetting.

d) Luminaire:

   i) Incorrect positioning of lamp;

   ii) Incorrect positioning of optical components;

   iii) Choice of photometric centre;

   iv) Misalignment of the luminaire in the goniophotometer; and

   v) Mechanical deformation of the luminaire during movement.

e) Lamp and auxiliary apparatus:

   i) Electrical setting of the ballast;

   ii) Luminous flux measurement; and

   iii) Incorrect supply voltage.

17.2 Possible Random Errors

Possible random errors may be due to any one or more of the following reasons:

a) Variation of voltage or frequency of power supply;

b) Instability of lamp;

c) Variation of lamp characteristics between different burning periods;

d) Temperature variation and air movement due to movement of the luminaire; and

e) Effect of draughts due to air conditioning.

18 UNCERTAINTY IN MEASUREMENT

Uncertainty in measurement, which can be evaluated by the statistical analysis of a series of observations, is known as type A uncertainty. Uncertainty in measurement that cannot be evaluated in this way is known as type B uncertainty.

19 PRESENTATION OF TEST RESULT

The test report should provide all the useful information necessary to permit proper interpretation of photometric data and consequent lighting calculations.

The purpose of the information provided should be:

a) To correctly inform the user of the data as to the nature of the various controlled conditions under which the luminaire was measured.

b) To give sufficient information to relate the photometric data to the particular luminaire tested.

20 TEST REPORT

Listed below, as a guide is the information which should be included in a test report covering photometric measurements of a luminaire.

a) General information

b) Type of test:

   i) Descriptive title to indicate what is being reported; and

   ii) Testing agency name, report number and date.

c) Description of the luminaire:

   i) Manufacturer's name, type, catalogue number;

   ii) Photograph for identification or detailed description of the luminaire including a description of the optical components such as refractors, reflectors, etc, especially if the luminaire is available in several versions;

   iii) Relevant dimensions; and

   iv) Other essential information, including the method of sample selection.

d) Description of auxiliary equipment (ballast, capacitors, starters, etc):

   i) Manufacturer's name, type, catalogue number;

   ii) Type of circuit; and

   iii) Rated voltage, wattage and frequency.

e) Description of test lamps:

   i) Manufacturer's name, type, catalogue number;

   ii) Rated wattage, colour, and bulb shape, type of lamp cap; and

   iii) Number of lamps and how selected.

f) Test procedure:

   i) Short description of the photometric procedure and equipment used; and

   ii) Test distance.

g) Test conditions:

   i) Reference to standard conditions of relevant Indian Standards, if any, or to specific service conditions: any relevant measurement correction factors should be applied before reporting;

   ii) Alignment of lamp (discharge tube or filament for lamps with clear bulbs) in the luminaire;

   iii) Attitude of mounted luminaire, angle of tilt for measurement;

   iv) Reference centre of the luminaire for the measurements and relative position of the luminaire to the coordinate system;

v) Test voltage and frequency;

vi) Uncertainities; and

h) Photometric Data

The photometric data provided in the test report relates to a particular luminaire, but its purpose is to provide the basis for further calculations, for example, for the design of practical lighting installations. The information may include luminous flux values for the bare lamp(s), light output ratios, light intensity distributions, luminance figures, etc.

NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 1 Industrial Lighting

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

The purpose of industrial lighting is to provide energy efficient illumination and to enhance visibility and productivity within a pleasant and safe environment.

Industry encompasses seeing tasks, operating conditions and economic considerations of a wide range. Visual tasks may be extremely small or very large; dark or light; opaque, transparent or translucent; on specular or diffuse surfaces and may involve flat or contoured shapes. Lighting must be suitable for adequate visibility in developing raw materials into finished products. Physical hazards exist in manufacturing processes and therefore, lighting contributes to the safety factor in preventing accidents. The speed of operations may be such as to allow only minimum time for visual perception and, therefore, lighting must be a compensating factor to increase the speed of seeing.

The design of a lighting system and selection of equipment may be influenced by many economic and energy related factors. Economic decisions in regard to the lighting system should not only be based on the initial and operating costs of the lighting, but also on the relationship of lighting costs to other plant facilities and costs of labour. The lighting system should be a part of an overall planned environment.

Taking into consideration the increasing industrial activities in India, a large number of people have to work on tasks and processes of increasing intricacy and detail with working hours extending into the night, there is a need for well planned and efficient industrial lighting which could create easier seeing conditions and an agreeable atmosphere.

The following Indian Standards are necessary adjuncts to this section.

IS No.	*Title*
2440:1975	Guide for daylighting of buildings (Second Revision)
3646(Part 1):1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for working interiors (First Revision)
3646(Part 2):1966	Code of practice for interior illumination: Part 2 Schedule for values of illumination and glare index.
5572:1994	Classification of hazardous areas (other than mines) having flammable gases and vapours for electrical installations (Second Revision)
6060:1971	Code of practice for daylighting of factory building
10322(Part 1):1982	Luminaires: Part 1 General requirements

NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 1 Industrial Lighting

1 SCOPE

This section of the code covers the principles and practice governing good lighting for various industrial premises. It recommends the levels of illumination and quality requirements to be achieved by the general principles of lighting.

2 TERMINOLOGY

For the purpose of this section the definitions given in Part 1 of this code and those given in IS 1885(Part 16/ Sec 1) shall apply.

3 FACTORS OF GOOD INDUSTRIAL LIGHTNG

3.1 Good industrial lighting should take into account:

a) adequate quantity of illumination; and
b) good quality of illumination.

3.1.1 *Quantity of Illumination*

The desirable quantity of light (illuminance) for an installation depends primarily upon the seeing task, and the importance of speed and accuracy in performing the task.

Illuminance recommendations for industrial tasks are given in Table 2. In addition, in several instances industry representatives have established tables of single illuminance values which, in their opinion, can be used in preference to employing Table 2. However, illuminance values for specific operations can also be determined using illuminance categories of similar tasks and activities found in Table 2 and the application of the appropriate weighting factors. In either case, the values given are considered to be target maintained illuminance.

3.1.1.1 To ensure that a given illuminance will be maintained, it is necessary to design a system to initially give more light than the target value. In locations where dirt will collect very rapidly on luminaire surfaces and where adequate maintenance is not provided, the initial value should be even higher.

Where tasks require workers to wear protective devices with tinted lenses that reduce the light reaching the eye, the illuminance for individual tasks should be increased accordingly.

3.1.1.2 The utilization goal of a lighting system is to provide for optimal performance of a given task. The starting point will be the determination of the relationship between illumination and performance, but the final recommendation has to take into consideration other factors such as avoidance of fatigue, physiological and psychological effects, economics, etc. Desirable criteria for determining the quantity of illumination are:

a) adequacy for preventing occupational eye strain and the risk of accidental injury due to bad visibility;
b) adequacy for creating an agreeable luminous environment; and
c) adequacy for different satisfactory levels of visual performance, each standard being applicable to a particular range of visual tasks.

3.1.1.3 A general lighting system should be designed to provide a uniform distribution of light over the entire work area. Where work areas are close to walls, such as work benches, the first row of luminaires should be located closer to the wall or additional lighting should be provided over the particular work space to compensate for loss or absorption of light due to the wall reflectance.

3.1.1.4 While designing lighting requirements higher initial values shall be provided to compensate for the absorption of the light.

3.1.2 *Quality of Illumination*

3.1.2.1 Quality of illumination pertains to the distribution of luminance in the visual environment. The term is used in a positive sense and implies that all luminances contribute favourably to visual performance, visual comfort, ease of seeing, safety and aesthetics for the specific visual task involved. Glare, diffusion, direction, uniformity, colour, luminance and luminance ratios all have a significant effect on visibility and the ability to see easily, accurately and quickly. Certain seeing tasks, such as discernment of fine details, require much more careful analysis and higher quality illumination than others. Areas where the seeing tasks are severe and performed over long periods of time require much higher quality than where seeing tasks are casual or of relatively short duration.

Industrial installations of very poor quality are easily recognized as uncomfortable and are possibly hazardous. Unfortunately, moderate deficiencies are not readily detected, although the cumulative effect of even slightly glaring conditions can result in material loss of seeing efficiency and undue fatigue.

3.1.2.2 *Direct glare*

To reduce direct glare in industrial areas, the following steps should be taken:

a) Decrease the luminance of light sources or luminaires or both;

b) Reduce the area of high luminance causing the glare condition;

c) Increase the angle between the glare source and the line of vision; and

d) Increase the luminance of the area surrounding the glare source and against which it is seen.

There is such a wide divergence of tasks and environmental conditions in industry that it may not be economically feasible to recommend a degree of quality which will satisfy all cases. The luminance control required depends on the task, length of time in which the task is performed, and the mounting height of the luminaires. In production areas, luminaires within the normal field of view should be shielded to at least 25 degrees from the horizontal, preferably to 45 degrees.

When glare is caused by the source of lighting within the field of view, whether daylight or electric, it is described as direct glare. Recommended maximum luminance ratios are given in the following table:

Environmental Classification	*A*	*B*	*C*
Between tasks and adjacent darker surroundings	3 to 1	3 to 1	5 to 1
Between tasks and adjacent lighter surroundings	1 to 3	1 to 3	1 to 5
Between tasks and more remote darker surfaces	–	10 to 1	20 to 1
Between tasks and more remote lighter surfaces	–	1 to 10	1 to 20
Between luminaires (or windows, skylights, etc) and surfaces adjacent to them	20 to 1	–	–
Anywhere within normal field of view	40 to 1	–	–

Classifications are:

A — Interior areas where reflectance of the entire space can be controlled in line with recommendations for optimum seeing conditions;

B — Areas where reflectance of the immediate work area can be controlled but control of the remote surrounding is limited; and

C — Areas (indoor and outdoor) where it is completely impractical to control reflectance and difficult to alter environmental conditions.

Luminance ratio control is possible through increasing the areas of high luminance of light sources and/or luminaires, the angle between the source of glare and the line of vision, and the luminance of the area surrounding the source of glare against which it is seen.

Unshaded factory windows are frequent causes of direct glare. They may permit direct view of the sun, bright portions of the sky or bright adjacent buildings. These often constitute large areas of very high luminance in the normal field of view.

Luminaires that are too bright for their environment will produce glare; discomfort glare or disability glare, or both. The former produces visual discomfort without necessarily interfering with visual performance or visibility. Disability glare reduces both visibility and visual performance and is often accompanied by visual discomfort. To reduce direct glare, luminaires should be mounted as far as possible above the normal line of sight. They should be designed to limit both the luminance and the quantity of light emitted in the 45 to 85 degree zone because such light, likely to be well within the field of view, may interfere with vision. This precaution includes the use of supplementary lighting equipment.

3.1.2.3 *Luminance and luminance ratios*

a) *Ratios*

The ability to see detail depends upon the contrast between the detail and its background. The greater the contrast, that is, difference in luminance, the more readily the seeing task is performed. However, the eyes function most comfortably and more efficiently when the luminances within the remainder of the environment are relatively uniform. Therefore, all luminances in the field of view should be carefully controlled. The recommended procedure for planning brightness pattern and controlling glare is detailed in IS 3646(Part 1) and IS 3646(Part 2);

b) To achieve the recommended luminance relationships, it is necessary to select the reflectances of all finishes of the room surfaces and equipment as well as control the luminance distribution. The recommended reflectance values for industrial interiors and equipment are given in Table 1. Reflectance should be maintained as near as practical to recommended values;

Table 1 Reflectance Values
[*Clause* 3.1.2.3 a)]

Surfaces	Reflectance percent
Ceiling	80 to 90
Walls	40 to 60
Desks and bench tops, machines and equipment	25 to 45
Floors	Not less than 20

c) High reflectance surfaces are generally desirable to provide the recommended luminance relationships and high utilization of light. They also improve the appearance of the work space. It is also desirable that the background is slightly darker than the seeing task.

It is necessary to select the reflectance of all the finishes of the room surfaces and equipment as well as control the luminance distribution of the lighting equipment.

In many industries machines are painted such that they present a completely harmonious environment from the standpoint of colour. It appears desirable to paint stationary and moving parts of machines with contrasting colours to reduce accident hazard by aiding identification; and

d) *Reflected Glare*

Reflected glare is caused by the reflection of high luminance light sources from shiny surfaces. In manufacturing processes this may be a particularly serious problem where critical seeing is involved with highly polished surfaces such as polished sheet metal, vernier scales, and critically machined metal surfaces.

Reflected glare can be minimized or eliminated by using light sources of low luminance or by orienting the work so that reflections are not directed in the normal line of vision. Supplementary lighting is a solution to such problems. Often it is desirable to use reflections from a large-area, low-luminance luminaire located over the work. In special cases it may be practical to reduce the specular reflection (and the resultant reflected glare) by changing the specular character of the offending surface.

3.1.2.4 *Distribution, diffusion and shadows*

Uniform horizontal illuminance (where the maximum and minimum level is not more than one sixth above or below the average level of the area) is frequently appropriate for specific industrial interiors where tasks are closely spaced and where there are similar tasks requiring the same amount of light. In such instances, uniformity permits flexibility of functions and equipment and assures more uniform luminances. Alternate areas of extreme luminance differences are undesirable because it tires the eyes to adjust to them.

Maintaining uniformity between contiguous areas which have significantly different visibility (and illumination) requirements might be wasteful of energy; for example, a storage area adjacent to a machine shop. In such instances, it is prudent to design and apply non uniform lighting between those areas. It may be accomplished by using luminaires of different wattage and/or by adjusting the number of luminaires per unit area. Local lighting restricted to a small work area is unsatisfactory unless there is sufficient general illumination.

Harsh shadows should be avoided, but some shadow effect may be desirable to accentuate the depth and form of objects. There are a few specific visual tasks where clearly defined shadows improve visibility and such effects should be provided by supplementary lighting equipment arranged for the particular task.

3.1.2.5 *Colour quality of light*

For general seeing tasks in industrial areas, there appears to be no effect upon visual acuity by variations in colour of light. However, where colour discrimination and colour matching are a part of the work process, the light source selected should have the desired colour rendering properties.

Colour, of course, has an effect upon the appearance of the work space and upon the complexions of personnel. Therefore, the selection of the lighting system and the decorative scheme should be carefully coordinated.

3.1.2.6 *Veiling reflections*

Where seeing task details are specular, care should be taken to minimize veiling reflections which will decrease task visibility.

3.1.2.7 *Brightness consideration*

The eye adapts itself to the prevailing brightness of the surroundings. The apparent brightness of the various surfaces or objects will depend on this adaptation level. For instance, when a room interior is seen through an open door from outside with bright daylight, it will appear gloomy. But on entering the room, after the eye has adapted, things will appear brighter. When a room is lit by daylight the eye has a fairly high adaptation level due to the bright sky seen through the window opening. Therefore, the parts of the room remote from the windows will appear gloomy even if the illumination in these parts is of the order normally recommended for this type of visual task. It is, therefore, necessary to brighten up these parts if a proper balance of brightness is to be restored which will create a comfortable visual environment. This second consideration is at least as important as the first while determining the amount of light to be supplied by the supplementary lighting system. This requirement in some cases may result in having higher levels of illumination than required for the particular visual task involved.

During the night time since the entire area is illuminated to a level recommended for the satisfactory performance of the task carried out in the work area concerned, no additional problem of balance of brightness is involved, provided the general requirement of avoidance of high brightness contrast by having suitably finished surfaces in the room is satisfied.

4 GENERAL CONSIDERATIONS OF DESIGN FOR LIGHTING INDUSTRIAL AREAS

4.1 The designer of an industrial lighting system should consider the following factors as the first and all important requirements of good planning:

a) Determine the quantity and quality of illumination desirable for the manufacturing processes involved;

b) Select lighting equipment that will provide the quantity and quality requirements by examining photometric characteristics, and mechanical performance that will meet installation, operating and actual maintenance conditions;

c) Select and arrange equipment so that it will be easy and practical to maintain; and

d) Balance all of the energy management considerations and economic factors including initial, operating and maintenance costs, versus the quantity and quality requirements for optimum visual performance. The choice of the electric distribution system may affect overall economics.

4.2 Light Sources in Industrial Lighting

4.2.1 For industrial lighting the sources of light generally available in the country at present are tubular fluorescent lamps, high pressure mercury vapour (HPMV) lamps, high pressure sodium vapour (HPSV) lamps and metal halide lamps. The selection of any one of these or a combination of these depends on:

a) Type of application;

b) Atmospheric conditions of industrial interiors and/or exteriors;

c) Structural features;

d) Initial outlay;

e) Running cost; and

f) Ease of maintenance.

4.2.2 Apart from these, the following factors such as luminous efficacy, lamp luminance, lamp life, lumen depreciation, colour temperature, colour rendering properties and ease of optical control, play a very vital role in the choice of light sources. All these aspects should be carefully considered while designing an industrial lighting scheme.

4.2.3 It may also be added here as a broad guideline that for low and medium height ceilings in industry, tubular fluorescent lamps are used for general uniform lighting whereas for high bays it is desired from lighting technique, economic and maintenance considerations to use HPMV or HPSV lamps or a combination of HPMV, HPSV and metal halide lamps. Application of tungsten filament lamps is limited according to modern lighting practice, to local lighting and in certain cases also for colour appreciation and in case of infrequent use for short durations.

4.2.4 In spite of very low initial outlay due to poor efficacy, short life and eventual frequent replacement, tungsten filament lamps are not employed for the general lighting of industries. Tubular fluorescent lamps, HPMV lamps, HPSV lamps and metal halide lamps for general lighting have to be selected after considering the above noted aspects.

4.3 Luminaires for Industrial Lighting

The manner in which the light from the lamps is controlled by the luminaire governs to a large extent the important effects of glare, shadows, distribution and diffusion. Luminaires are classified in accordance with the way in which they control the light.

Most industrial applications call for either the direct or semi-direct types. Luminaires with upward components of light are preferred for most areas because an illuminated ceiling or upper structure reduces luminance ratios between luminaires and the background. The upward light reduces the 'dungeon' effect of totally direct lighting and creates a more comfortable and more cheerful environment. Industrial luminaires for fluorescent, high intensity discharge and incandescent filament lamps are available with upward components. Good environmental luminance relationships can also often be achieved with totally direct lighting if their illuminance and room surface reflectance are high.

In selecting industrial luminaires, it will be noted that other factors leading to more comfortable installations include:

a) Light coloured finishes on the outside of luminaires reducing luminance ratios between the outside of the luminaire and the inner reflecting surface and light source;

b) Higher mounting heights to raise luminaires out of the normal field of view;

c) Better shielding of the light source by deeper reflectors, cross baffles or louvres. This is particularly important with high wattage incandescent filament or high intensity discharge sources and the higher output fluorescent lamps; and

d) Selecting light control material, such as specular or non specular aluminum or prismatic configurated glass or plastic that can limit the luminaire luminance in the shielded zone.

Top openings in luminaires generally minimize dirt collection on the reflector and lamp by allowing an air draft path to move dirt particles upward and through the luminaire to the outer air. Therefore, ventilated types of luminaires have proven their ability to minimize maintenance of fluorescent, high intensity discharge, and incandescent filament types of luminaires. Gasketed dust tight luminaires are also effective in preventing dirt collection on reflector surfaces.

Special attention is required to be paid to the selection of luminaires for industrial interiors with highly corrosive atmosphere or fire and explosion hazards [*see* IS 10322(Part 1)]. Luminaires made of corrosion resistant material specially designed for corrosive atmospheres are to be selected for chemical factories, fertilizer plants and other similar industries where corrosive fumes are present in the atmosphere. For industrial areas containing inflammable dust and gases, the choice of luminaire will be guided by the relevant Indian Standard.

4.4 Luminaires for Direct Lighting

In industrial luminaires for direct lighting, light distributions vary from wide to narrow.

The wide distribution types comprise porcelain enamelled reflectors and various other types of diffuse white reflecting surfaces. Aluminium, mirrored glass, prismatic glass, and other similar materials may also be used to provide a wide distribution when the reflector is designed with the proper contour. This type of light distribution is advantageous in industrial applications where a large proportion of the seeing tasks are vertical or nearly vertical.

Narrow distributions are obtained with prismatic glass, mirrored glass and aluminium reflectors. This type of light distribution is useful where the mounting height is approximately equal to or greater than the width of the room or where high machinery and processing equipment necessitate directional control for efficient illumination between the different equipment.

In making a choice between luminaires with wide and narrow distributions on the basis of desired horizontal illuminance, a comparison of coefficients of utilization for the actual room conditions involved will serve as a guide in selecting the most effective distribution. Care should be taken to use such coefficients based as closely as practical to actual ceiling, wall and floor reflectances as well as actual room proportions.

If, however, it is desired to determine illuminance at specific points, then a point calculation method should be used to obtain accurate results. This is particularly true for high mounting heights.

4.5 Other Types of Luminaires for Direct Lighting

Where low reflected luminance is a necessity, low luminance luminaires with a large area should be used. Such a luminaire may consist of a diffusing panel on a standard type of fluorescent lamp reflector or an indirect light hood. A completely luminous ceiling can also serve the purpose.

4.6 Luminaires for Semi-Direct Lighting

This classification of distribution is useful in industrial areas because the upward component (10 to 40 percent) is particularly effective in creating more comfortable seeing conditions. Fluorescent and high intensity discharge lamp luminaires designed specifically for industrial application can give this distribution.

While the semi-direct type of distribution has a sufficient upward component to illuminate the ceiling, the downward component of 90 to 60 percent of the output contributes to good illumination efficiency, particularly where ceiling obstructions may minimize the effectiveness of the indirect component.

4.7 Industrial Applications of Other Light Distribution Classifications

There are semi-industrial applications, where a superior quality of diffused, low luminance illumination is required and where environmental conditions make such systems practical. An example of such applications includes the precision industries where a completely controlled environment is important, including lighting, air conditioning and carefully planned decoration.

4.8 Lighting Related to Structure of Industrial Premises

4.8.1 *Lighting of Factory Spaces with Skylights*

Where daylighting is given due consideration in the design of a building, the shape of the building is primarily determined by this requirement. The working area is also planned on the basis of daylighting.

While planning the artificial lighting, the layout of the luminaires has to be related to the layout of the working area to obtain the most comfortable working conditions. The lighting can be integrated with the natural shape and structure of the building while still meeting the requirements of the lighting effect on the working place to achieve a better result. Close coordination between the architect and lighting engineer can result in a lighting installation which is in tune with the architectural form of the building.

4.8.2 *Lighting of Factory Spaces with Closed Ceilings*

In this type of construction there is very little dependence on daylighting. The artificial lighting has to be designed purely on the needs of the nature of work, layout of machinery, etc. Where a false ceiling is provided, the luminaires may be recessed in the false ceiling for better aesthetics.

It is generally desired from the user's point of view that the luminaires should, as far as possible, be fixed to the existing members in the roof structure like the bottom members of the trusses or longitudinal tie members. The luminaires have to be oriented according to the layout of the machinery to obtain the most satisfactory seeing conditions.

A layout decided on such a consideration may not coincide with the existing structural elements and additional members may have to be provided specifically for fixing the luminaires. An interesting development which takes care of this problem economically is the trunking system. The trunking, which is essentially metal channels with cover plates at the bottom, of standard lengths joined together, is run across the hall with suspensions at necessary intervals. Incidentally, this minimizes the number of suspension points compared to individually mounted luminaires each with two suspension pipes. The wiring is run through the trunking itself and the luminaires are attached to the trunking at the required locations.

4.8.3 *Highbay Lighting*

Generally high roofing is provided in the heavy engineering industry, where overhead travelling cranes are provided and/or fumes and smoke have to be evacuated. The artificial lighting has to be located at a greater height in the roof structure to allow unobstructed movement of cranes, etc. While for low and medium mounting height fluorescent lamp lighting is an immediate choice, for highbay lighting it is advantageous to use a smaller number of high lumen output sources like the high wattage high pressure gas discharge lamps.

5 FACTORS FOR SPECIAL CONSIDERATION

5.1 Lighting and Space Conditioning

With the use of higher illuminance, it is often practical to combine the lighting, heating, cooling and atmospheric control requirements in an integrated system. The lighting system can often provide most of the heat energy during winter. When cooling is required, much of the lighting heat can be removed by the air exhaust system.

5.2 High Humidity or Corrosive Atmosphere and Hazardous Location Lighting

Enclosed gasketted luminaires are used in non-hazardous areas where atmospheres contain nonflammable dusts and vapors, or excessive dust. Enclosures protect the interior of the luminaire from conditions prevailing in the area. Steam processing, plating areas, wash and shower rooms, and other areas of unusually high humidity are typical areas that require enclosed luminaires. Severe corrosive conditions necessitate knowledge of the atmospheric content to permit selection of proper material for the luminaire.

Hazardous locations are areas where atmospheres contain inflammable dusts, vapours or gases in explosive concentrations. They are grouped on the basis of their hazardous characteristics, and all electrical equipment must be approved for use in specific classes and groups. Luminaires are available specifically designed to operate in these areas, which are classified as Class I, Class II and Class III locations (*see* IS 5572).

5.3 Abnormal Temperature Conditions

Low ambient temperatures must be recognized as existing in such areas as unheated heavy industrial plants, frozen food plants and cold storage warehouses. Luminaire equipment should be selected to operate under such conditions and particular attention should be given to lamp starting and light output characteristics if fluorescent lamps are considered. With high intensity gas discharge lamps, temperature variation has practically no effect on light output, but the proper starting characteristics are a must. With incandescent filament lamp equipment, neither the starting nor the operation is a problem at low temperature.

Abnormally high temperatures may be common at truss height in foundries, steel mills, forge shops, etc. Caution should be observed in selecting luminaires for mounting in such locations. It is particularly important to consider the temperature limitations of fluorescent and high intensity gas discharge lamp ballasts under such conditions. Often ballasts should be remotely located at a lower and cooler level or special luminaires suitable for high temperatures should be used. The reduction in fluorescent lamp lumen output at high operating temperatures should be kept in mind.

5.4 Maintenance

Regular cleaning and prompt replacement of lamp outages is essential in any well operated industrial lighting system.

It is important for the lighting designer to analyze luminaire construction and reflector finish and also to make provisions for maintenance access so the system can be properly serviced. It may be necessary to do the servicing during the plant operating hours. Further details on maintenance, access methods and servicing suggestions are given in Part 13 of this code.

Special mention should be made of group replacement of the lamps and starters in the case of fluorescent lamp luminaires. The desirability of group replacement is largely determined by lamp replacement costs and should be considered on its merit in each case.

6 SUPPLEMENTARY LIGHTING IN INDUSTRY

Difficult seeing tasks often require a specific amount or quality of lighting which cannot readily be obtained by general lighting methods. To solve such problems supplementary luminaires are often used to provide higher illuminance for small or restricted areas. Also, they are used to furnish a certain luminance, or colour to permit special aiming or positioning of light sources to produce or avoid highlights or shadows to best portray the details of the task.

Before supplementary lighting can be specified it is necessary to recognize the exact nature of the visual task and to understand the light reflecting or transmitting characteristics. An improvement in the visibility of the task will depend upon one or more of the four fundamental visibility factors — luminance, contrast, size and time. Thus, in analyzing the problem, the engineer may find that seeing difficulty is caused by insufficient luminance, poor contrast (veiling reflections), small size, or that the task motion is too fast for existing seeing conditions.

The planning of supplementary lighting also entails consideration of the visual comfort of both those workers who benefit directly and those who are in the immediate area. Supplementary equipment must be carefully shielded to prevent glare for the user and his associates. Luminance ratios should be carefully controlled. Ratios between task and immediate surroundings should be limited as far as possible. To attain these limits it is necessary to coordinate the design of supplementary and general lighting.

7 PORTABLE LUMINAIRES

Wherever possible, luminaires should be permanently mounted at the location to produce the best lighting effect. Adjustable arms and swivels will often adapt the luminaires to the required flexibility. Portable equipment, however, can be used to good advantage where it must be moved in and around movable machines or objects such as in airplane assembly, garages, or where internal surfaces must be viewed. The luminaires must be mechanically and electrically rugged to withstand possible rough handling. Lamps should be guarded and of the rough service type. Guards or other means should protect the user from excessive heat. Precautions should be taken to prevent electrical shock.

8 CLASSIFICATION OF VISUAL TASKS AND LIGHTING TECHNIQUES

Visual tasks are unlimited in number, but can be classified according to certain common characteristics. Classification is made according to their physical and light controlling characteristics and suggests lighting techniques for good visual perception.

It should be noted that the classification of visual tasks is based on the prime and fundamental visual task characteristics and not on the general application.

9 SPECIAL EFFECTS AND TECHNIQUES

Colour as a part of the seeing task can be very effectively used to improve contrast. While black and white are the most desirable combinations for continual tasks such as the reading of a book, it has been found that certain colour combinations have a greater attention value. Black on yellow is most legible and the next combinations in order of preference are green on white, red on white, blue on white, white on blue, and finally black on white.

It is sometimes necessary to inspect and study moving parts while they are in operation. This can be done with stroboscopic illumination which can be adjusted to stop or slow up the motion of constant speed rotating and reciprocating machinery. Stroboscopic lamps give flashes of light at controllable intervals (frequencies). Their flashing can be so timed that when the flash occurs an object with rotating or reciprocating motion is always in exactly the same position and appears to stand still.

10 DAYLIGHTING

10.1 Most people prefer to work in buildings having good daylighting. One of the characteristics of daylight which gives it this appeal is the constant change both in quality and quantity, creating interest and avoiding monotony. This variation is taken into account when planning a scheme to ensure that at no time will the illumination over the working area be less than that recommended for the particular visual task. In some buildings it will be possible to achieve this by natural lighting alone, but in other buildings, especially those located in obstructed city areas, it will be necessary to supplement the natural lighting by artificial lighting designed to operate permanently during the day time; this should be properly coordinated with natural lighting as recommended in IS 3646(Part I). For detailed aspects of daylighting, reference may be made to IS: 2440 and IS 6060 as well as part 11 of this code.

10.2 The uniformity of illumination will depend on the design of the fenestration. Since this is part of the overall design of the building, many factors come into the picture. Generally there appears to be greater scope and freedom in industrial buildings for providing window arrangements which will give the desired daylighting conditions. Industrial buildings are generally located in unobstructed areas where there are sufficient open spaces all around. They have mostly one storey so that there is possibility of having skylights or windows in the roofing, as for example, saw tooth roofing and monitor windows. The heights of the buildings are also enough to have a satisfactory spacing to height ratio of the windows.

11 PERMANENT SUPPLEMENTARY ARTIFICIAL LIGHTING (PSALI)

11.1 This refers to artificial lighting provided for use in the daytime to supplement natural daylight.

11.2 The need for providing PSALI in buildings arises due to two reasons:

a) Due to various reasons adequate daylighting over the whole working area may not be available; and

b) To create acceptable brightness levels on the various surfaces in the working interior.

For areas where the depths of the rooms are much more than the height of the room and windows may be available at one or two sides only, it is necessary to raise the lighting to a level necessary for the task. At the darker zones, supplementary lighting is required.

12 RECOMMENDED ILLUMINANCES

12.1 Recommended illuminances should be graded according to the difficulty of the visual task. These values should be maintained in service through proper cleaning and relamping of luminaires, the cleaning of windows, and the maintenance of reflectance values of the room surfaces. Initial values from the artificial lighting system shall be greater by a percentage sufficient to compensate for the normal depreciation expected in service. An industry may also have an office or a conference room and for lighting of these spaces, the illumination values as given under the head 'Offices, Schools and Public Buildings' in IS 3646 (Part I) shall apply. The recommended illuminance and limiting values of glare index for industrial buildings and processes are given in Table 2.

12.2 It is not a simple matter to specify suitable illuminances if these are to be based upon sound reasoning. Since there is no distinct threshold level of illumination below which the performance of a particular visual task is greatly impeded, some compromise has to be sought between an ideal level and one which is obviously inadequate. Generally, a recommended level is arrived at after being carefully weighed in the relation it bears to the eyesight, the visual task, the environment, and the economics involved. Any specification is, therefore, always open to a great deal of controversy. It may, however, be summarized that any of the above recommended illuminances could serve chiefly as a guide to good practices. It is not always sufficient to provide just enough light and leave it at that. Adequate illumination will benefit people with normal sight, but the benefit will be far greater to those with faulty vision. For example, elderly people require higher illumination values for the same facility of seeing as young people [*see* IS 3646 (Part I) and Part 2, Section 2 of this code].

12.3 In any lighting arrangement the required illuminance could be achieved through a combined usage of the natural daylighting and the artificial lighting. The object of designing artificial lighting specifically to supplement the available natural light is to provide light which satisfies the recommendations of both quantity and quality in all parts of the room or building, while at the same time preserving the sense that the lighting is predominantly natural [*see* IS 3646(Part 1) and (Part 2/Section 2) of this code].

Table 2 Recommended Values of Illumination and Limiting Values of Glare Index
(*Clause* 12.1)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
General Factory Areas		
a) Canteens	150	—
b) Cloakrooms	100	—
c) Entrances, corridors, stairs	100	—
Factory Outdoor Areas		
Stockyards, main entrances, exit roads, car parks, internal factory roads	20	—
Aircraft Factories and Maintenance Hangers		
a) Stock parts productions	450	25
b) Drilling, riveting, screw fastening, sheet aluminum layout and template work, wing sections, cowling welding, sub-assembly, final assembly, inspection	300	25
c) Maintenance and repairs (hangers)	300	25
Assembly Shops		
a) Rough work, for example, frame assembly, assembly of heavy machinery	150	28
b) Medium work, for example, machined parts, engine assembly, vehicle body assembly	300	25
c) Fine work, for example, radio and telephone equipment, typewriter and office machinery	700	22
d) Very fine work, for example, assembly of very small precision mechanisms, instruments	1 500[1)]	19
Bakeries		
a) Mixing and make-up rooms, oven rooms, wrapping rooms	150	25
b) Decorating and icing	200	25
Boiler Houses (Industrial)		
a) Boiler fronts and operating areas	100	—
b) Boiler rooms:		
i) Boiler fronts and operating areas	100[2)]	—
ii) other areas	20 to 50	—
c) Outdoor plants:		
i) Catwalks	20	—
ii) Platforms	50	—
Bookbinding		
a) Pasting, punching and stitching	200	25
b) Binding and folding – miscellaneous machines	300	22
c) Finishing, blocking and inlaying	300	22
Boot and Shoe Factories		
a) Sorting and grading	1 000[3)]	19
b) Clicking and closing, preparatory operations	700	22
c) Cutting table and presses, stitching	1 000	22
d) Bottom stock preparation, lasting and bottoming, finishing	700	22
e) Shoe rooms	700	22
Breweries and Distilleries		
a) General working areas	150	25
b) Brew house, bottling and canning plants	200	25
c) Bottle inspection	Special lighting	—

Table 2 (*Continued*)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
Canning and Preserving Factories		
a) Inspection of beans, rice, barley, etc.	450	22
b) Preparation: Kettle areas, mechanical cleaning, dicing, trimming	300	25
c) Canned and bottled goods: Retorts	200	25
d) High speed labelling lines	300	25
e) Can inspection	450	—
Carpet Factories		
a) Winding, beaming	200	25
b) Designing, jacquard card cutting, setting pattern, tufting, topping, cutting, hemming, fringing	300	22
c) Weaving, mending, inspection	450	22
Ceramics (see Pottery and Clay Products)	—	—
Chemical Works		
a) Hand furnaces, boiling tanks, stationary driers, stationary or gravity crystallizers, mechanical driers, evaporators, filtration plants, mechanical crystallizing, bleaching, extractors, percolators, nitrators, electrolytic cells	150	28
b) Controls, gauges, values; etc.	100[2)]	—
c) Control rooms:		
i) Vertical control panels	200 to 300	19
ii) Control desks	300	19
Chocolate and Confectionery Factories		
a) Mixing, blending, boiling	150	28
b) Chocolate husking, winnowing, fat extraction, crushing and refining, feeding, bean cleaning, sorting, milling, cream making	200	25
c) Hand decorating, inspection, wrapping, packing	300	22
Clothing Factories		
a) Matching-up	450[3)]	19
b) Cutting, sewing:		
i) Light	300	22
ii) Medium	450	22
iii) Dark	700	22
iv) Pressing	300	22
c) Inspection:		
i) Light	450	19
ii) Medium	1 000	19
iii) Dark	1 500	19
d) Hand Tailoring:		
i) Light	450	19
ii) Medium	1 000	19
iii) Dark	1 500	19

Table 2 (*Continued*)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
Collieries (Surface Buildings)		
a) Coal preparation plant:		
i) Working areas	150	—
ii) Other areas	100	—
iii) Picking belt	300	—
iv) Winding houses	150	—
b) Lamp rooms:		
i) Main areas	100	—
ii) Repair sections	150	—
iii) Weigh cabins	150	—
c) Fan houses	100	—
Dairies		
a) General working areas	200[4)]	25
b) Bottle inspection	Special lighting	—
c) Bottle filling	450	25
Die Sinking		
a) General	300	—
b) Fine	1 000	19
Dye Works		
a) Reception, 'grey' perching	700	—
b) Wet processes	150[5)]	28
c) Dry process	200[5)]	28
d) Dyers' offices	700[3)]	19
e) Final perching	2 000[3)]	—
Electricity Generating Stations: Indoor locations		
a) Turbine halls	200	25
b) Auxiliary equipment; battery rooms, blowers, auxiliary generators, switchgear and transformer chambers	100	—
c) Boiler houses (including operating floors), platforms, coal conveyors, pulverizers, feeders, precipitators, soot and slag blowers	70 to 100	—
d) Boiler house and turbine house	100	—
e) Basements	70	—
f) Conveyor houses, conveyor gentries, junction towers	70 to 100	—
g) Control rooms:		
i) Vertical control panels	200 to 300	19
ii) Control desks	300	19
iii) Rear of control panels	150	19
iv) Switch houses	150	25
h) Nuclear reactors and steam raising plants:		
i) Reactor areas, boilers, galleries	150	25
ii) Gas circulator bays	150	25
iii) Reactor charge/discharge face	200	25
Electricity Generating Stations : Outdoor Locations		
a) Coal unloading areas	20	—
b) Coal storage areas	20	—
c) Conveyors	50	—

Table 2 (*Continued*)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
d) Fuel oil delivery headers	50	—
e) Oil storage tanks	50	—
f) Catwalks	50	—
g) Platforms, boiler and turbine decks	50	—
h) Transformers and outdoor switchgear	100	—
Engraving		
a) Hand	1 000	19
b) Machine (*see* Die Sinking)	—	—
Farm Buildings (Dairies)		
a) Boiler houses	50	—
b) Milk rooms	150	25
c) Washing and sterilizing rooms	150	25
d) Stables	50	—
e) Milking parlours	150	25
Flour Mills		
a) Roller, purifier, silks and packing floors	150	25
b) Wetting tables	300	25
Forges (General)	150	28
Foundries		
a) Charging floors; tumbling, cleaning, pouring, shaking out, rough moulding and rough core making	150	25
b) Fine moulding and core making, inspection	300	25
Garages		
a) Parking areas (interior)	70	28
b) Washing and polishing, greasing, general servicing, pits	150	28
c) Repairs	300	25
Gas Work		
a) Retort houses, oil gas plants, water gas plants, purifiers, coke screening and coke handling plants (indoor)	30 to 50[6)]	28
b) Governor-, meter-, compressor-, booster- and exhauster-houses	100	25
c) Open type plants:		
i) Catwalks	20[6)]	—
ii) Platforms	50[6)]	—
Gauge and Tool Rooms (General)	700[7)]	19
Glass Works and Processes		
a) Furnace rooms, bending, annealing lehrs	100	28
b) Mixing rooms, forming (blowing, drawing, pressing, rolling)	150	28
c) Cutting to size, grinding, polishing, toughening	200	25
d) Finishing (bevelling, decorating, etching, silvering)	300	22
e) Brilliant cutting	700	19
f) Inspection:		
i) General	200	19
ii) Fine	700	19

Table 2 (*Continued*)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
Glove Making		
a) Pressing, knitting, sorting, cutting	300	22
b) Sewing:		
i) Light	300	22
ii) Medium	450	22
iii) Dark	700	22
c) Inspection:		
i) Light	450	19
ii) Medium	1 000	19
iii) Dark	1 500	19
Hat Making		
a) Stiffening, braiding, cleaning, refining, forming, sizing, pouncing, flanging, ironing	150	22
b) Sewing:		
i) Light	300	22
ii) Medium	450	22
iii) Dark	700	22
Hosiery and Knitwear		
a) Circular and flat knitting machines, universal winders, cutting out, folding and pressing	300	22
b) Lock stitch and over locking machines:		
i) Light	300	22
ii) Medium	450	22
iii) Dark	700	22
c) Mending	1 500	19
d) Examining, finishing, light, medium and dark	700	19
e) Linking or running on	450	19
Inspection Shops (Engineering)		
a) Rough work, for example, counting, rough checking of stock parts etc.	150	28
b) Medium work, for example, 'Go' and 'No-go' gauges, sub-assemblies	300	25
c) Fine work, for example, radio and telecommunication equipment, calibrated scales, precision mechanisms, instruments	700	22
d) Very fine work, for example, gauging and inspection of small intricate parts	1 500	19
e) Minute work, very small instruments	3 000[1)]	10
Iron and Steel works		
a) Marshalling and outdoor stockyards	10 to 20	—
b) Stairs, gangways, basements, quarries, loading docks	100	—
c) Slab yards, melting shops, ingot stripping soaking pits, blast furnace working areas, picking and cleaning lines, mechanical plants, pump houses	100	28
d) Mould preparation, rolling and wire mills, mill motor rooms, power and blower houses	150	28
e) Slab inspection and conditioning, cold strip mills, sheet and plate finishing, tinning, galvanizing, machine and roll shops	200	28
f) Plate inspection	300	—
g) Tinplate inspection	Special lighting	—

Table 2 (*Continued*)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
Jewellery and Watch making		
a) Fine processes	700[1)]	19
b) Minute processes	3 000[1)]	10
c) Gem cutting, polishing, setting	1 500[8)]	—
Laboratories and Test Rooms		
a) General laboratories, balance rooms	300	19
b) Electrical and instrument laboratories	450	19
Laundries and Drycleaning Works		
a) Receiving, sorting, washing, drying, ironing (calendaring), despatch	200	25
b) Drycleaning, bulk machine work	200	25
c) Fine hand ironing, pressing, inspection, mending, spotting	300	25
Leather Dressing		
a) Vats, cleaning, tanning, stretching, cutting, flashing and stuffing	150	28
b) Finishing, staking, splitting and stating	200	28
Leather working		
a) Pressing and glazing	450	22
b) Cutting, scarfing, sewing	700	22
c) Grading and matching	1 000[3)]	19
Machines and Fitting Shops		
a) Rough bench and machine work	150	28
b) Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	300	25
c) Fine bench and machine work, fine automatic machines, medium grinding, fine bulling and polishing	700	22
Motor Vehicle Plants		
a) Sub-assemblies, chassis and car assembly	300	25
b) Final inspection	450	25
c) Trim shops, body assembly, sub-assemblies	300	25
d) Spray booths	450	—
Paint Works		
a) General automatic processes	200	25
b) Special batch mixing	450	22
c) Colour matching	700[3)]	19
Paint Shops and Spraying Booths		
a) Dipping, tiring, rough spraying	150	25
b) Rubbing, ordinary painting, spraying and finishing	300	25
c) Fine painting, spraying and finishing	450	25
d) Retouching and matching	700[3)]	19
Paper Works		
a) Paper and board making:		
i) Machine houses, calendaring, pulp mills, preparation plants, cutting, finishing, trimming	200	25
ii) inspection and sorting (overhauling)	300	22
b) Paper converting processes:		
i) Corrugated board, cartons, containers and paper sack manufacture, coating and laminating processes	200	25
ii) Associated printing	300	25

Table 2 (*Continued*)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
Pharmaceuticals and Fine Chemical Works		
a) Raw material storage	200	28
b) Control laboratories and testing	300	19
c) Pharmaceuticals manufacturing: grinding, granulating, mixing and drying, tableting, sterilizing and washing, preparation of solutions and filling, labelling, capping, cartoning and wrapping, inspection	300	25
d) Fine chemical manufacture:		
i) Plant processing	200	25
ii) Fine chemical finishing	300	25
Plastic works		
a) Manufacture (*see* Chemical Works)	—	—
b) Processing:		
i) Calendaring, extrusion		
ii) Moulding – compression, injection	300	25
c) Sheet fabrication:		
i) Shaping	200	25
ii) Trimming, matching, polishing	300	25
iii) Cementing	200	25
Plating Shops		
a) Vat and baths, buffing, polishing, burnishing	150	25
b) Final buffing and polishing	Special lighting	—
Pottery and Clay Products		
a) Grinding, filter pressing, kiln rooms, moulding, pressing, cleaning, trimming, glazing, firing etc.	150	28
b) Enamelling, colouring, decorating	450[3)]	19
Printing Works		
a) Type foundries:		
i) Matrix making, dressing type, hand and machine casting	200	25
ii) Front assembly, sorting	450	22
b) Printing plants:		
i) Machine composition, imposing stones	200	25
ii) Presses	300	25
iii) Composing room	450	19
iv) Proof reading	300	19
c) Electrotyping:		
i) Block-making, electroplating, washing, backing	200	25
ii) Moulding, finishing, routing	300	25
d) Photo-engraving:		
i) Block-making, etching, masking	200	25
ii) Finishing, routing	300	25
e) Colour printing: Inspection area	700[3)]	19
Rubber Processing		
a) Fabric preparation creels	200	25
b) Dipping, moulding, compounding calendars	150	25
c) Tyre and tube making	200	25

Table 2 (*Continued*)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
Sheet Metal Works		
a) Bench work, scribing, pressing, punching, shearing, stamping, spinning, folding	200	25
b) Sheet inspection	Special lighting	—
Soap Factories		
a) Kettle houses and ancillaries, glycerin evaporation and distillation, continuous indoor soap making, plants:		
i) General areas	150	25
ii) Control panels	200 to 300	25
b) Batch or continuous soap cooling, cutting and drying, soap milling, plodding:		
i) General areas	150	25
ii) Control panels, key equipment	200 to 300	25
c) Soap stamping, wrapping and packing, granule making, granule storage and handling, filling and packing granules:		
i) General areas	150	25
ii) Control panels, machines	200 to 300	25
d) Edible products processing and packing	200	25
Structural Steel Fabrication Plants		
a) General	150	28
b) Marking off	300	28
Textile Mills (Cotton or Linen)		
a) Bale breaking, blowing, carding, roving, slubbing, spinning (ordinary counts), winding, heckling, spreading, cabling	150	25
b) Warping, slashing, dressing and dyeing, doubling (fancy), spinning (fine counts)	200	25
c) Healding (drawing-in)	700	—
d) Weaving:		
i) Patterned cloths, fine counts dark	700	19
ii) Patterned cloths, fine counts light	300	19
iii) Plain 'grey' cloth	200	19
e) Cloth inspection	700[3)]	—
Textile Mills (Silk or Synthetics)		
a) Soaking, fugitive tinting conditioning, setting of twist	200	25
b) Spinning	450	25
c) Winding, twisting, rewinding and coning, quilting, slashing :		
i) Light thread	200	25
ii) Dark thread	300	25
d) Warping	300	25
e) Healding (drawing-in)	700	—
f) Weaving	700	19
g) Inspection	1 000[3)]	19
Textile Mills (Woollen)		
a) Scouring, carbonizing, teasing, preparing, raising, brushing, pressing, back-washing, gilling, crabbing and blowing	150	25
b) Blending, carding, combing (white), tentering, drying, cropping	200	25
c) Spinning, roving, winding, warping, combing (coloured), twisting	450	25
d) Healding (drawing-in)	700	—

Table 2 (*Concluded*)

Industrial Buildings and Processes	Average Illumination (lux)	Limiting Glare Index
e) Weaving:		
i) Fine worsteds	700	19
ii) Medium worsteds, fine woolens	450	19
iii) Heavy woolens	300	19
f) Burling and mending	700	19
g) Perching:		
i) Grey	700	—
ii) Final	2 000[3]	—
Textile Mills (Jute)		
a) Weaving, spinning, flat, jacquard carpet looms, cop winding	200	25
b) Yarn calendar	150	2525
Tobacco Factories		
All processes	300 [9]	22
Upholstering		
Furniture and vehicles	300	22
Warehouses and Bulk Stores		
a) Large material, loading bays	100	28
b) Small material, racks	150	25
c) Packing and dispatch	150	25
Welding and Soldering		
a) Gas and arc welding, rough spot welding	150	28
b) Medium soldering, brazing and spot welding, for example, domestic hardware	300	25
c) Fine soldering and spot welding, for example, instruments, radio set assembly	700	22
Woodworking Shops		
a) Rough sawing, and bench work	150	22
b) Sizing, planing, rough sanding, medium machine and bench work, gluing, veneering, cooperage	200	22
c) Fine bench and machine work, fine sanding and finishing	300	22

[1] Optical aids should be used where necessary.
[2] Supplementary local lighting may be required for gauge glasses and instrument panels.
[3] Special attention should be paid to the colour quality of the light.
[4] Supplementary local lighting may be required for sight glasses.
[5] Supplementary local lighting should be used where necessary.
[6] Supplementary local lighting should be used at important points.
[7] Supplementary local lighting and optical aids should be used where necessary.
[8] Special attention to colour quality of light may be necessary.
[9] Special attention should be paid to the colour quality of the light in all processing areas.

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NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 2 Office Lighting

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Office work can be understood as comprising a host of frequently varying activities, involving the processing of files, communicating with other workstations, operating the communication media, communicating with other members of staff, thinking, organizing, and so on. Each activity imposes different requirements on the office space, workstation, surroundings, furnishings, equipment, and also the lighting. Equally, each activity demands a different relationship with other rooms in the building or elsewhere. As every company or public authority differs in structure and organization, so does the emphasis put on each specific activity, therefore affecting these relationships. The result is that individual workstations have to meet very complex requirements. Traditionally, the 'surface' is the main object of interest in lighting; today the 'space' starts to play a major role.

Needless to mention, that mostly all office workers are inside a 'box', spending long hours staring at a computer screen. It was not long ago that an important criteria in office lighting was to ensure the legibility of pencil written text without any specular reflections on paper. Today a laser printer delivers perfectly sharp, matt, black texts, which makes lighting of such visual tasks much simpler. Today, designers are challenged with lighting up a space, creating an environment, and ensuring comfort to the users by eliminating glare on the screen. Lighting is thus not limited to selection of a few good looking products, but more a design job.

Irrespective of the requirements that have already been discussed above, a number of basic human needs have to be taken into account in the design of office workstations. These human needs reflect a person's desire for:

a) orientation in space and time (including biorhythm);

b) privacy and communication;

c) information and familiarity; and

d) variation and surprise (not monotonous).

These human needs can be incorporated into a scheme for lighting designers.

Key elements that should be taken into account are listed below.

a) The lighting should facilitate orientation and definition of a person's location in space and time;

b) Lighting should be an integral part of the architecture and interior design, namely planned from the beginning and not added as an afterthought. Through the choice of form, colour and material and in its design and details, lighting should support the intentions of the architecture and interior design rather than function independently;

c) Lighting should create a mood and atmosphere that meets people's demands and expectations; and

d) Lighting should facilitate and promote communication among people.

Thus, understanding the office space and the needs of users, forms the fundamental basis of a good office lighting design. The more developed countries, have now accepted the new model in lighting which evolves around the autonomy of the employee or department and the importance of communication amongst employees.

The following Indian Standard is a necessary adjunct to this section.

IS No.	*Title*
3646(Part 1):1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for working interiors (First Revision)

NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 2 Office Lighting

1. SCOPE

This section of the code covers the principles and practices governing good lighting of offices. It recommends the levels of illumination to be achieved by general principles of lighting.

NOTE — General aspects of interior lighting, including assessment of glare, are dealt with in IS 3646(Part 1):1992.

2. TERMINOLOGY

For the purpose of this section, the definitions given in Part 1 of this code shall apply.

3 LIGHTING REQUIREMENTS

3.1 The provision made for lighting will depend on the type of office, for example, general office, executive office, drawing office, etc and the subdivision of the floor space. Where the layout of partitioning is unknown or subject to alteration, provision should be made for a flexible installation that will allow luminaires to be placed in proper relation to any arrangement of partitioning. This flexibility may be achieved by either:

a) providing fixed outlets on a modular system sufficient in number to ensure that luminaires can be located satisfactorily irrespective of how the interior is partitioned; or

b) by using continuous lines of trunking or lighting track along which luminaires can be located as required.

Both the above methods can facilitate group and individual switching of luminaires to suit workstations which may carry on working outside the general office hours.

General overhead lighting will normally be satisfactory but, in relatively deep offices, integration of daylight and artificial light may be required in order to give properly balanced seeing conditions while still retaining the effect of natural lighting.

The layout should be designed to limit glare and care should be taken to avoid specular reflection of the light sources from polished furniture, glossy paper, machine surfaces or glazed partitions.

Office lighting requirements are now changing from fixed uniform illuminance levels on the working plane, for different types of areas to variable and/or dynamic, zoned lighting that is derived from human needs, well-being, the task, and the perception of the space.

4 INTEGRATION WITH OTHER SERVICES

4.1 Wherever possible, the layout and operation of the lighting system should be designed in conjunction with other services. This involves dimensional coordination with the building module and positional coordination with the air input and exhaust terminals. The electrical power of the lamp and control gear contributes to the heat input of a building and allowance should be made for this in the design of the heating and cooling system.

Air conditioning and lighting may be combined in such a way that the return air is exhausted through the luminaires. This is done primarily to:

a) reduce heat radiation from lamps and luminaires;

b) reduce temperature of the air surrounding the lamps thereby increasing their luminous flux and hence their efficacy; and

c) minimize openings in the ceiling to the extent the air exhaust can be effected through some luminaires.

The data (from luminaire manufacturers) concerning luminaires for use in an integrated system should provide information on the rate of heat removal, increase in luminous flux, air distribution and level of noise (due to exhaust air), apart from the usual lighting characteristics.

5 LIGHTING LAYOUTS

5.1 The three main types of installation are as follows:

a) individual luminaires; ceiling mounted or suspended, supplied from fixed outlets or from continuous trunking or tracks;

b) recessed luminaires, usually modular, which may be inserted in the false ceiling; and

c) combination of localized lighting with (a) or (b) above (sometimes referred to as task lighting in conjunction with ambient lighting of a lower level).

Recessed modular luminaires do not provide any appreciable light on the ceiling and may be unsatisfactory in interiors having surfaces of low reflectance.

6 CHOICE OF LIGHTING EQUIPMENT

6.1 The choice of the light source and luminaire is made to meet both functional and architectural requirements. Layout is decided considering partitions (where known in advance), structural beams or waffles in the ceiling, suspended ceiling (if any), and likely layout of office furniture and VDTs. Before the layout is finalized the integration of the above with the layout of the air conditioning outlets and fire protection equipment should be verified and adjustments made as required.

6.2 The most preferred light sources for general lighting still remain the fluorescent lamps (T8, T5 and also high wattage CFLs). Fluorescent lamps offer the user and designer the best combination of luminous efficacy, choice of colour appearance, high colour rendering, and dimmability. For task and accent lighting , choices range from compact fluorescent, low voltage halogens, ceramic discharge metal halides to LEDs. Optical performance (efficiency, light distribution and brightness control) is a key criterion in the selection of luminaires. However, mechanical construction (especially suitability of mounting), maintainability and luminaire design should also be given due importance. A variety of designs in luminaires are available to choose from, depending on the place of installation and the economics. Modern material technology now makes it possible to strike an optimal balance between technical performance and visual aesthetics.

7 VISUAL TASK REQUIREMENTS

7.1 In modern offices, the activity is not restricted to reading alone. Therefore, a good balance must be achieved between the lighting level in the task area (mostly where reading and computer related work is done) and the surrounding area. The lighting level in the task area is governed by the size of the print, contrast with the background and the viewing duration. Visual performance is high when the task size is large, the contrast is high and viewing duration is long. The level of illuminance required is also related to the age of the occupants, higher levels for more aged persons, but increase beyond a certain level will not be correspondingly beneficial. It may not be possible for a designer to have precise input in regard to all these parameters and therefore reasonable assumptions based on experience are required to be made.

7.2 An average horizontal illuminance for task area, as per IS 3646(Part 1) is 300-500-750, depending on the criticality of the task, and the ambient conditions. International guidelines now allow lower lighting levels in the surrounding areas, which allow energy saving options but also maintain good adaptation.

Where the precise requirements of partitions are known, fixed lighting and individual or group switching arrangements may be installed accordingly. In an open plan office, a lower illuminance value than the above can be adopted for the general office area, supplemented with specific task lighting as may be necessary. Where the area is large with different task lighting requirements, a lighting system with local dimming or multi-level switching facility at specific points may be adopted. In the case of office rooms (as distinct from office halls), it is expected that the general illumination itself is likely to provide the required task illumination. If, however, the reflectance of the walls and partitions is very low in certain rooms, additional localized task lighting may be necessary.

Where the layout of partitions is unknown or subject to alteration and one is to speculate, provision should be made for a flexible installation that will allow luminaires to be placed in proper relation to any likely arrangement of partitioning. This flexibility may be achieved by introducing limited redundancy, by either:

a) providing fixed light outlets on a modular system, sufficient in number to ensure that luminaires can be located satisfactorily (with minimum shifting, if at all) irrespective of how the interior may be partitioned; or

b) by using lines of trunking or lighting track from which supply to luminaires can be tapped as required.

The above method (a) can be arranged for group and/or individual switching of luminaires as required.

7.3 Whereas good horizontal illuminance is necessary for the tasks of writing or reading, vertical illuminance is essential for presenting a true and pleasing appearance of the interiors and occupants. This may be provided by the choice of appropriate luminaires, and high surface reflectances.

To create a good lighting ambience, it is important that there should be a well balanced distribution of the luminous flux (and consequently lux) between the task area, walls and ceilings.

The wall illuminance needs to be considered to ensure that the walls do not appear dark in relation to the working plane. With pure downlighting, there is a danger of the upper walls, especially, appearing dark. In certain spaces wall washing may be needed. To achieve a good luminance balance in a space, the average wall illuminance above the working plane, from both the direct and reflected components, should be at least 50 percent of the average horizontal illuminance on the working plane. Where these walls may be seen reflected in any display screens, care must be taken to avoid bright scallops or patches appearing on the walls, that is, gradual changes in illuminance will be necessary on these walls.

To prevent the ceiling from appearing dark, the ceiling average illuminance from both the direct and reflected components should be at least 30 percent of the average horizontal illuminance. This could be from the sides of surface mounted downlights, from uplighting elements of suspended luminaires, from dropped elements of recessed downlights or from supplementary uplights. In large spaces with unusually low ceilings this may be difficult to achieve and in such circumstances, the proportion of light on the ceiling should be as high as is practicable.

7.4 Office lighting for any new office should be done as for a modern electronic office in which the visual tasks will include viewing of paper as well as visual display terminals (VDTs).

8. VISUAL ENVIRONMENT REQUIREMENTS

8.1 A good visual environment is necessary for creating the required subjective impression about the space both to the short time and long time users. Broadly, colour contrast and luminance distribution pattern are the two basic factors which influence the resultant visual environment. For instance even where there are no prolonged visual tasks to be performed, variations in luminance and colour can contribute towards an attractive interior environment in areas like lounges, corridors and conference rooms.

8.2 The colour appearance is dictated by the spectral power distribution (SPD) of the light source and the colour of the reflecting surfaces (walls, partitions, ceilings, furnishings, etc). While considering the SPD it may be kept in view that a correlated colour temperature (CCT) upto 3 000 K will provide a warm environment and above 5 000 K a cool environment. The range between the two will tend towards neutral colours. A CCT of about 4 000 K will be suitable for integrating the artificial lighting with daylighting. In modern offices, and as per current international guidelines, lamps with a Ra > 80 are recommended. Coordination with the interior designer is especially important in these areas so as to make the lighting really effective and lively.

8.3 Viewing conditions inside an office space are influenced very much by the finishes and furnishings. Interior finishes and furnishings should have reflectances of not less than 70 percent for ceilings and 50 percent for walls. Dark coloured floors, furnishings and curtains, wooden panelling, etc, should be avoided as these will absorb the incident light and the resultant surface luminance will be poor. In such cases, especially on walls, additional lighting will have to be directed. Where it is desired to use bright colours their effect will be enhanced by directing extra light with appropriate SPD onto them.

8.4 It is very necessary that glare is avoided from lighting. A glossy surface will cause veiling specular reflection like a mirror and can produce patches of very high brightness on polished floors or table tops and VDT monitors and may even produce images of the luminaires. The selection of table top surfaces as well as the location of the lighting with reference to the direction of viewing is thus important. Lighting from the sides of the work area will eliminate reflected glare through the table top from the normal viewing position.

8.5 Discomfort glare can be minimized by keeping the light source farther from the line of sight and also trying to reduce the area of brightness of the source from the viewing position. This aspect is to be considered particularly when the space is long, or when the height of luminaires above the floor level is rather low. Luminaires with cut-off distribution or with suitable louvres will be necessary for such locations.

9 DESIGN ISSUES RELATED TO SPECIFIC AREAS IN OFFICES

9.1 Certain considerations are useful and may be necessary in specific area applications in offices, in addition to compliance with the general requirements brought out so far.

The illuminance and its distribution on the task area and the surrounding area have a great impact on how quickly, safely and comfortably a person perceives and carries out the visual task.

Ranges of useful reflectances for the major interior surfaces are:

a) ceiling: 0.6 to 0.9;

b) walls: 0.3 to 0.8;

c) working planes: 0.2 to 0.6; and

d) floor: 0.1 to 0.5.

The illuminance of immediate surrounding areas shall be related to the illuminance of the task area and should provide a well balanced luminance distribution in the field of view.

Large spatial variations in illuminances around the task area may lead to visual stress and discomfort.

It is important to keep a balance between task illuminance and its surrounding areas (*see* Table 1).

Table 1 Relation Between Task Illuminance and Illuminance of Immediate Surrounding Area

(*Clause* 9.1)

Task illuminance (lux)	Illuminance of immediate surrounding areas (lux)
≥ 750	500
500	300
300	200
Uniformity: ≥ 0.7	Uniformity: ≥ 0.5

10 LIGHTING FOR VISUAL DISPLAY TERMINALS (VDTS)

10.1 The aspects of the visual environment which are likely to cause problems for VDT operators are basically:

a) The reflection of high luminance surfaces on the monitor screen; and

b) An excessive range of luminance within the field of view especially between the screen and documents on the desk.

High luminance reflections occurring on the VDT screen can have disturbing effects. First they can reduce the contrast of the characters making up the display which may make some parts difficult to read. The most common sources of high luminance in an interior are windows and luminaires. White clothing worn by the operator seated immediately in front of the VDT may also at times be a high luminance source.

The VDT and, in some circumstances, the keyboard may suffer from reflections causing disability and discomfort glare. It is therefore necessary to select, locate and arrange the luminaires to avoid high brightness reflections.

The designer shall determine the offending mounting zone and shall choose equipment and plan mounting positions which will cause no disturbing reflections.

Controlling the shielding angle and luminance of the luminaire is an important factor to control direct and reflected glare. It is important to note that when either direct lighting or low luminance luminaires are used, the surface reflectance of the walls, ceiling and floor should be moderate or high if an impression of gloom is to be avoided.

10.2 Luminaire Luminance Limits with Downward Flux

The following are the luminance limits for luminaires which may be reflected in DSE screens for normal viewing directions. Table 2 below gives the limits of the average luminaire luminance at elevation angles of 65° and above from the downward vertical, radially around the luminaires for work places where display screens, which are vertical or inclined up to 15° tilt angle, are used.

NOTE — For certain special places using, for example, sensitive screens or variable inclination, the above luminance limits should be applied for lower elevation angles (for example, 55°) of the luminaire.

Table 2 Luminance Limits of Luminaires which can be Reflected in the Screen

(*Clause* 10.2)

Screen Class	I	II	III
Screen Quality	Good	Medium	Poor
Average luminances of luminaires which are reflected in the screen	$\leq$ 1 000 cd /m^2		$\geq$ 200 cd /m^2

For the ceiling not to appear dark, it is recommended that the average illuminance on the ceiling (from direct and reflected component) be at least 30 percent of the horizontal illuminance of the task areas. In large spaces, especially with ceiling heights less than 2.4 m and using only recessed direct luminaires, it may be very hard to achieve. In such instances a combination of dropped lenses and additional uplighting elements should be considered. Also, it is preferable that the average illuminance on the walls is 50 percent of the task illuminance.

Finally, lighting in offices should be sustainable and aim to optimize energy usage by linking or integrating with daylight, movement sensors and many modern day energy saving equipment. At the same time it should create exuberance and a comfortable visual environment and meet the visual requirements of lighting levels as per standards as well.

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PART 5 INTERIOR ILLUMINATION
Section 3 Lighting for Educational Facilities

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Educational facilities in the context of lighting, refers to buildings of educational institutions from school level to the university level, covering not only the class rooms, but also laboratories, libraries, gymnasiums, multipurpose halls, circulation spaces etc, forming part of the institutional campus. The visual task requirements are different in each of these spaces and the lighting scheme is designed, considering these in detail for each area. The lighting system should be designed and installed for good visual comfort to both students and instructors. New teaching aids and video display terminals (VDTs) are being introduced gradually. These should also be considered for new lighting installations.

The following Indian Standards are necessary adjuncts to this section.

IS No.	*Title*
2672:1966	Code of practice for library lighting
6665:1972	Code of practice for industrial lighting

NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 3 Lighting for Educational Facilities

1. SCOPE

This section covers the principles and practices governing good visual environment for education. It also recommends the level of illumination and quality requirements to be achieved by general principles of lighting.

2. TERMINOLOGY

The definitions of the terms used in this section are given in Part 1 of this code.

3. VISUAL TASK REQUIREMENTS

3.1 The primary activity for a student is reading and writing. These may range from easy tasks of reading clear and bold printed matter to more difficult ones like pencil writing, maps or graph sheet work. There may also be fine and detailed work such as art work, needle work, dissection activity in biology laboratory, etc. The difficult tasks would need higher levels of illumination.

3.2 The students may have to look up at the board from a distance while the teacher will be required to have a general surveillance of the whole class while teaching. Such distant viewing calls for a good level of illumination, considering also that the illuminance requirement increases with age.

3.3 The illuminance required is governed by the size of the object to be seen, contrast and period of viewing. Generally an illuminance level of 300 lux (horizontal) is considered adequate for teaching areas, 100 lux in corridors and 200 lux in gymnasiums. Higher illuminance should be provided for more exacting visual tasks by supplementary localised lighting. Where tasks with different requirements are to be performed at the same time in a space, the level of illuminance should satisfy the most demanding task. If this calls for excessive levels, then levels lower than those may be adopted, with localized supplementary lighting for specific tasks requiring higher levels (Example: drafting tables, chalk board, etc).

3.4 Illumination in the vertical plane is required for good viewing conditions, especially on chalk boards, display charts, etc. In many applications, this requirement is automatically satisfied by the source meant for general (horizontal plane) lighting. Supplementary local lighting will however be needed in certain cases. For example, corridors, which not only serve as passage areas, but may also be used for display of bulletins, charts, posters and notices, etc, and local lighting has to supplement the general corridor lighting.

3.5 In areas where colour rendition is an important parameter (for example, art rooms and chemistry laboratories) the source should be selected for a high CRI (above 75). Fluorescent lamps are most commonly used for indoor applications. HID lamps can be used in gymnasium halls where colour is not that important.

3.6 In rooms where VDTs are in place, consideration for such areas should be given as indicated in the section on office lighting, for good visual comfort, free from reflected glare.

4 VISUAL ENVIRONMENTAL REQUIREMENTS

4.1 A student has to look at various objects with close attention for a long duration. There would be requirements of both nearby and far off viewing alternately. Where the eyes are required to adapt to vastly different luminances for short durations at frequent intervals one is likely to experience discomfort and fatigue. In order that such viewing is without discomfort, the visual environment should be good. The aspects discussed hereunder contribute towards this.

4.2 Walls should have a reflectance of 40 to 60 percent, ceiling 70 to 90 percent and flooring over 25 percent, so as to provide a comfortable luminance pattern.

4.3 For a good visual adaptation, the lighting system and the environment should be coordinated so as to achieve the following end results:

a) Luminance of desk top, immediately adjacent to the task must not exceed the task luminance, nor be below one third of the same;

b) No surface in view should have a luminance lower than one third of the task luminance; and

c) Luminance of any surface in view should not exceed 5 times the task luminance.

4.4 Direct glare from the lighting should be avoided, as students will often have to look across the room, shifting their view from their desks at frequent intervals. Luminaires should have a limited brightness from normal angles of viewing. The ceiling should be bright enough to allow the luminaires to be seen against a comfortably bright background environment.

4.5 Objects in critical view, namely, boards, paper (books), etc, need special attention for visual comfort. White chalk over black boards and dark marking pens over white boards, ensure a high contrast. Paper used in books, notebooks, etc, should be opaque and matt; shiny sheet surfaces should be avoided. Printed matter should have liberal spacing between lines, and print size should not be very small. All these aspects contribute to good seeing conditions.

4.6 Most of the class rooms have windows, bringing in substantial daylight. Direct sunlight should be prevented inside the class rooms. Glare should be avoided from the windows, while getting the benefit of daylighting. These requirements are met through suitable provision of exterior architectural appendages such as shades, blinds, louvres or baffles and roof overhangs and also by proper orientation of the building. Daylight itself is a variable source and needs to be supplemented with an electric lighting system with necessary switching arrangements.

4.7 In lecture theatres in colleges, (where the room sizes are larger compared to schools) attention should be given for unobstructed viewing and dimming of lights for the use of various visual aids. This dimming facility may be needed in large halls where visual aids are likely to be used, and also where practical experiments are conducted.

5 LIBRARY AND READING ROOM

5.1 General

5.1.1 The library is an important area in an educational complex, which requires detailed consideration. General reading, both casual and sustained of a wide variety of printing types and styles, examination of drawings and maps, writing, etc, are among the more common visual tasks that will be encountered in a library. The accommodation may range from the small private library, modestly equipped, to the large town or country library with a multiplicity of requirements. The latter may include gramophone records and picture loan departments necessitating the critical examination of items returned by users.

5.1.2 The lighting should be of very high quality since printed illustrative matter involves veiling reflections from overhead lighting; special care should be taken to use lighting equipment that will minimize the concentration of the light directly downward which in turn causes reduction of contrast. As in the case of offices, particular attention should be paid to the avoidance of direct and indirect glare, and the use of decorations and furnishings with a non gloss finish is recommended.

5.2 Installation

5.2.1 Modern ideas on library design favour the open plan with provision for rearrangement of furniture as needs change. There is much to be said, therefore, for a general lighting system designed specifically to avoid the need for providing local lighting of tables and desks. In practice, it is not always possible to do this as the positioning of the luminaires and the general distribution may be dictated by the form of the building and the predetermined arrangements of book stacks and tables, and often a compromise has to be accepted.

5.2.2 Continuous line sources, such as tubular fluorescent lamps, housed in louvered luminaires which control the light so as to minimize glare when looking along the aisle, is a commonly adopted and good method. The luminaires should be mounted centrally between the stacks at a height that does not interfere with the removal of books. Depending on the layout and frequency of use, it may be advisable to install local switching for each row of book stack luminaires.

5.2.3 In reference rooms and reading rooms which are infrequently fully occupied, local lighting combined with general lighting giving a lower illuminance may be an economic solution. A further exception is in book storage areas where restricted height and width of aisles may necessitate a system of lighting more directly related to the individual book stacks.

5.2.4 If local luminaires are used, their positioning will be largely influenced by the design of the desks and tables and the physical size of the literature to be read. Particular attention should be paid to avoiding direct glare. Reflected glare from glossy paper will be minimized if the luminaires are placed on each side of the reader rather than being mounted directly in front of the reader.

5.2.5 Indirect lighting by means of concealed lamps, placed on the tops of symmetrically arranged book stacks, is sometimes adopted, as it avoids the presence of visible luminaires. Unless augmented with local lighting, however, running costs (energy and maintenance) will be relatively high and the ceiling may become a source of discomfort glare or distraction.

5.3 Book Stacks

5.3.1 Since it is necessary to identify books by number and author on book spines, the visual task in book stacks may be difficult. Perimeter book stacks located around the walls of reading rooms are usually illuminated by the general lighting system of the room, and stacks along the centre of the aisles are illuminated by continuous rows of fluorescent luminaires with specially designed distributions.

5.3.2 Although the visual task encountered in book stack areas is relatively simple, factors such as labelling, lettering and book positioning may affect ease of seeing. The restricted width of the aisle between the stacks makes the achievement of constant illuminance from top to bottom of shelving impracticable. The material or finish of the shelving and the floor covering should be of a light colour to help interreflection of light at the bottom of the stack. If the minimum illuminance on the vertical plane is about 50 lux, however, and the luminance contrast between the book titles and their background is good, visual performance will be of an acceptable standard. For bookshelves a high level of illumination in the vertical plane is paramount since students have a tendency to leaf over or read a book at the bookshelf. This should be applicable up to the bottommost shelf and hence the work plane should be taken at floor level for designing a lighting scheme.

5.4 The above gives the general guidelines to be followed in designing the lighting for libraries. For further details regarding principles and practices governing good lighting, reference should be made to IS 2672:1966.

6 LABORATORIES

6.1 These involve laboratory tables or benches at which very detailed work is carried out in dissection, inspection of reactions, instrumentation and measurement. Good diffusion with some directional component and appropriate colour quality is required. Localised lighting may be needed if the building design (window sizes, orientation, etc) so demands; and these should be coordinated with users.

6.2 In laboratories where chemical analysis is done or where the presence of corrosive fumes and vapour is expected, it is recommended to use luminaires which are able to withstand the ill effects of the chemical fumes present in the atmosphere. Alternatively, painting of the body and supports should be done with anticorrosive paint.

6.3 Provision in the form of convenient outlets should be kept for portable lighting equipment required for microscope work and in reading precision instrument and meters.

6.4 In electronics laboratories care should be taken to provide for suitable filter circuits in fluorescent lamp luminaires for radio frequency suppression.

7 AUDITORIUM

7.1 General

The auditorium serves as an assembly and lecture hall, study room, theatre, concert hall and for many other activities. Because of this it should be well planned and properly equipped to satisfy the requirements of all the functions. From general lighting to supplementary illumination, care should be taken to provide good lighting which should blend well with the architecture and at the same time avoid veiling reflections. In particular due consideration should be given as indicated in 7.2 and 7.3.

7.2 Specific Areas in an Auditorium

7.2.1 *Foyer*

Usually a restful, subdued atmosphere is desirable in the foyer. Illumination from large, low luminance elements, such as coves, is one good method. Wall lighting and accents on paintings, posters and plants are important in developing atmosphere. Care must be taken so that light does not spill into the auditorium.

7.2.2 *Seating Area*

The seating areas should be provided with well diffused comfortable illumination. Luminaires for the basic illumination may include general downlights, coves, curtain and mural lights. Supplementary illumination, preferably by a downlighting system should be provided evenly over the seats since the seating area is also used for visual tasks and this should be controlled separately. All these lights should be under dimmer control.

7.2.3 *Stage Area*

Proper lighting for dramatic presentation extends beyond visibility to the achievement of artistic composition, production of mood effects, and the revelation of forms as three dimensional. These functions of stage lighting result from the manipulation of various qualities, quantities, colours and directions of lights and these vary from one performance to the next and even continually throughout a single performance. The layout is affected by the amount and kind of use planned for the theatre.

7.3 Control System

Dimming facilities should be made available for an auditorium even if it houses a small stage. Wherever dimming facilities are required, the illumination should preferably be designed incorporating GLS light sources. Selection of dimmers should, however, be decided on budget and simplicity requirements. Dimmers have been constructed using autotransformers (manual and motor driven), thyratrons, saturable reactors, magnetic amplifiers and thyristers (SCRs), etc.

Care should be taken in designing the arrangement which should enable a group or groups of lights to be controlled in specific areas whenever required.

Emergency lighting is essential in any auditorium be it small or big. It should be ensured that all aisle lights, lights for steps and lights provided at the rear of the seating area are connected to the emergency circuit. Besides, exit lights should be provided at every access to guide the audience towards the exits in the event of a power failure.

It is not uncommon to use the multipurpose hall as a gymnasium especially in small institutions. While the general lighting level need not be high for this application, there should not be glare from the light source. When used for indoor games, lighting as recommended for the type of sports activity should be provided. See Part 6, Section 6 of this code for more details on sports lighting.

8 STAFF ROOMS

The staff room is a place where teachers assemble for discussions, study or rest during recess periods. These rooms should have general illumination for performing visual tasks like reading and writing (correcting papers and notebooks).

The switching arrangement should be such that a group of lights may be switched off for a subdued level (say 200 lux) whenever the occupants wish to relax. Supplementary local lighting should be provided at the side of the user in the form of a table lamp or wall lamp so that an individual could continue with his/her work without disturbing the others who may relax at the same time.

9 LIGHTING CRITERIA FOR VISUAL PERFORMANCE AND COMFORT IN EDUCATIONAL INSTITUTIONS

9.1 General

The detailed design of the artificial lighting should commence with a close study of the range of visual tasks that occur in school and college buildings. These may range from normal reading and writing, to close and detailed work such as dissection in biology, fine needlework or technical drawing.

Each teaching room may be used in many ways, sometimes with all the groups working on different activities. The room is normally planned to allow for this variety of use, and the lighting should be arranged to give an adequate general illuminance over the whole of the room including the walls. Local lighting, as necessary, on chalkboards, display areas and fixed working positions, that are at a distance from the windows will also be required.

Lighting for classrooms should be evaluated in terms of the effects on students and their performance. Specifically, the lighting in classrooms will have bearing on:

a) Ability to see visual tasks with speed and accuracy;

b) Visual comfort; and

c) Visual pleasantness of a space in which to study and work.

9.2 Illumination

An illuminance of 300 lux is recommended for teaching areas. Higher luminance should be provided for more exacting visual tasks, for example, 500 lux for laboratories.

9.3 Quality of lighting

9.3.1 Special attention should be given to designing for visual comfort. Direct glare from the lighting should be avoided, as students will often have to look across the room, as well as down at their desks. Luminaires should have a limited brightness from normal angles of views, and ceilings should be bright enough to allow the luminaires to be seen against a light background.

The interior needs to be treated on its own merits. Full details of the proposed display should be available to ensure the adoption of efficient lighting techniques. General lighting using tubular fluorescent lamps and accent lighting using tungsten filament lamps will meet the requirements of most free standing displays. Wiring systems should preferably be of a flexible nature to facilitate changes in exhibit layout and consequently the installation of luminaire track systems may be appropriate.

10 GENERAL AREAS

10.1 Lecture Rooms

A comfortable general system which is flexible enough to provide a moderately high level for general use and a subdued level for use during projection or special demonstrations should be provided for a typical lecture room. Special chalkboard lighting significantly improves visibility and attention powers.

10.2 Corridors

Corridors in educational institutions not only serve as mere passage or transition areas, but also are used to put up displays, bulletin boards, wall magazines, posters, notices, etc. Special lighting should, therefore, be provided in addition to a good general lighting to enhance the visual vitality of such corridors.

11 SPECIFIC AREAS

11.1 Art Rooms

As colour is important here, light sources with high colour rendering capability should be used to bring out a more natural appearance of colours over a wide range. Supplementary lighting from directional concentrating sources should be used on displays and models for improved visibility and for modelling purposes.

11.2 Workshops

Lighting in workshops should not only provide necessary quantity and quality of illumination required for optimal performance of a given task, but should also be an aid to safety of the personnel. For guidance regarding general features and factors influencing good lighting practices for workshops, reference should be made to IS 6665:1972.

NOTE — Further details on industrial lighting are given in Part 5, Section 1 of this code.

11.3 Gymnasiums

A gymnasium is a multipurpose as well as multi-sport area, serving a variety of needs of the student body and the community in general, including such activities as assemblies, concerts and dances. Besides a good general illumination, use of portable temporary auxiliary equipment should be made wherever creation of mood or atmosphere is the objective.

Wire guards or other means of protection should be provided on the luminaires to prevent breakage, because the luminaires in a gymnasium are vulnerable to flying balls, shuttles, etc, used in aerial sports played inside a gymnasium.

The openings in the luminaires for use in gymnasiums can present serious problems. Similarly improperly located luminaires and unshielded fenestration could be hazardous.

11.4 Cafeterias and Kitchens

In eating areas the lighting should create a cheerful, comfortable area. Dining areas are frequently used for other activities and when so used the lighting should provide levels of illumination recommended for the task. Where the appearance of food is of prime consideration, as in the cafeteria, pleasant colours and appropriate sources should be used. Additional incandescent lighting may be used over the serving counter to give good eye appeal, provide heat and to speed up the selection of food.

Good general lighting is needed in the kitchen especially at ranges, work tables and sinks to assure cleanliness, safety and good housekeeping.

12 DAYLIGHT CONSIDERATIONS

12.1 Special attention should be paid to the location of windows and openings in educational institutions which allow in a good amount of daylight, while designing a lighting system for any of the areas specified in this section of the code. Illumination should, however, be planned for night time use considering the various factors like evening classes, topography of the institution (for example, for an institution located in the eastern part of India, where the sun sets much earlier), climatic conditions of the place where the institution is located (for example, places where monsoons are prolonged or places in the northern part of India where till noon the sun remains hidden due to heavy fog during winter). Then in order to effect energy saving in the event of sufficient daylight filtering through the openings, due consideration should be given to switching arrangements so that an array of lights close to the windows could be switched off to extract the advantages of natural light.

13 RECOMMENDED ILLUMINATION LEVELS AND GLARE INDEX

13.1 The levels of illumination and glare index recommended for the different areas in educational institutions are given below:

Areas	*Illumination (lux)*	*Glare Index*
a) Classrooms	300	16
b) Lecture rooms (including) Demonstration areas)	300	16
c) Reading rooms	150 to 300	19
d) Laboratories	300	16
e) Corridors	70	—
f) Libraries	300	16
g) Auditorium		
i) Hall	70	—
ii) Foyer	70	—
iii) Stage area	300	16
h) Gymnasiums	150	—
j) Cafeterias	100	—
k) Staff Rooms	150	—

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NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 4 Hospital Lighting

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Complex requirements of hospitals both by the nature of their construction and the diverse needs of users complicate the lighting problem. Many of the areas are highly specialized in nature. These are operation theatres, clinics, treatment rooms and wards, where special lighting techniques and fittings will be required to achieve the desired standard of lighting, hygiene, electrical safety, reliability and ease of maintenance. Some areas (such as kitchens, offices and laboratories) have the same lighting requirements as of similar areas in other buildings.

Provision of a good lighting system calls for coordination from the initial stages among the various parties concerned, namely, the architect, the medical consultant and the illumination engineer. Therefore, it is essential that information regarding lighting should be exchanged between the parties from the stage of planning to installation.

The following Indian Standards are necessary adjuncts to this section.

IS No.	*Title*
1885(Part 16/Sec 1):1968	Electrotechnical vocabulary: Part 16 Lighting, Section 1 General aspects
3646(Part 1):1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for working interiors (First Revision)

NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 4 Hospital Lighting

1. SCOPE

This section of the code covers the principles and practices governing good lighting of hospitals. It recommends the levels of illumination to be achieved by general principles of lighting.

NOTE — General aspects of interior lighting, including assessment of glare, are dealt with in IS 3646(Part 1).

2. TERMINOLOGY

For the purpose of this section the definitions given in Part 1 of this code, IS 1885(Part 16/Sec 1) and IS 3646 (Part 1) shall apply.

3. GENERAL

3.1 The complex nature of a hospital layout and its requirement introduces conflicting considerations that have to be reconciled. For convenience, the accommodation can be divided into four main groups:

a) Rooms occupied by the patients, for example, wards, day spaces for the sick and visiting rooms;

b) Special rooms, for example, operation theatres, recovery rooms, diagnostic centers, laboratories, and examination rooms;

c) Service areas, for example, kitchen and dining rooms, sterilizing rooms, laundry and maintenance rooms; and

d) Administration rooms, for example, offices.

4 LIGHTING OF PATIENTS' ROOMS

4.1 General

The patients' rooms in a hospital often account for more than half of the useful floor space. The lighting of patients' rooms is of great importance and has to satisfy the needs of the patients as well as those of the medical and nursing staff. Moreover, the total lighting effect should be such as to contribute to the general decor and should be free of glare to the recumbent patient.

4.2 Lighting for the Wards

4.2.1 For the patients in the wards the lighting should create a cozy and pleasant atmosphere. Illumination level shall be as specified in IS 3646(Part 1). Some of the patients may like to sleep before the scheduled time of 'lights out' for which a provision shall be made for switching off and/or dimming of the lights.

4.2.2 Apart from general lighting, individual patients should be provided with additional lighting for any occasional reading or other handiwork that they may choose to do. This should be in the form of bed head lights which can be switched on or off by the patients themselves. These lights also contribute to the general appearance of the wards by breaking the monotonous uniformity that will result from the general lighting.

4.2.3 It may also become necessary under certain emergencies to examine the patient in the ward itself for which an additional examination light capable of achieving 500 to 1 000 lux may be provided.

4.2.4 At night after 'lights out' the wards cannot be left in complete darkness. The nursing staff should be able to take in the ward at a glance to satisfy themselves that everything is all right. Those patients who can move should also be able to make their way to the lavatory. A night lighting system which gives enough illumination (about 1 lux) for this purpose but which does not disturb the sleeping patients is also, therefore, necessary in a ward.

4.2.5 The lighting installation in a ward, therefore, calls for:

a) general lighting;

b) reading lamps;

c) examination lighting; and

d) night lighting.

4.2.6 *Lighting for the Medical and Nursing Staff*

This lighting is mainly utilitarian for the staff so that it should be adequate to enable them to carry out their routine tasks, such as, reading thermometers, making charts, and attending patients. A level of illumination as specified in IS 3646(Part 1) shall be provided. However, provision should be made for switching off and/or dimming some of the lights for the patients' comfort.

4.3 Maternity Department

4.3.1 *Nursery Lighting*

Nursery lighting should be subjected to the same recommendations as for ward lighting. Lighting of rooms of a special baby care suite may be similar as for nurseries.

4.3.2 *Luminaire Design*

The mechanical and electrical design of luminaires should take account of the high ambient temperatures and relative humidity experienced in rooms of the special baby care suite.

4.4 Physiotherapy Department

4.4.1 Special lighting applicable to this department should have the following average illumination levels at 0.8 m above the floor:

Gymnasium	100 lux; and
Hydrotherapy	100 lux.

It should be borne in mind that illumination will be required to the bottom of the bath or pool used for hydrotherapy.

4.5 Installation

The mounting height of the luminaires, for general lighting, should be determined by the geometry of the viewing angle and the provision for upward light. In wards 3 m high and greater, it will usually be possible to suspend luminaires from the ceiling, but in wards of less than 2.5 m in height, recessed or surface mounted luminaires are recommended. It is now generally possible to light a multi-bed ward by the use of wall mounted luminaires alone using their indirect component for the aisle.

4.6 Bed Head

A bed head luminaire should be mounted over each bed and be capable of being controlled by the patient in such a way that adequate illumination is provided on reading matter, for example, without causing visual discomfort to other patients. The luminaire should be designed to allow for reading, whether a patient is sitting up or lying down, and it should be capable of being swung back to allow beds and apparatus to be moved. To permit continuous and adequate observation of seriously ill patients, after the general lighting is switched off, provision should be made for night watch lighting. The most convenient arrangement is an additional small wattage lamp housed in the bed head luminaire or a dimming circuit controlling the normal reading lamp. An illuminance of 5 lux is considered adequate for this purpose.

4.7 Consistent with the above broad requirements, recommendations as to how these could be achieved are given below.

4.7.1 *General and Reading Lighting*

The following two systems are possible:

a) General lighting is provided by pendant fittings hanging from the middle of the ceiling and having an indirect or direct light distribution. Reading lighting is provided by a small bedside luminaire fixed to the wall behind the bed; and

b) In the other system both the general lighting and reading lighting elements are incorporated in the same luminaire fixed on the wall above the beds.

4.7.1.1 In both the systems the general lighting is controlled from a central point and the reading lights by the individual patients.

4.7.2 *Examination Lighting*

It is never satisfactory to use the reading lamp as an examination lamp also. Whether a separate examination lamp is to be provided at each bed will depend on the frequency of its likely use. Where such use is only occasional, a good solution will be to have a mobile examination lamp that can be wheeled along and connected to a wall socket by the bedside.

4.7.3 *Night Lighting*

A satisfactory night lighting system can be provided by a number of small luminaires (with low wattage lamp) recessed into the wall at a height of about 30 cm above the floor level. Efforts should be made to screen the luminaire to avoid direct glare.

4.8 Glare

The glare in hospital wards should be limited, on the assumption that the patient may get a direct view of the luminaire when in a recumbent position.

With the exception of recessed luminaires the amount of light directed on to the ceiling by any luminaire should, in general, be between 40 percent and 10 percent of its total light output. The luminaires selected should not harbour dust and should be easy to clean.

5 LIGHTING OF SPECIAL ROOMS

5.1 Operation Theatre

5.1.1 *General*

The main visual problems are the detailed examination of human tissue and organs and the manipulation of surgical instruments at the site of the operation.

The size of critical detail can be exceedingly small and the contrast very low. The required illuminance ranges between 10 000 lux and 50 000 lux.

Operation table lighting equipment can be divided into two main categories:

a) Adjustable luminaires, containing one or more tungsten filament lamps, with cantilever suspension from the ceiling, operated locally by the surgeon or an assistant. The vast majority of luminaires are within this category. They have the advantage of being simple to control and easy to maintain and relamp. The main criticisms are that it is difficult to ensure that such luminaires are thoroughly hygienic and that they produce location concentration of radiant heat; and

b) A number of sealed and adjustable projectors installed in the ceiling of the theatre are located outside so as to direct their light through a transparent ceiling. They are operated by remote control and thus require skilled manipulation. Such systems are highly versatile and are very useful in teaching hospitals, as they do not obscure the views to observers. They are more complex than (a).

Portable floor standing lighting equipment is normally required for supplementary use with systems (a) and (b).

Provision should be made for the dimming of the general lighting in operation theatres. To prevent interference to sensitive medical equipment, high frequency filters and shielding bonded to earth should be considered for fluorescent lighting in operation theatres.

To ensure a satisfactory gradation of brightness between the high illuminance at the site of the operation and the surrounding areas, a minimum general illuminance of 300 lux is recommended and this is normally adequate for staff operating the ancillary equipment.

5.1.2 *Other Rooms*

The general lighting throughout the operation theatre suite including recovery rooms, laboratories, plaster rooms, endoscopy rooms and anaesthetic rooms, should be similar in type to that of the theatre. The recovery room requirements are similar to those for the general wards, but provision should be made for connecting an examination lamp and separate switching should allow the illuminance over each bed to be raised to 400 lux.

In view of the proximity of the anaesthetic room to the operating theatre, a general illuminance of 300 lux is recommended with provision for dimming to enable anaesthetists to provide suitable environmental conditions. Provision should also be made for a fixed or portable spotlight.

5.1.3 *Luminaires*

Luminaires should meet the requirements of hygiene and should be totally enclosed to provide adequate mechanical protection to the lamp and to prevent hot particles falling into the danger zone in the event of lamp breakage.

5.1.4 *Light Sources*

For the general lighting of the operation theatre suite, tubular fluorescent lamps that have the colour temperature about 4 000 K and CRI over 90 are recommended. One advantage in the use of tubular fluorescent lamps is that they radiate appreciably less heat than tungsten filament lamps. For lighting the operation table, however, tungsten filament lamps are generally preferred because of their suitability for optical control.

The colour rendering properties of the light sources should be the same as those used for the general lighting of the theatre. Colour rendering of skin and tissue is a critical aspect of hospital lighting and primary light sources should have an emission spectrum that provides clinically acceptable colour rendering.

5.2 Standby Lighting

Failure of the electric supply or lamps during an operation may have serious consequences and it is necessary therefore to provide a permanent, reliable and safe emergency lighting system for the operation theatre, anesthetic room, sterilizing sink and recovery rooms. The emergency lighting of the operation table should be equal in all respects to the normal lighting of this area, and should be of the 'no break' type to ensure continuous illumination.

5.3 Anaesthetic Room

In view of the close association of this room with the theatre proper, a general illumination of 300 lux is recommended with provision for a spotlight (which can be either fixed or portable). The general lighting should not be directly over the centre of the room but the luminaires should be designed to provide some illumination on the ceiling. Dimming of the light may be required to enable the anaesthetist to provide suitable environmental conditions.

5.4 Recovery Room and Intensive Care Units

The presence of large quantities of other portable apparatus renders the use of portable lighting equipment undesirable. General lighting should be installed as in a normal ward with a separate system to raise the illumination level up to 400 lux for each bed independently. This should be provided over an area of 3 m x 2 m centered on the bed and the luminaire designs should be such as to limit the spread on adjacent beds. A dimming arrangement of the individual bed lights should be provided for. Some discomfort glare to a conscious patient is unavoidable under these conditions, but the recommended general lighting will produce a bright ceiling which will mitigate this effect.

5.5 Hazardous Areas

5.5.1 The zone of risk in an area where anaesthetic gases are used is defined as being 1.4 m above the floor and extending to a radius of 1.2 m beyond any point where an anaesthetising machine may travel.

5.5.2 Luminaires installed either in or above the zone of risk should be totally enclosed to provide adequate mechanical protection to the lamp, and to prevent hot particles falling into the zone in the event of lamp breakage (other requirements, for example, limitation of glare, provision for hosing down, demand that the lamps should be fully enclosed, should also be taken into consideration while selecting the luminaires in hazardous areas).

5.5.3 Ballasts, capacitors and other control gear associated with luminaires should be installed outside the zone of risk. If installed above the zone of risk they should be totally enclosed in incombustible housings.

5.6 Radiograph Department

5.6.1 In the screening room due to the necessity of maintaining low brightness levels, normally incandescent lamps of ruby red glass bulbs or fluorescent lamps with red fluorescent powder are used. Red is chosen because this colour of light has only little effect on the state of adaptation of the eye. In the processing room, 15 watt dark room lamps, green or reddish brown depending on the film material, are used.

5.6.2 In the viewing room where the radiographs are studied and assessed, artificial lighting is used in the viewing boxes. Use of fluorescent lamps of about 8 to 10 watts is recommended.

5.6.3 For the general lighting required for the cleaning of the rooms, for setting up the apparatus, etc, an illumination of 100 lux is provided in all these rooms.

6 OTHER TREATMENT AND SERVICE ROOMS

6.1 The lighting of other treatment rooms does not present any special problem. A normal general illumination of 200 lux will serve the purpose. The lighting of service rooms, such as offices, laboratories, kitchens and laundries, can be tackled in the same way as corresponding interiors in other buildings [*see also* IS 3646(Part 1)].

7 CORRIDOR LIGHTING

7.1 Corridors in a hospital serve a more important function than in many other buildings because they act as transitional areas between the wards and the service rooms and between the naturally lit and artificially lit rooms. Doctors discuss their work with their colleagues and make notes. Thus the corridors act as a working area. Corridors also fall within the visual range of the patients in the wards and therefore require special attention. The artificial lighting to be provided in the corridors will depend on the architectural layout adopted for the building. Generally two types of layouts are followed.

7.2 In the 'single corridor' lay out, the wards and the service rooms are on both sides of the corridor. The corridor itself will have enough daylighting. In the evening the service rooms will have an illumination of about 200 lux and the lighting level in the ward will be of the order of 100 lux. The corridors shall have an illumination of about 100 lux so that the staff moving between the service rooms and the wards will gradually adapt themselves to the different illumination levels. But after 'lights out' there will be only night lighting in the wards and the corridors should also be provided with a similar night lighting arrangement. The service room lighting should also be reduced to half its value in the evening.

7.3 In the 'double corridor' or 'race track' plan the wards are placed around the outside of the building and are normally daylighted. In the centre of the building are the service rooms which will have no access to daylight and will require artificial lighting all the times. During the day the staff will move between the wards receiving daylight of 500 to 1 000 lux and the internal rooms artificially lit to a level of 200 lux. The corridor should bridge these two levels and an illumination of 150 lux shall be provided in the corridors during the daytime. In the evenings the ward lighting will fall to 100 lux and the corridor lighting may be reduced to the same level. After 'lights out' both the ward and the corridor will have night lighting and the service room illumination shall therefore be reduced to about 100 lux which will be just sufficient for the staff to carry on their normal work and will also reduce the excessive contrast between the brightness levels in the service rooms and the wards or corridors.

8 RECOMMENDED ILLUMINATION VALUES AND GLARE INDEX

8.1 The levels of illumination and glare index recommended for the different areas in a hospital according to IS 3646(Part 1) are given in Table 1.

Table 1 Illumination Values and Glare Index
(*Clause* 8.1)

Sl. No.	Classification	Illumination (Lux)	Limiting Glare Index
(1)	(2)	(3)	(4)
i)	Reception and waiting room	150	16
ii)	Wards		
	(a) General	100	134*
	(b) Beds	150	—
iii)	Operating theaters:		
	(a) General	300	10
	(b) Tables	special lighting	—
iv)	Laboratories	300	19
v)	Radiology departments	100	—

*Care should be taken to screen all bright areas from view of patients in bed.

9 LIGHT SOURCES

9.1 The choice of light source is generally a matter of economy. In hospitals an additional factor comes into play, especially in clinical areas like the operation theatres and post operative wards. This is the effect of the artificial lighting on the natural skin colour of the patients. In the past, most artificial light was produced by tungsten filament lamps and the doctors became familiar with the appearance of patients in varying conditions in this light. But in view of the improved economy and advent of new technology, new generation energy efficient lamps are now being extensively used in important installations in hospitals so as to have better electrical, photometric and colour rendering properties.

10 COLOURS IN HOSPITALS

10.1 Colour can play an important and useful role in creating the desired atmosphere in hospital interiors. It will be necessary not only to consider the colour scheme design in daylight, but also to find out the effect on it of the light source to be used. A well chosen colour scheme can also support the effect of the lighting by increasing or decreasing the effect of contrast. Depending on the use to which the room is to be put, a correct combination of light and colour can result in the desired liveliness or a quiet atmosphere.

11 PERMANENT SUPPLEMENTARY ARTIFICIAL LIGHTING

11.1 Permanent supplementary artificial lighting of interiors as described in IS 3646(Part 1) may be useful in hospitals not only to permit deep wards to provide good overall lighting of the appropriate quality, but also in laboratories, service and ancillary rooms where a controlled level of working illumination is desirable and in administration offices where the lighting problems are similar to office lighting elsewhere.

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NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 5 Lighting for Other Public Buildings

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Requirements of lighting in public buildings are complex and require custom-made solutions. The requirement depends on the nature and type of application which is substantiated through availability of provisions. The following Indian Standard is a necessary adjunct to this section.

IS No.	*Title*
3646(Part 1):1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for working interiors (First Revision)

NATIONAL LIGHTING CODE

PART 5 INTERIOR ILLUMINATION
Section 5 Lighting for Other Public Buildings

1 SCOPE

This section covers the principles and practices governing good lighting of public buildings, such as shops, hotels and places for public assembly and entertainment. It recommends the levels of illumination to be achieved by the general principles of lighting.

NOTE — General aspects of interior lighting, including assessment of glare, are dealt with in IS 3646(Part 1).

2 TERMINOLOGY

For the purpose of this section, the definitions given in Part 1 of this code shall apply.

3 SHOPS

3.1 General

Most selling areas do not receive a significant amount of natural light and reliance is placed on artificial light sources. While adequate general lighting should be provided for safe movement over the whole area used by the public, higher illuminance levels are needed for selling and display.

3.2 Lighting Layouts

3.2.1 There are two quite separate lighting techniques:

a) An overall high illuminance of 600 to 1 000 lux, as used in supermarkets and multiple stores; and
b) An illuminance of 100 to 200 lux from a general lighting system with additional highlighting of display areas, as in a boutique or jeweller's shop. This requires a more flexible electrical installation than that of **3.2.1**(a) above to permit frequent changes of display layouts. Systems incorporating a light track with bus bar connection for spotlights and pendant luminaires are suitable, including dimming of certain sections.

3.3 Lighting Requirements for Shop Interiors

3.3.1 A good shop lighting design will effectively create a good balance between general lighting and accent lighting. Attention should be paid to vertical displays, especially shelves along the periphery, areas of special interest, etc. New generation fluorescent lamps (T8 and T5), compact fluorescent lamps, ceramic discharge metal halides, dichroic halogen lamps are preferred light sources for such applications.

3.4 Lighting Requirements for Shop Windows

3.4.1 The lighting should primarily enhance the merchandise and the display treatment and the level of illuminance should be chosen bearing in mind the immediate surroundings.

If window displays are to be lit during the day, a very high value of illuminance is usually needed, both to compete with the general daylight illumination and to minimize reflections of the street seen in the front glass.

For single aspect windows, the main lighting should be from the front, and interest may be added by using limited back lighting. The avoidance of glare is no problem provided that bare lamps are not exposed to public view.

Multi-aspect windows always present a problem if glare is to be avoided from opposing viewpoints. Large scale louvres or baffles over the ceiling can be used to screen luminaires and, in general, the light should be directed more vertically than in single aspect window displays. Spotlights with optical systems giving reasonably precise light cut-offs are usually the necessary components of this type of installation.

It is common practice to use a variety of light sources within a single window. The general lighting will often be provided by tubular and compact fluorescent lamps, but accent lighting will invariably be from high intensity discharge lamps like ceramic discharge and quartz metal halide lamps housed in appropriate luminaires. Colour filters are also used for special effects.

In many windows the lighting arrangements have to be changed frequently to suit new displays, so a light track system should make this both possible and convenient.

Provision should be made for adequate ventilation in order to avoid overheating the lighting equipment and merchandise.

Window lighting may be required after the shop has closed and this is normally achieved by controlling the light circuit with a time switch.

4 RESIDENTIAL

4.1 General

This clause deals with the lighting requirements of kitchens, bathrooms, living rooms, entrance halls, landings, stairs, bedrooms, garages, workshops and the external lighting of houses, flats and apartment houses, study and bedrooms of hostels and guestrooms and lounges of hotels.

4.2 Illumination

Unlike industrial and commercial interiors, the uniform illumination of domestic areas is seldom necessary or even desirable. Low-key general lighting plus supplementary lighting, where needed is usually acceptable. Lighting can also be used primarily for decorative effect.

a) *Kitchen and Dining Areas*

General lighting should be provided by at least two luminaires, one of which should be arranged to give a higher level of lighting over the main working areas, that is, the sink unit and cooker. The luminaires should preferably be switched separately. Tubular fluorescent lamps are particularly suitable for kitchens in view of the reduced shadowing effect. The lamps should have a colour rendering index greater than 80 to enable the proper colour of foodstuffs to be seen;

b) *Main living areas*

Although individual requirements will vary widely, more than one light source will always be required to provide a range of illuminance. Consideration should be given to the provision of wiring points for the lighting of pelmets, pictures, etc;

c) *Bathrooms*

Lighting should be switched from outside the room or by a pull cord inside the room. All luminaires should be earthed or double insulated. A luminaire should be provided for the bathroom mirror for facial illumination;

d) *Bedrooms*

Lighting control with local switches is normally required near the bed head position. A high illuminance is required for the dressing table; in the absence of information regarding its position, one solution is the use of portable luminaires; and

e) *Hallway and stairs*

Two way switching is required at the top and bottom of staircases and also for large hallways. In the latter case, one switch should be near the main door entrance and the other switch close to the staircase. The staircase luminaire should be positioned so as to illuminate all stair treads and glare should be avoided.

4.3 Special Requirements

Provisions should preferably be made for:

a) lighting in the loft or in cellars with a switch close to the trap door;

b) lighting outside all external doors;

c) an illuminated house number and bell push;

d) lighting in the garage switched from the normal exit door (two way if necessary); and

e) lighting in deep cupboards with door operated switches.

4.4 Multistorey Residences

Separate 'landlord' lighting circuits are required for corridors, lobbies and exterior paths. An all night lighting system should be installed in these areas and this can be provided economically by the use of miniature tubular or compact fluorescent or other low wattage discharge lamps.

5 HOTEL

There is a great diversity in the lighting requirements of hotels and catering establishments, ranging from the illumination of public rooms such as ballrooms and large dining rooms, where the emphasis is on lighting of a decorative character, to the more modest requirements of hotel bedrooms and private sitting rooms.

Bedrooms should have supplementary lighting over writing desks, bed heads and wash basins.

General lighting in the lounge should be sufficient for casual reading.

Desks should be provided with local lighting luminaires; care should be taken to ensure that these do not cause glare elsewhere in the room, that is, adjustable luminaires may need to have a limited range of movement.

Special attention should be given to the illumination of fire escape routes.

Many of the hotel lighting requirements are also applicable for hostels.

5.1 Hotel Dining Rooms and Restaurants

In hotel dining rooms and restaurants, the character of the lighting is often more important than illuminance. A minimum illuminance of 100 lux on dining room tables is recommended, but this should be applied with discretion.

In many schemes, the lighting is often required to be subdued and intimate in character. Tungsten filament or compact fluorescent lamps in table luminaires are often used for this purpose and these can provide satisfactory 'highlights' on the silver and glassware, and at the same time provide sufficient general light to reach the faces of the diners. One alternative is to use 'downlights' to light tables, and in this case wall lights may be required in addition, to give the necessary subdued general lighting and to improve the modelling effect.

Where a room is required for a variety of functions, it may be necessary to provide for a high illuminance with suitable switching and dimming facilities. Reduced lighting should not be obtained by switching off some of the lamps in multilamp luminaires if this gives rise to a patchy appearance.

In large rooms, where daylight alone may be adequate only in some parts of the room, it may be necessary to supplement the daylight permanently with artificial lighting. Separate lamp circuits and control switches may be required to provide the necessary flexibility for both daytime and night time use.

5.2 Canteens

When lighting canteens, an attempt should be made to give the interior a more relaxing character than obtainable by a purely functional approach, even if the installation is confined to overhead lighting. A suitable average illuminance is 200 lux and, if tubular fluorescent lamps are used, they should have a colour rendering index of not less than 80 and give a reasonably warm colour appearance.

5.3 Hotel Bars

In lounges and public bars a minimum average illuminance of 70 lux is recommended. Focal points, such as tables and bar counters, however, should have a higher illuminance than the remainder of the room.

In cocktail bars, provision should be made for two values of illuminance, low for normal use and higher for use by cleaners, for example. In all bars, particular attention should be given to lighting the till and the sink in the service areas with local luminaires, in addition to providing a well diffused illumination for the whole service area. A typical arrangement includes low wattage tungsten filament or compact fluorescent lamps in 'downlights' over the counter, recessed tubular fluorescent lamps over the service area, and enclosed local luminaires to light the sink. Attractive lighting of bottles on display, either from behind or from the front can be attempted.

5.4 Hotel and Restaurant Kitchens

In the kitchens of catering establishments, the lighting has to be designed to cater for the wide range of activities associated with the preparation and serving of food. A general illuminance of 200 lux is recommended and working areas should have an illuminance of 300 lux. In kitchens where there are hoods over the cookers and other equipment, the luminaires may be installed within the hoods themselves and, consequently, they should be suitable for the higher temperatures and humidities involved.

All luminaires should be totally enclosed with clear acrylic or glass covers so as to exclude moisture and to facilitate cleaning. Lamps that have a satisfactory colour rendering should be chosen. Food service areas should be treated in the same way as the kitchen, with lamps having the same colour rendering.

6 PUBLIC ASSEMBLY AND ENTERTAINMENT

6.1 General

This clause deals with assembly halls, concert halls, theatres, cinemas, dance halls and exhibition halls and parts of such buildings to which the general public have access, for example, foyers, corridors, stairways, auditoria and service areas. Safety lighting is required to assist members of the public to leave the premises if the normal lighting is switched off. Emergency lighting is also required to be immediately available in the event of failure of the mains supply.

6.2 Foyers

In foyers, the lighting should be such that visual adaptation can be satisfactorily achieved when entering or leaving the building during both day and night.

The necessity for visual adaptation coupled with the advertising value of bright surroundings, has often led to the adoption of higher illuminances than the minimum recommended. Tungsten filament, compact fluorescent and tubular fluorescent lamps can be used for these areas, the choice generally depending on aesthetic considerations.

The problem of visual adaptation between the brightly lit foyer and the darker auditorium should be solved by progressively reducing the illuminance in the connecting corridors.

In cinema and theatre foyers the luminaires should be decorative, but at the same time provide adequate illuminance.

6.3 Auditoria

In multipurpose halls the lighting system should be as versatile as possible. If a substantial reduction in illuminance is required, the lighting should be capable of being dimmed smoothly or switched in stages.

Cinemas and auditoria may be provided with direct or indirect lighting, or a mixture of both, but all visible luminaires should be decorative and compatible with the interior design.

6.4 Stage Areas

In assembly and concert halls a means should be provided to highlight the performers either by increasing their illuminance or by subtly dimming the auditorium lighting in order to focus the attention in the required direction. To enhance modelling, some light may be directed onto the stage from the sides of the auditorium and from as high up as possible.

6.5 Dance Halls

Dance halls require good general lighting, usually capable of being dimmed, over the dance floor and adjacent areas. Although this may be provided by tubular fluorescent lamps, it is usual to add a degree of sparkle and modelling by the use of luminaires with incandescent lamps. In addition, the provision of special effects produced by coloured lighting or ultraviolet radiation is often a permanent feature of dance hall installations.

6.6 Exhibition Halls

Exhibition halls should be uniformly illuminated by general lighting having reasonable colour rendering properties. Provision should be made for additional electrical outlets for the directional lighting of exhibits.

6.7 Special Lighting Requirements

Recommended systems of lighting in cinema premises and other similar public premises are as follows:

a) In auditoria during the entertainment: both safety lighting and subdued general lighting;
b) In auditoria during intervals: both safety lighting and normal general lighting; and
c) Passages, stairs, etc and exterior exit ways: in the absence of adequate daylight, both safety lighting and general lighting.

7 RELIGIOUS PLACES

7.1 General

The lighting of places of worship usually has to comply with two requirements:

a) there should be sufficient illuminance for devotees to congregate, read prayer and hymn books; and
b) the lighting should be designed to blend with the architectural character of the interior and contribute to the ceremonial aspects of the 'service'.

The architectural features of buildings designed for public worship (churches, mosques, temples, etc) vary widely in respect of each building. Because of this diversity, there is great scope to relate the lighting to each of those architectural designs and it is not possible to do more than mention a few of the possible lines of approach.

For churches, lighting equipment can usually be concealed behind roof trusses, in windows, in recesses, in vaulted roofs and in arches. Luminaires positioned behind the chancel arch can be concealed from the congregation and be so mounted as to illuminate the chancel, choir and sanctuary.

For mosques or temples with vaulted high ceilings, a similar procedure can be adopted. A simple and effective method of general lighting is the use of pendants and wall brackets which should be aesthetically harmonious with the building. Luminaires should be so positioned that they are not within the normal line of vision of the congregation and pleasing in appearance when the interior is viewed as a whole.

Direct downward lighting will result in dense roof shadows and so a proportion of upward light is recommended.

8 LABORATORIES AND RESEARCH ESTABLISHMENTS

8.1 General

The relationship between daylight and artificial light in laboratories requires special consideration. Some laboratories require a degree of environmental control that may be difficult with large windows. In others, a blackout may be required. Wall space is often at a premium in respect of storage. For these and other reasons, design solutions with smaller windows and the integration of daylight and artificial light may be favoured.

Work in laboratories ranges from reading and writing and other simple visual tasks where the detail is fairly large and the contrast good to very exacting tasks with minute detail and low contrast. Typical of the latter tasks are the reading of vernier scales or pipette marks, the identification of substances by their colour or texture, dissection work or the identification of fast moving objects.

Other important considerations are as follows:

a) Most scientific work involving the use of apparatus is done more easily when there is a fair degree of modelling. In practice, it is usually possible to achieve this, as well as to comply with the relevant recommended limiting glare indices. In cases where a high degree of modelling is required, adjustable local luminaires are necessary;
b) Deep cupboards may require internal lighting with door operated switches;
c) In some laboratories, because of the presence of corrosive or explosive atmospheres, luminaires designed to withstand these conditions should be used; and
d) Cleanliness is essential in many laboratories, and the luminaires should not harbour dust or insects and should be easy to clean.

8.2 Illumination

A research laboratory should have a uniform illuminance of not less than 600 lux. Tasks requiring higher illuminances should have additional local lighting. In many instances instruments such as microscopes or balances are provided with built-in lighting. Elsewhere, adjustable bench luminaires will be satisfactory for supplementing the general lighting. For critical tasks such as accurate colour matching the illuminance should be 1 000 lux minimum.

In order to compensate for the complexity of the equipment and the wide range of visual tasks, walls and other large background surfaces should be as plain as possible. Although in some instances the preferred bench top materials are inevitably dark, it is desirable to keep other main surfaces as light as possible so as to avoid introducing excessive brightness contrast.

8.3 Light Sources

In some laboratories, accurate colour rendering will be needed for the identification of materials or stages in a process and, in such cases, light sources that may distort the relationship of colours should be avoided. Colour rendering is not always critical, but where it could be, a source having a colour temperature of about 4 000 K and with a colour rendering index greater than 90 should be used. Preferably the illuminance should not be less than 1 000 lux.

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NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 1 General Features

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Well designed exterior lighting systems can make important contributions to the aesthetics, efficiency and safety of the public, and to commercial and industrial outdoor environments. While designing, it is necessary to take into account the interests and needs of users and to meet the general requirements of the authorities concerned.

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 1 General Features

1 SCOPE

This section of the code deals with the general aspects of lighting design, lighting equipment and photometric requirements of exterior lighting installations.

2 TERMINOLOGY

The definitions given in Part 1 of this code shall apply.

3 BASIC PERFORMANCE REQUIREMENTS

3.1 Area Lighting Objectives

The objectives of area lighting are to ensure:

a) efficient and safe working conditions for personnel;
b) easy and safe movement of vehicles, ships, railway wagons, aircraft, etc and pedestrians;
c) security of people and property; and
d) a pleasing visual environment, particularly for decorative lighting.

3.2 Visual Perception and Basic Lighting Principles

3.2.1 In order to meet the above objectives, the lighting system must create the right conditions for good visual performance for efficient and fast assessment of form, movement, distance and colour.

The visual performance for a given visual task depends on:

a) the luminance of the visual task;
b) the luminance of the background of the visual task;
c) limitation of direct and reflected glare; and
d) the colour rendering properties of the lighting (if the visual task includes colour discrimination).

3.2.2 *Luminance and Illuminance*

In practice visual perception tends to improve with the apparent size of the visual task, its contrast with the background and the average luminance level of the visual field. It is not normally possible to change the size of viewed objects; however, the visual tasks can be made easier if the size of critical detail is increased (for example, the size of print on labels) and if light colours are used against dark backgrounds (for example, yellow painted vehicle barriers). In a given situation the average luminance is dependent on the lighting system employed. In principle the lighting design should be based on luminances, but in practice it is not always possible to do this because of the complexity of the visual scene.

The use of illuminance as a criterion in area lighting is more convenient as people do not normally have a well defined line of sight (as in traffic situations). When illuminance criteria are used as a basis for design, then they must be used in such a way that adequate luminances are achieved.

Usually illuminance is given in a horizontal plane, but often the vertical illuminance values are more important (for example, on the sides of ships in shipyards or reading the labels of goods on pallets).

Therefore, when planning the lighting, the relative importance of horizontal and vertical illuminances and the direction of the light must be borne in mind.

3.2.3 *Uniformity of Illuminance*

In this field of area lighting application, uniformity of illuminance is best defined as the ratio of the minimum illuminance to the average illuminance over the relevant area.

In certain cases the use of the ratio of the maximum illuminance to the minimum illuminance may be required.

Uniformity depends on the luminous intensity distribution, the spacing to mounting height ratio and the direction of the beams of the luminaires.

3.2.4 *Glare Limitation*

Glare is a condition of vision which causes discomfort or disability reducing the ability to see significant objects. It arises because of an unsuitable luminance distribution or extreme luminance contrasts in space and/or time. Therefore, when designing lighting installations care should be taken to limit glare. Important factors affecting glare are the choice of the type of luminaire, the mounting height, the direction of the beams and the background luminance.

3.2.5 *Colour Appearance of Lamps and Colour Rendering*

The colour qualities of light sources are characterized by two properties; the colour appearance of the light and the colour rendering index. The colour appearance of the light can be described by the correlated colour temperature of the light.

In area lighting, colour discrimination is not normally very important, but the colour appearance of the light may be an important factor for psychological reasons.

4 LIGHTING EQUIPMENT

Care should be taken to select the right combination of lamp, luminaire and mounting system to fulfill the lighting requirements. Necessary details on light sources, control gear and luminaires are given in Part 3, Section 1 and Section 2 and Part 4, Section 1 respectively.

4.1 Mounting and Suspension Systems

4.1.1 *Columns upto 15 Meters*

These columns can be manufactured from steel, concrete, aluminium, glass reinforced plastic or wood. Access for maintenance and lamp replacement is possible using portable manually operated towers or vehicle mounted access units. On the more substantial columns access can be gained by means of built-on hooped rung ladders.

4.1.2 *Hinged Steel Columns*

These columns are available for mounting heights up to about 25 metres, and they allow the luminaires to be brought down to ground level for maintenance and lamp replacement.

4.1.3 *High Masts*

These are made from hollow steel, aluminium welded sections or concrete and can be used for mounting heights up to 50 metres or more. The luminaires can be mounted on a carriage which can be lowered to ground level by means of cables and winches for maintenance purposes. Masts can also be made as a steel lattice construction, often with built-on hooped rung ladders and maintenance platforms.

4.1.4 *Building or Wall Mounting Luminaires*

Considerable savings can be achieved if use can be made of these. However, the question of access can often be a problem, which can sometimes be solved by the use of a raising and lowering system for the luminaires.

4.1.5 *Column and Suspension System Design*

The design must be suitable for the weight and windage of luminaires, control gear, etc, that are to be carried. The effect of wind induced or other vibrations must be taken into account.

5 AREA LIGHTING DESIGN

5.1 Recommended Illuminance and Uniformity Ratio

Table 1 gives a survey of recommended illuminances and uniformity ratios for different visual tasks.

Table 1 Recommended Value of Illuminance, Uniformity Ratio and Glare Limitation

(*Clauses* 5.1 *and* 5.4)

Visual task: Category	Visual task: Typical example	Maintained average horizontal illuminance, E_{av}(lux) not less than	Uniformity ratio E_{min}/E_{av} not less than
i) Safety and security			
low-risk areas	Industrial storage areas: occasional traffic only	5	0.25
medium-risk areas	Vehicle storage areas	20	0.25
	Container terminals with frequent traffic	20	0.40
high-risk areas	Critical areas within oil refineries, chemical plants	50	0.40
	Critical areas within electricity and gas works	50	0.40
ii) Movement and traffic			
pedestrian	Movement of people only	5	0.25
slow moving vehicles	Movement of fork-lift trucks and/or bicycles (10km/h)	10	0.25
normal traffic	Road lighting in container terminals (40km/h)	20	0.40
iii) General work			
very rough	Excavation, site clearance	20	0.25
rough	Handling timber	50	0.40
normal	Brick laying, carpentry	100	0.40
fine	Painting, electrical work	200	0.50

NOTES

1 If these requirements for horizontal illuminance are met, in general the vertical illuminance will be satisfactory.

2 If the visual task is in a vertical or an inclined plane the horizontal illuminance values given here may be used as surface illuminances.

Maintained average illuminance means that the average illuminance should not be allowed to fall below the given value during the life of the installation. In order to determine the initial illuminances required, maintenance factors which include schedule for cleaning and servicing, luminaire depreciation and lamp ageing should be taken into account.

Uniformity here is the ratio of minimum to average illuminance.

5.2 Colour Appearance of Lamps and Colour Rendering

The type of work carried out under area lighting seldom demands exact colour discrimination; normally lamps with a colour rendering index (Ra) between 20 and 60 are acceptable. If a particular area requires good colour discrimination, use should be made of lamps with a colour rendering index of over 70.

For more information on light sources, reference may be made to Part 3, Section 1 of this code. Further data, if required, may be sought from the manufacturers.

It is necessary to prevent confusion between the colour of general lighting and signal lights.

5.3 Lighting Design

5.3.1 *General*

A good lighting design produces good lighting with correct illuminance, uniformity and glare restricted to an acceptable level and at the same time employs the minimum number of light sources, columns and masts in order to minimize costs and the number of obstacles in the working area.

In important areas, light should be received from at least two different directions and from two or more sources to reduce harsh shadows and minimize the effect of a single lamp outage.

In many exterior lighting installations, where there is a risk of hazards such as fire or explosion, it is necessary to install a separate emergency lighting system, providing sufficient light for escape, aid, rescue and fire fighting.

5.3.2 *Mounting Heights*

The choice of mounting height tends to depend on the relative importance of various factors such as the visual task, the importance of minimizing obstructions, installation costs and any local site limitations and requirements.

5.3.2.1 *High mounting heights (over 18 metres)*

These are generally used for lighting large unencumbered areas with the advantage of minimizing the number of obstacles in the working area, so that mechanical handling equipment, cranes, etc, can operate unimpeded. From the maintenance point of view they have the advantage of collecting at a single point a large number of light sources. This can reduce the cost of maintenance.

5.3.2.2 *Medium mounting heights (between 12 and 18 metres)*

Although medium mounting heights increase the number of obstructions, they are often more suitable for medium and small installations and situations where there are a number of large tall obstructions such as buildings, storage silos, etc.

5.3.2.3 *Low mounting heights (up to 12 metres)*

Low mounting heights are normally only used for areas where local high level lighting is required, and/or where good light penetration is required between closely spaced obstacles (goods, stores, buildings, etc).

5.3.3 *Spacing and Mounting Height*

Generally the mounting height determines the maximum spacing between adjacent columns or masts. The recommended spacing is 3.5 times the mounting height. In certain cases this spacing can be reduced or increased, but special care will have to be taken to avoid excessive glare, long shadows and uniformity problems.

In order to restrict glare, luminaires should not emit significant amounts of light above 75 degrees from the downward vertical, when correctly installed and aimed. Otherwise they may produce excessive glare, both in the area intended to be lit and in its surroundings.

5.3.4 *Siting of Masts*

In planning the location of masts, special attention should be paid to the following:

a) Correct horizontal illuminance and uniformity over the working area;

b) Correct illuminance on vertical and horizontal surfaces of particular importance (sides of containers, for example);

c) Any point in important working areas should be lit by two or more sources from at least two directions;

d) Shadows cast by large obstructions such as buildings;

e) Siting masts to avoid obstructing work or movement of vehicles and pedestrians;

f) Where necessary, barriers should be used to protect columns or masts from accidental damage by vehicles;

g) Siting to avoid underground obstructions, drains, etc;

h) Directing light into adjacent areas should be restricted for example, residential areas, roads, railways, vicinity of airports, waterways, harbours; and

j) Access for maintenance purposes.

5.4 Lighting Calculations

Established methods for calculating of illuminance should be used taking into account relevant data for light sources and luminaires as published by manufacturers.

As the recommended illuminance values in Table 1 are maintained values, due consideration must be given to ageing of lamps, dirt accumulation, etc, in luminaires by applying a maintenance factor.

The calculations should be made for the specific installation and the associated operating and environmental conditions. The point by point method of calculation should be used to obtain average illuminance value and uniformity ratios. The calculation area should be divided into rectangular areas. Grids approximating a square are preferred; the ratio of length to width of a grid cell should be kept between 0.5 and 2. The maximum grid size (p) should not be bigger than 10 metres and can be calculated as

$$p \leq 0.2 \times 5^{\log d}$$

where

d = the width of the calculation area.

The illuminance values should be calculated at the centre of each rectangular grid. The horizontal illuminance is calculated on the average height of the task. If the height is not specified, it should be taken as 1 m above ground level. For traffic areas it should be ground level.

In the case of irregular shaped areas, points outside the main area must be ignored.

The average illuminance is calculated as the arithmetic mean of illuminances at all the calculation points. From these calculation points, minimum and maximum illuminances can be obtained for calculation of uniformity ratios.

5.5 Measurement of Illuminance

Care must be taken during measurements to check the compliance with the design calculations or how much the installation has depreciated or any improvement due to maintenance.

5.6 Maintenance

Part 13 of this code may be referred to determine the maintenance schedule, so that the average illuminance in an installation does not fall below the designed value of the maintained average illuminance.

5.7 Energy Conservation

A good lighting system should be energy effective without sacrificing the quantitative and the qualitative aspects of lighting. An energy effective lighting system is cost effective too. Details on this can be had from Part 9 of this code.

5.8 Environmental Aspects

Exterior illumination, if not properly designed, executed and maintained, can throw light in the wrong direction at the wrong time. This can then cause what is known as light pollution, which should also be seen as waste of energy and money.

Given below are some recommendations:

a) Lights, when not required, may be switched off;

b) For illuminating a task, wherever possible light should be directed downwards, not upwards. If there is no alternative to uplighting, then to keep spill light to a minimum, appropriate shields and/or baffles may be used;

c) Luminaires should be so designed that after installation the light distribution near or above the horizontal is minimal; and

d) The lighting standards for various tasks and applications may be strictly followed.

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NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 2 Industrial Area Lighting

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

This section of the code deals with all areas where industrial processes are carried out in the open, including the petrochemical industry and other hazardous areas, electricity generating stations, water and sewage works, etc. Also included are storage areas for raw materials, finished products, containers or crated goods, vehicles, etc and short term parking areas for vehicles, lorries and cars.

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 2 Industrial Area Lighting

1 SCOPE

This section provides details about the recommendations on exterior industrial area lighting.

2 TERMINOLOGY

The definitions of the terms used in this section are given in Part 1 of this code.

3 GENERAL LIGHTING REQUIREMENTS

3.1 Function of the Lighting

In general, the function of lighting systems in all categories mentioned above is to provide sufficient and suitable lighting for work, safe movement of vehicles and security of goods and premises.

In particular, it should be possible to use tools, machinery and instruments for assembly, construction and finishing of products in industrial processes, such as prefabrication of sections of bridges and buildings, cutting and grinding stone, welding and flame cutting, maintenance of production equipment, reading of meters and values in chemical processing, etc.

Petroleum and chemical plants involve some means of receiving, storing, processing, refining and shipping of petroleum or similar fuels or other gaseous, liquid or solid materials.

The visual tasks are reduced to very basic operations such as turning a valve, starting a pump, or just walking or driving through the areas. Supplementary local lighting should be provided where more critical visual tasks are to be performed.

In most modern continuous process plants maintenance work is scheduled during the daytime shifts. When maintenance is required at night, portable lighting should be employed.

Generally, modern refineries have sophisticated automatic control systems that eliminate or simplify the visual tasks. Consequently, many areas require illumination only for the safe movement of personnel, whilst areas that are only used during the day do not require lighting except possibly for emergency and security reasons.

Electricity generating stations include fuel storage and handling yards, substations, transformers and switching yards, etc. In these areas lighting has to provide clear indication of areas of restricted access; safe and fast emergency repairs and replacement of critical parts and strict security.

Water and sewage works have chemical treatment and filter beds, pumping areas, etc. There has to be clear indication of the position of walkways and ladders, operation of valves, pumps and other equipment, discouraging intruders (in particular children), etc.

In storage areas, identification of goods, accurate handling of containers, goods and materials and reading of labels are the main tasks.

In parking areas, general orientation, finding entrances and exits, location and identification of particular vehicles and perception of obstacles are the requirements.

Steps must be taken to ensure that the lighting does not cause any danger due to glare, deep shadows or confusion with signal lamps. The lighting installation must be carried out in such a way that there is no risk of explosion (from gases given off in sewage works or from the fuels used by an electricity generating station) or electrical shock. Masts and towers must not cause hindrance to work or movement.

3.2 Recommended Values for Illuminance and Uniformity Ratio

General guidelines on these can be had from Table 1 of Part 6, Section 1 of this code. Table 1 below gives typical examples for different category of visual tasks, in industrial storage and parking areas, electricity generating stations and water and sewage works.

Table 2 gives a survey of the recommended values for different areas, machinery and equipment, and working tasks in petrochemical industries.

The recommendations in this table have been established on the basis of the quantity and quality requirements commonly experienced for refinery exterior lighting.

Where particular visual tasks require a supplementary local lighting, a lower uniformity in the surrounding area than that given in Table 2 may be acceptable.

Horizontal illuminance is the main consideration, but sometimes it is necessary to consider illuminance on vertical surfaces (for example, vertical storage racking, measuring instruments and reading gauges.)

Table 1 Typical Example for Different Category of Visual Tasks, in Industrial Storage and Parking Areas, Electricity Generating Stations and Water and Sewage Works

(*Clause* 3.2)

Sl. No.	Category	Typical Example
i)	***Security***	The level of risk is determined by considering the probability of accidents and the consequence of loss or damage to the equipment, plant or community.
	Low risk areas	Outside perimeter, coal storage yards.
	Medium risk areas	Oil storage yards, waterworks, switchyards of electricity works.
	High risk areas	Switchyard entrances.
ii)	***Movement and Traffic***	
	Pedestrian	Movement of personnel in dangerous areas (for example, high-voltage walkways).
	Slow moving vehicles (5-10 km/h)	Locations of cars, avoiding obstacles in parking areas, excavating machines.
	Normal traffic (40 km/h)	Lighting of access roads, parking areas in main arteries.
iii)	***Work***	
	Very rough	Handling large objects and raw materials (short duration), loading and unloading bulk materials, unloading coal trucks.
	Rough	Handling large objects and raw materials (continuously), stowing cargo, toll booth in parking areas and general inspection work.
	Normal	Ordinary work with tools, reading labels, general maintenance work and meter reading.
	Fine	Printing, electrical work, all work with power tools, pipe fitting, inspection, repair of electrical equipment.

Table 2 Recommended Values for Illuminance, Uniformity Ratio E_{min}/E_{av} in Lighting of Petrochemical Industries and Other Hazardous Areas

(*Clause* 3.2)

Sl. No.	Visual Task: Category	Visual Task: Typical example	Maintained Average Horizontal Illuminance E_{av}(lux)(min)	Uniformity Ratio E_{min}/E_{av}(min)
(1)	(2)	(3)	(4)	(5)
i)	***Areas***			
		Working areas		
		a) General process area	10	0.25
		b) Cooling towers and water pump area	50	0.40
		c) Boiler and air compressor area	50	0.40
		d) General loading areas	50	0.40
		e)Fuel loading and unloading points	100	—
		Storage areas		
		a) Without obstacles	10	0.15
		b) With obstacles high risk areas	50	0.40
		Electrical substation		
		a) Outdoor switch yards and general substations	20	0.40
		b) Switch racks	50*	—
		c) Substation operating aisles	100	0.40
		Tanker dock facilities		
		a) General areas	10	0.25
		b) Hose handling, manifold and loading point	50	0.25
ii)	***Machinery and Equipment***			
		General process units		
		a) Maintenance platforms, infrequently used ladders and stairs	10	0.15

Table 2 (*Concluded*)

Sl. No.	Visual Task: Category	Visual Task: Typical example	Maintained Average Horizontal Illuminance E_{av}(lux)(min)	Uniformity Ratio E_{min}/E_{av}(min)
(1)	(2)	(3)	(4)	(5)
		b) Pump rows, valves, manifolds	50	—
		c) Operating platforms, (frequently used) ladders and stairs	50	0.25
		d) Gauge glasses and instruments on process units	50*	—
		Specialty Process units		
		a) Process units	20	0.15
		b) Conveyor transfer points	50	—
iii)	*Working Tasks*			
		Ordinary work		
		a) Operating valves operating manually, switches and starting motors	20	—
		b) Firing boilers or heaters	20	—
		c) Loading tank trucks or railroad cars	50	—
		d) Reading meters, gauges or labels	50	—
		Maintenance work		
		a) Moving maintenance equipment	20	—
		b) Checking leaks, piping, packing, etc.	50	—
		c) Repacking pumps	100*	—
		d) Repairing mechanical and electrical equipment or instruments	200**	

*Vertical illuminance

**This value may be obtained by local lighting

4 LIGHTING EQUIPMENT

4.1 General information on lighting equipment is given in Parts 3 and 4 of this code.

In general there are no special requirements for lighting equipment in the industrial area lighting, except where there is a corrosive or explosive atmosphere.

In parking areas the use of low pressure sodium lamps is not recommended, because the monochromatic light makes it difficult to recognize the colour of the cars.

For portable local lighting the use of low voltage lamps (≤ 55 V) is recommended. Because of the rough nature of industrial work, portable local lighting equipment should be protected against mechanical impact and misuse.

4.2 Hazardous Atmosphere

For lighting of hazardous areas, place refer to Part 7 of this code.

4.3 Corrosive Atmosphere

A variety of corrosive chemicals is likely to be present in petrochemical plants. The usual method of protection against these is to use materials that will resist attack; special surface preparations such as polyvinyl chloride coatings and epoxy resin finishes. In addition to the corrosive conditions related to the process and any adjoining plants, the action of elements such as fog, high humidity and salt laden sea air, must be considered when selecting the proper protective system for luminaires and their mounting and suspension equipment.

4.4 Lamps

For general illumination high intensity discharge (HID) lamps should be used. Where colour discrimination is important, metal halide lamps or tubular fluorescent lamps should be used. In cases where colour rendering is not critical, high pressure mercury lamps or high pressure sodium lamps may be used, the latter being preferable from the point of view of economy and energy conservation. The type of lamp selected and the wattage are also dependent on the mounting height and the process being carried out.

4.5 Mounting Systems

It is advisable to mount luminaires as high as possible because the atmosphere is cleaner, which reduces the risk of explosion.

Furthermore, the lower rate of dirt deposition and corrosion results in significantly less maintenance.

Wherever possible, existing structures may be used as mounting systems. Further information is given in Part 6 Section 1 of this code.

5 LIGHTING DESIGN

5.1 General Requirements

Part 6 Section 1 of this code should be consulted for general guidelines on the design of lighting installations. Information is given there on the choice of lamps, luminaires and mounting systems to fulfill the lighting requirements.

Furthermore, the following items may be considered:

a) The use of local lighting can be an economic way to achieve the recommended illuminance needed in small areas;

b) A switching system to obtain reduced illuminance outside working hours is recommended. The lower illuminance should not be detrimental to security (*see* Part 6 Section 3);

c) If the situation in (b) above is effected by switching off a certain number of lamps, care should be taken to avoid dark spots which could adversely affect security and safety;

d) The installation should be such that a single lamp outage does not interfere with work or safety in critical areas;

e) The use of high mounting heights has many advantages: the lights produce better uniformity, are less glaring and less likely to cause confusion with signal lights. For areas where flammable products are handled the need to use flameproof luminaires is recommended. Furthermore the luminaires remain cleaner and require cleaning less often; and

f) Particular attention should be paid to the lighting of industrial works, car park entrances and exits for ease of identification by drivers.

5.2 Lighting Design

The outdoor processing units, storage areas, loading and unloading points and other areas can be effectively illuminated by high wattage floodlights. For areas in between silos, containers, etc and other small areas not adequately lit by the main lighting system, low wattage local luminaires may be used. With floodlighting, care should be exercised to avoid glare inside and outside the areas of the facility. Asymmetrical floodlights have proved to be very helpful in controlling glare.

Luminaires mounted on the top of platforms, on masts or ladder tops are normally equipped with optical systems which concentrate the light in downward directions. Luminaires mounted on intermediate platforms normally emit light in most directions in order to illuminate adjacent structures and to mitigate sharp shadows with the light reflected therefrom.

High colour rendering properties are seldom required in refinery outdoor areas, except for areas containing hazardous materials identified by coloured signs or labels.

For basic design calculations and other information on area lighting design refer to Part 6 Section 1 of this code.

For electricity generating stations and water and sewage works (*see* **5.3**) the following items may be considered additionally:

a) a switching system to conserve energy is recommended. It should be designed to maintain security at all times, and to enable illuminance to be increased where and when inspection, maintenance or repair work has to be carried out;

b) because in these fields of application the number of possible mast positions is severely restricted, the use of a small number of high masts is recommended for general lighting; and

c) the design of the installation should pay particular attention to providing good illumination to personnel access routes to critical work points (narrow walkways, ladders, etc).

For transformer substations and switchyards, the type of the lighting system employed depends mainly on the height of the transformer and switching installations including overhead cables.

For specific repair work (critical tasks), portable local lighting is recommended. Sufficient power points should be provided. The system should partially be fed from an emergency supply, so that the basic lighting functions can always be fulfilled.

The use of fluorescent or incandescent lighting on the emergency supply can overcome problems arising from relatively long restarting times of other gas discharge lamps.

The systems described above provide sufficient light from above and below to see the overhead visual task. Care however should be taken to prevent glare reducing visibility in critical directions.

All lighting equipment must have adequate clearance distances from high voltage conductors; moreover, it must be possible to maintain the lighting equipment without danger to personnel. The use of portable ladders and/or hinged masts for maintenance purposes is not recommended.

5.3 Water and Sewage Works

The main characteristic of these installations is the presence of large open water tanks and filter beds. Deep water channels connect these, in which the water can be fast moving. Parts of the water or sewage installation differ in height (approximately 5 m). There are many connecting walkways, ladders and stairs; normally with railings, at least on one side. Often the operation of the installation is mainly computer controlled, so that personnel are not always present. In this type of installation, repair work need not be done immediately; there is often ample time available, so that local temporary mounted lighting can be used for the more difficult visual tasks.

The visual tasks are generally simple: there is little critical detail and colour discrimination is not always necessary. A typical task is to locate small foreign floating objects. The main function of the lighting thus is to provide safe orientation and movement for personnel during control rounds and to deter unauthorized intruders and playing children. For specific tasks such as meter reading, sampling, etc, local lighting is the best solution.

As the number of potential mast positions is limited, a lighting system is recommended based on the use of medium to high mounting heights (12-20 m).

As colour discrimination is not important sodium lamps can be used with advantage. Road lighting luminaires or floodlights can be used. Masts should be positioned to avoid deep shadows on walkways, on ladders and near deep water channels.

In certain areas of sewage works a corrosive or explosive atmosphere can exist (methane may be stored in tanks), in which case suitable luminaires or high mounting heights must be employed.

5.4 Maintenance

Taking into account the typical rate of corrosion and dirt deposition in a refinery outdoor atmosphere, the maintenance factor should not be higher than 0.6 (0.75 for mounting heights over 20 m) from an economic point of view. More details are given in Part 13 of this code.

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NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 3 Security Lighting

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

The main purpose of security lighting is to protect areas, personnel and property by means of illumination which discourages or deters attempts at entry by intruders and to facilitate the movement of security patrols through the areas.

This objective can be achieved by the provision of adequate illumination with minimum disabling glare to security personnel, roadways, railroads, marine operations, and nearby residences; for monitoring pedestrian passage through entrance gates, along walkways and along the security perimeter; and for closed circuit television monitoring.

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 3 Security Lighting

1 SCOPE

This section of the code gives recommendations for lighting installations which help to protect people, property, buildings, materials and equipment from harm or theft after sunset. The lighting must provide the security personnel adequate viewing conditions for them to carry out their work effectively.

2 TERMINOLOGY

The definitions of the terms used in this section are given in Part 1 of this code.

3 TYPES OF SECURITY AREAS

Security areas which may need lighting are given below.

3.1 Isolated Remote Strips

These are at a distance from buildings or main storage yards and may be defined as a strip of property both inside and outside a perimeter wall or fence. Typically, illumination of such strips should cover a width of 25 m, of which at least 5 m is outside and 20 m is inside the perimeter. However, new international standards on environment light pollution is relooking at light spillage outside the owner's perimeter.

3.2 Close-in Strips

These are strips of property along a perimeter which are in close proximity to buildings or storage yards, and which may or may not be enclosed by a fence. Illumination of such areas should include at least 5 m outside the defined perimeter and the area within the building walls or storage yards. However, new international standards on environment light pollution is relooking at light spillage outside the owner's perimeter.

3.3 Waterfront Strips

These include docks, quays and the water alongside them. Illumination of the security area should extend outwards for a distance of 12 to 15 m on the waterside, and inwards for a distance of 20 m or to dock buildings within that distance. However, new international standards on environment light pollution is relooking at light spillage outside the owner's perimeter.

3.4 Storage Zones

These are areas where materials or equipment are stored or where cars or trucks are parked.

3.5 Entrance Zones

These areas include entrance gates and the adjacent areas where people, goods and documents are checked.

3.6 Traffic Zones

These consist of walkways and roads through the area from the entrances to buildings and storage areas.

3.7 Special Security Fences

These could be outside jails, defence establishments or other high security areas. These areas are subject to constant scanning by the human eye and/or CCTV, so a lighting installation which produces good visual perception and good camera sensitivity is recommended.

4 RISK CLASSIFICATIONS

4.1 General

The initial step in designing a system of security lighting is to assess the degree of risk involved. Risk itself is a combination of the probability of illegal entry and the consequences, the amount or nature of the loss sustained through such an entry.

4.2 Classification

a) *Low Risk Area*

Premises with reasonably efficient security and merchandise or equipment not particularly attractive to intruders. Example: premises fronting a lighted main street with buildings on either side and a main road at the rear;

b) *Medium Risk Area*

Premises relatively easy to enter, or which has merchandise or equipment attractive to intruders. Example: some buildings with no road or a poorly lit road at the rear; and

c) *High Risk area*

Premises easy to enter at night, or in isolated locations; or other secure premises with merchandise, equipment or other items which have a significant value, or where the consequences of damage are serious. Example: the building or premises that backs up to a waterfront, or to a railroad siding with no adjacent buildings.

5 SECURITY LIGHTING TECHNIQUES

5.1 Isolated Remote Strips

Industrial properties not inside buildings are generally enclosed by walls or fencing. Properly applied security lighting at such a perimeter will enable security forces on the inside of the fence to observe movements of a suspicious nature outside or close to the fence.

The longer the time available to see intruders, the more likely they will be detected. It is, therefore, desirable to illuminate a strip of 20 to 50 metres outside the fence.

Two techniques are recommended.

a) Floodlights mounted on masts higher than 10 metres should allow visual detection of movement at ground level. If directed at 45 degrees below the horizontal, the floodlights will provide approximately equal illuminance on horizontal and vertical surfaces at the same point. The spacing to height ratio must be carefully chosen to fulfill the uniformity requirements in Table 1; and

b) Luminaires mounted at eye level and directed outwards would provide very little illuminance on the ground, but will force intruders to face glaring lights, enabling security guards to see intruders, and making it difficult for intruders to see the guards. Illuminance levels in Table 1 are those on the faces of approaching trespassers.

5.2 Entrance Zones

Good entrance zone lighting should enable people, vehicles, goods and documents to be thoroughly checked. Lighting inside the gate office should not cause reflections on the glass walls and hinder the visibility of the guards. Lights may be provided on the canopy of the gate office to permit the guards to see vehicles, their occupants, papers, etc.

5.3 Revealing Intruders by Floodlighting

Floodlighting a building or a wall creates a bright background against which an intruder can be easily seen in silhouette.

5.4 Lighting for Security CCTV

It is necessary to provide at least two luminaires to illuminate objects for surveillance using a CCTV system.

6 RECOMMENDED ILLUMINANCE AND UNIFORMITY RATIO

The recommended illuminance and uniformity ratios for various zones and degrees of risk are given in Table 1. The values stated are in principle for areas outside built-up areas. If ambient lighting in the nearby surroundings is considerable the illuminance values for security purposes should be higher than the ambient lighting, so that the area to be protected does not appear as a dark spot.

7 POWER SUPPLY

7.1 It is preferable to split alternate lights on different circuits and also to provide a standby or back up power supply from a diesel generator set.

Table 1 Recommended Values of Illuminance and Uniformity Ratio for Security Lighting

(*Clauses* 5 *and* 6)

Application	Risk Classification	Maintained average horizontal illuminance (lux)	Uniformity ratio E_{min}/E_{av}
Isolated remote strips	Low risk	5	0.15
	Medium risk	10	0.25
	High risk	20	0.25
Close-in strips	Low risk	10	0.25
	Medium risk	20	0.25
	High risk	50	0.30
Waterfront strips	Low risk	10	0.25
	Medium risk	20	0.25
	High risk	50	0.30
Storage zones	Low risk	5	0.15
	Medium risk	10	0.25
	High risk	20	0.25
Entrance zones	All	50	0.30
Traffic zones			
a) Walking	All	5	0.15
b) Traffic	All	10	0.25
Special security fences	High risk	50	0.30

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NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 4 Decorative Lighting (Monument, Park and Garden)

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

A well lit environment makes a place agreeable to live in. It improves the quality of life for the inhabitants of that place and attracts tourists. An investment in urban decorative lighting thus has both social and economic impact. Such investments have become very reasonable as during the course of the 20th century the relative cost of lighting has steadily diminished.

There has been another significant change. Earlier, a decorative lighting project was expected to enable recognition of the object. Today modern architects use light as an additional tool for showing the buildings at night in a way that is original and quite often differently from the daytime view.

Hence, decorative lighting is increasingly planned at the very initial stage of a project. This has enabled the designer to place light sources inside the building or construction to bring out additional effects, unlike earlier when light sources were found only on the outside.

This approach reinforces the three dimensional images of the architecture. Also due to developments in the technical and electronic fields in lighting, light can be varied according to the desires of the user to an unprecedented degree.

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 4 Decorative Lighting (Monument, Park and Garden)

1 SCOPE

This section of the code provides the details about the site study, planning, lighting hardware and photometric requirements required for decorative lighting of monuments, gardens, parks and similar locations.

2 TERMINOLOGY

For the purpose of this section, the definitions given in Part 1 of this code shall apply.

3 APPROACH

Apart from the technical and artistic aspects of a decorative lighting project, there are several points to be considered for success.

3.1 Initial Research

For lighting a monument or an artistic construction, it is essential to study the historical, architectural, and local information on the subject. This permits the designer to understand the importance of the different parts of the monument and what to highlight.

3.2 Permission of Concerned Authorities

a) For lighting and for installing the lighting equipment, permission of the owner, the administrative or the architectural authority responsible for conservation or maintenance and coordination of the work should be obtained;

b) Depending on the site of the object to be illuminated, it may be necessary to consult the aviation and maritime authorities in order to ascertain if the lighting would interfere with the air or ship traffic; and

c) In cities, community interests need be to ascertained and necessary permissions obtained.

3.3 Preliminary Site Study

a) Maps, floor plans, elevation views, photographs, etc, are to be studied;

b) Night time lighting of the surrounding area is to be examined to determine the illuminance necessary to achieve the desired effect on the subject;

c) Seasonal influences must be carefully studied, particularly the presence of trees and bushes and seasonal growths of the foliage, availability and levels of water on the waterfront, when the fountains are stopped, etc. The position and colour of light sources might depend on this kind of information;

d) Accessibility of the site by a tower wagon or other mobile equipment, if particularly needed, should be known, as the positioning of lighting equipment will depend on the maintainability of those;

e) The view or observation points for the visitors or passers-by should be known for deciding the preferred aiming of the light, while minimizing the risk of glare; and

f) Easy access to electric power supply for all lighting equipment must be ensured.

3.4 Planning for Decorative Lighting

a) It is most important to determine the lighting effects which are appropriate for the monument or site, or whether these are feasible;

b) A greater degree of expertise is required when the subject has large dimensions, complex structure, or is of great historical importance. For large and complex installations, it is advisable to carry out trial installations for typical parts to visualize the effects and obtain valuable information for detailed planning;

c) The choice of light sources, their wattages, the selection of the luminaires are to be made based on the dimensions, colour, etc, of the subject and the proposed nature and frequency of the use of installation; daily, periodic, seasonal or temporary; and

d) Alongwith the primary objective to achieve a high quality of lighting, the lighting solution must be both cost- and energy-effective.

4 LIGHT SOURCES

Necessary details on these and their control gear can be had from Part 3 of this code.

5 LUMINAIRES

Part 4 of this code may be referred to for all the information on these including photometric characteristics.

6 FLOODLIGHTING TECHNIQUES

Floodlighting is an effective means of highlighting a constructed or a natural subject. The sources of light are generally placed in the immediate surroundings of the subject in order to illuminate its various surfaces. These may also be mounted directly on the subject if the setting, the installation or the use requires it. The positions of the floodlights and their desired luminous outputs and photometric characteristics are decided taking several factors into account, such as, the quality, the colour and the volume of the surface to emphasize, the relative locations of the viewpoints, the distances of the lighting equipment from the subject, lighting in the environment and the intended effect.

6.1 Bringing out Hierarchy

When the observer views several illuminated subjects from a single spot; say a vantage point overlooking an urban area or a city square, all these subjects are not of equal value. The floodlighting must recreate this hierarchy and major elements must get clearly emphasized.

Floodlighting has the ability to highlight an element of quality by keeping the surroundings, which are of no interest or unsightly, in shadow. However, it is generally preferable to light the surroundings to some extent in order to give the subject a setting. Sometimes this is achieved by linking the main subject visually to another element tied by history or architecture. In an urban area, public lighting helps in achieving this.

Care must be taken:

a) not to distort the appearance of the monument;
b) not to detract from the observation of the subject due to the intensity or direction of lighting installations nearby, such as stadia, railway yards, multilevel road interchanges, etc; and
c) to avoid the light source causing deterioration of the objects and the environment.

6.2 Bringing out the Relief

While floodlighting a monument or building, it must not be literally flooded with light. By judicious use of more light, less light or shadow, the relief of the different planes or volumes can be brought out. It is the presence of shadows that brings out the relief of a facade. The lighting design must provide the modelling effect.

6.2.1 *Angle of Incidence*

Lighting directed perpendicularly does not create shadow and the surface in question appears flat. The size of a shadow depends on the relief of the surface and on the angle of incidence of the light. The average minimal lighting directional angle shall be 45 degrees with the normal to the surface. This angle has to be increased for highlighting a particularly low relief.

6.2.2 *Aiming of Luminaires*

In order to make the lighting effect appear natural and balanced, all shadows must be cast in the same direction (as happens under natural light). So, all the luminaires (principal floodlights) lighting surfaces seen in one field of view must have the same orientation. However, large projections can create large shadow obscuring some parts. This shadow is to be softened by means of light of less intensity at about 90 degrees (complementary floodlights) with respect to the principal lighting direction.

6.2.3 *Aiming vis-a-vis Viewpoint of Observers*

Direction of light has to be different from the viewing direction of observers for the shadow, and thus the relief, to be visible. The angle between these directions must be at least 45 degrees.

For monuments visible from several places, a principal observation point must be determined and the lighting designed for this preferred viewing direction.

6.2.4 *Position of Luminaires*

This is determined by the requirements given in clauses **6.2.2** and **6.2.3**. However, in urban areas, there are often physical constraints in locating the luminaires in optimal positions and the most satisfactory compromise must be arrived at.

6.2.5 *Daytime Appearance of the Installation*

It is very important to ensure that the luminaire positions determined for nighttime floodlighting are aesthetically appropriate and do not spoil the view of the site during the day.

6.2.6 *Glare*

It is necessary to eliminate direct and/or reflected glare which could disturb occupants of neighbouring buildings or drivers of motor vehicles on roads nearby.

6.2.7 *Accessibility for Maintenance*

For periodical maintenance, lamp replacement, cleaning of luminaires and readjustment of disturbed luminaires should be as easy as possible. Care has to be taken during the designing stage to make the installation accessible and ensure easy handling of luminaires.

6.3 Lighting Design Calculations

6.3.1 *Luminance*

For proper visibility the mean luminance of an illuminated facade must be in proportion to the demands of the environment, the size and the situation of the monument in question. The higher the mean luminance of the environment, particularly the background, the greater should be the luminance of the monument. However, a monument lit for a very high luminance may be too jarring in a poorly illuminated environment.

For proper visual impact, a small isolated surface must have a luminance. Under similar conditions, a large surface will need lower luminance.

Similarly, for a similar size of monument and environmental conditions, to be visible a monument from far needs more lighting then one seen from nearby. Generally accepted mean luminances for various situations are.

a) Rural areas poorly or dimly lit 4cd/m ^{2};
b) Small towns, suburban areas 6cd/ m ^{2}; and
c) Recreational and commercial centres in urban areas 12cd/ m ^{2}

6.3.2 *Illuminance and Reflection Factor*

The illuminance on a facade or surface can be calculated from its luminance and reflecting properties with the following equation applicable to diffused surfaces

$$E=L\frac{\pi}{\rho}$$

where

E = the illuminance in lux;

L = the average luminance in cd/m^2; and

ρ = the mean reflection factor.

The reflection factor is not always the same at all points on a surface, so the mean value must be used. This value can be measured by an appropriate instrument or usually estimated from known values.

The value should be corrected according to the spectral composition of the lamp to be used and the colour of the surface to be illuminated. For example, a yellow surface reflects more light from a low pressure sodium lamp than from a high pressure mercury lamp.

The formula given above cannot be used, when the surface finish of the subject to be illuminated is highly polished for example, glass, polished marble, stainless steel or anodized aluminium with predominant specular reflection. For these cases only by conducting trials can the right amount of light be determined.

For the luminaires mounted at a low height, light will be reflected from the subject upwards and outside the field of vision of the observer. On the other hand, where the luminaires are to be mounted at a higher level on a pole or from another building, care has to be taken to avoid unacceptable reflections for the observers.

6.3.3 *Luminous Flux*

After deciding on the illuminance required, the luminous flux required can be found by using the following formula:

$$\Phi=\frac{E.S}{U}$$

where,

Φ = the luminous flux in lumens;

E = the maintained average illuminance in lux;

S = the total area to be illuminated in m^2; and

U = the efficiency coefficient of the system.

The coefficient 'U' is dependent on:

a) the light output ratio of the luminaire (obtained from published data of the manufacturer);
b) the maintenance factor, which is dependent on environmental conditions and the frequency of cleaning and lamp replacement and can be assumed to be 0.8 very generally for regular cleaning and lamp replacement (*see* Part 13 of this code); and
c) the wastelight factor; depending on the beam angle of the floodlight, dimensions of the area to be illuminated, the distance between the luminaire and the surface, light scattering due to the amount of dust in the atmosphere, etc, a part of the luminous flux may miss the subject.

A typical value of U is 0.3.

6.4 Backlighting

This is done by using floodlights to illuminate a surface forming a backdrop to the main subject, which stands out as a dark object against the backdrop. The floodlighting must achieve a fairly uniform bright background.

Sometimes, in order to bring out the shape of the subject, a very low intensity of light on the facade of the subject may be necessary.

Backlighting effects may also be obtained by lighting the rear surface of the subject. It is possible to create patterns of light, bring out the volumes and openings, due to some construction features or projections on the rear surface.

Backlighting is only interesting for subjects that are not massive in order to bring into evidence the lightness of the structure.

6.5 Use of Coloured Light

In decorative floodlighting the use of coloured light is very delicate. It must only be used when the implied idea or situation is easily interpreted by the observer.

It must be remembered that coloured light reinforces corresponding colours, but detracts from other tones. Juxtaposing coloured lights may liven adjacent surfaces, but using different colours may create violent contrasts.

The same care has to be taken for a facade made of different materials. Coloured light changes the tonal values leading to an unbalanced effect.

If coloured filters are used over the floodlights to obtain coloured light, like in theatres and in sound and light shows, care has to be taken to select filters of proper material. In permanent installations, the filters will experience high temperature, unlike those in show lighting which are subjected to very brief and sporadic use. Plastic filters offer an extended range of colours, but are sensitive to heat. Plastic filters will have to be frequently inspected to check their condition, thus increasing the operating cost of the project. Glass filters can be heat resistant, but have limited choice of colours.

With the use of coloured filters, the luminous flux output goes down, necessitating an increase in either lamp wattage or the number of lamps and luminaires. Also, the floodlights must be provided with a suitable attachment for facilitating installation and replacement of filters.

7 LIGHTING OF STATUES AND SCULPTURES

The number of lighting points and their arrangement depends on the form of the subject. The task is to light it in its entirety, but not uniformly, in order to have the modelling effect.

The lighting design has to be according to the situation of the subject and its surroundings.

When the subject is on the ground and isolated in the middle of a lawn, the floodlights are preferably mounted flush in the ground, thus preserving the appearance of the lawn and reducing the risk of glare. Alternatively, they can be at ground level behind a barrier of vegetation or masonry.

When the subject is on a pedestal but isolated in a lawn, the floodlights must be located farther away than in the above case, to limit the brightness of the pedestal and to avoid the possibility of shadow on the base of the subject cast by the edge of the pedestal.

When the subject on a pedestal is in an area accessible to pedestrians, it is generally not possible to have floodlights around the pedestal. Floodlights then are to be mounted either on public lighting poles nearby or on adjacent buildings. In either case, the risk of glare must be avoided.

For statues, generally it is the face which is the principal element to be lit, followed by the front of the figure. The back needs very little or no lighting. Extreme care has to be taken with the direction of light while lighting the face, as any error can give it a very displeasing appearance.

8 LIGHTING OF PARKS AND GREEN BELTS

Total lighting of a green space is not possible, both for aesthetic and economic reasons. The most eye catching subjects, judged by their colour, development or grouping are to be highlighted.

The type of lighting will depend on the following:

a) general form, conical, spherical, dispersed, dense or airy; if seen from far, individual forms are not taken into consideration, only the total volume;
b) the colour of the foliage and if it changes with the seasons; and
c) viewing point, single or many, with consideration for glare restriction; also the foreground must not be lit at all or have less light, in order not to detract from the view of the distant subjects.

Generally the luminaires are installed at ground level for better daytime appearance. Sometimes these are mounted on low concrete blocks, so that accidental contact with lawn mowers is avoided. Shrubberies behind the luminaires improve the daytime appearances and eliminate glare.

Trees are generally lit by floodlights installed at ground level. Mounting luminaires on a tree is not recommended as branches may get damaged or leaves burnt. If it becomes necessary to position the luminaires at a higher level, suitable poles or supports may be used.

Flower beds at the ground level and viewed from above, are illuminated by low height mushroom luminaires directing light downward. These are either placed in the middle or on the edges of the flower beds, their height depending on that of the flowering plants.

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NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 5 Lighting for Utility Areas
(Dock and Harbour, Railway and Airport Apron)

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

This section of the code deals with lighting of harbours including waterways, quays, jetties; shipyards including docks, repair and construction sites; railway areas; and airport aprons.

The lighting of harbours and shipyards has to facilitate safe and efficient navigation, handling of cargo, passenger facilities, etc. The lighting function should provide hindrance free light and light free from direct glare caused by reflected light from the water surface.

Railway areas covered are those for passengers, freight, yards, servicing, maintenance and repair. Descriptions of the visual tasks to be performed in railway areas as well as data are also given.

Airport apron floodlighting is located so as to provide adequate illuminances on all apron service areas, with a minimum of glare to pilots of aircraft in flight and on the ground, airport controllers and personnel on the apron. The aiming arrangement of the floodlights should be done in such a way that an aircraft stand receives light from two or more directions to minimize shadows. This section also deals with the issues related to the airport parking area.

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 5 Lighting for Utility Areas
(Dock and Harbour, Railway and Airport Apron)

1 SCOPE

This section of the code covers the principles and practices governing good visual environments for utility areas such as docks and harbours, railway areas and airport aprons.

2 TERMINOLOGY

The definitions of the terms used in this section are given in Part 1 of this code.

3 DOCKS AND HARBOURS

3.1 General Lighting Requirements

3.1.1 *Function of the Lighting*

The function of lighting of harbours and shipyards is to permit:

a) Safe navigation and mooring of ships;

b) Accurate handling of general cargo, containers and bulk cargo (for example, oil, ore, grain);

c) Efficient handling, storage and transport of cargo by rail or lorry;

d) Quick and easy disembarkation, embarkation and transit of passengers, crews and vehicles;

e) Easy surveillance for security;

f) General service duties; and

g) Construction, repair and maintenance work in shipyards and docks.

Steps must be taken to ensure that neither the lights, nor lighting equipment interfere with cranes or traffic or cause hindrance to the navigation of ships.

This applies to direct glare from the luminaires as well as indirect glare caused by reflected light from the water surface.

3.2 Recommended Values for Illuminance and Uniformity Ratio in Docks and Harbours

A survey of the recommended values for different visual tasks is given in Table 1.

3.3 Lighting Equipment

3.3.1 For general information on lighting equipment Parts 3 and 4 of this code may be referred to.

Generally in harbour and dock areas there is a salt laden atmosphere; special precautions must be taken to ensure that lighting equipment will resist corrosion.

Luminaires for use in submersible lighting installations should be watertight (IP classification 68) or embedded in watertight compartments with glass fronts, which can withstand the water pressure. The rough nature of dock work requires this front glass to be protected against shock and mechanical impact by special grills.

Table 1 Recommended Value for Illuminance and Uniformity Ratio in Docks and Harbours
(*Clause* 3.2)

Areas to be lit; Operations performed	Maintained average horizontal illuminance (lux)	Uniformity ratio E_{min}/E_{av} not less than
Work areas or task		
Very rough work for example, short term handling of large units	20	0.25
Rough work, for example, cleaning of ship hull	50	0.25
Accurate work, for example, painting and welding of ship hull	100	0.40
Fine work, mounting of electrical and mechanical components	200	0.50
Traffic areas		
Walking passages exclusively for pedestrians	5	0.15
Traffic areas for slow moving (max. 10 km/h) vehicles, for example, bicycles and forklift trucks.	10	0.40
Normal traffic (max. 40 km/h) for example, container terminals	20	0.40
Safety and security		
General lighting on shipyard area, storage areas for prefabricated goods.	20	0.25

3.4 Lighting Design

3.4.1 *General Remarks*

For general guidelines for the design of lighting installations Part 6, Section 1 of this code should be consulted. Guidelines given there on the choice of lamps, luminaires and mounting systems may be followed for meeting the requirements mentioned in Table 1.

Furthermore, the following items may be considered:

a) The use of local lighting to provide an economic way of achieving the recommended illuminance needed in small areas;

b) A switching system to obtain reduced illuminance outside working hours, but not compromising the requirements of security lighting (*see* Part 6, Section 3).

   Sometimes this can be effected by switching off a certain number of lamps. However, care should be taken to avoid dark spots which could adversely affect security;

c) The installation should be such that a single lamp outage does not significantly interfere with work or safety in critical areas;

d) The use of high mounting heights has certain advantages; the lights are less likely to mask navigation or beacon lights or cause confusion with signal lights. For quays handling flammable cargoes the need to use flameproof luminaires may not arise. Limitation of both direct and reflected glare is easier to achieve because relatively small angles of incidence are possible; and

e) The installation of floodlights on cranes may be required to facilitate the operations of loading and unloading by supplementing the ships' own lighting and avoiding shadows which the arm of the crane may produce during its movement. Luminaires mounted on swinging jibs or rotating towers are not recommended, because they can cause excessive glare and/or unwanted moving patches of light. The vibration of the cranes may be detrimental to the life of lamps.

3.5 Harbours

Harbour areas comprise:

a) Waterways for navigation, mooring and berthing ships;

b) Quays, wharfs and jetties with equipment for loading and unloading cargo; jetties projecting into the waterway. They are often used for handling bulk cargo such as oils and grain;

c) Areas such as outdoor storage areas on wharfs and container stations;

d) Warehouses; and

e) Roads and track systems for lorries and trains.

In this section only the first two items are dealt with; for the remaining items see other parts and sections.

Lighting of quays has three specific functions:

a) facilitate the work involved in loading, unloading, deposit and transport of merchandise;

b) to reduce the risk of accidents and to facilitate the transit of personnel and vehicles through the areas in question; and

c) to improve security in the areas around the ships and harbour installations as well as in areas where merchandise is stored.

While function (b) does not make particularly high demands, functions (a) and (c) require good conditions for visual perception, either owing to the cost of the merchandise dealt with or to the necessity of rapidly carrying out the operations of loading and unloading so as not to hold up the vessel in port.

Harbours and especially container harbours (terminals) can be efficiently lighted with high mast floodlighting. Since the eyes of ships' pilots are usually 'dark adapted', special attention should be paid to the prevention of direct and indirect (reflections on the water) glare, and the choice of floodlight should be done accordingly.

3.6 Docks and Shipyards

3.6.1 *General Remarks*

Docks are used for ship repair and maintenance work or for building and construction of ships.

They can be of two types: dry docks and floating docks.

Because of the high cost of withdrawing vessels from use, ship repairs and maintenance have to be carried out in the shortest possible time; often repair work is done throughout the day and night.

Docks for shipbuilding are associated with extensive neighboring workshop areas where parts are prefabricated, material storage areas and car parks. A vessel is built in a dock until it reaches the launching stage, after which it passes to a nearby berth, where the construction work is completed. The main activities require the use of different types of cranes having a wide sweep and great lifting power with clear runs along the length of the docks. In order to move vessels into and out of dry docks, the docks have to be flooded; thus a distinction has to be made between area lighting installations and submersible lighting installations.

3.6.2 *Recommended Lighting Systems*

For the area lighting, especially in shipbuilding docks, high mast lighting usually offers a good solution.

For the dock lighting itself floodlights can be mounted along the upper edges of the dock. A high degree of uniformity is required and generally luminaires should be mounted at intervals not exceeding 1.5 times the distance between the wall of the dock and the hull of the vessel.

3.6.3 *Submersible Lighting Installations*

These are used to illuminate the keels and lower parts of the hulls of vessels. Normal dockside lighting is usually inadequate for scraping, painting and welding on the lower parts of the hull.

For these tasks floodlights are necessary, placed along longitudinal lines, one at each side of the dock at a height of approximately 1 m above the dock floor. The spacing between the floodlights is usually 5 to 10 m. Luminaires should be recessed in the walls of the dock.

4 RAILWAY LIGHTING

4.1 Function of Lighting

Adequate lighting of railway areas is essential to:

a) Promote the safety of the passengers and the staff;
b) Allow railway yard operations and freight handling to be performed;
c) Prevent damage to rolling stock and railway material; and
d) Allow maintenance and repair work.

4.2 Visual Tasks in Railway Areas

4.2.1 *Passenger Areas*

Exterior passenger areas include the railway platforms, where the best illuminance should be at the platform edge. The illumination in the entrances of passenger tunnels should be sufficient to prevent adaptation problems. The passenger capacity should be taken into consideration when deciding on lighting parameters.

4.2.2 *Freight Areas*

Wagons can be loaded either directly from lorries parked alongside the wagons or from uncovered or covered platforms. Cranes may be used. Illuminance levels should be chosen according to the visual tasks to be carried out.

Container terminals have areas for the loading and unloading of containers from lorries or trailers onto wagons. Cranes may pick up the containers from any part of the container storage or trailer parking area and place them in precise locations on the wagons or unload them. Higher illuminance levels are recommended under the cranes. Adequate vertical illuminance is required on all the container sides to permit identification labels to be read. The lighting should be sufficient to enable tying down or releasing of containers on the wagons or trailers.

4.2.3 *Railway Yards*

Railway yards can be divided into general areas where different visual tasks are performed. By considering each type of yard separately, and by further breaking down each type into areas involving specific visual tasks, specific lighting requirements can be defined. Table 2 lists the recommended illuminances and uniformities.

Railway regulations must be observed with respect to the location of any lighting equipment above or adjacent to the tracks.

Steps must be taken to ensure that the visibility of railway signals is not impaired by the lights. Emergency lighting may be necessary to prevent accidents in hump operation.

4.2.4 *Flat Switching Yards*

In most yards of this type light is required for track switching operations and locomotive drivers, throwing switches and safe conditions for switchmen walking around the head and pull-out end of yards.

There may be a special turnout track where the trainman uncouples the wagons and the locomotive pushes the wagons to another track, where the wagons are coupled again. If the wagons do not have an automatic coupling mechanism, the trainman must get enough light between the wagons to see the mechanism and handle the coupling. The staff may also be required to read wagon numbers or labels at the head end of the yard in order to assign wagons to their proper tracks. In the body of the wagon yard, inspectors are moving along inspecting the brakes and the wagon under frames using hand-held inspection lamps. These may also be useful for reading wagon numbers or lists.

4.2.5 *Retarder Classification Yards*

Classification yards of this type are large and often highly automated with supporting yards and servicing facilities. Fig.1 shows a typical layout.

Different types of visual tasks and operations are involved in this type of yard, as given below:

a) Reception yard (area A, B in Fig. 1).

   Inbound freight trains generally pull into a reception yard where their locomotives are uncoupled. Visual tasks for the wagon inspectors throughout the area consist of walking between the wagons, bleeding air systems, inspecting hoses and safety appliances by using an inspection lamp. When the wagons do not have automatic coupling mechanisms, the pulling hooks must be uncoupled. Consequently the operator must be able to read the wagon number or label both on the wagon and the wagon list to

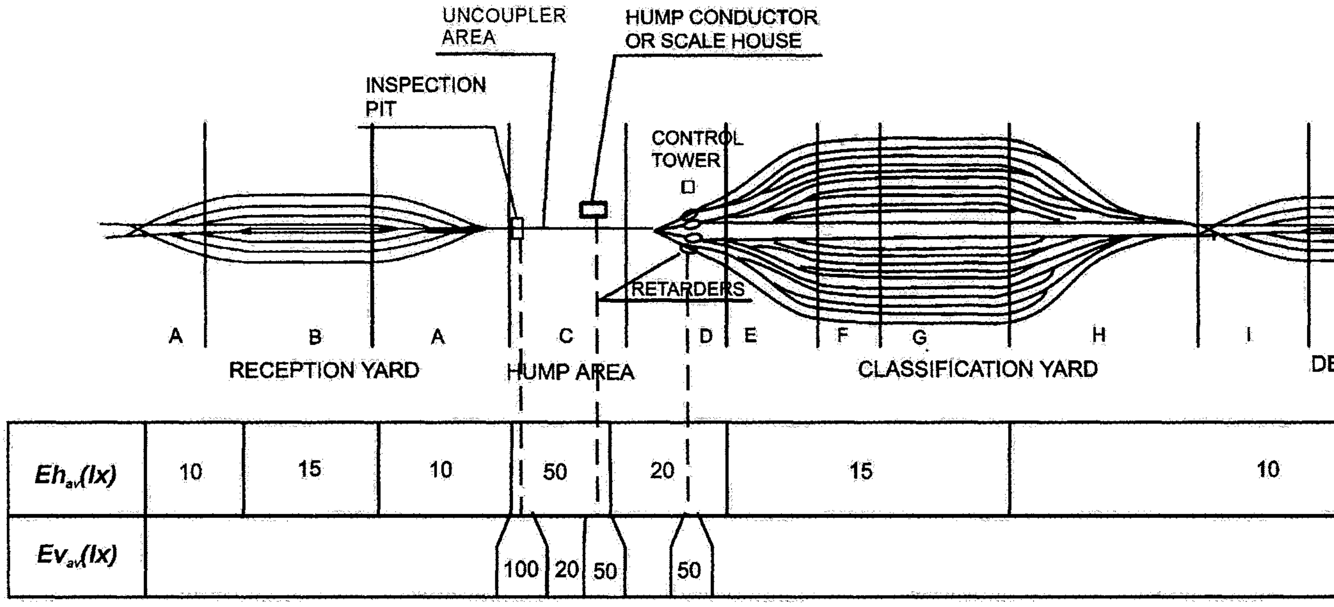

Fig 1. Layout of a Retarder Classification

know which one to loosen. A locomotive then pushes the wagons to the hump for classification;

b) Hump area (area C in Fig.1).

The hump area may have a wagon inspection pit, where the wagon inspectors will require illumination on the bogie side and underneath the wagon, to permit precise inspection of a wagon in motion. The wagon uncoupler should be able to see the coupling mechanism, and perhaps read a wagon list to know which one to uncouple. The scale operator, if a scale is used and the hump conductor are required to check the wagon numbers against their list and will therefore require the sides of the wagons to be adequately lit;

c) Control tower and retarder area (area D in Fig.1).

Retarder classification yards are equipped with various methods for determining the speed of wagons coming from the hump, track occupancy, etc. Some yards are fully automated, where retarders are automatically set by some devices, thus enabling a wagon to roll from the hump to its proper position in the yard without any action of the control tower operator. Other less automated yards may require the operator to visually check the extent of track occupancy in the yard, judge the speed of the wagon coming from the hump and manually set the amount of retardation to be applied to the wagon. This manual operation may also be required in the automated yard in the event of failure of one or more of the automatic features. In many yards the control tower operator must check the wagon number to ensure that the wagon goes to the correct track.

Control tower lighting shall be such that can facilitate adaptation of the operator's eye to the visual conditions outside. In some cases the use of dimmers in the control tower lighting circuit may help.

It is important that there be no direct light projected towards the operator in clear atmospheric conditions. However, under adverse atmospheric conditions like dense fog, it is the general practice to use auxiliary lighting equipment on the side of the tracks opposite the control tower to reveal the outline of the wagons in silhouette. In this situation, the operator cannot check wagon numbers, but can observe and regulate the movement of wagons.

In some smaller yards the wagons may be slowed down by placing a brake shoe on a braking rail under the speeding wagon and reading the wagon list to know which track the wagon is to be sent to;

d) Head end of classification yard (area E, F in Fig.1).

The operator should be able to see when wagons entering the classification yard have passed the switch points in order to avoid possible damage to the following wagons. Even in highly automated yards with wagon and track occupancy indicating systems, it is important for the operator to be able to see the yard conditions accurately in case the automatic system fails. In most yards the switches at the head end are automatically operated, but in some yards they are hand operated. If the switches are hand operated the switchman must be able to read the wagon lists in order to know to which track the wagons are to be sent. In some less automated yards the end braking of the wagons is performed by wagon receivers who operate brakes on the wagons in area F before the wagons reach their destination on the track. The wagon receivers may have to read wagon lists;

e) Body of classification yard (area G in Fig. 1).

In many yards, the operator must be able to see the yard sufficiently well to determine track occupancy. Wagon inspectors are required to move along wagons in the body of the classification yard to inspect bearings, wagon brakes, under frames, etc, using inspection lamps;

f) Pull out end of classification yard (area H in Fig.1).

In this area, switchmen are required to walk along the tracks to determine switch positions and operate them if necessary. Illumination is required to provide safe walking conditions along the switch tracks; and

g) Departure yard (area I, J in Fig.1).

The main task in the departure yard consists of walking between the wagons and coupling them to the locomotive in the body of the yard and operating the switches in the head ends.

4.2.6 *Passenger Station Tracks*

The main task consists of walking between wagons, coupling them to the locomotive and operating switches.

4.2.7 *Servicing and Stabling Tracks, Maintenance and Repair Tracks*

Passenger coach cleaning areas should have sufficient illumination to allow the cleaning personnel to walk

Table 2 Recommended Values of Illuminance and Uniformity Ratio for Railway Lighting
(*Clauses* 4.2.3 *and* 4.3)

Sl.No.	Areas to be Lit; Operations Performed	Maintained Average Horizontal Illumuminance (Lux)	Maintained Average Vertical Illumuminance(Lux)	Uniformity Ratio E_{min}/E_{av} not less than
(1)	(2)	(3)	(4)	(5)
1.	*Passenger areas*			
	a) Open platforms, small stations	10	—	0.25
	b) Open platforms, medium size stations	20	—	0.25
	c) Open platforms, large stations	50	—	0.40
	d) Covered platforms, small stations	50	—	0.40
	e) Covered platforms, large stations	100	—	0.50
2.	*Freight areas*			
	a) Freight track, temporary or quick operation	10	—	0.25
	b) Freight track, continuous operation	20	—	0.40
	c) Open platforms	20	—	0.40
	d) Covered platforms, temporary or quick operation	50	—	0.40
	e) Covered platforms, continuous operation	100	—	0.50
	f) Traffic areas for mobile cranes and coaches	20	—	0.40
	g) Container handling areas	20	—	0.50
	h) Container storage areas	10	—	0.25
	j) Track for trailer loading on wagon	20	—	0.40
3.	*Railway yards (flat marshalling yards)*			
	a) Switching areas	10	—	0.25
	b) Body of yard, temporary or quick operation	10	—	0.40
	c) Body of yard, continuous operation	15	—	0.40
	d) Turn-out track, uncoupling area	10	—	0.50
4.	*Retarder marshalling yards*			
	a) Switching area	10	—	0.25
	b) Body of yard	15	—	0.40
5.	*Hump area*			
	a) Wagon inspection pit	—	100	—
	b) Uncoupling area	50	20	0.40
	c) Hump crest, wagon number reading area	20	50	0.40
6.	*Classification yards(hand operated wagon rolling, switching and braking)*			
	a) Braking rail with brake shoe	20	—	0.40
	b) Switching area, head and braking area with brake shoe	15	—	0.40
7.	*Automatic wagon rolling and switching*			
	a) Retarders	—	50	—
	b) Continuous control retarders.	15	—	0.40
	c) Switching zone, head end	15	—	0.40
	d) Body of classification yard	15	—	0.40
	e) Switching area, pull-out end	10	—	0.25
	f) Departure yard, switching area, body of yard	10	—	0.25
8.	*Passenger station tracks*			
	Switching area, body of yard	10	—	0.25
9.	*Servicing and stabling tracks for coaches, trains and locomotives*			
	a) Passenger coach cleaning area	10	—	0.25

Table 2 (*Concluded*)

Sl.No.	Areas to be Lit; Operations Performed	Maintained Average Horizontal Illumuminance (lux)	Maintained Average Vertical Illumuminance(lux)	Uniformity Ratio E_{min}/E_{av} not less than
(1)	(2)	(3)	(4)	(5)
	b) Passenger coach servicing area	20	20	0.40
	c) Passenger coach washing area	20	20	0.40
	d) Stabling tracks for wagons and coaches	5	—	0.25
	e) Stabling tracks for locomotives	20	—	0.40
10	*Maintenance and repair tracks for wagons and coaches*			
	a) Maintenance track area	20	20	0.25
	b) Repair track area	50	50	0.40
11	*Level crossings*	20	—	0.40

between the coaches and enter them. Coach servicing, washing, maintenance and repair areas should have sufficient illumination on the vertical sides of the coaches. Stabling tracks should have sufficient lighting for safety and security. Handlamps may be necessary for coupling of wagons.

4.2.8 *Shadow of Railway Wagons*

In order to obtain good illumination on both sides of the wagons and in the space between the wagons on adjacent tracks, the transverse distance between two luminaires has to be between 1.2 and 1.4 times the mounting height.

4.2.9 *Level Crossings*

The visual tasks are the same as those as for street lighting, unless remote CCTV control.is used, where the illuminance may have to be increased.

4.3 Recommended Values for Illuminance and Uniformity Ratio

Table 2 gives a survey of the recommended values for different railway areas; the illuminance values mentioned are maintained average illuminance levels.

4.4 Maintenance Factor

In the course of designing and installing, a maintenance factor, depending on surroundings, light source and luminaire, has to be taken into consideration. This is very important, for railway areas are full of smoke and dust particles. Also it has to be kept in mind that light is absorbed by smoke and dust alongwith moisture. This amount of absorption must be considered even in an apparently clean atmosphere, especially in the yards where luminaires are located at a distance from the task and/or the task is viewed from a distance. The illuminance on the task would have to be increased by a factor to obtain the same visibility as at 100 percent atmosphere transmittance.

4.5 Illuminance Measurements

Measurements have to be made on railway yards without wagons, and in clear weather conditions. Horizontal illuminance should be measured at a height of the work task. If it is not known, this should be measured at 1 m above ground level. Vertical illuminance should be measured at 1 m above ground level.

4.6 Lighting Systems

4.6.1 *High Tower/Mast System*

The function of this system is to provide illumination from a minimum of locations throughout the various work areas of the yard.

Advantages of this system are:

a) Use of high poles on towers reduces the number of mounting sites;
b) Light distribution is flexible. Both general and local lighting are readily achieved. (The aiming of projectors however may be more critical);
c) The projectors are effective over long ranges;
d) Maintenance problems are restricted to a few concentrated areas;
e) Physical and visual obstructions are minimized; and
f) The electrical distribution system serves a small number of concentrated loads.

4.6.2 *Distributed System*

Distributed lighting differs from the high tower technique in that luminaires are in many locations rather than at a relatively few.

Advantages of this system are:

a) Good uniformity of illuminance on the horizontal;
b) Good utilization of light;

c) Reduction of undesirable shadows;

d) Less critical aiming;

e) Lower mounting heights (Floodlight maintenance is facilitated);

f) Reduced losses because of atmospheric absorption and scattering; and

g) Electrical distribution system services as a large number of small, distributed loads.

5 AIRPORT AREA FLOODLIGHTING

5.1 Airport Parking Area Lighting

5.1.1 The lighting of automobile parking areas and roadways in and around an airport must provide visibility for control tower operators and pilots and promote safe and efficient movement of motor vehicles and pedestrians.

The lighting must not interfere with night time visibility of the control tower operators and incoming pilots. At night, control tower operators work in semi-darkness. Their eyes must be dark adapted to enable them to see aircraft manoeuvring in the air and on the ground. Any appreciable amount of brightness in their fields of vision will greatly reduce their ability to see. The same is true for incoming pilots. But, in addition to their ability to see under dark adaptation, the nearby roadway and parking area luminaires should not be visible above the horizontal to avoid confusion between the pattern that the luminaires may form and the pattern of runway marker lights.

For the parking area, where the public park their own cars, the major considerations in providing illumination are to eliminate accidents, make it easier to locate parking spaces, to locate cars on return, and to discourage theft and criminal assault.

5.1.2 Recommended Illuminances and Uniformities

In the general parking area, the maintained average horizontal illuminance shall be between 10 and 20 lux.

Entrances and exits shall have an illuminance of at least twice that of the general parking area. Heavy pedestrian crossing points shall also have the same increased illuminance.

The uniformity ratio, minimum/average illuminance, shall be:

a) 0.33 on the roadway; and

b) 0.25 in the parking area.

5.1.3 Design Considerations

The ambient light on the control tower windows should be limited within 1 lux. This ambient light includes direct high angle light from luminaires and reflected light from paved surfaces.

Direct light may be controlled by using floodlights which have a positive optical control such that no direct or stray light is emitted above the horizontal, and by proper location of floodlights with relation to the control tower and its height.

To control reflected light and glare, factors that contribute to reflected light may be controlled as much as possible. These are:

a) the location of lighting equipment with relation to the location of the control tower; and

b) the luminous intensity and angle at which the main beam is directed in relation to the control tower.

The reflected angle should not be in the direction of the tower. The view of the runways and runway approaches, taxiways and ramp areas from the control tower should be considered when locating luminaires, so that after sunset this view is not hindered due to glare from these luminaires. The design of lighting poles and towers also must not obstruct this view.

5.2 Apron Floodlighting

5.2.1 *General*

An apron is a defined area on a land aerodrome intended to accommodate aircraft for the purpose of loading and unloading passengers, mail or cargo, refueling, parking or maintenance. Aircraft would normally be expected to move into these areas under their own power or by towing, and adequate lighting is necessary to enable these tasks to be performed safely and efficiently at night.

The part of the apron containing the aircraft stands requires a relatively high level of illuminance. The size of each aircraft stand is largely defined by the size of the aircraft and the amount of space necessary to manoeuvre the aircraft safely into and out of this position.

5.2.2 *Functions*

The primary functions of apron floodlighting are to:

a) assist pilots in taxiing the aircraft into and out of the final parking position;

b) provide lighting suitable for passengers to embark and disembark and for personnel to load and unload cargo, refuel and perform other apron service functions; and

c) maintain airport security.

5.3 Aircraft Taxiing

The pilot mainly relies on apron floodlighting when taxiing on the apron. Uniform illuminance of the pavement within the aircraft stand and elimination of glare are major requirements. On taxiways adjacent to aircraft stands, a lower illuminance is desirable in order to provide a gradual transition to the higher illuminance on the aircraft stands.

5.4 Apron Service

These functions require uniform illuminance of the aircraft stand area of a sufficient level to perform most of the tasks. In case of unavoidable shadows, some tasks may require supplementary lighting.

5.5 Airport Security

Illuminance should be sufficient to detect the presence of unauthorized persons on the apron and to enable identification of personnel on or near aircraft stands.

5.6 Performance Requirements

A variety of light sources are used for airport area floodlighting. The spectral distribution of these lights shall be such that all colours used for aircraft markings connected with routine servicing, and for surface and obstruction markings, can be correctly identified. Practice has shown that incandescent halogen as well as different high pressure gas discharge lamps are suitable for this purpose. Discharge lamps by the nature of their spectral composition will produce colour shifts. Therefore, it is imperative to check the colours produced by these lamps under daylight as well as artificial light to ensure correct colour identification. Occasionally it may be advisable to adjust the colour scheme used for the surface and obstruction markings.

5.6.1 *Illuminance*

An average illuminance of not less than 20 lux is needed for colour perception and is considered the minimum requirement for the tasks to be carried out on the aircraft stands. In order to provide optimum visibility, it is essential that illuminance on the aircraft stand be uniform within a ratio of 4 to 1 (average to minimum). In this connection, the average vertical illuminance at a height of 2 m should not be less than 20 lux in the relevant directions.

To maintain acceptable visibility conditions, the average horizontal illuminance on the apron, except where service functions are taking place should not be less than 50 percent of the average horizontal illuminance of the aircraft stands within a uniformity ratio of 4 to 1 (average to minimum) in this area.

It is recognized that some visual tasks require additional supplementary lighting, for example, portable lighting. However, the use of vehicle headlights for purposes other than guidance during driving should be avoided. For security reasons additional illuminance greater than that specified above may be required.

The areas between aircraft stands and the apron limit (service equipment, parking area, service roads) should be illuminated to an average horizontal illluminance of 10 lux. If the higher mounted floodlights do not light this adequately, then glare free lighting of the street lighting

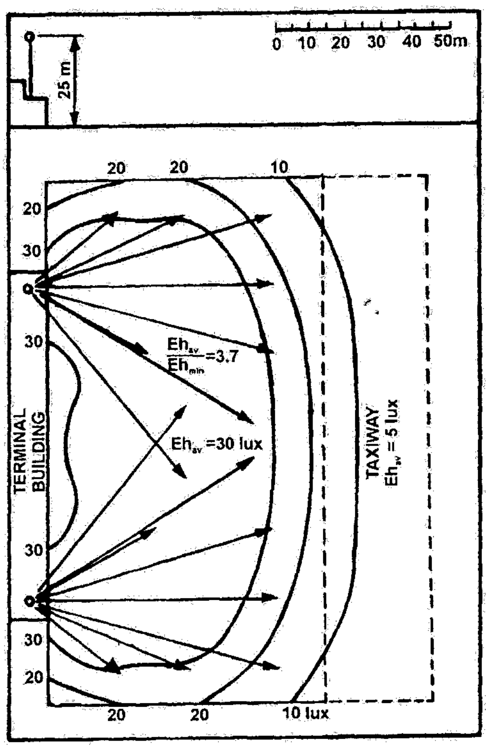

Fig. 2 Typical Isolux Curves for Horizontal Illuminance

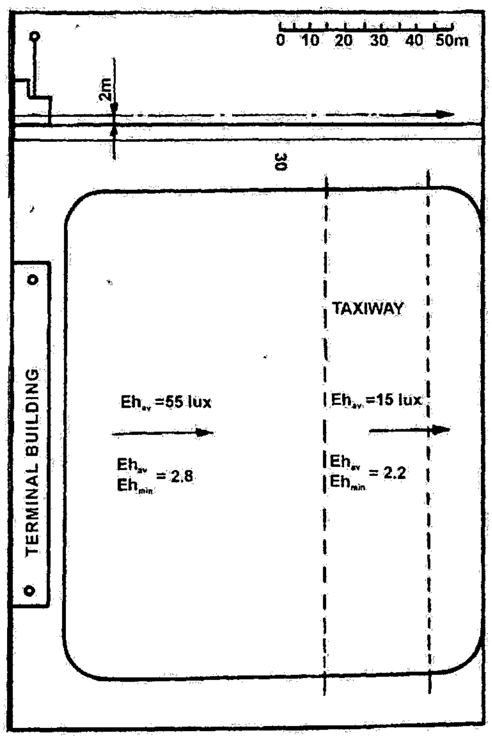

Fig.3 Typical Average Vertical Illuminance at 2 m Height

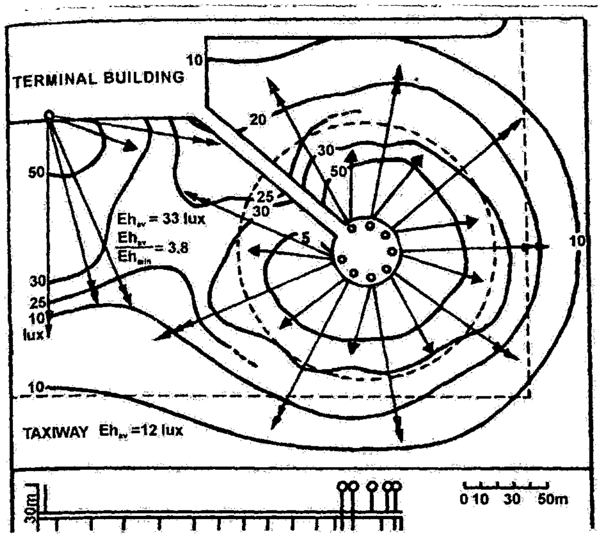

Fig. 4 Typical Isolux Curves for Horizontal Illuminance

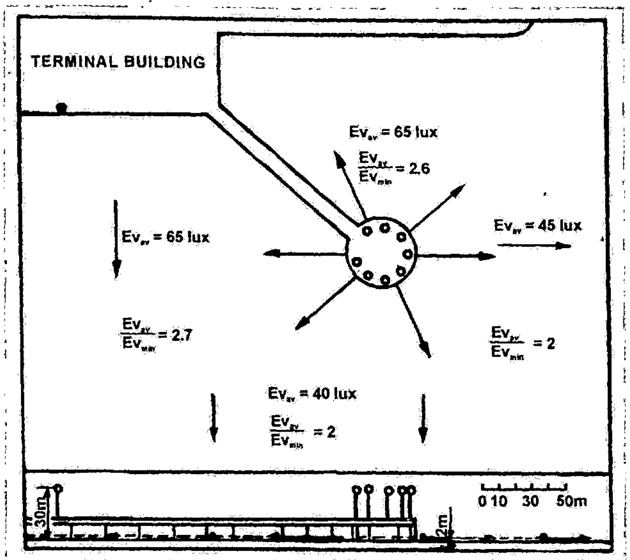

Fig. 5 Typical Average Vertical Illuminance at 2 m Height

type could be used. Some examples of illuminance on aprons are presented in Figs. 2 to 5.

5.6.2 *Glare*

Aiming of floodlights should be as far as practicable in the directions away from the control tower or landing aircraft. Direct light above the horizontal plane through a floodlight should be restricted to the minimum (*see* Figs. 6 and 7).

To minimize direct and indirect glare:

a) The mounting height of floodlights should be at least two times the maximum eye height of pilots inside the aircraft regularly using the airport; and

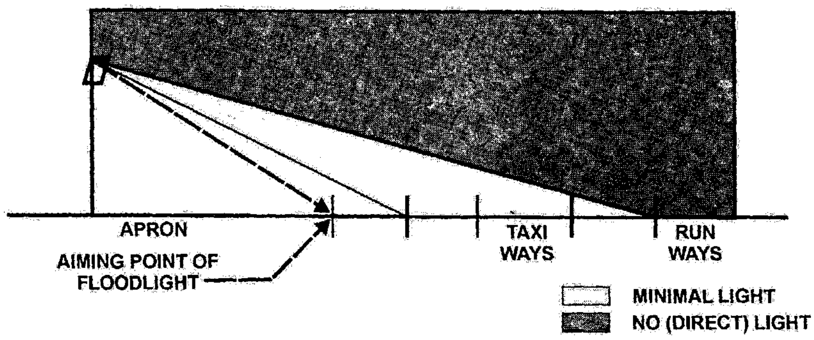

Fig. 6 Typical Aiming Pattern for Floodlights

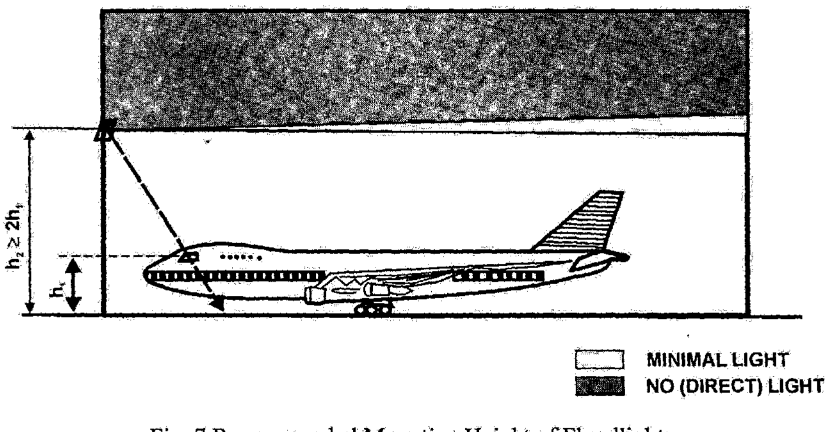

Fig. 7 Recommended Mounting Height of Floodlights

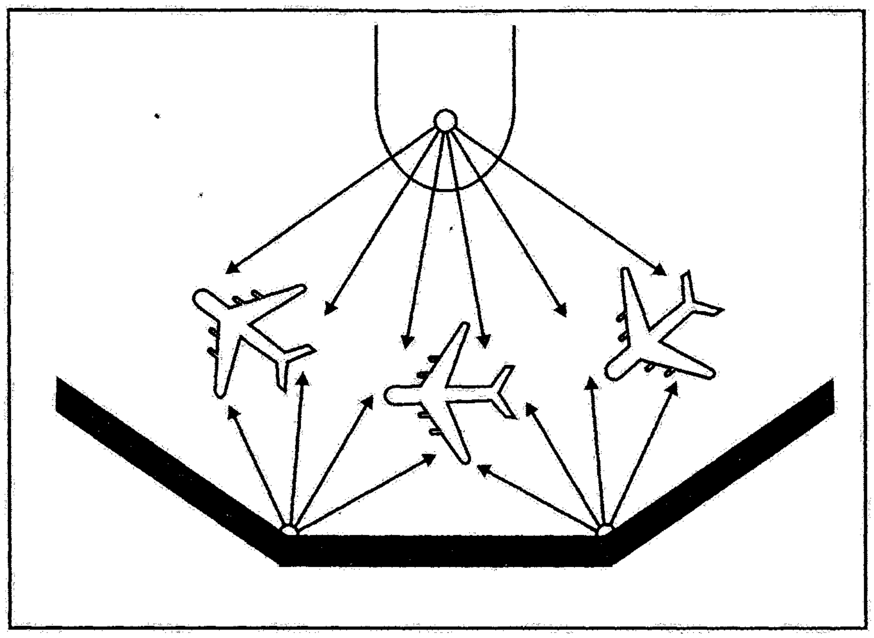

Fig. 8 Typical Aiming of Floodlights from Two Sides

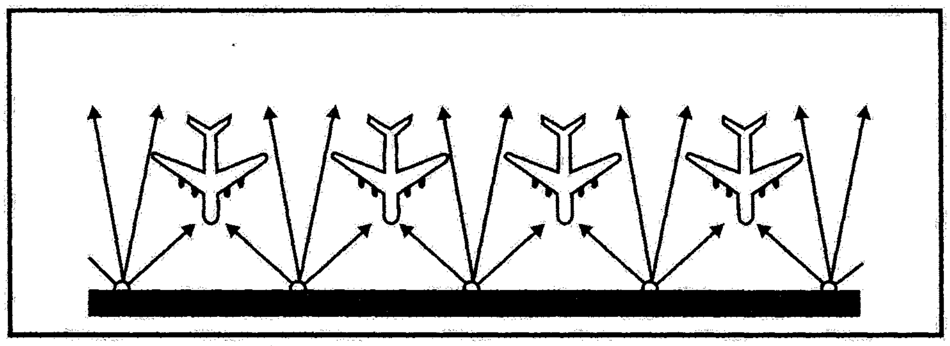

Fig. 9 Typical Aiming of Floodlights from One Side

b) The location and height of the masts should be such that inconvenience to ground personnel due to glare is kept to a minimum.

In order to meet these requirements, floodlights will have to be aimed carefully, giving due consideration to their light distribution. Light distribution may be controlled by the use of screens.

5.7 Emergency Lighting

In the event of a power failure, it is recommended that provision be made for sufficient illumination to ensure passenger safety.

5.8 Design Criteria

5.8.1 *Lighting Aspects*

In addition to the design criteria derived from the performance requirements, the following aspects should be considered in designing an apron floodlighting system.

a) The height of the apron floodlighting masts should be in accordance with the relevant obstacle clearance requirements;

b) Obstructions to the view of control tower personnel should be avoided. In this respect special attention should be paid to the location and height of the floodlighting towers; and

c) The arrangement and aiming of floodlights should be such that aircraft stands receive light from different directions to minimize shadows. Better results are obtained by uniform illuminance of the total area than by directing individual floodlights at the aircraft (*see* Figs. 8 and 9).

5.8.2 *Physical Aspects*

During the design stage of an airport due consideration should be given to the physical aspects of the apron in order to provide efficient apron floodlighting. The ultimate choice of the location and height of the floodlights depends on:

a) Dimension of the apron;

b) Arrangement of aircraft stands;

c) Taxiway arrangement and traffic scheme;

d) Adjacent areas and buildings especially the control tower; and

e) Location and status of runways and helicopter landing areas.

5.8.3 *Electrical Aspects*

If discharge lamps are used, a three phase electrical supply system should be utilized to avoid stroboscopic effects. If high pressure discharge lamps are used, emergency lighting can be arranged by either halogen incandescent lamps or by special circuitry of some of the high pressure discharge lamps (dedicatedly on UPS).

5.8.4 *Maintenance Aspects*

The lighting system should be so designed that maintenance expense can be held to a reasonable value. If access to lights is difficult, it is most economical to change lamps on a group replacement basis. Since cost of replacing lamps in high mounted lights can be significant, long life lamps should be used. Where possible, the lights should be so placed that they will be easily accessible without using special equipment. Tall poles could be equipped with pole steps or raising and lowering devices for servicing.

SP 72 : 2010

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 6 Sports Lighting

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Lighting of sports arenas is important from the viewpoint of providing adequate light, coverage, angles, illuminance, colour, etc. The lighting and lighting arrangement has a bearing on the game played and therefore, the designing should be according to the requirement of the particular sport.

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 6 Sports Lighting

1. SCOPE

This section of the code covers the principles and practices governing good visual environment for sports lighting.

2. TERMINOLOGY

The definitions of the terms used in this section are given in Part 1 of this code. (*See also* **20**.)

3 BASIC CONSIDERATIONS

3.1 Primary Users and their Requirement

For designing of the lighting of a sports facility, careful consideration has to be given to the visual requirement and comfort of its principal users. Broadly, the users of a sports facility can be grouped as players and team officials allowed on the bench near the playing area.

The players must be able to clearly see all that is going on in the playing area, so that they can deliver the best possible performance.

Spectators in the stadium have to be able to follow the performances of the players and the developments of the game in an agreeable environment. The latter requirement means that they must be able to see their surroundings and immediate neighbours as well. The lighting should also help the spectators to safely enter and leave the sports facility. With large crowds this security aspect is very important. Also important in high end facilities is the ambience in the stadium.

For colour TV film crews, sports photographers, journalists and for television and film coverage, the lighting should provide the conditions necessary to guarantee good picture quality (today usually in colour) not only of the game, but also close-ups of the players and spectators. The transition from daylight to artificial light should be as smooth as possible, so that adjustment for both players and the camera is minimal.

To comply with the requirement for continuity of normal or high definition television (HDTV) coverage in the event of power failure of the mains supply, it is usual to install a secondary power supply system capable of providing the emergency TV lighting level.

3.2 Type of Sport

Two factors related to the type of sport have a major influence on the quality of lighting required. These are the apparent size and the apparent speed of the playing object (often a ball). The former is dependent upon the physical size of the object and the viewing distance; the latter upon its speed and direction of movement relative to the direction of view. Higher demands will be made on the lighting as the speed of the playing object increases, its size becomes smaller and the playing area, that is, the viewing distance increases, for example, cricket.

Certain types of sport have only a limited number of main viewing directions for the players (for example, with tennis the main viewing direction is in the longitudinal direction of the court). These main viewing directions can influence the positioning of the luminaires, especially to limit direct glare.

3.3 Type of Sports Area

Important considerations regarding a sports area, as far as the lighting is concerned, are its dimensions (principal playing area and total playing area), whether or not the stands are covered, the spectator facilities, reflectances of playing surfaces and for indoor facilities, whether or not there is daylight penetration and the material and hence reflectance of the playing surface, walls and ceiling.

The dimensions of a sports area influence the quality requirement of the lighting (because different viewing distances are involved) and also the locational possibilities of the luminaires. The overall dimensions of a sports area are determined by the type of sport or sports catered for and by the sort of spectator facilities provided, for example, no grandstand, grandstand at one side, grandstand totally enclosing the playing area, etc.

3.3.1 *Principal Playing Area (PPA)*

This is the actual playing area needed for the performance of a certain sport. Usually this means the actual marked out 'field' area for that sport (for instance, football), but in some cases this area comprises an extra playing area around the marked area (for example, tennis, volleyball and table tennis).

3.3.2 *Total Playing Area (TPA)*

Generally this area comprises the principal area (PA) plus an additional safety area outside the principal area.

Often the height and construction of the ceiling have an important bearing on the lighting possibilities. Halls with daylight penetration call for special attention to avoid adaptation problems, whereas this problem cannot arise in halls without daylight penetration.

A surface is made visible by virtue of lighting being reflected from it and entering the eye of the observer. It should thus be appreciated that the reflectance of the surfaces of the sports area, such as the ground (grass, gravel, etc) and, in halls also the walls and ceiling, play a role in the final lighting effect achieved.

4 LIGHTING CRITERIA

Knowing the user requirements, it is possible to say what lighting criteria should be satisfied in order that all these requirements will be met. Relevant Lighting Parameters are:

a) Horizontal Illuminance;

b) Vertical Illuminance;

c) Illuminance Uniformity and Illuminance Gradient;

d) Glare Restriction;

e) Modelling and Shadows; and

f) Colour Appearance and Colour Rendering.

The brightness, or more correctly the luminance of a surface is dependent on the amount of light incident on that surface (that is, the illuminance), the angle from which it is viewed and its reflectance. In sports we are confronted with a wide variety of reflecting surfaces (for example, the ball, the players' clothing and the playing surface) and an almost infinite range of viewing angles. Consequently, each different viewing direction toward a surface may lead to a different surface luminance. Because of this, the calculation of luminance values for sports lighting is extremely difficult, if not simply impossible. Designs and specifications in sports lighting are therefore generally based on illuminance. The designer or the person drawing up the specifications should, however, always bear in mind that surfaces with high reflectance (light surfaces) will, for a given illuminance, result in a higher luminance than surfaces with lower reflectance (darker surfaces).

4.1 Horizontal Illuminance

As the illuminated field forms a major part of the field of view of both the players and spectators, it is the horizontal illuminance on this that chiefly serves to establish the adaptation state of the eye. Because of this, and because the illuminated field serves for the players, spectators and cameras as a visual background, an adequate horizontal illuminance on the field is important.

To ensure that spectators can safely enter and leave the stands, a certain minimum horizontal illuminance on the stands must be maintained. A value of 10 percent of the average playing field illuminance will suffice, although for reasons of comfort a value of 20 percent is preferred.

$$Eh\,(st)/Eh\,(field) > 0.2$$

4.2 Vertical Illuminance

Vertical illuminance is essential for viewing vertical objects. The side of a player that can be seen by an observer can be approximated by a vertical plane at right angles to the observer's line of view.

To guarantee identification of players from all directions, the illuminance on four, mutually perpendicular, vertical planes taken at a height of 1.5 m should be adequate. For this purpose, the vertical planes facing the four sidelines of the playing area are usually taken.

To guarantee that a ball or playing object can also be clearly seen when it is at a certain height above the playing area, the vertical illuminance at such a height should also be adequate. In general, the vertical illuminance (at players and ball positions) should, of course, be adequate for the players and spectators, but also for cameras, if present.

In practice, the vertical illuminance required for players and spectators will usually be obtained automatically if the requirements regarding the horizontal illuminance are fulfilled. The vertical illuminance requirement of television coverage has to be addressed separately.

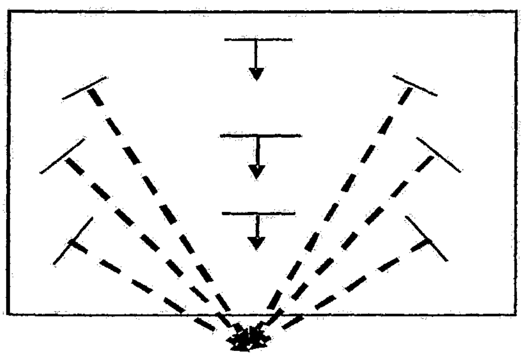

Fig. 1a) Fixed Camera Location

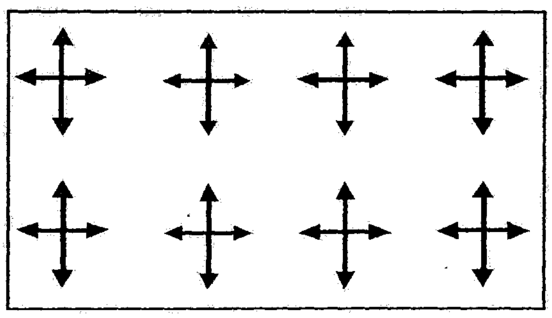

Fig.1 b) Unrestricted Camera Positions

For televising or filming with fixed camera positions, it is sufficient to ensure that the illuminance on vertical planes at right angles to the camera position(s) are adequate in order to obtain an acceptable picture.

The orientation of the vertical planes can be indicated as the direction at right angles toward a reference point. In the case of a single camera position, the reference point is the camera position itself [*see* Fig. 1a)]. In the case of an unrestricted choice of camera positions, the vertical illuminance on planes facing all four sides of the pitch should be taken [*see* Fig 1b)].

4.3 Illuminance Uniformity

Good illuminance uniformity in the horizontal and vertical planes is important in order to avoid adaptation problems for players and spectators, and adjustment problems for cameras, respectively, for different directions of view. Moreover, if the uniformity is not good enough, there is a certain risk (especially with television cameras) that the ball or a player will not be seen clearly at certain positions on the field.

Uniformity can either be expressed as the ratio minimum-to-maximum illuminance or as the ratio minimum-to-average illuminance. For colour television lighting the ratio minimum-to-maximum is more critical, whereas the minimum-to-average ratio is usually considered for non-televised activity and lower levels of play.

4.3.1 *Vertical Illuminance Uniformity*

On planes facing a sideline bordering a main camera area or facing a fixed main camera position this should be:

$$Ev_{min} / Ev_{max} > 0.4 \text{ , } Eh_{min} / Eh_{av} \geq 0.6$$

where

Ev_{min} = the minimum vertical illuminance, in lux;

Ev_{max} = the maximum vertical illuminance, in lux; and

Ev_{av} = the average vertical illuminance, in lux.

The uniformity of vertical illuminance at a single grid point over the four planes facing the sides of the playing area shall be:

$$Ev_{min} / Ev_{max} > 0.3$$

where

Ev_{min} = the minimum vertical illuminance, in lux; and

Ev_{max} = the maximum vertical illuminance, in lux.

4.3.2 *Relation between Horizontal and Vertical Illuminance*

As the illuminated field forms a major part of the field of view of the camera, an adequate horizontal illuminance is important. A sufficiently good balance between the horizontal and vertical lighting levels is obtained when the average horizontal to the average vertical illuminance (relative to each of the main camera areas or main camera positions) is such that:

$$0.5 \leq Eh_{av} / Ev_{av} \leq 2$$

where

Eh_{av} = the horizontal average illuminance, in lux; and

Ev_{av} = the vertical average illuminance, in lux.

4.3.3 *The Uniformity of the Horizontal Illuminance*

On the playing field shall be:

$$Eh_{min} / Eh_{max} \geq 0.5, \; Eh_{min} / Eh_{av} \geq 0.7$$

where

Eh_{min} = the minimum horizontal illuminance, in lux;

Eh_{max} = the maximum horizontal illuminance, in lux; and

Eh_{av} = the average horizontal illuminance, in lux.

4.3.4 *Gradient*

It is also important that there is not too great a change in horizontal illuminance over a given distance. For example, on large playing fields such as football pitches the maximum gradient of horizontal illuminance shall be not greater than 25 percent change per 5 m.

4.4 Glare Rating

Needless to say, glare has a disturbing effect on the visual comfort of both players and spectators. Glare can be minimised by paying careful attention to the aiming of the floodlights relative to the main direction of view for the sport or sports considered.

Some measures for limiting glare may be taken from CIE Publication 117-1995.

The glare rating shall be calculated for agreed observer positions and angles of view.

For viewing directions not directly toward the floodlights, study has led to a measure for the degree of glare restriction for outdoor sports floodlighting installations. The measure is dependent upon two lighting parameters:

a) the veiling luminance produced by the luminaires: L_{vl}; and

b) the veiling luminance produced by the environment: L_{ve}.

L_{ve} can be approximated from the average horizontal field illuminance Eh_{av}

L_{ve} (veiling luminance produced by the environment) $= 0{,}035 \times Eh_{av} \times \rho/\pi$, where ρ = the field reflectance.

L_{vl} (veiling luminance, produced by the luminaires) $= \sum_{i=1}^{n} \frac{E_{eye,i}}{\theta_i^2}$

where

$E_{eye, i}$ = illuminance on the eye produced by the *i*th light source (lux); and

θ_i = angle between direction of view and the direction of light incidence from the *i*th light source (degrees).

For L_{vl} the light sources are the floodlights, while for L_{ve} the bright field and bright surroundings are treated as an infinite number of small light sources. The following interrelationship between these two parameters describes the degree of glare rating (GR) possessed by the installation for a certain observer position and viewing direction:

$$GR = 27 + 24 \log [L_{vl} / (L_{ve})^{0.9}]$$

Here GR stands for Glare Rating for Floodlighting. The lower the GR, the better the glare restriction.

The assessment scale given below corresponds with the values of the glare rating GR,

GR	Interpretation
90	unbearable
80	
70	disturbing
60	
50	just admissible
40	
30	noticeable
20	
10	unnoticeable

For outdoor floodlighting installations, where GR has validity, a maximum GR value of 50 is required. With the aid of the GR concept it is possible to find out how much better or worse, as far as glare is concerned, one situation is compared with another.

So far, glare has only been considered for the players and spectators on or very close to the lighted area. However, stray light from exterior lighting installations can also be disturbing to people outside the lighted area, for example for traffic on adjacent roads and for inhabitants of houses in the neighbourhood of the area. In order to limit this problem, the floodlights must be carefully aimed and the luminous intensities outside the main beam of the floodlights severely reduced.

4.5 Modelling and Shadows

The ability of the lighting to reveal form and texture, in short, its 'modelling' ability is particularly important if it is to give a pleasant overall impression, not only for the players and spectators, but also for the television cameras. A quantitative measure of modelling having general validity for all kinds of (indoor and outdoor) sports lighting is very difficult to arrive at. To limit the length and hardness of the shadows caused by the players, the ratio between the total flux installed (in the case of an asymmetrical floodlight arrangement), shall be generally 60 percent from the main camera side and 40 percent from the secondary camera side.

4.6 Colour Properties of Lamps

Two important aspects of the colour properties of lamps have to be distinguished.

The colour appearance of the lamp (T_c) is the colour impression received when looking at the lamp itself. The colour rendering (Ra) of the lamp is the ability of the light to reproduce the colours of an object faithfully. Colour is important in most sports, and while some colour distortion attributable to the artificial lighting is acceptable, colour discrimination should not present a problem.

Television and film cameras call for a correlated colour temperature (T_c) in the range of 2 000 K and 6 000 K in order to avoid colour matching and balance problems. This is provided that differences in the colour temperature between individual lamps are not too great. When artificial lighting is used in combination with daylighting (during the transition stage), it is preferred that lamps should have a colour temperature greater than 4 000 K, to avoid balance problems.

Colour rendering of lamps (Ra) shall always be better than 65 but the preferred value is greater than 80.

5 LIGHTING PARAMETER RECOMMENDATIONS

5.1 The illuminance needed on the playing area primarily depends on:

a) the level of sporting activity taking place;
b) For vertical illuminance lighting for colour television, the following parameters are critical:
   i) the apparent speed of the ball (rapid movements of players should also be considered); and
   ii) the maximum distance between the players, or between the spectators and players, or between the players or spectators and the ball.

5.2 The activity in any sports arena can be classified into class I, II and III. The level of competition and the lighting classification is as given below (*see also* Table 1):

a) Lighting Class I: Top level competitions such as international and national competitions which will generally involve large spectator capacities with long potential viewing distances. Top level training can also be included in this class;
b) Lighting Class II: Mid level competitions such as regional or local club competitions which generally involve medium size spectator

capacities with medium viewing distances. High level training can also be included in this class; and

c) Lighting Class III: Low level competition such as local or small club competition which generally do not involve spectators. General training, physical education (school sports) and recreational activities will also come into this category.

Table 1 Level of Competition and the Lighting Class
(*Clause* 5.2)

Sl. No.	Level of Competition	Class		
		I	II	III
(1)	(2)	(3)	(4)	(5)
i)	International and National	x	-	-
ii)	Regional	x	x	-
iii)	Local	x	x	x
iv)	Training	-	x	x
v)	Recreational	-	-	x

5.3 Sports can be classified into three groups A, B and C characterized mainly by speed of action occurring during camera shots as stated below. This is an important parameter in determining vertical illuminances.

a) Group A : Archery, athletics, billiards, bowling, curling, darts, diving, horse jumping, shooting, snooker and swimming;

b) Group B: Badminton, baseball, basketball, bob sleigh, luge, football (soccer, American, rugby), gymnastics, handball, hockey, ice skating, judo, karate, lawn tennis, racing (motorcar, cycle, dog and horse), roller skating, ski jumping, ski racing, softball, speed skating, volleyball and wrestling; and

c) Group C: Boxing, cricket, fencing, ice hockey, lacrosse, racquetball, squash and table tennis.

5.4 Each of these groups is then subdivided into three subsections according to maximum shooting distance and vertical illuminances (in lux) recommended as given in Table 2.

Table 2 Maximum Shooting Distance
(*Clause* 5.4)

Sl. No.	Maximum Shooting Distance		25m	75m	150m
(1)	(2)		(3)	(4)	(5)
i)	Group of Sport	A	500	700	1 000
ii)		B	700	1 000	1 400
iii)		C	1 000	1 400	—

5.5 Recommended vertical illuminances for various groups of play and camera shooting distance are given in Fig. 2.

6 LIGHTING RECOMENDATIONS

6.1 For non televised events, any event can be classified into the following:

a) t/r = Training and Recreational;

b) ca = Amateur Competition; and

c) cp = Professional Competition.

6.2 Recommended Average (Maintained) Minimum Illuminance for Non Televised Activity

Recommended horizontal illuminance for different level of sports activity for non televised events for outdoor and indoor sports events are given in Table 3A and Table 3B. All recommended horizontal and vertical illuminances are the average values.

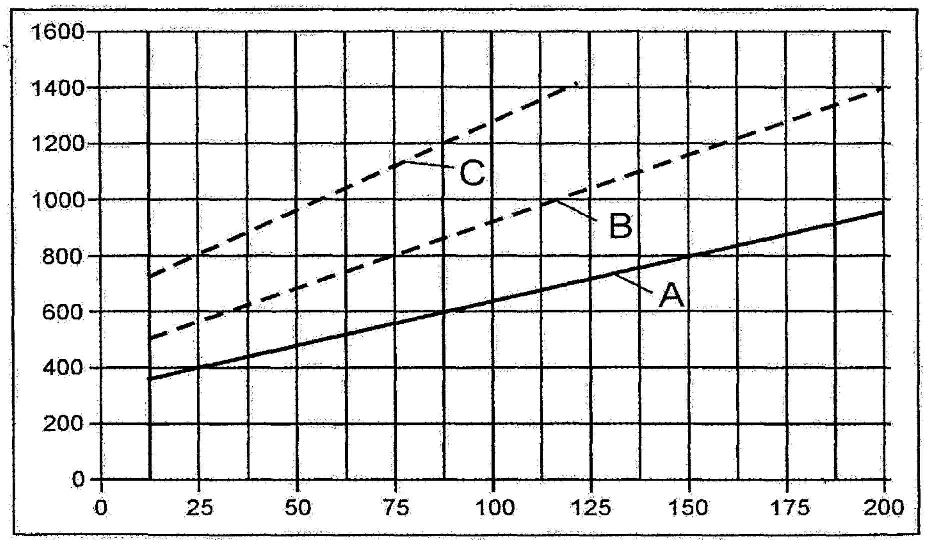

Fig. 2 Recommended Vertical Illuminances Related to Camera Shooting Distance

Table 3A Recommendations for Non Televised Events: Outdoor Sports
(*Clause* 6.2)

Class	Horizontal Illuminance(Lux)	Uniformity (E_{min}/E_{av})	Ra	Glare Rating
American Football , Athletics, Basketball, Cycle Racing, Equestrian Sports, Fistball, Football, Handball, Netball, Rugby and Volleyball				
I	500	0.7	>60	<50
II	200	0.6	>60	<50
III	75	0.5	>20	<55
NOTE — For Class III athletics and equestrian sports the minimum illuminance is 100 lux.				
Swimming				
I	500	0.7	>60	<50
II	300	0.7	>60	<50
III	200	0.5	>20	<55
NOTE — For diving, vertical uniformity should also be considered. Class I: 0.8 Eh/Ev. Class II: 0.5 Eh/Ev. Class III: 0.5 Eh/Ev.				
Tennis				
I	500	0.7	>60	<50
II	300	0.7	>60	<50
III	200	0.6	>20	<55
NOTE — Values refer to 'Total Playing Area' as defined by ITF.				
Baseball, Bandy, Cricket, Hockey, Ice Hockey, Ice Skating, Motorcycling and Softball				
I	750	0.7	>60	<50
II	500	0.7	>60	<50
III	300	0.7	>20	<55
Outfield for Baseball, Cricket and Softball				
I	500	0.5	>60	<50
II	300	0.5	>60	<50
III	200	0.3	>20	<55
Bobsleigh and Luge				
I	300	0.7	>60	<50
II	200	0.7	>60	<50
III	50	0.5	>20	<50
Bowls sport (Lawn, Raff and Petanque)				
I	200	0.7	>60	<50
II	100	0.7	>60	<50
III	50	0.5	>20	<55
Archery				
I,II,III	200	0.5	>60	<50
Vertical Illuminance in luxI,II,III on target	750	0.8	>60	<50
Alpine and Freestyle Skiing				
I	150	0.5	>60	<50
II	100	0.4	>20	<50
III	50	0.3	>20	<55

Table 3A (*Concluded*)

Class	Horizontal Illuminance(Lux)	Uniformity (E_{min}/E_{av})	Ra	Glare Rating
Ski Jump Landing Area				
I	300	0.7	>60	<50
II	200	0.6	>60	<50
III	200	0.6	>20	<55
NOTE — Run Down, Class I 50 lux (0.5), Class II 50 lux (0.3), Class III 20 lux (0.3)				

Table 3 B Recommendations for Non Televised Event: Indoor Sports
(*Clause* 6.2)

Class	Horizontal Illuminance(Lux)	Uniformity (E_{min}/E_{av})	Ra	Glare Rating
Aikido, Basketball, Bodybuilding, Cycle Racing, Fistball, Floorball, Football, Handball, Jujutsu, Judo, Karate, Korfball, Netball, Powerlifting, School Sports, Sumo, Taekwondo, Volleyball, Weightlifting, Wrestling, Wushu				
I	750	0.7	>60	–
II	500	0.7	>60	–
III	200	0.5	>20	–
Boxing				
I	2000	0.8	>80	–
II	1000	0.8	>80	–
III	500	0.5	>80	–
NOTE — Vertical illuminance at 1.5 m should be >50 percent of Eh.				
Athletics, Dancing, Equestrian Sports, Gymnastics, Roller Sports and Wall Climbing				
I	500	0.7	>60	–
II	300	0.6	>60	–
III	200	0.5	>20	–
NOTE — For wall climbing Class I: 500 lux vertical. Class II: 300 lux vertical. Class III: 200 lux vertical				
Swimming (Aquatic Sports)				
I	500	0.7	>60	–
II	300	0.7	>60	–
III	200	0.5	>20	–
NOTE — For diving, vertical uniformity should also be considered. Class I: 0.8 Eh/Ev. Class II: 0.5 Eh/Ev. Class III: 0.5 Eh/Ev.				
Tennis				
I	750	0.7	>60	–
II	500	0.7	>60	–
III	300	0.5	>20	–
NOTE — Values refer to 'Total Playing Area' as defined by ITF.				
Badminton, Basque Pelota, Cricket, Cricket Nets, Curling, Fencing, Hockey, Ice Hockey, Ice Skating, Racquetball, Squash and Table Tennis				
I	750	0.7	>60	–
II	500	0.7	>60	–
III	200	0.7	>20	–
NOTE — For fencing, Class I: 500 lux vertical. Class II: 300 lux vertical. Class III: 200 lux vertical. Cricket nets, Class I: 1500 lux (0.8). Class II: 1000 lux (0.8). Class III: 750 lux (0.8)				

Table 3B (*Concluded*)

Class	Horizontal Illuminance(Lux)	Uniformity (E_{min}/E_{av})	Ra	Glare Rating
Billiards				
I	750	0.8	>80	–
II	500	0.8	>80	–
III	500	0.8	>80	–
Bowls Sport (Lawn, Raff, Petanque)				
I	500	0.8	>60	–
II	500	0.8	>60	–
III	300	0.5	>20	–
Bowling, Archery, Shooting				
I	200	0.5	>60	–
II	200	0.5	>60	–
III	200	0.5	>60	–
Vertical Illuminances in lux I, II, III				
on pins	500	0.8	–	–
on target at 25 m	1 000	0.8	–	–
on target at 50 m	2 000	0.8	–	–

7 EMERGENCY AND STAND LIGHTING

7.1 Emergency lighting is either part of the main lighting system or a separate system designed to operate for a specified period when the main supply has failed. It should provide sufficient illumination to allow for the safe movement of people away from the affected area.

Sports centres and stadiums suitable for holding different games and having a flexible switching system for each of these games should have provision of emergency or escape lighting to suit this flexibility of usage of the total arena and the main lighting system.

Spectators using the sports arena may be expected to be unfamiliar with the layout. Consideration should be given therefore to the installation of a maintained system particularly in respect of exit signs. Illumination is required not only in the event of a complete failure of the supply of normal lighting, but also when there is a localized failure if such failure presents a hazard.

Luminaires for emergency should be placed near the intersection of corridors, at each exit door, near each change of direction, staircase, change of floor level, etc.

Emergency lighting calls for a minimum level of 1 lux to be provided in areas requiring emergency/escape illumination.

The use of high pressure discharge lamp lighting within sports halls or centres is most common today. With discharge lamps, the run up time of 2 to 5 minutes and restrike time of 1 to 15 minutes to reach maximum lumen output is usual. Some discharge lamps are also available with a hot restrike version, where the light is restored immediately as soon as power becomes available. It is recommended that a certain number of luminaires which will provide lights to maintain the minimum lighting level for emergency TV broadcast, should be with hot restrike option. However in the interim period, between a power failure and restoration either of the main supply or of an alternate source (like standby generators), a standby system of low voltage luminaires (TL or halogen) with battery back up should be provided especially at strategic locations like evacuation paths and exit doors.

8 SPECIAL EVENTS, LANDSCAPE AND OUTDOOR LIGHTING

More and more a sports facility is no longer treated as an infrastructure for a game to be played. Increasingly, it is a social area, and major sports events are even treated as a spectacle. Provision should also be made to install lighting for special effects and light shows, especially during opening and closing ceremonies. Decorative floodlighting of the external structure and landscape lighting should also be well integrated during the planning of the projects.

9 DATA REQUIRED BEFORE START OF LIGHTING DESIGN

As sports lighting design is a fairly complex process, it is important to gather the following field data as accurately as possible before the start of the process:

a) Detailed drawings of the stadium;

b) Field dimensions;

c) Feasibility of different luminaire arrangement;

i) For corner mast location, a site survey needs to be done, to assess the practical situation of mast location and to check if the recommended location is as per the relevant standards; and

ii) For roof mounting, structural feasibility of mounting luminaires, gear tray, cables, walkways, etc and the length of covered roof are required;

d) For camera locations, distance from the field centre and height are required. Usually there will be a media room in the main stands, and the main camera is located in front of it. It is important to check the location of secondary and other cameras; and

e) Agreement on specifications and calculations are required. It has to be checked whether vertical illuminance calculation will need to be done for secondary cameras also.

10 LIGHTING RECOMMENDATION FOR COLOUR TELEVISION BROADCASTING

10.1 For sports like soccer, hockey, tennis and athletics, individual guidelines issued from time to time by FIFA, FIH, ITF, and GAISF shall be followed. For televised sports, the federation guidelines and standards should be followed:

a) FIFA Guide to the artificial lighting of football pitches;

b) FIH Guide to the artificial lighting of hockey pitches;

c) ITF Guide to the artificial lighting of tennis courts;

d) GAISF Guide to the artificial lighting of indoor and outdoor sports venues;

e) IAAF Manual;

f) CIE 112 (1994) - Glare evaluation system for use within outdoor sports and area lighting;

g) CIE 83-1989 Guide for the lighting of sports events for colour television and film systems;

h) CIE 169-2005 Practical design guidelines for the lighting of sport events for colour television and filming; and

j) EN 12193:1999 Light and lighting. Sports lighting.

As a general guideline, the average maintained vertical illuminance levels given in Table 4A and 4B, can be considered at a height of 1.5 m above the area of competition, parallel to the four sidelines in case of unrestricted camera position or towards the direction of fixed camera position. A brief summary of lighting standards can also be taken as a general guideline.

11 DESIGN CONSIDERATIONS

The fundamental lighting criteria that have to be considered when designing sports lighting installations are discussed in the previous sections. This section gives practical design guidelines.

11.1 Type of Lamp

In sports lighting the following lamp types are used:

Table 4.A Average Maintained Illuminance Levels for Major Events
(*Clause* 10.1)

	Eh	Uniformity		Ev	Uniformity		Ra	GR
		E_{min}/E_{av}	E_{min}/E_{max}		E_{min}/E_{av}	E_{min}/E_{max}		
HDTV	1 500-3 000	0.8	0.7	2 200	0.7	0.6	>90	<50
Slow motion Camera	1 500-3 000	0.8	0.6	1 800	0.7	0.5	>80	<50
Fixed Camera	1 500-3 000	0.8	0.6	1 400	0.7	0.5	>80	<50
Mobile Camera	1 500-3 000	0.8	0.6	1 200	0.5	0.3	>80	<50

NOTE — It is recommended that the ratio for horizontal illuminance (Field of Play) is between 0.75 and 1.5 of the vertical illuminance for cameras. Where there is HDTV, all horizontal values for other cameras are as for HDTV.

Table 4 B Average Maintained Illuminance Levels for National Events
(*Clause* 10.1)

	Eh	Uniformity		Ev	Uniformity		Ra	GR
		E_{min}/E_{av}	E_{min}/E_{max}		E_{min}/E_{av}	E_{min}/E_{max}		
Camera	1 000-2 000	0.7	0.5	1 000	0.6	0.4	>80	<50

a) tubular fluorescent;
b) metal halide; and
c) high pressure sodium.

Tubular fluorescent lamps are mostly used in interior sports lighting with low mounting heights, they are employed to advantage in ceiling luminaires to obtain glare free installations.

The metal halide lamp has an efficacy between 65 and 90 lm/W. Its white light (T_c between 4 000 and 6 000 K) has good colour rendering properties (Ra between 65 and 90) and its spectrum is especially suitable for colour television and filming. Its very compact shape and its high luminous output make it very suitable for use in precision floodlights. A wide range of metal halide lamps are available these days, the compact short arc lamps ideally suited for international level of play. It is these lamps, which are generally used for outdoor sports lighting installations for colour television broadcasting.

The high pressure sodium lamp has an even higher efficacy, up to 130 lm/W. Its colour rendering is moderate (Ra approximately 25), and this restricts its use to those applications like recreational outdoor sports, where colour does not play an important role.

11.2 Type of Luminaire

11.2.1 *Photometric Characteristics*

Two photometric characteristics of major importance in any luminaire are its light output ratio and its light distribution. A design combining a high light output ratio and a good light distribution is essential if good quality lighting at minimum operating costs is to be obtained.

Floodlights are characterized according to their light distribution:

Circular Floodlights with Rotationally Symmetrical Beam

These have a conically shaped symmetrical beam. Both narrow and wide beam types are available; and

Rectangular Floodlights

These are available in two versions:

a) With a symmetrical light distribution in the horizontal and vertical planes. In the horizontal plane the beam is wide, while in the vertical plane it is either wide or narrow; and
b) With a symmetrical light distribution in the horizontal plane and an asymmetrical distribution in the vertical plane. Also here the horizontal beam is wide.

The rectangular floodlight offers the advantages over the circular unit when mounted closely spaced along the sides of a playing field, the normal arrangement for a small field, of giving a more uniform light distribution and less wastage of light (*see* Fig. 3).

The circular floodlight however is more efficient than the rectangular unit when used in the four corner, diagonal arrangement provided several units per mast are used (*see* Fig. 4).

12 LIGHTING DESIGN AND INSTALLATION ASPECTS

Prior to the start of design of any project, it is important to first know, what level of play the sports facility will be used for.

Sports facilities can be classified in the following categories:

a) Outdoor or indoor stadium;
b) Type of sports being played;
c) Level of competition; and
d) Whether events will be directly televised or non televised.

The following issues are related to the lighting design and installation aspects:

a) Type of lighting arrangement;
b) Lighting calculation;
c) Switching steps; and
d) Aiming and commissioning.

12.1 Design Aspects

a) Listing of quality criteria based on which lighting design is done;
b) Integrating the architectural features of the sports complex especially for indoor halls. Lighting will add a number of elements, such as floodlights,

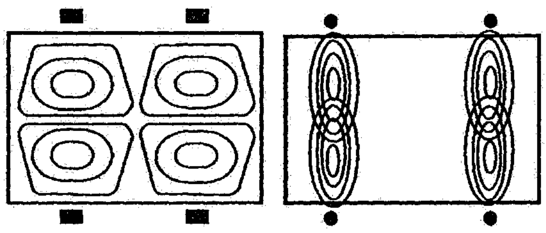

Fig. 3 Rectangular and Circular Floodlights Mounted Closely Spaced along the Sides of a Playing Field

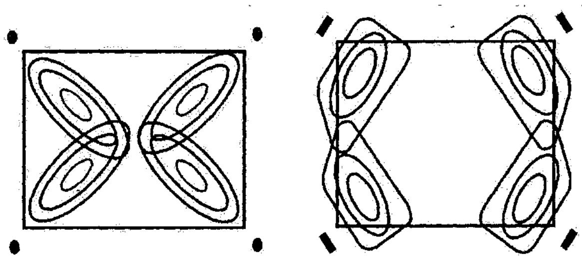

Fig. 4 Circular and Rectangular Floodlights Mounted in Corners, Diagonal Arrangement, of a Playing Field

lighting masts, catwalks, mounting cables, switchgear, etc;

c) In the case of a large stadium, the lighting system can be integrated in the roof structure. However, this is not possible always, as there may be limitations in the location and height of the roof, its ease of access, its load carrying capability and so forth. If an integrated system is not feasible, then masts have to be installed. These can be employed in a corner or in a side arrangement, but mixed arrangements making use of the roof over the main stand and masts at the opposite side are also used. The choice will depend on the architectural features of the stadium in combination with the lighting requirements; and

d) Mast Locations.

   Where masts are used, the light output of the floodlights should be obstructed as little as possible either by the luminaires themselves or by the head frame construction. Tilting the headframe forward is usually sufficient to overcome this problem, provided there is adequate space between the floodlights and the frame. Many popular sports like soccer, field hockey and tennis have laid down guidelines on probable mast locations for various levels of play. The height of the mast must increase proportionally (to minimize glare) if they are taken farther off from the playing arena.

   It is recommended that the line joining the center of the headframe carrying the floodlights to a point in the centre of the pitch should make an angle not less than 25° (*see* Fig. 5).

13 LIGHTING CALCULATION AND INTERPRETATION

It is common nowadays, when designing sports lighting installations to make use of computer aids. Computer printouts support the lighting design in showing quantitative values of most of the lighting parameters such as horizontal and vertical illuminance, uniformity ratios, glare marks, etc.

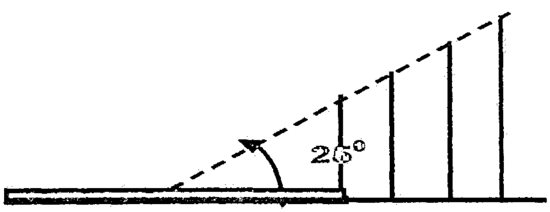

Fig. 5 Position of Headframe

For recreational sports, the following calculations are normally done:

a) Average Horizontal Illuminance;
b) Horizontal Uniformity Ratio $U1 = E_{min}/E_{max}$; and
c) Horizontal Uniformity Ratio $U2 = E_{min}/E_{av}$.

For professional level play, the most common calculations required will be:

a) Average Horizontal Illuminance;
b) Horizontal Uniformity Ratio $U1 = E_{min}/E_{max}$;
c) Horizontal Uniformity Ratio $U2 = E_{min}/E_{av}$;
d) Ratio between Eh and Ev;
e) Uniformity Gradient - Horizontal;
f) Average Vertical Illuminance towards main camera, and other auxiliary cameras as demanded by sport and broadcasting authorities;
g) Vertical Uniformity Ratio $U1 = E_{min}/E_{max}$;
h) Vertical Uniformity Ratio $U2 = E_{min}/E_{av}$;
j) Uniformity Gradient - Vertical; and
k) Glare Rating Calculation.

13.1 Calculation Grids

For lighting calculation, the playing surface is subdivided into smaller sections and calculations are carried for that point. These are called grid points. The value shown at a grid point is representative for the area surrounding that point, provided the grid size follows the guidelines given below for various games:

a) For small playing area, grid size of 1m x 1m , or 2 m x 2 m is considered;
b) For soccer, hockey, grid size of 5 m x 5 m; and
c) For large areas like cricket, grid size of 10 m x 10 m is considered.

For the specification of horizontal illuminance, the grid considered is at ground level, for vertical illuminance it is normally considered 1.5 m above ground level.

Glare calculations are carried out for particular observer positions. The standard observer positions and viewing directions for glare evaluations are defined for various sports under separate guidelines.

14 CAMERA AND OBSERVER LOCATIONS

The camera locations are usually indicated in the specifications and drawings.

The main camera is usually located to the side of the playing area in line with the centre line (for example, football, athletics, basketball, volleyball and handball). But for some sports (tennis, badminton, table tennis and squash) it may be located instead, at one end. In sports where there is a finishing line (for example, athletics, cycling, horse racing and swimming) a (second) main camera may be located in line with this.

Additional camera(s) can be located behind the goal (football and hockey) or to the side of the baseline (tennis), with portable cameras where needed (athletics, cycling, skating and tracked camera for swimming). In general, there is a tendency to use multiple camera locations for most types of sport.

In the computer programmes the (vertical) planes face a specified reference point which can be given. This reference point should be specified according to the camera position(s) considered.

Separate calculations are very often made for a number of these positions (main camera, auxiliary cameras, etc).

In designs that are critical with regard to glare, it may be required to include glare calculations for various observer locations.

14.1 Interpretation/Tolerances in Computed Values

The photometric values shown in the calculations are as exact as the input data on which they are based. In practice however, there can be a difference between calculated and measured values due to tolerances in the lamp and luminaire and in the way the installation is realized.

15 LUMINAIRE AIMING

Once properly installed, the luminaires must be aimed. This can be done either with aids incorporated in the floodlights or, with special aiming devices. For smaller installations, the former method is more usual, the elevation of the floodlight being set using, for example, a scale on the housing calibrated in degrees.

16 ELECTRICAL INSTALLATION

The lighting systems for recreational and training purposes (categories r and c) are normally very simple. In most cases only one switching option is included, although for a multipurpose sports facility switching steps can be built in for the various sports, perhaps for different smaller courts (for example, handball), or for the total area.

Where the lighting is for (professional) competition level, a 50 percent switching step is very often included, along with steps appropriate to recreation and training purposes. These switching steps may also be accompanied by a provision for switching the lighting to suit various types of sport.

In large installations, the number of switching steps included for the sporting activities themselves often conforms to the two examples given here, one a main stadium and the other a multi-sports hall.

Switching steps for lighting for recreational purpose is pretty simple and is usually one simple switching step. For multipurpose halls, different switching options may be made available for different sports played.

For professional level play, it may be more complex. Apart from providing additional switching for training and national level competition, additional switching options are required.

Typical switching steps for a soccer and athletics stadium can be:

a) Training : Soccer;
b) Training : Athletics;
c) Competition : Soccer;
d) Competition : Athletics;
e) Emergency TV : Soccer;
f) Emergency TV : Athletics;
g) CTV : Soccer; and
h) CTV : Athletics.

Steps e) and f) are usually necessary because of guarantees required by broadcasting corporations for maintaining CTV coverage in the event of power failure. The floodlights required for maintaining the minimum acceptable CTV quality (main camera only) are connected to generator sets, UPS or alternative source, and may be equipped with hot restrike devices.

17 MEASUREMENTS

Lighting measurements should only be made using suitable (amongst other things, cosine corrected), accurate and recently calibrated instruments. Correction factors may be necessary according to the type of light source being measured to correct the instrument used. Voltage measurements should also be done to avoid difficulties when comparing calculated and measured data. It is evident that voltage values, weather conditions, the accuracy of the measuring equipment, etc. are important when explaining differences in measured and calculated values.

Interpretation/Tolerances in Computed Values

A difference between the measured and calculated values is likely to occur as a result of :

a) Tolerances in manufacturing luminaires, lamps, etc;
b) Tolerances in the photometric measurements; and
c) Tolerances in position and aiming of luminaires.

Additional differences can be caused by voltage variation, which have to be taken into account.

18 LIGHT DEPRECIATION AND MAINTENANCE

The lighting level provided by a lighting installation will decrease throughout its life as a result of:

a) depreciation of the lamps and the luminaires;

b) dirt accumulation on the lamps and the luminaires;

c) depreciation of room surfaces; and

d) lamp survival rate.

Planning the maintenance operation is therefore essential if the original design parameters are to be met throughout the life of the installation. As such, it is expected that lamp change and cleaning intervals will form a part of the lighting design for a specific area.

The maintenance factor shall be agreed between the designer and customer at the outset. This shall include the planned maintenance programme on which the maintenance factor is based. If no maintenance factor is agreed, a value of 0.8 shall be used.

19 COST AND ENERGY

Many factors play a role in determining the cost and energy effectiveness of a lighting installation. There are, for example, the lamp and luminaire type, the luminaire arrangement and mounting height, and aids for mounting the luminaires (masts, ceiling, stands, etc) and the maintenance operations. The relative importance of each of these factors is dependent upon the local circumstances prevailing regarding such things as the cost of labour and the cost and availability of materials and energy.

20 GLOSSARY OF TERMS

Term	*Symbol*	*Explanation*
Illuminance toward camera	Ecam	Illuminance on a plane 1.5 m above the pitch and perpendicular to the lens axis of a specific camera.
Illuminance Uniformity	–	Describes how evenly light is distributed over the pitch surface and is expressed by the ratios of U1 and U2.
	U1	Uniformity expressed as the ratio of Emin/Emax.
	U2	Uniformity expressed as the ratio of Emin/Eav.
Illuminance Gradient (%)	–	The difference in illuminance between two adjacent points on the pitch.
Glare Rating	GR	The degree to which a lighting installation is disturbing to persons on or near the pitch.

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
SECTION 7 LIGHTING FOR MASS RAPID TRANSIT TRANSPORT SYSTEM (MRTS)

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Metros form an integral part of Mass Rapid Transit Transport System (MRTS), in urban centres. The metro system can be described as an electric passenger railway in urban areas with high capacity and frequency. Metro systems are typically either in tunnels or elevated above street level. Service is provided on designated lines using electrical multiple units on rails. It shares many characteristics with suburban rail systems. The illumination of metro systems requires proper attention right at the planning stage, keeping in mind the diverse areas and its special requirements. The metro apart from being a means of transport also fulfils many social needs. Lighting design should be sustainable and efficient, through proper selection of lighting equipment, and at the same time serve to create a pleasant ambience. In view of the large number of people availing metro services, proper care must be given to the safety and security needs of the passenger and staff.

The following Indian Standards are necessary adjuncts to this section.

IS No.	*Title*
10322(Part 1):1982	Luminaires: Part 1 General requirements
13383(Part 1):1992	Method of photometry of luminaries: Part 1 Luminaires for use in interior lighting
13383(Part 2):1992	Method of photometry of luminaries: Part 2 For road and street lighting
13383(Part 3):1992	Method of photometry of luminaries: Part 3 For flood lighting
14700(Part 3/Sec 2):2008	Electromagnetic compatibility(EMC): Part 3 Limits, Section 2 Limits for harmonic current emissions (equipment input current $\leq$ 16 A per phase) (First Revision)

NATIONAL LIGHTING CODE

PART 6 EXTERIOR ILLUMINATION
Section 7 LIGHTING FOR MASS RAPID TRANSIT TRANSPORT SYSTEM (MRTS)

1 SCOPE

This section covers the guidelines for design, installation, and maintenance of lighting to be followed for metro systems.

2 TERMINOLOGY

The definitions given in Part 1 of this code shall apply.

3 METRO SYSTEM

The metro system may be divided into the following three categories:

a) Underground: Trains run in a network of tunnels under the city. This format of the metro is popular where land costs are high;

b) Elevated/Surface: Trains run on dedicated corridors, at street level or elevated above street level; and

c) Mixed: Trains run on a network comprising underground tunnels along with elevated and surface corridors.

4 APPLICATION AREAS

4.1 The application areas can be broadly divided into two categories: Public Areas and Non-Public Areas.

4.2 Public Areas: These can be described as areas used by passengers. The public areas in a metro system are:

a) Private/Public Parking Areas and Approach Roads;

b) Entrance/Exit Areas (Public Assembly);

c) Train Display Area;

d) Circulation Area;

e) Platform;

f) Platform Edges;

g) Concourse (paid and unpaid area);

h) Building Facades, Signages and (Artificial Greeneries and Water bodies, if any);

j) Landing; and

k) Restrooms and Toilets.

4.3 Non-Public Areas: These can be described as areas restricted to passengers and are used by metro staff for operation of metro services. The non-public areas in a metro system are:

a) Railway Yards;

b) Workshops and Car Sheds;

c) Inspection Bays;

d) Tunnels;

Fig. 1 Typical Metro Concourse Area

Fig. 2 Views of Typical Metro Platform Area

e) Railway Offices;

f) Signaling Room;

g) Station Control Room;

h) Store Rooms; and

j) Battery Rooms.

5 PERFORMANCE REQUIREMENTS

5.1 General Requirements

The lighting system should be installed throughout all station areas, tunnels, ancillary buildings, station forecourts, parking areas, auto, taxi and bus drop off points, relocated and new access roads. The lighting should take into account efficiency, symmetry, application, glare, glare to CCTV or signage, computer screen environments, maintainability and long life. The lighting design should achieve a bright look, avoid any dark patches and afford easy safe access to all the areas. The lighting should be sufficient to avoid any unsafe situation under any normal or abnormal conditions. The type and quantity of lighting equipment and their luminous intensity should relate to the space being illuminated and take into account the effect of the architectural space, concept and colour scheme. Emergency lighting systems should be installed to ensure that all the escape routes including tunnels, from the various areas can be safely and effectively identified in an emergency situation. All station and passageways should have emergency lighting powered from the essential power switchboard.

The lighting system requirements associated with the electrical systems and equipment should comply with the relevant latest standards and codes of practice.

5.2 Criterion for Design and Selection of Lighting Equipment

Selection of lighting equipment will depend on the following factors:

a) Ceiling type;

b) Mounting height/Mounting possibility;

c) Application areas (for selection of IP classification);

d) Criticality of restricting glare;

e) Importance of colour rendering index (mainly for selection of lamps); and

f) Use of lamps with proper colour temperature.

6. LAMPS

For indoor areas linear and compact fluorescent lamps should be used. Preference should be given to environment friendly lamps with low mercury content (less than 3 mg).

For semi-outdoor and outdoor applications preference should be given to high intensity discharge lamps.

6.1 Linear Tubular Fluorescent Lamps

These lamps are available in different wattages, diameters, lengths, efficacies, colour temperatures, CRI, and life in burning hours. Recent developments in linear lamps have resulted in further reduction of lamp diameter and increase of lamp life. The increase of lamp life is highly advantageous for the metro where the daily usage of lamps is high, and relamping is disruptive causing inconvenience to passengers. Taking these points into consideration, it is preferable to use lamps with longer life in burning hours, in the range of 24 000 to 42 000 burning hours and above. The lamp life further increases when used with standard electronic ballasts. The use of lamps with longer life causes a reduction of maintenance cost per point, which leads to a high amount of saving, as the number of fluorescent lamps used is quite high in a metro installation, typically 1 000 and above. Fluorescent lamps with a diameter of 16 mm (T5) also offer significant advantages. These lamps have higher efficacies than standard 26 mm diameter (T8) lamps, bringing down the energy costs significantly.

The availability of different wattages from 14W to 80W and lumen output from 1 350 lumens to 7 000 lumens, increases the utility of FTL lamps in metro applications. The smaller diameter of these lamps also permits the use of luminaires with sleeker dimensions, resulting in better aesthetics. Shatter-proof lamps with protective coating can also be used where open luminaires are used, for increased safety.

For metro applications it is recommended that the lamp selected should meet the following criteria:

a) Lamp Efficacy: > 90 lm/W;

b) Colour Rendering Index: > 80;

c) Colour Temperature: 4 000 to 6 500 K; and

d) Life: with HF at least 16 000 burning hours.

6.2 Compact Fluorescent Lamps (CFL)

These lamps have been developed to provide a very energy effective lighting solution. CFLs are a compact light source and like linear fluorescent lamps they are available in different sizes, wattages, efficacies, colour temperatures, CRI and life in burning hours. CFLs are ideal for use in, orientation, decoration, security, task lighting and areas with relatively low lighting requirements. Their compact size makes them very popular for use in downlighters. The development of high wattage CFLs up to 120 W and high lumen output, now permits its use in medium and highbay indoor lighting. The high wattage lamps are very useful in lighting double height areas such as escalator areas, staircase landings, etc. While selecting

CFLs for metro application, the following parameters should be met:

a) Instant Start;

b) Colour Rendering Index: > 80; and

c) Colour Temperature: 4 000 to 6 500 K.

6.3 High Pressure Sodium Vapour Lamps

High pressure sodium lamps should be used where efficacy and long life are more important than colour rendering. Sodium lamps have the highest lamp efficacies among all high intensity discharge lamps. High pressure sodium lamps give a golden white light which gives a warm appearance and better visual acuity. These lamps have a universal burning position and low sensitivity to voltage fluctuations, which make them a very reliable choice for outdoor applications. The sodium lamps selected should meet the following criteria:

a) Lamp Efficacy: > 130 lm/W;

b) Colour Rendering Index: > 23;

c) Colour Temperature: 2 000 K;

d) Life: > 10 000 burning hours; and

e) Restriking Time: < 30 s.

6.4 Metal Halide Lamps

Metal halide lamps should be used where lamps with high efficacy as well as good CRI are required. Metal halide lamps have the highest efficacies and lamp life after sodium type lamps. Metal halide lamps give attractive white light, thus increasing visibility and creating a pleasant ambiance. The metal halide lamps selected should meet the following specifications:

Colour Rendering Index: > 65 for 250 W and 400 W; for lower wattage 70 W and 150 W, it should be > 80.

In the family of metal halide lamps, there is a type with a ceramic discharge tube. These are compact in size and are available in low wattages. These can be used indoors in areas with high ceilings and outdoors in decorative applications and for floodlighting in pedestrian precincts. The compact ceramic discharge metal halide lamps selected for metro applications should meet the following criteria:

a) Lamp Efficacy: > 95 lm/W;

b) Colour Rendering Index: > 80; and

c) Life: 6 000 to15 000 burning hours.

7 LUMINAIRES

Luminaires should have a downward light output ratio of the order of 70 percent and should not cause glare to the passengers and the train drivers. Luminaires should be weather proof so as to avoid failure due to water seepage in tunnels. Collection of dust on the optical/reflecting surface impairing the light output should be prevented. It should be possible to clean it with ease and the reflecting surface should not get defaced for at least 10 years. The luminaires when mounted outside the station areas must have suitable protection against dust, moisture and rain (IP52/54 is preferred). The luminaire shall not emit toxic gases in case of fire. All the components including the internal wiring of the luminaires should be manufactured of material which are of the low smoke and zero halogen type. Luminaires should be the instant start type and without any restriking time for the underground areas and tunnels.

Luminaires selected should have the following features:

a) Luminaires should be designed for good performance under the following ambient temperatures:

   i) Indoor luminaires at 45°C; and

   ii) Outdoor luminaires at 35°C.

b) Luminaires should be able to operate at ± 6 percent voltage fluctuation without appreciable lighting level variation;

c) Luminaires should conform to IS 10322(Part 1);

d) Photometry testing should be carried out as per IS 13383(Part 1 to Part 3); and

e) Luminaires for fluorescent lamps should preferably be with electronic ballasts.

8 BALLASTS/CONTROL GEAR

Ballasts are required to drive the lamp. There are two kinds of ballasts available: electromagnetic or EM ballasts and electronic or high frequency ballasts. Regardless of which type is chosen, the ballasts should be of high efficiency. The traditional electromagnetic ballast remains popular, but electronic ballasts offer significant advantages over traditional ballasts; they last longer, tolerate high voltage fluctuations, operate flicker-free and start quicker. Additionally, they save costs by using less power and extending the lives of lamps. The electronic ballast gives project designers far greater flexibility, to dim lamps, for instance. They also enhance safety by protecting against surges in voltage and operating at noticeably lower temperatures. Electronic ballasts also save electricity costs by generating less heat and reducing the load on air conditioning units. Electronic high frequency ballasts are also much lighter than conventional electromagnetic ballasts making them ideal for metro applications which are very prone to vibrations because of the continuous passage of trains.

For low pressure lamps such as fluorescent lamps used in metro applications, only high frequency electronic ballasts should be chosen because of their merits discussed above. For high pressure gas discharge lamps, high frequency electronic ballasts up to medium wattages have been developed and they provide the same benefits as ballasts for low pressure lamps.

Electronic ballasts selected for metro applications should have extremely low ballast losses, long life, capability of withstanding wide voltage fluctuations of ± 20 percent, and cause no electromagnetic interference with other equipment. The ballasts should be designed so that it should function continuously without any noise or hum. While selecting ballasts for metro applications the following parameters should be met:

a) All luminaires for fluorescent lamps shall preferably be with electronic ballasts;
b) It is desirable to have high power factor ballasts for linear fluorescent lamps and CFLs;
c) Ballast efficiency defined as a ratio of lamp wattage to total input power should not be less than 0.95;
d) Ballasts should maintain consistent light output for all fluorescent lamps over a voltage range of 192 to 288 V; and
e) Input harmonic content should be < 10 percent. Individual supply current harmonics should conform to IS 14700(Part 3/Sec 2).

9 LIGHTING LEVEL REQUIREMENTS

9.1 Public Areas

Sl. No. (1)	*Areas* (2)	*Average Maintained Illuminance (lux)* (3)
i)	Private/Public Parking Areas	50
ii)	Entrance/Exit (Public Assembly)	300
iii)	Train Display/Reservation Checking	300
iv)	Ticket Counters	300
v)	Platform	200
vi)	Platform Edges	250
vii)	Concourse	300

NOTE — 30 percent of the above illumination will be catered by luminaires on essential supply.

9.2 Non - Public Areas

Sl. No. (1)	*Areas* (2)	*Average Maintained Illuminance (lux)* (3)
i)	Railway Yards	15-20
ii)	Workshops/Loco sheds	300
iii)	Inspection Bays	500
iv)	Signalling Rooms	500
v)	Station Control Rooms	500
vi)	Store Rooms/Battery Rooms	150

10. DESIGN REQUIREMENTS

Lighting circuits should be divided into emergency and normal situations. At station entrances passengers enter passages from sunlit streets and there should be gradation of the lighting level. Escalators and stairways should be well illuminated. Concourse and ticket hall areas require a reduced level of lighting except at ticket machines, automatic fare collection (AFC) gates and the tops and bottoms of escalators and stairs. The lighting intensity at platform level should be compatible with that of the train vehicle, reducing in intensity at platform ends, particularly the leading end, thus reducing glare to the driver on entering the station. Lighting should provide a continuous run adjacent to the platform so that the threshold of the platform edge is well illuminated. The lamp should not be directly visible to the driver. Platform lighting should also take into account the need to highlight information panels. This should take care of uniformly illuminating the train surface for ease of passengers to alight or board the train. Luminaires used for lighting should also be of high efficiency to increase the spacing to height ratio. Care should be taken in the distribution of luminaires in relation to the performance of closed circuit television cameras.

Lighting should conform to the lighting level given in **9.1** and **9.2**. Care should be taken to define the decision and transition points and areas of potential hazard through proper lighting. The lighting system should be designed to minimize initial capital costs as well as the frequency and expense of maintenance. Luminaire locations should permit accessibility for relamping and periodic cleaning. Lighting should be designed to satisfy security requirements and to provide a pleasant environment. Lighting should emphasize directional signage, indicating preferred circulation paths and the informational signage that provides for quick recognition of danger and decision points. The lighting layout should be such that the failure of any single lighting unit shall not leave the area in total darkness.

11 GLARE

The lighting design should minimize glare by the correct choice of location, number, type, and luminance of luminaires and shielding of lamps. Luminaires in control rooms shall be positioned so that no reflected glare from dials or monitor screens interferes with the operator's vision.

12 EMERGENCY LIGHTING

For security and safety of passengers and staff it is essential that in the event of a power failure there should not be total darkness. So it is recommended that in critical areas a certain number of luminaires be placed on emergency supply. This emergency line should be on uninterrupted power supply. The luminaires connected to emergency supply should be so chosen that they provide at least 30 percent of the general illuminance level in that area. This will ensure that till the DG set takes over or the power comes back, there will be sufficient illumination to ensure the safety and security of the passengers and staff. Emergency lighting should be provided in all public areas, on escalators and stairways, escape routes including those in the tunnels, control rooms, main offices, and plant rooms.

13 AREAWISE SPECIFIC LIGHTING REQUIREMENTS

13.1 Public Areas

13.1.1 *Approach Roads:*

Lighting of approach roads should be designed to have:

a) Average maintained illumination of 20 Lux; and

b) Uniformity (min/av) = 0.40.

Luminaires used should have good aesthetics, be durable, provide efficient and glare free lighting and should be easy to maintain.

13.1.2 *Private/Public Parking Areas*

The lighting design of private and public parking lots should consider the following:

a) General lighting with highmasts with use of high pressure sodium vapour/metal halide lamps. Height and number will depend on area to be illuminated;

b) Avoidance of 'spill' light and objectionable glare with proper choice of luminaires, like asymmetric luminaires (*see* Fig. 3);

c) Use of high efficacy lamps to reduce number of light points and energy consumption;

d) Lamp with low reignition time; and

e) Greeneries and parking lots with isles demarcated.

For semi-enclosed parking lots a typical mounting height is 4 to 6 m. The luminaire is mounted on trusses. Luminaires

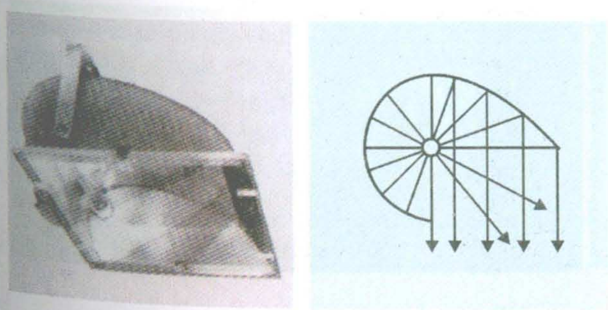

Fig. 3 Asymmetric Luminaire

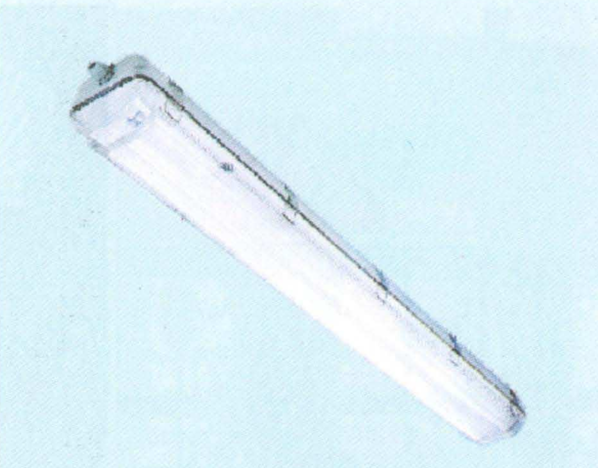

Fig. 4 Dust and Moisture Proof

selected should be suitable for surface mounting and lamps used, fluorescent and metal halide.

For parking areas with sheds the luminaires used should be:

a) Dust and moisture proof (IP65) (*see* Fig. 4);

b) Impact resistance proof; and

c) Light weight and sturdy with polycarbonate or diecast aluminium housing and with cover.

13.1.3 *Platform Areas*

Platforms can be considered as semi-outdoor areas with a typical height of 2.7 to 4 m.

For platform areas, luminaires selected should meet the considerations mentioned under design requirements. Luminaires recommended for use in platform areas are:

a) Mirror optics luminaires with acrylic or glass cover;

b) General purpose luminaires with polycarbonate cover; and

c) Symmetric-Asymmetric luminaires for platform edge lighting (*see* Fig. 5).

13.1.4 *Concourse*

Concourse areas generally have a height of 2.4 to 5 m. The concourse area can be divided into two parts; paid concourse and unpaid concourse. The lighting treatment for both these areas is generally the same. The light level requirement is high, in the range of 300 lux. This area has

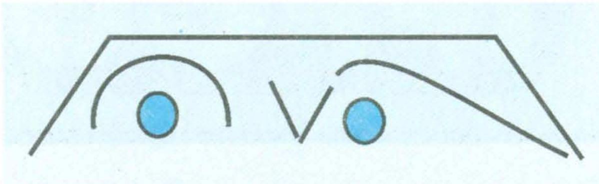

Fig. 5 Symmetric-Asymmetric Luminaire

very high footfalls. Linear fluorescent lamps with good colour rendering, lamp life and efficacy should be used in these areas. Luminaires selected should be suitable for recessed mounting with mirror optics. They should also have good efficiency to achieve optimum spacing as well as good aesthetics so that it is visually pleasing to the passengers. The luminaires used should have at least twin lamps so that in the event of a lamp failure, that particular area is not left in total darkness.

13.1.5 *Restrooms*

Restrooms are generally areas with false ceilings. Lighting should be done using downlighters to minimize energy consumption. CFL lamps are generally chosen for their compact size, ease of installation, high efficacy alongwith long life and good colour rendering.

13.1.6 *Facades and Signages*

Advertising forms a major form of revenue for metro authorities. Major companies find it as an extremely attractive medium to communicate to a huge cross section of people availing metro services daily. Proper lighting effects applied to facades and signages increase the commercial and prestige value of the metro as well as create interest in the mind of the passengers (*see* Fig. 6). For facade and signage lighting, LED solutions should be used to get a vibrant and dynamic effect. Station names can be displayed prominently through LED signages. For facade lighting LED fixtures can be integrated into the architecture itself to enhance the night time view without spoiling the day time view. Using the striking and unique features of LEDs, lighting effects can be created. The long life and low energy consumption of LEDs also makes them an ideal product for these applications.

13.2 Non-public Areas

13.2.1 *Yard Lighting*

Lighting of yards should be designed to have:

a) Average maintained illuminance of 15-20 Lux; and
b) Uniformity (min/av) = 0.33.

Lighting should consider:

a) General lighting with highmasts with use of high pressure sodium vapour or metal halide lamps. Height and number will depend on area to be illuminated;
b) Use of asymmetric luminaires to avoid glare and maximum energy efficiency; and
c) Lamp with low reignition time.

13.2.2 *Workshop/Car Shed*

Workshops and carsheds should be designed to have:

a) Average maintained illuminance of 300 lux; and
b) Uniformity (min/av) = 0.40.

13.2.3 *Inspection Bays*

Inspection Bays should be designed to have:

a) Average maintained illumination of 500 lux; and
b) Uniformity (min/av) = 0.40.

13.2.4 *Signalling/Control Rooms*

In control and equipment rooms, as well as substations, particular attention shall be given to the illumination of vertical surfaces such as screens, control panels, switches, and meters. Supplementary lighting may be used to achieve proper visibility and minimize shadows and reflection in glass faces. In battery rooms, industrial battens with or without reflectors may be used.

13.2.5 *Tunnel/Trackway*

Lighting systems should be installed in all tunnels. Lighting interference or distraction with the signal lamps should be taken into consideration. Lighting fixtures should contain instant start lamps. All tunnel lighting systems should be on emergency supply in running tunnels. Care should be taken that luminaires placed in the tunnel do not infringe on train clearance. The luminaires should have proper impact resistance protection. Trackways should be provided with sufficient light to define a path for evacuation under emergency condition.

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NATIONAL LIGHTING CODE

PART 7 LIGHTING FOR HAZARDOUS AREAS

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Many liquids, gases and vapours which are generated, processed, handled and stored in an industrial plant are combustible. These, when mixed with air in appropriate proportions may burn readily if ignited. With regard to lighting installations potential ignition sources are, arcs, sparks or hot surfaces produced either in normal operation or under fault conditions.

As distinct from the hazardous areas in plants and buildings on the surface, environmental conditions in mines demand special consideration. This part of the code does not include provisions for installations in underground mines.

The following Indian Standards are necessary adjuncts to this part.

IS No.	*Title*
1554(Part 1):1988	PVC insulated (heavy duty) electric cables: Part 1 For working voltages upto and including 1100 V (Third Revision)
IS/IEC60079-1(2007)	Explosive atmospheres: Part 1 Equipment protection by flameproof enclosures "d" (Superseding IS 2148:2004)
5572:1994	Classification of hazardous area (other than mines) having flammable gases and vapours for electrical installations (Second Revision)
6381:2004	Electrical apparatus for explosive gas atmosphere-increased safety "e" (Fourth Revision)
IS/IEC60079-0(2004)	Electrical apparatus for explosive gas atmospheres: Part 0 General requirements (Superseding IS 13346:2004)

NATIONAL LIGHTING CODE

PART 7 LIGHTING FOR HAZARDOUS AREAS

1 SCOPE

This part of the code deals with the design and selection of lighting equipment and lighting installations in hazardous areas excluding underground mines.

2 TERMINOLOGY

For the purpose of this part the definitions given in Part 1 of this code shall apply.

3 HAZARDOUS AREAS AND AREA CLASSIFICATION

a) A hazardous atmosphere is an atmosphere where any flammable gas or vapour occurs in a concentration capable of ignition under certain conditions of operation or occurrence;

b) In accordance with the petroleum rules, an area is deemed to be a hazardous area where

   i) Petroleum having a flash point below 65°C or any flammable gas or vapour in a concentration capable of ignition is likely to be present;

   ii) Petroleum or any flammable liquid having a flash point above 65°C is likely to be refined, blended, handled or stored at or above its flash point; and

c) The basis for hazardous area classification recognizes the differing degrees of probability with which flammable atmospheres may arise in installations in terms of both the frequency of occurrence and the probable duration of existence on each occasion. With this underlying philosophy, a hazardous area is divided into zones as follows:

   Zone 0 — An area in which a flammable atmosphere is present continuously or is likely to be present for long periods;

   Zone 1 — An area in which a flammable atmosphere is likely to be present periodically or occasionally during normal operation; and

   Zone 2 — An area in which a flammable atmosphere is not likely to occur in normal operation. If it does occur, it will exist for a short time only.

Further elaborations on the subject may be had from the Indian Petroleum Rules and recommended practice given in IS 5572.

4 LIGHTING SYSTEM DESIGN

4.1 Generally a lighting system is designed for a 415/240 V system with illumination levels as per good engineering practice and as recommended elsewhere in this document. The system consists of a lighting distribution board, lighting and power panels, lighting fixtures, junction boxes, 3 pin 6 A/16 A combination socket outlets, cable glands, etc, as required. Lighting and power panels are often located in the field and are fed power from a central lighting distribution board. These panels are generally provided with miniature circuit breakers or switch and fuse combination units for the control and protection of individual lighting circuits. An earth leakage (residual current) protective device (RCCB) is provided in these panels to meet the statutory requirement.

4.2 Hazardous area luminaires generally are not required in non-plant buildings, open areas and roads.

4.3 All the equipment required for lighting systems are selected in conformance to the required area classification and environmental conditions.

5 SELECTION OF EQUIPMENT FOR HAZARDOUS AREAS

5.1 For selection of the suitably protected equipment for hazardous areas, the following information is necessary:

a) Classification of the area, that is, the zone;

b) The ignition temperature of the gas or vapour involved, or the lowest value of ignition temperature if more than one combustible material is present. This will permit determination of the temperature classification required for the apparatus as per IS 13346;

c) The characteristics of the gas or vapour involved; and

d) Safe gap data in the case of installation for flameproof enclosures. This will determine the appropriate apparatus group for flameproof enclosures as per IS/IEC 60079-1.

5.2 Apparatus certified to the constructional and design requirements for a particular group may also be used with compounds of lesser risk, subject to consideration of temperature classification and chemical compatibility. Similarly, some electrical apparatus is designed so that it may be used with certain flammable material in zones of lesser risk without restriction, provided it is determined that flammable materials likely to be present are compatible with the following characteristics of the apparatus:

a) The apparatus grouping (where that is applicable);
b) The temperature classification; and
c) The chemical compatibility.

5.3 Tables 1 and 2 may be referred to for selection of lighting equipment for hazardous areas.

5.4 Statutory Regulation

The various statutes and regulations in force in the country, applicable to the installation and approval of electrical apparatus in hazardous areas shall be kept in view.

Manufacture and use of equipment in hazardous areas is controlled by the statutory authorities listed below for the area of their jurisdiction:

a) The Director General of Mines Safety, Dhanbad;
b) The Chief Controller of Explosives, Nagpur; and
c) The Director General, Factory Advice Services and Labour Institute (DGFASLI), Mumbai.

6 WIRING IN HAZARDOUS AREAS

6.1 General

The types of wiring generally used in hazardous areas are:

a) Cables drawn into screwed solid or seamless conduits; and
b) Cables which are otherwise suitably protected against mechanical damage.

6.2 Factors Affecting Choice of Wiring System

6.2.1 Screwed steel conduit systems are satisfactory for many situations but are not recommended to be used for areas of high vibrations or where corrosion or excessive internal condensation of moisture is likely to occur.

6.2.2 Steel wire armoured cables are suitable for underground installation.

Table 1 Luminaires for Use in Hazardous Areas
(*Clause* 5.3)

Zone–0	Zone–1	Zone–2
No luminaire shall be used in this area	All luminaires shall be of flame proof construction. Unless luminaires are protected against mechanical damage by virtue of the area in which they are installed, a suitable guard shall be provided.	Luminaires suitable for Zone-1 area as per IS/IEC 60079-1.
	Pendant luminaires shall be connected by means of cable in screened steel conduits.	Luminaires with type of protection "e" as per IS 6381
	Suitable provision for permanent and effective bracing against lateral displacement shall be provided.	Type 2 Luminaires as per IS/IEC 60079-1.

Table 2 Switchgear & Control Gear for Use in Hazardous Areas
(*Clause* 5.3)

Zone–0	Zone–1	Zone–2
No switchgear or control gear shall be used in this area.	All switches, circuit breakers, fuses and other switchgears and control gear shall be provided with flameproof enclosures. In each case the enclosures together with the enclosed apparatus shall be approved as a complete assembly.	All switches, circuit breakers, fuses and other switchgears and control gear in which arcing may occur under normal conditions of operation shall be provided with flameproof enclosures. Unless the interruption of the current occurs within a chamber hermetically sealed against the entrance of gases and vapours, the equipment is provided with a general purpose enclosure. If the equipment is such that current interrupting contacts are oil immersed, enclosed-break switches for lighting shall be used with flameproof breaking chamber, mercury in glass switches and enclosed-break micro-swi tches.

6.2.3 PVC insulated and armoured cables complying with IS 1554(Part 1) are generally used for above or underground installations.

6.3 Cable Wiring System

6.3.1 Cable wiring for the hazardous areas is generally carried out using PVC or XLPE armoured cables conforming to IS 1554(Part 1) with an extruded PVC outer sheet. Aluminium conductor cables shall not be used. Only copper conductor cables shall be used.

6.3.2 Correctly designed termination complete with armour clamp shall be provided for armoured cables. The armouring should be carried out into the clamp to provide mechanical support to the cable and to ensure electrical continuity.

6.3.3 Switching devices provided for the circuits in hazardous areas shall be of the double pole type to isolate phase as well as neutral during the switching off operation of the individual circuit feeding the luminaires located in the hazardous area.

6.3.4 *Laying of Cables*

6.3.4.1 The cable system includes cables laid above ground or cables laid underground directly buried in concrete trenches or in cable ducts. The types of the cable for use in hazardous areas shall be as specified in this section.

6.3.4.2 Cable-runs shall be continuous and free from intermediate joints as far as practicable. Where discontinuities cannot be avoided either during installation or subsequently, the apparatus used for interconnection shall be provided with the type of protection appropriate to the hazardous zone.

6.3.4.3 All cables shall be provided with proper mechanical protection. Cables shall be adequately supported throughout their length taking care to avoid excessive pressure when clamp supports are used. Horizontal cables may be carried on supports, cable trays or through protective troughs to tubes. Rising cables are clipped, cleated or otherwise attached to suitable supports which provide adequate mechanical protection.

6.3.4.4 The passage of the cable from a hazardous area to a non-hazardous area is provided with adequate means to prevent the transmission of flammable material into the non-hazardous area. Consideration is generally also given to the treatment of cables against fire transmission.

6.3.4.5 Where trunking ducts, pipes or trenches are used to accommodate cables, precautions should be taken to prevent the passage of combustible gases, vapours or liquids from one area to another, and to prevent the collection of combustible gases, vapours or liquids in trenches. Such precautions may involve the sealing of trunking ducts and pipes and the adequate ventilation or sand filling of trenches.

6.3.4.6 Cables capable of transmitting gases or vapour through the core shall be sealed in the hazardous location in such a manner as to prevent passage of gases or vapours into a non-hazardous location.

6.3.4.7 Cable glands, where used, shall be of a flameproof type for flameproof enclosures and double compression type for enclosures having protection other than the flameproof type.

6.3.4.8 Where the cable passes through the floor, wall, partition or ceiling, the unused hole or entry must be made good with cement or similar incombustible materials.

6.4 Conduit Wiring System

6.4.1 For conduit wiring, care is to be taken to seal the ends to prevent entry of hazardous gases or vapour and subsequent propagation from one area to the other.

6.4.2 Conduit fittings used must be duly tested and approved for use in the respective class and zone of hazard.

6.4.3 Where the conduit passes through the floor, wall, partition or ceiling, the hole or entry provided for them must be made good with cement or similar incombustible material to the full thickness of the wall, floor, partition or ceiling.

6.4.4 Aluminium conductor cables shall not be used. Only copper conductors shall be used.

6.5 Connections to Portable and Transportable Apparatus for Lighting

6.5.1 Flexible cable of the types specified below may be used for connection between a fixed source of supply and the portable and transportable apparatus through flameproof plugs and sockets.

a) Ordinary tough rubber sheathed flexible cables;

b) Ordinary tough polychloroprene sheathed flexible cables;

c) Heavy tough rubber sheathed flexible cables; and

d) Plastic insulated cables equivalent to ordinary tough rubber sheathed flexible cables.

Use of screened cables is also permitted.

6.5.2 An effective cable clamping device so designed as not to damage the insulation of the flexible cables, are provided at the points of entry of the flexible cable to the apparatus and plug. In addition, means are provided to prevent sharp bending of the cable at both points of entry.

7 LIST OF APPLICABLE INDIAN STANDARDS

Sl. No.	IS No.	Title
1.	IS/IEC60079-1(2007)	Explosive atmosphere: Part 1 Equipment protection by flameproof enclosures "d" (Superseding IS 2148:2004)
2.	5571:2000	Guide for selection of electrical equipment for hazardous areas (First Revision)
3.	5572:1994	Classification of hazardous area (other than mines) having flammable gases and vapours for electrical installations (Second Revision)
4.	IS/IEC 60079-11(2006)	Electrical apparatus for explosive gas atmospheres-intrinsic safety "i" (Second Revision) (Superseding IS 5780:2002)
5.	IS/IEC60079-0(2004)	Explosive atmosphere: Part 0 General requirements
6.	7820:2004	Electrical apparatus for explosive gasatmosphere-method of test for ignition temperature (First Revision)
7.	9570:1980	Classification of flammable gases or vapours with air according to their maximum experimental safe gaps and minimum igniting currents
8.	IS/IEC60079-15(2005)	Electrical apparatus for explosive gas atmospheres: Part 15 Construction, test and marking of type of protection "n" electrical apparatus
9.	13408(Part 1):1992	Code of Practice for the selection, installation and maintenance of electrical apparatus for use in potentially explosive atmosphere (other than mining application or explosive processing and manufacture): Part 1 General recommendations

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NATIONAL LIGHTING CODE

PART 8 ROAD LIGHTING

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Road lighting has always been an effective tool for promoting a city. It is not only a functional requirement which provides safety and security to motorists and residents as well as pedestrians, but it helps in creating an identity and image.

Fixed lighting of public ways for both vehicles and pedestrians can create a night time environment in which people can see comfortably, and can quickly and accurately identify objects on the roadway being travelled. Roadway lighting can improve traffic safety, achieve efficient traffic movement, and promote the general use of the facility during darkness and under a wide variety of weather conditions.

As a supplement to vehicular headlight illumination, fixed lighting can enable the motorist to see details more distinctly, locate them with greater certainty, and react safely to roadway and traffic conditions present on or near the roadway facility. Pedestrians must be able to see with sufficient detail to readily negotiate the pedestrian facility and recognize the presence of other pedestrians, vehicles, and objects in their vicinity. Road lighting shall not be solely based on providing a recommended amount of light to a roadway. Energy-effective street lighting design integrates efficient lamp technologies, optimum pole spacing, efficient luminaire distribution and pleasing aesthetics.

The following Indian Standards are a necessary adjunct to this part of the code.

IS No.	*Title*
1944(Part 1) and (Part 2):1970	Code of practice for lighting of public thoroughfares: Part 1 and 2 for main and secondary roads (Group A and B)

NATIONAL LIGHTING CODE

PART 8 ROAD LIGHTING

1 SCOPE

This part of the code generally covers all aspects of road lighting including normal street lighting, associated with service roads, pedestrian pathways and road junctions, excluding the traffic signals or painted boards.

2 TERMINOLOGY

The following definitions in addition to the definitions given in Part 1 of this code shall apply.

2.1 Overall Uniformity (U_o) — It is the ratio of the minimum to the average road illuminance. A good overall uniformity ensures that all spots on the road are sufficiently visible.

2.2 Longitudinal Uniformity (U_L) — It is the lowest ratio of the minimum to the maximum road illuminance in the middle of each lane.

2.3 Surround Ratio — It is the ratio that measures the amount of light falling on the surrounds as a proportion of that falling on the road.

3 PURPOSE OF ROAD LIGHTING

In road and street lighting the following aspects are considered:

a) Energy saving through selection of efficient lamp technologies and design practices;
b) Capital cost saving using proper spacing and placement;
c) Maintenance cost saving using lamps with longer life and optimum spacing;
d) Reduced glare and improved visibility by careful selection of luminaires and lamps;
e) Improved sense of security by selection of efficient systems and incorporating proper design. This can make an area appear safer and more secure;
f) Improved sense of economic development of communities; and
g) Improved safety of motorists, cyclists and pedestrians, improved traffic guidance and a pleasant environment.

4 DESIGN PRINCIPLES

4.1 Requirements of Road Users

a) Visibility of the road and its surroundings;
b) Visual guidance of the shape of the road. The motorists should be able to clearly identify bends and curves, and change in road widths;
c) Identification of obstacles;
d) The visual comfort of the driver. The visual field comprises the carriageway, the surrounds to the road, including road signs, the sky and the bright luminaires; and
e) Lighting of the street should appear continuous and uniform.

4.2 Fundamental Quality Criteria

The quality of lighting should meet the requirements of road users from their individual angle. The users being drivers and pedestrians, in practice, the requirements of the drivers are more stringent. However, it is the 'principles of vision' which are the guiding factors in public lighting. Hence, the function of a good road lighting installation is to provide good visual performance and visual comfort to the road users.

The most important quality criteria to be considered in road lighting are:

a. Luminance level;
b. Illuminance level;
c. Illuminance uniformity;
d. Degree of glare limitation; and
e. Visual guidance

4.2.1 *Luminance*

The most generally used approach to selecting quality criteria for lighting roads for motor traffic is based on the luminance concept. This is minimum value to be maintained throughout the life of the installation. It is dependent on the light distribution of the luminaires, the luminous flux of the lamps, the geometry of the installation and on the reflection properties of the road surface (*see* Fig. 1).

4.2.2 *Illuminance*

The illuminance level for road lighting in India is governed by IS 1944(Parts 1 and 2). These values must of course satisfy the basic principles of vision, criteria of quality etc and are classified as per the different types of roads. The lighting levels as specified are average values only.

4.2.3 *Uniformity*

A good overall uniformity ensures that all spots on the road are sufficiently visible. A good longitudinal uniformity

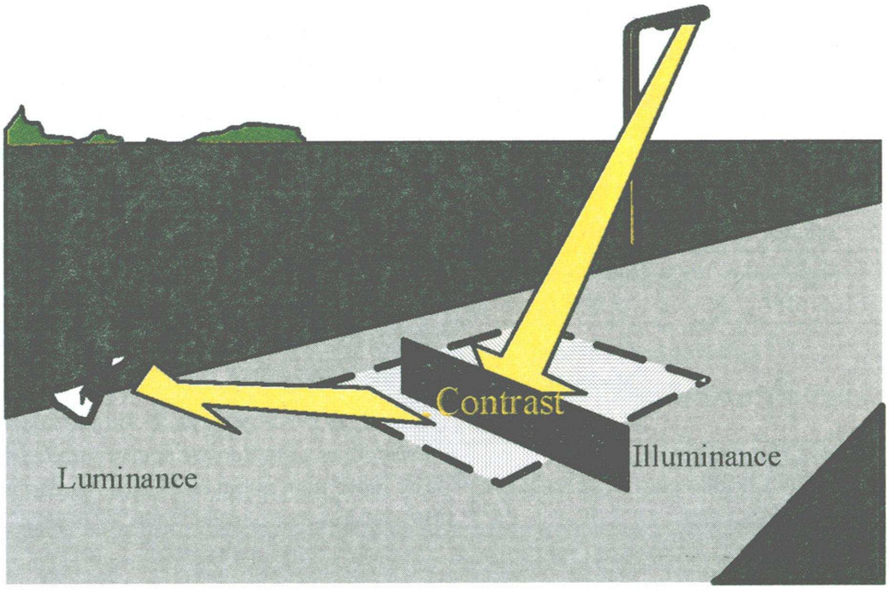

Fig. 1 Relation between Illuminance and Luminance

ensures comfortable driving conditions without the 'zebra' effect.

4.2.4 *Glare*

This is caused due to the sudden presence of a very bright source in the visual field. Glare in public lighting is caused by luminaires. There are two types of glare namely, disability glare which impairs vision and discomfort glare which creates unpleasant viewing conditions.

Glare depends on the illumination produced by the luminaire on the eye of the observer. The light from the glare source scattered in the direction of the retina will cause a bright veil to be superimposed on the sharp image of the scene in front of the observer. This veil can be considered as having a certain luminance

$$L_{veiling} = k \sum_{i=1}^{n} \frac{E_{eye}i}{\theta_i^2}$$

where

$E_{eye\,i}$ = Illuminance on the eye (in a plane perpendicular to the line of sight) caused by the ith glare source (lux);

q_i = angle between viewing direction and direction of light incidence on the eye of the ith glare source (degrees); and

k = age factor (usually taken as 10).

The equivalent veiling luminance and the adaptation state of the eye, which under road lighting conditions is determined by the average road luminance L_{av}, together play a role in determining the final loss of visual performance due to glare.

The amount of disability glare can be represented by the veiling luminance values and threshold increment.

The Threshold Increment (TI) is the percent increase in the luminance level required to make an object equally visible as in the absence of glare.

$$TI = 65 \frac{L_{veiling}}{(L_{av})^{0.8}}$$

The glare control mark (G) is a measure for discomfort glare in road lighting designs. It is calculated from certain luminaire and installation characteristics. The higher the value of G, the less will be the glare, resulting in a higher visual comfort for the road user. The glare control mark is given by the formula:

$$G = SLI + 0.97 \log L_{av} + 4.41 \log h - 1.46 \log p$$

where

SLI = specific luminaire index;

L_{av} = average maintained road luminance;

h = luminaire height minus eye height; and

p = number of luminaires per kilometer.

The SLI is a luminaire characteristic and is given by:

$$SLI = 13.84 - 3.31 \log I_{80} + 1.3 \log (I_{80}/ I_{88})^{0.5} - 0.08 \log I_{80}/ I_{88} + 1.29 \log F + C$$

where

I_{80} = luminous intensity at an elevation angle of 80 degrees in the C = 0 plane of the luminaire;

I_{80}/ I_{88} = ratio of the luminous intensity at an elevation angle of 80 degrees and 88 degrees in the C = 0 plane, also called the Run Back Ratio;

F = flashed area of the luminaire; and

C = colour factor (dependent on the lamp type).

NOTE — For low pressure sodium vapour lamps, $C = 0.4$, for others $= 0$.

Typical values for G are shown in Table 1.

Table 1 Typical Values of G
(*Clause* 4.2.4)

Sl. No. (1)	G (2)	Assessment (3)
i)	< 3	Bad
ii)	5	Moderate
iii)	> 7	Good

The formula for G is valid for the following ranges of values:

a) $50 < I_{80} < 7000$ (cd);

b) $1 < I_{80}/I_{88} < 50$;

c) $0.007 < F < 0.4$ (m^2);

d) $0.3 < L_a < 7$ (cd/m^2);

e) $5 < h < 20$ (m); and

f) $20 < p < 100$.

Number of luminaire rows = 1 or 2

4.2.5 *Surround Ratio*

The function of the Surround Ratio (SR) is to ensure that sufficient light falls on the surrounds to provide a bright background for objects towards the edge of the carriageway to be revealed. It also helps the driver to anticipate the movement of pedestrians about to cross the road. It is important in curved roads where the surround forms the greater part of the background against which objects are seen. The surround ratio is formally defined as the ratio of the average illumination on strips 5 m wide, or less if space does not permit, which are adjacent to the edge of both sides of the carriageway to the average illumination on the adjacent strips, 5 m wide or half the width of the carriageway, whichever is the smaller in the carriageway.

For dual carriageways, both carriageways together are treated as a single carriageway unless they are separated by more than about one-third the carriageway width and there are obstructions such as trees.

The surround ratio is usually determined by calculating the illuminance on a regular array of points on the strips and finding the average. In a situation where the surround ratio is applicable, a value of 0.5 is recommended.

4.2.6 *Visual Guidance*

This can be effectively created by the following principles (*see* Fig. 2a to Fig. 2d):

a) Positioning of poles;

b) Using different lamp colours; and

c) Use of high masts (> 20 m).

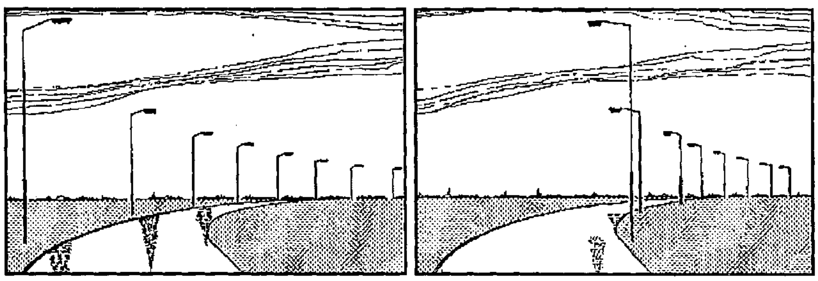

Fig. 2a Fig. 2b

NOTE — Single sided left preferred to right for a curve to the right

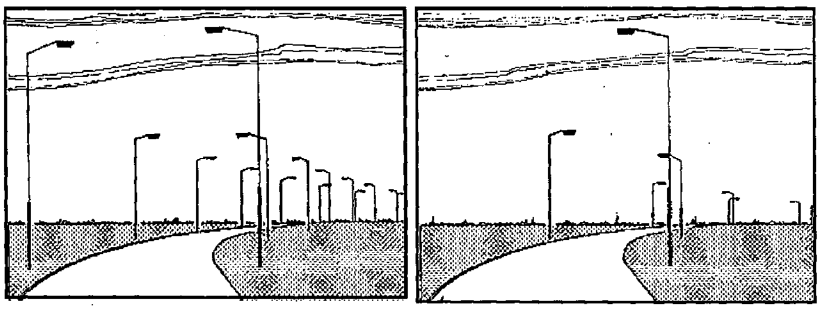

Fig. 2c Fig. 2d

NOTE — Opposite arrangement preferred to stagger for a curve.

Fig. 2 Positioning of Poles for Visual Guidance

5 EFFECT OF ROAD SURFACE

The road surface plays a very important part in road lighting. The same illuminance may result in a different visual scene because of a difference in the road surface (*see* Fig. 3).

It is obvious that road surface luminance rather than illuminance should be the accurate measure of the effective light on a road surface. In the present state of lighting techniques and the knowledge of reflection properties of road surfaces, calculation and measurement of luminance is difficult.

Thus illuminance values are taken as standards for road lighting. However, it should be kept in mind, that the visual appearance of a road is solely determined by the luminance values and uniformity.

6 DEFINING ROAD AND POLE INSTALLATION

6.1 Carriageway

Illustration of single and dual carriageway are shown in Fig. 4 and Fig. 5.

6.2 Type of Configuration

Illustration of road lighting configurations is shown in Fig 6a) and Fig. 6b).

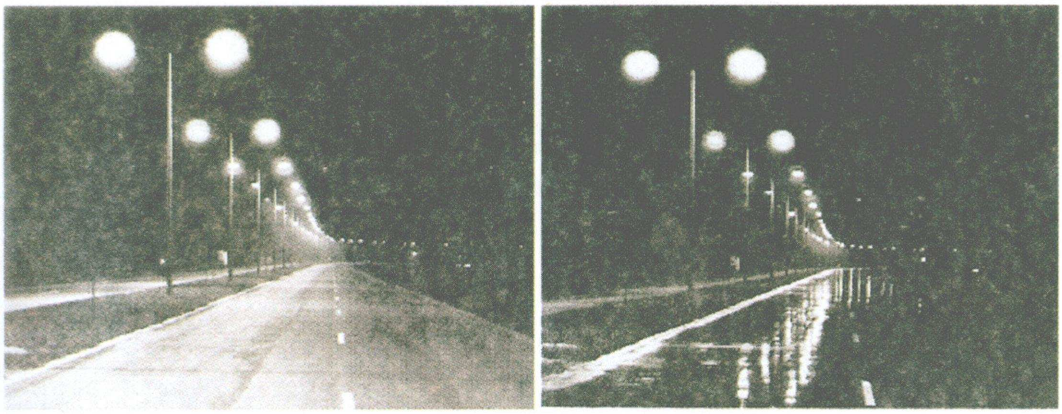

Fig. 3 Different Visual Impressions of the Road Surface Under the Same Lighting Level for Dry (Left) and Wet (Right) Conditions

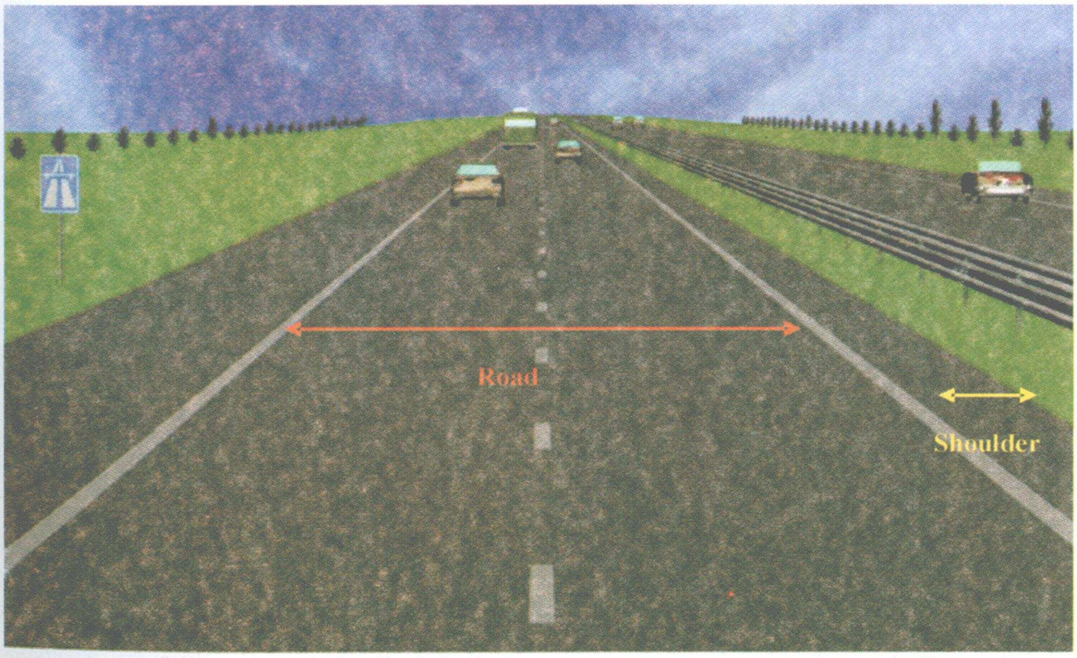

Fig. 4 Single Carriageway

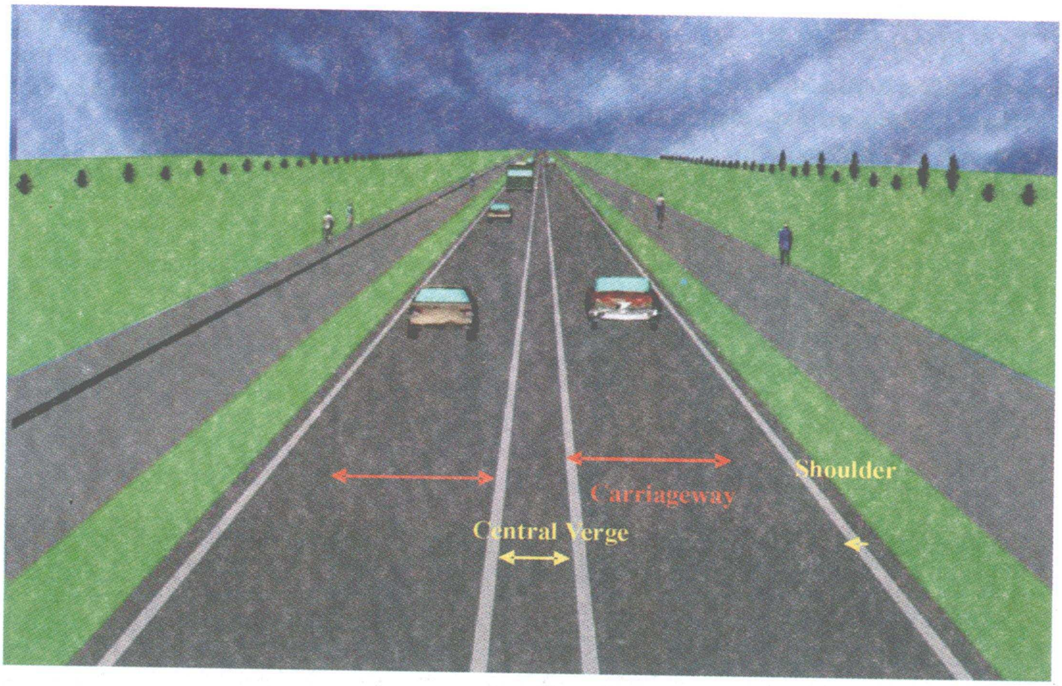

Fig. 5 Dual Carriageway

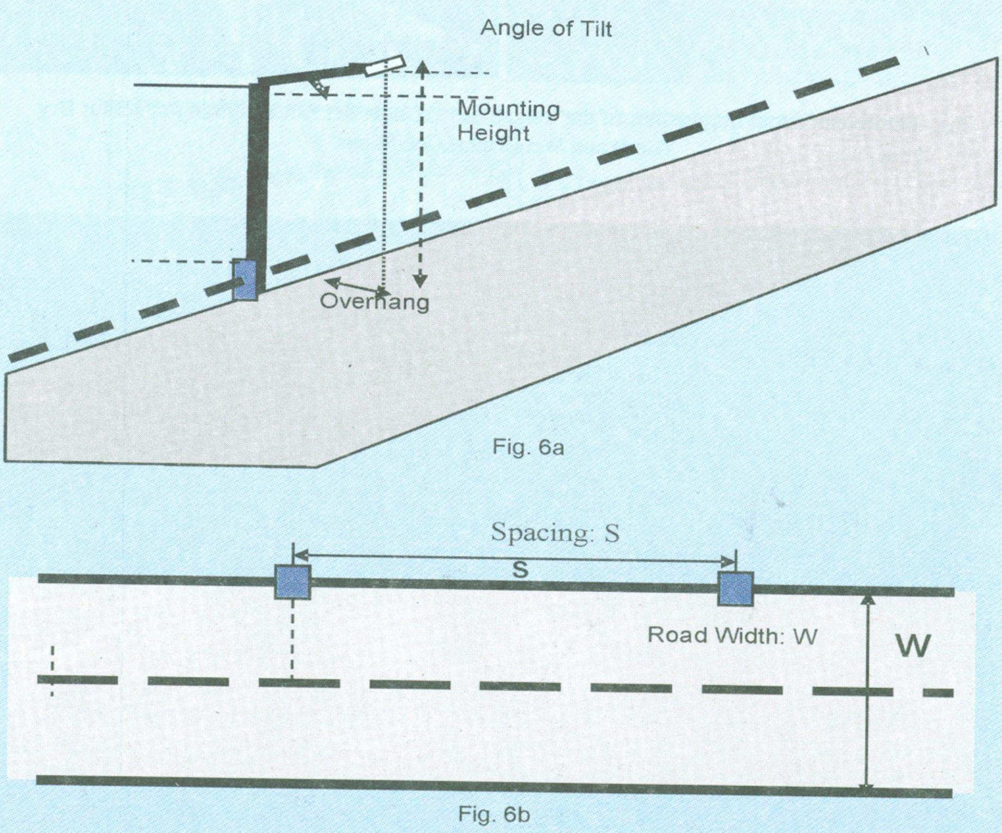

Fig. 6 Road Lighting Configurations

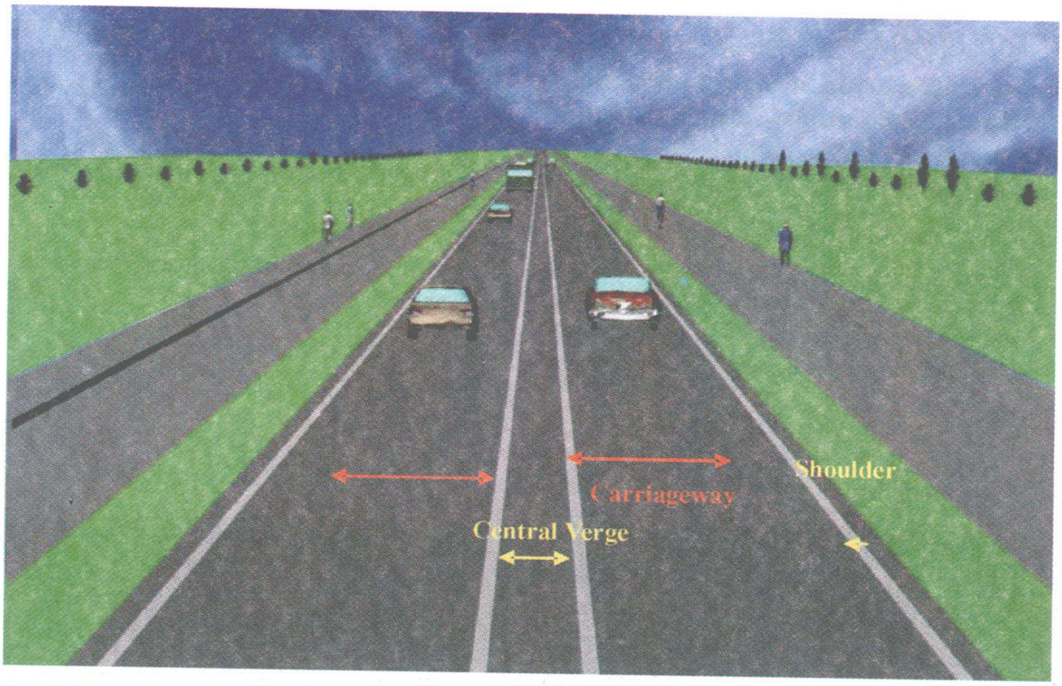

Fig. 5 Dual Carriageway

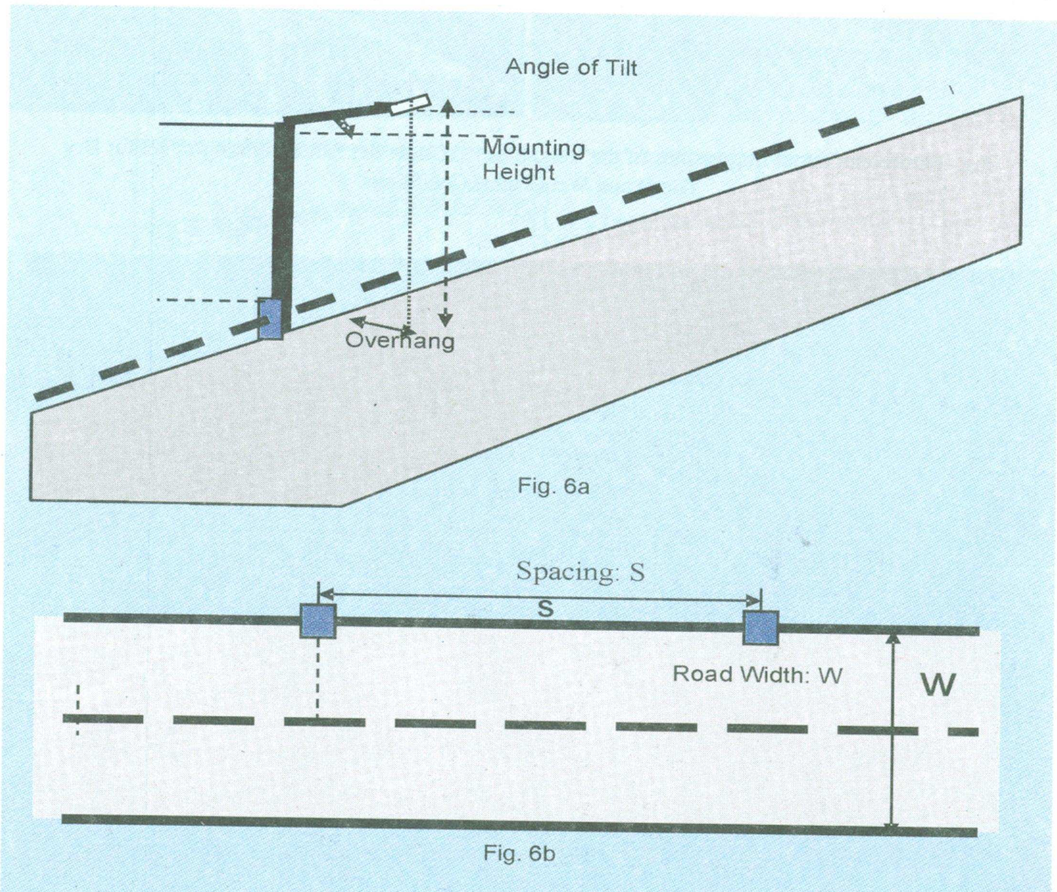

Fig. 6 Road Lighting Configurations

6.3 Types of Arrangement

Various types of arrangement of poles are shown in Fig. 7a) to Fig. 7e).

6.3.1 *Single-sided Arrangement [see Fig.7a)]*

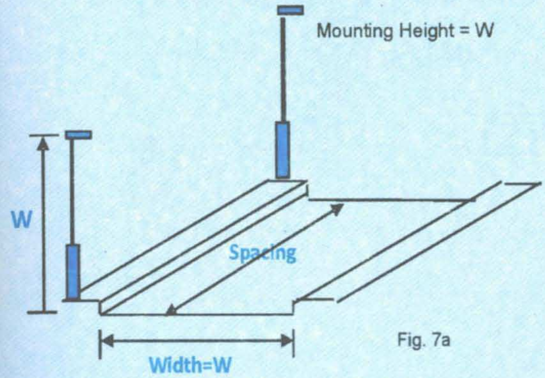

Fig. 7a

6.3.2 *Opposite-Sided Arrangement [see Fig.7b)]*

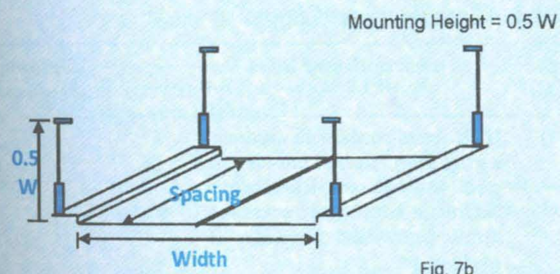

Fig. 7b

6.3.3 *Staggered Arrangement [see Fig. 7c)]*

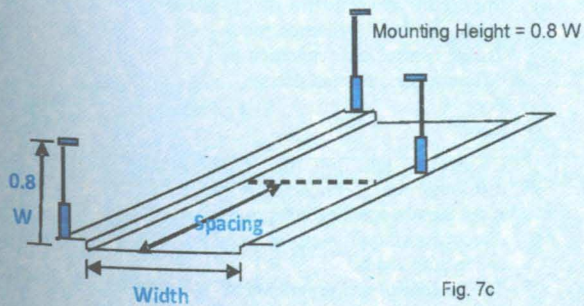

Fig. 7c

6.3.4 *Twin Central Arrangement [see Fig. 7 d)]*

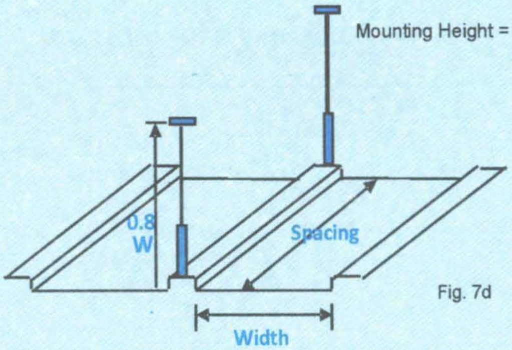

Fig. 7d

6.3.5 *Twin-Central and Opposite Arrangement [see Fig. 7 e)]*

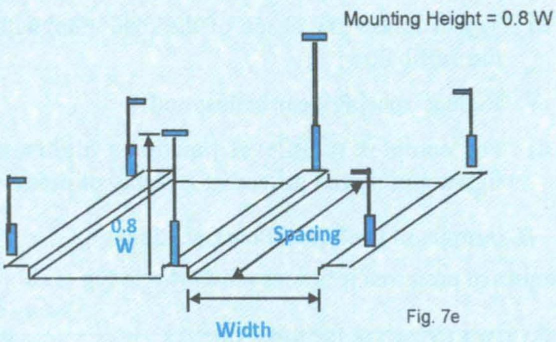

Fig. 7e

Fig. 7 Type of Pole Arrangements

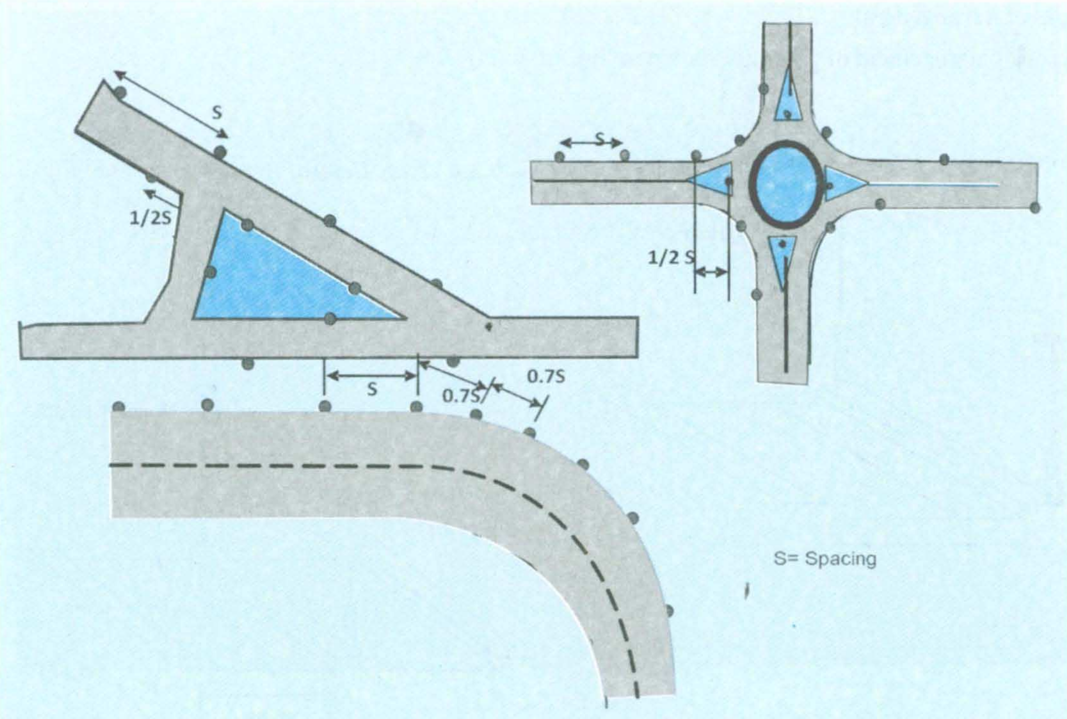

Fig. 8 Layout of Preferred Pole Locations

7 PREFERRED POLE LOCATIONS

7.1 The following may be taken into consideration for the pole locations:

a) Trace the traffic flow and direction;

b) Try to follow the shape of the road alongwith the traffic flow;

c) Reduce spacing near bends; and

d) For complex multilevel junctions, highmast lighting preferred instead of an array of poles.

7.2 Examples of Preferred Pole Locations

Examples of preferred locations are shown in Fig. 8.

8 GUIDELINES TO BE SPECIFIED

8.1 Road lighting systems use products namely, lamps, luminaires and control gear to achieve certain specified lighting conditions.

It is a good practice, to specify requirements of both products and lighting parameters.

8.1.1 *Lighting Parameters*

a) Lighting levels (Illuminance in lux and luminance in cd/m²); and

b) Uniformity.

8.1.2 *Classification of Roads*

Sl. No.	*Description of Road*	*Lighting Classification*
i)	High speed roads with separate carriageway, free of crossings at grade and with complete access control, motorways, express roads. Traffic density and complexity of road layout:	
	High	M1
	Medium	M2
	Low	M3
ii)	High speed roads, dual carriageway roads. Traffic control, such as the presence of signals, and separation of different types of road user into lanes:	
	Poor	M1
	Good	M2
iii)	Important urban traffic roads, radial roads, distinct distribution roads. Traffic control and separation of different types of road users:	
	Poor	M2
	Good	M3
iv)	Connecting less important roads, local distributor roads, residential major access roads, roads which provides direct access to property and lead to connecting roads. Traffic control and separation of different types of road users:	
	Poor	M4
	Good	M5

Table 2 Lighting Recommendations for Different Road Types — CIE Classification
(*Clause* 8.1.3)

Sl. No.	Lighting Class	All Roads L_{av}	All Roads U_O	All Roads U_L (min)	Roads with few junctions TI(%) (max)	Roads with Foot ways Surround Ratio (SR)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	M1	2.0	0.4	0.7	10	0.5
ii)	M2	1.5	0.4	0.7	10	0.5
iii)	M3	1.0	0.4	0.5	10	0.5
iv)	M4	0.75	0.4	–	15	–
v)	M5	0.5	0.4	0.4	15	–

where

L_{av} = Average luminance;

U_O = Overall uniformity;

U_L = Longitudinal uniformity; and

TI = Threshold increment.

8.1.3 *Lighting Recommendations for Different Road Types — CIE Classification*

The lighting recommendations for classes M1 to M5, which are selected according to the functions of the roads, traffic density, traffic complexity, traffic separation and the existence of facilities for traffic control, such as traffic lights are given in Table 2.

8.1.4 *Lighting Recommendations for Different Road Types — IS Classification* (*see* Table 3).

8.1.5 *Lighting Recommendations for Junctions* (*see* Table 4).

9 PRODUCT SPECIFICATION

A lighting system shall generally consist of the following:

Housing Optical System Lamp	Luminaire
Ballast Ignitor Capacitor	Control gear

Table 3 Lighting Recommendations for Different Road Types — IS Classification
(*Clause* 8.1.4)

Sl. No.	Classification of Lighting Installation	Type of Road	Average Illuminance on Road Surface	Uniformity Ratio E_{min}/E_{av}	Transverse Uniformity (E_{min}/E_{max})
(1)	(2)	(3)	(4)	(5)	(6)
i)	Group A1	Important traffic routes carrying fast traffic	30	0.4	0.33
ii)	Group A 2	Other main roads carrying mixed traffic like main city streets, arterial roads and throughway roads	15	0.4	0.33
iii)	Group B 1	Secondary roads with considerable traffic like principal local traffic routes and shopping	8	0.3	0.2
iv)	Group B 2	Secondary roads with light traffic	4	0.3	0.2

NOTE — Transverse uniformity: Ratio of E_{min} and E_{max} across the road.

Table 4 Lighting Recommendations for Junctions
(*Clause* 8.1.5)

Sl. No.	Junction Type	E_{av} (Lux)	E_{min}/E_{av}
(1)	(2)	(3)	(4)
i)	Key Junctions & Complex Flyover interchanges	50	0.4
ii)	Main City Junctions without any interchanges	20	0.4
iii)	Other smaller junctions	15	0.4
iv)	Pedestrian Crossings	50*	–
v)	Bus Bays	5	–

* This value is vertical illuminance on pedestrians at 1.2 m.

9.1 Luminaires

9.1.1 *Selection Criteria*

a) Mechanical;
b) Electrical;
c) Required lamp types;
d) Ambient operation temperature;
e) Required IP rating;
f) Air resistance, with/without bowl, with/without gear unit;
g) Component exchangeability, accessories;
h) Mounting functionality; and
j) Material requirement.

9.1.2 *Mechanical Characteristics*

a) Deformation temperature of the material/heat resistance;
b) Rigidity;
c) Corrosion resistance;
d) UV resistance;
e) Economical value/cost;
f) Service life;
g) Maintenance properties; and
h) Environmental friendliness.

9.1.3 *Electrical Characteristics*

a) Applicable mains (voltage/frequency);
b) Ballast type (basic, encapsulated, constant wattage);
c) Ignitor system (semi-parallel, superimposed/ series, parallel);
d) Required power factor;
e) Insulation class;
f) Special features (dimming, photocell); and
g) Wiring requirements (mains and internal).

9.1.4 *Housing Materials and Options*

a) *Metals*
   i) Pressed or deep drawn sheet steel or aluminium (treated); and
   ii) Die cast or extruded aluminium.
b) *Plastics*
   i) Polycarbonate (PC);
   ii) Polypropylene (PP); and
   iii) For plastics there are many different materials and even more different grades.

9.1.5 *Cover Materials*

a) Acrylic (PMMA);
b) Polycarbonate (PC); and
c) Toughened (Security) glass.

9.1.6 *Reflector Material and Finish*

a) Pressed aluminium sheet reflector or deep drawn pot-reflector; and
b) Pre-anodized material or post-treatment anodization or metallization.

9.1.7 *Optical Characteristics*

a) Type of distribution;
b) Multiple optics;
c) Luminaire efficiency;
d) Standard tilt angle; and
e) Need for optic or lamp position adjustment.

9.1.8 *Impact of IP on Maintenance factor*

The IP of a luminaire basically influences the selection of the maintenance factor (*see* Table 5).

For example, an IP 65 luminaire in a medium polluted area with a cleaning interval of 24 months should have a maintenance factor of 0.89. For design calculation, this is a major contributing factor.

9.2 Lamps

9.2.1 *Selection Criteria*

a) Colour temperature (T_c);

Table 5 Maintenance Factor
(*Clause* 9.1.8)

Sl. No.	Cleaning interval in months	MIN IP 5X Pollution Category			MIN IP 6X Pollution Category		
		High	Medium	Low	High	Medium	Low
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	12	0.89	0.90	0.92	0.91	0.92	0.93
ii)	18	0.87	0.88	0.91	0.90	0.91	0.92
iii)	24	0.84	0.86	0.90	0.88	0.89	0.91
iv)	36	0.76	0.82	0.88	0.83	0.87	0.90

b) Colour rendering (CRI);

c) Lumen output;

d) Lamp efficacy;

e) Lumen depreciation; and

f) Lamp life (hours).

For road lighting generally high efficacy (117,132, 141 lm/W), high pressure sodium vapour lamps (150, 250, 400 W) are being used. But nowadays for better colour appearance (CRI > 80) at junctions and city centres, ceramic discharge metal halide lamps (efficacy, 90 lm/W) are also being used to make a differentiation in lighting colour appearance.

9.3 Gear Unit Material and Process Options

9.3.1 *Metal*

a) Pressed steel; and

b) Pressed, deep drawn or cast aluminium.

9.3.2 *Plastic*

a) Glass fibre reinforced polyester; and

b) Nylon.

9.4 Mounting Unit Options

a) Integral part of the luminaire housing;

b) The rear part of the housing is shaped to mount the spigot. This construction is usually for side entry only; and

c) Mounting device is fixed to the housing with bolts.

9.5 Control Points

Streetlights are spread over long distances and it is difficult to operate these individually. One of the important links is the use of underground cables or special overhead wires to form a group control point.

9.5.1 *Control Switch*

The contactor can be operated manually if the switch is installed in a manned control point. However, such an operation is subject to human error. It is recommended that instead of that, an automatic switching device be adopted. A few of these are given in **9.5.1.1** to **9.5.1.3**.

9.5.1.1 *Time switch*

This has been the most widely used device in street lighting for quite a number of years. These switches are either operated by a mechanically wound clock or electrically by a synchronous motor. The former requires weekly rewinding. The latter are acceptable as long as the mains supply frequency is stable over a reasonable period of time.

9.5.1.2 *Photoelectric switch*

The other useful device is the photoelectric switch. These switches have the inherent advantage of being linked to sunrise and sunset. As such these switches do not need readjustment.

9.5.1.3 *Computerized switches*

The advent of microprocessors has also added a device for streetlighting applications. Some pioneers have manufactured programmable timers which can store the data of sunrise and sunset over the entire year. These are more dependable and comparatively inexpensive. Many of these have additional optional contacts which can be used for alternate functions including energy conservation by switching on additional lamps at evening peak traffic times.

9.5.2 *Step Dimming*

High intensity discharge lamp dimming is used to save energy during lean periods in the case of outdoor lighting, such as, streetlighting, tunnel lighting and lighting of many public places. During the period when the traffic is less, the required lighting level can be reduced. Lights can be dimmed to deliver 50 percent of the nominal light output by reducing the input power by 40 percent.

A step dimming system can be applied by one or more of the following combinations:

a) Step dimming ballast;

b) Preprogrammed timer;

c) Power factor improvement capacitor; and

d) Semi-parallel ignitor.

9.5.3 *Telemanagement*

This enables individual light points to be switched on or off at any given time, or to be set to any dimming level that the lamp allows, ensuring maximum flexibility for the lighting installation. For example, one section can be switched off, another dimmed to 90 percent and yet another to 40 percent, without any special electrical connections being required. It is also possible to program scenarios so that the lighting installation modifies its output depending on programmed times, weather sensors and/or traffic measurement devices. Telemanagement systems are based on the LON protocol. This protocol is open and is supported by a multiple of media and sensors. This makes integration with complex traffic management systems and geographical information systems easier and more reliable. The management software offers exceptional flexibility and easy configuration in a user-friendly graphical interface and performs a swift analysis of the situation with a map-based interpretation of the installation (*see* Fig. 9).

The salient features of the software system are as follows:

a) Software is used to configure the automatic control of the lighting installation and to provide feedback of information;

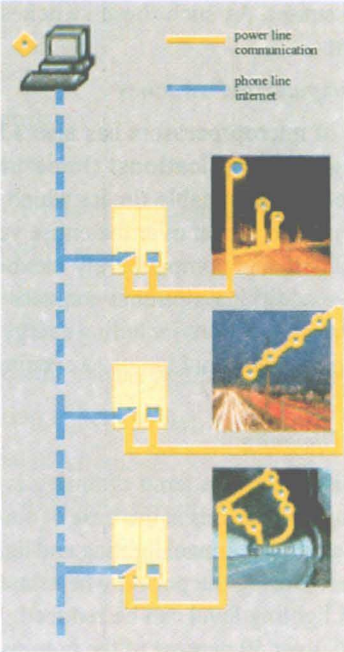

Fig. 9 Telemanagement System

b) Protocol for communication is carried out by LON;

c) Outdoor luminaire controllers (OLC) are built into the luminaire or into the base of the pole; they switch and dim the lamp, but also detect lamp failure and count burning hours;

d) Segment controllers (SC) are built into the feeder pillar. These command the OLCs and gather information from the segment to communicate it to the PC; and

e) The digital input unit is built into the feeder pillar. It allows interface with external sensors or systems and can generate commands that the outdoor luminaire controllers (OLCs) understand and execute.

Telemanagement is suitable for any outdoor lighting installation, for example, on motorways, ring roads, primary roads, in street lighting, tunnels and dynamic lighting systems.

10 PHOTOMETRIC SPECIFICATION

10.1 Key Element

This is a key element of street light luminaires, as it will determine the lighting quality on the road surface. Photometric specification may include the following:

a) Type of distribution;

.b) Luminaire efficacy; and

c) Need for optic or lamp position adjustment.

10.2 Lighting Control Elements

a) Reflector;

b) Refractor;

c) Diffuser;

d) Filter; and

e) Screening Device.

These elements (eventually used in combination) define the light distribution.

10.3 Luminaire Photometric Principle

a) Throw — The extent to which the light from the luminaire is distributed along a road;

b) Spread — The amount of sideways spread of the light, across a road; and

c) Control — The extent of the facility for controlling glare from the luminaire.

The Throw is defined by the angle (γ_{max}) that the beam axis makes with the downward vertical. The beam axis is determined by the direction midway between the 2 directions of 90 percent I_{max} in the vertical plane of maximum intensity. Fig. 10 shows the polar intensity curve through the plane of maximum luminous intensity, indicating the angle γ_{max} used for determination of the Throw.

Three degrees of Throw are defined as follows:

$\gamma_{max} < 60°$	: short throw;
$60° \leq \gamma_{max} \leq 70°$	: intermediate throw; and
$\gamma_{max} \geq 70°$	: long throw.

The Spread is defined by the position of the line, running parallel to the road axis that touches the far side of the 90 percent I_{max} contour on the road. The position of this line is defined by the angle □90. Fig. 11 shows the degrees of throw and spread as defined by CIE, where h is the mounting height. The three degrees of spread are defined as follows

$\gamma 90 < 45°$	: narrow spread;
$45° \leq \gamma 90 \leq 55°$	: average spread; and
$\gamma 90 \geq 55°$	: broad spread.

The Control is defined by the specific luminaire index (SLI) of the luminaire. This is the part of the glare control mark G,

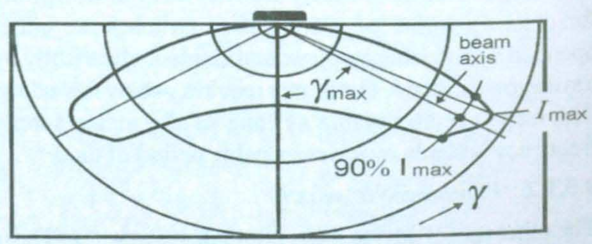

Fig. 10 Polar Intensity Curve showing Throw

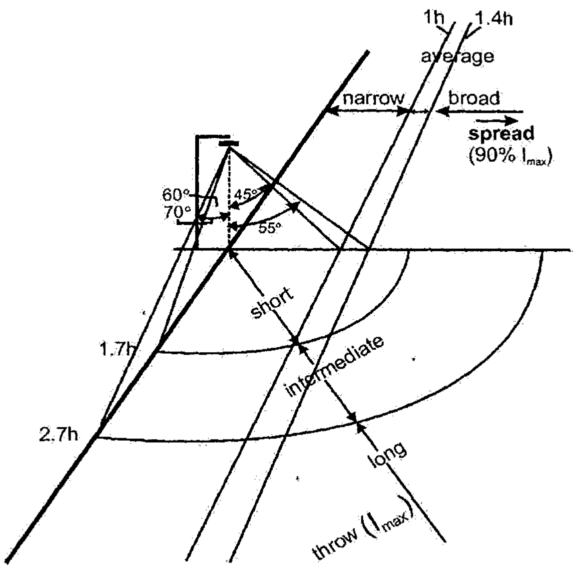

Fig. 11 Degree of Throw and Spread Defined by CIE

that is determined by the luminaire properties alone (*see* **4.2.4**).

Three degrees of controls are recognized:

SLI < 2	=	limited control;
2 ≤ SLI ≤ 4	=	moderate control; and
SLI > 4	=	tight control.

Summary of CIE Classification for Photometric Properties of Luminaire is given in Table 6.

11 EVALUATION OF GOOD ROAD LIGHTING INSTALLATION

11.1 The most practical method for evaluating a Road Lighting System is by the Cost of Ownership Analysis.

11.1.1 *Cost of Ownership*

The aim should be to create the most economic solution looking both at the initial investment costs and the running costs.

The total cost is split in two parts:

Preparation phase: Design, purchase and installation cost = Initial Investment

Running phase: Energy cost and maintenance cost

Total cost = Investment + Energy + Maintenance

Investment Cost:

a) Cable costs including trunk digging;
b) Power supply;
c) Cost of pole, bracket, base and foundation; and
d) Luminaire installation.

Reducing Investment Costs:

a) Increase luminaire spacing;
b) Use single sided or central arrangement;
c) Use of energy efficient luminaire;
d) Use existing cable and photocell; and
e) Post top luminaire mounting.

Energy Cost:

a) Installed power;
b) Number of burning hours; and
c) Energy cost per kWh.

Reducing Energy Costs:

a) Install the most efficient lighting system = lamp efficacy and luminaire application efficiency (for example using adjustable optics); and
b) Choice of maintenance factor (lamp depreciation and IP classification).

Maintenance Cost:

a) Lamp replacement cost;
b) Scouting;
c) Cleaning;
d) Eventual safety check and replacement of electrical components; and
e) Maintenance of pole and electrical supply.

Reducing Maintenance Cost:

a) Minimize number of light points by increasing luminaire spacing;
b) Lamps with long life and low early failure rate;
c) Conscious decision for group or spot replacement;

Table 6 Photometric Values of Luminaires

(*Clause* 10.3)

Sl. No.	Throw		Spread		Control	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Short	γ max < 60°	Narrow	γ90 < 45°	Limited	SLI < 2
ii)	Intermediate	60° ≤ γ max ≤ 70°	Average	45° ≤ γ90 ≤ 55°	Moderate	2 ≤ SLI ≤ 4
iii)	Long	γ max ≥ 70°	Broad	γ90 ≥ 55°	Tight	SLI > 4

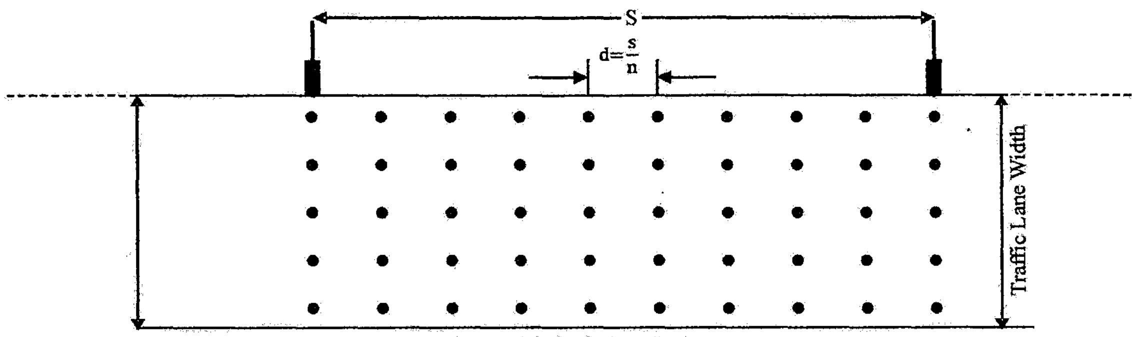

Fig. 12 Calculation Grid

d) Reliable, longer life gear;

e) Luminaire with high IP rating; and

f) Luminaire which is easy to maintain.

12 APPROACHES TOWARDS MASTER PLAN

12.1 For some roads technical specs are the first priority and for some other roads aesthetics are the first priority.

Technical specifications are required for the following roads:

a) Ring roads/peripheral expressways;

b) City roads, main vehicular traffic; and

c) Residential roads.

Aesthetics are required for the following roads:

a) Heritage roads/celebration routes; and

b) City centre/shopping areas/pedestrian plazas.

The aesthetics can be achieved by selecting one or more of the following procedures:

a) Different lighting levels;

b) Different shape of luminaires;

c) Different pole design; and

d) Different pole arrangement.

13 LIGHTING MEASUREMENTS

13.1 CIE Method

The CIE (1976a) recommends that where the luminaire spacing does not exceed 50 m, there should be 10 evenly spaced transverse rows of calculation points over its length, while for luminaire spacing greater than 50 m, the number of transverse rows should be such that the distance between two successive rows does not exceed 5 m (*See* Fig. 12).

The calculation grid as proposed by CIE (1976a): S = Spacing; d = longitudinal spacing between calculation points; n = no. of transverse rows. For, $S \leq 50$ m, $n = 10$; $S > 50$ m, n = smallest integer giving $d \leq 5$ m.

Finally the CIE also recommends that there should be 5 points across each traffic lane, with 1 point positioned on the centre line of each lane. It is stated that where the uniformity is good, $U_o \geq 0.4$, subsequent calculations may be based on 3 points instead of 5.

13.2 Field Measurements

For practical on-site measurements, the 9 point method is most acceptable. Fig. 13 illustrates the layout of a 9 point measuring grid of the kind sometimes used when checking new road lighting installations. The formula above the figure gives the weighting procedure that should be followed when calculating the average lighting level. Where extreme accuracy is required, the CIE recommends using as many measuring points as specified earlier.

$$\text{Average illuminance } E_{av} = \frac{P1+P3+P7+P9}{16} + \frac{P2+P4+P6+P8}{8} + \frac{P5}{4}$$

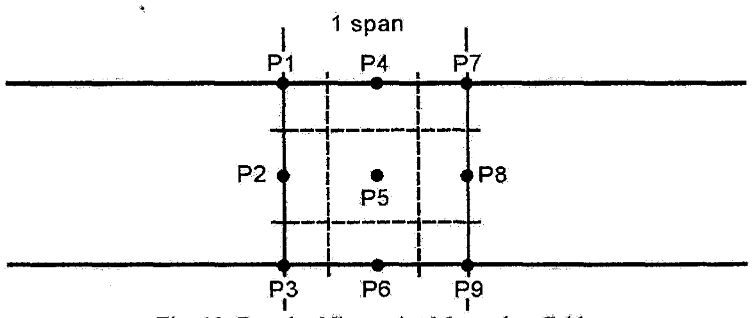

Fig. 13 Regular Nine-point Measuring Grid

SP 72 : 2010

NATIONAL LIGHTING CODE

PART 9 ENERGY-EFFECTIVE LIGHTING SYSTEMS

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Energy saving in lighting became a top priority all over the world with the tremendous energy crunch in the 1970s. For India, it has been considered even more important, as the demand for electricity is going up every year, what with the need for rapid industrialization and all-round growth. With the rise in demand and depleting natural resources, energy will be dearer and scarcer. On the other hand, the cost of setting up electric power generating capacity is also going up, making funding extremely difficult.

The total consumption for lighting in all the sectors; domestic, industrial, commercial and public utilities is quite substantial.

As energy prices continue to increase, energy legislation is enacted and energy codes become more restrictive, energy efficiency in design and practice has become essential to a successful lighting system. It has also created lucrative investment opportunities for corporations and institutions, who can make capital investments to upgrade their existing lighting systems to generate energy savings that provide an economic return.

The concept behind energy efficiency is simple. If lighting design goals can be achieved using equipment and approaches that use less energy during operation, then the owner will save money on an ongoing basis. Or put another way, the ongoing cost of operating an inefficient system can be avoided. The catch is that for some equipment types, the initial cost is higher and for some, such as controls, some installation expertise is required. While some energy efficient lighting may present a higher initial cost, the owner will realize savings that will pay for this investment over time, the most desirable time period generally being from one to three years. Advanced lighting controls, for example, can reduce energy consumption by as much as 50 percent. In fact, if one looks at the life cycle cost of the system, including initial cost plus operating and maintenance costs, energy efficient lighting becomes an investment in profitability with an excellent return on investment.

NATIONAL LIGHTING CODE

PART 9 ENERGY-EFFECTIVE LIGHTING SYSTEMS

1 SCOPE

This part of the code describes the energy conservation measures in any lighting installation and lighting system.

2 TERMINOLOGY

The definitions given in Part 1of this code shall apply.

3 ENERGY CONSERVATION MEASURES

3.1 The incandescent lamp (GLS) is used as a major light source in India. These lamps have an efficacy of 10 to 20 lm/W and a life of 1 000 burning hours. There are varieties of gas discharge lamps with efficacies ranging between 50 and 200 lm/W and having a life between 5 000 and 15 000 burning hours. These gas discharge lamps are:

a) Tubular fluorescent lamps;

b) Compact fluorescent lamps (CFLs);

c) High pressure mercury vapour lamps (HPMV);

d) High pressure sodium vapour lamps (HPSV); and

e) Metal halide lamps.

CFL lamps are available in lumen packages, so that they can replace GLS lamps of equivalent lumen output. The fluorescent lamps have been made further energy effective with the use of triband phosphors instead of the conventional fluorescent powder. The luminous efficacy of this new family of lamps is 35 percent higher.

There is another area, which can give good energy saving. Every gas discharge lamp needs a ballast. Today, most of these ballasts are the conventional electromagnetic type. All these ballasts, when the lamp is in operation, consume electric power known as ballast loss. With proper design, the ballast loss can be substantially reduced. Use of such low loss ballasts can result in a lot of energy saving.

However, the best solution in this area is to gradually introduce electronic ballasts. These ballasts, not only have very low losses because of electronic components, but increase the luminous efficacy of fluorescent lamps because of high frequency operation. The overall luminous efficacy of an electronic ballast and high frequency fluorescent lamp combination is 25 percent higher than that of a conventional ballast and fluorescent lamp combination.

Even the best lamp and ballast combination may not give the ideal result if used in luminaires which are poorly designed. A lot of light will be wasted in such luminaires. It is imperative today to look into all the aspects of application and select the most optimum solution for all lighting installations. For example, luminaires with mirror optics and widespread light distributions save approximately 25 to 33 percent energy for the same lighting level in offices. Similarly, road lighting luminaires using pot optics and tubular HPSV lamps achieve the same lighting parameters with 30 percent less number of poles and luminaires than the conventionally designed luminaires. The associated energy and material savings are enormous.

3.2 There are enormous saving opportunities in almost all the sectors of lighting if following steps are taken:

a) Incandescent lamps replaced with fluorescent lamps, retrofit compact florescent lamps and non-retrofit compact fluorescent lamps;

b) Conventional fluorescent lamps replaced with T5 fluorescent lamps;

c) Electronic ballasts installed in place of electromagnetic ballasts;

d) High pressure sodium vapour lamps and ballasts used instead of high pressure mercury vapour lamps and ballasts; and

e) Metal halide lamps used in place of high pressure mercury vapour lamps and tungsten halogen lamps.

With proper implementation of energy-effective lighting design and good engineering practices, it is possible to conserve energy.

4 METRICS

All lighting equipment requires electric power, measured in Watts (W). As the lighting system operates over time, it consumes energy, which is expressed as kilowatt hours (kWh). One kWh is 1 000 W utilized for one hour. Power and energy are the two major products that the electric utility charges for; the total electrical load of the building in kW and the amount of energy consumed in kWh. Therefore, in any lighting upgrade the goal will be to reduce the amount of power the lighting system requires and, when possible, the hours of operation.

4.1 Demand Charge

This is the monthly cost based on the connected electrical load of the building. Actual demand is metered by the utility and the charge is based on the month's demand peak. With this in mind, it not only pays to reduce wattage, but reduce consumption during the day's peak load period, which is typically at midday. The utility may also impose a ratchet clause based on demand, locking in the demand charge at maximum demand for the recent past.

4.2 Energy Use Charge

4.2.1 It is the monthly charge by the kWh for electrical energy consumed by the building's electrical systems. The lighting energy management goals therefore can be clearly stated as:

a) Reduce wattage (power) required by the lighting system; and

b) Reduce energy (power x time) consumed by the lighting system.

4.2.2 To measure the energy performance of lighting systems, a variety of metrics can be used:

Total wattage: For all lighting equipment (does not include impact of controls);

Total energy consumed : For all lighting equipment;

Watts per square metre : This metric, called light power density (LPD), is determined by dividing total watts by the total area of the space in square metres. Lighting requirements in the National Building Code (NBC) and Energy Conservation Building Code (ECBC) typically set restrictions on light power density; and

kWh per square metre : This metric, called the energy utilization index, is determined by dividing the total kWh of energy consumed by the lighting system in a space by the total area of the interior space in square metres. The advantage of using the energy utilization index is that it includes the factor of time, and encourages the use of lighting controls that reduce the amount of time the lighting system operates when it is not needed.

4.3 Relevant Formulae

Using local environmental data and system performance data from manufacturers' literature, we can use the formulae below to determine the energy characteristics of an application:

Demand for power (kW) = System input wattage (W) ÷ 1 000;

Energy consumption (kWh) = System input wattage (kW) x hours of operation/year;

Hours of operation/year = Operating hours/day x Operating days/week x Operating weeks/year;

Lighting system efficacy (lumens per watt or LPW) = System lumen output ÷ Input wattage;

Light power density (W/m^2) = Total system input wattage (W) ÷ Total area (square metres);

Watts (W) = Volts (V) x Current in amperes (A) x Power factor (pf); and

Voltage (V) = Current in amperes (A) x Impedance (Ohms) [This is called Ohm's Law].

5 UPGRADE STRATEGIES

5.1 Several simple strategies can be employed to adopt energy-effective lighting in existing installations, commonly called an 'upgrade' or 'retrofit.' Regardless of strategy, however, every lighting upgrade requires the same thought process, as shown below in a simplified form.

a) Determine the required maintained light level. As the industry proverb goes, "Light is for people, not buildings." The lighting system's first task is to provide sufficient quantity and quality of light for occupants to perform relevant tasks. In existing installations, this will require a lighting system audit;

b) Determine the qualitative lighting requirements. Identify all quality issues such as glare, colour, aesthetics, distribution and attendant factors (such as surface reflectances and ceiling heights) that must be given priority during equipment selection and design. In existing installations, this will require a lighting system audit;

c) Identify equipment options that produce the desired maintained quantity and quality of light and also save energy. Equipment options will include lamps, ballasts, luminaires and advanced controls (occupancy sensors, dimming controls, photocells, lighting management systems, etc);

d) Identify strategies that support the goal of reducing energy consumption, such as planned lighting maintenance, repainting room surfaces to give them a higher reflectance (if appropriate) and developing a written lighting energy policy; and

e) Choose the best package of equipment and strategies that will achieve the desired lighting goals while delivering desired economic performance.

5.2 Lighting Upgrade Strategies

5.2.1 *Maintained Light Levels*

With this strategy, the same level is maintained as in the existing system after upgradation.This goal can be accomplished by incorporating automatic controls and more efficient lamps and ballasts into the lighting system.

5.2.2 *Optimized Light Levels*

In some applications, lighting audit may reveal considerable opportunities to reduce lighting levels. In a renovation or new construction situation, we can reduce light levels by focusing higher intensities closer to the task. For example, in an open plan office, indirect lighting can be specified to provide lower light levels for ambient illumination, while higher light levels are provided at the task by workstation task lighting.

5.2.3 *Increased Light Levels*

This strategy entails increasing light levels via strategies such as planned lighting maintenance, higher room surface reflectance and higher luminaire efficiency.

Other considerations are:

a) Incorporate daylighting into the lighting scheme as much as possible; there are many ways that help daylight penetration into the building and distribute the light; glare controls should be provided and daylight harvesting controls can be specified for significant energy savings;

b) In new construction or renovation projects, the interior designer can affect the overall efficiency of light distribution by providing finishes that give proper ceiling, wall and task reflectance values;

c) All lighting components must be compatible to operate properly;

d) All applicable safety requirements and regulations should be strictly adhered to when any work is done on an electrical system;

e) Consider a planned lighting maintenance programme and opening retrofit opportunities that reduce light output and energy consumption;

f) Ensure that all retrofits are permanent and understood by the maintenance personnel in a written and communicated lighting policy, so that old components are not reintroduced back into the lighting system later;

g) Be sure to include provisions for legal compliance in disposing of any lighting waste; and

h) Ensure compliance with the Energy Conservation Act and other statutory regulations.

6 EQUIPMENT SELECTION

The lighting system operates within a larger system that includes the space itself, with its various values of reflectances for room and task surfaces, and availability of daylighting. When planning a lighting upgrade, equipment that changes any combination of these components can be specified.

7 COMPARING SYSTEMS

7.1 To compare the relative efficiencies of lighting systems, the following may be considered:

a) Compare efficacies for various light sources and lighting systems.

   Efficacy, expressed in lumens (light output) per watt (electrical input), is often used to compare the relative efficiencies of lamps and lighting systems. It is abbreviated LPW or lm/W. To determine efficacy, divide the lumen output of a lamp or lighting system by its rated input wattage;

b) Compare power requirements.

   Determine the light level goals and compare various options that achieve these goals at the lowest wattage possible. From this we can also compare LPD, or watts per square metre; and

c) Compare energy usage.

   Determine the light level goals and compare various options that achieve these goals with less energy consumption. This is advantageous as it includes automatic lighting controls, which reduce operating time, not watts. From this we can also compare the energy utilization index, or kWh consumed per square metre.

7.2 Efficacy is a popular metric used to assess the relative efficiencies of lighting systems. It can be used to easily screen a wide range of options, helping to narrow down choices that can be compared. However, efficacy alone does not ensure that more light will be delivered to the task.

A luminaire may be optimized for one type of lamp but may be relatively inefficient with a different lamp type. Both the light output ratio (LOR) and the coefficient of utilization (COU) of the system need to be taken into account.

Comparing energy usage for various systems that achieve the same maintained light level target is useful in that it includes controls, which affect energy consumption over time but not system wattage. With this metric, we can include more specific parameters about the installation, such as its target light level and hours of operation.

LPD is most useful when screening a space for lighting efficiency and to ensure compliance with applicable lighting codes when conducting a building activity that is governed by these codes.

Typical efficacies of common light sources are given in Fig. 1.

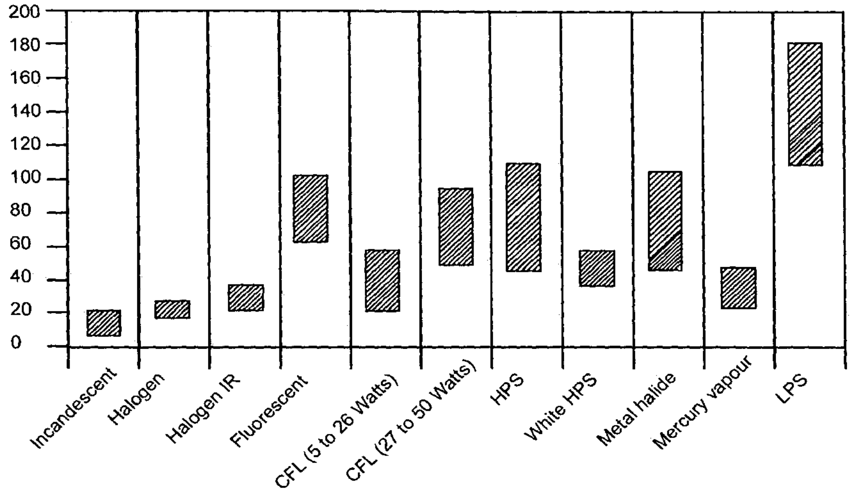

Fig. 1 Typical Efficacies for Common Light Sources

7.3 Typical Fluorescent Luminaire Upgrades

Lighting system upgrade options for fluorescent lighting systems include:

a) T5 and T8 lamp and ballast systems;

b) Low loss electromagnetic ballasts and electronic ballasts (full output, dimmable, light-level switching and low wattage); and

c) Optics upgrade.

7.4 Typical Incandescent Luminaire Upgrades

Lighting upgrade options for incandescent fixtures include:

a) Compact fluorescent lamps;

b) Halogen lamps;

c) Low wattage metal halide lamps; and

d) New luminaires that offer a higher efficiency.

7.5 Typical High Intensity Discharge (HID) Lighting Upgrades

Lighting system upgrade options for HID lighting systems include:

a) Switching to metal halide or high pressure sodium vapour from high pressure mercury vapour lamps;

b) Dimming ballasts; and

c) New luminaires that offer a higher efficiency.

7.6 Typical Control Upgrades

Upgrades for lighting controls include:

a) Lighting management systems;

b) Dimmable fluorescent and HID systems;

c) Daylight dimming systems that measure ambient daylight and dim light levels accordingly, producing energy savings;

d) Illuminance maintenance dimming systems;

e) Electronic time clocks;

f) Occupancy sensors; and

g) Manual, step-level and panel-level dimming systems.

7.7 Typical Exit Sign Upgrades

Upgrade options for exit sign fixtures include:

a) Light emitting diodes (LEDs);

b) Electroluminescent panels;

c) Light panels;

d) FTL cold cathode lamps; and

e) New exit signs.

8 ECONOMICS

8.1 When upgrading an existing installation, a capital investment is made that produces energy savings, which deliver a payback and return on the investment. There are several ways of using economics to compare lighting systems. The most popular for screening purposes are simple payback and return on investment.

a) First, determine the initial cost of the new lighting system, and then compare energy usage to the existing system to determine energy savings.

Initial Cost (Rs) = Equipment Cost
+ (Installation Hours x Labour Rate); and

Annual Energy Savings = (A - B) x Energy Rate charged by utility

where

A = [Existing system wattage (kW) x Annual operating hours (h)]; and

B = [New system wattage (kW) x annual operating hours (h)].

b) Now determine simple payback, five year cash flow and simple return on investment.

Simple Payback on an Investment (Years) = Initial Cost (Rs) ÷ Annual Energy Savings (Rs);

5 Year Cash Flow (Rs) = 5 Years – Payback (Years) x Annual Energy Savings (Rs); and

Simple Return on Investment (%) = [Annual Energy Cost Savings (Rs) ÷ Net Installation Cost (Rs)] x 100.

c) Another method of comparing lighting systems is to look at the cost efficacy of the system, expressed as rupees per lumen hour, and the total cost of ownership for the system over its life.

Cost of Light/Lumen Hour = (Initial Cost + Total Operating Cost) ÷ (Total Lumens Delivered x Hours of Operation). Total Operating Cost and Hours of Operation are set for any period of time that the specifier or owner wishes to consider.

Simple Life Cycle Cost = Initial Cost + (Annual Operating Cost x Life of System in Years). Annual Operating Cost is Annual Energy Cost + Annual Maintenance Cost, with the annual maintenance cost assuming all labour costs, replacement components, etc. The life of the system in years must be estimated. The owner can participate in determining this figure, but otherwise one could assume 20 years.

Once simple values are achieved, one can determine which lighting system makes the most economic sense to replace the existing system with. Then one can conduct a full economic analysis, including life cycle costing and return on investment that takes into account many economical factors such as the future value of money.

NATIONAL LIGHTING CODE

PART 10 INSTALLATION ASPECTS FOR LIGHTING
Section 1 Mechanical

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

The provision of artificial lighting for various applications is achieved through proper design, engineering, installation (erection) and maintenance. Each one of these is important in its own right. While design in this context refers primarily to the design aspects of lighting such as illuminance, glare, uniformity, colour, etc, as relevant to the respective application, the other three would include the mechanical and electrical aspects relating to the erection of the lighting equipment and the associated electrical distribution equipment. The work of a lighting installation involves multidisciplinary coordination to correctly transform the design concept to the final installation which is safe and satisfactory functionally as well as aesthetically. The various aspects in respect of all these are considered in 3 sections under this part. This section covers the mechanical aspects as applicable to lighting installation work, followed by the electrical aspects in Section 2 and coordination aspects in Section 3 of this part.

NATIONAL LIGHTING CODE

PART 10 INSTALLATION ASPECTS FOR LIGHTING
Section 1 Mechanical

1 SCOPE

This section of the code prescribes the mechanical aspects of any lighting installation.

2 TERMINOLOGY

The definitions given in Part 1 of this code shall apply.

3 STORAGE AND HANDLING

3.1 It is not uncommon that the luminaires are received at site, well ahead of the actual time of installation. Temporary storage thus remains inevitable in most installation works. After verification on receipt, it would be a safe practice to store the luminaires and accessories in the respective packing cases, lest they be damaged in storage or while handling later.

3.2 Luminaires and packed cases (as the case may be) should be stacked so that there is no risk of moisture ingress or exposure to sun or weathering. The storage should be in a covered, lockable space and yet it would be desirable to cover the stored material by an overall polythene sheet especially when stored without the packing cases (where inevitable).

3.3 Packages of the luminaires, lamps and electrical components should be handled with care to avoid mechanical damage or breakage during transportation and installation. The packages should be marked for the purpose in bold letters and symbols.

3.4 Luminaires should be handled with clean hands. They should be held, to the extent possible, symmetrically during installation. Reflectors are generally made from thin sheet material and can easily get deformed with slight pressure. Particular care is needed, not to disturb or damage the reflectors.

3.5 The protective layer laid over reflectors in the factory should not be removed till commissioning. Lamps may also be fixed in position only during commissioning.

4 GENERAL INSTALLATION CONSIDERATION

4.1 The interior lighting layouts may not at times indicate the precise distances from walls. The installation at site should, however, be done with due care to see that the functional design concept is not upset, and at the same time the aesthetics are maintained, as for example, maintaining symmetry, alignment, relation with other outlets like air conditioning.

4.2 Mechanical integrity is important in the installation of lighting equipment so that its position, alignment, aiming, etc, do not get altered under conditions of normal use, maintenance and the environmental conditions at site where it is installed. Supporting and anchoring arrangements to the walls or structures as the case may be, as well as the associated hardware items shall be of adequate strength for taking the load of the luminaire, and control gear where applicable. In the case of outdoor installations, the effect of wind force should also be considered.

4.3 Pendant type luminaires should be installed in such a way that the weight should not come on to the electrical terminations. Suitable clamps for the cord should be provided in the ceiling rose or suspension box for the purpose. Where possible the cord may be knotted at the luminaire end holder, if the luminaire is suspended by only the cord.

4.4 Where the luminaire is heavy (for example, chandelier) a suitably sized chain or pipe should be provided to take the weight and the cord should be free from the weight of the luminaire. Hooks should be provided as necessary to suspend such heavy luminaires. Alternatively, if the luminaire is to be fixed to the ceiling directly, appropriate fixing arrangements should be employed. It must be ensured that holes drilled in the structure for the purpose are exactly the required size, as otherwise the integrity of fixing thereto may not be assured.

4.5 When luminaires are to be installed as part of a false ceiling, it has to be first confirmed whether the false ceiling can take the load of the luminaire. It is often convenient to suspend the luminaire from the main structure above the false ceiling using chains (in preference to pipes), which will permit easy adjustments at site through a stud of about 25 mm length welded to each end of the chain.

4.6 In installations where site adjustment will be called for (for example, flood lighting), one or two fixing holes may be elongated instead of being circular. Spring washers and lock nuts should be used with normal bolts and nuts to ensure rigidity of fixing at such locations.

4.7 The likely effect of corrosion should be considered for the hardware items in high humidity areas and coastal areas. Certain chemical and petrochemical industries, chemistry laboratories in educational and research institutions, lead acid battery rooms, etc, are likely to introduce corrosive fumes in the atmosphere. The metallic components should either be made of corrosion resisting material, or be protected by an appropriate coating of anticorrosive material or paint. In most cases, mild steel is used for the hardware, and it should be derusted, and galvanized before installation or painted with red lead or epoxy paint after installation. Threads in particular are areas highly vulnerable to attack on the base metal. These should be protected by an application of anticorrosive material. Depending on the extent of corrosion likely in the area, painted surfaces will need repainting at certain intervals.

4.8 Where heat energy is likely to be generated from a luminaire (for example, one with incandescent lamps, or from a magnetic ballast), the installation should be such that the heat is readily dissipated away. If this is not done (for example, a luminaire with an enclosure as part of a false ceiling), it can create heat traps and may even lead to fire with long time use.

4.9 Magnetic ballasts may cause a disturbing hum. This may not be acceptable in certain locations (for example, studios and conference halls). It may be then desirable to install the ballasts outside such sensitive areas, subject to the limitation of distance (*see* Section 2 of this part). Here again, necessary provisions need to be made to dissipate the heat effectively.

4.10 Wherever gaskets are used either as part of the luminaire or part of the installation, the material of the gasket should be suitable for the operational conditions of the luminaire and the installation (for example, in an outdoor luminaire the gasket should be fixed on the cover, so that it does not tend to come off, when the cover is opened for lamp replacement or maintenance).

4.11 In the erection of luminaires and electrical distribution conduits and cables in trusses, suitably designed clamps should be used, since quite often drilling holes in the structural members may not be permitted.

5 PARTICULAR CONSIDERATIONS

5.1 Wall mounted luminaires are very common in residential installations. Apart from aesthetics, wall mounting enables easy cleaning of the luminaire and replacement of lamps without seeking assistance from outside. For room depths up to 5 m, a mounting height of about 2.4 m is generally adopted.

Wall mounted luminaires are installed either directly on to a phenolic laminated sheet or to a wooden base which in turn is fixed either to the wall or to the electrical outlet box. The fixing screws should be of adequate length and the use of a single screw for fixing should not be permitted so that the installed luminaire is not disturbed from its position during maintenance and relamping. Where wood is used, it should be of good quality and be coated with varnish on all sides before installation. Wood screws should be used for screwing the luminaire to the wooden base.

5.2 Where the floor height is low (for example, mezzanines, passages below attics and depressed ceilings for toilets) luminaires should be installed on wall space to avoid mechanical damage. In areas with normal floor heights, luminaires can be installed at the ceiling level. Where installed directly under the ceiling, it is preferable to fix the luminaires on round wooden blocks. This improves ventilation of the luminaire and also hides any unevenness in the finishing work of the ceiling.

If ceiling fans are used for ventilation, the positioning should be such that the cut-off of the luminaire beam is lower than the ceiling fan so that disturbing shadows are avoided. Where this is not feasible, the luminaire may have to be brought down suitably using down rods. In the case of fluorescent tube luminaires, a ball and socket arrangement is provided where the length of the down rod is over 300 mm.

Utmost care is needed in such installations in maintaining the alignment of the luminaire as well as the uniformity or spacing between the down rods of every luminaire.

5.2.1 Accessibility of the luminaire for maintenance and lamp replacement is very important. No useful purpose is served if any luminaire is installed either for illumination or for decoration in such a location that relamping or maintenance is not possible. This applies equally where accessories (if any) are installed in a separate box.

5.2.2 In installations with high ceilings such as auditoria and exhibition halls, catwalks may be incorporated in the design stage itself for access to the luminaire and control gear.

5.3.3 Access to the luminaire may also be achieved through mechanical or electromechanical raising and lowering mechanisms (for example, highmast lighting and adjustable indoor pendants). Suitable catwalks of adequate mechanical strength are very essential for initial installation and subsequent maintenance for auditoria and outdoor installations such as sports lighting, arena lighting and hangar lighting.

5.4 It is common to provide the cable terminations and looping and the over current protection of the lamp in a box at the foot of every pole for street lighting and exterior lighting of buildings. It is a safe practice to locate these at a height of at least 600 mm above ground, and this will also enable easy accessibility. In the interest of safety, such termination boxes should have covers with latches to a fail-safe design.

5.5 In respect of installations for underwater lighting as in swimming pools, the luminaire and cable termination should be in a chamber adjoining the pool, so that relamping and maintenance is conveniently done. There should then be a clear glass of suitable thickness between the luminaire and the pool, with a necessary gasket to prevent seepage of water.

5.6 Needless to mention, all safety precautions required for any mechanical installation should be taken in the process of the installation of luminaires and distribution cables. Only tools appropriate for the action and size involved should be used. The installing person should stand on an adequate and reliable support, since the installation work will be done at some height. Wherever necessary, safety belts should be used.

5.7 'As fitted' drawings should be prepared on completion of the installation. In the case of floodlighting and sports lighting installations, the record of aiming angles should be maintained immediately after the initial installation for reference during maintenance.

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NATIONAL LIGHTING CODE

PART 10 INSTALLATION ASPECTS FOR LIGHTING
Section 2 Electrical

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Electricity is the main source of energy for modern lighting. While the lamps and luminaires are selected to provide the required illumination to satisfy the functional requirements, electrical energy should be made available safely to the lamps at the desired supply parameters of voltage and frequency. The electrical system should be designed, installed and maintained as per relevant standards so as to ensure the supplying of electricity at the required supply parameters to operate the lamps through their control gear (wherever applicable). This section is devoted to aspects relevant to electric supply and distribution to lighting installations.

The following Indian Standard is a necessary adjunct to this section.

IS No.	*Title*
732:1989	Code of practice for electrical wiring installations (Third Revision)

NATIONAL LIGHTING CODE

PART 10 INSTALLATION ASPECTS FOR LIGHTING
Section 2 Electrical

1 SCOPE

This section of the code prescribes the electrical aspects of any lighting installation.

2 TERMINOLOGY

The definitions given in Part 1 of this code shall apply.

3 STANDARDS

3.1 There are Indian Standard Specifications for all important components of the electrical installation in the form of product standards, for example, wiring accessories, cables, switchgear and lamps). There are also codes of practices (COP) to indicate the best engineering practices with regard to the installation. A list of the most commonly applicable Indian Standards is given in Annex 1 of this section.

3.2 In order to ensure quality and safety, it is always the proper practice to use certified products. Where it is not possible to do so for any reason, conformity to the relevant Indian Standards shall be insisted upon supported with test certificates. Out of the many standards, IS 732-1989 relates to wiring installation. Electrical installations for lighting circuits shall need to comply with this standard.

3.3 The National Electrical Code brings out the various important aspects as applicable to all types of electrical installation works. References to the respective standards and codes applicable have also been made therein at appropriate places. Compliance to the NEC will ensure an electrically safe installation.

4 WORKMANSHIP

4.1 The workmanship of the electrical installation must be of a high order, so as to ensure integrity (security grade) of service and safety from shock hazard and fire hazard. No short cut procedure should be adopted anywhere in the installation work (for example, twisting wire terminations instead of screwed connections).

4.2 The contractor (agency) responsible for the work of electrical installation should be licensed by the state government concerned for the type of work to be executed. The skilled workers should also possess the necessary license for the trade involved. These requirements of IE Rules 1956 are mandatory and must be complied with.

5 ASPECTS PERTAINING TO DESIGN

5.1 It is a fundamental requirement that every part of the electrical system shall be capable of carrying the currents involved for the period of current flow, safely. Every conductor carrying current will produce heat energy equivalent to I^2Rt (where I is the current, R is the resistance of the conductor and t is the time of current flow) and the consequent rise in temperature should be such that the insulation material over the conductor will not be adversely affected by the resultant final temperature of the conductor. The current may be a continuous operating current for a long time, or be a large inrush current for a short time during switching on, or be a fault current due to an earth fault or short circuit fault for a period which will be governed by the operating time of the protective device concerned. In the case of discharge lamp circuits, the continuous current will correspond to the lamp load plus the losses in the control gear.

The cabling and wiring material selected for lamp circuits should take into consideration, not only the load current, but also conditions of installation such as open bunching in conduits and hot or cold environment around the wiring. Oversizing may be required to compensate for any likely reduction in the permissible temperature rise due to any such adverse condition. In fact this will apply even to the wiring cables forming part of the luminaires.

5.2 Every part of the electrical system shall have the required level of insulation. Normally lighting circuits operate on single phase 240 V ac supply and the voltage grade of the materials as per standards will be 650 V. In larger installations, the supply is 3 phase 415 V ac and the insulation will be to 1 100 V grade. In certain discharge lamps an electronic device is used to give high voltage pulses to the lamp to strike. The insulation material used for the wiring and cabling should be capable of withstanding this voltage.

5.2.1 Every luminaire should be controlled by a switch. There can, however, be group control of more than one luminaire by a switch or a single luminaire may be controlled by 2 switches. The switching arrangement is designed on a case to case basis for the best functional utility. As far as possible discharge lamps may have individual controls because such loads are predominantly inductive and there can be sparking at the switches during on off operations thereby reducing the life of the switch. It is good to oversize the switches in such circuits to say, at least double the normal operating current of the circuit, considering the effect of sparking during switching where group switching is involved.

5.2.2 A semiconductor device may be used for switching circuits for certain lighting installations. This is not suitable for disconnection under overcurrent conditions and should always be backed up by a necessary current protective device.

5.2.3 Group dimming facilities should be available in auditoria and multipurpose halls. The grouping of luminaires for switching or dimming should be decided at the design stage. Dimming facilities should be available in all areas where projection of transparencies, slides, etc, are likely, such as selected lecture halls, seminar halls and conference rooms. The dimmers may be the autotransformer type or electronic type.

5.2.4 Discharge lamps operating on a voltage higher than 1 000 volts (like neon signs) will need a fireman emergency switch located in an easily accessible place and it should be marked accordingly.

5.3 As far as possible the control gear should be placed near the lamp as part of the luminaire. Where the control gear is proposed to be located away from the lamp the distance between them should not be excessive. Lamp manufacturers may be consulted in individual cases. It must also be ensured that there is proper dissipation of heat from the control gear.

5.4 It is a common practice not to mix the lighting circuits with circuits for appliances (socket outlet circuits). This is because the lighting service is likely to be adversely affected if any defective appliance is connected in a lighting circuit.

5.4.1 The luminaires should be distributed in different circuits, each circuit controlled by a 6 A fuse miniature circuit breakers (MCB) not exceeding 800 W. The switches and MCBs should be rated for switching low power factor load. The circuits may be distributed in all the phases where 3 phase supply is used.

5.4.2 Lighting of corridors and common areas of public buildings should be connected in a separate circuit preferably fed from a standby supply.

5.4.3 It is a safety requirement that exit lighting, foot lights, fire escape route lighting and security lighting are all connected to essential circuits so that these could be supplied from a standby generator, where provided. These are wired in circuits independent of the general lighting circuits and other loads.

5.5 Where the lighting installation is very close to the substation (for example, substation lighting) the switches and distribution boards selected should have as high a fault rating as may be encountered in such situations.

5.6 A rotating object in a space illuminated by discharge lamps will appear to be revolving at a speed lower than the actual speed due to the 'Stroboscopic Effect'. In an extreme case, the object may appear stationary or even revolving in opposite direction. The electrical distribution should be done in 3 phase to avoid this problem. For example, where the lamps are installed in a row, the first one may be connected to R phase, the second to Y phase and the third to B phase and so on. This will be a simple and economical method. Alternatively, fluorescent lamps with electronic chokes, which feed supply to the lamps at a very high frequency, can be used.

5.7 Lighting in exhibition areas are designed for flexibility. The types of exhibits and the internal layout of exhibition stalls will be different for each event. The task lighting is provided examining the requirements on a case to case basis. The flexibility in the electrical distribution is effected by providing a light track or by providing a number of socket outlets on the walls with suitable spacing so that the luminaires can be connected as required. In large exhibition halls different floor areas are allotted to different exhibitors, who in turn provide accent lighting for the exhibits. Most of the wiring for lighting in stalls is temporary in nature, with the electric supply drawn from bus ducts. In the interest of safety from electrical leakages in such cases, it will be necessary to provide earth leakage protection at the circuit level. This will also avoid major disruption of the lighting service if there is a fault in any luminaire circuit.

5.8 In the case of outdoor lighting such as street lighting and compound lighting, it is desirable to provide earth leakage circuit breakers (ELCB) in the circuits so as to reduce shock risk. From the point of view of energy conservation, luminaires may be divided in two circuits so that one circuit can be switched off late at night without compromising the security. It is also essential to provide protection for every light outlet in the form of a fuse or MCB at each pole to improve the integrity of service. The distribution may be from properly designed feeder pillars which may accommodate the control gear also.

5.9 Protection against earth leakage or fault is necessary from the safety point of view in accordance with the provisions contained in IS 732. Basically this code calls for bonding to earth all 'exposed' and 'extraneous' conducting parts (like the metallic body of equipment conduits) in an equipotential zone and coordinating the characteristics of the disconnecting (protective) device so as to disconnect the faulty circuit within a time period that can prevent fatal electric shock. Earthing is an extremely important aspect of electrical installations in this regard. The metallic body of all luminaires are looped and connected to an earth terminal as per the earthing scheme to be prepared in accordance with IS 732 so that the 'touch potential' does not exceed 50 volts anywhere in the system. This applies equally to the outdoor installations as well. ELCB shall be provided at the level of distribution boards if the over current device is not likely to operate within a safe time by earth leakage (fault) current prescribed in the relevant Indian Standard.

5.10 Electromagnetic radiation may emanate at radio frequency (RF) from discharge lamp operations in the form of radiation in space around and/or through the electrical wiring. The latter is called conducted electromagnetic interference. This may be suppressed by suitable filters in the lighting circuits. These are particularly important in installations having equipment sensitive to RF. The effect of radiated EMI can be controlled by providing necessary shielding over the radiating body.

5.11 Harmonic currents are very common in discharge lamp circuits due to the non linear voltage current relationship in the discharge and consequent drawl of non-sinusoidal currents. The odd harmonics, especially the 3rd harmonic, cause heating of neutrals and distort the supply voltage wave form (dictated by the source impedance and circuit parameters) in the installation and this may not be desirable for certain other equipment connected to the same source of supply. Corrective actions to filter out harmonics may be called for near the main switch board, where the number of discharge lamps connected is large.

5.12 Since the content of harmonic current in the neutral conductor becomes a high proportion of the load current in discharge lamp circuits, a balanced three phase distribution is a common practice. The neutral conductor may have a reduced cross-sectional area appropriate to the expected value of the neutral conductor. In any circuit where the load is predominantly due to discharge lighting, the neutral conductor shall have a cross-sectional area not less than that of the phase conductor(s).

5.13 All discharge lamp circuits employ an inductive ballast (choke) or stabilizer. This results in drawing a certain lagging (reactive) component of current that is the total current drawn from the mains is more than the active component of current to deliver the required amount of power to the lamp. This low power factor situation results in unnecessary oversizing of the wiring. Though a power factor improvement capacitor is usually provided with individual luminaires for discharge lamps, still this may be required for the complete installation especially for large installations (such as industries and multistoried buildings).

6 ASPECTS PERTAINING TO INSTALLATION AT SITE

6.1 Intermediate joints in wiring should be avoided from the fire safety point of view. Where such joints are unavoidable, the joints shall not be permitted in any location which is inaccessible for inspection such as the space above false ceilings. The joint shall never be the twisted type, but the crimped type with proper crimping accessories and sleeving and/or insulation so that a fault does not develop from there.

6.2 The wiring should invariably be terminated in an outlet in the form of a ceiling rose, or connector or switch, all of which must have proper screwed terminations. The twisting of conductors at terminations shall not be permitted at all.

6.3 Wherever possible, the terminations should be with crimped lugs. Where the termination arrangement is other than with screws (such as pressure type connections), the type of accessory used with the wiring at the termination shall be suitable for this use. These precautions are necessary to avoid any local heating at terminations.

6.4 Earth conductor connections are as important as phase and neutral conductor connections. The integrity of the loop earth in conductor terminations at the metallic body of the luminaire box containing the accessories and the distribution equipment, should be very high by using proper screwed connections with metallic washers. The twisting of conductors should not be permitted either at terminations or in the runs. Where the integrity of mechanical connections of metallic conduits is likely to be affected (for example, flexible metallic conduits), independent earth continuity conductors must be run with such wiring, terminated on screws at both ends.

6.5 The arrangement of the connection of luminaires and any box containing their accessories should be such that removal of any of them for the purpose of maintenance, repair or replacement, shall not cause any disturbance to the loop earthing system or the electrical distribution to other luminaires, nor should there be any possibility of causing a fault.

6.6 Where luminaires are to be installed in a false ceiling, it would be preferable to run the electrical wiring, suitably fixed to the false ceiling framework depending on the type of false ceiling, in preference to laying conduits in the ceiling and taking the working to the luminaires by either rigid or flexible conduits, so that the wiring is easy for inspection and maintenance. If the wiring has to be necessarily taken from the ceiling level, it should as far as possible be extended to the luminaire in the false ceiling without a joint. Also, it should be taken in a conduit and not be left naked. If the same is terminated on the ceiling, it must be readily accessible for inspection and maintenance.

6.7 PVC cables should not be installed exposed to the sun as a permanent installation, since PVC turns brittle over a period of time on exposure to ultraviolet radiation from the sun unless specially protected.

6.8 The luminaires shall be connected on the neutral side only. The controlling switches of the luminaires shall be placed on the phase side of the circuit. If this is reversed there is a risk of full electric potential being available at the luminaire terminal even if the switch is in the off position and this will be quite unsafe.

6.9 Where Edison screw lamp holders are used, the center of these should be connected to the phase and the outer screw to the neutral as part of the precaution against shock protection while changing the lamp.

6.10 The location of controls of lighting in different areas should be arranged to suit the functionality and ease of operation, for example, the positions of the control switches are very important in wards and operation theatres. In operation theatres each luminaire should be independently controlled to enable individual requirements for special operations to be met. In ICUs and recovery rooms dimming of individual bed lights is also desirable.

6.11 Control switch positions and the type of control switches should match with the décor of the interior, especially in hotel guest rooms, lounges, conference rooms, etc.

6.12 In outdoor lighting installations the loop in box should preferably be located at a height of 1m above ground level from the point of view of easy maintenance. This is subject to approval by the Architect from aesthetic considerations. In any case, such boxes shall not be placed at a location near ground level since this not only causes maintenance problems, but is also unsafe both from the point of view of flooding during the monsoon and also the possibility of anyone (like children) coming in contact with a live box.

6.13 Lamp holders within a distance of 2.5 m from the bathtub, shower, cubicle shall be designed to prevent a shock hazard.

ANNEX 1

(*Clause* 3.1)

LIST OF APPLICABLE INDIAN STANDARDS

IS No.	*Title*
371:1999	Ceiling roses (Third Revision)
694:1990	PVC insulated cables for working voltages upto and including 1100 V (Third Revision)
1293:2005	Plugs and socket outlets of rated voltage upto and including 250 volts and rated current upto and including 16 A (Third Revision)
3854:1997	Switches for domestic and similar purposes (Second Revision)
IS/IEC 60898-1(2002)	Electrical Accessories - circuit breakers for over current protection for household and similar installations Part 1 Circuit breakers for ac operation (Superseding IS 8828)
9537(Part 2):1981	Conduits for electrical installations: Part 2 Rigid steel conduits(Superseding IS 1653)
9537(Part 3):1981	Conduits for electrical installations: Part 3 Rigid plain conduits of insulating material(Superseding IS 2509)
12640(Part 1):2000	Residual current operated circuit breakers for household and similar use: Part 1 Circuit-breakers without integral overcurrent protection(RCCBs) (First Revision)
12640(Part 2):2001	Residual current operated circuit-breakers for household and similar use: Part 2 Circuit-breakers with integral overcurrent protection(RCVOs) (First Revision)
14772:2000	Enclosures for accessories for household and similar fixed electrical Installations[Superseding IS 5133(Part 1 and 2)]
14927(Part1):2001	Cable trunking and ducting system for electrical installations: Part 1 General requirements
14927(Part2):2001	Cable trunking and ducting system for electrical installations: Part 2 Cable trunking and ducting systems intended for mounting on walls or ceilings

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NATIONAL LIGHTING CODE

PART 10 INSTALLATION ASPECTS FOR LIGHTING
Section 3 Coordination with Related Disciplines

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Lighting is an important service element in a building. Lighting is used not merely at nights enabling normal movement and activities and assisting in security, but is also extensively used even during the day time especially in non residential buildings, for various reasons such as conduct of normal activities (for example, offices), security (for example, offices, hotels), decoration (for example, hotel lounges), accents (for example, exhibition areas and shopping malls), special functional needs (for example, operation theatres, auditoria and indoor sports halls) and so on. A good lighting installation indeed provides life to a building.

The luminaire and control switches are the only visible items of the system and these should be integrated with the environment and should be installed for ease in maintenance. Electric supply should be given to the lamps safely and without any difficulty. Coordination of the Lighting Engineer is essential with the Architect, the Electrical Engineer and the Civil Engineer to achieve a satisfactory lighting installation. This section is devoted to the aspects relating to such interdisciplinary coordination.

NATIONAL LIGHTING CODE

PART 10 INSTALLATION ASPECTS FOR LIGHTING
Section 3 Coordination with Related Disciplines

1 SCOPE

This section of the code gives a broad outline of the coordination with various agencies and authorities in the execution of lighting installations.

2 TERMINOLOGY

The definitions given in Part 1 of this code shall apply.

3 DESIGN AND EXECUTION

3.1 While there can be no compromise on the functional requirements of lighting, the lighting system should necessarily merge with the surroundings, whether it is internal or external installation. This calls for detailed interaction by the Lighting Engineer with the Architects and Structural Engineers concerned.

3.2 The Lighting Engineer should study the architectural drawings and understand the basic parameters such as space dimensions, space utilities, provision of false ceiling and its type, provision of central air conditioning service, availability of wall space for control switches, etc. The Lighting Engineer should also interact to ascertain the type of structure, beam positions and sizes. The user should be consulted for special requirements if any and also in regard to the acceptability of the final design of the layout as well as selection of luminaires.

3.3 Lighting layouts in buildings should be so designed that the luminaires are symmetrically placed within the bays formed by the beams. In a structure without any false ceiling, where the beams will be visible, any asymmetry within the bays will spoil the aesthetics.

Where the ceiling is with waffles, the dimensions should be such that the desired luminaire can be installed conveniently within.

3.4 The layout of luminaires, air conditioning system, fire protection system, etc should be coordinated so that all the outlets are integrated for the best aesthetics without loss of functionality for any of the services. As far as possible, luminaires below the duct should be avoided, so that any condensation on duct work does not drip over the luminaires.

It will be also necessary to check the space available above the luminaires for recessed installation in the false ceiling, taking into account the layout of other services like ducts, pipes, etc. While doing so, dissipation of heat produced at the luminaires should be considered.

3.5 The method of installation of luminaires direct to the ceiling with or without round blocks, provision of chains or down rods and their sizes is to be decided in consultation with the Architect. Where a false ceiling is proposed, the decision on the method of installation may be taken only after consultation with the Civil Engineer on the ability of the false ceiling to carry the weight of the luminaires and the wiring.

Where the luminaire is heavy and needs suitable provision like hooks to suspend it or where a cluster of luminaires needs to be installed as in an outdoor installation, interaction with all disciplines is extremely important.

3.6 Close coordination with the Electrical Engineer is required in regard to the switching and distribution arrangements, control positions, dimming facilities, wiring needs, etc.

NATIONAL LIGHTING CODE

PART 11 DAYLIGHTING FOR BUILDINGS

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Daylight has been intimately connected with architecture from the days of early human civilization as man's visual activities could be performed only under daylight even inside buildings, before the invention of the early artificial light sources like the plain oil lamp or the candle. All artificial lighting, including electric lighting, was in fact meant for use during the night to enhance the period of human visual activities. Due to a sense of euphoria on the availability of electricity and due to the undesirable thermal gain and losses associated with windows used for daylight inside buildings, the use of artificial lighting became popular inside buildings even during daytime hours, particularly in air conditioned interiors. However, surveys conducted on occupants' responses showed preference for the dynamic and variable quantity and quality of daylight with windows providing a desirable view of and contact with the outside world.

The present energy scenario of limited fossil fuels and of degradation of the environment in the generation of energy from fossil fuels, has given daylight a new and very important dimension related to energy conservation and a clean environment. Daylight is a renewable source of light whose utilization for lighting of building interiors during the period it is available, could lead to energy conservation and promotion of a friendly environment.

Since daylight is external to a building and varies with the time of the day and seasons of the year, planning for daylighting inside a building has to be made right at the time of the planning of the building. The sun is the main source of daylight, whereas skylight is the effect of scattering of sunlight by the atmosphere. In a tropical country like India, direct sunlight causes excessive glare in the visual field and is thus unsuitable for daylighting of building interiors. Skylight on the other hand, can be a major source of interior lighting. However, as skylight varies with the time of day and seasons of the year, the orientation and the design of windows should be the factors taken into consideration.

The following Indian Standards are necessary adjuncts to this part.

IS No.	*Title*
2440:1975	Guide for daylighting of buildings (Second Revision)
3646(Part 1):1992	Code of practice for interior illumination: Part1 General requirements and recommendations for working interiors (First Revision)
6060:1971	Code of practice for daylighting of factory buildings
7942:1976	Code of practice for daylighting of educational buildings

NATIONAL LIGHTING CODE

PART 11 DAYLIGHTING FOR BUILDINGS

1 SCOPE

This part of the National Lighting Code (NLC) covers the general principles and methods of daylighting of dwellings, offices and hospitals. It recommends the minimum illumination values to be achieved by daylighting principles and gives general guidance for realizing the values in practice.

2 TERMINOLOGY

For the purpose of this part of the NLC, the following definitions shall apply in addition to those given under Part 1 of this code.

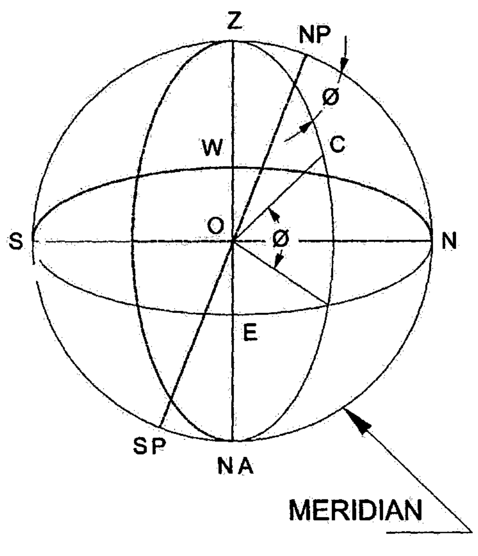
2.1 Altitude (θ) — The angular distance of any point of celestial sphere, measured from the horizon, on the great circle passing through the body and the zenith.

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

2.3 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 observed minimum sky luminance, the luminance at an altitude (θ) in the region away from the sun, is given by the expression:

$$L_\theta = L_Z \operatorname{cosec} \theta$$

where, θ lies between 15° to 90°, and L_θ is constant when θ lies between 0° and 15°.



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

Fig. 1 Azimuth of a Celestial Body

2.4 Daylight Factor — It is a measure of the 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 a clear design sky at an exterior point open to the whole sky vault, direct sunlight excluded.

2.5 Daylight Area — The superficial area on the working plane illuminated to not less than a specified daylight factor.

2.6 Daylight Penetration — The maximum distance upto which a given daylight factor contour penetrates into a room.

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

2.8 Internal Reflected Component (IRC) — The ratio (or percentage) of that part of the daylight illumination at a point on a given plane which is received by direct reflection or interreflection from the internal surfaces as referred to the simultaneous exterior illumination on a horizontal plane due to the entire hemisphere of an unobstructed clear design sky.

2.9 North and South Points — The points in the respective directions where the meridian cuts the horizon.

2.10 Reveal — The side of an opening for a window.

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

2.12 Direct Solar Illuminance — The illuminance at a point due to the sun with the light from the sky excluded.

2.13 Working Plane — The horizontal plane at a level at which work shall normally be done. For the purpose of this code the working plane, unless specified otherwise, shall be assumed as the horizontal plane 80 cm from the floor (normal table top level) in houses, flats, offices, and hospital wards and 90 cm (normal or bench level) from hospital operation theatres.

2.14 Roof Light — Opening of one horizontal or nearly horizontal top boundary surface of a building.

2.15 Shading Device — Device to reduce or obstruct the solar or sky radiation or prevent excessive heat gain and glare.

2.16 Skylight (Diffuse) — Illuminance at a point due to the sky on a horizontal plane from the whole hemisphere.

NOTE — Skylight is also commonly known as sky illuminance.

2.17 Window — Opening on a vertical or nearly vertical surface of a room for admission of daylight.

3 DAYLIGHTING

3.1 Sources of Daylighting

3.1.1 The primary source of light for daylighting is the sun. The light received by the earth from the sun consists of two parts; direct solar illumination and skylight. For the purpose of the daylighting design, direct solar illumination shall not be considered and only skylight shall be taken as a contributing factor to the illuminance of the building interiors during the day.

3.1.2 The amount of skylight depends on the position of the sun defined by its altitude, which in turn varies with the latitude of the location, the day of the year and the time of the day.

3.1.3 The external available horizontal skylight (diffuse) 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 climates, 8 000 lux for composite climate, 9 000 lux for warm humid climates, 9 500 lux for temperate climates and 10 500 lux for hot dry climates. For integration with the artificial lighting during daytime working hours, an increase of 500 lux in the recommended sky design illuminance for day lighting is suggested. The external available horizontal illumination which may be assumed for design purposes in the country, broadly covering India from north to south under clear sky condition, may be taken as 8 000 lux. Since the design is based on the solar position of 15° altitude, the corresponding illumination from the design sky has been found to be nearly constant all over the country. However, the prevalent atmospheric haze which varies from place to place may necessitate a 25 percent increase in the value of 8 000 lux design illumination suggested in this code, where haze conditions prevail at the design time.

3.1.4 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 (*see* **2.3**).

3.2 Components of Daylight Factor

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

a) The direct sky visible from the point;

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

c) Internal surfaces reflecting and interreflecting light to the point.

NOTES

1. External surface reflection may be computed approximately only for points at the centre of the room. 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.

3.2.2 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 class rooms, blackboards, pictures and paintings hung on walls.

3.3 Sky Component (SC)

3.3.1 The sky component for a window of any size is computed by the use of the appropriate table of Annex A.

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

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

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

c) At fixed locations, such as school desks, blackboards and office tables.

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

3.3.2 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.

3.4 Corrections for Window Bars

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

4 WINDOW DESIGN

4.1 Clauses **4.1.1** to **4.2.5.4** give a simplified method of arriving at the window dimensions to provide a given daylight factor on the working plane in rooms where the floor area is less than 60 sq m and the proportions of the rectangular rooms with side lengths in the ratio of 2:3.

4.1.1 The location of the window(s) on the shorter or longer wall has to be taken into consideration, as it influences the availability of daylight at the centre of the room or nearby area.

4.1.2 The relation between the daylight factor at the centre of a room (or the rear of it, that is near the rear wall) and window are expressed as a percentage of the floor area that will provide the daylight factor is shown in Fig. 2 and Fig. 3 for four possible situations: (a) the aperture is just an opening in the wall, (b) the opening is glazed with 3 mm thick glass, (c) the glazed opening is a wooden window, and (d) the glazed opening is a metal window (it is to be noted that a wooden window frame cuts off more daylight as compared to a metallic window frame). The abscissa is marked accordingly.

4.1.3 The effect of unobstructed windows on the long or short wall on the daylight availability at the centre of a room or its rear can be ascertained from Fig. 2 and Fig. 3. The following assumptions were made:

a) The interior of the room possesses the following reflection factors:
   i) walls: 45-50 percent;
   ii) ceiling: 70-75 percent; and
   iii) floor: 24-30 percent.
b) Ceiling height is taken to be 2.75 m;
c) Windows are provided with louvres to cut the incursion of sunlight;
d) The combined thickness of wall and width of louvre is taken to be 60 cm;.
e) The ground reflection factor is taken as 0.25; and
f) No external obstruction.

4.1.4 The fenestration percentage of the floor area arrived at by using Fig. 2, Fig. 3 and Table 1 is expected to provide the required amount of daylight at the point in question. However, the presence of dirt on the glass reduces the quantity of light entering the room and the glazing has to be cleaned periodically. The area of the window arrived at may be split into two or three and located on the window wall will provide uniformly distribution of daylighting on the working planes. The sill height should be between 80 and 105 cm to get the maximum advantage of vertical and horizontal plane illumination. The need to provide suitable louvres or overhangs to avoid direct sunshine should be considered.

4.2 Lux-Grid Method

The lux-grid method may be used within 10 percent accuracy to:

a) assess the illumination level on the working plane

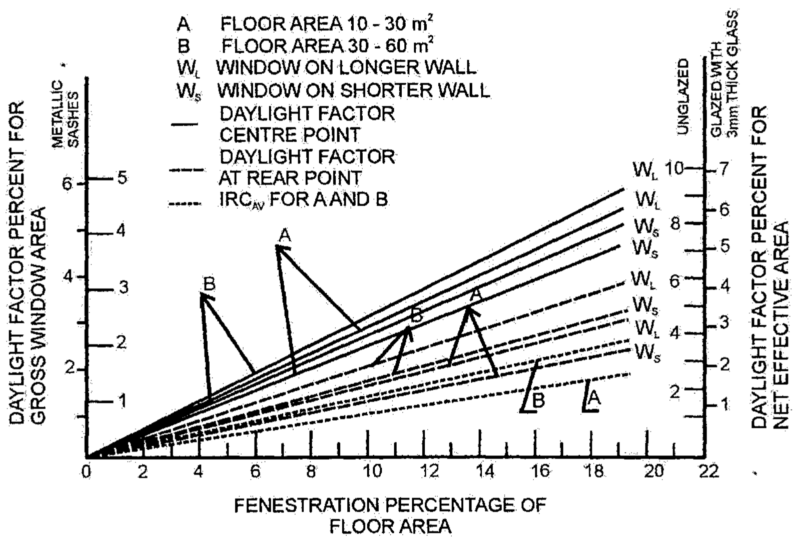


Fig. 2 Daylight Factor on the Working Plane for a Corner located Window

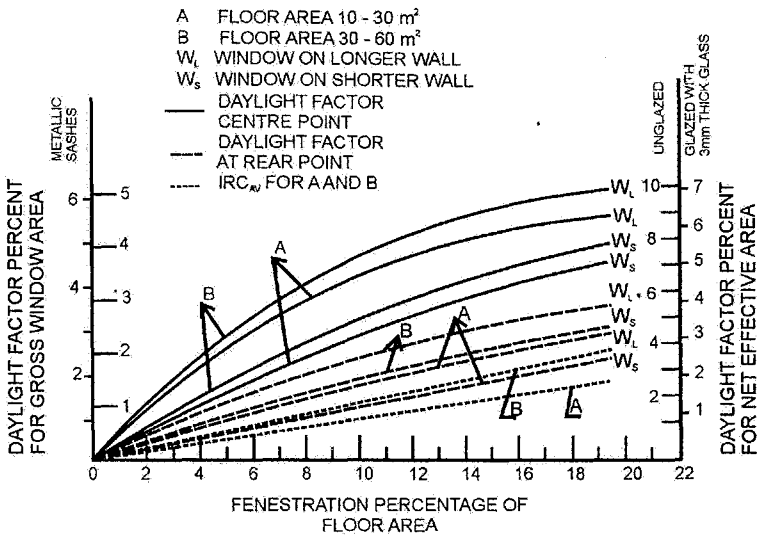


Fig. 3 Daylight Factor on the Working Plane for a Centrally Located Window

or other horizontal surfaces as provided by a given arrangement of windows; and

b) calculate window sizes to give desired illumination levels on the working planes.

4.2.1 The grid (Fig. 4 and Fig. 5) represents the window wall of a room above the working plane. The window wall is divided into small squares and each square contains a few dots and a few crosses. The system is symmetrical about the vertical line PY passing through the point P. The horizontal PW through P corresponds to the plane of reference, usually the working plane. By drawing the elevation of the window on the grid and counting the number of dots and crosses within the window outline, the illumination can be found. If the desired illumination is known, the size of the windows can also be determined.

Table 1 Recommended Illuminance Levels on Work Areas for Educational Buildings

(*Clause* 4.1.4)

Sl. No.	Work Area/ Visual Task	Illuminance (lux)	Corresponding Daylight Factor(%)
(1)	(2)	(3)	(4)
i	Class-room desk, writing boards	150-300	1.9-3.8
ii	Laboratories	200-300	2.5-3.8
iii	Library (reading tables)	150-300	1.9-3.8
iv	Drawing, typing, sewing	300	3.8
	Toilets	150	1.9

NOTE — The levels suggested in this table do not take into account the decrease in illumination due to occupancy (and the variations in the reflectance of school uniforms) and should be used as a guide only. However, in the first instance this reduction can be treated as negligible. The grid is based on measurements of sky luminance and daylight availability all over India.

4.2.2 *Size of Grid*

The squares on the grid have a scale dimension relative to the distance of a particular point on the working plane (where illumination is to be found) from the window wall, measured normally from the plane of the glazing. Unit distance on the grid is one-tenth the distance between the point on the working plane and window plane. For example, if the point on the working plane is located 375 cm from the window wall, each side of the small grid is 37.5 cm.

4.2.3 *Sill-Height of Window*

Since illumination on a horizontal working plane comes mostly from that part of the window which is above its level, the sill of the window should be arranged either at or above the working plane height. Where due to special reasons, the sill is below the level of the working plane, only the dots and crosses above the working plane level will contribute to the daylight significantly.

4.2.4 *Lux-Grid I for Use with Negligible External Obstructions*

Fig. 4 shows the lux-grid to be used for determining the illumination when obstructions outside the windows are at a distance more than three times the height of obstructions from the window.

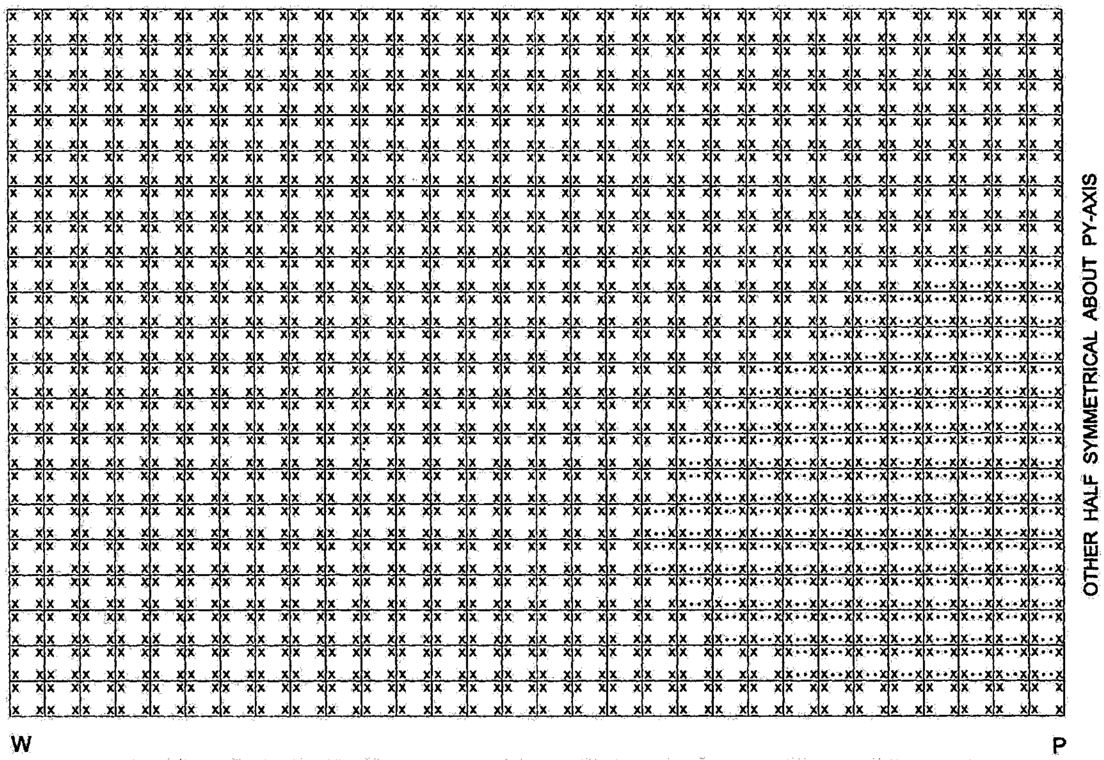


Fig. 4 Lux-Grid I for Daylighting of a Side-lit Windows in absence of External Obstruction

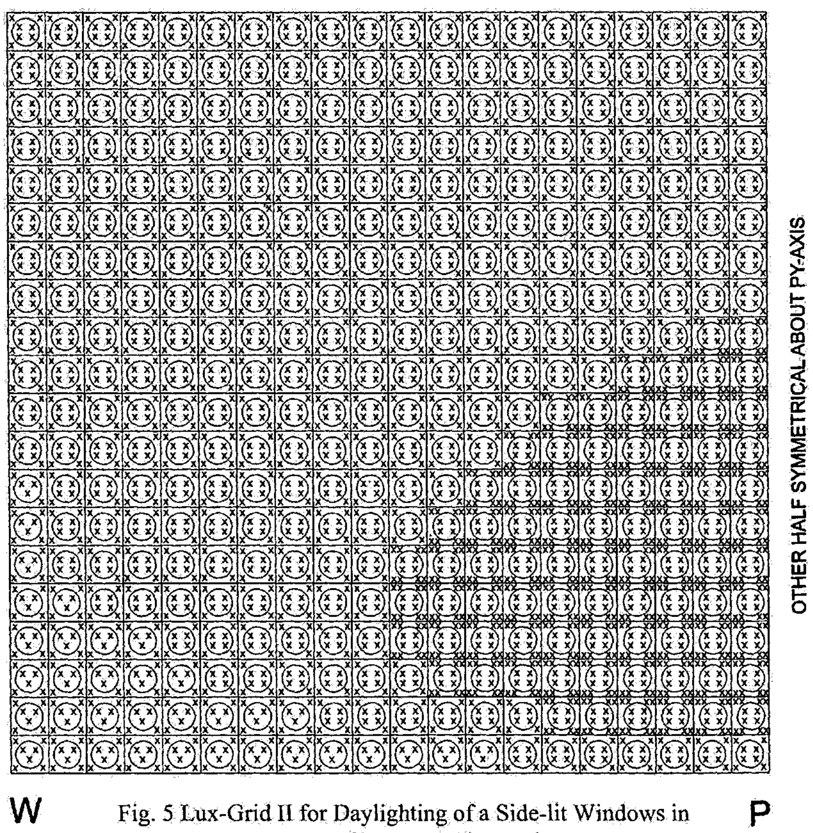


Fig. 5 Lux-Grid II for Daylighting of a Side-lit Windows in presence of External Obstruction

4.2.4.1 *Dots and crosses*

In Fig. 4 one dot has a value of 0.5 lux and one cross has a value of 2.0 lux.

4.2.4.2 The correction factor for interior finish illumination level calculated using lux-grid I, shall be corrected for interior finishes of the room with different reflectances using figures in Table 2A and Table 2B.

4.2.4.3 *Limitations of the method*

a) It is assumed that the ground outside the window has a reflection factor of 0.25 that is, grass with some brick or concrete paving;

b) The ceiling is 2.75 m above the floor level; and

c) It is assumed that the window has a 60 cm box type louvre around it or a 60 cm horizontal louvre. It is supposed to be glazed.

When a verandah or overhang obstructs the window, the portion of the window obscured from the point of observation as seen projected on the window plane should be treated as not contributing to the daylighting of the point in question.

4.2.4.4 *Illustrative example*

A worked example has been given in Annex A to explain the use of the method.

NOTE — The example given in Annex A deals with the determination of the total illumination due to two windows with external obstructions, where in both, Lux-grid I and II have been involved.

For irregular obstructions like a row of trees parallel to the plane of the window, equivalent straight boundaries, horizontal and vertical may be drawn, and the methods indicated in Annex A.

For bay windows, dormer windows or corner windows, the effective dimensions of window openings computed should be taken when using the figures to find the total illuminance.

4.2.5 *Lux-Grid II for Use in Presence of External Obstructions*

Fig. 5 shows the lux-grid to be used for determining the illumination when obstruction (having reflection factor lying between 0.4 and 0.6) outside the windows are at a distance three times or less their own height from the window.

Table 2A Correction Factor Per Square ($\alpha \times \alpha$) Lux

(*Clauses* 4.2.4.2 *and* 4.2.5.2)

Distance of point from the window D(cm)	Size of one square in the grid A (cm)	Floor area within (10-25 mm^2)			Floor area within (25-50 mm^2)			Floor area within (50-100 mm^2)		
		A[1]	B[2]	C[3]	A[1]	B[2]	C[3]	A[1]	B[2]	C[3]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
900	90	+26.6	+18.0	+9.5	+9.5	+5.2	+1.0	+1.0	-1.2	-3.3
840	84	+22.2	+14.7	+7.3	+7.3	+3.6	0	0	-2.0	-3.9
780	78	+18.0	+11.7	+5.2	+5.2	+2.0	-1.2	-1.2	-2.8	-4.4
720	72	+14.3	+8.8	+3.3	+3.3	0	-2.1	-2.1	-3.5	-4.9
660	66	+10.8	+6.2	+1.6	+1.6	-0.7	-3.0	3.0	-4.2	-5.3
600	60	+7.6	+3.8	0	0	-1.9	-3.8	-3.8	-4.8	-5.7
540	54	+4.7	+1.6	-1.4	-1.4	-3.0	-4.5	-4.5	-5.3	-6.1
480	48	+2.1	0	-2.7	-2.7	-4.0	-5.2	-5.2	-5.8	-6.4
420	42	0	-2.0	-3.9	-3.9	-4.8	-5.7	-5.7	-6.2	-6.7
360	36	-2.1	-3.5	-4.9	-4.9	-5.5	-6.2	-6.2	-6.6	-6.9
300	30	-3,8	-4.8	-5.7	-5.7	-6.2	-6.7	-6.7	-6.9	-7.1
240	24	-5.2	-5.8	-6.4	-6.4	-6.7	-7.0	-7.0	-7.1	-7.3
180	18	-6.2	-6.6	-6.9	-6.9	-7.1	-7.3	-7.3	-7.3	-7.4
120	12	-7.0	-7.1	-7.3	-7.3	-7.4	-7.4	-7.4	-7.5	-7.5

NOTES

1. Finish A - ceiling walls (reflection factor 0.7 to 0.8), walls off-white (reflection factor 0.45 to 0.55) and floor gray (reflection factor 0.3)
2. Finish B - ceiling off -white, walls off-white and floor grey.
3. Finish C - ceiling off-white, walls dark (reflectance factor 0.25 to 0.3) and floor grey.

Table 2B Correction Factor per Square (α x α) Lux

(*Clauses* 4.2.4.2 *and* 4.2.5.2)

Distance of point from the window D(cm)	Size of one square in the grid A (cm)	Floor area within (10-25 mm²)			Floor area within (25-50 mm²)			Floor area within (50-100 mm²)		
		A[1]	B[2]	C[3]	A[1]	B[2]	C[3]	A[1]	B[2]	C[3]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
900	90	+10.6	+ 7.2	+ 3.8	+ 3.8	+ 2.1	+ 0.4	+ 0.4	- 0.5	- 1.3
840	84	+8.9	+ 5.9	+ 2.9	+ 2.9	+ 1.4	0	0	- 0.8	- 1.6
780	78	+7.2	+4.7	+ 2.1	+ 2.1	+ 0.8	- 0.5	- 0.5	- 1.1	- 1.8
720	72	+5.7	+ 3.5	+ 1.3	+ 1.3	0	- 0.9	- 0.9	- 1.4	- 1.9
660	66	+ 4.3	+ 2.5	+ 0.6	+ 0.6	- 0.3	- 1.2	- 1.2	- 1.7	- 2.1
600	60	+3.0	+ 1.5	0	0	- 0.8	- 1.5	- 1.5	- 1.9	- 2.3
540	54	+1.9	+ 0.7	- 0.6	- 0.6	- 1.2	- 1.8	- 1.8	- 2.1	- 2.4
480	48	+0.9	0	- 1.1	- 1.1	- 1.6	- 2.1	- 2.1	- 2.3	- 2.6
420	42	0	- 0.8	- 1.6	- 1.6	- 1.9	- 2.3	- 2.3	- 2.5	- 2.7
360	36	-0.9	- 1.4	- 1.9	- 1.9	- 2.2	- 2.5	- 2.5	- 2.6	- 2.8
300	30	-1.5	- 1.9	-2.3	-2.3	- 2.5	- 2.7	- 2.7	- 2.8	- 2.9
240	24	-2.1	- 2.3	-2.5	-2.5	- 2.7	- 2.8	- 2.8	- 2.9	- 2.9
180	18	-2.5	- 2.6	- 2.8	- 2.8	- 2.8	- 2.9	- 2.9	- 2.9	- 3.0
120	12	-2.8	- 2.9	- 2.9	- 2.9	- 2.9	- 3.0	- 3.0	- 3.0	- 3.0

NOTES

1. Finish A - ceiling walls (reflection factor 0.7 to 0.8), walls off -white (reflection factor 0.45 to 0.55) and floor gray (reflection factor 0.3)
2. Finish B - ceiling off -white, walls off-white and floor grey.
3. Finish C- ceiling off-white, walls dark (reflection factor 0.25 to 0.3) and floor grey.

4.2.5.1 *Circle, dots and crosses*

In Fig. 5 (lux-grid II) in addition to dots and crosses inside each grid, a circle enclosing a few dots and crosses is present. The dots and crosses within the circle correspond to the daylight contributed by obstruction, while those outside the circle represent the contribution due to the unobstructed window including all external reflections. One dot has a value of 0.5 lux, one cross outside the circle has a value of 2.0 lux and one cross inside the circle has a value of 1.0 lux.

4.2.5.2 *Correction factor for interior finish*

Illumination levels calculated using lux-grid II, shall be corrected for interior finishes of the room (and of different reflectance) using figures in Table 2A and Table 2B.

4.2.5.3 To estimate the available daylight at a point, the outline of the window and the obstruction are projected on the lux-grid using proper scales corresponding to the distances of window and obstruction from the point in question.

4.2.5.4 Depending on the height H and distance D of the obstruction from the point and window wall respectively, four cases arise:

a) D > 3H: This case can be dealt as unobstructed as far as daylighting is concerned and lux-grid I shall be used;

b) 1.5H < D < 3H:

First Step: The contribution due to unobstructed portion of the window using lux-grid I and lux-grid II shall be found out and the mean value taken.

Second Step: The contribution due to the obstructed portion by counting the dots and crosses enclosed circle (in the obstructed part) should be found out using lux-grid II and the value so obtained be multiplied by a factor 1.8.

Third Step: The values obtained in the above two steps should be added;

c) 0.5H < D < 1.5H:

The contribution of the unobstructed and obstructed portions of the window should be found out using lux-grid II separately and the values be added; and

d) D < 0.5 H:

First Step: The daylight due to the unobstructed part should be found out using lux-grid II.

Second Step: The daylight due to the obstructed part should be found out using lux-grid II and the value so obtained be reduced by 50 percent.

Third Step: The values obtained in the above two steps should be added.

5 DAYLIGHTING REQUIREMENTS

5.1 Design External Illumination

The daylight factor to be maintained in any internal environment shall be specified in relation to the external illumination.

5.2 Illumination Levels Necessary for Different Visual Tasks

Illumination levels necessary for different visual tasks shall be [*see* IS 3646(Part 1)]. If the required amount of illumination is not achieved by daylighting only, it may have to be supplemented by artificial lighting.

5.3 Recommended Daylight Factor to be Maintained in Different Interiors

5.3.1 If design for daylighting based only on sky component values are recommended, as sky components are easily determinable, this will tend to make the day lighting more easy. However, where more precise values are desired, account may be taken of ERC and IRC values.

5.3.2 Based on an assumed external design illumination level of 8 000 lux and the acceptable levels of minimum illumination necessary for different visual tasks the daylight factors recommended for different locations are given in Table 3.

Table 3 Recommended Daylight Factors for Interiors
(*Clause* 5.3.2)

Location	Daylight Factor (%)
Dwellings	
Kitchen	2.5
Living room	0.625
Study	1.9
Circulation	0.313
Schools	
Class room	1.9
Lecture room	2.0 to 2.5
Study hall	2.0 to 2.5
Laboratory	1.9 to 3.8
Offices	
General	1.9
Enquiry	0.625 to 1.9
Hospitals	
General ward	1.25
Pathological laboratory	2.5 to 3.75
Libraries	
Stock room	0.9 to 1.9
Reading room	1.9 to 3.75
Counter area	2.5 to 3.75
Catalogue room	1.9 to 2.5

NOTE — 100 lux is equal to a sky component of value 1.25 percent based on 8 000 lux.

5.3.2.1 Daylight factor values for other external intensities may be obtained by evaluation.

Example:

For external design illumination levels of 10 000 lux the illumination of 100 lux will be 100 × 100/10 000 = 1 percent daylight factor.

5.3.3 The recommended daylight levels should be ensured generally on the working plane at the following positions:

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

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

c) At fixed locations, such as school desks, blackboards, and office tables.

5.3.3.1 In selecting any one position for design purposes, due consideration should be given to the needs of the situation.

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

5.3.5 Supplementary artificial illumination may have to be provided:

a) against the possibility of the level of illumination falling below the specified values at such times when the outside illumination falls below the design value; and

b) where the fineness of the visual task may demand a higher level of illumination at special locations, occasionally.

5.3.6 The figures in general give a number of window sizes contributing to the recommended illumination. Economic and architectural considerations should decide the final choice.

5.3.7 The daylight factor values corresponding to the particular location shall be increased by appropriate factors if the window is to be glazed and/or is externally obstructed and/or is to be provided with window bars.

6 GENERAL PRINCIPLES OF WINDOW DESIGN TO AFFORD GOOD DAYLIGHTING

6.1 Generally, while taller windows give greater penetration, broader windows give better distribution of light. It is preferable that some area of the sky at an altitude of 20 degrees should light up the working plane.

6.2 However, broader windows may also be equally or more efficient provided their sills are raised by 30 cm to 60 cm above the working plane. Such raised sills will not cut the outside view appreciably and in most situations afford, valuable wall space within easy reach, especially in schools and hospitals where it may be utilized to carry electric wiring, gas and water connections.

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

6.4 Unilateral lighting from side windows will in general be unsatisfactory if the effective depth of the room is more than two to two and a half times the distance from the floor to the top of the window.

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

6.6 Cross lighting with windows on adjacent walls tends to increase the diffused lighting within a room.

6.7 Windows shall be provided with suitable louvres, baffles or other shading devices, to exclude, as far as possible, direct sunlight entering the room.These devices reduce the effective height of the windows for which due allowance shall be made. Broad and low windows are, in general much easier to shade against sunlight entry. Direct sunlight when it enters increases the inside illumination considerably. Glare will result if it falls on walls at low angles, more so when it falls on floors, especially when the floors are dark coloured or less reflective, which increases the difference in brightness between floor, window opening and immediate surroundings.

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

6.9 The design should be such that in addition to direct illumination, provision should be made for diffuse lighting by internal reflections and interreflections. The design should also ensure that the luminance ratio of the task to its immediate surrounding and distant areas in the room should be 10:3:1 and not exceeded.

6.10 To ensure a good level of diffused lighting, all internal surfaces should be light coloured and have good reflectance.

6.11 The illumination level in a given room for 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 colour 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 decorations in the room. Whatever may be the colour the occupants want to use, it is most desirable to maintain proper values of reflectance factors for the ceiling, wall and floors so that the level of daylight illumination is maintained.

7 GENERAL NOTES ON DAYLIGHTING OF BUILDINGS

7.1 Aim of Daylighting

The main aim of daylighting design for buildings is to provide a visual field inside buildings for the efficient performance of different visual tasks by the occupants of the buildings, without resulting in uncomfortable glare or thermal discomfort for the occupants.

Because of the highly variable nature of daylight from hour to hour and from season to season, no simple formula for daylighting can be given which is valid for the entire day and for the entire year.

7.2 Sunlight

Direct sunlight admitted into a building could lead to glare and thermal discomfort particularly in summer. However in latitudes above 23°N in India, admitting sunlight in winter may mean thermal comfort and daylighting design may have to take into account the shading devices for admitting sunlight and avoiding glare depending on the local climate and the nature of the activity in the interior space.

7.3 Visual Task and Time Factor

When designing for an interior where specific visual tasks have to be performed, the time and duration of the task have to be taken into account while designing for daylight and a suitable provision made for supplementing with electric lighting as may be required.

7.4 Window

For daylighting of building interiors two types of windows may be used, those situated in a side wall and those placed in the roof. In the case of a side wall window, larger height and smaller width would result in more light in the distant interior of the room than in the case of larger width and smaller height. However, the view and the contrast with the outside would be better in the case of larger width and similar height of the window. A balance has to be reached depending on the nature of the visual tasks in the distant interior of the room and the expectations of the occupants.

Though roof lights are more efficient in admitting daylight into buildings, they are useful only in single storey buildings or in the top floor of multistorey buildings. Water condensation, dripping and rain water penetration may be a source of trouble with roof lights.

7.5 Shading Devices

Some shading devices like projections from the walls above windows are part to architectural design. They have to be planned in relation to the climate, the sun path diagram at the place and the possible orientation of the windows.

Manually operated shading devices are those which can be rolled up and down as desired. Venetian blinds are also manually operated and can be rolled up and down as well as openings controlled.

Automatic shades which work on motors can be controlled through sensors and automatically operated depending upon the entry of direct sunlight.

7.6 Daylight Luminous Efficacy

Luminous efficacy is lumens per watt of input power. In the case of daylight, it is lumens per watt of radiant power. This differs for the different components of daylight. The average of sunlight is about 95 lm/W, and, for diffuse skylight it is about 120 lm/W. The thermal balance of any interior depends upon this parameter in so far as this is an indication of the level of irradiance associated with a given level of illuminance. While outdoor luminous efficacy values are different for different components of daylight like, sunlight, diffuse skylight and global illuminance, the luminous efficacy values of interior daylight, in cases where the externally reflected component from buildings and trees is strong, would be lower than the outdoor values. Proper evaluation of this aspect has to be made before determining the irradiance levels associated with different illuminance levels inside buildings.

7.7 Directional Property of Daylight

Daylight which enters a building from a side wall window, is incident on a horizontal working plane at an angle other than the vertical, though the light internally reflected from the walls and ceiling comes from all directions. This condition could produce glare for tasks viewed at low angles in the direction of window. This has to be taken into account when fixing work positions and task desks in relation to the window position.

7.8 Window Glazing

Common window glazing materials suitable for admission of daylight are glass, plastics, and fiberglass. Plastic materials degrade under UV radiation which accompanies daylight and change their transmission characteristics, while glass is not subject to such degradation. Tinted glass and glass with sun film are used for their antiglare and heat filtering properties. Glass with different transmission properties is also used taking into account the climatic factors and orientation of the window.

7.9 Noise

Windows can be the cause of excessive noise inside buildings. Noise control is an important requirement which should go with window design for the daylighting of buildings. Factors like site selection, orientation of windows with respect to noise sources like continuous and heavy traffic, wind direction etc., need to be taken into account.

Another problem of windows is that the window panes go into resonance at low audio frequencies. A solution for this problem is possible if one can foresee the direction of low frequency noise and avoid windows in that direction.

8 AVAILABILITY OF DAYLIGHT IN MULTISTOREYED BUILDINGS

8.1 Proper planning and layout of buildings 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. The relative availability of daylight in multistoreyed blocks of different relative orientations is given in Table 4.

8.2 Where a number of similar building blocks are to be raised fairly close to each other, it would be more advantageous to have alternative blocks perpendicular to each other than to have all in a parallel formation. Building heights and spacing are interdependent and can in general be adjusted to provide optimum daylighting advantage, for any density of building development, that is, for any ratio of floor area to the overall site area.

Table 4 Relative Availability of Daylight on the Window Plane at Ground Level in Four-Storeyed Building Blocks (Clear Design-Sky as Basis, Daylight Availability Taken as Unity on an Unobstructed Facade, Values are for the Centre of the Blocks)

(*Clause* 8.1)

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)
0.5	0.15	0.15	0.25
1.0	0.30	0.32	0.38
1.5	0.40	0.50	0.55
2.0	0.50	0.60	0.68

ANNEX A

(*Clauses* 3.3.1, 3.4, 4.2 *and* 4.2.4.4)

ILLUSTRATIVE EXAMPLE OF DESIGN OF WINDOWS WITH EXTERNAL OBSTRUCTION

A.1 EXAMPLE

A.1.1 Consider (Fig. 6) a point P_1 at 6 m away the window wall. Assume that the room in which the point is located has finish B, and floor area is approximately 43 m^2. The room has two windows each of size 2.4 x 1.5 m^2 at a height of 30 cm above the working plane symmetrically located with respect to point P_1. The windows face an infinitely long parallel distance (reflectance 0.5) located at a distance of 18 m (D) from the windows and of height (H) 6.0 m above the working plane.

This corresponds to case (b) of **4.2.5.4** where $1.5H < D < 3H$

First Step:

The projection of the obstruction on the lux-grid I and II are shown in Fig. 7A and 7B. The contribution due to the unobstructed portion of the windows using lux-grid I (Fig. 7A) and lux-grid II (Fig. 7B) are determined as follows:

i) Use grid I (*see* Fig. 7A).

The number of grid squares for the unobstructed part of the window = 4.

Correction factor for interior finish B (Table 2) = –1.9 lux.

Total correction for 4 squares = 4x (–1.9) = –7.6 lux.

Illumination at P_1 from Fig.7A:

Crosses 16	= 32.0 lux
Dots 32	= 16.0 lux
Total	= 48.0 lux
Correction	= 7.6 lux
Net illumination	= 40.4 lux

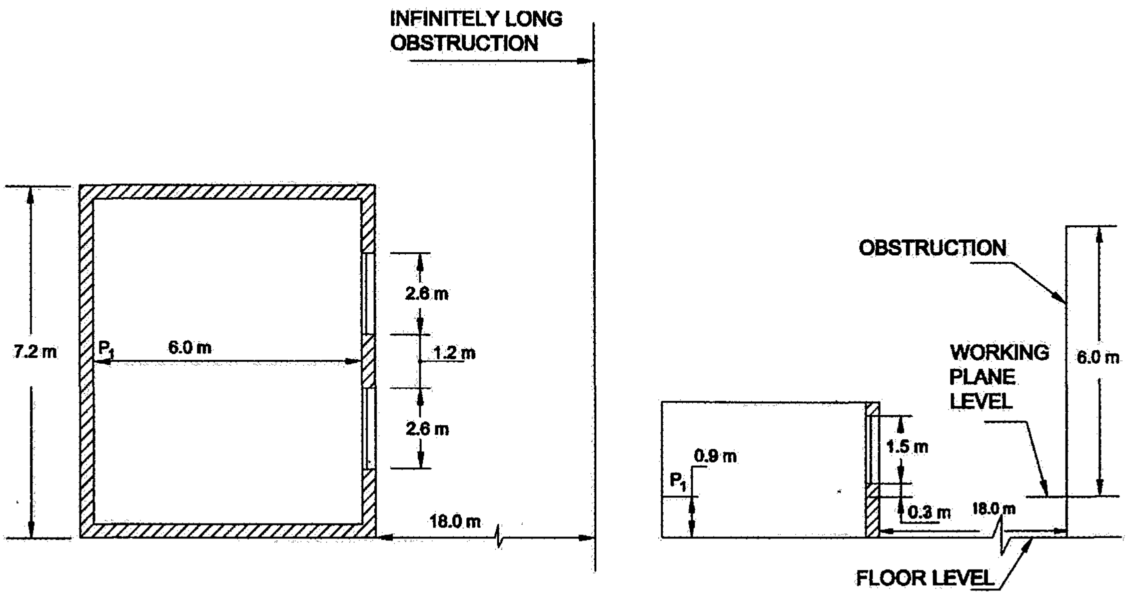
ii) Use grid II (*see* Fig. 7B).

The number of grid squares for the unobstructed part of the windows is again 4 but these include now 28 crosses and 4 dots giving a total illumination at P1 = 28x1.0 + 4x0.5 = 30.0 lux.

Correction factor per square, using Table 3 = –0.8 lux.

Hence total correction 4 x (0.8) = –3.2 lux.

Net illumination as given by lux-grid II = 30.0–3.2 = 26.8 lux.



6 A Plan

6 B Section

Fig. 6 Typical Examples for Windows with External Obstruction

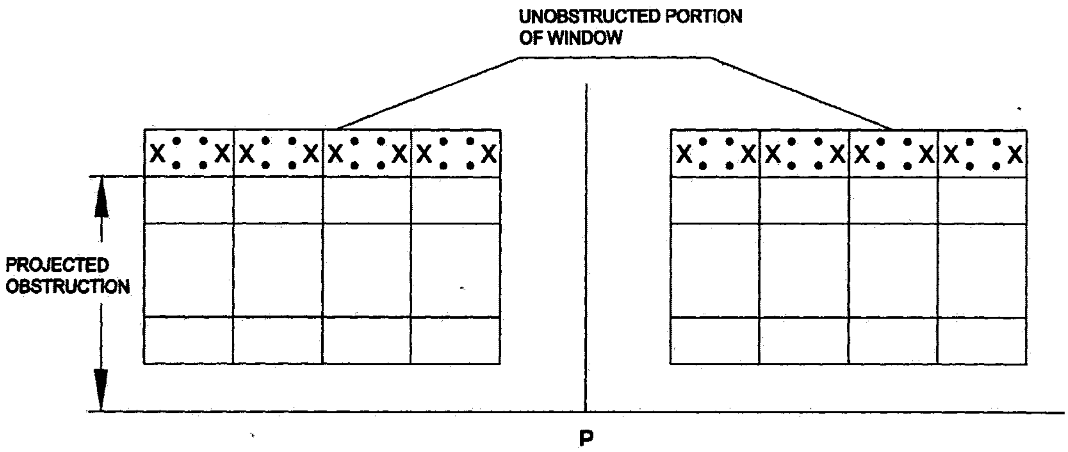


Fig. 7A Typical Projection of Obstruction on the Lux-Grid I

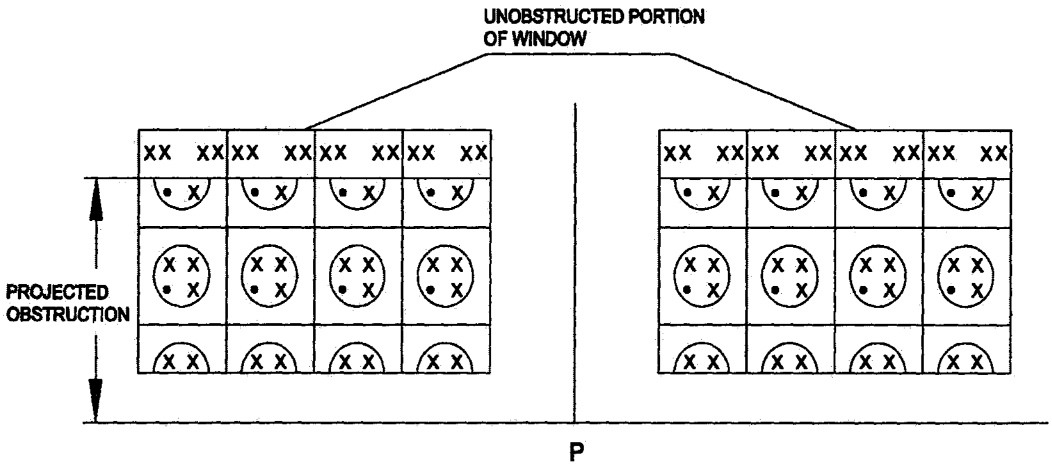


Fig. 7B Typical Projection of Obstruction on the Lux-Grid II

The mean values obtained from grid I and II 1/2(40.4+26.8) = 33.6 lux, which is the net illumination from the unobstructed part of the windows.

Second Step:

The number of squares enclosed by the obstructed part of the windows (Fig. 7B) = 16

Correction factor from Table 3 = – 0.8 lux

Net correction = 16 · (– 0.8) = –12.8 lux

Total illumination at P_1 from Fig. 7B

Crosses 48	= 48.0 lux
Dots 16	= 8.0 lux
Total	= 56.0 lux
Correction	= – 12.8 lux
Net illumination	= 56.0 – 12.8 = 43.2 lux

which is the net illumination due to obstructed portion of the windows.

SP 72 : 2010

NATIONAL LIGHTING CODE

PART 12 EMERGENCY LIGHTING

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

Emergency lighting denotes the quantity of lighting to ensure adequate visibility in a time of emergency. Basically it is different from the lighting which is provided in any building when the normal power supply is not available and the minimum functions are performed with the help of power made available from a standby diesel generator or standby power system provided for the building. *Inter-alia* it means that in the case of power failure (both the normal power supply and the standby power supply) the illumination required to light up the escape routes will fall under the scope of emergency lighting. Evidently, such an emergency lighting shall be available for a minimum continuous period to tide over the panic situation and enable the evacuation of the building to take place. So the emergency escape lighting in all places of work and premises open to the public falls under the scope of emergency lighting.

In order to understand the details about the categories of emergency lighting, escape lighting and escape route illumination, it is necessary to first define various terms which relate to emergency lighting.

The following Indian Standard is a necessary adjunct to this part of the code.

IS No.	*Title*
9457:2005	Safety colours and safety signs-Code of practice (First Revision)

NATIONAL LIGHTING CODE

PART 12 EMERGENCY LIGHTING

1 SCOPE

The aim of this part of the code is to lay down the basic principles of emergency lighting as applicable to building interiors and, thereby, to furnish guidance on the various aspects that should be considered when seeking to design an effective and reliable installation.

This part deals solely with the principles of lighting; no attempt has been made to review suitable lighting hardware.

2 TERMINOLOGY

For the purpose of this part of the code, the following definitions in addition to those given in Part 1 of this code shall apply.

2.1 Exit — A way out of the building that is intended to be used at any time whilst the building is occupied.

2.2 Emergency Exit — A way out of the building that is intended to be used only during an emergency.

2.3 Escape Route — A route from a point inside the building to an exit or emergency exit.

2.4 Normal Lighting — All permanently installed artificial lighting normally used when the building is occupied.

2.5 Emergency Lighting — Lighting provided for use when the supply to the normal lighting fails.

2.5.1 *Escape Lighting* — That part of emergency lighting that is provided to ensure that an escape route can be effectively identified and used.

2.5.2 *Safety Lighting* — That part of emergency lighting that is provided to ensure the safety of people involved in a potentially hazardous process.

2.5.3 *Standby Lighting* — That part of emergency lighting that is sometimes provided to enable normal activities to continue.

2.5.4 *Maintained Emergency Lighting* — Emergency lighting that is on at the same times as the normal lighting and that remains on when the supply to the normal lighting fails.

2.5.5 *Non-Maintained Emergency Lighting* — Emergency lighting that comes on when the supply to the normal lighting fails.

3 CATEGORIES OF EMERGENCY LIGHTING

3.1 There are various reasons why special lighting facilities (defined here as emergency lighting) may have to be installed in certain buildings in the event of a failure of the supply to the normal lighting. Three categories of emergency lighting can be identified, according to the purpose for which each is designed.

3.1.1 *Escape Lighting*

Escape lighting is necessary in most types of buildings in order to enable the occupants to leave the interior safely in the event of an emergency.

3.1.2 *Safety Lighting*

Safety lighting is necessary in those situations where the failure of the normal lighting could place people in danger. The danger may relate to the operator, as in the use of a circular saw or the handling of hot metal, or to others, as in an operating theatre.

Note that in order to prevent panic and enable help to be summoned, safety lighting should always be provided in lifts (elevators).

Generally speaking, an escape lighting installation is necessary in addition to the safety lighting.

3.1.3 *Standby Lighting*

Standby lighting is provided in buildings where it is decided that, for reasons other than safety, work or activities should be continued in the event of failure of the normal lighting. (Examples are shops and certain industrial activities).

Note that escape and safety lighting are enforced by law in some countries. Standby lighting, on the other hand, is not generally covered by official regulations.

4 ESCAPE LIGHTING

When the normal lighting of an occupied building fails, the escape lighting is required to fulfill the following functions:

a) to indicate clearly and unambiguously the escape routes;

b) to provide sufficient illumination along the escape routes to enable any obstructions to be seen and so facilitate safe movement towards and through the exits and emergency exits provided; and

c) to ensure that all fire alarm call points and firefighting equipment provided along the escape routes can be readily located.

4.1 Escape Route Indication

In times of emergency, the escape route or routes should be clearly indicated. In some buildings the escape routes may lead either towards normal exits or to emergency exits which are indicated by means of appropriate signs. Normal exit signs should be illuminated at all times that the building is in use and should remain so when the normal supply fails. Emergency exit signs are required to be illuminated in times of emergency.

Where direct sight of an exit is possible, a directional sign or series of signs should be provided which should be so placed that a person following them will be guided towards the nearest suitable exit, which may be either the normal exit or an emergency exit. These directional signs should be illuminated when the corresponding exit signs are illuminated.

Methods used for illumination of signs may be:

a) lamps external to the sign; and

b) lamps contained within the sign.

It is recommended that the method of illumination described under (b) be used within any area where the normal lighting may be deliberately dimmed or extinguished. On no account should the lamps within the signs be dimmed.

In the event of failure of the supply to the normal lighting, escape route signs should receive the power needed for illumination from the emergency lighting supply.

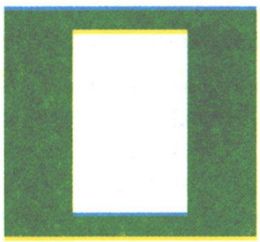
All signs used for the escape route indication should bear an appropriate pictograph in accordance with the local regulations. When no local regulations are in force in this respect, it is recommended that the signs as given in IS 9457 are used. Some of these are shown in Fig. 1. The colours of the signs should be in accordance with IS 9457.

4.2 Visual Impact and Legibility of Signs

Visual impact and legibility are dependent upon size, viewing distance, contrast, luminance and positioning.

The size of the pictograph in an exit or emergency exit sign should be at least 1/300 of the maximum distance from which the sign is expected to be viewed.

The contrast between the illuminated face of a sign and the background against which a sign will be viewed in times of emergency, should be sufficient to make that sign easy to see but not so great as to produce disability glare. The contrasts contained within the pictograph must be such as to make its message instantly clear when illuminated during times of emergency. Effective contrast in either case may be in brightness and/or in colour.

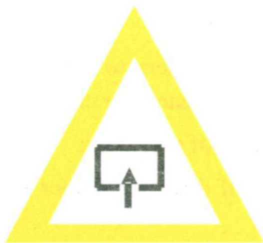


Sign no. 4

Emergency exit

Square or rectangular sign
Background green, symbol white

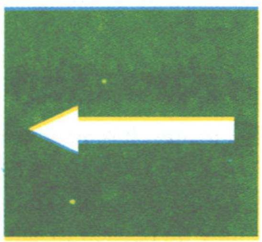
This sign should always be accompanied by a directional sign indicating the position of the exit (sign no. 12 or 13) unless the exit sign is on or above a door.



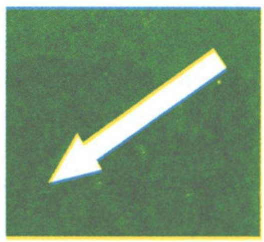
Sign no. 6

Danger – no way out

Triangular sign
Background yellow, symbol black



Sign no. 12



Sign no. 13

Directional signs for escape routes

Square or rectangular sign; background green symbol white
These signs can be accompanied by Sign no. 4.

Fig. 1 Examples of Escape Route Signs

It is recommended that the lowest luminance present in the pictograph should be at least 15 cd/m^2 and that the highest should not be greater than 300 cd/m^2, the minimum and maximum luminances on any sign should be in the ratio 1:10.

In order to give the signs maximum visual impact they should be placed perpendicular to the line of sight of persons using the escape route.

4.3 Escape Route Illumination

The horizontal illuminance (E) at floor level on the centre line of any escape route must at no point be less than 0.2 lux in order to enable occupants to avoid bumping into obstructions. However, the higher the illuminance the more likely it is that the occupants will move swiftly and confidently along the escape route so that in many cases a minimum of 1 lux may be regarded as preferable. For safe movement a uniformity ration E_{max}/E_{min} = 40:1 along the centre line should not be exceeded.

The escape route illumination should come on within 15 seconds after failure of the normal supply. Local regulations may require a shorter delay time.

Escape lighting luminaires should be sited:

a) near each exit door;

b) near each emergency exit door;

c) at all points where it is necessary to emphasize the position of a potential hazard, for example:

   i) near each interaction of corridors;

   ii) near each change of direction (other than on a staircase);

   iii) near each staircase so that each flight of stairs receives direct light;

   iv) near any other change of floor level; and

   v) outside each exit and emergency exit and close to it, leading to an agreed safe area.

Additional luminaires, as required, should be sited so as to ensure that the lighting throughout the escape routes complies with the recommendations for minimum illuminance and illuminance uniformity given above. Good illuminance uniformity is more easily achieved by using a greater number of luminaires with lower light output than by employing a lesser number of more widely spaced units with higher light output.

In many cases the luminaires also bear the signs used for escape route indication. The restrictions regarding the admissible range of luminances (*see* **4.2**) then only refer to the illuminated face of the sign; the underside may be brighter.

4.4 Visibility of Hazards

By itself, illuminance is not a sufficient criterion of visibility, since it refers only to the light falling on a surface and not to the amount reflected back to the eye; a white object can be seen with much less light than a dark one. It is recommended that all permanent potential obstructions or hazards on an escape route be light in colour with contrasting surround. Such hazards include the nosings of stair treads, barriers and other changes in floor level, and walls at right angles to the direction of movement. In restricted areas, such as corridors, light coloured decoration throughout is an advantage, and under emergency conditions easily seen vertical surfaces can assist considerably.

4.5 Illumination of Fire Alarm Call Points and Fire Fighting Equipment

Fire alarm call points and fire fighting equipment provided along escape routes should be illuminated, either by emergency lighting or by normal artificial or daylighting at all times while the building is occupied.

5 SAFETY LIGHTING

The Illuminance on the working area given by safety lighting should not be less than 5 percent of that given on the same area by the normal lighting, although for tasks of particular danger this should be increased to 10 percent.

In operating theatres and other hospital interiors involving critical medical tasks, the safety lighting system should normally be designed to provide the same illuminance as the regular system. In practice, the same luminaires are often used, powered by an alternative supply.

Safety lighting should be supplied within 0.5 seconds of the failure of the normal supply.

6 STANDBY LIGHTING

Standby lighting is, by definition that lighting provided to enable normal activities to continue, should the supply to the normal lighting fail. The quantity and quality of the standby lighting must, therefore, satisfy the minimum requirements of the various activities concerned.

Standby lighting is often provided by some or all of the normal luminaires. It is recommended that the illuminance should not be less than 10 per cent of that normally recommended for the activity concerned, or such higher value as may be needed to satisfy special requirements. The interruption time in switching from normal to standby lighting is a matter of economic consideration. In general, it should not exceed 15 seconds, although shorter interruption times may be desirable, for instance, 1.5 seconds in commercial applications to prevent shoplifting.

7 POWER SUPPLY SYSTEMS FOR EMERGENCY LIGHTING

Emergency lighting is provided for use when the supply to the normal lighting fails and must, therefore, be powered by a source independent from that of the normal lighting.

7.1 Choice of Operating Mode

For most types of building either a maintained or a non-maintained system will normally prove to be equally satisfactory. However, a maintained system should invariably be employed in buildings where the normal lighting can be dimmed or reduced below the levels required for escape route identification and illumination whilst the building is occupied, for example, most places of public entertainment.

7.2 Period of Operation

The power supply system for emergency lighting should be designed to supply the required load for the desired period of operation. The period of operation considered desirable will depend on a number of factors, such as the category of the emergency lighting being powered, the scale and structure of the building and the nature of the activities being carried out in it. No recommendations are made on this point, but it might be useful to note that, for many applications, it is considered that a period within the range 1 hour to 3 hours should be satisfactory. This item will, in many cases, be covered by legislation.

8 MAINTENANCE

A regular schedule of testing and maintenance of all components should be established. This should include a check on the provision of the required illuminance during the stipulated period. Further details are available in Part 13 of this code.

NATIONAL LIGHTING CODE

PART 13 LIGHTING MAINTENANCE

CONTENTS

Illumination Engineering and Luminaires Sectional Committee, ET 24

FOREWORD

During the life of a lighting installation, the light available for the task progressively decreases due to accumulation of dirt on surface and ageing of equipment. The rate of reduction is influenced by the equipment choice and the environmental and operating conditions. In lighting scheme design it is important to take account of the decrease by the use of a maintenance factor and plan suitable maintenance schedules to limit the decay. The lighting scheme should be designed with an overall maintenance factor calculated for the selected lighting equipment, the environment and a specified maintenance schedule. A high maintenance factor with an effective maintenance programme promotes energy efficient design of lighting schemes and limits the installed lighting power requirements.

This part describes the parameters influencing the depreciation process and develops the procedure for estimating the maintenance factor for indoor electric lighting systems. It provides information on the selection of equipment, estimation of economic maintenance cycles and gives advice on servicing techniques. Some examples of data are given here, but for accuracy it recommends that data should be obtained from the manufacturers.

Light has an effect on the physiology and psychology of the human being, and it enables him to perceive what is going on around him. There exists a close relationship between the way the visual scene is presented to us and the ability of the eye to fulfill its task properly.

This part of the code is based on CIE Publication CIE 97 (2005) Guide on the maintenance of indoor electric lighting systems and CIE Publication CIE 154 (2003) Guide on the maintenance of outdoor electric lighting systems.

The following Indian Standard is a necessary adjunct to this part of the code.

IS No.	*Title*
12063:1987	Classification of degree of protection by enclosures of electrical equipment

NATIONAL LIGHTING CODE

PART 13 LIGHTING MAINTENANCE

1 SCOPE

This part covers the guidelines about the maintenance of indoor and outdoor lighting installations.

2 TERMINOLOGY

The following definitions in addition to those given in Part 1 of this code shall apply.

2.1 Cleaning Agent — Material used to aid the removal of dirt.

2.2 Group Replacement (lamps) — replacement of a large number of lamps at one chosen time in an installation.

2.3 Initial Illuminance — The average illuminance on the reference surface based on initial lamp lumens when the installation is new and the room surfaces are clean.

2.4 Initial Luminous flux — The luminous flux (lumens) measured after an initial aging period in reference conditions.

2.5 IP Code — Ingress Protection Code of enclosures against the entry of dust and moisture.

2.6 Maintained Luminance/Illuminance — The average luminance/illuminance on the reference surface below which an installation is not allowed to fall. It is the luminance/illuminance at which maintenance must be carried out.

2.7 Maintenance Cycle — Repetition of relamping and/or cleaning intervals.

2.8 Rated Average Lamp Life — The period over which the lamp survival factor falls to 50% in reference conditions.

2.9 Spot Replacement (lamps) — Replacement of individual lamps as they fail.

2.10 Abbreviations

2.10.1 *Lamp Lumen Maintenance Factor (LLMF)* — Ratio of luminous flux of a lamp at a given time in the life to the initial luminous flux. The initial luminous flux of lamps is usually declared at 100 hours for discharge lamps.

2.10.2 *Lamp Survival Factor (LSF)* — Fraction of the total number of lamps which continue to operate at a given time under defined conditions and switching frequency.

2.10.3 *Luminaire Maintenance Factor (LMF)* — Ratio of efficiency of a luminaire at a given time to the initial efficiency value.

2.10.4 *Maintenance Factor (MF)* — Ratio of maintained luminance/illuminance to initial luminance/illuminance.

2.10.5 *Surface Maintenance Factor (SMF)* — Ratio of surface reflectance at a given time to the initial reflectance value.

2.10.6 *Room Surface Maintenance Factor (RSMF)* — Ratio of surface reflectance at a given time to the initial reflectance value.

3 INDOOR LIGHTING SYSTEMS

3.1 General

Maintenance of all lighting installations is essential as it keeps the performance of the system within the design limits and promotes safety and efficient use of energy. It is a fact that the lighting level provided by a lighting installation will decrease gradually throughout the life of the installation. Several terms have been used to describe the factor to account for this reduction but in this part throughout the term maintenance factor is used.

Maintenance factor is defined as the ratio of the average illuminance on the working plane after a certain period of use of a lighting installation to the initial average illuminance obtained under the same conditions for the installation therefore taking account of all losses including lamp lumen maintenance.

NOTES

1. The term light loss factor, having the same definition as maintenance factor, has been used in the past.
2. The term depreciation factor has been formerly used to designate the reciprocal of the above ratio.
3. The light losses take into account dirt accumulation on luminaire and room surfaces and lamp depreciation.

The recommended illuminance for lighting design is now based on maintained illuminance which is the average illuminance at a certain period of use when maintenance has to be carried out and is given by,

$$E_{mainatined} = E_{initial} \times MF$$

Lighting systems have different maintenance characteristics and this should be one of the important assessments made in the early stages of project design.

This part discusses the various influencing factors and gives data based on practical solutions that enable the maintenance factor for different types of systems, buildings and locations to be derived. The derived maintenance factor should be applied to all formulae used for lighting scheme calculations, such as illuminance and luminance on areas or at points. Methods for estimating economic maintenance periods and advice on cleaning techniques are also given.

This part also provides a limited selection of typical current data to allow the calculation methods to be explained. The examples of data have been updated with new lamp types, luminaire types and improvements in the interior cleanliness. A 'very clean' environment category has been added and a new method with data extending to six years is proposed for the room surface maintenance factor. However, to take advantage of the continuing developments of lighting products and techniques, up-to-date data should be obtained from manufacturers.

3.2 Need for Maintenance

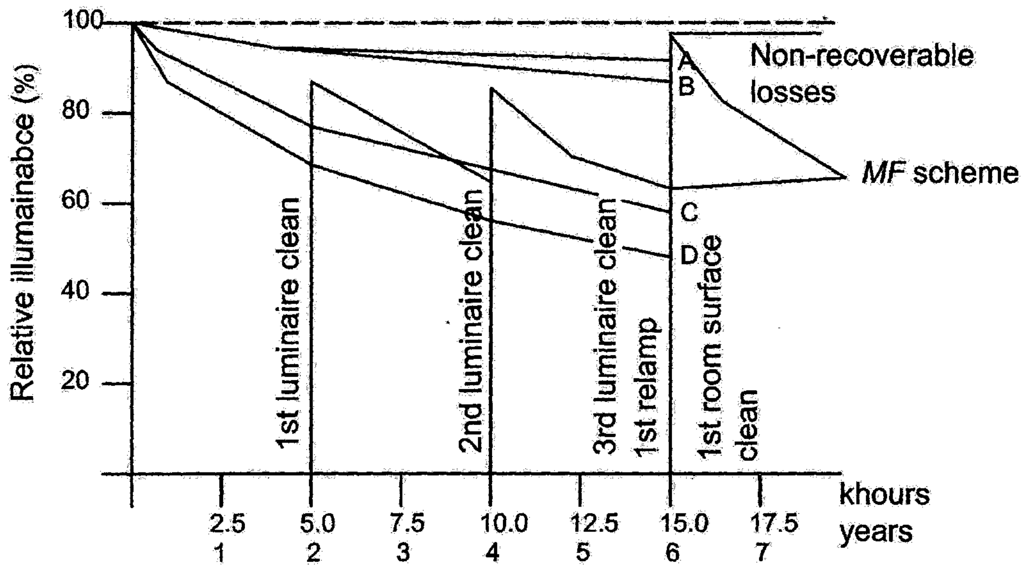
All lighting schemes within a building will deteriorate progressively from the moment these are put into use. The losses are due to the accumulation of dust and dirt on all exposed surfaces of lamps, luminaires and room surfaces, reducing the transmittance or reflectance and to the decay in lamp lumen output, failing lamps and ageing of surfaces. If this process is unchecked, it will result in the illuminance falling to very low values as shown in Fig.1, and the scheme could become very energy inefficient, unsightly and dangerous. As the decay in illuminance is gradual, the workers may not notice the loss immediately. But over a period, this gradual reduction will cause increased visual strain, more errors and mistakes in the work; the task will take longer to complete and accidents may occur.

Regular maintenance is, therefore, most important for an effective lighting installation. The lighting system should not only be cleaned correctly and thoroughly but the cleaning should be carried out at regular intervals. A well designed maintenance schedule and programme will yield a higher maintenance factor and will maintain the required illuminance, reduce capital and operating costs, reduce the installed power requirements and run the system safely. It will ensure satisfactory appearance and comfort for the occupants.

However, even with a well designed and operated maintenance programme some loss of illuminance is inevitable. This loss has to be estimated, at the time the lighting scheme is planned, and an allowance in the form of maintenance factor should be included in the scheme design calculations.

3.3 Influencing Factors

There are several factors that can reduce the light output of an installation. These are grouped under non-recoverable and recoverable depreciation.



A – room surface maintenance curve (reflectance 70/50/20, *DFF* 0.0 in clean environment);
B – lamp lumen maintenance curve (HF linear triphosphor fluorescent lamp);
C – luminaire maintenance curve (type C luminaire in clean environment);
D – unmaintained system output;
MF scheme – is the design maintenance factor and indicates the relative maintained illuminance.

NOTE — The lamp survival rate is not included as in this case between bulk relamping spot replacement is assumed.

Fig. 1 Variation of Illuminance through Life (Linear Fluorescent Lamp in Industrial Reflector Luminaire Operated with Spot Lamp Replacement Programme)

3.3.1 *Non-recoverable Factors*

Non-recoverable factors (NRF), such as ageing and fading of materials, operating temperature and voltage are inherent in the installation and its environment and cannot be improved during normal maintenance or are uneconomical to overcome. These factors in general are small (< 3 percent) but should be taken into account together with the planning of a maintenance programme at the design stage of the lighting scheme and the right equipment for the environment should be selected.

Once the non-recoverable reductions, by ageing or soiling, have occurred the lighting equipment cannot be brought back to their original condition and replacement of the luminaire may be necessary. This is the case with luminaires if they are in, say, dusty or oily atmospheres so that dust or oil particles become burnt onto the reflector. In such cases it is not economically viable to bring the reflector back to its original condition and, therefore, it is advisable (sometimes essential) to replace the reflector. If this is not done the lighting installation will not provide the maintained illuminance.

If the influence of other factors such as voltage, frequency, temperature and ballast, are permanent and significant then at the design stage the magnitude of these effects should be estimated and an allowance similar to the maintenance factor should be made in the calculations. These factors although important are not used in the methods described. However, it is worth stating that the influence of random occurrences may be ignored, provided they do not harm the operation of the lighting system.

3.3.2 *Recoverable Factors*

Recoverable factors, of lamp lumen maintenance, lamp survival, luminaire maintenance and room surface maintenance can be made good during service and routine maintenance. These should be defined in the maintenance schedule and implemented by relamping, cleaning, replacing failed components or painting the surfaces.

The value of such a maintenance programme is indicated by an example in Fig.1. This clearly shows that the illuminance in the unserviced scheme will fall to 50 percent of the initial value within six years and will continue to decline albeit at a reduced rate. But by implementing a programme of biannual luminaire cleaning and 6 yearly bulk relamping and room surface cleaning, the decline is checked and can be restored to over 98 percent of the initial value. At this time the maintained scheme provides double the illuminance of that given by the unmaintained system. The maintenance programme will yield a maintenance factor of 0.70 for the scheme.

3.4 Inspection Intervals and Cleanliness Category

Regular inspection of lighting installations is advisable. In some countries the provision of adequate illuminance for working is required by law. Independent inspectors enforce the task illuminance.

As a guide for those who have their lighting inspected and/or measured, Table 1 shows the maximum time intervals between inspections of various areas. Table 1 also indicates the cleanliness category of typical places of work.

NOTE — There may be cases, particularly in certain areas in industrial processes, where the environment is exceedingly dirty which are outside the scope of the above classification.

Table 1: Recommended Inspection Intervals of Lighting Systems in Different Working Environments.
(*Clauses* 3.4 *and* 3.10.1)

Inspection Interval	Environment	Activity or task area
3 years	Very Clean (VC)	Clean rooms, semiconductor plants, hospitals, clinical area*, computer centres
	Clean(C)	Offices, schools, hospital wards
2 years	Normal (N)	Shops, laboratories, restaurants, warehouses, assembly areas, workshops
1 year	Dirty (D)	Steelworks, chemical works, foundries, welding, polishing, woodwork

* For reason of hygiene control, more frequent inspection may be required.

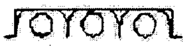
3.5 Cleaning Schedule

To assist operators of maintenance schedules Table 2 gives a quick indication of the cleaning intervals for different luminaire types used in various environments. As far as maintenance is concerned Table 2 and Table 3 can also be used as a guide for the selection of luminaires for particular environments. The data are typical for the luminaires using any lamp types with the exception of those using high pressure discharge reflector lamps. These reflector lamp luminaires will have characteristics similar to type B luminaires.

3.6 Analysis of Depreciation

Several factors contribute to light losses and the effect and magnitude vary with the type of activity and the location. For example, areas vary as to the amount and type of dirt in the air; the amount of dirt in a foundry is greater than that found in an air conditioned office. But the amount and type of dirt in an office located near an industrial area is different to that for an office located in the country. The black dirt found in steel mills is most unlike the relatively light coloured dust in bakeries. It is

Table 2 : Approximate Cleaning Intervals (marked by X) for Luminaires Used in Various Environments
(*Clauses* 3.5, 3.10.1 *and* 3.15)

Cleaning Intervals	3 years			2 years			1 year		
Environment/ Luminaire type	VC C	N	D	VC C	N	D	VC C	N	D
A Bare batten 	X				X				X
B. Open top housing (natural ventilated) 	X				X				X
C. Closed top housing (unventilated) 	X			(X)				X	
D. Enclosed IP2X 	X			(X)				X	
E. Dust proof IP5X 	X	X				X			
F. Enclosed indirect (uplight) 				X			(X)	X	
G Airhandling, forced ventilated 	X	X				X			

Where VC is very clean, C is clean, N is normal and D is dirty atmosphere in the environment (*see* Table 1). The selection of intervals is based on having a luminaire maintenance factor (*LMF*) of over 0.80.

Table 3 : Examples of Luminaire Types
(*Clause* 3.5)

Type	Luminaire types in Table 2	Luminaire descriptions
A	Bare batten	Bare lamp luminaires
B	Open top housing (natural ventilated and so called 'self cleaning' types)	Direct-indirect luminaires without cover
		Direct-indirect luminaires with indirect reflector and closed optical device Wall washing luminaires (vertical opening) Wall mounted luminaires open top and base Downlights with open top
C	Closed top housing (unventilated)	Recessed and surface mounted luminaires (for example, with louvres), downlights, sspotlights
D	Enclosed IP2X	General purpose luminaires with closed (natural ventilated) covers and optics
E	Dust proof IP5X	Dust proof IP5X (protected, clean room luminaires)
F	Indirect lighting and uplight	Free standing, pendant, wall mounted uplighters with closed base, cove lights.
G	Air handling and forced ventilated	Air handling body and optic used with air conditioning or ventilation systems

Luminaires C, D and F are not recommended for dirty environments.

important to be able to recognize these variations when assessing light losses.

3.6.1 *Lamp Lumen Maintenance Factor*

The lamp lumen maintenance factor is the relative light output during the lifetime of a burning lamp to the initial output. The light output of all lamp types decreases with burning hours. Table 4 gives examples of lamp operating hours (burning hours) for a range of activity areas. The exact rate, however, depends on the specific lamp type and for discharge lamps, also on the ballasting system. The losses due to this effect can be reduced by more frequent lamp replacement, perhaps by group replacement. Table 5 shows typical examples of lamp lumen maintenance factors. It is therefore very important to obtain up-to-date data from the manufacturers for estimating the maintenance factor and the maintenance programme, particularly when using a new type of lamp.

For accurate data always consult the manufacturer.

3.6.2 *Lamp Survival*

Lamp survival factor is the probability of lamps continuing to operate for a given time. It indicates the percentage of a large representative group of a type of lamp remaining operational after a certain period. The survival rate depends on lamp type and particularly, in the case of discharge lamps, the frequency of switching and the ballasting system. Traditionally the lamp life is the declared time in hours when 50 percent of the lamps in a test batch have survived (*see* Fig.2). Failed lamps in schemes will cause reduction in illuminance and uniformity, but the effect can be minimized by spot replacement of lamps. Table 5 shows typical examples of lamp survival data. The *LSF* value should be used in conjunction with the *LLMF* value to establish an economic working life for the lamp as the declared life is often much longer than the economic light output lamp life.

For accurate data the manufacturer may be contacted.

3.6.2.1 *Differences between lamp types*

Different lamp types behave differently. For example, the working principle of an incandescent lamp is a glowing filament whilst a fluorescent lamp is by arc discharge combined with phosphor emission.

3.6.2.2 *Differences within one lamp type*

Even if the working principle of the lamp type is identical this does not mean that the lamp maintenance characteristics are the same. For example, manufacturers produce several types of halogen lamps for different purposes and the 50 percent survival rate varies between 1 000 h and 5 000 h.

3.6.2.3 *Differences by external influence on lamp*

Many external issues like burning position, environmental conditions, ballasting system, frequency of switching, etc, significantly influence the maintenance characteristics of lamps.

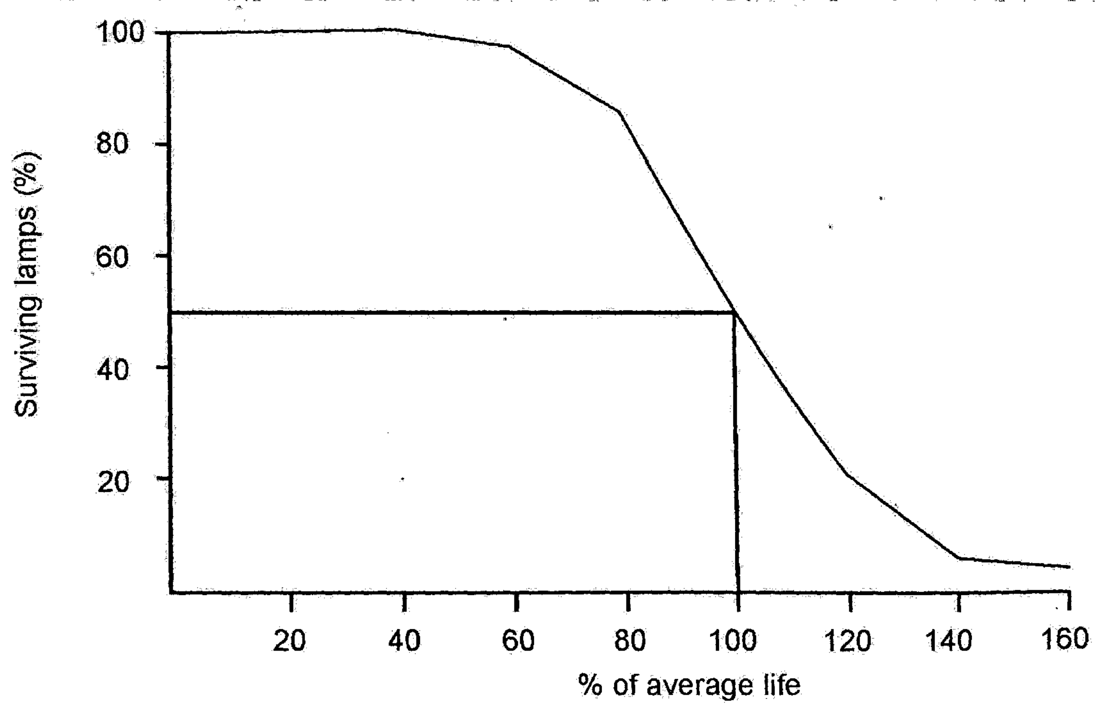


Fig. 2 Typical Lamp Mortality Curves
(statistical group of linear fluorescent lamps on 8 switch cycles per 24 hours)

Table 4: Typical Annual Operating Hours (burning hours)
(*Clauses* 3.6.1 *and* 3.14.1)

Activity Include shifts	Period of occupancy No. of days	Hours/day	Daylight link controls Yes/No*	Operating hours Hours/year
Industrial				
Continuous	365	24	no	8760
Process	365	24	yes	7300
Two shifts	310	16	no	4960
Six days/week	310	16	yes	3720
Single shift	310	10	no	3100
Six days/week	310	10	yes	1760
Single shift	258	10	no	2580
Five days/week	258	10	yes	1550
Retail				
Six days/week	310	10	no	3100
Offices				
Five days/week	258	10	no	2580
	258	10	yes	1550
Schools				
Five days/week	190	10	no	1900
	190	10	yes	1140
Hospitals				
7days/week	365	16	no	5840
	365	16	yes	3504

* Assuming adequate daylight is available during the daytime for about half the working days. As daylight penetration varies across the areas, the switching or dimming arrangements will need to be organized accordingly.

NOTE — Frequent switching of the lamps will reduce the lamp life, see Fig.2.

Table 5: Typical Examples of the Lamp Lumen Maintenance Factor (*LLMF*) and The Lamp Survival Factor (*LSF*) Data
(*Clauses* 3.6.1 *and* 3.6.2)

			Burning hours in thousand hours											
		differences[1]	1.0	5.0	1	2	4	6	8	10	12	15	20	30
Incandescent	*LLMF*	moderate	1.00	0.97	0.93									
	LSF	big	1.00	0.98	0.50									
Halogen	*LLMF*	big	1.00	0.99	0.97	0.95								
	LSF	big	1.00	1.00	0.78	0.50								
Fluorescent triphospor	*LLMF*	moderate	1.00	0.99	0.98	0.97	0.93	0.92	0.90	0.90	0.90	0.90	0.90	
	LSF	moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.97	0.94	0.50	
Fluorescent triphospor	*LLMF*	moderate	1.00	0.99	0.98	0.97	0.93	0.92	0.90	0.90	0.90	0.90		
	LSF	moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.92	0.50		
Fluorescent halophosphate	*LLMF*	moderate	1.00	0.98	0.96	0.95	0.87	0.84	0.81	0.79	0.77	0.75		
	LSF	moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.92	0.50		
Compact fluorescent	*LLMF*	big	1.00	0.98	0.97	0.94	0.91	0.89	0.87	0.85				
	LSF	big	1.00	0.99	0.99	0.98	0.97	0.94	0.86	0.50				
Mercury	*LLMF*	moderate	1.00	0.99	0.97	0.93	0.85	0.82	0.80	0.79	0.78	0.77	0.76	
	LSF	moderate	1.00	1.00	0.99	0.98	0.97	0.94	0.90	0.86	0.79	0.69	0.50	
Metal halide (250/400 W)[2]	*LLMF*	big	1.00	0.98	0.95	0.90	0.87	0.83	0.79	0.65	0.63	0.58	0.50	
	LSF	big	1.00	0.99	0.99	0.98	0.97	0.92	0.86	0.80	0.73	0.66	0.50	
Ceramic metal halide (50/150 W)	*LLMF*	big	1.00	0.95	0.87	0.75	0.72	0.68	0.64	0.60	0.56			
	LSF	big	1.00	0.99	0.99	0.98	0.98	0.98	0.95	0.80	0.50			
High pressure sodium (250/400 W)	*LLMF*	moderate	1.00	1.00	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.96	0.94	0.90
	LSF	moderate	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.97	0.95	0.92	0.50
LED[3]	*LLMF*	big	Data is changing too rapidly.											
	LSF	big	Data is changing too rapidly.											

[1]Indicates differences in *LLMF* and *LSF* among lamps, which belong to the same lamp type category.

[2]Differences in group of metal halides are extremely remarkable. Very high and very low wattage lamps have significantly shorter lives than the values given here.

[3]Data of LEDs is changing rapidly and no values can be given.

It is always advisable to consult manufacturers for detailed and up-to-date lamp data.

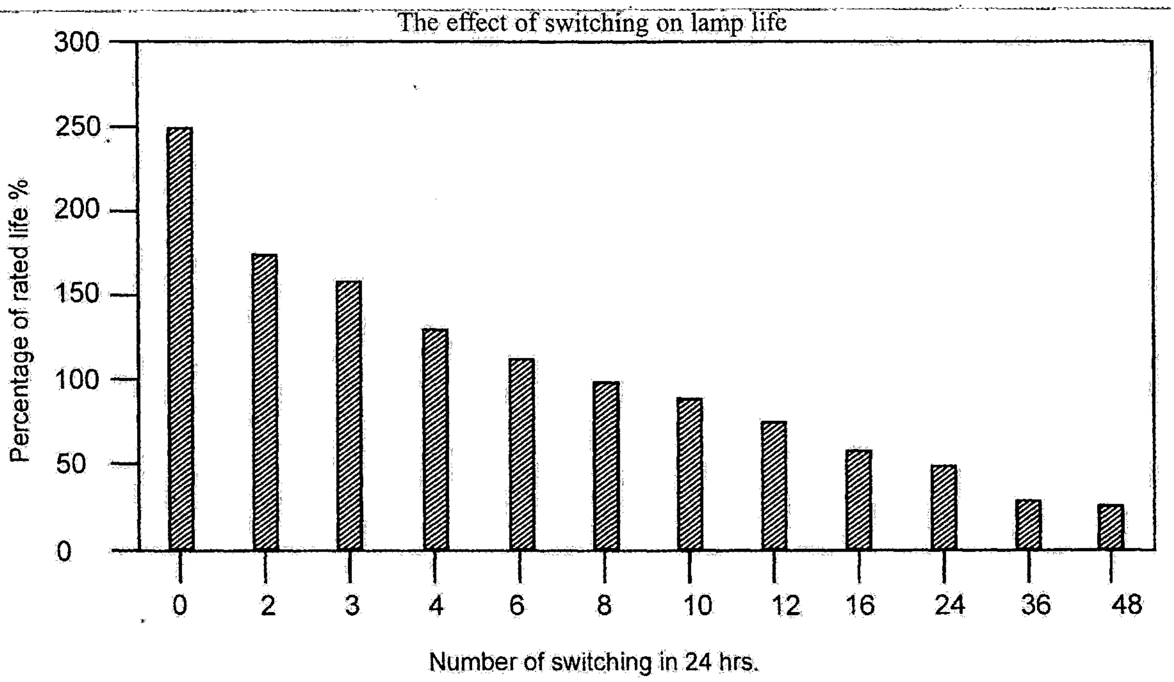


Fig. 3 Example of the Effect of Switching on Lamp Life for Fluorescent Lamp on Lagging Switch Start Circuit

NOTE — The glow switch in a switch start circuit should be changed with each lamp change.

3.7 Circuits and Controls

Except the mains voltage rated incandescent lamps, all other lamp types require some form of control gear (ballast or transformer) to provide for voltage match or limiting lamp current. Some lamps, particularly compact fluorescent types, have this control gear integral (built in) and are disposed of at the end of lamp life. However, the majority of lamps use remote control gear that last several lamp changes.

For safe and reliable operation during lamp change it is important to ensure that the replacement lamp is compatible with the control gear. The manufacturers of luminaires use both magnetic and electronic control gear and they should be consulted on the choice. The control gear may be fixed or variable (dimmable) output and can be coupled with lighting management systems. These systems can be linked to timed controls or people presence detection and/or daylight sensing to switch or dim the lamps accordingly.

The lamp life is based on a defined frequency of switching with a 24 hour period. Frequent switching will reduce lamp life (*see* Fig. 3). Studies have shown that correct dimming of lamps has no adverse effect on lamp life, in fact, incandescent lamps can benefit. Fig. 3 and Table 6 give examples of how ballasting systems and switching frequency influence the lifetime of linear fluorescent lamps.

Table 6. Examples of Switching Frequency and Ballast Influence on Lamp Life (50 Percent Survivor) of the TLD and T5 Linear Fluorescent Lamps

(*Clause* 3.7)

	High frequency electronic ballast		Conventional (magnetic) ballast	
Switching cycle	Programmed start (preheat)	Instant start (non-preheat)	Inductive circuit	Lead lag circuit (50 percent capacitive, 50 percent inductive)
12 h	23 000 h	19 000 h	18 000 h	15 000 h
8 h	22 000 h	17 000 h	16 000 h	14 000 h
3 h	20 000 h	Not available	15 000 h	12 000 h
1 h	16 000 h	Not available	12 000 h	9 000 h

NOTE — T5 lamps use only electronic ballasts.

For accurate data the luminaire manufacturer may be consulted.

3.8 Luminaire Maintenance Factor

Luminaire maintenance factor is the relative output of the luminaire due to dirt deposited on lamps and on or in the luminaires over a period. The rate of reduction depends on the construction of the luminaire and on the nature and density of airborne dirt present in the atmosphere. Black dirt or dust will generally cause the greatest loss of

Table 7 : Examples of Luminaire Maintenance Factors (*LMF*)
(*Clause* 3.8)

Elapsed time between cleanings in years	0	0.5				1.0				1.5				2.0			
Luminaire type (*see* Table 2)														Environment			
	Any	VC	C	N	D	VC	C	N	D	VC	C	N	D	VC	C	N	D
A	1	0.98	0.95	0.92	0.88	0.96	0.93	0.89	0.83	0.95	0.91	0.87	0.80	0.94	0.89	0.84	0.78
B	1	0.96	0.95	0.91	0.88	0.95	0.90	0.86	0.83	0.94	0.87	0.83	0.79	0.92	0.84	0.80	0.75
C	1	0.95	0.93	0.89	0.85	0.94	0.89	0.81	0.75	0.93	0.84	0.74	0.66	0.91	0.80	0.69	0.59
D	1	0.94	0.92	0.87	0.83	0.94	0.88	0.82	0.77	0.93	0.85	0.79	0.73	0.91	0.83	0.77	0.71
E	1	0.94	0.96	0.93	0.91	0.96	0.94	0.90	0.86	0.92	0.92	0.88	0.83	0.93	0.91	0.86	0.81
F	1	0.94	0.92	0.89	0.85	0.93	0.86	0.81	0.74	0.91	0.81	0.73	0.65	0.88	0.77	0.66	0.57
G	1	1.00	1.00	0.99	0.98	1.00	0.99	0.96	0.93	0.99	0.97	0.94	0.89	0.99	0.96	0.92	0.87

light. It is not uncommon to find 50 percent loss, due to dirt, from industrial lighting systems between long cleaning intervals. The amount of light loss depends on the nature and density of airborne dirt, luminaire design, luminaire material and finish and lamp type. Ventilated luminaires collect less dirt if the location of openings is arranged so that convection air currents can carry dust and dirt, past the optics and lamp (sometimes referred to as self cleaning action) rather than allow it to deposit and accumulate on the reflecting or emitting surfaces. Dirt accumulation on reflecting surfaces can be minimized by sealing the lamp compartment against entry of dust and moisture. Significant benefits can be obtained with the luminaire housing and optics sealed to at least IP 54 protection. Luminaire finishes differ in their resistance to dirt accumulation. For example, anodized aluminium will stay clean longer than white enamel, but the former will have slightly lower initial reflectance whilst the latter can be cleaned easily. Also, the dirt deposit can affect the intensity distribution of the luminaire. It can turn a specular surface reflector into a matt finish or a prismatic controller into a diffuser. Table 7 shows typical data for a range of luminaires.

For more accurate data the luminaire manufacturer may be consulted.

3.9 Room Surface Maintenance Factor (*RSMF*)

Room surface maintenance factor (*RSMF*) is the relative proportion of the initial interreflected component of illuminance from the installation after a certain period due to dirt on room surfaces. Tables 9 to 11 provide examples of *RSMF* data. The room surface maintenance factor can also be regarded as the ratio of the utilance of a given installation after a specified time to the utilance of the same installation (without a change of the relative distribution of the direct fluxes onto all reflecting surfaces) when new or after the last cleaning. The room surface maintenance factor depends on the room proportion, on the reflectance of all surfaces and on the direct flux distribution of the installed luminaires. The room surface maintenance factor also depends on the nature and density of dust present or generated in the room. This build up of dirt on the room surfaces over a period of time will reduce the available amount of interreflected light. While periodic cleaning and painting of walls and ceilings is advisable in all installations it should be done more frequently in areas where a large proportion of light arrives on the task by reflection from the room surfaces or curtains, pictures and furniture. Clean room surfaces will help the luminance balance in the environment. In some countries redecoration of the room surfaces is required at regular intervals set out in hygiene regulations.

Under the assumption that the decrease of the reflectance of any particular room surface over time can be expressed by using the formula shown below, the room surface maintenance factor can be evaluated for any maintenance interval. For a set of realistic values of c and t the room surface maintenance factor values can be calculated for very clean, clean, normal and dirty environment conditions and the results presented for different reflectance conditions in tables just like utilization factors. For practical reasons it is sufficient to generate tables for only one medium proportion room size (k = 2.5) but for at least 3 flux distributions [Downward Flux Fraction (DFF) of 0.0, 0.5 and 1.0] for maintenance intervals of up to 6 years. Table 8 provides values for the constants c and t and Tables 9, 10 and 11 gives *RSMF* values for cosine distribution type luminaires having flux fraction of 0.0 or 0.5 or 1.0 for a set of reflectance and environment. Clearly RSMF values can be generated for other luminous intensity and flux distribution type luminaires.

NOTE — The Downward Flux Fraction (DFF) is the ratio of the Downward Light Output Ratio (DLOR) and the Light Output Ratio (LOR) of the luminaire.

$$DFF = \frac{DLOR}{LOR}$$

$$\rho(t) = \rho_0 . [c + (1 - c) . e^{-t/\tau}]$$

where

$\rho(t)$ is the reflectance at a specified time t in years;

ρ_0 is the initial reflectance; and

c, τ are constants of the dust accumulation process.

Table 8 Table of Values for Constants c and τ

(*Clause* 3.9)

Environment	Ceiling cc	Walls cw	Floor cf	τ (applied to time in years)
Very clean	0.96	0.92	0.85	6/12
Clean	0.92	0.84	0.70	5/12
Normal	0.83	0.70	0.50	4/12
Dirty	0.70	0.45	0.30	3/12

NOTE — Maintenance data is usually provided in tabular form. However, it is often convenient to present the data in graphical forms.

Some examples for fluorescent lamps/luminaires and room surface are shown in Fig. 4.

3.10 Maintenance Factor

Maintenance factor is defined as the ratio of illuminance produced by the lighting system after a certain period to the illuminance produced by the system when new.

Maintenance factor $$MF = \frac{E_m}{E_{in}} \quad (1)$$

where

E_m = maintained illuminance; and

E_{in} = initial illuminance.

By calculating the maintenance factor for different times and taking into account the proposed maintenance schedule, it is possible to predict the pattern of illuminance in an installation over a period of time.

The maintenance factor is a multiple of factors.

Maintenance Factor $MF = LLMF \times LSF \times LMF \times RSMF$ (2)

where

$LLMF$ = lamp lumen maintenance factor;

LSF = lamp survival factor (used only for group replacement programmes);

LMF = luminaire maintenance factor; and

$RSMF$ = room surface maintenance factor.

3.10.1 *Determination of Maintenance Factor*

The magnitude of each of these factors varies with the lamp, luminaire, environment, interior and time.

For accurate assessment the manufacturer's data should be used. However, some typical data are shown in Tables 5 and 7.

The maintenance factor can be determined by the following step-by-step procedure.

Step 1 Select lamp and luminaire for the interior application (*see* Table 2).

Step 2 Determine group replacement intervals of lamps (if practical).

Step 3 Obtain *LLMF* and *LSF* from Table 5 for period established in Step 2.

If spot lamp replacement procedure is followed then *LSF* will be 1.

Step 4 Assess the cleanliness category of the interior (*see* Table 1).

Step 5 Determine cleaning interval of luminaires and room surfaces.

Step 6 Obtain *LMF* from Table 7 for period established in Step 5.

Step 7 Obtain *RSMF* from Table 9 to 11 for period established in Step 5.

Step 8 Calculate *MF*

$= LLMF \times LSF \times LMF \times RSMF\ (\times NRF)$.

Calculate maintenance factor to not more than two significant figures.

NOTE — If there are significant non-recoverable factors (*NRF*) then these should be included in the final *MF* value.

Step 9 It is advisable to repeat Steps 1 to 8, by adjusting the various components, so that a range of maintenance programme options are considered at the initial design stage.

3.11 Use of Maintenance Factor (*MF*)

In any lighting design calculation an appropriate maintenance factor has to be included to allow for depreciation. The magnitude of the maintenance factor significantly affects the number of luminaires needed to produce the specified illuminance. High maintenance factors are beneficial and can be achieved by careful choice of equipment and electing to clean the installation more frequently. It is recommended to select solutions so that the maintenance factor does not fall below 0.7. Typical values are shown in Table 12.

The maintenance factor can be used in the lumen method of illuminance calculation to estimate the average illuminance of the installation at a particular stage in its life. This is achieved by using the following formula:

$$E_m = \frac{\Phi_{in} \times n \times N \times UF \times MF}{A} \quad (3)$$

where

E_m = maintained illuminance (lux);

Φ_{in} = initial luminous flux of the light source (lumen);

n = number of lamps per luminaire;

N = number of luminaires;

A = area to be illuminated (m^2);

UF = utilization factor for the luminaire in the room; and

MF = maintenance factor.

NOTE — This expression does not allow for the depreciation caused by non-recoverable losses.

The maintenance factor can and should be applied to all formulae used for lighting scheme calculations, for example luminance patterns and point-by-point illuminance plots.

It should be noted that the maintenance factor discussed here and the variation of illuminance shown in Fig. 1 and Fig. 5 are from fixed power schemes. There is increasing use of controllable electronic ballasts that allows a lighting scheme to provide constant illuminance. In these schemes the depreciation is compensated for by increased power supply to the lamps and thereby increasing the light output. Experience on maintenance of these recently introduced controllable installations is still being gathered and precise advice cannot be offered. It is recommended that maintenance be carried out when about 50 percent of the lamps are operating at full power.

Table 9 Table of Room Surface Maintenance Factor (*RSMF*) for Direct Flux Distribution (DFF = 0.0)
(*Clause* 3.9)

Reflectances ceiling/walls/ floor	Time/yrs environment	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
		Room surface maintenance factors – utilization plane												
0.80/0.70/0.20	very clean	1.00	0.97	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	clean	1.00	0.93	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
	normal	1.00	0.88	0.86	0.86	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	dirty	1.00	0.81	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
0.80/0.50/0.20	very clean	1.00	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	clean	1.00	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	normal	1.00	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	dirty	1.00	0.86	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
0.80/0.30/0.20	very clean	1.00	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
	clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	normal	1.00	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	dirty	1.00	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
0.70/0.70/0.20	very clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	clean	1.00	0.94	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	normal	1.00	0.89	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	dirty	1.00	0.83	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
0.70/0.50/0.20	very clean	1.00	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	clean	1.00	0.96	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	normal	1.00	0.92	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	dirty	1.00	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
0.70/0.30/0.20	very clean	1.00	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
	clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	normal	1.00	0.95	0.94	0.94	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	dirty	1.00	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
0.50/0.70/0.20	very clean	1.00	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	clean	1.00	0.95	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	normal	1.00	0.91	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
	dirty	1.00	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
0.50/0.50/0.20	very clean	1.00	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	clean	1.00	0.97	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	normal	1.00	0.94	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	dirty	1.00	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
0.50/0.30/0.20	very clean	1.00	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
	clean	1.00	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	normal	1.00	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	dirty	1.00	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92

Table 10 Table of Room Surface Maintenance Factor (*RSMF*) for Direct/Indirect Flux Distribution (DFF = 0.5).
(*Clause* 3.9)

Reflectances ceiling/walls/ floor	Time/yrs environment	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
		Room surface maintenance factors – utilization plane												
0.80/0.70/0.20	very clean	1.00	0.95	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	clean	1.00	0.90	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	normal	1.00	0.81	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
	dirty	1.00	0.70	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
0.80/0.50/0.20	very clean	1.00	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	clean	1.00	0.93	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	normal	1.00	0.85	0.83	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
	dirty	1.00	0.76	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
0.80/0.30/0.20	very clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	clean	1.00	0.94	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	normal	1.00	0.89	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
	dirty	1.00	0.81	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
0.70/0.70/0.20	very clean	1.00	0.96	0.94	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	clean	1.00	0.91	0.89	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
	normal	1.00	0.83	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
	dirty	1.00	0.72	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
0.70/0.50/0.20	very clean	1.00	0.97	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	clean	1.00	0.93	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
	normal	1.00	0.87	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
	dirty	1.00	0.77	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
0.70/0.30/0.20	very clean	1.00	0.98	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	clean	1.00	0.95	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	normal	1.00	0.90	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	dirty	1.00	0.82	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
0.50/0.70/0.20	very clean	1.00	0.97	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	clean	1.00	0.93	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	normal	1.00	0.86	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
	dirty	1.00	0.76	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
0.50/0.50/0.20	very clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
	clean	1.00	0.94	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	normal	1.00	0.89	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
	dirty	1.00	0.81	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
0.50/0.30/0.20	very clean	1.00	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	clean	1.00	0.96	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	normal	1.00	0.92	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	dirty	1.00	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84

Table 11 Table of Room Surface Maintenance Factor (*RSMF*) for Indirect Flux Distribution (DFF) = 1.0)
(*Clause* 3.9)

Reflectances ceiling/walls/ floor	Time/yrs environment	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
		Room surface maintenance factors – utilization plane												
0.80/0.70/0.20	very clean	1.00	0.93	0.91	0.90	0.90	0.90	0.90	0.89	0.89	0.89	0.89	0.89	0.89
	clean	1.00	0.86	0.82	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
	normal	1.00	0.72	0.67	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
	dirty	1.00	0.54	0.50	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
0.80/0.50/0.20	very clean	1.00	0.94	0.93	0.92	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
	clean	1.00	0.88	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
	normal	1.00	0.76	0.72	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	dirty	1.00	0.59	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
0.80/0.30/0.20	very clean	1.00	0.96	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	clean	1.00	0.90	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	normal	1.00	0.80	0.76	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	dirty	1.00	0.64	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
0.70/0.70/0.20	very clean	1.00	0.93	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	clean	1.00	0.86	0.83	0.82	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
	normal	1.00	0.73	0.68	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
	dirty	1.00	0.55	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.70/0.50/0.20	very clean	1.00	0.95	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	clean	1.00	0.89	0.86	0.85	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
	normal	1.00	0.77	0.73	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	dirty	1.00	0.60	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
0.70/0.30/0.20	very clean	1.00	0.96	0.94	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	clean	1.00	0.91	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
	normal	1.00	0.80	0.77	0.76	0.76	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.75
	dirty	1.00	0.65	0.61	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
0.50/0.70/0.20	very clean	1.00	0.94	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
	clean	1.00	0.87	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
	normal	1.00	0.75	0.70	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
	dirty	1.00	0.57	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
0.50/0.50/0.20	very clean	1.00	0.95	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
	clean	1.00	0.90	0.87	0.86	0.86	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	normal	1.00	0.78	0.74	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
	dirty	1.00	0.61	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
0.50/0.30/0.20	very clean	1.00	0.96	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
	clean	1.00	0.91	0.89	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
	normal	1.00	0.87	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
	dirty	1.00	0.66	0.62	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61

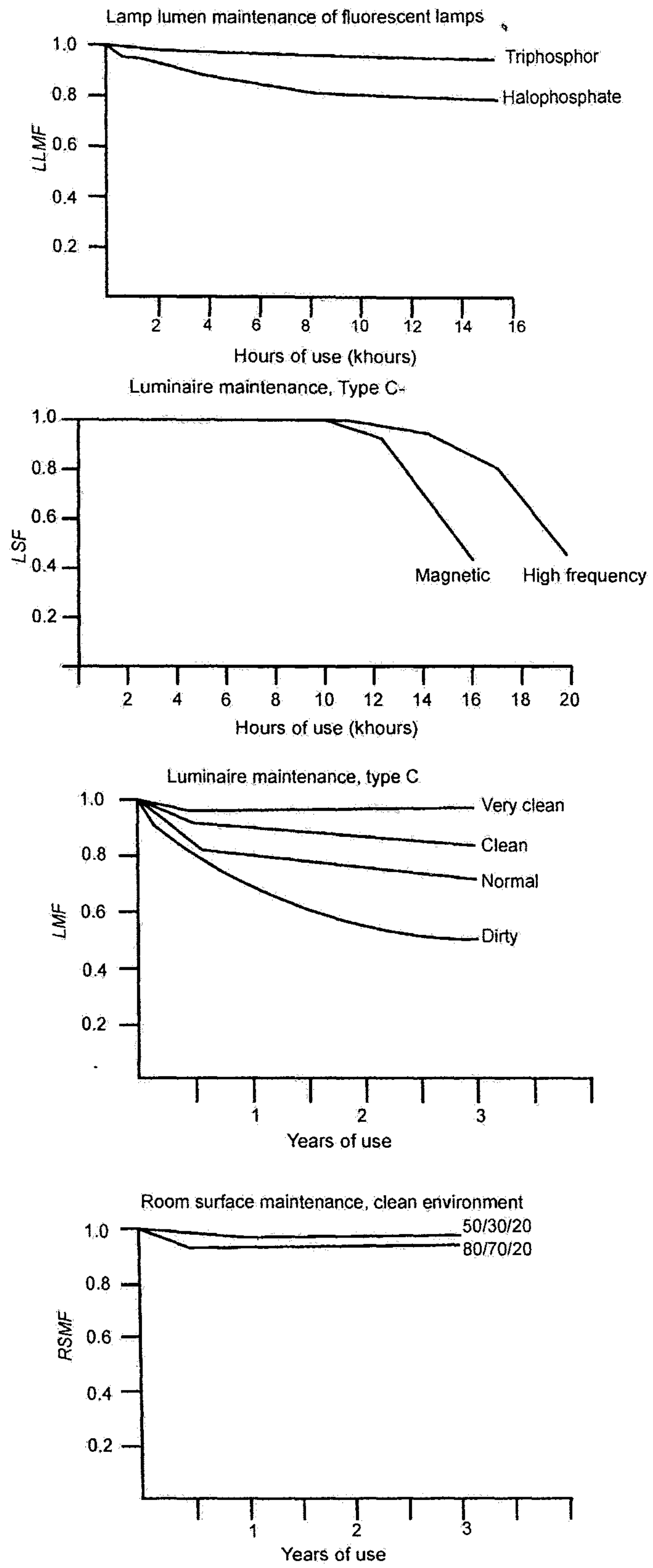


Fig. 4 Examples of Recoverable Maintenance Factor Data

Table 12 Typical Set of *MF* Values for a Medium Sized Room and the Various Lamp and Luminaire Type Comb

(*Clause* 3.11)

Lamp type		Incandescent halogen				Compact fluorescent				HF with preheat fluorescent linear triphosphor				Metal halide (250/40 W)			
Environment		VC	C	N	D	VC	C	N	D	VC	C	N	D	VC	C	N	D
Luminaire																	
Type	*DFF*																
A	0.5	0.87	0.80	0.70	0.59	0.87	0.75	0.66	0.55	0.82	0.76	0.66	0.56	0.79	0.74	0.64	0.54
B	0.5	0.86	0.78	0.73	0.59	0.80	0.73	0.64	0.55	0.81	74	0.64	0.56	0.79	0.71	0.62	0.54
C	0.0	0.87	0.79	0.69	061	0.81	0.74	0.65	0.57	0.82	0.75	0.66	0.58	0.79	0.73	0.63	0.56
D	0.0	0.87	0.79	0.70	0.63	0.81	0.74	0.65	0.59	0.82	0.74	0.66	0.60	0.79	0.72	0.64	0.58
E	0.0	0.88	0.84	0.77	0.70	0.83	0.79	0.72	0.66	084	0.80	0.73	0.67	0.81	0.77	0.70	0.64
F	1.0	0.81	0.69	0.55	0.39	0.76	0.64	0.52	0.36	0.77	0.65	0.52	0.37	0.74	0.63	0.51	0.35
G	0.0	0.92	0.88	0.82	0.76	0.86	0.83	0.77	0.71	0.87	0.84	0.78	0.72	0.84	0.81	0.75	0.70

This table is based on the following assumptions

Medium sized room (k 2.5) with reflectance 70/50/20 for ceiling, walls and floor respectively

Cleaning intervals of lamps and luminaires – 1 year

Cleaning intervals of room surfaces – 6 years

Failed lamps are spot replaced

Bulk relamping intervals (burning hours)	Incandescent halogen	2 000 hours	(*LLMF* 0.95)
	Compact fluorescent	6 000 hours	(*LLMF 0.89)*
	HF fluorescent linear	15 000 hours	(*LLMF* 0.90)
	Metal halide	4 000 hours	(*LLMF 0.87)*
	High pressure sodium	20 000 hours	(*LLMF* 0.94)

3.12 Designing Scheme for Optimal Maintenance

During the design of lighting installations, the designer has the possibilities as stated below, to choose components, systems and finishes that will result in the maintenance being kept to a minimum:

a. Choosing luminaires in which the lamp is in a dust proof enclosure having a suitable gasket to allow the luminaire to breathe without sucking in dust;
b. Adopting open luminaires (self-cleaning type) where the convection currents from the heat produced by the lamp are directed to flow over the reflecting surfaces to prevent airborne dry dust from settling;
c. Using air handling luminaires where the forced ventilation assists in the removal of dust and dirt;
d. Only recommending optical systems that are fit for the prevailing environmental conditions, for example, plastic louvres are not suitable for dusty locations;
e. Reducing the number of variants on a scheme;
f. Using luminaires having few components, thus, when requiring service, can be easily handled or removed for off-site servicing;
g. Recommending surface finishes that remain clean for long periods and are easily cleanable; and
h. Using reflector lamps or bare batten luminaires where the dirt is oily or sticky.

Other ways the designer can help the maintenance and thus improve the effectiveness of maintenance are:

a) Planning for ease of maintenance; ensuring access, types of tools needed for servicing, ensuring availability of spare lamps, optics or even luminaires. Early liaison with the maintainer to ensure understanding of requirements and procedures is also advantageous;
b) Preparing a comprehensive maintenance schedule with instructions; and
c) Organizing effective information feedback of mistakes, failures or difficulties and use these to avoid a repetition in future projects.

3.13 Sustainability

More and more nations in the world are introducing legislations that are supporting sustainability and these rules will impact the choice of electric lighting solutions and their operation.

A brief insight for consideration of sustainability as applied to electric lighting systems is explained below.

An electric lighting system has a major impact on sustainability. A sustainability approach will ensure that the needs of the present generation are met without loss or compromising the ability of future generations to meet their needs. Sustainability can be practised through product design and by the selection and use of sustainable lighting solutions. These techniques can also be described as eco-design or design for the environment.

The ideal sustainable design is a lighting solution that can continue forever. This can be achieved by using products, processes or systems that can be manufactured, used and disposed indefinitely. The ideal arrangement is perpetual reuse without waste of energy, materials or emissions.

Eco-design is designing the lighting solution with the entire life cycle in mind. The life cycle covers the whole life of the product or system from material acquisition, material refining, manufacture, installation, use, maintenance and disposal. Employing life cycle assessment will check the environmental impact of a solution through its life including all the materials, energy and environmentally significant releases used and created during the life cycle.

Design for environment is mainly concerned with the design for disassembly and recycling at the end of the useful life of the lighting product or solution.

Observing these three elements of design will yield the highest sustainability of the selected, installed and operated lighting solutions.

3.14 Economics of Servicing

3.14.1 *Lamp Replacement*

The total lamp replacement costs comprise the cost of lamps and the cost of labour involved including cost of ordering, stocking, installation, disposal, etc. The labour cost depends on the lamp change system adopted and on the inconvenience involved. The alternatives are spot replacement where each failed lamp is changed or group replacement where all the lamps (failed or good) are changed at some time that is less than the rated average lamp life. However, in some projects a combined spot/group lamp replacement programme is practiced. It is very important that in places where loss of a lamp may lead to dangerous working conditions or unsafe movement the failed lamp is replaced immediately. Installation of luminaires with more than one lamp is least affected by random lamp failures.

The most economical system can be assessed as follows:

Cost of spot replacement per lamp C_s is:

$$C_s = L+S \tag{4}$$

where

L = cost of lamp; and

S = cost of labour.

Cost of group replacement per lamp C_g

$$C_g = L+B \quad (5)$$

where

L = cost of lamp; and

B = cost of labour for group replacement per lamp.

Cost of combined group and spot replacement per lamp C_t

$$C_t = \frac{100 x C_g + F x C_s}{l} \quad (6)$$

where

F = percentage of lamps failed at relamping interval; and

l = percentage of rated lamp life at group relamping interval.

NOTE — Lamps may be bulk purchased and stored for spot replacement. Also spares can be part of the initial scheme purchase.

If the good lamps (kept after group replacement) are used for subsequent spot replacement, then [F.C_s/ 1] simplifies to [F.S/ 1].

The economy of group replacement depends heavily on the lamp survival rate. The more lamps that survive the replacement interval, the fewer costly spot replacements are needed.

It is important to note that the lamp replacement interval very much depends on the lamp burning hours. These vary according to the working hours, shifts and lighting management operating in the premises. Examples of annual burning hours are given in Table 4.

3.15 Cleaning of Luminaires

The optimum interval between cleaning (*T*) of a luminaire is reached when the cost of the lost light output equals the cost of cleaning.

The optimum cleaning interval *T* can be determined from the expression:

$$T = \frac{-C_c}{C_a} + \sqrt{\frac{2C_c}{\Delta C_a}} \text{ years} \quad (7)$$

where

T = optimum cleaning interval;

C_c = cost of cleaning the luminaire once;

C_a = annual cost of owning and operating the luminaire without cleaning; and

D = annual average rate of luminaire dirt depreciation. Values are given in Table 13.

NOTES

C_c - cost of cleaning includes the cost of any cleaning agent, special tool, platforms or equipment and the labour. The labour costs are also affected by the timing at which the cleaning is done; during normal working hours or in unsociable hours.

C_a - cost of operating includes the amortized installation cost (proportion of capital written off per year), the annual energy cost (derived from energy used in kWh x cost of energy per unit) and relamping cost (cost of lamps and replacement labour per annum).

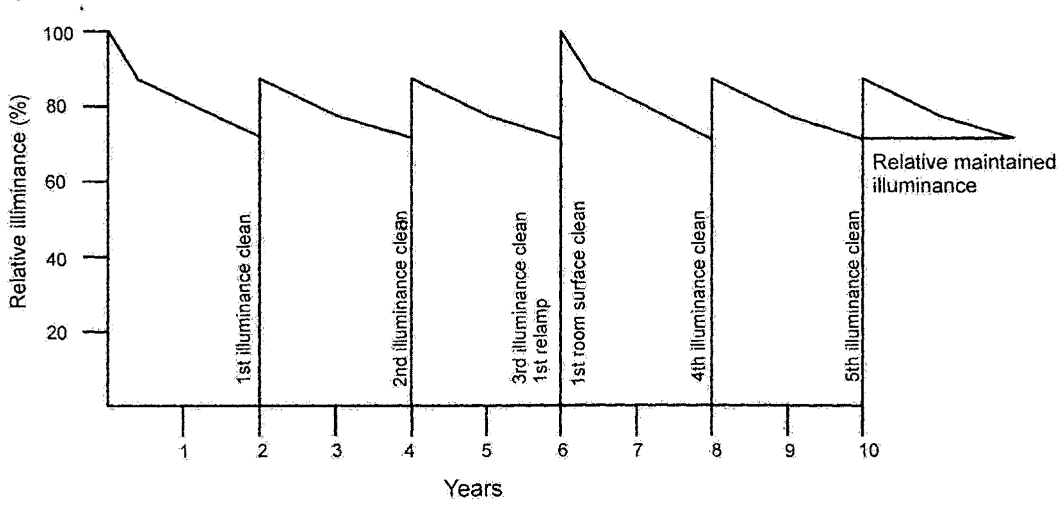


Fig. 5 Equi Interval Maintenance Programme

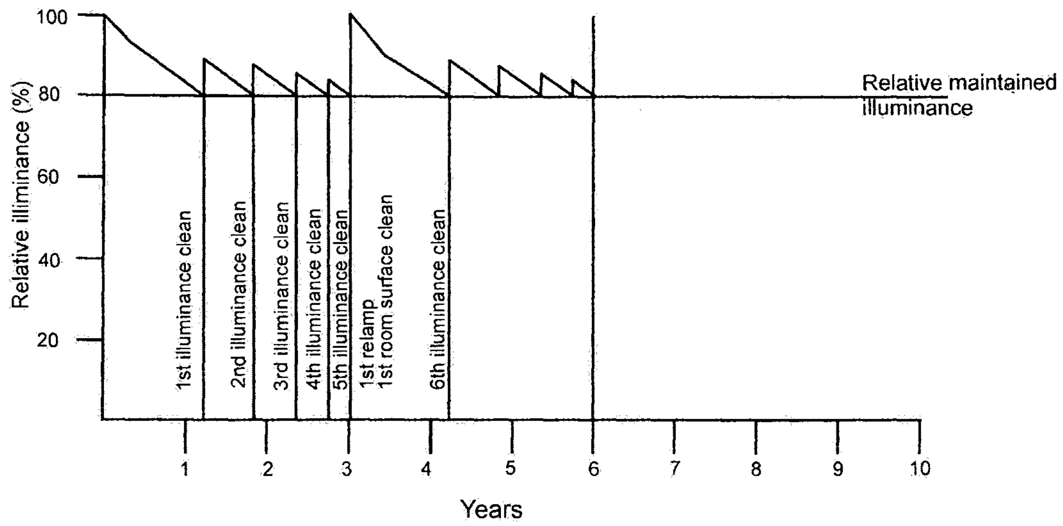


Fig. 6 Variable Interval Maintenance Programme

Table 13 Typical Rate of Luminaire Dirt Depreciation the First Year
(*Clause* 3.15 *and* Annex A)

Environment	Types of Luminaires (*see* Table 2) A	B	C	D	E	F	G
Very clean	0.03	0.05	0.06	0.07	0.02	0.09	0.01
Clean	0.07	0.10	0.11	0.12	0.06	0.14	0.03
Normal	0.11	0.14	0.19	0.18	0.10	0.19	0.06
Dirty	0.17	0.17	0.28	0.23	0.14	0.26	0.09

3.16 Maintenance Programmes

Each lighting scheme should be designed with an overall maintenance factor calculated for the selected lighting equipment, environment and specified maintenance programme or schedule. The maintenance programme should include the lamp, luminaire and room surface cleaning intervals, the frequency of lamp replacement and the cleaning method. The maintenance can be set for an equi or variable interval programme. The equi interval programme defines a regular pattern for cleaning and servicing (*see* Fig. 5) whilst in the variable interval maintenance programme the cleaning is carried out at uneven intervals (*see* Fig. 6). The variable interval programme is particularly advantageous where the initial and the energy cost of the lighting installation is high but the maintenance costs are low as it yields a slightly higher maintenance factor than obtained with the equi intervals method.

3.17 Equipment and Installation

In some situations leaving failed lamps in the circuit may cause failure of other components. The replacement of these components must be judged on the potential hazard to the safe operation of the installation. As lighting technology is constantly advancing there are many instances where old installations, although operating safely, will benefit from new types of lamps or optical systems or even from changing the whole installation. In these cases the investment can be estimated against the potential savings in energy cost and service cost. Another benefit could be the improvements in the visual environment, well-being and productivity.

3.18 Servicing Lighting Systems

It is important to schedule and plan in detail the access to site, type of cleaning equipment required and times when servicing of the lighting installations may be made to cause least interruption in the workplace. However, servicing of live lighting equipment should be avoided.

3.19 Access

It is important that provision is made for access to luminaires for relamping and cleaning. Equipment to help in servicing is discussed in Annex A.

The maintenance staff will need to determine how to reach the luminaire, that is, what equipment will be needed, platforms, ladders, bridging, etc, and what furniture will have to be moved or protected, such as desks, machinery and display cases. It is vital to ensure that access equipment is so located that the operators can work comfortably (avoid overreach) and safely on the luminaires (work inside safety barriers), and have space for temporary placement of parts and lamps.

3.19.1 *Cleaning Luminaires*

Extreme caution should be exercised when cleaning all surfaces. Some surfaces are very susceptible to abrasion for example; polished (unanodized) aluminium is very sensitive, as are some plastics, acrylic in particular. It is vital to consult or read the manufacturer's instructions to ensure that the correct methods are used for handling and cleaning the products.

The maintenance staff should experiment on a small test area with a method before starting the whole job.

The maintenance staff should take care in handling plastic components, as with age they tend to get brittle and break easily. Depending on the environment and on the UV emission of the light source, some plastics can yellow badly and there is no successful way of cleaning this and in such cases replacement of the part should be recommended.

Aluminium reflectors should be washed with a warm, soapy solution and rinsed thoroughly before being air-dried. Plastic, opal or prismatic lenses should be cleaned with a damp cloth (using a non-ionic detergent and water) and treated with antistatic polish or spray and allowed to dry.

Vitreous enamel, stove enamel and glass optics should be wiped with a damp cloth using a light concentration of detergent in water.

Plastic or metal louvre (rectangular or square cell) optics should be dipped in a warm water and non-ionic detergent solution and rinsed. Specular finished (particularly plastic) louvres are very difficult to clean and their appearance deteriorates over years of use. Therefore, they should only be used where air quality is very clean, such as new office buildings, banks, etc.

3.19.2 *Cleaning Agents*

Choice of cleaning materials and methods is determined by the type of dirt to be removed and the type of material to be cleaned. In some countries certain procedures and cleaning agents may not be permitted for use under environmental health regulations. It is always advisable to consult the authorities.

The first and most commonly used cleaning agent is a dry chemical detergent with additives in different concentration levels that is used for general cleaning. It is an advantage to use compounds that require no rinsing after the wash. For plastic materials a final treatment with an antistatic substance is recommended.

The second type of cleaner is a heavy duty liquid cleaner that may contain detergents, solvents and abrasives. It is useful for the removal of oily dirt found for example in auto garages, oily factories, etc. The cleaning agent must be tested on a sample surface to ensure that it does not damage materials or leave deposits.

In some very heavy oily applications the use of a high pressure steam cleaner is recommended for schemes that have been designed with this cleaning technique in mind.

3.19.3 *Relamping*

Lamps may be replaced by a variety of skilled people, therefore, clear instruction will be needed on how to remove the lamps so as not to damage the lamp holders or any other components of the luminaire.

When new lamps are not being put in the luminaires after the cleaning process, the old lamps should be carefully examined and any lamp showing age should be replaced at that time with the lamp specified by the designer. It is also advisable to replace the glow starter switch in switch start fluorescent lamp circuits, as aged starters may stay stuck in the pre-start position and continue to draw cathode heating current that over a short period of time can damage the ballast.

Relamping with new lamps should be done after the luminaire is clean and dry. Generally the replacement lamps should be only those that are recommended by the designer of the scheme. However, consideration should be given to the use of improved lamps provided they are suitable for the luminaire and application and are compatible with the circuit. Always check with the luminaire manufacturer or the scheme designer.

4 OUTDOOR LIGHTING SYSTEMS

4.1 General

The luminance/illuminance initially provided by a lighting installation will decrease gradually throughout the life of the installation. Several terms to describe the factor which accounts for this reduction have been used. The term maintenance factor which is the more commonly used and understood term is the ratio of the average luminance/illuminance on the working plane after a certain period of use of a lighting installation to the average luminance/illuminance obtained under the same conditions for the installation considered conventionally as new.

NOTE — The term depreciation factor has been formerly used to designate the reciprocal of the above ratio.

The recommended parameters for lighting design are now generally based on 'maintained values' which are the average luminance/illuminance at the 'certain period' of the above definition when maintenance has to be carried out.

Lighting systems have different maintenance characteristics and this should be one of the important assessments made in the early stages of project design.

This part discusses the various influencing factors and gives data based on practical solutions which enable the maintenance factor for different types of systems and environments to be derived. The derived maintenance factor should be applied to all formulae used for lighting

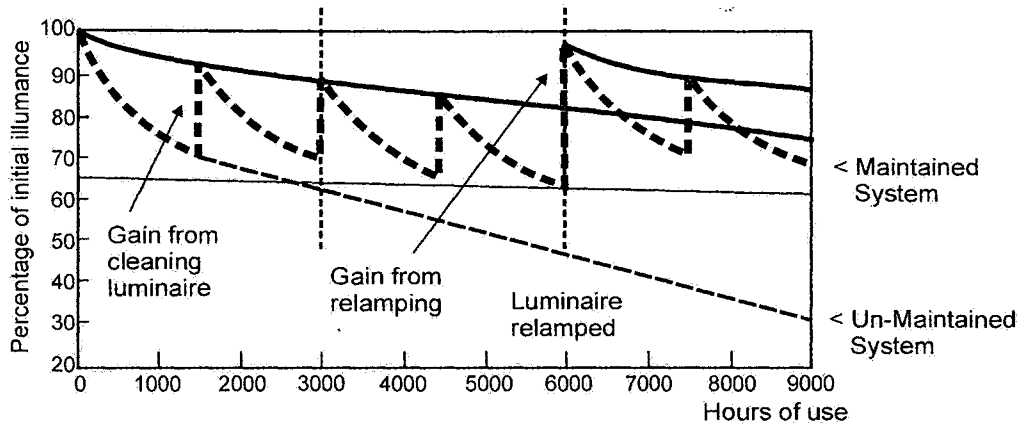


Fig. 7 Effect of Maintenance Program

scheme calculations, such as luminance/illuminance on areas or at points. Methods for estimating economic maintenance periods and advice on cleaning techniques are also given.

The maintenance of the mechanical fixtures supporting the luminaires is also covered. This is because in most outdoor situations this is of considerable importance to the overall installation performance and quite often has major safety factors of its own. Correct luminaire alignment is also an important factor in this aspect regarding both task and environmental considerations.

This part also provides a limited selection of typical data to allow the calculation methods to be explained. However, to take advantage of the continuing development of lighting products, up-to-date data should be obtained from manufacturers.

4.2 Need for Maintenance

All lighting schemes will deteriorate progressively from the moment they are put into use. The losses are due to the accumulation of dust and dirt on all exposed surfaces of lamps and luminaires, reducing the transparency or reflecting power and to the decay in lamp lumen output and failing lamps.

For the luminaires within the installation if this process is unchecked, it will result in their light output falling to very low values as shown in Fig. 7 and the scheme becomes poor and dangerous. As the decay in light output is gradual, the loss may not be noticed immediately. But over a period of time this gradual reduction will cause problems relevant to the tasks at hand.

Regular maintenance is therefore most important for an effective lighting installation. The lighting system should not only be cleaned correctly and thoroughly but the cleaning should be carried out at regular intervals. A well designed maintenance programme will maintain the required luminance/illuminance, reduce capital and operating costs and run the system safely. It will ensure satisfactory appearance, security and safety for the users.

However, even with a well designed and operated maintenance programme some loss of light level is inevitable through equipment deterioration. This loss has to be estimated at the time the lighting scheme is planned and an allowance in the form of maintenance factor should be included in the scheme design calculations.

In outdoor lighting situations, surfaces other than the walls and ceilings of pedestrian or vehicular tunnels or underpasses are not normally within the control of the lighting maintenance engineer. This part will therefore concentrate on that part of the installation which is under control.

4.2.1 *Influencing Factors*

There are several factors which can reduce the light output. These are grouped under non-recoverable and recoverable depreciation.

Non-recoverable factors, such as ageing, are inherent in the installation and its environment and cannot be improved during normal maintenance or are uneconomical to overcome. At the specification stage of a lighting installation, these factors should be taken into account together with the planning of a maintenance programme.

If the influence of other factors such as voltage, frequency, temperature and ballast are permanent and significant, then at the design stage the magnitude of these effects should be estimated and an allowance similar to the maintenance factor should be made in the calculations. The influence of random occurrences may be ignored, provided they do not harm the operation of the lighting system.

Recoverable factors of lamp lumen maintenance, lamp survival and luminaire maintenance can be made good during routine maintenance by relamping, cleaning and replacement of components.

The value of such a maintenance programme is indicated as an example in Fig.7. Clearly the depreciation in the unmaintained scheme will fall by around 65 percent of the initial value within 3 years and will continue to decline. But by comprehensive cleaning the decline is checked at under 40 percent depreciation.

Once the non-recoverable reductions by ageing or soiling have occurred the installation cannot be brought back to their original condition and replacement of the outer glazing or even the complete luminaire may be necessary. This is the case with luminaires if they are in say, dusty or oily atmospheres. In such cases it is well worth considering at the design stage, the use of sealed luminaires of high IP ratings, for example, IP 6X.

4.2.2 *Inspection and Recording Intervals*

A regular inspection and performance recording of lighting installations is advisable and is discussed further in **4.4.1** and **4.4.2**. While having a cost, it may well eventually result in cost savings from a more refined maintenance requirement for the environment concerned. Such inspections may also lead to required adjustments in the maintenance procedures, in order to ensure that minimum required lighting performance is maintained at all times.

4.2.3 *Cleaning Schedules and Environmental Pollution Categories*

A regular cleaning schedule of lighting installations, of both internal and external surfaces, is advisable, the frequency of which will depend on:

a) Type of environment;

b) Equipment used; and

c) Design parameters.

In many countries luminaires are classified by IP ratings as per IS 12063, against their ability to deter the ingress of moisture and water. The first integer indicates the particle size that is, fine dust or large grit, the higher the number, the smaller the particle. The second integer indicates the degree of protection to moisture from indirect spray through high pressure jet to total immersion. The higher the number, the better the seal.

The optical compartments of luminaires used in medium or high pollution environments should be of a rating of IP4X or higher.

4.3 Analysis of Depreciation

Several factors contribute to light losses and the effect and magnitude vary with the type of lamp, luminaire, its installation geometry and the environment. For example, areas vary as to the amount and type of dirt in the air; the amount of dirt in the centre of an industrial city is greater than that found in a rural village. But the type of dirt is also important.

The dry dust from a stone quarry is very different from the crop spray and insects on a rural traffic route. It is important to be able to recognize these variations when assessing luminaire types and cleaning requirements.

4.3.1 *Lamp Lumen Maintenance*

The output of all lamp decreases during use. The exact rate, however, depends on the lamp type and ballasting system. The losses due to this effect can be reduced by more frequent lamp replacement, perhaps by group replacement.

Table 14 shows typical examples. It is therefore very important to obtain up-to-date data from the manufacturers for estimating the maintenance factor and the maintenance programme, particularly when using a new type of lamp.

Table 14 Lamp Lumen Maintenance Factors (*LLMF*)
(*Clause* 4.3.1)

Lamp type	Operating time (thousands of hours) 4	6	8	10	12
HPSV	0.98	0.97	0.94	0.91	0.90
MH	0.82	0.78	0.76	0.74	0.73
HPMV	0.87	0.83	0.80	0.78	0.76
LPSV	0.98	0.96	0.93	0.90	0.87
FTL*(Tph)	0.95	0.94	0.93	0.92	0.91
(Hph)	0.82	0.78	0.74	0.72	0.71
CFL*	0.91	0.88	0.86	0.85	0.84

* relates to value at an ambient temperature of 25°C, therefore check location.

NOTE — The lamp abbreviations given in the table relate to the following lamps:
HPSV High Pressure Sodium
FTL Tubular fluorescent
MH Metal Halide
CFL Compact fluorescent
HPMV High Pressure Mercury
LPSV Low Pressure Sodium
Tph Triphosphor
Hph Halophosphate
For specific lamp data, the manufacturers may be consulted.

4.3.2 *Lamp Survival*

Lamp survival factor is the probability of lamps continuing to operate for a given time. The survival rate depends on lamp type and particularly, in the case of discharge lamps, the wattage, frequency of switching and the ballasting system. Failed lamps cause reduction in illuminance and uniformity, but the effect can be minimized by spot replacement of lamps. Table 15 shows typical examples.

Table 15 Lamp Survival Factors (*LSF*)
(*Clause* 4.3.2)

Lamp type	Operating time (thousands of hours) 4	6	8	10	12
HPSV	0.98	0.96	0.94	0.92	0.89
MH	0.98	0.97	0.94	0.92	0.88
HPMV	0.93	0.91	0.87	0.82	0.76
LPSV	0.92	0.86	0.80	0.74	0.62
FTL (Tph)	0.99	0.99	0.99	0.98	0.96
(Hph)	0.99	0.98	0.93	0.86	0.70
CFL	0.98	0.94	0.90	0.78	0.50

NOTE — The lamp abbreviations given in the table relate to the following lamps:

HPSV High Pressure Sodium
FTL Tubular fluorescent
MH Metal Halide
CFL Compact fluorescent
HPMV High Pressure Mercury
LPSV Low Pressure Sodium
Tph Triphosphor
Hph Halophosphate

For specific lamp data, the manufacturers may be consulted.

4.3.3 *Dirt on Lamps and Luminaires*

Dirt on lamps and luminaires will generally cause the greatest loss of light. The amount of light loss depends on the nature and density of airborne dirt, luminaire design and lamp type. Dirt accumulation on reflecting surfaces can be minimized by sealing the lamp compartment against the entry of dust and moisture. Significant benefits can be obtained with the luminaire optical compartment sealed to at least IP5X protection. Table 16 shows typical data for a range of luminaires.

Table 16 Luminaire Maintenance Factors (LMF)
(*Clause* 4.3.3)

Optical compartment IP Rating	Pollution Category	Exposure time (years) 1.0	1.5	2.0	2.5	3.0
IP2X	High	0.53	0.48	0.45	0.43	0.42
	Medium	0.62	0.58	0.56	0.54	0.53
	Low	0.82	0.80	0.79	0.78	0.78
IP5X	High	0.89	0.87	0.84	0.80	0.76
	Medium	0.90	0.88	0.86	0.84	0.82
	Low	0.92	0.91	0.90	0.89	0.88
IP6X	High	0.91	0.90	0.88	0.85	0.83
	Medium	0.92	0.91	0.89	0.88	0.87
	Low	0.93	0.92	0.91	0.90	0.90

4.3.3.1 *Definition of pollution categories*

a) *Low* — No nearby smoke or dust generating activities and a low ambient contaminant level. Light traffic. Generally limited to residential or rural areas. The ambient particulate level is no more than 150 micrograms per cubic metre;

b) *Medium* — Moderate smoke or dust generating activities nearby. Moderate to heavy traffic. The ambient particulate level is no more than 600 micrograms per cubic metre; and

c) *High* — Smoke or dust plumes generated by nearby activities are commonly enveloping the luminaires.

4.3.4 *Long Term Depreciation of Reflector and Diffuser Materials*

4.3.4.1 *Outer glazing - refractors and diffusers*

a) *Glass*

Glass is easily cleaned to restore the original finish.

A lack of long term cleaning can lead to surfaces being more difficult to restore, especially prismatic surfaces. In extreme cases surface damage may result (for example, etching).

Lack of cleaning leads to reduced light output and change in the light distribution by diffusion of the light, resulting in reduced lighting levels and degraded distribution;

b) *Plastics - Acrylic (PMMA - Polymethyl Methacrylate) and Polycarbonate (PC)*

Degradation is generally from dirt and atmospheric contaminants, and material ageing. Inappropriate use or exposure to solvents can produce rapid degradation as the plastic structure is attacked.

Regular cleaning with mild detergent and water will restore clarity. Intense grime should be removed with white spirit or other cleaners specifically formulated for PMMA or PC, and rinsed well. Abrasives and scourers will damage the surface and add diffusion.

Adhesives used in construction or fixing must be compatible otherwise degradation (short to long term) may occur;

c) *Acrylic*

Performs well in the presence of UV. Over the long term (of the order 10 years +) the plastic will have begun to deteriorate by crazing with gradual loss of strength. The component should be regarded as a replaceable item.

The principal drawback is its relative brittleness, lack of impact resistance, where vandalism for example, may be a problem, although toughened versions that improve this characteristic are available; and

d) *Polycarbonate*

The principal advantage over PMMA is its (initially) higher strength and resistance to impact. However, the material degrades in the presence of UV, daylight, and UV emitting lamps. The effect is accelerated by temperature. It is important therefore to keep the material service temperature below around 90°C to 100°C, particularly when UV is present (for example, by ensuring the lamp wattage used in the luminaire is limited appropriately). The degradation can be rapid so the material is normally protected by UV absorbers, either additives integral with the raw material or applied as a surface treatment. These absorbers are used up gradually and only delay degradation, but normally allow a service life of several years.

Degradation results in embrittlement, loss of strength and impact resistance, yellowing and loss of light transmission. The component should be regarded as a replaceable component.

Opal polycarbonate is usually more susceptible to UV as the diffusing additive can increase the radiation absorbed. Surface UV absorber treatment is particularly recommended.

Cleaning is as above, but PC is softer than acrylic and has a poor resistance to abrasion.

4.3.4.2 *Reflectors*

a) *Aluminium*

The reflecting surface of aluminium will degrade by oxidation unless protected. The usual method is by anodizing (a controlled sealed oxide surface), either performed as a separate operation after the reflector is formed, or as a treatment during the production of the aluminium sheet. The film thickness can typically be from 1 micron to 25 micron thick, the thicker the film, the more protection it gives, but the more it diffuses the finish. Lighting grades have anodic films of typically around 2 micron to 3 micron to balance ccrrosion resistance with a wide range of high reflectance surface finishes.

Exposure to a moist atmosphere will lead to surface pitting and a gradual reduction in reflectance and specularity. Dirt ingress will also lead to significant loss of reflectance and specularity with consequent loss of light output and degradation of the shape of the light distribution, leading to poorer light levels and uniformity for example. Protection inside a sealed enclosure is necessary for an acceptable life. Cleaning is then largely unnecessary. If cleaning is necessary, low surface tension water with a special bonded fibre fabric or chamois leather, can be used;

b) *Metallised plastic*

Protection is usually by lacquering the aluminium surface, applying the lacquer by spraying and then curing it by heat. The lacquer may eventually degrade to some extent by yellowing. Operating at too high a temperature (by excessive lamp wattage for example) will accelerate degradation and may also damage the bond between the metallised coating and the substrate.

Cleaning, if necessary, should be gentle without abrasives or solvents to avoid damaging the protective lacquer. In a sealed fitting this should be unnecessary; and

c) *Glass*

Silvered glass is little used now except in specialized applications. The backing on the reflecting surface protects the silver from oxidation; the edges are vulnerable to degradation from moisture, particularly marine, and using such reflectors within a sealed luminaire is appropriate. Cleaning the glass will maintain the reflective properties providing care is taken not to damage the protective backing.

4.3.5 *Dirt on Light Reflecting Surfaces; for example, Arcades, Tunnels and Underpasses*

Dirt on structural surfaces tends to reduce the amount of interreflected light which, in both pedestrian and vehicular tunnels and underpasses, plays an important part in the visual scene. Structural proportions and the distribution of light from luminaires determines the amount of light which strikes the walls and ceiling. Regular maintenance of all reflecting surfaces is advisable in all such installations. Clean surfaces will also maintain the luminance balance in the environment.

4.3.6 *Corrosion of Luminaire Supports*

While recognizing that most supports are chosen for their design strengths, aesthetic factors and overall suitability, it must be recognized that during the life of a structure, periodic maintenance may be necessary.

In general, modern supports have been protected against corrosion. However, the problems of environmental degradation and accidental damage can significantly affect the life and therefore their structural integrity.

A regular programme of inspections should be made where visual and possibly electronic studies are recorded to ensure that appropriate remedial action is taken in advance of any structural decay. Particular attention should be paid to welded steel structures, to planted steel structures and to internal surfaces where corrosion may go undetected. Wooden supports can be equally susceptible to damage from vehicles and inspections should be made at frequencies which coincide with electrical and luminaire maintenance visits and corrective action taken where appropriate.

4.4 Economics of Servicing

During the design of a lighting installation it is often possible to choose components, systems and finishes that will result in the maintenance being kept to a minimum.

a) Choosing luminaires in which the optical compartment is easy to clean and/or has a high IP rating;
b) Reducing the number of variants on a scheme;
c) Using luminaires having few components which, when requiring service, can be easily handled or removed for off-site servicing; and
d) Where applicable, recommending surface finishes that remain clean for long periods and are easily cleanable.

Other ways the designer can help the maintenance and thus improve the effectiveness of maintenance are:

a) Planning for ease of maintenance, considering access, types of tools needed for servicing, ensuring availability of spare lamps, optics or even luminaires. Early liaison with maintenance engineers to ensure understanding of requirements and procedures is also advantageous;
b) Preparing a comprehensive maintenance schedule with instructions;
c) Organizing effective information feedback of mistakes, failures or difficulties and using these to avoid a repetition in future projects; and
d) Using concrete plinths that keep steel structures away from the corrosive effects of the ground.

4.4.1 *Lamp Replacement*

The total lamp replacement costs comprise the cost of lamps and the cost of labour involved, including cost of ordering, stocking, installation, disposal, etc. The labour cost depends on the lamp change system adopted and on the accessibility of the luminaire. The alternatives are spot replacement where each failed lamp is changed or group replacement where all the lamps (failed or good) are changed at some time which is less than the rated average lamp life. In most projects a combined spot/group lamp replacement programme is practised. It is very important that in places where loss of a lamp may lead to unsafe movements that the failed lamp is replaced immediately. Installation of multilamp luminaires are least affected by random lamp failures.

With lamp lumen depreciation, it can also become a waste of energy resources to operate lamps well past their most efficient life cycle.

Costs can be assessed as follows:

Cost of spot replacement per socket C_s is:

$$C_s = L + S + E + D \qquad (8)$$

Cost of group replacement per socket C_g is:

$$C_g = L + B + E + D \qquad (9)$$

where

L = cost of lamp;

S = cost of labour (including initial sighting costs);

B = cost of labour for group replacement per lamp;

E = cost of access equipment; and

D = cost of disposal.

Cost of combined group and spot replacement per socket C_t is:

$$C_t = C_g + FC_s \qquad (10)$$

Where, F = fraction of lamps failed and replaced prior to the relamping interval.

NOTE — Lamps may be bulk purchased and stored for spot replacement. Also spares can be part of initial scheme purchase.

If the good lamps (that is, those which were recovered during group replacement) are used for subsequent spot replacement, then FC_s simplifies to FS.

The economy of group replacement depends on lamp lumen depreciation and heavily on survival rates. The more lamps that survive the replacement interval, the fewer costly spot replacements are needed.

It is important to note that lamp replacement intervals very much depend on the lamp operating hours. Examples of annual burning hours are given in Table 17.

Table 17 Examples of Typical Annual Lamp Operating Hours
(*Clause* 4.4.1)

Installation	Hours/year
Continuous	8 760
All Night (Sunset to sunrise)	4 200
Sunset to 24:00 hr	2 600
Sunset to 22: (5 nights/week)	1 300
4 hrs/week	208

4.4.2 *Cleaning of Luminaires*

The optimum cleaning interval T for a luminaire is reached when the cost of the lost light output equals the cost of cleaning.

The optimum cleaning interval T can be determined from the expression:

$$T = \frac{-C_c}{C_a} + \frac{2C_c}{LMF^{(1)} x C_a} years \quad (11)$$

where

T = optimum cleaning interval;

C_c = cost of cleaning the luminaire once;

C_a = annual cost of owning and operating the luminaire without cleaning; and

LMF $^{(1)}$ = first year rate of luminaire maintenance factor. Values are given in Table 16 Column 3.

NOTES

1. C_c – cost of cleaning includes the cost of any cleaning agent, special tool, platforms or equipment and the labour. The labour costs may also be affected by the timing at which the cleaning is done (during normal working hours or not).
2. C_a – cost of operating includes the amortization installation cost (proportion of capital written off per year), the annual energy cost (derived from energy used in kWh x cost of energy per unit) and relamping cost (cost of lamps and replacement labour per annum).

4.4.3 *Luminaire Supports*

In many outdoor lighting installations, particularly road lighting, the care and maintenance of the luminaire supports is an important part of the overall maintenance responsibility.

For fixed poles, towers or wall brackets, frequent inspections and painting will be necessary, together with occasional monitoring of below ground conditions.

For structures over 20 years old, thought should be given to overall structural stability and to eventual, planned replacement.

Where hinged or winched poles or masts are installed, regular inspection of the ropes and pulleys by a special competent person should be included. The cleaning and lubrication of all moving parts should be a part of the routine maintenance schedule.

Where the accurate alignment of luminaires is of task and/or environmental importance, this too should be checked and corrected as necessary.

4.4.4 *Electrical Components*

Any electrical installation is a potential safety hazard and its regular inspection, maintenance and testing is of great importance, which in many countries is required by law. The replacement of any components must be judged on the potential hazard to the safe operation of the installation. As lighting technology is constantly making advancements, there are many instances where old installations, although operating safely, will benefit from new types of lamps or control systems or even the change of the whole installation. In these cases the investment can be estimated against the potential savings in energy cost and service cost. Another benefit could be in the improvements in the visual environment.

In some situations the group replacement of photoelectric control units (PECU's) may be considered beneficial, especially when combined with a group lamp change.

4.4.5 *Monitoring and Patrolling for Lighting Defects*

As forms of remote monitoring of lighting schemes become more practicable, and their relative expense more cost effective, simple patrolling is likely to decline in use.

However, the cost benefit of remote monitoring or direct patrolling for lighting defects is difficult to assess. In cases where non illumination is a major safety risk then routine monitoring or patrolling is a necessity. In other cases where it could be interpreted as more of a public relations exercise, then other factors must be considered such as encouraging the public to notify the authority concerned. A very effective method is to establish a toll free telephone number or prepaid postcard for the public to use. The local police and/or security forces can also be asked to help in this respect. However, for this to work, it is even more important to have a clear and simple identification system for the various lighting points.

An example of how to establish the optimum frequency of professional patrolling for lighting defects in road lighting installations is given in Annex B.

4.4.6 *Obstruction of Light by Trees*

Tree branches and foliage can pose a continuing problem in achieving proper outdoor lighting. Periodic trimming of trees becomes essential. Field personnel must work closely with forestry organizations and property owners to achieve lighting requirements with minimum visual and horticultural damage to the trees.

In road lighting, the presence of low overhanging foliage may seriously obstruct the light delivered to the road as well as impede traffic movement. Judicious pruning can reduce or eliminate the screening effect. There are instances where pruning increases the average lighting effectiveness by approximately one third, and approximately doubles the lighting effectiveness in the critical areas of low visibility.

4.5 Maintenance Factor

In any lighting design calculation an appropriate maintenance factor has to be included to allow for depreciation. The magnitude of the maintenance factor can significantly affect the lamp wattage and number of luminaires needed to produce the specified luminance and illuminance. High maintenance factors are beneficial for achieving the best safety levels and can be achieved by careful choice of equipment and electing to clean the installation more frequently.

Maintenance factor is defined as the ratio of luminance and illuminance produced by the lighting system after a certain period to the luminance and illuminance produced by the system when new.

Maintenance factor:

$$MF = E_m / E_{in} \quad (12)$$

Where

E_m = maintained luminance/illuminance; and

E_{in} = initial luminance/illuminance.

By calculating the maintenance factor for different luminaires and environmental conditions, and taking into account the proposed maintenance schedule, it is possible to predict the pattern of illuminance in an installation over a period of time.

The maintenance factor is a multiple of factors.

Maintenance factor

$$MF = LLMF \times LSF \times LMF\ (\times SMF)^* \quad (13)$$

* Where appropriate (for example pedestrian subways);

Where

LLMF = lamp lumen maintenance factor;

LSF = lamp survival factor;

LMF = luminaire maintenance factor; and

SMF = surface maintenance factor.

4.5.1 *Determination of Maintenance Factor*

The magnitude of each of these factors varies with lamp, luminaire, environment and time.

For an accurate assessment of *LLMF*, the manufacturer's data should be used. However, some typical data are shown in Tables 14.

For an accurate assessment of *LSF*, the manufacturer's data should be used. However, some typical data are shown in Tables 15.

For *LMF*, considerable research has been done with reference to the degree of sealing (that is, IP rating) of luminaires which is shown in Table 16.

The total maintenance factor can be determined by the following step-by-step procedure.

Step 1 Select lamp and luminaire for the application.

Step 2 Determine group replacement interval of lamps (if applicable) (*see* Table 17).

Step 3 Obtain *LLMF* from Table 14 for period established in Step 2.

Step 4 Obtain *LSF* from Table 15 (if applicable).

Step 5 Determine cleaning interval of luminaires and surrounding surfaces if applicable (*see* Table 2).

Step 6 From an assessment of the luminaire IP rating, environmental pollution category and cleaning interval from step 5, obtain the *LMF* from Table 16.

Step 7 Obtain *SMF* from Table 9 to 11 (Tables of Room Surface Maintenance Factor) for period established in Step 5 (if applicable).

Step 8 Calculate $MF = LLMF \times LSF \times LMF\ (\times SMF)^*$.

* If applicable. Calculate maintenance factor to not more than two significant figures.

Step 9 It is advisable to repeat Steps 1 to 7, by adjusting the various components. so that a range of maintenance programme options are considered at the initial design stage.

4.6 Servicing Lighting Systems

4.6.1 *Safety of Personnel*

Certain procedures and cleaning agents may not be permitted for use under environmental health regulations. It is always advisable to consult the authorities.

Servicing live lighting equipment should be avoided if possible and if necessary, only carried out by well trained persons.

4.6.2 *Access*

It is important that provision is made for access to luminaires for relamping and cleaning. Equipment to help in servicing is discussed in **B-3**.

The maintenance engineers will need to determine how to get at the luminaire, that is, what equipment will be needed; hydraulic platforms, staging, ladders, safety harnesses, etc, and whether the general public will have to be protected. It is vital to ensure that access equipment is so located that the operators can work comfortably and safely on the luminaires. Their arms should not be fully stretched and all vehicles should have suitable safety coning arrangements.

4.6.3 *Cleaning Luminaires*

Extreme caution should be exercised when cleaning all surfaces. Some surfaces are very susceptible to abrasion for example, polished (unanodized) aluminium is very sensitive, as are some plastics, acrylic and polycarbonate in particular.

The maintenance engineers should experiment on a small test area with a method before starting the whole job.

The maintenance engineers should be instructed to take care in handling plastics, as they tend to get brittle with age. Depending on the actual material, the environment and attitude of the site (higher attitudes have an increased ultraviolet content), the light source and the temperature at which the unit operates, plastics may also yellow badly and will need to be replaced.

Aluminium reflectors should be washed with a warm, soapy solution and rinsed thoroughly before being air-dried. Plastic opal or prismatic lenses should be cleaned with a damp cloth (using non-ionic detergent and water) and treated with antistatic polish or spray and allowed to dry. Vitreous enamel, stove enamel and glass optics should be wiped with a damp cloth using a light concentration of detergent in water.

Care should be taken not to seal up luminaires before they are totally dry.

4.6.4 *Cleaning Agents*

Choice of cleaning materials and methods is determined by the type of dirt to be cleaned and the type of material to be cleaned. For plastic materials a final treatment with antistatic substance is recommended.

a) *General cleaning* — The first and most commonly used is a chemical detergent with additives in different concentration levels. It is an advantage to use compounds that require no rinsing after the wash;

b) *Heavy duty cleaning of oil concentrations* — The second type of cleaner is a heavy duty liquid cleaner which may contain detergents, solvents and abrasives. It is useful for the removal of oily dirt. These must be tested to ensure that they do not damage materials or leave deposits;

c) *Excessive oily industrial conditions* — In some very heavy oily applications, such as road tunnels, the use of a high pressure steam cleaner is practical, provided the installation has been designed with this cleaning technique in mind; and

d) *Ultrasonic cleaning* — This is a system in which the items to be cleaned are normally removed from the site and placed within special tanks containing the cleaning liquid and a series of transducers. These transducers produce sound waves that in turn create microscopic bubbles that provide an intense cleaning action over a small area. Normal cleaning times vary between 2-10 minutes. If the item is extremely dirty a pre-clean may be necessary and rinsing afterwards is also required. Its main use is in the cleaning of glass refractor bowls. Care needs to be taken to ensure that this system does not damage the materials being cleaned.

4.6.5 *Relamping*

The maintenance personnel will require instruction on the removal of the lamps so as not to damage the sockets or any components of the luminaire in any way.

If the aiming position of the luminaire has to be disturbed, care must be taken to note and mark its original position so that this can be reset when the relamping has been carried out.

When new lamps are not being put in the luminaires after the cleaning process, the old lamps should be carefully examined and any lamp showing age should be replaced at that time with the lamp specified by the designer. Lamps must be replaced with care so that no damage is caused to the luminaire.

Relamping with new lamps should be done after the luminaire has been cleaned. Generally the replacement lamps should be only those that are recommended by the design of the scheme. However, consideration should be given to potential use of improved lamps and control gear, but their suitability for the luminaire and application must be checked with the installation designer.

4.6.6 *Equipment Disposal*

4.6.6.1 *Disposal of lamps*

Uncontrolled breakage or crushing should be avoided whenever possible and incineration is not a recommended disposal route. However, the producer or subsequent manager of the waste may undertake the crushing of lamps to reduce bulk or allow materials recovery. If recycling is not an option, discarded lamps may be disposed of through a landfill at suitably licensed and contained sites.

Low pressure sodium lamps contain sodium metal, which reacts with water. Hazards to be considered are the potentially corrosive sodium hydroxide solution and the extremely flammable and explosive hydrogen gas, which result from the reaction between sodium with water. These lamps should be broken and reacted with water under controlled conditions prior to disposal in the following manner.

Working in a dry atmosphere not more than 20 lamps should be carefully broken into a large dry container. When the container is not more than one quarter full of lamp debris, the operator should fill it with water from a distance, that is, by the use of a hose. The water will react with the sodium and may be disposed of as a weak caustic soda solution and the glass debris as a controlled waste. These instructions are supplied with each individual lamp. Again, the breaking of lamps should only be carried out under controlled and approved conditions after carrying out a full risk assessment.

ANNEX A

(*Clause* 3.19)

MAINTENANCE FACTOR, CLEANING INTERVAL AND MAINTENANCE EQUIPMENT

A-1 Example of Maintenance Factor Estimation

Site : factory assembling television receivers on the outskirts of a large city

Size : large open area having normal environment

Finishes : 70/30/20 % reflectance of ceiling/walls/floor respectively

Lighting system : slotted top white metal reflector using triphosphor fluorescent lamps

Operation conditions:

Burning hours : 4000 hrs per year with spot changes of failed lamps

Maintenance schedule : cleaning and relamp every two years

From Table 5 *LLMF* = 0.90 for 8000 hours of replacement time *LSF* = 1.00 (as spot change is practised)

From Table 7 *LMF* = 0.80 for two yearly cleaning of type B luminaire

From Table 9 *RSMF* = 0.93 for 6 yearly cleaning of surfaces $MF = 0.90 \times 1.00 \times 0.80 \times 0.93 = 0.669 = 0.67$

If cleaning is carried out annually, the *LMF* = 0.86 and $MF = 0.90 \times 1.00 \times 0.86 \times 0.93 = 0.72$

This makes the installation 7 percent more efficient. This will result in over 7 percent saving in the lighting installation size and the energy consumed whilst maintaining the design illuminance.

NOTES

1. To achieve a specified maintained illuminance various maintenance schedules can be considered and the appropriate factors obtained from the data. All factors relate initial to maintained conditions.
2. It is common practice to carry out lamp change and cleaning at the same time but cleaning of lamp and luminaire between relamping may be beneficial in dirty locations or when a longer lamp replacement period is used.
3. Luminaire Maintenance Factor and Room Surface Maintenance Factor are not related to lamp burning hours.

A-2 Example of Luminaire Cleaning Interval Estimation

Lighting system = 1 200 mm x 300 mm low brightness reflector recessed troffer using two T8 1 200 mm 36 W nominal rated fluorescent tubes operating on high frequency ballast. (The total luminaire power demand is 72 W).

Installed luminaire cost = 100

Life of luminaire = 10 years

Lamp cost = 10 per luminaire

Cleaning cost = 3 per luminaire

Relamp cost = 0.5 per luminaire

Luminaire power demand = 72 W (circuit)

Lamp burning hours per year = 3 000

Relamping intervals = 3 years

Unit energy cost = 0.05 (This should include portion of the maximum demand cost if applicable.)

Dirt depreciation factor for Type B luminaire in normal environment (Table 13) = 0.14

NOTE — All costs are in relative terms. It is important to use real costs based on local circumstances.

Cost of cleaning the luminaire once = $C_c = 3$

Cost of owning and operating the installation per year = C_a

This includes annual energy cost, amortized installation cost per year (including interest on capital) and total relamping cost per year.

$$Annual\ energy\ cost = \frac{72 \times 300 \times 0.5}{1000} = 10.8$$

$$Annual\ installation\ cost = \frac{100}{10} = 10$$

$$Annual\ relamp\ cost = \frac{10 + 0.5}{3} = 3.5$$

and $C_a = 10 + 3.5 + 10.8 = 24.3$

The optimized cleaning interval T is given by

$$T = \frac{-C_c}{C_a} + \sqrt{\frac{2C_c}{\Delta . C_a}}\ years$$

$$T = \frac{-3}{24.3} + \sqrt{\frac{2 \times 3}{0.14 \times 24.3}} = -0.123 + 1.328 = 1.2\ years$$

These luminaires should be cleaned not later than at 14 month intervals. In practice annual cleaning should be practiced with lamps replaced after 3 years.

A-3 Equipment for Maintenance

Time, labour and expense of maintaining a lighting system can be greatly reduced by choosing maintenance equipment with features most suitable to the requirements of each system. Many different kinds of maintenance devices are available to facilitate the cleaning task. The choice of equipment will depend on several factors such as mounting height, size of area, size of doors, lifts and stairs leading to area, accessibility of lighting units and obstacles in the area. Some of the most commonly available maintenance equipment is given in **A-3.1** to **A-3.10**.

A-3.1 *Ladders*

Ladders are often used in lighting maintenance because their low weight, low cost and simplicity make them desirable for simple maintenance tasks. However, safety and mobility restrictions limit their use in some cases.

A-3.2 *Scaffolding*

Portable scaffolding generally has greater safety and mobility than ladders. More equipment can be carried and the maintenance man has a firm platform from which to work. In general, scaffolds should be light, sturdy, adjustable, mobile, and easy to assemble and dismantle.

Special requirements often dictate the type of scaffolding which can be used, for example, for mounting on uneven surfaces or for clearance of obstacles such as tables or machines.

A-3.3 *Telescopic Scaffolding*

The telescopic scaffold provides a quick means for reaching lighting equipment at a variety of mounting heights. This equipment comes in various sizes that have platforms which can be raised and lowered either manually or electrically.

A-3.4 *Lift Truck or Hoist*

Often the quickest and most efficient maintenance device is the lift truck or hoist. Although there are different types available the method of operating is basically the same. The platform can be raised or lowered automatically and, in some types, the truck can be driven from the platform. While the initial investment for such equipment is high, the maintenance savings can be large enough to make this viable. Check that the device can enter the area.

A-3.5 *Disconnecting Hangers (raising and lowering devices)*

Disconnecting hangers lower lighting units to a convenient work level, enabling the worker to maintain them with a minimum of equipment. When a lighting unit is raised into place, the hanger positions the unit and makes the proper electrical circuit connection automatically. An additional safety feature of this type of device is that the electrical circuit is disconnected when the luminaire is lowered. However, installation and maintenance of winches, pulleys and line can be a major item.

A-3.6 *Lamp Changers*

Spot lamp replacement can often be simplified by the use of lamp changers. By gripping the lamps either mechanically or with air pressure, as in a vacuum type, the lamp changer can be used to remove and replace lamps.

A-3.7 *Catwalks, Cranes, Cages, etc.*

Lighting maintenance can be incorporated as an integral part of the lighting system. This can be accomplished in many ways. Luminaires can be maintained from catwalks, cranes or maintenance cages. The catwalks and maintenance cages can be installed alongside each row of lighting units so that maintenance can be performed from them with safety, speed and efficiency.

A-3.8 *Vacuum Cleaners and Blowers*

A blower or vacuum cleaner is sometimes used to remove dust from lighting units. While some of the dirt can be removed in this way, the units still have to be washed at some time. The periodic use of a vacuum cleaner or blower can, however, prolong the cleaning interval.

A-3.9 *Wash Tanks*

It is desirable to have a wash tank specifically designed for lighting maintenance. Tanks should have both wash and rinse sections and be the proper size for the luminaire parts to be washed. Heating units, mounted in each section, are generally desirable. Louvres or reflectors can be set on a rack to drip dry after washing and rinsing while another unit is being cleaned. Special cleaning tanks have been designed for fluorescent luminaire parts and for flexible types of ceiling panels.

NOTE — After cleaning plastic luminaires or optics they will need antistatic treatment to avoid build up of static charges.

A-3.10 *Ultrasonic Cleaning*

This method removes foreign matter from metals, plastics, glass, etc, by the use of high frequency sound waves. Basic equipment consists of a generator, a transducer, and a suitable tank. The generator produces high frequency electrical energy which the tank mounted transducer converts to high frequency sound waves that travel through the cleaning solutions. These waves cause a cavitations effect, that is, the formation of bubbles that grow in size and then violently collapse, thus creating a scrubbing action. This effectively removes dirt from the material immersed in the solution.

ANNEX B

(*Clauses* 4.4.5 *and* 4.6.2)

PATROL VIABILITY , MAINTENANCE FACTOR AND EQUIPMENT

B-1 Patrol Viability Calculations

The formulae below have been devised to help calculate the most cost effective patrol intervals for a road lighting installation. They incorporate cost factors not directly associated with, but affected by the frequency of night patrolling.

a) Patrol costs are likely to vary pro rata to any change in patrol interval; and

b) Repair costs are affected by the patrol interval. Extending the interval increases the number of repairs to be carried out in a given area, thus increasing the working/traveling time ratio. In effect an optimum is reached at about 2.5 percent outages.

B-1.1 *Social Cost Factor (SCF)*

Patrolling is undertaken primarily to reduce the period of time between failure and subsequent repair of a luminaire. The cost effectiveness of patrolling can, therefore, only be assessed when a value is assigned to the cost of a luminaire being inoperative. The cost is equal to the sum of the costs of providing, financing, energizing and maintaining the luminaire. The cost has been termed the Social Cost Factor (SCF).

B-1.2 *Out of Schedule Repair (OSR)*

Much of the theoretical saving achieved by prolonged patrol intervals is, in practice, absorbed by response to sporadic, individual public complaints. Such Out of Schedule Repairs (OSR) increase administration and operational costs and reduce the number of repairs available for the routine repair visit. The cost effectiveness of that visit is, therefore, reduced.

B-1.3 *Patrol Interval Viability Formulae*

a) Patrol cost per luminaire per period =

$$\frac{\text{cost per hour x No. of patrols}}{\text{Luminaires patrolled per hour in period}} \qquad (14)$$

b) Repair cost per luminaire per period =

$$\frac{\text{Cost per day}}{\text{Luminaires repaired per day}} \times \frac{\text{\% outage per period}}{100} \qquad (15)$$

c) Social cost factor (SCF)

$$\text{Annual cost} = \frac{\text{Avg. Capital Cost}}{\text{Anticipated life (Yrs)}} + \text{Maintenance Cost} + \text{Interest on Capital} \qquad (16)$$

Luminaire cost per outage per period

$$= \text{Annual Cost} \times \frac{\text{\% Burning hours in period}}{100} \times \frac{\text{Avg. Outage time in weeks}}{\text{No. weeks in period}} \times \frac{\text{\% Outage in period}}{100} \qquad (17)$$

NOTES

1. Period usually summer or winter, but could be whole year or any part.
2. Avg. outage time = half patrol interval + Avg. repair time (Avg. repair time includes material and cable fault delays).

d) Average cost of out of schedule repairs (OSR) per outage =

(Cost of each unscheduled repair x percentage of repairs done out of schedule) + (Cost of each schedule repair x percentage of repairs done in schedule).

Subtracting the cost of a schedule repair gives the average increased cost per outage due to undertaking OSRs.

The value can be related to a period of time by multiplying by the relevant total percentage outage over that period.

B-2 Example of Maintenance Factor Estimation

Location: Urban motorway on the outskirts of a large industrial city (Medium Pollution)

Lighting system: 12 m twin arm columns equipped with IP65 luminaires utilizing high pressure sodium lamps.

Operation conditions (operating hours): 4 000 hrs (Sunset to Sunrise) per year.

Maintenance schedule: Cleaning and relamp every three years.

From Table 14, *LLMF* = 0.90 for 12 000 hours of replacement time

From Table 16, *LMF* = 0.87 for three yearly cleaning of IP 65 luminaire.

Therefore: *MF* = 0.90 x 0.87 = 0.783 = 0.78

If cleaning is carried out annually, the *LMF* = 0.92 and *MF* = 0.90 x 0.92 = 0.828 = 0.83. This makes the installation 5 percent more efficient. This could result in over 5 percent saving in the lighting installation size and the energy consumed while maintaining the designed illuminance.

NOTES

1. To achieve a specified maintained illuminance various maintenance schedules can be considered and the appropriate factors obtained from the data. All factors relate initial to maintained conditions.

2. It is common practice to carry out lamp change and cleaning at the same time, but cleaning of lamp and luminaire between relamping may be beneficial in dirty locations or when a longer lamp replacement period is used.
3. Luminaire maintenance factor is not related to lamp burning hours.

B-3 Maintenance Equipment

Varieties of equipment for maintenance are described in **A-3**. Out of those Ladders (**A-3.1**), Scaffolding (**A-3.2**), Telescopic Scaffolding (**A-3.3**), Catwalks, Cranes, Cages, etc (**A-3.7**), and Vacuum Cleaners and Blowers (**A-3.8**) are relevant for outdoor lighting systems. Additionally, the following equipment is also used:

Hydraulic Truck — Often the quickest and most efficient maintenance device is the hydraulic lift truck or hoist. Although there are different types available the method of operating is basically the same. The platform can be raised or lowered automatically. Where such equipment is required for off-roadway works, it is important to check that the surface can take the weight of the vehicle.

Hinged Columns (and other raising and lowering devices) — Lowering lighting units to a convenient work level, enabling the worker to maintain them with a minimum of equipment. When a lighting unit is raised into place, the luminaire unit makes the proper electrical circuit connection automatically. An additional safety feature of this type of device is that the electrical circuit is disconnected when the luminaire is lowered. However, installation and maintenance of winches, pulleys and line can be a major job.

मानक : पथप्रदर्शकः

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