भारत सरकार / GOVT. OF INDIA
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GENERAL SERVICES

ELECTRICAL LIGHTING

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PREFACE

The book of "Electrical Lighting" was brought out by Institution of Railway Electrical Engineers (IREE) long back. Since, lot of changes have taken place in the field of Illumination, it has become necessary to incorporate the changes in this volume. Few technological modifications in the field of illumination engineering has been added. Technical literature on latest development in lighting like LED lighting has been included.

For bringing out this book Shri Suryawanshi M.A., Raj Bhasha Superintendent and Shri Sanjay Swarup, Section Engineer have made substantial efforts, under the guidance of Shri D. Ramaswamy, Senior Professor (Academics).

I am delighted to note that lot of efforts have been put-up in bringing out this book on "Electrical Lighting" in the present form. I am sure that this book will serve the needs of Electrical Engineers working in the field of General Services.

Nasik Road
27th April, 2010

A.K.RAWAL
DIRECTOR

ELECTRIC LIGHTING

CONTENTS

1. BASIC LIGHTING TERMINOLOGIES

1.0 BASIC LIGHTING TERMINOLOGIES

* Radiation	:	Is the emission or transfer of energy in the form of electromagnetic waves.
* Light	:	Is any radiation capable of causing a visual sensation on the eye directly. The band of wave length that corresponds to visible light lies between 380 nm and 760 nm (1 nm = 10^{-9} m)
* Visual spectrum	:	The band of wave length that causes a visual sensation. The various color bands 380 nm - 435 nm : violet 435 nm - 500 nm : blue 500 nm - 566 nm : green 566 nm - 600 nm : yellow 600 nm - 630 nm : orange 630 nm - 760 nm : red
* Vision	:	The eye is capable of picking up visual information due to the two nerve fibres present in the retina i.e rods & cones.
* Rods	:	Responsible for black/white vision, called scotopic vision and acts at intensities = 0.035 cd/m2
* Cones	:	Responsible for color vision, called photopic vision & acts at higher values of intensities =>3.5 cd/m2
* Eye sensitivity	:	The human eye is sensitive to different wave lengths (color) with varied efficiency. It is different for scotopic and photopic vision.

* Luminous flux : Quantity of radiant flux (light) emitted by a lamp. The unit is 'lumen'.

* Luminous efficacy : Quantity of light (lumen) emitted for each unit of electrical power (watt) consumed. The unit is 'lumen/watt' (lm/W).

* Illuminance (E) : Quantity of light (lumens) incident on a surface per unit area (m^2). The unit is 'lux' (lumen/ m^2).

* Luminance (L) : Intensities (candela) of light reflected back from a surface per unit area (m^2) in a given direction. The unit is candela/ m^2

* Color rendering : Expression for the effect of an illuminant on the colour of an object in conscious comparison with their color as seen under a reference illuminant (daylight).

* Color rendering index (Ra): Measure of the degree to which the colors of objects illuminated by a source conform to that when illuminated by a reference source (daylight).

* Color temperature : Temperature of the black body that emits radiation identical as the radiation under study. The unit is °K

* Black body : A thermal radiator that absorbs all incident radiations. The emitted radiation corresponds to specific color appearances at a given temperature.

* Glare : A condition which leads to discomfort or a reduction in the ability to see objects, or both, due to distribution of intensities/ extreme contrasts in the field of vision.

* Light output ratio (LOR) : The ratio of the total flux from the luminaire, to the sum of the luminous fluxes of lamps.

* Downward light output ratio (DLOR) : The ratio of the flux emitted below the horizontal plane passing through the luminaire to the total bare lamp flux.

* Color appearance : There are 3 broad categories as :-
  i) 5300°K : cool (bluish white)
  ii) 3300 - 5300°K : intermediate(white)
  iii) 3300°K : warm(reddish white)

* Coefficient of utilization (C.O.U.) : It is the ratio of the lumens reaching the working plane to the total lumens produced. It is also called "Utilisation Factor". C.O.U. depends on, light distribution of the luminaire; light output ratio of the luminaire; reflectance of the ceiling, walls & working plane; room index and arrangement of the luminaires in the room. C.O.U. is based on new, clean equipment and in practice a maintenance factor is introduced to convert initial to in-service illumination.

* Maintenance Factor : The maintenance factors is the ratio of the lumens produced by the system while in service to the lumens produced by system when newly installed

* Room Index (K) : The room index K is a function of the room luminaire and is given as follows

$$K = \frac{L \times W}{Hm \times (L + W)}$$

L = Length of room
W = Width of Room
Hm = Mounting height of the luminaires

* Uniformity Ratio (UR) : It is the ratio of minimum lux in a given plane to the average lux.

* Lamp lumen Depreciation (LLD) : The lumen output of all lamps decrease with use, but the rate of decrease varies widely between lamp types and between manufactures. Lighting calculation must take into account specific depreciation in lumen output of the light source.

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2. LIGHT SOURCES

2.0 INCANDESCENT LAMPS

The incandescent lamp is the oldest electric light source still in general use,. It is also the most varied as regards types. It can be found in almost any application, especially where comparatively small light packages are required and where simplicity and compactness are favoured. The incandescent lamp produces its light by the electrical heating of a wire (the filament), usually tungsten filament to such a high temperature that radiation in the visible region of the spectrum is emitted.

Performance characteristics

Energy balance

Fig. 1 shows the energy balance in an incandescent Lamp. An incandescent lamp operates at about 2800K and emits radiation throughout the visible spectrum with a bias towards the higher wavelengths. The outer glass envelope is filled typically with a mixture of nitrogen and argon whose function is to limit the evaporation of tungsten and also to prevent arcing across the filament. The luminous efficacy of practical tungsten incandescent lamps is always considerably low since most of the radiation is in the infra red range of wavelengths. For example, for modern GLS lamps with a rated operating life of 1000 hours it varies between 8 and 21.5 Lm/W.

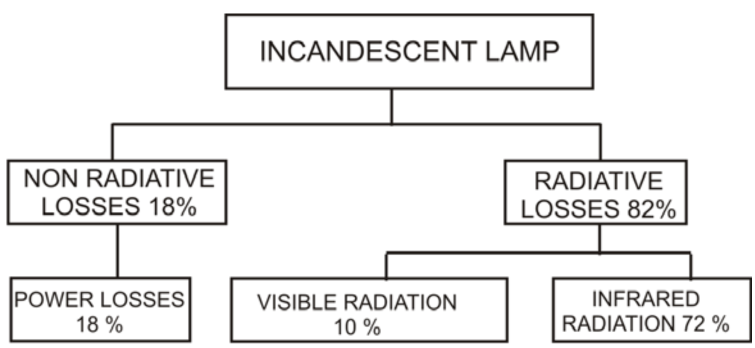


Fig. 1 Energy Balance of Incandescent Lamp

Colour appearance and colour rendering

The normal incandescent lamp with its low colour temperature of around 2800 K, is generally described as having an excellent colour appearance. The radiation emitted by the lamp covers the entire visible spectrum which means that its colour rendering ability, with its Ra of 100, is second to none.

switching

Frequent switching is not normally detrimental to lamp life. It is only when the filament has become critically thin through age that the mechanical strain caused by the rapid temperature change as a result of switching will be sufficient to cause its breakdown.

Dimming

Normal incandescent lamps can be dimmed without restriction. A dimmed lamp will have a lower filament temperature, which results in a lower colour temperature, a lower luminous efficacy and a longer operating life. Thus, the advantage of a longer life is at the cost of efficacy and it is generally better, in a situation where a lamp is almost continually dimmed, to use one of a lower wattage rating. Below 50% of the nominal operating voltage the light output of an incandescent lamp is negligible, but energy consumption is nevertheless still appreciable. It is strongly recommended therefore, that dimmers be used in such a way that switch the lamp off at the point of 50% of voltage

Effect of voltage variations

Any variation in voltage applied to an incandescent lamp causes a change in its operating characteristics. For example a 5% over voltage reduces the lamp life substantially

2.0.1 Tungsten Halogen lamps

Tungsten Halogen incandescent lamp is a comparatively recent development. Although originally designed for use in specialized applications such as flood lighting, studio lighting and projection lighting, it has rapidly penetrated many other areas of lighting application once smaller lumen packages became available.

The high temperature of the filament in a normal incandescent lamp causes tungsten particles to evaporate off and condense on the bulb wall, resulting in blackening of the glass bulb and loss of tungsten material in the filament. Tungsten Halogen lamps have a halogen (eg. iodine, chlorine, bromine) added to the normal gas filling and work on the principle of-a halogen regenerative cycle to prevent blackening. The evaporated tungsten combines with the halogen to form a tungsten halogen compound. This stays in the form of a gas and does not condense at the bulb surface since the temperature of the bulb is high enough (250° C) to prevent condensation. When this gas comes near to the incandescent filament it is broken down by the high temperature into tungsten which is redeposited on the filament, and into the halogen which continues its role in the regenerative cycle.

The main point of difference with a normal incandescent lamp, apart from the halogen additive already mentioned, concerns the bulb. Because the bulb temperature must be high, halogen lamps are much smaller than normal incandescent lamps The tubular envelope is made of a special quartz glass, which is resistant to the high temperatures needed for the halogen cycle to function. The Tungsten halogen lamp operates with an internal pressure above atmospheric pressure.

Since their introduction in 1960 tungsten halogen lamps have made inroads into almost all applications where normal incandescent lamps used to be employed. Advantages of tungsten halogen lamps over normal incandescent lamps are;

- a much longer life time,
- a higher luminous efficacy
- compactness,
- a higher colour temperature and
- a little or no light depreciation with age.

<u>Performance characteristics</u>

Luminous efficacy

The tungsten halogen lamp is characterized by its high efficacy (some 10% higher than that of a comparable normal incandescent) and its almost perfectly maintained light output throughout life.

Colour appearance and colour rendering

Tungsten halogen lamps for normal lighting purposes have a colour temperature of between 3000° K and 3400°K. The source can therefore be described as providing a whiter light, with a correspondingly cooler colour appearance, than that given by normal incandescent.

The tungsten halogen lamp, with its Ra of 100, provides excellent colour rendering.

2.1 TUBULAR FLUORESCENT LAMPS

The fluorescent lamp is a low pressure mercury discharge lamp in which light is produced predominantly by fluorescent powders activated by the ultraviolet energy of the discharge. The lamp, generally is in the form of a long tubular bulb with an electrode sealed into each end contains mercury vapour at low pressure with a small amount *of* inert gas for starting and arc regulation. The inner surface of the bulb is coated with a fluorescent powder or phosphor, the composition of which determines the quantity and colour of the light emitted. In the fluorescent lamps the electrical discharge produced are mainly in the wave lengths of 253 nm and 185 nm, both in the ultraviolet region of the optical radiation. The phosphor coating absorbs the ultraviolet light and re-radiates them into visible part of the spectrum. Initially halophosphates were used as phosphor coatings to make white lamps, but research in phosphor development has lead to development of narrow band phosphors, which separately emit the red, blue and green primary colors (Tri-phosphors). The combination of these emissions then create white light with colour rendering indexRa between 60 to 80 The earlier tubular fluorescents were the T 12 type, whose tube diameter was 1 ½ inches. This was followed by the T 8 version whose diameter is 1 inch.

2.1.1 Compact Fluorescent lamps

These have been developed for use in those applications mainly as a replacement for incandescent lamps. The compact fluorescent lamps (CFL) have very thin fluorescent tubes in various shapes. Some of the types are Twin tube, Quad tube and spiral type lamps. They have an electronic ballast of the basic type inbuilt in them which ensures quick start and higher efficiency. They combine high efficacy and better colour rendering characteristics than the normal tubular fluorescent lamps with low energy consumption and longer life (typically 6000 to 8000 hours as against 1000 hours of a GLS lamp). Their colour rendering index Ra varies between 60 to 80 depending on the type and quality of lamp

Performance characteristics

Energy balance

Fig. 2 shows the energy balance of a 36/40 W (Normal T12 or T8) fluorescent lamp.

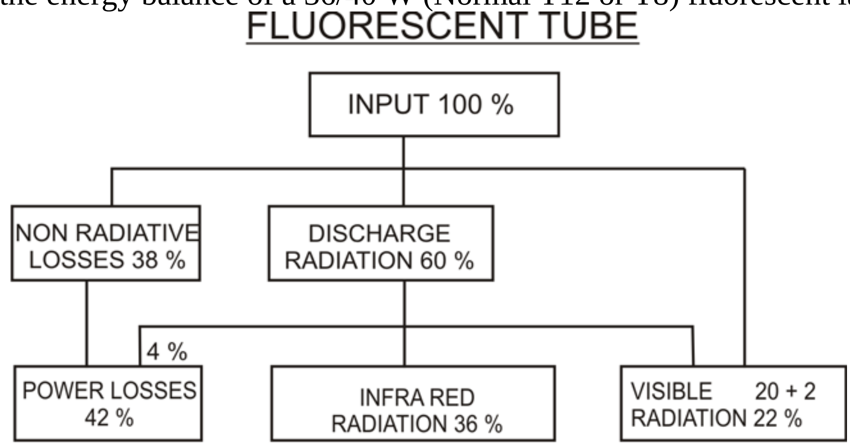


Fig. 2 Energy Balance of Flouroscent Tube

Light output versus ambient temperature

The light output of the lamp reaches a maximum at an ambient temperature of 25°C in still air. At ambient temperature below 15°C the output rapidly decreases, while at temperatures above the optimum also the light output decreases, but at a slower rate.

Luminous efficacy

The luminous efficacy of a fluorescent lamp expressed in terms of system efficacy is influenced by the type of circuitry and the components used. Two factors influencing the luminous efficacy of the lamp itself, besides the phosphors used are the ambient temperature and the frequency of the supply voltage. The luminous efficacy is hence substantially improved by use of high frequency electronic ballast.

Influence of temperature

Just as with the light output, the luminous efficacy of the tubular fluorescent lamp decreases if the ambient temperature is above or below the optimum value. However, since the power dissipated by the lamp also decreases rapidly with increase in temperature, the luminous efficacy will in fact fall off less rapidly than the luminous flux.

Influence of supply frequency

Operation on a high frequency supply will result in an increase of the luminous efficacy of about 10%. This is one of the reasons for employing high frequency electronic ballasts.

Colour characteristics

Tubular fluorescent lamps are available in various combinations of colour appearance and colour rendering index to suit a wide range of applications.

Performance comparison - Tubular fluorescent lamps (36/40 W)

Colour Group	Colour Temp.(K)	Colour Rendering Index (Ra)
	2900	51
	2700	85
Warm - white	3000	85
	2700	95
	3000	95
White	3500	57
	4100	63
Cool - white	4000	70
	4000	85
	3800	95
Day light	5300	98
Cool -	6200	72
Day light	6500	85
	6500	97

Depreciation

During the life of a fluorescent lamp the luminous flux decreases. After 6000 hours it will be between 70 and 90% of the initial value. The main cause of depreciation is that the fluorescent powders slowly become less effective. When mixtures of different fluorescent powders are used, it may sometimes happen that older lamp will show a slight discoloration compared with new ones. A secondary cause of depreciation is the blackening of the tube wall (especially at its ends), by dispersed emitter material. Employing high frequency ballasts will result in less sputtering of the emitter material, which, in turn will give a lower depreciation rate.

2.1.2 Lamp circuits

The fluorescent lamp has a negative resistance characteristic and so must be operated in conjunction with a current limiting device (or ballast) to prevent current runaway.

The ballast, which has a positive resistance characteristic can be :

- a resistor
- a choke or inductor
- an electronic circuit.

Each has its specific advantages and disadvantages, but they have all found practical application in some form.

Inductive ballasts

An inductor choke is the most widely used ballast for normal a.c. applications. In combination with a switch starter, it can also be made to produce the high voltage pulse needed to ignite the lamp.

A practical choke/ ballast consists of a large number of windings of copper wire on a laminated iron core. Heat losses, occurring through the ohmic resistance of the windings and hysteresis in the core, depends upon the mechanical construction of the ballast and the diameter of the copper wire.

Electronic Ballast

Although more expensive, electronic ballasts offer important advantages over conventional choke ballasts, such as :

- Improved lamp and system efficacy
- no flicker or stroboscopic effects
- instantaneous starting without the need for a separate starter
- increased lamp life
- excellent light regulation possibilities
- Higher power factor
- less temperature increase (due to lower losses)
- no hum or other noise
- lower weight, especially for big lamp sizes
- can also be used on d.c.

A popular approach is to rectify the current drawn from the mains supply and convert it into high frequency square wave signal in the range 20 KHZ to 100 KHZ. This square wave is filtered by appropriate harmonic filters depending upon the T.H.D (Total harmonic distortion) required. The improvement in luminous efficacy and characteristics of light depends on the quality of the ballast. A good quality electronic ballast will give rise to high power factor and low T.H.D.

Ignition

The internal resistance of a cold tubular fluorescent lamp is far too high for it to start automatically when the mains voltage is applied. Some sort of aid to starting is therefore, needed to ignite the lamp. Fluorescent lamp circuits can be divided into three groups as far as starting is concerned. Preheat starter circuits, preheat starter less circuits and cold start circuits.

Run up

After ignition, it takes two to three minutes before the mercury vapour in the fluorescent lamp has reached its working pressure. During this period the luminious flux gradually increases to a maximum. However, as the initial flux is about 60% of the final value, this increase will not normally be noticeable.

Reignition

When the lamp is switched off, the vapour pressure drops so quickly that instantaneous reignition will seldom, if ever, pose any problems.

Dimming

Present day dimming equipment for fluorescent lamps is either of the thyristor (chopper) type or of the variable frequency type (HF electronic light regulation).

2.1.3 T5 Fluorescent lamp

The latest development in the fluorescent lamp is the T5 lamp. This lamp has a diameter of only 5/8 "(15 mm) and has an inbuilt electronic ballast of high quality. The main advantage of T5 lamps are very high luminous efficacy between 85 to 90 lumens/watt for the 2'T5 tube and up to 104 Lumens/watt for the 28 W 4' T5 tube. The T5 lamp also a very high power factor greater than 0.85 and colour rendering index Ra of 90

The T5 uses less quantity of mercury vapour in the tube. A coating of calcium nitrate on the inside surface prevents absorbtion of mercury by the walls of the tube thereby prolonging the life of the lamp. The narrow tube along with the powerful electronic ballast substantially improves the luminous efficacies to the range of 90 to 104 Lumens/watt. The life of T5 lamp is between 15000 to 18000 burning hours. Another salient feature of this lamp is its low lumen depreciation factor due to calcium nitrate coating. Even after 12000 burning hours the luminous efficacy depreciates by only 5%. A comparison of T5 tube with T12 and T8 fittings are shown below

COMPARISON OF T5 WITH T12 AND T8 FITTINGS

TECHNICAL DATA

Parameter	T-12	T-8	T-5
Wattage	40w	36w	28w
Length (mm)	1240	1240	1149
Wattage with elect ballast	44w	40w	30w
Lumen output	2200	2350	2900
Efficacy	49	58	104

2.2 HIGH PRESSURE MERCURY LAMPS

In these lamps the discharge takes place in a quartz discharge tube containing small quantity of mercury and an inert gas filling, usually argon to aid starting. A part of the radiation from the discharge occurs in the visible region mainly in the blue and green region)of the spectrum as light, but a part is also emitted in the ultra violet region. By coating the inner surface of the outer bulb in which the discharge tube is housed with a fluorescent powder that converts this ultraviolet radiation into visible radiation, the lamp will give more light than a similar uncoated version. Further the phosphor coating will considerably improve the lamps colour rendering properties.

Working principle

When examining the working of the high-pressure mercury lamp, three distinct phases have to be considered: Ignition, run-up and stabilisation.

Ignition

Ignition is achieved by means of an auxiliary or starting electrode placed very close to one main electrode and connected to the other through a high value (typically 25 k) resistor. When the lamp is switched on, a high voltage gradient occurs between the main and starting electrodes, ionising the gas in the region in the form of a glow discharge, the current being limited by the resistor. The glow discharge then spreads throughout the discharge tube under the influence of the electric field between the two main electrodes. When the glow discharge reaches the farthest electrode, the current increases considerably. As a result the main electrodes are heated until the emission is increased sufficiently to allow the glow discharge to change completely into an arc discharge, the auxiliary electrode playing no further role in the process by virtue of the high resistance in series with it. At this stage the lamp is operating as a low pressure discharge (similar to that in tubular fluorescent lamp). The discharge fills .the tube and has a blue appearance.

Run up

Ionisation of the inert gas having been accomplished, the lamp still does not burn in the required manner or give its full light output until the mercury present in the discharge tube is completely vaporised. This does not occur until a certain time, termed the run-up time has elapsed.

As a result of the arc discharge in the inert gas, heat is generated resulting in a rapidly increasing temperature with the discharge tube. This causes the mercury to gradually vaporise increasing the vapour pressure and constricting the discharge to a narrow band along the tube's axis. With further increase in pressure the radiated energy is concentrated progressively toward the spectral lines of longer wavelengths and a small proportion of continuos radiation is introduced so that the light becomes whiter. Eventually, the arc attains a point of stabilisation at a vapour pressure in the range of 2 to 15 atmospheres and the lamp is said to have reached the point of local thermodynamic equilibrium. All the mercury is then vaporised and the discharge takes place in unsaturated mercury vapour, The run up time which is defined as the time needed from the moment of switch on for the lamp to reach 80% of its full light output is about four minutes.

Stabilisation

The high pressure mercury lamp like the vast majority of discharge lamps, has negative resistance characteristics and so cannot be operated on its own in the circuit without a suitable ballast to stabilise the current flow through it.

Performance characteristics

Energy Balance

The energy balance in a high pressure mercury lamp 400 w is shown in fig. 3.

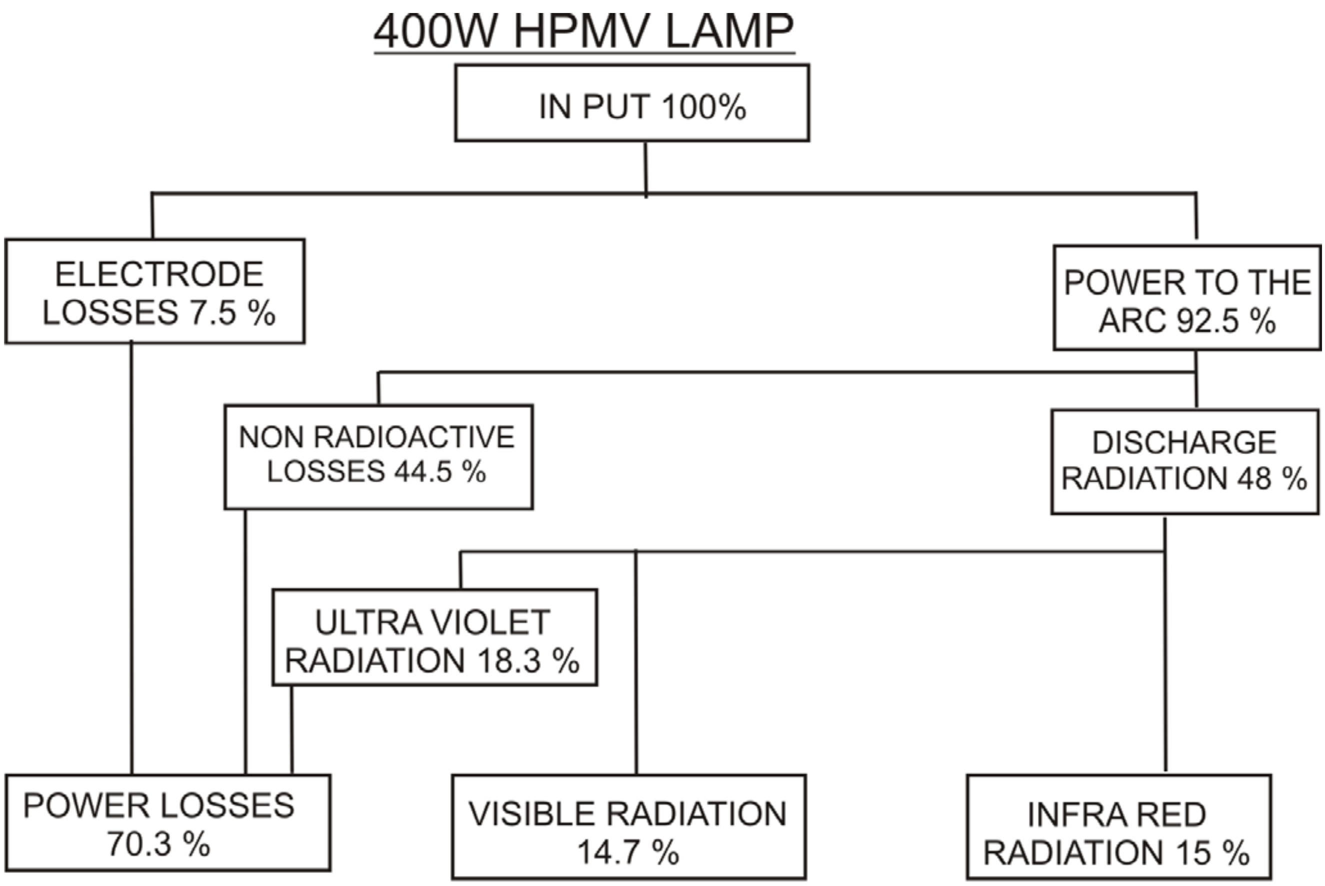


Fig. 3 Energy Balance of HPMV Lamp

External influences

Temperature

The light output, lamp voltage and life of these lamps are not significantly affected by changes in ambient temperature.

Mains voltage fluctuations

The high pressure mercury lamp is often found in those countries where the power supplies on which they must operate are rather poor. Where other lamps, when run on such supplies, may be prone to premature failure or else are unable to function at all the mercury lamp is untroubled :n this respect.

Burning position

The high pressure mercury lamp has a universal burning position.

Reignition

Once extinguished, the lamp will not restart until it has cooled sufficiently to lower the vapour pressure to the point where the arc will restrike with the voltage available. This time, termed the reignition (one-strike) time, is in the order of five minutes.

2.2.1 Blended light lamps

The blended light lamp is derived from the conventional high pressure mercury lamp. The principal difference between the two is that whereas the latter is dependent on an external ballast to stabilise the lamp current, the blended light lamp has the ballast built in the form of a tungsten filament connected in series with the discharge tube. The light from the mercury discharge and that from the heated filament combine, or blend (hence the name) to give a lamp with operating characteristics that are different to those possessed by either a pure mercury lamp or an incandescent lamp.

2.2.2 Metal Halide lamps

The lamps are similar in construction to the high pressure mercury lamp. The major difference between the two types is that the discharge tube of the former contains a number of metal halides in addition to the mercury. Some of the halides used include dysprosium, sodium, lithium and thallium. Some of the metal halide lamps also have in addition phosphor coatings to further improve the colour rendering property of light rendered. These halides are partly vaporised when the lamp reaches its normal operating temperature. The halide vapour is then dissociated in the hot central region of the arc into the halogen and the metal, with the vaporised metal radiating its appropriate spectrum.

Energy balance

The energy balance in a 400 W Metal Halide lamp is shown in fig.4.

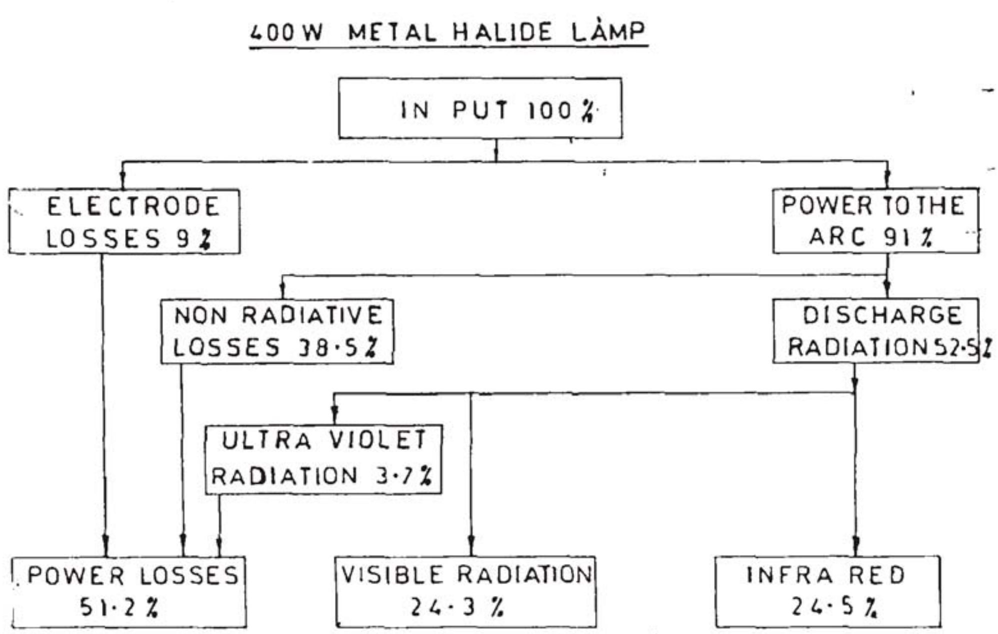


Fig 4 Energy balance of metal halide lamp

The important characteristics of metal halide lamps are
1) Long life of 12000 to 15000 burning hours
2) Good colour rendering index Ra between 60 to 80 depending on the model and type
3) Various types of warm and cool type lamps are available with different co-related colour temperature.
4) Most suitable for high bay fittings , industrial medium and high bay fittings , area lighting and road lighting.
The main disadvantages are
1) High strike and re-strike time of 10 to 15 minutes with traditional ballasts
2) At 40% life, the lumen depreciation is more than 30%
3) Lower colour rendering when the lamp ages

Different colors are produced in metal halide lamps by using various arc tube shapes and metal halide salts. In new lamps these halides need to "burn-in" for approximately 100 hours before they reach their optimum color. This is why new lamps can sometimes be unstable or vary in color.

2.2.3 Uni-form pulse start ballasts

Pulse start metal halide ballasts provide the proper combination of open circuit voltage and high voltage pulses to start the lamp. The pulse is provided by a specially designed ignitor, or starter, that is used in conjunction with the ballast.
As soon as the ignitor senses that the lamp has started, it discontinues the pulsing operation. At this point, the ballast sustaining voltage must be sufficient to maintain lamp operation. High intensity Discharge (HID) lamp ignitors provide a brief, high voltage pulse or pulse train to breakdown the gas between the electrodes of an arc lamp. Pulses can range from several hundred volts to 5KV. Typical durations are in the µsec range. They are usually timed to coincide with the peak of OCV. If they are timed too early or too late, lamps may not start reliably.
A positive feature of this system is that the lamp will hot restart in 3-4 minutes following a power interruption
The purpose of HID ballasts are to
1) Provide voltage to breakdown the gas between the electrodes of arc lamps and initiate starting.
2) Provide voltage and current to heat the electrodes to allow a low voltage, high current arc mode to develop (referred to as glow-to-arc transition, GAT).
3) Provide enough current to heat and evaporate the light emitting components after an arc has been established.
4) Provide enough sustaining voltage to maintain the arc during warm-up and operation.
5) Set lamp current once all the evaporable materials have reached thermal equilibrium.

2.3.1 High pressure sodium lamps

Physically high-pressure sodium lamp is characterized by high pressure in the tube. which is responsible for, the properties of light emitted. As a consequence of the neon/argon gas filling within the discharge tube, the lamp output is initially a red glow slowly becoming monochromatic

The discharge tube in a high-pressure sodium lamp contains an excess of sodium to give saturated vapour conditions when the lamp is running. Mercury is also present to provide a buffer gas and xenon is included to facilitate ignition and limit heat conduction from discharge and to tube wall. The discharge tube is housed in an evacuated protective glass envelope.

They are available with luminious efficacies upto 120 Lumen/watt .They can be used for railway yards where colour rendering is not important. The sodium vapour lamps are now being replaced by T5 lamps and metal halide lamps in railway stations, important railway yards, street lighting, colony lighting etc due to poor colour rendering index Ra of 23

Ignition and run up

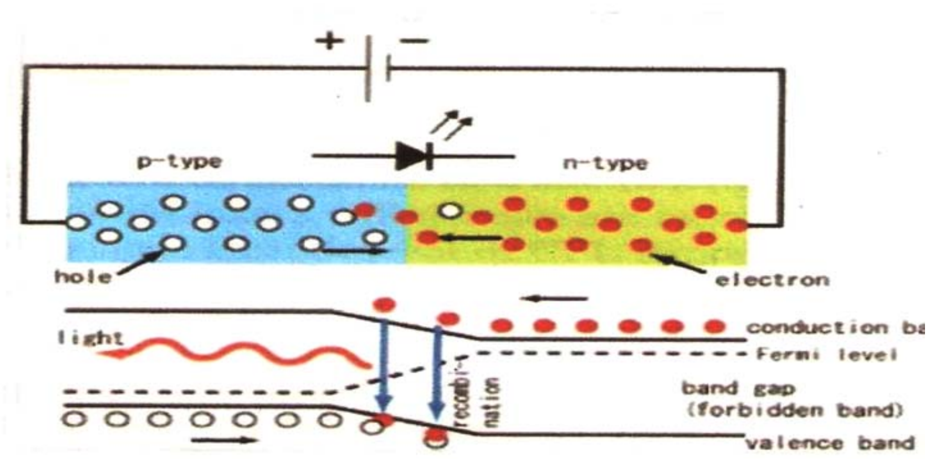
The high pressure sodium lamp must be ignited by a high voltage pulse, typically 1.8 KV to 5 KV depending on lamp type and wattage. Once ignition has taken place, the build up to normal operating pressure and full light output takes several minutes.

Re-ignition

Should the lamp extinguish because of an interruption to the mains supply, the lamp will first have to cool down enough for the vapour pressure in the discharge tube to be such that the sodium atoms can again be ionised by the ignition pulse, and this takes about one minute.

2.4 LED Lamps

Like a normal P-N junction diode the LED consists of a chip of semi-conducting material doped with impurities. When voltage is impressed across the junction, current flows from the p-side or anode to the n-side or cathode but not in the reverse direction. Charge carriers, electrons and holes flow into the junction from electrodes with different voltages. When an electron meets a hole, it falls into a lower energy level and releases energy in the form of photon. The wavelength of the light emitted, and therefore its color depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes the electrons and holes recombine by a non-radiative transition which produces no optical emission, because these are indirect band gap materials. The materials used should have a direct band gap with energies corresponding to near – infrared, visible or near ultraviolet light. A diagram indicating the working of LED is as follows.



The inner workings of an LED

LED development began with infrared devices made with Gallium Arsenide. Advances in material science have made possible the production of devices with ever shorter wavelengths, producing light in a variety of colors. LED’s are usually built on an n-type substrate, with an elecrode attached to the p-type layer deposited on its surface. P-type substrates are also used but less common. Blue LEDs are based on the wide band gap semiconductors Gallium nitride (GaN) and Indium Gallium Nitride (InGaN).

One way to produce white light is to use individual LEDs that emit three primary colors red, green and blue and then mix all the colors to produce white light. This method is involved with electro-optical design to control blending and diffusion of different colours. The other method is to use phosphor material coating to convert the ultraviolet or blue light of LED to broad spectrum white light similar to fluorescent lamp. The phosphor based LED method involves coating an LED of one colour (mostly the blue LED made of InGaN) with phosphorof different colours to produce white light. A fraction of the blue light is re-radiated by the phosphor coating to light of longer wave lengths. When several phosphor layers of different colours are applied, the emitted spectrum is broadened effectively increasing the CRI value of the LED. The phosphor method is the most popular technique for manufacture of high intensity white LEDs.

One of the key advantages of LED lighting is its high efficiency as measured by light output per watt. Research has made it possible to commercially produce LEDs with efficiency of about 130 lumens per watt which is better than that of any other light source. It should be noted that high power LEDs are necessary for practical general lighting applications. High power (one watt) LEDs have been developed for practical general lighting operations. LEDs have several advantages over other light sources . The main advantages are :

1) Long burning life of more than 60,000 burning hours
2) High luminous efficacy of 120 lumens per watt
3) Wide variety of color LEDs have been developed which are suitable for canopy and façade lighting

However when power LEDs are used suitable design of thermal management should be made so that the junction temperature increase is kept within specified limits. The LED should have a proper electronic driver circuit to drive the LEDs with constant current. If it is not driven by constant current the light output will depreciate when the LED burns for more time and will not give the desired performance.

Currently the price of LED luminaries are still high. Recently street light fittings of 36 watt and 60 watt have been developed by reputed manufacturers which have good potential for street and colony lighting. Continuous research is in progress in various countries in the field of LED lighting and the future for LED lighting is indeed very bright.

3. ILLUMINANCE CALCULATION

3.0 LUMEN METHOD

The idea of a lumen method of interior design had been proposed earlier, but it was not until 1920 that M/s. W. Harrison and E.A. Anderson introduced a standardised procedure which include both direct and reflected lumens. This gives a simple solution to the problem of providing average horizontal illuminance.

By definition,

Illuminance (lux) = Luminous flux/Area (Lumens/Sq.Mtr.).

To obtain this average illuminance we need to determine the total luminous flux reaching the work plane. This flux is composed of two components:

- Flux which comes directly from the luminaire to the work plane (direct component).
- Flux which is reflected from room surfaces and reaches the work plane (reflected component).

In the Lumen method the fraction of the initial lamp lumen which ultimately reaches the work plane both directly and from reflection is called co-efficient of utilisation (C.O.U.). It should be realised that C.O.U. includes both, the efficiency in room surface in redirecting these lumens to the work plane.

The C.O.U. is the function of three factors:

- Room surface reflection.
- Room size and proportion.
- Luminaire (efficiency and intensity distribution).

For example, if a particular luminaire has C O.U' of 0.70, then 70% of the lumens produced by the lamp would reach the work plane and 30% of the lumens would be lost, some would be trapped inside the luminaire and others would be absorbed by the room surfaces, such as walls, floors. These factors will be examined individually.

Room surface reflectance

All surfaces in the room (walls, ceilings, floors, furniture, machines, and people) absorb and reflect light. If these surfaces are highly reflective, less light is absorbed and more light is reflected back into the space. Since some of the reflected light will eventually reach the work-plane, luminaires will perform more efficiently in rooms with high reflectance surfaces than in rooms with surfaces of low reflecting value.

Room size and proportions

Except from a totally indirect system, light travels directly from the luminaire to the work-plane while other light travels to the walls where some is absorbed and some reflected towards the work-plane. In small rooms, a larger percentage of the total light produced by the luminaires strikes the walls than in large rooms (fig. 1).

Note that in the small room a large part of the light from the luminaire strikes the walls wheras in the large room, some light from the end luminaire hits the wall, but the luminaires in the centre send all their light to the work-plane. This means that luminaires have a higher C.O.U. in large rooms than in small rooms since a larger percentage of the total light produced by the systems goes directly to the work plane.

Luminaire (efficiency and intensity distribution)

The design and light distribution characteristics and efficiency of the luminaire also affect the C.O.U. It depends upon the following factors:

- Light distribution of the luminaire.
- Efficiency and light output ratio.
- Spacing to mounting height ratio.

Determination of C.O.U.:

1. Get the C.O.U. table from the luminaire manufacturer for a particular luminaire,
2. Find out the room index (K) of the room:

$$K = \frac{L \times W}{Hm\ (L + W)}$$

where L = length of the
W = Width of the room
Hm = Mounting height (Distance between the centre of the luminaire to the working plane

3. Select reflectance factors depending upon the colour of the walls, ceiling or working plane.
4. Knowing K and wall reflectance, ceiling reflectance and work plane reflectance, C.O.U has to be read from the photometric data sheet which is given below:

Coefficient of utilization (C.O.U.)(Typical data for a luminaire provided by manufacturer)

C.O.U. calculated in accordance with IS: 3646 (Part 3) – 1968

Room reflectance		Room Index										
F	C	W	0.60	0.80	1.00	1.25	1.50	2.00	2.50	3.00	4.00	5.80
10	70	10	.56	.62	.67	.71	.74	.78	.79	.82	.83	.85
		30	.52	.59	.63	.68	.71	.75	.78	.79	.82	.83
10	50	50	.55	.61	.66	.70	.73	.76	.79	.80	.82	.83
		30	.52	.58	.63	.67	.70	.74	.76	.78	.80	.82
10	30	30	.52	.58	.62	.67	.69	.73	.75	.77	.79	.80
		10	.49	.53	.60	.64	.66	.71	.74	.76	.78	.79

C.O.U = D.C + U.C

D.C = Downward co-efficient

U.C = Upward co-efficient

C.O.U = (LFU x DLOR) + (UFU x ULOR)

LFU = Lower flux utilance

DLOR = Downward light output ratio

UFU = Upward flux utilance

ULOR = Upward light output ratio

In the IS 3646 Part II for each type of fitting classified under the BZ class (BZ1 to BZ10) the values of LFU as well as UFU are given for particular room index values. The LFU values and UFU values are different for different reflectance factors for ceiling , floor and walls. Type of fitting should be given by the manufacturer. Generally a metal halide high bay fitting comes under BZ1 class and fluorescent tube fitting falls between BZ5 and BZ6. The classification of the BZ class is based on the intensity distribution based on the polar curve.

The values of DLOR and ULOR is the ratio of downward output fraction to upward output fraction which depends on the luminaire. The C.O.U value is now calculated.

INITIAL LUMEN OUTPUT

$$\text{Illuminance} = \frac{\text{Luminous flux} \times \text{C.O.U.}}{\text{Area}}.$$

This illuminance corresponds to the initial value of the brand new lighting installation.

Maintained illuminance

We are interested in average maintained illuminance rather than average initial illuminance, we must include a light loss factor (maintenance factor) in our calculation. Hence, the equation becomes:

$$\text{Illuminance} = \frac{\underline{\text{Lamp Lumens}} \times \text{C.O.U.} \times \text{M.F.}}{\text{Area}}.$$

Maintenance Factor (Light Loss Factor)

Total light loss is divided conventionally into unrecoverable and recoverable losses and the light loss factor should include as many of each of these as are quantifiable.

Recoverable losses

There are four recoverable losses:

a) Lamp Burnouts (LBO)
b) Lamp Lumen Depreciation (LLD)
c) Luminaire Dirt Depreciation (LDD)
d) Room Surface Dirt Depreciation (RSDD)

a) Lamp Burnouts

It may not be feasible to replace a lamp every time one burn out. If burnt-out lamps are not replaced immediately, the average illuminance level will be tolerated in a given installation before they are replaced. Then the LBO factor is the ratio of the number of lamps remaining lighted to the total number of lamps, when the maximum number of burnouts is reached.

b) Lamp Lumen Depreciation

The Lumen output of a lamp decreases as it ages. The LLD factor is generally taken at the 70% life point for high intensity discharge lamps, and fluorescent lamps. Lamp lumens at 70% life is divided by the initial lamp lumens to obtain the LLD.

c) Luminaire Dirt Depreciation

The greatest loss of light output is mainly attributed to the dirt on the lamp and the luminaire reflecting surface. It depends upon following two parameters:

- Type of the luminaire (either the luminaire is enclosed or open, whether or not it is having louvres or diffusers etc).
- Degree of dirtiness of the luminaire environment (very clean, clean, medium dirty, very dirty).

d) Room Surface Dirt Depreciation

Dirt on room surfaces reduces the reflected component of luminous flux and thus the illuminance on the work plane. The resulting RSDD factor is a function of the dirtiness of the environment, the time between cleanings, the luminaire flux distributions, and the room proportions.

Unrecoverable factor

a) Luminaire Ambient Temperature (LAT)

Fluorescent lamp and luminaire ratings are established in still air at 25°C. Furthermore, fluorescent luminaire photometry is relative in that the luminaire output is adjusted for a 25°C lamp operating temperature. In an actual installation, the luminaire operating temperature is likely to differ from the test condition. Operation above or below the test value decreases lumen output . For example, if the operating temperature for a fluorescent luminaire is 30°C, the lamp output would decrease by about 7.5%, giving a temperature correction factor of 0.925. There is no significant variation with ambient temperature for incandescent and HID Lamps.

b) Voltage at the Luminaire (VL)

Deviations in supply voltage from rated value can affect the light output of all types of lamps. A 1% change in voltage causes a 3% change in-lumen output for incandescent lamps.

c) Luminaire Surface Depreciation (LSD)

Effects such as yellowing of plastic with age and pitting and discoloration of enamel overtime can cause a reduction in light reflected within the luminaire and transmitted through the diffuser. No numbers are available for this factor.

d) Ballast Factor (BF)

Ballast factor is the ratio of the lamp lumens when the lamp is operated on its ballast to the rated lamp lumens determined on a standard lamp and ballast testing circuit. Commercial Ballasts do not generally perform as efficiently as test ballasts.

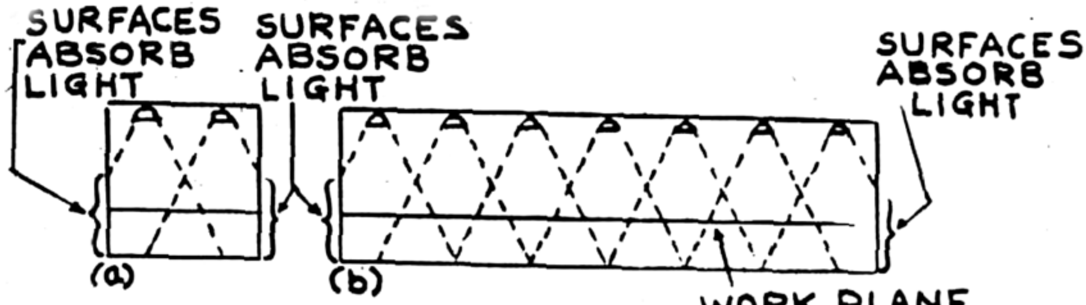


FIGURE-2 FIGURE-1

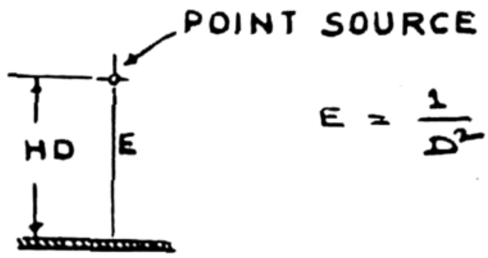


FIGURE-2A

Illuminance Calculation

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4. LIGHTING FOR OFFICES AND EDUCATIONAL BUILDINGS

4.0 INTRODUCTION

People working in today's offices spend just as much of their time on telephone and in communicating with the computer and office colleagues as they do reading and writing. Each of these tasks has its own specific visual requirements and it is necessary that the lighting be designed accordingly. Moreover, since feelings of well being, interest and enthusiasm, which are so important to productivity, are affected by the office environment, it is clear that the lighting should be designed to make 'this as pleasant as possible.

4.1 GENERAL RECOMMENDATIONS

Illuminances

Levels

For the vast majority of office tasks, the "working plane is usually horizontal at a height of between 0.75m and 0.85m above floor level. The recommended average illuminances on this plane for various types of office interiors are given in IS:3646 (Part-II) 1992.

Research into the illuminances preferred in working interiors has shown that there is no value at which everyone is satisfied. Added to this is the fact that various office tasks are often being performed simultaneously in one and the same office.

Clearly, each individual should be able to decide for him or herself exactly what level of lighting is needed at a given moment, provided that this can be arranged without causing disturbance to others. Such control, ideally should be possible from the desk or work station concerned, and can be achieved by either switching or dimming individual luminaires.

Uniformity

In the case of general lighting, the ratio of the minimum to the average illuminance (Emin/ Eav) should be greater than 0.8.

In the case of localised general lighting or local lighting plus general lighting, the average illuminance in non-working areas should normally not be less than 50% of the level for the working areas, with a minimum of 350 lux.

The ratio between the average illuminances for any two adjacent areas (eg. Office and adjacent corridor) should not exceed 5:1 and the area with the lower level should have an illuminance of at least 150 lux.

4.2 LUMINANCES

Excessively large differences in luminance in an office can create visual adaptation problems or, in extreme cases, glare. Conversely, if the luminance differences are too small, the surroundings will appear dull and uninteresting. Both these effects can be avoided by ensuring that the luminance ratios in the field of view are proper.

The luminance ratio between the visual task itself and its immediate background (viz. the desk) should be smaller than 3:1, but greater than 1:1.

Some recommended luminances are listed in the table below:

Surface	Luminance (cd/m^2)
Walls	50-150
Ceiling	100-300
Task area	100-300

The above recommendations can be satisfied by adhering to the reflectance ranges listed in the table below:

Surface	Reflectance
Ceiling	0.7 or above
Walls	0.5-0.7
Partitions or screens	0.4-0.7
Floors	0.1-0.3
Furniture and equipment	0.2-0.5
Window shades	0.4-0.6

4.3 GLARE CONTROL

Glare is experienced if lamps, luminaries, windows or other areas are too bright compared with the general brightness . Glare is defined as a condition of vision in which there is discomfort or a reduction in the ability to see significant objects or both due to an unsuitable distribution of intensity or extreme contrasts in range of luminance in the field of vision. Glare index is a number representing the amount of discomfort glare in a lighting installation to which upper limits are given for variety of room sizes and surface reflection factors. For an office the permissible glare index is given as 19. The glare index for interior spaces where light fittings with equal spacing are provided can be obtained with the help of photometry data and IS3646. The glare increases when the glare index is more.

4.4 LAMP COLOUR

4.4.1 Colour appearance

The choice of the colour appearance of the lamps employed in a particular office depends on the illuminance level, the presence or absence of daylight, climatic conditions and, of course, personal preference.

The lamps normally employed in interior lighting may be divided into three groups according to their colour appearance as described by their colour temperature.

Correlated colour temperature (CCT)	Colour appearance
> 5300 K	Cool (bluish white)
3300 - 5300 K	Intermediate (white)
< 3300K	Warm (reddish white)

Research has indicated that a higher colour temperature (colder colour appearance) is preferred at higher lighting levels, and that in the absence of day light, a low colour temperature (warm appearance) is preferred. In warmer climates, the personal preference is usually for higher colour temperatures, while in cooler climates the preference is more for low colour temperatures.

Light sources should not be mixed without first establishing that their colour appearances match.

4.4.2 Colour rendering

Light sources with a colour rendering index (Ra) of at least 80 are recommended for all offices.

4.5 LIGHTING FOR VDU WORK-STATIONS

In general, the visual requirements for office lighting listed above are equally valid, for video-display-unit work-stations for both word processors and CAD systems. However, there are certain additional features that have to be taken into account when planning the light if visual performance and comfort are not to be impaired.

4.5.1 Reflections

In the first place, the screen of the VDU constitutes an important, additional part of the task area and light sources such as luminaires and windows that reflect in the screen can produce a-considerable deterioration in the legibility of the characters.

Such reflection can best be minimised by taking into account the position of VDU workstations and light sources in relation to one another at the initial planning stage. But care in the choice of the lighting installation can also help to obviate this problem.

Both indirect and direct lighting systems can be used, the best choice depending on the height of the room, the type of VDU and the sort of luminaire screening.

4.5.2 Indirect lighting

Good indirect lighting employing uplighters creates more or less equal brightness on walls, ceiling and furniture. There will therefore, be no bright spots to cause reflections in the screens of the monitors or VDUs. This means that, at least as far as the artificial lighting is concerned, these can be moved about at will.

But indirect lighting does have certain disadvantages'

- The luminaires and ceiling become dirty sooner. Some of the dust collecting in the Iuminaire is carried upward by the warm air currents to settle on the ceiling. The lighting level is thereby reduced, as is the efficiency of the installation.
- In low-ceilinged areas, the ceiling brightness will be uneven, creating reflectors in the VDU.
- The very uniform lighting is devoid of shadows, which is not natural.

4.5.3 Direct lighting

Generally speaking, direct lighting is more efficient and does not get dirty so quickly as indirect lighting. Moreover, the heat from the (recessed) luminaires can be drawn away via. the ceiling, keeping the heat loading in the room to a minimum.

The degree of freedom allowed in the sitting of the VDUs with direct lighting will depend on the type of screen involved-where dark-screen (positive screen) monitors are in use. Strict requirements are placed on the luminaire screening employed. This should be such as to give a very directional downward light distribution, so lessening the chance of the luminaire causing reflections in the screen. But this also means that they produce quite high contrasts (highlights and deep shadows) on the objects illuminated whilst leaving the walls in relative darkness and such illumination creates a rather sombre impression

Where coated, light-screened VDUs are employed, on the other hand (which is generally the case), minor or prismatic luminaires giving a broader light distribution can be chosen without the risk of producing disturbing reflections. Such lighting is more acceptable in terms of the modelling effect produced.

Where high ceilinged areas are concerned (3.5m and above), pendant luminaires providing a combination of direct and indirect lighting offer a suitable alternative for both types of screens. However, especially with dark screens, it is still necessary to ensure that the ceiling does not exhibit great differences in brightness. And the "screening” of the direct component of lighting should also be critically examined.

4.5.4 Illuminance level

The choice of the correct illuminance at the workstation is very important. If it is: too low, it will reduce visual performance for conventional work, while if it is too high it can result in a reduction in character contrast on the VDU screen Excessive jumps in luminance between the documents and the screen must also be avoided if adaptation problems are to be avoided.

Research and experience indicate that the optimum illuminance will lie somewhere between 400 lux for light screens and 250 lux for dark screens.

4.6 OFFICE TYPES

4.6.1 General offices

General (Fixed) Lighting

Most general offices are moderate to large and their layout is seldom fixed: office furniture is re-arranged from time to time, and partition walls may be added, shifted or removed. One way of ensuring that all work positions will be adequately illuminated, no matter what the office layout, is to install a system of general lighting in which luminaires (surface mounted or recessed) are arranged in a regular, fixed pattern over the ceiling

If the building is designed with provisions for the future erection of partition walls along the axis of its modules, the lighting arrangement should be planned with this possibility in mind. This normally means that the layout of the luminaires will be a function of the modular building structure and window spacing.

Two feet T5 luminaires (4 x 14 W) with suitable reflectors and screening are ideally suited for equally spaced light fittings for general office lighting

Flexible lighting

Energy savings can be obtained by employing a flexible approach to the design and use of the lighting. There are two alternatives namely: lighting controlled by switching and/or dimming and task lighting with uplighters. A further possibility is supplementary local lighting, which allows the level of general lighting to be reduced.

Desk lights (decorative or otherwise) fitted with incandescent lamps are not really suitable, not only are they insufficient, with high heat emission, but they also create a far from uniform luminance distribution over the task area.

It is better to employ desk-mounted reflector luminaires equipped with (compact) fluorescent lamps. These have the broad, even light distribution needed for an even luminance distribution, and the heat emission is negligible. They should be mounted above the line of sight (viz, higher than 0.6m above the desk-top) and equiped with an adequate louvre to screen the lamp(s) from view. Adjustable (pivoted) luminaire mounting is appreciated because it allows for easy repositioning for various tasks.

These lighting systems should be carefully planned if an irregular, and possibly unpleasant luminance pattern is to be avoided. The local lighting should, of course, allow a task to be performed in comfort for all possible positions of the worker, and the low-level general lighting should provide approximately 50% of the total task illuminance

4.6.2 Drawing offices

As drawing involves the accurate discrimination of fine detail, the illuminance in drawing offices should be at least 1000 lux.

Ceiling reflections can occur on the surfaces of drawing boards that are badly positioned with respect to the luminaires. The easiest way of minimising such reflections is to position the boards accordingly.

Disturbing shadows and all forms of glare can be avoided by using luminaires that have a large luminous area.

The problem of providing suitable lighting is much simplified if it can be arranged that all occupants of the office face one way, and the office layout is limited to fixed rows of work positions. Rows of fluorescent luminaires can then be mounted parallel to the direction of view on both sides of the drawing boards. With this arrangement the absence of any luminaire directly above a given work position serves to keep glare and ceiling reflections to a minimum, while the lighting coming from both sides of a worker effectively eliminates hard shadows.

4.7 EDUCATIONAL BUILDINGS

The visual environment in an educational building, apart from providing the comfortable seeing conditions needed for the performance of a wide variety of work tasks, must also satisfy the psychological and emotional needs of learners. Good lighting can enhance pleasant and attractive surroundings, stimulate learning and influence behaviour in a positive way.

Educational buildings are usually designed to be lit by day light. Whenever and wherever possible, lighting controls should therefore ensure that the artificial lighting can be easily adjusted to suit the prevailing daylight conditions

4.7.1 Class-rooms

In a conventional class-room the window wall will be parallel to the direction of view (ideally to the left of the students). Good, glare-free lighting can then be provided by employing low-brightness or well screened ceiling luminaires arranged in parallel rows running parallel to the window wall. The rows should be spaced sufficiently far apart to allow the rows of desks to be positioned between the rows. This last precaution serves especially to reduce reflected glare from the work surface.

The Black board should be "provided with its own lighting system in which both direct glare and ceiling reflections in board are eliminated. The simplest arrangement is to have one or more fluorescent luminaires mounted on the ceiling and screened from the students so as to light the board at an angle of not less than 60° from the normal to any part of its surface.

Where necessary window blinds can be employed to prevent reflected glare from windows occurring in the Black board and to eliminate sun on desks. These same blinds, perhaps, in conjunction with a dimming device for the artificial lighting, will in any case be needed if it is planned to use the class-room for slide /film shows.

Depending on the depth of the class-room it may be necessary to arrange that the luminaires remote from the window wall can be switched on independently of the remainder of the installation to compensate for fading day light.

4.7.2 Lecture Halls

In lecture halls and auditorium day light is often shut out altogether and there is complete dependence on artificial lighting. The following points may be mentioned as being of importance in such areas.

- Reading and writing require an illuminance of more than 300 lux, preferably 500 lux
- Special care has to be taken to prevent glare.
- Equipment for dimming the lighting during demonstrations, film and slide shows has to be provided.
- Local lighting is required near the chalk board.

Ideally a control panel should be installed at the lecturer's position to enable him to switch the various groups of lights on and off, operate the dimming equipment, and possibly control also an automatic projection system.

It is important that careful attention be paid to the provision of emergency lighting and exit lighting. Steps and stairs should, also be equipped with local orientation lighting.

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5. LIGHTING FOR HOMES

5.0 INTRODUCTION

In the past, the approach to home lighting was to accept the traditional control pendant light-point, and then ask where the supplementary lighting, if any, should be located. Today, the reverse is more likely to be true: first we meet the local requirements, and then ask whether anything more is desirable.

Although it is accepted that home lighting will always remain a sector in which personal taste plays a dominant role, there are nevertheless certain points on which useful guidance can be given.

5.1 TRAFFIC ZONES

The 'Traffic Zones' in and about the home are the various door-ways, the hall, landings, passages and staircases. These zones need special attention as far as the lighting is concerned, for it is here that many accidents attributable to poor vision conditions occur. It is a matter of providing ample, glare-free lighting, with the right shadow effects. In the entrance hall a welcoming atmosphere is also most important. In general, lighting of special features (eg. Pictures, tapestries, sculptures) is more effective than overall general lighting.

5.2 PRIMARY INDOOR AREAS

5.2.1 The living-room

There is no other room in the home to compare with the living-room as regards the number and diversity of the activities taking place there. Talking, reading, and watching television are the main ones, but writing and, of course, eating can also take place in the same room. In fact the living-room is the very heart of the home, which is sufficient reason to light it well

Because of its many different uses, the keynotes of the lighting must be flexibility combined with aesthetics. There should be light fittings for all occasions, and it should be possible to use them all, or only a few at a time, at any chosen brightness and intensity according to the needs of the moment.

<u>Orientation (Ambient) lighting</u>

A single ceiling mounted luminaire can provide the ambient lighting. But this should not be the only lighting in the room. This is because the eye is always attracted to the highest brightness, and if this is found in the centre of the room, the space will be perceived as being 'around this centre', and thus smaller. Also since all walls will be of very similar brightness, the volume of the room will be weakly rendered by the lighting.

<u>Reading</u>

Reading demands a relatively high illuminance, the correct amount depending upon the age of the reader. Generally speaking, 400 lux should be considered a minimum on the visual task (viz. book, magazine etc.).

The traditional floor or standard lamp in all its simplicity is excellent. It provides an abundance of light upwards (ambient lighting) and permits comfortable, close-up reading. But energy-saving lamps can also be used: for example a suitable CFL lamp, or the new generation LED pin type lamps can give excellent results.

Work like knitting and embroidery calls for more or less identical lighting to that outlined above, although if anything it should be slightly more intense.

Writing

Writing, whether in the living-room or elsewhere, demands adequate local lighting. But here also, some form of ambient lighting should be present. The luminaire providing the local lighting should be relatively large: the shadows will then be smaller, with softer contours.

The incandescent lamps employed for reading are good (no reflector lamps), but a PL 11W lamp is perfect with lots of soft light, from a source that is just the right size for the job.

Conversation (sitting corner)

Conversation is one of the main activities in the living room. The lighting should therefore facilitate eye-contact and model faces in a pleasant way.

Good ambient lighting is usually sufficient to provide eye-contact. But the need for modelling means that the light should come from more than one direction. A couple of floor or table lamps or pendent luminaires with large, diffusing screens will provide the required lighting harmony in a sitting corner.

With dimmmers, the general lighting level can easily be adjusted to create the required mood or atmosphere.

Watching Television

Watching television in the dark is very strenous on the eyes. A luminaire should therefore be placed on or close to the TV set, or else the surrounding wall area should be lighted by, say, a spot aimed at a painting.

Out-door contact

The happy few having a living room looking out into a garden can make use of this to increase the visual size of the room. At night, the garden windows acts as a black mirror, and the lighted interior is seen strongly reflected in it. Lighting the garden attracts the eye to faraway brightnesses and gives an impression of increased space in the room, even where there are net curtains across the window.

5.2.2 Dining room/Dining area

Many (if not the vast majority) of homes do not have a separate dining room, but a dining-area that forms part of the living room. The approach to the lighting is the same in both cases.

A feeling of intimacy can be emphasised by concentrating the light on the dining table instead of uniformly lighting the entire area or room. However, the faces of the diners should be included as well. A single luminaire suspended above the table is the usual solution, although with bigger tables, two or three small, matching luminaires might be used. Suitably screened Luminaires with a glass or fabric shade providing some direct lighting on the faces are to be preferred. However care must be taken to avoid glare.

The provision of a dimmer is useful in enabling the lighting level to be adjusted to suit the occasion or task, or simply to leave the table corner lighted when not in use, as a part of the living-room 'landscape'.

5.2.3 Kitchen

The kitchen is in fact a sort of work-shop and therefore needs virtually shadow-free general lighting. This should reach all surfaces, not only the horizontal work surfaces, but also the vertical ones to facilitate the task of finding things in the cupboards.

Additional local lighting may be needed to fill in the shadows cast by cup-boards and/ or by the occupant(s) of the kitchen standing at the work surfaces.

The lighting, both general and local, must be such as to make it easy to discern even slight colour differences in the food. This means, of course, that all the lamps should have a high colour rendering index (Ra> 80). At the same time, the colour appearance created by the lighting should be in accord with that in the rest of the house.

For the breakfast bar or corner, now customary in many larger kitchens, an attractive luminaire on a separate switch would be appropriate.

5.2.4 Bedroom

Main Bedroom

Besides general lighting, local lighting will be required to provide adequate illumination for the dressing-table and for reading in bed.

The dressing-table can perhaps best be lighted using two vertically mounted low-brightness luminous panels, one on each side of the mirror.

Good bed-head lighting is provided by twin wall-mounted luminaires having a medium-spread light distribution and individually adjustable and switched to suit individual requirements.

Children's Bedrooms

Children prefer to have more lighting. Dim light often preferred by older people for relaxation, might well prove frightening for young children. But long harsh shadows and glaring, unscreened lamps must be avoided.

For the teenager's room, adjustable spotlights on a power track in combination with adjustable clip-on spots that can be placed anywhere in the room offer good lighting flexibility.

Guest room

Although a more straightforward approach may be adopted to the lighting, the guest-room is in principle similar to the main bedroom. Pleasant and well-thought-out lighting will be appreciated by the guests and help make themselves feel 'at home'.

5.2.5 Bathroom

The main needs in the bathroom, as in the kitchen, are for good general lighting of the interior as a whole, and local lighting.

The general lighting should be strong enough to penetrate the shower curtain or screen. It can be provided by a separate ceiling mounted luminaire (out of reach of anyone standing in the bath), but adequate general illumination is usually provided by the local lighting at the mirror above the wash-basin. This should direct light toward the person and not into the mirror. It should be as shadow-free as possible, which means using large-surface luminaires, preferably mounted vertically on both sides of the mirror.

Safety regulations

- A wall mounted on/off switch must be positioned outside the room.
- Any switch in the bath-room must be of the pull-cord type.
- No socket outlets other than shaver-sockets designed for use in the bath-room

- Light fittings must be enclosed, steam/condensation-proof and positioned (fixed) where they are unlikely to be splashed.

5.3 SECONDARY INDOOR AREAS

The other spaces and rooms in a home - the loft, the cellar, the hobby room, the shed and the garage - call for functional lighting (providing good seeing conditions), with longer burning hours and a higher efficiency than the decorative lighting found elsewhere in the home.

Tubular fluorescent tubes preferably T5 lamps in robust industrial type luminaires are ideally suited for use in these kinds of areas.

5.3.1 Hobby room

The hobby room, preferably decorated in light tones, should be equipped with general lighting giving good colour rendition (i.e. R_a - 80)

The luminaires can be mounted in the centre of the ceiling, but it is often better to have localised lighting (500-1000 lux) concentrated over the work-bench or table. For very difficult tasks (small details), an adjustable table lamp giving more light or light from several directions is a convenient solution.

A power-track in the hobby room can be very handy, not only as a means of obtaining a flexible lighting system, but also to serve as a power-supply outlet to allow various electrical tools to be used wherever needed.

5.3.4 Garage

A well-lighted approach to the garage will make it easier to avoid unexpected obstacles in the drive, such as bicycles and carelessly abandoned toys.

The basic need inside the garage is for orientation lighting, but this should be positioned with the size of the car in mind so as to allow inspection of the engine when the car bonnet is raised as well as illuminating the open boot.

If the garage is equipped with a work-bench, this should have its own lighting.

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6. LIGHTING FOR HOSPITALS

6.0 INTRODUCTION

Lighting requirements in hospitals vary in the different areas of the hospital and depend also on a wide range of visual conditions needed by the various users; patients, doctors, nurses and cleaners. In some cases, the requirements of the medical staff predominate, in others, comfortable lighting for the patients is of greater importance.

Colour, both that produced by the light sources and that reflected by the surroundings, is particularly important. Firstly, it can help ensure the best conditions are created for treatment and examination purposes - for instance, where the diagnosis of a patient's condition may be related to the colour, or change in colour, of the patients skin. Secondly, it is a factor of psychological significance in reducing the clinical appearance of the hospital and suggesting a more friendly atmosphere, which will contribute towards the recovery of the patient.

Interference free lighting should be provided in those areas where the use of radiation -sensitive electronic equipment is anticipated.

Emergency lighting should be installed in all internal traffic areas and exits and all other areas where life and safety would be endangered by the absence of lighting.

6.1 HOSPITAL WARDS

In ward areas the visual needs of the patients themselves and the medical and cleaning staff have all to be considered. Patients should be able to read and do handiwork in or next to their beds, to rest or sleep without being disturbed by any discomfort glare, and to safely move around the room by night as well as by day

Where fluorescent lamps are concerned, the colour of the light should be selected with care. In those areas where a homely atmosphere is wanted, and where medical examination is not critical, perfect colour rendering is not needed and a lamp colour appropriate to the climate can be chosen: warm-white colour 83 for hospitals in colder climates and cool-white colour 84 for hospitals in the tropics. In those wards where medical examinations are performed and better colour rendering is needed, colours 93 and 94 respectively are to be preferred.

The ward lighting should be installed in such a way as not to cause any discomfort glare to the patients-especially those whose field of view may include only the ceiling and the direction of the medical staff

6.1.1 General lighting in wards

The general lighting in the ward should be sufficient to allow routine medical and domestic duties to be properly performed. The indirect lighting is preferred for this purpose, which is often incorporated in the bed-head luminaires should provide an illuminance of between 100 and 200 lux. There should be a light switch located at the door-way.

6.1.2 Local lighting over the beds

This should be sufficient to provide good illumination for reading, handiwork etc. Illuminance at the bed-head should be between 100 and 300 lux over the full width of the bed. The luminance of the luminaires as seen by both patients and medical staff should not exceed 350 cd/m^2, and heat radiated by the source should be as low as possible. There should be a light switch located within easy reach of the patient.

6.1.3 Examination lighting

If examination or treatment of the patient cannot be carried out in an appropriate room, supplementary luminaires may be used in the ward. The lamps, which should be so screened that only the bed is illuminated, should give a minimum illuminance of 1000 lux. The light source should also have the desired colour rendering properties.

6.1.4 Night lighting

Night lighting should be sufficient to provide the minimum amount of light necessary for nurses and patients to find their way about during the hours of darkness. This corresponds to an illuminance of 1.0 lux at floor level. It requires that the lamp be adequately screened.

6.1.5 Night observation lighting

Night lighting intended for the observation.of patients should cause the minimum disturbance to other patients in the ward. An illuminance of 5 to 20 lux, restricted to the bed-head, is recommended. The light switch, located at the bed, should not be within reach of the patient.

6.2 CORRIDORS

The lighting in corridors should be related to the lighting in adjacent rooms so that there is no difference in illuminance when passing from one to the other. This often means that provision must be made for reducing the illuminance in the corridor at night-time.

In those cases where the corridor does not receive sufficient natural light during the day time, the artificial lighting in the corridor should facilitate visual adaptation by providing a rather high luminance on the wall opposite the door of a room that is illuminated by day light.

An asymmetrical lay-out of luminaires along corridors is less disturbing to patients who are being wheeled along the corridors on trolleys The day time illuminance should be 200-300 lux. This can be reduced during night time to 5-10 lux in corridors open to bed-bays and 10-50 lux in all other corridors.

6.3 EXAMINATION ROOMS

Examination lighting should be planned to accommodate a wide variety of possible visual tasks. This is normally achieved using a combined system of general and local lighting. The general lighting and the local lighting should be matched, as closely as possible, for colour temperature. The illuminance of the former type of lighting should be between 500 and 1000 lux.

6.4 THEATRE - SUITE LIGHTING

The lighting of the operating theatre calls for a delicate balance between the very special lighting used to light the centrally placed operating table and that providing the illumination in the remainder of the theatre.

The operating luminaire is designed to give shadow-free lighting of very high illuminance on the table variable in intensity between certain prescribed limits. The illuminance provided by the general lighting should be in the order of 1000 lux in order to always keep luminance differences within the theatre to an acceptable maximum.

The colour of the general illumination in an operating theatre should also be compatible with the illumination from the operating light, that is to say the colour temperature of the two sources should match as closely as possible. The preferred source for the general theatre lighting is the tubular fluorescent lamp having a colour temperature of around 4000 K and the best possible colour rendering. Luminaires should be of the multi-lamp recessed type, equipped with mirror reflectors to give maximum light output and low source luminance.

The illuminance level given by the general lighting in the other rooms comprising the theatre suite, viz. surgeons[1] and nurses' changing rooms, scrub room, sterilising room and necessary room, should be at least 50% of that given by the general lighting in the theatre itself in order to facilitate visual adaption when passing from one to the other. Colour rendering should be the same throughout the suite.

6.5 INTENSIVE-CARE ROOMS

The illumination here must be suitable for a wide variety of visual tasks. Furthermore, the lighting system should include provision for changing the illuminance level quickly in order to satisfy emergency conditions.

General illuminance should be variable from 300 lux down to almost zero. The preference is for ('TL' colour 84 or 94. Supplementary luminaires are needed to provide the localised lighting used for examination and treatment purposes portable surgical luminaires (operating lights) should also be available.

Curtains are needed to protect adjacent patients from illuminances that are disturbingly high.

For psychological reasons, the lighting in the intensive care unit should be as similar as possible to that in the ward.

6.6 X-RAY ROOMS

Rooms where x-ray examinations have to be carried out must be lighted according to the examination method adapted. For normal x-ray photography, no special demands are placed on the lighting, but where image intensifiers or television systems are in use it should be possible to reduce the general lighting to between 10 and 30 lux. Where direct observation of the screen is involved, orientation lighting giving no more than about 10 lux should be provided.

For the positioning of patients and for the purposes of room cleaning, a dimmer-controlled general lighting installation that gives an illuminance of 100 lux will suffice. Other tasks e.g. the giving of injections, will require localised lighting.

A pleasant, restful environment can be created by adding some decorative lighting for example a wall luminaire giving a low, comfortable level of lighting.

6.7 OTHER ROOMS

A hospital will usually have many other rooms in addition to those mentioned above. There will probably be laboratories, offices, lecture theatres, reception areas, therapy rooms, children's wards, incubation rooms, kitchens and a variety of service and communication areas. The lighting for these rooms and areas is, however, the same as that for similar areas in other buildings.

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7. INDUSTRIAL INTERIOR LIGHTING

7.0 INTROOCUTION

Industrial lighting covers an extremely wide range of different working interiors and work tasks from small workshops to huge factory halls and from the fine precision work often carried out in the former to the heavy industrial tasks generally associated with the latter.

The design of a work place may make the task of lighting the workplace easy; on the other hand, there may be obstructions formed by awkwardly-shaped machines to contend with. Again, the work itself may be easy to light, or it may impose certain special requirements on the lighting: such as, for example, freedom from producing reflections or, conversely, the deliberate creation of these to bring out surface detail or reveal imperfections in surface finish.

Careful attention has to be paid to these and other aspects of lighting, which includes the need to study the cost effectiveness of the various lighting systems available. This can maximise productivity, minimise accidents and save on operating costs, whilst also helping to promote the comfort and well being of the worker.

7.01 GENERAL

Protection and safety

In humid areas, luminaires affording protection against the ingress of water are needed, while in dry environments, the luminaires will have to be dust protected. In either case the IP classification of the luminaire employed will have to be considered

In areas where lamps or luminaires can be touched, electrical safety is specially important and in areas where explosive gases, vapours, or volatile liquids may be present, the luminaires will need to be of the type suitable for use in hazardous areas.

Environmental requirements

When called upon to operate in areas where the ambient temperature is very low, as in frozen food plants or cold storage ware-houses, special care should be taken to avoid problems with lamp starting and light output. This is more critical with tubular fluorescent lamps than with most high-intensity-discharge lamps. With incandescent lamps, this problem does not arise.

In areas where the temperature in the vicinity of the luminaires is high, as in foundries and steel mills, it is important to ensure that the working temperature of the ballasts is not exceeded.

7.02 LIGHTING LEVELS

Recommended illuminances for various interiors and tasks are given in IS: 3646 - (Part I) .1992. The illuminance values in the table are maintained illuminances. The mean value of the illuminance at the task location must not be lower than the illuminance indicated, irrespective of the age of the installation. Those tasks not covered by the above tables must be dealt with by experiment or by comparison with a task of a similar nature, the recommended illuminance for which is known.

7.03 LIGHTING SYSTEMS

There are three systems of lighting used in industrial interiors: general lighting, localised lighting and local lighting. Only general lighting and localised lighting may be used on their own. Local lighting is a back-up system, which may be used to supplement the main lighting as and when required.

General lighting

It is designed to produce a more or less uniform illuminance on the working plane throughout the area involved. Uniformity is generally considered adequate if the ratio of the minimum to the average values at any given work position is not less than 0.8. Lighting with this degree of uniformity will generally ensure complete freedom in the placement of machinery and work benches. It is achieved by employing a more or less regular array of overhead luminaires.

The choice between tubular fluorescent and high pressure or metal halide lamps for the general lighting will be influenced primarily by the mounting height available. This can, of course, vary considerably from one type of-industrial interior to another. For the purposes of lighting design, it is convenient to divide mounting heights into four groups according to the type of building involved.

Mounting height (M)	Typical industrial premises
2.5 - 3.0	Multi-storey office-type building
3.0 - 4.0	Single or multi-storey factory building
4.0 - 7.0	Single storey factory building
Above 7.0	High-bay factory hall.

Mounting height 2.5 - 3.0 M

Many modern light industries are housed in multi-storey buildings that architecturally have much in common with office blocks. These generally have smooth, white ceilings, which can serve as extended reflectors for the purpose of obtaining a better diffusion of the light and an improved luminance pattern.

Just as in offices, therefore, the best compromise between good lighting quality and efficiency in use is offered by fluorescent lighting. Where the layout of the work-stations is not known in advance or is subject to change, the overhead luminaires can either be arranged in equally-spaced rows or in a regular grid pattern so as to produce the desired lighting level throughout the interior. Energy efficient T5 luminaires are ideal for this purpose. On the other hand, where the work lay-out is permanent, it is possible to employ a rather more economical asymmetrical lighting arrangement that provides lower lighting levels in circulation areas.

Because of the limited mounting height available, special attention should be paid to the control gear, especially where VDU screens are used. This means employing well-screened luminaires. And where rows of luminaires are employed, these should run parallel to the windows and at right angles to the viewing direction of the workers.

Mounting height 3.0 - 4.0

For mounting heights upto 4.0 m, lighting employing reflector luminaires housing tubular fluorescent lamps again normally offers the best solution.

The luminaires are usually arranged in continuous or broken rows running parallel to the windows and the viewing direction and at right angles to the rows of work benches or machines. This both prevents troublesome shadows from being cost on the visual task and reduces the possibility of light being reflected into the eyes of the operators. The alternative arrangement in which the lines of luminaires with well shielded lamps run at right angles to the viewing direction gives an overall impression which is usually more restful It is not always possible, however, to gain the benefits of both these arrangements simultaneously. Usually, good viewing conditions at the working plane are more important than a pleasing overall impression. Modern energy efficient T5 fittings of 4 feet length or 2’length can be used. Surface mounted suitably screened fittings can be used to limit the glare.

In situations where the relocation of working areas is usual, the use of trunking systems containing the wiring for the luminaires is recommended. Single or twin-lamp luminaires can then be positioned on the rails of the system to provide the appropriate amount of light as and when required.

Mounting height 4.0 - 7.0

Single-storey industrial buildings of this height usually have a flat or saw tooth-shaped roof pierced by window openings, or side windows high up in the walls. Whatever the kind of work, however, it is necessary to add artificial lighting, even during daylight hours.

The usual solution is to employ reflector type fluorescent lamp luminaires in rows running either at right angles or parallel to the windows. For the lower roof heights these are mounted against the ceiling or the underside of the roof structure, while at greater heights, they are suspended from the roof. Dimmable high-frequency fluorescent lighting with day-light-dependent control can be an economic solution where day light levels are high. Energy efficient T5 luminaires are ideally suited as fluorescent lights for this purpose. Modern reflector type (4Nos x 2’T5) are also suited with equal spacing. Uniformity factor also improves with the use of more number of 2’T5 fittings.

An alternative to tubular fluorescent luminaires where the mounting height is about 6 metres is to employ a lesser number of more powerful metal halide lamps spaced farther apart. This leads to major economies in installation, operation and maintenance. However, care should be taken to maintain an acceptable lighting uniformity and to avoid the harsh shadows produced by employing too few light points.

The lamps which can be used are of three types: high-pressure mercury, high pressure sodium and metal halide. However due to poor colour rendering qualities, presently high pressure sodium lamps are not used except in general ware houses where colour rendering is of no importance. Even though high pressure mercury lamps can be used, metal halide lamps are ideally suitable due to their better luminous efficacy and better colour rendering index.. These lamps are housed in so-called high-bay reflector luminaires, the reflector of which, provides the desired degree of light concentration and also serves to shield the lamp from sight at normal angles of view. This shielding, together with the fact that the luminaires are normally well above the normal line of sight, means that glare is easily avoided.

Narrow-beam luminaires of this type are employed to advantage in those interiors where good light penetration is needed in order to illuminate floor areas between tall, closely placed items of machinery, piles of packing cases, and so forth. Wider beams are used in those areas where tall vertical surfaces, such as control panels and storage racks, have to be clearly visible.

Mounting height > 7.0 M

Where very high single-storey structures are concerned the light sources usually have to be mounted high up. This is done to keep them clear of the guide rails of traveling cranes or similar machinery ,because the equipment in the workshop is very tall.

The vast majority of installations employ rows of conventional high-bay luminaires. These have a symmetrical, narrow beam or wide light distribution, and house high-intensity (HID) lamps (metal halide, high pressure sodium or high pressure mercury) of upto 400W. Metal halide luminaries are best suited for this purpose in most of the workshops and industries due to their better colour rendering.

The flood light, with its more sophisticated optics capable of producing a symmetrical light distribution and housing HID lamps of 1 KW or more, comes into its own where it is necessary to create high illuminances on very high vertical surfaces.

From the technical as well as from the economic and maintenance points of view, all these light sources are well suited to these types of installations.

Localised lighting

On those interiors where the arrangement of the work position is permanent, the use of localised lighting in preference to general lighting can sometimes lead to advantages in terms of increased worker comfort and reduced maintenance and energy costs.

The luminaires should be concentrated relatively low above the work areas so as to provide the higher illuminances at these points whilst providing at the same time an adequate level of lighting in the gangways where orientation is required. Special care should be taken to ensure that the luminance of the environment as a whole does not suffer due to the limited amount of general lighting.

Local lighting

The requirement for certain types of task with regard to lighting level and lighting quality can be so stringent that it is neither technically feasible nor economically viable to satisfy these requirements by employing a system of general lighting alone. Where localised lighting is also unable to provide a solution, the answer is to install local lighting.

Local lighting is designed to illuminate the area occupied by the visual task, and its immediate surroundings. Local lighting is also employed to increase the illuminance at work positions that, due to the presence of obstructions (including the worker himself), are not sufficiently well lighted by the general lighting.

From the point of view of maintaining the desired brightness balance in the area of a visual task and in the visual field beyond it, it is advisable to look upon local lighting as a useful supplement to general lighting but never as a substitute for it.

7.04 SPECIAL TASKS IN INDUSTRY

Manufacturing processes often consist of tasks which, for economic or technical reasons, require special visual attention. In order to achieve optimum visual conditions for carrying out of a particular task, the task has first to be analysed. In most cases, the best way to determining the actual visual requirements is by attempting to carry out the task oneself. It will then soon become clear whether better lighting is necessary or not.

Once the visual requirements are known, the main problem is solved. The next requirement is usually the creation of the necessary contrast between the details to be distinguished and the background agSainst which they are to be seen.

For certain manufacturing processes and for the inspection of certain products, the normal general lighting system does not meet up with these requirements. In such cases, special solutions have to be found.

Some examples of certain tasks that call for the use of additional lighting aids are listed in the table given below:

Task	Lighting aid
Inspection of small objects or the assembly of minute mechanical parts or electronic components	Such tasks can often be simplified by the use of an illuminated magnifying glass.
Checking of dimensions.	This is often done by projecting a much enlarged image of the object on to a screen.
Inspection of machined parts while they are in motion.	The use of stroboscopic lighting may offer a very satisfactory solution. The frequency of the stroboscopic flash can be adjusted such that the object illuminated appears to be stationary.
Inspection of certain materials.	Objects made from certain materials, such as glass, can best be inspected under monochromatic light. Low pressure sodium lamps provide such a light.

Table: Examples of Industrial lighting aids

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8. MARSHALLING YARD LIGHTING

8.0 INTRODUCTION

Marshalling yard covers a huge area in thousands of square metres and comprises hundreds of metres length of rail tracks and innumerable junction points. During the hours of darkness, the men who keep things going in this extensive area are busy at various tasks. They can only work efficiently and safely if adequate lighting for visual tasks are available even after sunset,

8.1 MECHANISM OF MARSHALLING YARD

To gain an insight into the lighting problem involved in shunting of railway wagons, one must have some idea of how this is done and how a marshalling yard is equipped.

A marshalling yard acts as clearing house for the wagons which have to be distributed over different tracks. In this way, trains are made up of wagons having the same destination. Thus, in principle, every marshalling yard consists of a main feed line which spreads out fan-wise in a number of tracks on which the various trains are made up for number of destinations.

There are two types of marshalling yards - one with flat switching and the other with hump switching.

On a flat marshalling yard the wagons for a certain track are pushed off by the shunting engine accelerating for a moment and then suddenly braking. For pushing off of each wagon or cut off wagon, the engine has to make a short run again and again.

On a yard with a high shoulder of grounds, also called the hump, the cut off wagon is pushed with constant speed against the crest of the hump. Just before reaching the crest the wagons are uncoupled by a shunter with the aid of the hook. The wagon thus released, drops down by their own weight on to the track, being switched on the correct line for which the wagons are destined.

In smaller shunting yards the switches are mostly operated on the spot by the shunter; while the modern marshalling yards with hump are equipped with marshalling cabins having operation panels representing the entire grid of tracks, on which every wagon in motion is indicated. The switching operation is done from the cabin for directing the wagons as per the desired destination track. On being pushed away and also being released from the hump the wagons often gather too much speed. Marshalling yard with a shunting hump is usually equipped with a braking bridge for the braking of the wagons, which is operated from the marshalling cabin.

8.2 VISUAL TASKS & ILLUMINANCE REQUIREMENT

More and more work in marshalling yard is concentrated in a few key-points like top of the shunting hump, around the braking bridge and around the area where the switches are located. However, to facilitate the intensive scale shunting and assembling of trains, to improve productivity by speedy movement, to reduce accidents, to allow safe movement of wagons and railway personnel and to have better security and reduction in personnel and reduction in theft, it is essential to light up the entire marshalling yard having glare free general lighting. The recommended average illuminance in a marshalling yard varies from 10 to 20 lux. Of much more importance than the illuminance in marshalling yards, is the creation of bright images by reflection of the light sources in the surface of the railway tracks. These gleaming tracks afford a clear contrast between the rails and the surroundings;

an interruption in gleaming tracks indicate the presence of the wagons and other obstacles and movement of wagons is also much more easily observed in this way. The obstacles are observed as silhouette without details.

8.3 HUMP AREA

Special attention should be given to the lighting of the hump area. Operation must have a clear view in both directions without glare so that the chalk numbers on approaching wagons, the setting of the points and the amount of clear track left in each of the train sidings etc. can be seen easily. Viewing from the hump area, vertical plane illuminance also becomes important in assisting the identification of wagon markings or judging the speed of approaching or receding wagons.

The recommended value of illuminance in the vertical plane is 30 to 50 lux. This can be achieved by low or medium height installations", where broad beam asymmetric floodlights are most appropriate.

8.4 DESIGN CRITERIA

The performance of all above activities and achievements of quantitative and qualitative requirements of lighting call for various illumination engineering techniques like choice of type of installations, luminaires and light sources, aiming of luminaires, maintenance, etc.

8.5 SYSTEM OF MARSHALLING YARD LIGHTING

Different railways have adopted lighting system depending upon the size and complexity of yard, which can be divided broadly into the following types.

- High Tower lighting system -
- Distributed lighting system
- Gantry lighting in main areas
- Combination of the three to cover different areas.

There are no simple thumb rules for deciding the use of a particular type of installation. A careful analysis of many factors is necessary' in the context of the specific requirements and the particular local conditions. However, the major requirements of high tower installation is the high efficacy light source and narrow beam floodlight luminaire.

8.5.1 High Tower Lighting System

The recent experiments have indicated that there are many advantages in extra height of tower. Some of the advantages of high tower installations may be listed as follows:

- Large areas can be illuminated from relatively few positions, thus minimising the amount of obstruction in the working area.
- Cabling costs are lower as supply is required at only a few points.
- The glare is reduced.
- The whole of the light appears to come from the sky, or the uniformity at ground level is very good and the lighting is shadow free.
- Maintenance is facilitated as the floodlights are concentrated in batteries on tower platforms and in turn it results into reliability.
- Since there is a considerable overlapping of beams on a large installation, failure of one lamp does not result in an area of darkness.

Disadvantages

- In the proximity of air ports, the permissible height is restricted.
- Access to flood light projectors is hazardous, particularly in bad weather.
- More space is required between the railway tracks.
- Shadows become inevitable and lighting between lines cannot be fully arranged.

Light sources and lurninaires

This higher mounting height and their advantages now can be utilised in our country mainly due to the availability of indigenous high efficacy, high pressure mercury vapour (HPMV) and high pressure metal halide light sources and HPSV lamps of 250 & 400W. These light sources can be used in better optically designed floodlight luminaires.

The optical characteristics of the luminaires are such that it gives comparatively narrow beam light distribution, This is achieved by the scientific design of the reflectors and the highly specific mirror like finish of the reflectors

For marshalling yard lighting the floodlight luminaires should be heavy duty type and weather proof. The housing should be of cast aluminium alloy so that the same can withstand the normal seasonal weather conditions at that height. The reflector should be of anodised aluminium and mirror like finish for better optical control. The luminaires should be provided with heat resistant toughened glass cover in the front along with polychloroprene gasket to make the luminaire completely weather proof. The luminaires should have the earthing terminal for the safety requirements.

The design of the luminaires should be such that replacement of the lamp and other maintenance is easy. The electrical accessories required for the operation of the light sources should be designed and manufactured for optimum efficiency and life.

Aiming of floodlight luminaires

Having selected the tower height, light source and luminaires, the quantity requirement of the floodlight luminaires to achieve the illuminance desired is a matter of simple mathematics. However, in practice it is important to achieve the desired illuminance in horizontal and vertical planes, the desired uniformity ratio and glare free lighting in illumination of the marshalling yard. In the absence of the guidelines from the designer with regard to the aiming, this task is difficult. Usually in such cases it is customary to employ methods of trial and error involving a number of people working late and thereby incurring wasteful expenditure. Instead of this it is possible to prepare a detailed aiming diagram which gives accurate results of illuminance., uniformity or glare free lighting. Having obtained this diagram the use of 'Night Time Visual Method' or 'Daylight Aiming Methods' can be employed. The latter method also makes use of specially designed azimuth device and elevation angle device to set the horizontal and vertical angles of each of the floodlight luminaire.

Safety measures

Whatever type of installation is employed, safety requirements from both operational and maintenance points of view must be fully considered.

Towers or poles can be sited only where ample clearance between the lighting structures and the overhead electrical equipment is available.

Maintenance

If the luminaires are at greater height, certain maintenance problems also come into the picture. However, upto a height of approximately 30 M. towers may be climbed by making use of structure itself. Apart from this there are some advantages of the higher mounting height. As the luminaires are located at fewer points the replacement is easier. In such cases, the group replacement scheme is the most suitable, as the replacement of individual lamp at the time of failure is a very costly affair

To get maximum benefit of the high lumen pack light sources and luminaires the periodical cleaning of luminaires should be done at regular interval. For the marshalling yard located nearer to sea the hardware and movable parts should be treated with lubricant for ease of maintenance.

8.5.2 Distributed lighting system

Advantages

- Lower mounting height.
- Less of directional beam.
- More uniform illumination and effective utilisation of lights.
- Reduction of shadows.
- Reduced loss due to atmospheric absorption and scattering.

Disadvantages

- Large number of physical obstructions.
- Elaborate distribution network,
- Maintenance over large number of points.
- Failure of lamps cause dark spots.
- Special care is to be taken for ensuring visibility and sighting of signals.

8.5.3 Gantry lighting

This consists of erection of gantries over the spread of raiway tracks across the yard and providing illumination between tracks by seperate lights.

Advantages

- Gives excellent illumination for working.
- Eliminates shadows.
- Easy maintenance and acceptability. Disadvantages
- Very expensive in first cost.
- Can be used only in the main central portion of receipt,classification and, dispatch yards.

8.5.4 Combination

Most effective planning of yard lighting can be done by combination and judicious mix of all the three systems with a view to achieving the objectives at optimum cost. Design can be best suited for particular location in each area of the yard.

Different railways world over have adopted one or the other of these systems for lighting the yard. Indian Railways have a mixed practice, but in a majority of yards light fittings on high towers with HPMV lamps and recently with HPSV lamps is more common Adoption of a system depends on the availability of the space, capital costs, level of illumination and desirability of shadowless lighting.

8.6 SPECIFICATIONS FOR MARSHALLING YARD LIGHTING SYSTEM

8.6.1 Scope

The scope of this specification covers the illumination design for marshalling yard. The specification also covers the design and supply of floodlighting towers, luminaires and light sources including total installation but excluding electrical system.

8.6.2 Operating conditions

All the equipments shall be capable of continuous operations when exposed to all normal seasonal weather conditions in the country:

Ambient air temperature	–	45°C average
Maximum relative humidity	–	100%
Supply voltage	–	230V +/- 5% single phase 50Hz A.C. System.

8.6.3 Objectives

The basic functions of marshalling yard lighting shall be to provide:

3.1 Facilities for the intensive scale shunting and assembling of trains and thereby improving the productivity.

3.2 Adequate lighting for the safe movement of wagons and railway personnel and thereby reducing accidents.

3.3 Adequate lighting conditions for security and thereby reducing theft.

8.6.4 Design criteria

While designing the marshalling yard lighting system, the following factors shall be considered individually as well as together as a whole:

Obstruction clearance

The location of the floodlighting towers shall be such that ample clearance between the lighting structure and overhead electrical equipment is available. The location of the floodlighting towers shall not cause any obstruction of view either to the control cabin personnel or to the railway shunting staff,

Illuminance levels

The illumination design shall be such that an average horizontal illuminance of 10 lux is provided on the surface level of the marshalling yard and the vertical illuminance is 10 lux and 15 lux when looked along the direction of track or perpendicular to the track respectively.

Illuminance Uniformity

Uniformity of illuminance shall be maintained throughout the body of the marshalling yard where uniformity ratio (E_{min} / E_{avg}) shall not be less than 0 *.2* and in hump area the uniformity ratio (E_{min} / E_{avg}) shall not be less than 0.35.

Glare control

The mounting height, the light distribution and the aiming of the luminaires shall be such that minimum glare is caused to the shunting staff or to the operating staff in the control cabin. Low mounting luminaires shall be avoided to prevent glare to the shunting staff. If necessary, suitable screening louvres shall be fixed on the luminaires to prevent glare.

8.7 LIGTING OF AREAS OTHER THAN MARSHALLING YARDS

8.7.1 Railway stations

Platforms

Good platform lighting on small stations as well as large is essential for the safety and comfort of passengers as well as railway staff. Low built platform roofs offer better possibility for mounting the luminaires with proper distribution to provide optimum lighting conditions from the light incidence and distribution points of view.

Modern luminaries with T5 fluorescent lamps are best suited for the purpose. The fittings may be spaced symmetrically and so located to avoid shadows. The T5 fitttings may be suitable luminaries of 2' or 4' feet as required. The luminaires should be arranged in such a way that the light strikes the platform edge straight down and without shadow and at the same time provides reasonably uniform lighting right across the width of the platform. Generally, the recommended value of illuminance is 150 lux in Class A Model stations in the covered portion where as it is 100 lux in class A non model stations. The railway board has published the details of illuminance level required in covered as well as non-covered areas for Class A,B &C category model stations as well as non-model stations. For the non-covered portion of the railway station, street light fittings of (4 Nos x 2') T5 fluorescent lamps with wide angle distribution reflector are suitable. Modern LED street light fittings of 36/40 W also will be suitable for the purpose.

8.7.2 Goods depots

Normally, goods depots consist of siding for loading and unloading and standing or berthing sidings. The usual attention has to be paid to lighting the switch points and capstans and should be well lit to ensure their safe operation. The luminaires using either metal halides lamps are recommended. Suitable high masts with metal halide lamps can be provided. However HPSV lamps can be provided in small goods depots particularly when colour rendering is not important

The main concern is the loading and unloading area with its associated traffic space. Motor road systems within the yard should have average 30 lux for group Al road lighting as per IS:1944-1970.

The illumination of the loading area has to be raised to facilitate the reading of labels, schedules, etc. The illuminance value of 100 lux should be provided in the loading area.. Low or medium height installations using broad beam asymmetric floodlight luminaires are most appropriate for these areas. The recommended light source is metal halide lamps of 250/400W. The layout of towers/masts should be such that the system must give sufficient clearance for maneouvering of vehicles and movements of cranes, and high enough for light penetration into open wagons.

8.7.3 Carriage cleaning siding

Cleaning sidings are normally provided with narrow platforms between the lines of coaches to facilitate access by the cleaners while the electricity and water supply, points are installed at approximate 'coach length' intervals along the middle of the staging.

The task involved requires good vertical illuminance and shadow free lighting. The general illumination on the narrow platform should be good enough for safe movement of the personnel. The luminaires should have the wide beam optical characteristics and also should be splash-proof type to have the protection against the water coming from any direction. The luminaires should be mounted on the poles closely placed along the tracks

8.7.4 Locomotive fuelling area

These areas may be single or double, according to whether the oil and water supply points are situated along side one or between a pair of tracks. It must be possible to handle pipes easily and safely and also gauge readings should be clearly visible on the supply points and locomotives.

In the open type of fuelling area an illumination of at least average10 lux should be provided. The luminaires having proper light distribution mounted on low height poles should be located between the locomotive and line of supply dials, thus illuminating both.

8.7.5 Locomotive yards

Locomotive yards are the standing sidings adjacent to servicing and repair sheds and all that is needed is lighting for the general movement and safety. A value of 2 - 5 lux will meet the requirements. Light weight floodlights having wide distribution can be mounted along the face of the sheds for adequate lighting.

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9. ILLUMINATION SYSTEM CONTROLS

9.0 IMPORTANCE OF CONTROLS

Controls are switching devices which may manually "or automatically activate the lighting system. These may take the form of "on-off" control or controls which vary the power input to the system in accordance with actual needs. Controls cover a broad range of devices, each suited to a particular system's requirements. These requirements must be established prior to selecting any control device.

To save energy, two factors may be varied :

- Power allocated to the lighting system
- Length of time that power is used.

The length of time that power is 'ON' is dependent upon the needs of the occupants and the effective use of controls,

9.1 WHICH LIGHTS SHOULD BE CONTROLLED?

When the building operation requires round-the-clock use of lighting (such as a computer centre which operates 24 hours a day) extensive controls will be of little value. However, should the function of a building permit all or part of the lights in any particular space to be turned 'OFF' at times, an opportunity may exist to save electricity through controls.

When lamps are switched 'on' and 'off' their life may be reduced slightly so that in the past when electricity was cheap, lamps were never turned off. Now, lamp replacement casts are generally much less than the value of the electricity saved so that such replacement costs are no longer considered in energy studies

9.2 HOW TO SELECT A CONTROL SYSTEM

A control system must be based upon the use of the space. Where it is intended that the occupants will control their own lighting, the control devices must be located conveniently. Some of the examples are given below

- To obtain a greater degree of control in large rooms, individual work areas may be switched separately, This would permit some people to keep lights in their area 'ON' while adjacent unoccupied areas may have the lights 'OFF'.
- In rooms with more than one exit, it may be desirable to locate a control device at each entrance. This may increase the use of the control devices since the occupants can turn the lights off, when leaving from either exit.

9.3 VARIOUS CONTROL SYSTEMS

The following are the some of the types of controls employed to save electricity.

9.3.1 Circuit breaker control

The most common 'ON-OFF' control of lighting is by branch circuit breaker. This circuit breaker function, however, is not to work as a switch but to protect the circuit against overload. The wear and tear of repeated use is not intended by the manufacturer. Moreover, the building panel board is often inaccessible to the occupants of the space being served, depriving them of control over their own use of the lighting.

9.3.2 A.C. Snap Switch

The A.C. Snap Switch is wired directly into the power Circuit supplying the lighting fixtures. The switch provides manual 'ON-OFF' control by closing or breaking the power circuit which supplies electrical energy to the fixtures The switch is rated for operation at the power line voltage and to carry and interrupt maximum branch circuit current.

The A.C. snap switch is a low cost, simple device that may be installed in any location, where manual 'ON-OFF[1] operation is desired. Its usefulness in retrofitting will depend upon the extent of rewiring involved. Since the A.C. snap switch is manually controlled, it depends entirely on the occupants of the space to realize electricity savings.

9.3.3 Low Voltage Remote Control

The low voltage switch is not designed to directly switch the power to the fixture, rather it does so indirectly via control of a relay..

A power supply transformer is needed to provide control power to operate the relays. Relays can be controlled automatically by time clocks, photocells or computers.

Low voltage remote control permits greater flexibility than A.C.Snap Switches. It provides the ability to control loads from great distances, a number of different loads from one location and one load from multiple locations. When controlled automatically, local manual overrides may by provided to allow for overtime use.

For application in existing buildings, the higher equipment costs of the low voltage systems may be offset by lower wiring costs.

9.3.4 Time clock

Time clocks are automatic controls which may turn lights 'ON-OFF' at a preset time according to a predetermined schedule (usually a seven day schedule).

Time clocks may also be utilised to turn exterior lights 'ON' and 'OFF'. They may also be used in conjunction with other control systems, such as low voltage control, to control lights throughout the building. Although the 'ON-OFF' schedule may be changed, the time clock is not generally intended for use when requiring frequent schedule changes.

9.3.5 Timed switches

Timed switches may be used manually to turn lights 'ON' and will then automatically turn the lights 'off after a predetermined time interval (available from 5 minutes to 12 hours).

Timed switches are useful in all rooms which are not in continuous use (such as toilets) and in which occupants may neglect to turn lights 'OFF’. Timed switches are installed in a manner similar to the A.C. snap switch.

9.3.6 Photo cell controls

Photo cells are devices used to sense light. Based upon the level of light, the photo cell will open or close a relay or automatically adjust a dimmer setting.

Photo cells can be useful for control of lighting systems based upon quantity of available light.

The photocell, however, must be cleaned periodically to assure proper operation.

A common application of photocells is with exterior lighting systems. In this application, the photocells senses sunset and turns the lights 'ON' and then senses sunrise to turn the lights 'OFF'.

The photocell may be also used with other control devices such as the dimmer control.

9.3.7 Dimmers

Dimmers are used to vary the quantity of illumination. Their operation may either be manual or automatic. Dimmers may be useful electricity .conservation devices. A photocell can sense any available natural light and automatically reduce the output of electric lighting system, while constantly maintaining adequate lighting.

There are dimmers for incandescent lamps, fluorescent and HID. They are not interchangeable.

9.4 MAINTENANCE

Once installed, the efficiency of a light source depends to a large extent on how well the fixtures are maintained. A lamp that produces 20 lumens per watt when installed may actually distribute only 10 lumens when covered with dust. The reflecting value of fluorescent fixtures is directionally correlated to their illuminating ability, and their tendency to collect dust may be countered by frequent cleaning. Bulbs should be replaced when they first begin to dim, before they completely burn out.

When lighting systems are over designed and generate too much light initially, a 15 percent depreciation in output was neither noticed nor important. Now with the high cost of power, closely designed energy efficient systems cannot tolerate dirt accumulation.

Lighting system maintenance procedures are relatively few but most effective. The following procedures are recommended.

- Lamps should be wiped clean at regular intervals to assure maximum efficiency. Lamps which are exposed to an atmosphere with substantial amounts of dust, dust, grease, or other contaminants should be cleaned more frequently than lamps in relatively clean atmosphere.
- Cleaning of ceilings, walls and floors should be done frequently to improve reflective qualities. In rooms or areas where natural day light is used to maintain light levels, washing of windows should be done frequently.
- If any renovating or painting is planned, the use of white or light colours will improve light quality. The choice for walls and ceilings has a surprising effect on the efficiency of the lighting system. Light colours reflect more light than they absorb. Dark colours absorb more light. A given lighting system may be as much as twice as efficient in a light coloured area as it is in a predominantly dark one.

Repainting walls and ceilings should be considered in conjunction with other measures like lamp removal and replacement with energy efficient lamps etc for improving lighting efficiency. In some cases the owner may be able to maintain existing light levels by brightening his colour scheme while removing lamps or using lower wattage lamps. The colour selected does not necessarily have to be white but may be any lighter (more brilliant) hue.

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10. ENERGY EFFECTIVE LIGHTING STRATEGIES

1 0.0 INTRODUCTION

The real or total cost of lighting installation includes the capital cost, installation, maintenance and running energy consumption. Analysis of these costs over a number of years shows that the major contributing factor is the energy cost associated with the running of the lights. Proper energy management in both the initial design and the running of the lighting system alters the pattern of cost structure of the various items of the system and also results in improved lighting. Simple payback periods of one to three years are typically achieved.

10.1 HOW IT CAN BE ACHIEVED

Lighting installation - The purpose of every lighting installation is to provide the right amount and the right quality of light at the right time for the people to effectively carry out their tasks within the work space. The emphasis on energy saving must not compromise the definite relationship that exists between the lighting and the productivity of the people under the lighting system. The lighting system must enhance sales in a retail environment, it must not create headaches for office workers and it must allow warehouse operators to efficiently identify and pick products. Safety factors must not be compromised.

10.2 LIGHT SOURCE

To achieve an energy efficient installation the lighting designer must carefully choose the appropriate light source to give the highest possible lumen per watt output whilst considering the illuminance level, glare requirements and the demands of the task to be illuminated. It is not simply a matter of choosing fluorescent tubes over incandescent, for example. Choosing the most energy efficient type of fluorescent is also important. For example, triphosphor tubes have a 15% higher light output than standard tubes, together with a better depreciation curve. This allows less energy to be consumed over the life of the installation while achieving the same light levels. The modern T5 lamps are very energy efficient light sources.

The designer should also ensure that the luminaires chosen not only meet the aesthetic and dimensional requirements of the installation but that they have the highest light output ratio (LOR) suitable for the task and that they also meet all the other lighting requirements, such as glare and spacing to mounting height ratio limitations. Individual tube switching (to provide 0% - 50% - 100% control) should also be considered when choosing luminaires and associated wiring.

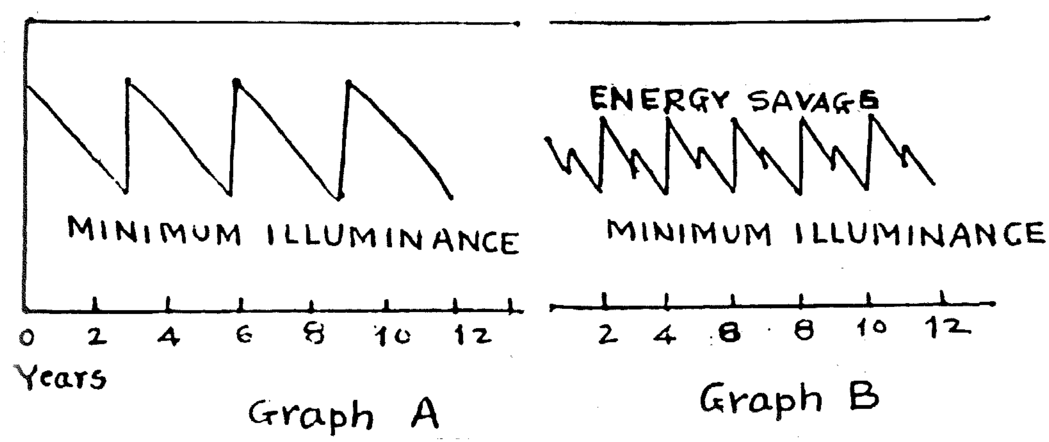
10.3 DESIGN

The IS:3646 (Pt. II), indicates recommended light levels for certain tasks in offices. The lighting system should be designed so that these levels are maintained throughout the life of the installation with as little excess as possible. Some over-design will always exist. Area and office grid layouts restrict luminaire layouts, whilst higher light levels are evident when the lamps are new. By ensuring that respective tasks are only illuminated to the recommended levels, and proper maintenance is carried out, the minimum amount of luminaires can be installed in the space to be illuminated. In new buildings this will mean cheaper capital costs, cheaper installation costs and lower energy costs.

10.4 MAINTENANCE

Regular maintenance is an important function in keeping the lighting system operating efficiently and therefore cost effectively. Dirt and dust accumulate on luminaire reflectors and diffusers whilst the lumen output of the lamps decreases with age. Keeping the luminaires clean and reducing the time between lamp changes means a higher maintenance factor when considering the design of the lighting system. A higher maintenance factor consequently results in less luminaires (and energy) to provide the required task illuminance.

The maintenance procedures in graph A include cleaning of luminaires and changing lamps every three years. The maintenance procedures in graph B include cleaning of luminaires annually and changing lamps every two years. Less luminaires are therefore needed in situation B to achieve the same minimum illuminance levels.



10.5 AUTOMATIC SWITCHING SYSTEMS

One of the most cost-effective measures for lighting energy management is the implementation of appropriate light switching. A proper energy effective switching system comprises many parts, but can lead to substantial energy savings. Some of its components are as discussed below.

10.5.1 Location of switches

In commercial office applications, the simple multi-gang switch plate by the door way is the most inefficient switching method used as it leads to every light on the entire floor being switched on even if only one occupant is present on that floor. This is a huge waste of energy. The entrance switch should provide background lighting only, with local switches being strategically located throughout the floor to enable occupants to turn on lights in their own area. Open plan offices should ideally have one light switch within each $100m^2$ of space whilst individual offices, stores, meeting rooms and so on, should be provided with their own control.

10.5.2 Automatic switching - auto off/manual on

Automatic 'on' light switching systems, such as those provided by a building management system should be avoided as it creates considerable wastage to have lights turned on when occupants are not present. On the other hand, it is important that an automatic system be installed to set automatic switching ‘off’ of lights after normal office hours because people simply do not bother to switch lighting off when they leave their workplace. Convenient local switches for after hours over-ride is imperative.

10.5.3 Luminaire wiring

Lighting designs should allow for variation in tasks, occupancy and light levels. This can be achieved by having individual switching in all luminaires.

10.5.4 Occupancy control of offices

There are always offices that are not occupied - staff are away at meetings, visiting clients, or on holidays or sick leave. Occupancy detectors should be installed in these rooms so that/ lighting is only activated when the room is occupied. Detectors should be chosen that has sufficient sensitivity to continuously detect the small hand movements that people make while doing routine office tasks.. As with all switching equipment, detectors should be suitably rated to switch the inductive load of fluorescent fittings by having in built inrush current protection for fluorescent tube start up.

10.5.5 Timer switching

Rooms such as stores need lighting only occasionally. Savings arise by providing controls so that lights are turned on manually through a local switch while being turned 'off' automatically on a time basis by an electronic timer The correct setting of the time delay on these timers is important.

10.5.6 Utilizing daylight

Circuit arrangements should allow switching of the outer row of luminaires (or individual tubes in outer luminaires) along perimeter faces of a building to compensate for natural lighting. This switching should be carried out automatically using photocell technology or on a time base. Manual local switching must be provided to allow the user to override the system if so desired. To ensure that sufficient daylight exists for implementation of this type of strategy, daylight linking should be limited to a maximum of approximately 1.5 times the window height.

10.6 BALLASTS

Various electronic ballasts can be used for the control of the same lamp or lamp types. It is the responsibility of the designer to select the appropriate ballast to successfully control the lamp and at the same time results in the lowest energy losses.

High frequency electronic ballasts are now available in both dimmable and non-dimmable types. A standard non-dimmable HF ballast can increase the light output of a standard tube by up to 10% and reduce the energy consumption of the luminaire as a whole due to the lower ballast losses. HF dimmable ballasts can add further energy savings on top of these already mentioned.

The quality of light from a luminaire fitted with HF ballasts is also better than that of its iron core counterpart. Stroboscopic effects, flicker and annoying off/on start ups are almost eliminated.

10.7 DIMMING

There are instances where over-design cannot be eliminated for one reason or another. One way of compensating for this is to overlay lighting with a dimming system. The two main energy-saving dimming systems currently available are high frequency electronic dimmable ballasts and wave chopping dimming. Dimming may also be used to compensate for daylight.

Careful consideration must be given to blinds on windows, the orientation of the building, individual offices and local over-ride facilities. Energy effective dimming of fluorescent luminaires is relatively new and several possible technical problems must be addressed when selecting dimming equipment. These include power factor correction, harmonic distortion, selection of lamp type and the withdrawal of lamp life warranties with certain wave chopping dimming equipment.

10.8 STRATEGY

Some of the important steps for cost-effective energy efficient lighting are

- Choose the right light source, including luminaire
- Choose the right number of luminaires and lamps.
- Implement proper maintenance procedures.
- Centralised off control with local on/off switches.
- Install presence detectors
- Consider daylight control.
- Consider HF ballasts or dimming.

10.9 SUMMARY

The lighting standards of existing installations and the design of new installations should be checked to ensure that most energy efficient lighting system possible is installed or is to be installed

The quality and quantity of light must be sufficient in order to meet the requirements of the visual task and to maximise productivity whilst not unnecessarily exceeding standards,

Maintenance procedures should be put in place in order to ensure the system continuously operates to maximum efficiency.

An energy effective switching system should be installed to allow good house-keeping and to correlate the number of lights which are switched 'ON' with the actual people carrying out useful work in the building. Essentially it means that the lights shall be switched off in areas where people are not present .

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11. ELECTRONIC BALLAST

11.0 Conventional Tube Light System :

11.1 Striking Voltage :

This is the voltage required to form an arc discharge across the tube. Normally this voltage requirement depends on the condition of the gas inside (ageing factor).

NOTE : Older the Tube, higher is the requirement of striking voltage.

11.2 Current Limiting :

Any gas discharge device is to be connected with a series impedance, so as to limit current through the device for safer operation. Once the arc is established, the voltage across the tube is relatively maintained constant. To produce a constant power/light output, it is necessary to maintain the current constant irrespective of supply voltage variations. Here the need of an impedance device termed Ballast comes in.

When the supply is given, the current is made to flow through the choke and filaments through a starter. The current is established and the filaments are heated up. After sometime, the starter opens and the current is made to stop abruptly. This causes a sudden collapse of magnetic field in the choke and produces high voltage surge in the order of 600-15O V which is sufficient enough to produce arc across the tube. The; current is reduced to a constant level. The starter gets inoperative then.

Now the path of the current is through the choke and tube. It gives inference that as and when the current is increased, the power fed into the tube increases and hence the brightness. Correspondingly the loss in the choke is also increased since it is connected in series.

Ideal inductance will Consume no power. But practically, there is some resistance present in the choke which results in I2R losses. There is also hysteresis and eddy current losses in the core of the choke. Hence there will be certain amount of power (18W) consumed and wasted as heat in the. choke which results in loss. A good quality choke will produce less loss compared to the low quality one. This device is inductive in nature & makes the current to lag and hence the power factor is less than unity around 0.5.

When the supply voltage is changed from its normal value, then the current through choke is affected and hence the brightness. Moreover, the change in the voltage is directly applied across the choke, since the voltage across the tube is constant.

11.0.3 Power Measurement :

The power fed into the system is nothing but the sum of power loss in the choke and the power fed into the tube.

The power fed into the system

$$Ps = V_1 \cdot I_1 \cos\theta$$

Where V_1 – is the RMS value of the supply voltage.

I_1 – is the RMS current measured.

$\cos\theta$ – is the power factor which is property of the choke, and nothing but the Cosine of the angle difference between the voltage and current wave form.

Note : Generally copper choke will produce a power factor of 0.5.

11.0.4 Efficiency :

We say the system is efficient, when it draws less power for the same light output. The efficiency is increased by

1. Reducing the loss in the choke.
2. Increasing the efficiency of the system by new techniques i.e. by increasing the luminous output per unit input of power.
3. Drawing appropriate current from the power line which reduces the loss in the line (line loss) i.e. improving the power factor.

11.1 Role Of Electronic Ballast :

By the use of electronic ballast, we could achieve the ideal goal of higher efficiency system. This operates on a totally different principle and hence the series loss in the choke is eliminated. But some meager amount of power is required {about 1.5W) for its own operation.

By operating the the light at higher frequency i.e. from conventional supply of 50Hz to say 20,000 Hz, we can achieve, higher luminous efficacy. The improvement of efficiency has been calculated as 13%. Hence, less amount of power (87%) is required to produce the same light output when we use the high frequency.

Since the Electronic Ballast operates at high frequency, the generation of high voltage is easy and possible even at very low supply voltages. Hence the starting is instantaneous and enables the tube light to operate at very low supply voltage.

The electronic ballast has no moving mechanical parts, no wear and tear and hence the life expectancy is higher. The parts can he replaced even if there is a failure.

The ballast operates by converting the AC supply into DC. Hence, the current wave will not be purely sinusoidal and results in distortion. This distortion produces HIGH Radio frequency signal. Good ballast will have a suppressor to arrest the RF produced inside.

Electronic ballast can withstand voltage range and fluctuations because the current regulation is much better. Electronic ballasts are ideal, for tube light application if reliability is established.

Good electronic ballast will have the RF .suppression circuit, spike suppression circuit, over load protection circuit as extra features. With these facilities the reliability will improve at an extra cost. The modern T5 fittings are coming with good quality electronic ballast integral to the unit. But the ENERGY SAVING, higher power factor and low voltage starting would out weigh the initial higher costs of the electronic ballast

11.2 Principle Of Electronic Ballast :

The electronic ballast provides all the necessary control actions required by the tube .light. The block diagram of the Electronic ballast is shown in Fig.2.

The second block is an oscillator. This oscillator frequency will be some where in the range of 15 kHz to 50khz. Oscillator output power is amplified to the level required. Now the source is ready at 20khz (15-45Khz) instead of 50hz. This high frequency source, is used to light the tube with a smaller choke in series.

11.2.1 Protection Circuits :

The Electronic ballast has the protection circuit against overload, short circuit, Input transients, Spikes and dips. These protection circuits are additional features only but these protection circuits play very important role in the reliability & in the life of the ballast.

11.3. Energy Saving Aspects :

The energy saving has two aspects.

1. Reducing the level of energy being wasted.
2. Achieving better efficiency by new techniques for the same application.

In the electronic ballast, both the approaches are done & hence the energy saving is considerable.

11.3.1 Reduced Wastages :

With Electronic ballast, the series loss encountered by the conventional ballast is avoided fully. Hence the total energy wasted as heat in the conventional ballast is fully saved as energy, which is around 10-18 Watts depending upon the quality of the Ballast. The Electronic Ballast requires only about 1.5-2.0 watts for its own operation. There by the saving is from 8.5 – 16.5 watts in the normal supply voltage conditions.

11.3.2 New Techniques :

It is a fact that the fluorescent lamp when operated with high frequency in the order 10 – 50kHz, the efficiency (i.e. The light output per unit of input power) will increase by about 13- 14%. At high frequencies, the number of peak light outputs per unit time will increase.

At every peak the phosphor coated on the wall of the tube starts giving maximum glow. In between the peaks the light output will start falling down towards zero. The phosphor requires a minimum amount of time for the light to decay to zero. If the frequency of applied voltage is high, then the peak to peak time gap is reduced and the decay of light output will become insignificant due to smaller time interval & hence the average light intensity is increased. It is not possible to get the increased light output by increasing frequency beyond certain level. There after the light output will become constant. Because the time gap interval is so small further increase in frequency can't increase the average light output. When the frequency is increased from 50 Hz to 10 kHz, the efficiency is increased from 1 to 13% and remains at 13% itself up to 50 kHz.

11.3.3 We can summarise the energy saving as follows:

1. The loss in conventional Ballast is fully eliminated.
2. The conventional Ballast will produce higher loss when the voltage is increased. Hence additional saving is obtained in the high voltage existing areas, particularly in the Industries.

1. Indirect Loss:

1. Heating of Ballast will increase the load on air conditioner & hence the extra load on air conditioners is saved with Electronic Ballast.
2. Since the conventional Ballast produces poor power factor of 0.5, the line current requirement is very high & hence the line losses in the wiring system. With electronic ballast this loss is reduced due to unity power factor. These indirect losses are reduced in the Electronic Ballast.
3. Electronic ballast operates by converting the 50Hz into high frequency, there by the lumen output is increased by about 13% OR less amount of power is required to produce the same lumen output.

11.4 Economy Analysis :

There are so many ways by which we can recover the investment made in the Electronic ballast. The savings are

1) The direct power saving.
2) Power factor is unity. Hence reduced VA RATING. The KVA demand is reduced thereby saving in penalty.
3) The saved VA can be used for other constructive work. or a lesser capacity generator is required to run the plant & hence saving in investment.
4) Heating is reduced. Load on air conditioners is reduced.
5) The life of the lamp is increased due to high frequency operation. Hence saving in inventory of Tube lights.

Considering only the direct electricity saving, leaving all other indirect Savings, we can workout the economics as below.

Energy consumed by Conventional Ballast for 1 x 40 w tube at 240V 54W

a) The Energy Consumed by Electronic Ballast f*or* same lumen output @ 240V is 35W
b) The direct Saving of Energy is 19W

Table – 1.

	Electronic Ballast 40W	Conventional Ballast 40W	Comments
Power consumed	35 W	54 .0W	Saving I9W
Cost of Ballast	Rs. 350/-	Rs. 120/-	Extra invest Rs. 230/-
Annual operating cost at 15 Hrs/day and 300 days a year @ Rs.3.00/unit	Rs. 471.5	Rs728.00	Saving Rs. 256.50

With the above example, we can conclude that the extra investment made for the Electronic ballast can be recovered well within one year period leaving all other indirect savings& benefits, which is also within the guarantee period of the Device. The life expectancy of the Electronic ballast is minimum 10 years.

Hence anybody can take a decision of going in for the changes immediately, by considering the other operational /maintenance/finance conditions.

11.5 Operational Problems With Electronic Ballast:

Following are the operational problems :

1). RF & Electromagnetic interference
2) Power factor
3) Light output
4) Wave form Distortion/Harmonics.

11.5.1 RF & EMI:

The main problem faced by the user in the operational side is Radio frequency & Electromagnetic Interference created by the Electronic Ballast.

Radio Frequency Interference :

Radio frequency interference is bound to be there whenever there is a distortion of current waveform. This is a common feature with all the electronic equipments such as TVs, Radios, Power Supply Units, Computers, Instruments, Thyristor Panels, Mixies, Motors with brushes etc. The level at which the RF emission produced depends upon the amplitude and the amount of distortion of the current wave form. Hence all the equipments connected to electrical system will produce RF signal, the spectrum of which may vary.

Measuring the RF signal is very difficult with oscilloscope etc. We need to have" RF free chamber and sophisticated RF measurement equipments, which are available only at few places in India.

The RF signal sometimes may interfere with radio receiver, if the RF spectrum falls on the range allotted for radio transmission purposes. Some people use radio receivers to test whether the Ballast produces RF or not. This is not a very correct method. The radio receivers are extremely sensitive and are designed to pick up even very weak signals. Bringing the Radio closer to the Ballast or any electrical gadget will produce some interference which is an indication of presence of RF signal in that particular frequency tuned in the receiver. But this will not give an indication about the strength of the signal.

The RF produced interferes with other equipments by two means.

1) Radiated Emission from the Ballast.
2) Conducted Emission through the power line.

Radiated Emission :

The ballast produces RF signal in the form of electromagnetic waves. This is radiated in the air. The strength of the signal will be maximum at the source and will be reduced with respect to the distance from source. Radiated emission can be controlled by using suitable enclosure and the suppressor at the source itself.

Conducted Emission :

One part of the RF produced is conducted through the mains cable and is transmitted to the other surrounding areas up to the transformer. This is most dangerous one, which causes interference in the other equipment connected in the same power line, some where away in the premises. This conducted emission is also to be measured and should he with in the standard specified limits. This conducted emission can be suppressed by using suitable suppressors at the source.

It is to he noted that even though the interference is heard on the receiver, the Ballast is said to he RF suppressed, if the strength of the RF signal radiated/conducted is below the FCC CLASS -A standard.

11.5.2 Power Factor :

It is an important factor to he considered for efficient power distribution. It determines how effectively the power is transferred from source to the load.

In general, when the voltage waveform and current waveform are in phase, the power transfer will be effective and we say that the power factor is unity. When there is a phase difference between the voltage waveform and current waveform, then the power factor is said to be less than unity and is equal to the Cosine of the phase angle difference, Cos θ (applicable only for the sinusoidal waveforms)

$$\text{Power Factor} = \cos\theta$$

(Where θ = is the phase difference between volt & current waveform in degrees.)

When the power factor is less than unity for the constant voltage line the current drawn will be increased for the same load. This excess current is to flow through the cable. This excess unwanted current will produce more drop on the power line and hence the power loss, called as line loss. This line loss is proportional to the square of the current drawn through the power line.

Hence in order to minimise the loss on the line, it is preferred to have unity power factor for the ballast. This power factor in no way. affects the Electricity Bill for the user. But the low level power factor will contribute a heavy line loss on the grid of the Electricity Distribution System and is a loss to the Nation.

Also it is important to note that all the Electrical Generators, Transformers etc., are rated for the KVA. lt is the product of voltage and current. We should not draw more than the KVA Rating of that equipment. For example, when a shop is having 5 KVA Generator set @ 230V it can draw 5000 Watts of power at unity power factor, (i.e. Voltage = 230V & Current = 21.73 Amps.) But when we connect 0.5 power factor load, the maximum current one can draw is only 21.73 Amps. But the load will be 230 x.0. 5 x 21.73 - 2500 Watts. Hence, we can utilise only 2500 Watts even though we have the generator capacity for 5000 watts.

Thus KVA plays a very important role in the industry. This overall KVA demand in every half an hour should not exceed the allotted value. If it exceeds the limit, then the industry will be penalised on the tariff. Maintenance of the KVA within the limit can he easily achieved by improving the power factor near unity. Here the importance of Electronic Ballast for Tube Light comes in.

11.5.3 Light Output:

The light output from the fluorescent tube operated in the Electronic ballast is essentially equal to the conventional system. Measurement of absolute value of lumen is very very difficult. "Lumen is defined as. the light energy emitted within unit solid angle by a uniform point of source Of unit luminous intensity of one candella". A relative value of lumen can be measured OR compared with that of the standard system. The Lux level can be measured with the Lux meter, kept at a particular distance. Relative measurement can be taken as explained below. Consider a standard system with standard ballast connected to the tube light at the rated voltage. Now measure the Lux level using the Lux meter, by keeping it at a particular distance, preferably at one meter from the geometrical centre of the tube light.

Now connect the Electronic ballast to the same tube light, at the rate voltage and measure the Lux value read on the meter as in the previous case, without disturbing the geometrical arrangement.

The difference in reading can be expressed in terms of percentage less or percentage more than that of the standard ballast system.

Note :

1) As far as possible avoid reflection coming on to the lux meter.
2) Avoid external light falling on the Lux meter.
3) Maintain the voltage constant while taking measurement.

11.5. 4 Wave Form Distortion :

Irrespective of the load conditions, the ideal power lines should provide a pure sinusoidal voltage at the rated frequency & voltage. Ideally all loads are expected to take only the sinusoidal current. But practically, the ballast consumes current as pulses. Hence the current wave form is non sinusoidal. Wherever the non sinusoidal current wave form is demanded by the load, the wave form distortion is caused. This is referred as wave form distortion OR Harmonic distortion. The non sinusoidal current wave form can be resolved into the fundamental and its harmonics. Usually their level is expressed in terms of the percentage of the fundamental value.

Generally all the odd harmonic will have the effect on the distribution system. Hence these levels are to be within the limits.

However ISI limitation on the various harmonics are listed below:

2nd	5%
3rd	30%
5th	7%
7th	4%

11.6 Maintenance Problems :

The maintenance problems are listed below :

1. Routine maintenance
2. Replacement of the Device
3. The reliability of the Device
4. Serviceability of the Device

11.6.1 Routine Maintenance :

With respect to Electronic ballast, there is no need of routine maintenance. Only maintenance required is monitoring the life of the tube by seeing its glow & its end blackening and to be replaced if need be.

11.6.2 Replacement of Ballast:

Replacement of ballast when it is defective is simple & wiring is less complicated than the conventional system, since there is no third component like starter.

11.6.3 Serviceability:

The Electronic ballast can be serviced and reused. Only the failed one is to be replaced which works out cheaper. Conventional ballast, is to be thrown out for a new one, when it goes defective.

11.6.4 Reliability:

This is the most important factor which governs the population of the Electronic ballast. In spite of all the merited benefits, the higher failure rate restricts the population of Electronic ballast widely.

The reliability of the ballast depends on the following :

i) The parameters taken into consideration while designing the ballast.
ii) The circuit design & component selection.
iii) The manufacturing Quality control.
iv) The power line condition at the user point.

i) Parameters which are to be considered while designing the ballast are
   a) The voltage fluctuations
   b) The expected spike level on the power line
   c) The atmospheric temperature conditions.
   d) Environmental conditions.
   a) Particularly in Indian conditions, where the power distribution line runs into several thousand kilometers, maintaining the voltage at remote point is very very difficult. Hence the circuit design should take care of the voltage range to which the ballast has to operate. Generally this range is from 160V-280V.
   b) Majority of the failure of electronic ballast is caused by the spike voltage existing on the power line. Hence the design should take care of the spikes which are anticipated in the power line.
   c) The temperature rise inside the ballast should not exceed about 5° - 10° above the ambient. Hence this temperature raise is to be limited & restricted within the limits to avoid failure of components. Good heat sinking arrangement is also to be considered while designing the ballast.
   d) The environmental conditions such as corrosive atmosphere, moisture etc., are to be considered in the design and to be carried out in the manufacturing.

ii) The circuit design :
   Considering all the above into account, the design should be made in order to get the maximum efficiency in the total system with prime purpose of reliability.
   All the components are to be selected carefully and sufficiently for its reliability.

iii) Manufacturing & Quality control :
   Even though the design is perfect, improper manufacturing can cause a failure to the major extent. The manufacturing methods should give importance to quality at all levels and stages of manufacturing.

iv) Power line condition :
   As discussed earlier, the power line condition is very very bad in the industrial atmosphere and is also carried over to the other domestic areas. There is no check on the instruments being installed & its effect on the power line. Hence all the gadgets connected to power line attribute pollution in the form of surges, spikes, dips, wave form distortion . etc.
   In heavy industries, loads driven using thyristors etc. produce spike voltages up to 6000V. These levels will vary from factory to factory. This is the main cause. of failure in electronic ballasts. However much we protect the ballast, the spike level exceeding the expected design value will cause the ballast to fail.

11.7 Conclusion : .

Even though the electronic ballast was introduced in the market in the early 1980's, the population of electronic ballast in real use is much less than expected. The main reason was due to its poor reliability. The failure rate of electronic ballast when introduced were in the range of 30-40%. Now this has been reduced to 2-10% by the quality conscious manufacturers. Intial failures were due to to the poor design, the poor manufacturing methods & due to the power line conditions existing in the industries. The power line condition attributes to a major factor for the ballast failure. Low cost ballast can't provide all the protection necessary for the ballast.

Power & light output comparison charts of electronic ballast and conventional ballast are given, which are self explanatory. (Fig. *5* and Fig.6)

Failure of 2-3% can't be avoided even when best design & manufacturing process is used. This is mainly due to the poor power line conditions. Considering the energy saving & low operational cost, the electronic ballasts are . best substitute for conventional ballast in the in the long run.

ELECTRONIC VS CONVENTIONAL
POWER SAVINGS

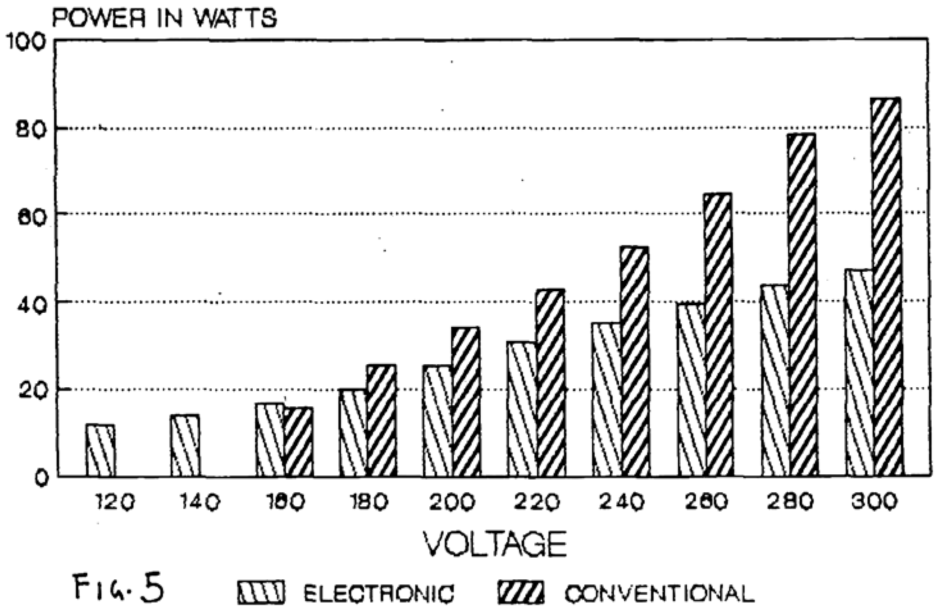

FIG. 5

ELECTRONIC VS CONVENTIONAL
LIGHT

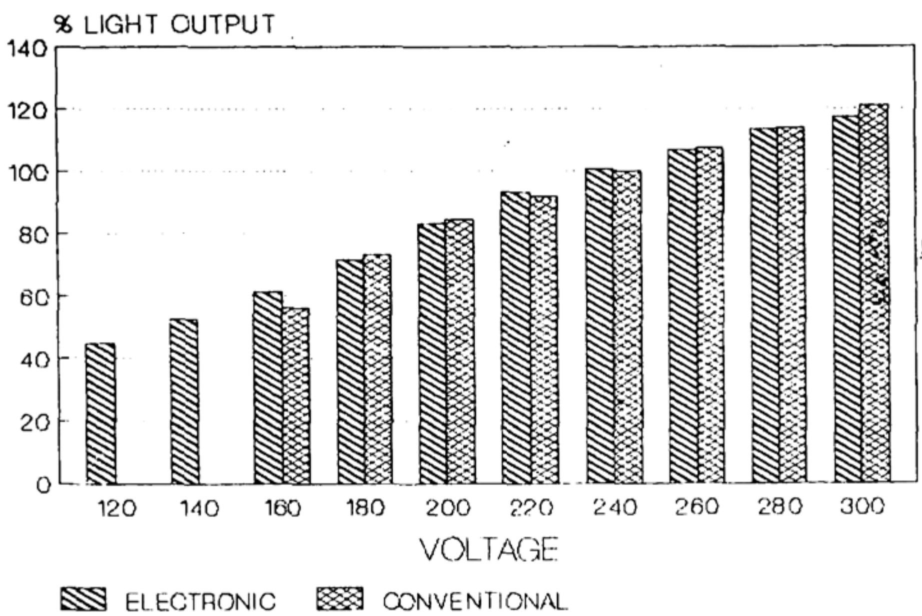

FIG. 6

12. ENERGY CONSERVATION

12.0 SYNOPSIS

Today in India the per capita availability of energy is much less than the energy in developed countries. The demand for energy is always outplacing availability, the shortfall being ten percent per annum. The present cost of thermal power is about Rs. 4.00 crores per MW and the others are higher. So, to tackle this demand of power, an enormous amount of investment is necessary. A review of the entire situation demands that to overcome the grim situation, some useful immediate measures have to be taken. One of the most fundamental step is to find the possibilities of conservation of energy by all means. In India 17% of the total energy is consumed by lighting. So, with careful measure, it is possible to achieve a substantial amount of energy saving in artificial lighting.

Energy conservation practice, can provide equivalent or improved visual performance and visual comforts while producing substantial energy and power savings. Referring back to the time when incandescent lamps gave way to fluorescent lamps in commercial buildings", other trends such as rising urban land costs, the advent of building air-conditioning systems and low cost electricity combined to eliminate daylight as an essential element in building design.

Any lighting system with an energy conservation objective and with the intention of providing increased productivity and safety should comply with **six** basic rules in order to produce the most cost effective results.

- Use of the most efficient light source practicable.
- Use of the lamp light output efficiently.
- Maintain lighting equipments in good order.
- Use well designed energy effective lighting schemes.
- Control the switching operation and usage of the lighting installation.
- Consider the utilization of daylight and the effect of the surrounding décor

12.1 Efficient light Source

The need is clearly, to use the type of lamp which gives the maximum amount of light (lumens) for each watt of electrical energy consumed, consistent with the colour rendering and other needs of the installation

For lighting, the commonly used light sources are incandescent, fluorescent lamps, T5 fluorescent lamps, CFL, high pressure mercury (HPMV), metal halide lamps and high pressure sodium vapour (SON) lamps, and the the LED lamps.

The high pressure sodium vapour lamp is undoubtedly a very efficient light source. This high efficacy lamp is ideal for all applications where colour rendition is not important.. But due to poor colour rendering index , they are being replaced by high luminous efficacy metal halide lamps except in general road highways and some rail yards. Modern T5 lamps are available with luminous efficacies ranging from 90 to 104 Lumens/watt and are now preferred for use in indoor lighting in offices, street lighting and in railway platforms. Future holds a lot of potential for LED lighting. Already street light luminaries with luminous efficacy of 120 Lumens/watt are available which are most energy efficient.

In India, many industries still use incandescent lamps because of their low cost. Vast amount of savings in energy are possible by replacing the high wattage incandescent lamps with CFLs or appropriate fluorescent luminaries.

Two types of fluorescent lamps are available in our country, namely the cool daylight (colour 54) with a colour temperature of 6500° K and the white (colour 33) with a colour temperature of 4300°K. The white fluorescent lamp gives 14% more light than the cool daylight fluorescent lamp and thus for the same illuminance a 14% saving of energy is possible, although the colour rendition of cool daylight fluorescent lamp is better than that of the white fluorescent lamp. The modern T5 lamps have even better luminous efficacy than the cool daylight and the white fluorescent lamps and are ideal for replacement.

For home lighting, the incandescent lamp can be conveniently replaced by CFL.

In the recent years, developments in the field of low wattage gas discharge lamps and High Frequency, Electronic lighting have changed the situation dramatically. The new generation 'fluorescent HF electronic lamps have achieved a luminous efficacy of more than 100 lumen power Watt. These lamps operate on a frequency of more than 25kHz and give exceptional performance. The important features of these lamps are

- Instant starting,
- Superb colour appearance with high colour rendering index.
- No stroboscoplc effects. -
- Excellent lumen maintenance, and
- Wide temperature range.

These lamps on HF electronic circuits are suitable for initial and conversion projects in a wide range of commercial and industrial applications.

In streetlighting, the preferred light sources are HID metal halide lamps and T5 lamps with wide angle reflectors. The latest developments are LED luminaries.

12.2 Efficient Use of lamp light output

It is all too common in many lighting installations to see instances of energy wastage with consequent total money-wastage due to poor quality or inefficient luminaries for either commercial, industrial, or road light use, purchased possibly on the grounds only of less capital cost

Generally, provided that the light distribution is acceptable and care is taken to reduce glare, the light output ratio is a reasonable indicator of efficiency. In addition to the photometric efficiency account should be taken of the power consumed by the luminaire control gear, e.g. ballast. The total wattage consumption of any discharge lamp circuit is always greater than the rated wattage of the lamp at a given reference voltage. The power loss in the control gear is dissipated as heat within the luminaire causing problem there. The amount of the power lost in this, way depends on the design and the quality of the components used. In a large installation, watt-loss may represent a significant waste of money. Lighting equipments should be checked as to the control gear losses before purchase.

Fur commercial interiors, from the energy saving point of view, the ideal solution would be to use the fluorescent lamps without any screening louvre or diffuser. However, from the point of view of illumination engineering, this is not advisable because bare lamps give rise to considerable amount of discomfort glare. lt is therefore, necessary to use louvres/diffusers, not only to screen the lamp from view in order to reduce glare, but also to give a aesthetic appearance to the room. The types of louvres/diffiusers normally used are - metallic louvre, clear polycarbonate diffuser , translucent diffuser and opal acrylic diffuser..

Use of some kind of louvre or diffuser will depend on the aesthetic requirement and the extent of glare. But the use of these could be limited to minimum possible areas. In air-conditioned interiors, it found that substantial savings in energy can be achieved by integration of lighting and air-conditioning system.

For industrial Interiors where decorative appearance is not important, the fluorescent lamps are normally used with through type reflectors, For mounting heights of 7m and above the work plane it is found that the use of highway luminaires with metal halide lamps are many times preferable.

For street lighting, the design of the luminaire is very important. This is because only by proper design of the luminaire it is possible to ensure that maximum light leaches the road surface.. In streets of rural areas and side streets , street lighting luminaires with fluorescent lamps are used. As earlier discussed (2' x 4 Nos) T5 fittings with reflector are very suitable even though single or twin 4' T5 lamps are also suitable.

12.3 Maintenance of Lighting Equipments

Poor maintenance and the accumulation of dirt and dust reduces the useful light output and so in effect increase the cost of the light provided and results in waste of energy.

Lighting systems operate efficiently only when they are properly maintained.. If lighting strategies are planned with more efficient light sources then, because of fewer points, The maintenance schedule can be improved. To cite an example, study of a fluorescent lighting system was made, where different maintenance procedures were in use. The result showed that,

When luminaries .were cleaned and relamped once every three years, the illumination dropped to 60% of the Initial value after three years.

When luminaires were cleaned every one and half years and relamped every three years, the illumination level dropped to 68% of the initial value after three years.

When luminaries were cleaned once a year and one third of the lamps replaced once a year, the illumination level dropped to 78% of the initial value after three years

Lighting schemes are sometimes designed with equipments which is difficult to keep clean and allowances are made. In lighting calculations to allow for lack of maintenance, typically, up to 20% extra luminaires, are installed.

12.4 Use of well designed energy effective lighting schemes

While designing lighting schemes, the illumination level should be chosen according to the task involved. The lighting scheme should be designed for an average level and then maintained at that level. It is uneconomic to design a lighting scheme for a higher level and then let it deteriorate to an average level for lack of proper maintennce. This involves wastage of energy and should be avoided. The effect of aesthetic considerations in lighting scheme should be fully evaluated in terns of energy costs and other parameters.

For major new building developments an Integrated Environmental Design Concept, where the total energy requirements of the building are considered from the above point of view should be made:

Orientation of the buildings
Surface to volume ratio of the building
Size of windows and glazing

12.5 Control of switching operations

By having a flexibility in the switching arrangement a situation is avoided where due to certain reasons a work area changes to a non- working area and yet has the same illumination level as before, thus involving wastage of-energy.

Switching operations of Artificial Lighting are,

Mannual on/off
Mannual dimming
Automatic on/off
Automatic stepwise control
Automatic dimming

For street lighting, after traffic has died down at night. it may not be necessary to provide high illumination levels and can be reduced by selectively switching off the luminaires. However, The luminaire arrangement must be so designed that selectively switches off the lamps and will not affect the uniformity.

For outdoor lighting in general, It is advisable to use photo-cell switches to switch off/on the lights instead of using time switches. Even a single hour saving per day can result in tremendous annual savings of energy.

12.5 Utilization of daylight and the effect of the surrounding décor

The surrounding decor can significantly affect the energy effectiveness of an interior lighting installation. The lighter the surface decor, the higher the reflection factor; less energy is therefore required for a given lighting result than when a darker decor is used.

The relationship between the surface reflection factors and the luminaire photometric characteristics does to some extent, influence glare and therefore quality of the lighting result. Nevertheless, the objective should be to use surface reflectances which are as high as practicable.

Use of daylight in buildings allows for some reduction of electricity for lighting purpose and thereby reduces the consumption of energy in buildings. The extent of this, however, shall depend on a number of variables, such as the availability of daylight and orientation of the bui1ding, size and location of light openings, level of lighting required. This is particularly advantageous because windows are typically located in the side walls of the room.

Our basic aim of keeping the use of daylight is to achieve an aesthetically pleasant environment in which the occupants can see efficiently and comfortably. Thermal environment produced in the interior space as a result of daylight is a factor to be taken care of. Also the placement and variety of windows and other openings in a building also have significant effects on the passage of natural ventilation.

12.7 Role of Energy Management

The fundamental objective of management is to avoid energy waste in a cost effective manner. The task of designing new energy/cost effective lighting schemes or the identification of energy/costs saving opportunities by converting existing lighting installations is frequently regarded as the responsibility of the engineering function. In practice, good energy management requires the assistance and co-operation of many other management and operational disciplines within the energy using organization.

The best overall result can only be achieved by the coordination of Engineering , Finance, Purchasing, Administration and operational Staff at all levels. In conclusion it can be stated that even with the limited resources indigenously available, it is possible to achieve substantial amount of energy saving if the lighting products and the lighting design are energy effective. The majority of existing lighting installations can be improved by adopting more efficient equipment and improved application techniques. Some conversions require very little investment to obtain substantial benefits. In other cases, investment in new equipment may be needed and evaluation of the capital Investment required against the operational savings is necessary. Experience has shown that in most of the cases, the pay back period has been quite short, often less than 3 years. Sometimes, it has been found that an increase in capital or replacement cost resulted in a significant reduction in the installed load for lighting. Many organizations have benefited from the approach of energy effective lighting; they have either saved power for other uses or improved their hitherto poor lighting without any additional power.
