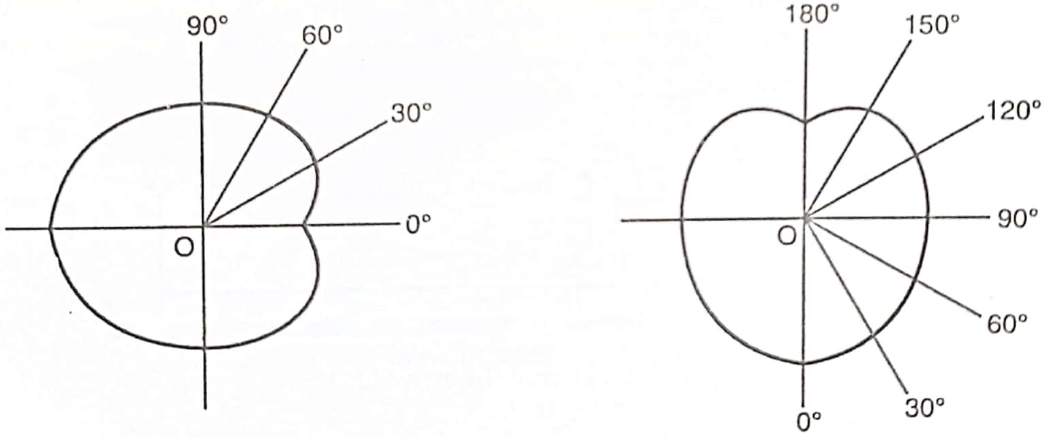
1.4. POLAR CURVES

The luminous intensity in most lamps or sources of light is not the same in all directions, because of their un-symmetrical shape. Often it is necessary to know the distribution of light in various directions to ascertain how the candle power of a light source varies in different directions. The luminous intensity in all the directions can be represented by ***polar curves.***

— If the luminous intensity *i.e.,* candle power is measured in a *horizontal plane* about a vertical axis and a curve is plotted between the candle power and the angular position, a "*horizontal polar curve*" or diagram is obtained.

— If the candle power is measured at angular position in a vertical plane, a polar curve in the vertical plane, called "*vertical polar curve*", is obtained.

Fig. 1.26 shows typical polar curves for an ordinary lamp.



(*a*) For horizontal plane. (*b*) For vertical plane.

Fig. 1.26. Polar curves.

The *polar curves are used to determine the following :*

(*i*) The mean horizontal candle power (M.H.C.P.) and mean spherical candle power (M.S.C.P.).

(*ii*) The actual illumination of a surface by employing the candle power in that particular direction as read from the vertical polar curve in illumination calculations.

- The M.H.C.P. of a lamp can be determined from the horizontal polar curve by taking the mean value of the candle power in a horizontal direction.
- The M.S.C.P. can be determined from the vertical polar curve by *Roussean's construction.*

1.8. ARC LAMPS

These lamps are used in *searchlights, projection lamps and other special purpose lamps like those in flash cameras.*

In an arc lamp electric current is made to flow through two electrodes in contact with each other which are drawn apart. The result is an arc being struck. The arc maintains the current, and is very efficient source of light.

The various forms of arc lamps are :

1. Carbon arc lamp
2. Flame arc lamp
3. Magnetic arc lamp.

- The carbon rods used with A.C. supply are of the same size as that used with D.C. supply. The positive rod is of larger size than the negative rod.
- The craters in the arc at the positive and negative rods are of the same size (with A.C. supply) while with D.C. supply, the positive crater is bigger and gives 85 per cent light at a temperature of 3500°C, while the negative crater is of smaller size. The efficiency of the lamp is 9 lumens/watt.
- The positive electrode gets consumed earlier than the negative electrode, if the size of the former is same as the latter. Hence the positive electrode is of twice the diameter than that of the negative.
- A resistance is used to stabilise the arc.
- The voltage drop across the arc is about 60 V (Fig. 1.37) and supply voltage is upto 100 V.

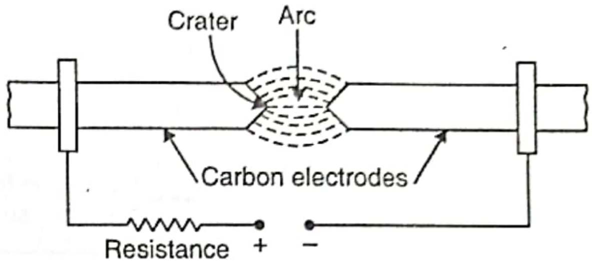


Fig. 1.37. Carbon arc lamp.

1.9. DISCHARGE LAMPS

- In all discharge lamps, *an electric current is passed through a gas or vapour which renders it luminous.* In this process of producing light by gaseous conduction, the most commonly used elements are *neon*, *mercury* and *sodium vapours.*
- The colours (*i.e.* wavelength) of light produced depends on the *nature of gas or vapour.*

— Neon discharge fields orange-red light ;

— Mercury-vapour light is always bluish ;

— Sodium vapour light is orange-yellow.

Types of discharge lamps. Discharge lamps are of the following *two* types :

Type-1. Those lamps in which *colour of light is the same as produced by the discharge through the gas or vapour.*

Example. Sodium vapour, mercury vapour and neon gas lamps.

Type-2. Those lamps which *use the phenomenon of fluorescence* ; these are known as *fluorescent lamps.* In these lamps, the discharge through the vapour produces ultra-violet waves which cause fluorescence in certain materials called as *phosphor.* The inside of the fluorescent lamp is coated with a phosphor which absorbs invisible ultra-violet rays and radiate visible rays.

Example. Fluorescent mercury-vapour tube.

In general, the discharge lamps are *superior* to metal filament lamps. However, they have the following **demerits :**

(*i*) High initial cost.

(*ii*) Poor power factor.

(*iii*) Starting, being somewhat difficult, requires starters/transformers in different cases.

(*iv*) Time is needed to attain full brilliancy.

(*v*) Since these lamps have negative resistance characteristic ballasts are necessary to stabilise the arc.

(*vi*) The flicker (caused due to the fluctuation of light output at twice the supply frequency) causes *stroboscopic effect.*

(*vii*) They are suitable only for a particular position.

1.9.1. Sodium Vapour Lamp

Construction and working of a sodium vapour lamp are described below.

Construction : Refer to Fig. 1.38.

This type of lamp is of *low luminosity*, so the length of this lamp is *large.* To get the required length it is made in the form of a *U-tube.* Two oxide-coated electrodes are sealed with the ends. The tube contains a little sodium and neon gas. The U-tube is enclosed in a *double-walled vacuum flask to keep the temperature within working range.*

Fig. 1.38 shows the connection diagram. *Capacitor is connected to improve the power factor* which will become low by using poor regulation transformer.

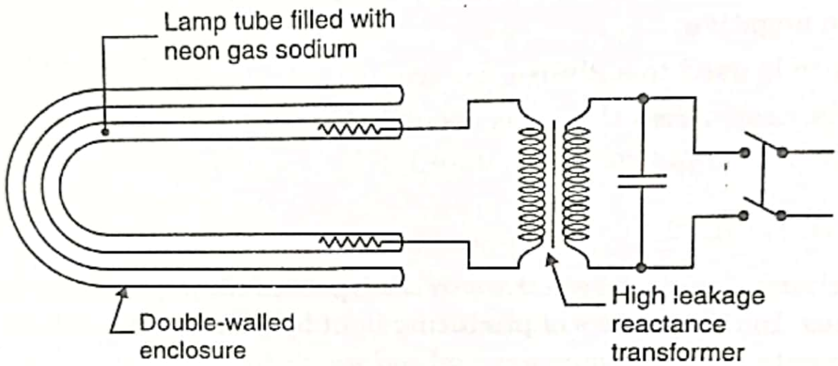


Fig. 1.38. Sodium vapour lamp.

Working :

Before the lamp starts working, the sodium is in the form of a solid, deposited on the sides of the tube walls. In the beginning when the switch is on, it operates as a low pressure neon lamp with pink colour. The lamp gets warmed, sodium is vaporised and it radiates yellow light and then, after sometime, about 10-15 minutes, the lamp starts giving full light.

In order to start the discharge lamp, a striking voltage of 380 V is required for 40 W lamp and 450 V for 100 W lamp. These voltages are obtained from a high reactance transformer or auto-transformer. At no load the voltage is very high which falls down as the lamp starts giving light, since the regulation of transformer is poor.

The lamp *fails to operate* when (*i*) the filament breaks or burns out, (*ii*) the cathode stops to emit electrons, (*iii*) the sodium particles may concentrate on one side of the tube, and (*iv*) the lamp is blackened owing to sodium vapour action on the glass, in which case the output will be reduced.

- The efficiency of a sodium vapour lamp under practical conditions is about 40-50 lumens/watt. Such lamps are manufactured in 45, 60, 85 and 140 watts ratings. The average life is about 3000 hours and is *not affected by voltage variations.* At the end of this period the light output will be reduced by 15 percent due to aging.
- This type of lamp is mainly used for highway and general outdoor lighting where colour discrimination is not required.

This lamp should be hung vertical otherwise sodium will blacken the inside of the tube.

1.9.2. High Pressure Mercury Vapour Lamp

Fig. 1.39 shows a high pressure mercury vapour lamp.

Construction :

It consists of two bulbs-an arc-tube containing the electric discharge and outer bulb which protects the arc-tube from changes in temperature. The inner tube or arc-tube is made of quartz (or hard glass) and the outer bulb of hard glass.

The arc-tube contains a small amount of mercury and argon gas. In addition to two main electrodes, an auxiliary starting electrode connected through a high resistance (about 50 kΩ) is also provided. The main electrodes consists of tungsten coils with electron-emitting coating or elements of thorium metal.

Working :

When the supply is switched on, initial discharge for the few seconds is established in the argon gas between the auxiliary starting electrode and the neighbouring main electrode and then in argon between the two main electrodes. The heat produced due to this discharge through the gas is sufficient to vaporise mercury. Consequently, pressure inside the arc-tube increases to about one to two atmospheres and p.d. across the main electrodes grows from about 20 to 150 V, the operation taking about 5 to 7 minutes. During this time, discharge is established through the mercury vapours which emit greenish-blue light.

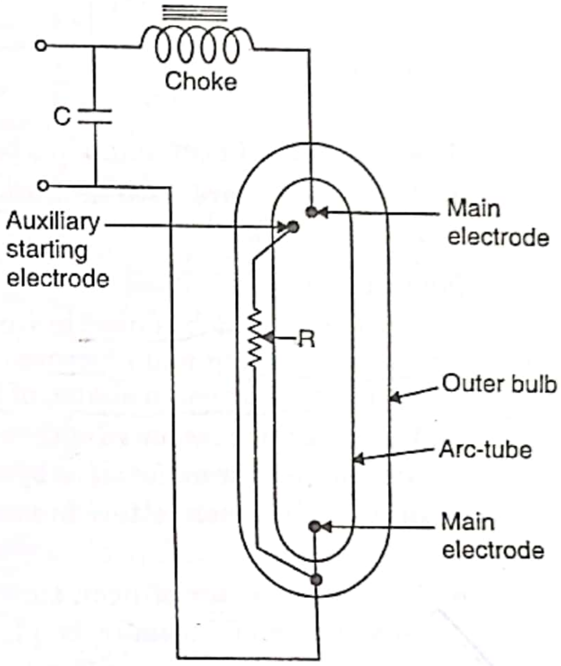


Fig. 1.39. High pressure mercury vapour discharge lamp.

The choke is provided to limit the current to a safe value. This choke lowers the power factor, so a capacitor *C* is connected across the circuit to improve the power factor.

The efficiency of this type of lamp is 30-40 lumens/watt. These lamps are manufactured in 250 W and 400 W ratings for use on 200-250 V A.C. supply mains.

These lamps are *used* for *general industrial lighting, railway yards, ports, work areas, shopping centres etc.* where greenish-blue colour light is not objectionable.

1.9.3. Mercury Iodide Lamps

- These lamps are similar in construction to high pressure mercury vapour lamps but in addition to mercury, a number of iodides are added which fill the gaps in the light spectrum, and thus, improve the colour characteristic of light. A *separate ignition device*, in addition to the choke, is required for such a lamp.
- Their *efficiency* is comparatively higher (75-90 lumens/watt)
- Such lamps are suitable for application in the fields of *flood-lighting*, *industrial lighting* and *public lighting*.

1.9.4. Neon Lamp

Neon lamps belong to *cold-cathode category*.

The electrodes are in the form of iron shells and are coated on the inside.

The colour of light emitted is red. If the helium gas is used in place of neon, pinkish white light is obtained. Helium and neon through coloured glass tubing produce a variety of effects.

Fig. 1.40 shows a circuit for a neon lamp. The transformer has a high leakage reactance which stabilizes the arc in the lamp. A capacitor is used for power factor improvement. High voltage is used for starting.

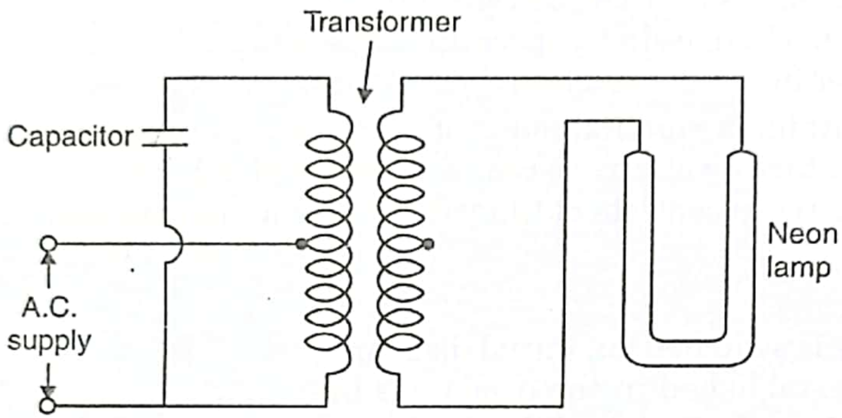


Fig. 1.40. Neon lamp.

The efficiency of neon lamp lies between 15-40 lumens/watt.

- These lamps are *used* as *indicator lamps, night lamps for determination of polarity of D.C. mains and in larger sizes on neon tubes for the purpose of "advertising"*.

Neon tube :

The *neon tube* which is used in varying lengths upto about 8 meters, may be bent into almost any desired shape during manufacture. It consists of a length of glass tubing containing two electrodes, normally cylindrical in shape, of iron, steel, or copper.

- The tubes are mounted either on a wooden frame or a metal base. These are matched with step-up transformers by connecting suitable tappings for the rated current. Connections between letters are made by nickel wires, the glass tubings being slipped over them.
- The power factor of neon tubes is quite low and is improved by using capacitors. The capacitors can, however, be placed on the low voltage side of the transformer.

1.9.5. Fluorescent Tube (lamp)

1.11. STREET LIGHTING

The street lighting entails the following *main objectives* :

(*i*) To make the traffic and obstructions on the road clearly visible in order to promote safety and convenience.

(*ii*) To enhance the community value of the street.

(*iii*) To make the street more attractive.

The following two general principles are employed in the design of street lighting installations :

1. Diffusion principle.
2. Specular reflection principle.

1. Diffusion principle :

- In this case the lamps fitted with suitable reflectors are employed. The design of the reflectors is such that they may *direct the light downwards and spread as uniformly as possible over the surface of the road.* In order to avoid glare the reflectors are made to have a cut-off between 30° to 45° so that the filament is not visible except underneath it.
- The diffusing nature of the road surface causes the reflection of a certain proportion of the incident light in the direction of the observer, and therefore the road surface appears bright to the observer.
- For calculating the illumination at any point on the road surface, point-to-point or inverse-square law method is employed. Over certain proportions of the road the surface is illuminated from two lamps and the resultant illumination is the sum of the illuminations due to each lamp.

2. Specular reflection principle :

- Here, the reflectors are curved upwards so that the light is thrown on the road at a very large angle of incidence. In this method, the requirement of a pedestrian, who requires to see objects in his immediate neighbourhood, is also fulfilled.
- This method is *more economical*, in comparison to diffusion method of lighting. However, it has the demerit that it *produces glare* for the motorists.

Illumination level, mounting height and types of lamps for street lighting :

- In *class A installations* (*e.g.*, important shopping centres and road junctions) the illumination level of 30 lm/m^2 is required, whereas for *poorly lighted suburban streets*, illumination level of 4 lm/m^2 is sufficient. For an *average well lighted street* an illumination level of 8 to 15 lm/m^2 is required.
- Normal spacing for standard lamps is 50 metres with a *mounting height of 8 metres.*
- For street lighting purposes, mercury vapour and sodium discharge lamps have been found to have certain particular advantages ; the most important of these is the *low power consumption for a given amount of light*, which inspite of the higher cost of the lamps, makes the overall cost of an installation with discharge lamps less than that employing filament lamps.

— The colour and monochromatic nature of light produced by discharge lamps does not matter much in street light installations.

- Lamp posts should be fixed at the junction of roads.

1.12. FACTORY LIGHTING

In an industrial establishment an adequate amount of light produces the following *good effects :*

1. The productivity of labour is increased.
2. The quality of work is improved.
3. Number of work stoppages are reduced.
4. Accidents are reduced.

A factory-lighting installation, in common with indoor equipments, should provide the following :

(*i*) Adequate illumination on the working plane ;

(*ii*) Good distribution of light ;

(*iii*) Simple and easily cleaned fittings ;

(*iv*) Avoid glare (from the lamp itself as well as from any polished surface, which may be within the line of vision) (10v)

General, local and emergency lighting :

- In factories and workshops the usual scheme is to mount a number of lamps at a sufficient height so that uniform distribution of light over the working the plane is obtained. In large machine shops the height is governed by the necessity of keeping the lamps above the travelling crane.
- On some points fairly intense illumination is required. For this purpose local lighting can be provided by means of adjustable fittings attached to the machine or bench in question or mounted on portable floor standards. Such lamps should be mounted in deep reflectors to avoid the glare.
- It is very desirable to provide auxiliary lighting from the sources other than the main electric supply preferably from batteries or from small petrol driven generator set. If however, emergency light circuits are operated from main electric supply, these should be completely separated from main lighting circuit

Reflectors for industrial purposes must be simple in design and easily cleaned ; these requirements of most of the installations can be met by one of the following types of fittings :

(*i*) Industrial lighting fittings ; (*ii*) Standard reflectors ; (*iii*) Diffusing fittings ; (*iv*) Concentrating reflectors ; (*v*) Enclosed diffusing fittings ; (*vi*) Angle reflectors.

1.13. FLOOD LIGHTING

The flooding of large surfaces with light from powerful projectors is called **flood lighting.** It may be employed for the following *purposes* :

(*i*) To enhance the beauty of ancient monuments by night.

(*ii*) To illuminate advertisement boards and show-cases.

(*iii*) To illuminate railway yards, sports stadiums, car parks, construction sites, quarries etc.

For small buildings, rather uniform flood lighting is used. Flood lights can be placed on other buildings nearby or on suitable posts at distances of not more than about 60 metres. Light should fall nearly perpendicular to the building.

Large or tall buildings are illuminated non-uniformly. Flood lights should be so located that contours and features of the building are well defined. If any shadows are cast, they should enhance the beauty of the building or movement.

As far as possible the projectors should not be visible to the passers by. In some cases the projectors may be housed in ornamental stands.

According to the beam spread, the projectors are *classified* as follows :

(*i*) ***Narrow beam projectors***—Beam spread between 12-25°. These are used for distance beyond 70 m.

(*ii*) ***Medium angle projector***—Beam spread between 25-40°. These are employed for distance between 30-70 m.

(*iii*) ***Wide angle projectors***—Beam spread between 40-90°. These are used for distance below 30 m.

- From view point of economy, use of wide angle projector with high wattage lamp is encouraged over narrow beam projector with low wattage lamp.
- In medium and wide angle projectors, standard gas-filled tungsten filament lamps of 250, 500 or 1000 W are used.

Following terms are used in flood lighting calculations :

(*i*) *Waste light factor.* What a surface is illuminated by a number of projectors there is certain waste of light. This effect is taken into account by multiplying the theoretical value of light (in lumens) by waste light factor which 1.2 for rectangular area and 1.5 for irregular objects like statues etc.

(*ii*) *Depreciation factor.* It is defined as the ratio of illumination under ideal condition to the illumination under normal conditions. The actual amount of light to be provided by the source is greater by 50 to 100% on account of dirt and dust depositing on the reflector surface etc. :

(*iii*) *Coefficient of utilisation.* It is also called *"beam factor"* and is defined as the ratio of beam lumens to the lamp lumens. Its value lies between 0.3 and 0.5.

For any desired intensity over a definite surface the number of projectors required is obtained from the following relation :

$$N = \frac{A \times E \times \text{Waste light factor} \times \text{Depreciation factor}}{\text{Utilisation factor} \times \text{Wattage of lamp} \times \text{Luminous efficiency of lamp}}$$

where, N = No. of projectors,

A = Area of surface to be illuminated, m², and

E = Illumination level required, lm/m².

Example 1.34. *The front of a building 45 m × 20 m is illuminated by twenty 1000 W lamps arranged so that uniform illumination on the surface is obtained. Assuming a luminous efficiency of 18 lumens/watt, coefficient of utilization 0.4, waste light factor 1.2 and depreciation factor 1.3, determine the illumination on the surface.* **(Madras University)**

Solution. *Given :* $A = 45 \times 20 = 900\ m^2$; $N = 20$; Luminous efficiency = 18 lumens/watt ; Utilisation factor = 0.4, Waste light factor = 1.2, Depreciation factor = 1.3.

Illumination on the surface, E :

$$N = \frac{A \times E \times \text{Waste light factor} \times \text{Depreciation factor}}{\text{Utilisation factor} \times \text{Wattage of lamp} \times \text{Luminous efficiency of lamp}}$$

$$20 = \frac{900 \times E \times 1.2 \times 1.3}{0.4 \times 1000 \times 18}$$

$$\therefore \quad E = \frac{20 \times 0.4 \times 1000 \times 18}{900 \times 1.2 \times 1.3} = \mathbf{102.56\ lm/m^2}. \quad \textbf{(Ans.)}$$

Example 1.35. *A building frontage 50 m × 16 m is to be illuminated by flood lighting projectors situated 25 metres away. If the illumination is 100 lux, coefficient of utilisation 0.5, depreciation factor 1.5, waste light factor 1.2, estimate the number and size of projectors. Sketch the projectors recommended indicating the usual adjustments provided.* **(A.M.I.E.)**

Solution. *Given :* $A = 50 \times 16 = 800\ m^2$; $E = 100$ lux ; Coefficient of utilisation = 0.5 ;

Depreciation factor = 1.5 ; Waste light factor = 1.2.

Assuming that 1000 W lamps having a luminous efficiency of 18 lumens/watt are used, we have :

$$N = \frac{A \times E \times \text{Waste light factor} \times \text{Depreciation factor}}{\text{Utilisation factor} \times \text{Wattage of lamp} \times \text{Luminous efficiency of lamp}}$$

$$= \frac{800 \times 100 \times 1.2 \times 1.5}{0.5 \times 1000 \times 18} = \mathbf{16}. \quad \textbf{(Ans.)}$$

Date

Reflector:

When light falls on the surface, depending upon the nature of surface, some portion of light energy is reflected, some is transmitted through the medium, rest is absorbed. Reflector used to divert the path of ~~indicident~~ incident light source to any direction.

The ratio of reflected light energy to the incident light energy is known as reflection factor.

There are two basic type of reflection

i) Mirror or Specular reflection

ii) Diffuse reflection.

In specular reflection the light is ~~is~~ reflected at a point surface from the incident source for ex. silvered mirror, polished metal etc.

In Diffuse reflection, the light source is diffuse uniformly in all direction. for ex. paper, dry ~~cal~~ earth, plaster.

A surface that is almost free from mirror reflection is called mat surface.