ILLUMINATION ENGINEERING PRACTICE

BY

BHIM CHANDRA CHATTERJEE,
B.A., B.L., B.Sc., M.I.E.E., M.I.E. (Ind.),

PATIALA PROFESSOR AND HEAD OF THE DEPARTMENT
OF ELECTRICAL ENGINEERING,
HINDU UNIVERSITY, BENARES.

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Foot Candle.—When a source of light gives one candle power in every direction and placed at the centre of a sphere of one foot radius, would give an illumination of one foot-candle at every point in the surface of the sphere. A fair average sky-brightness may be taken approximately 1 lambart or 2 candles per square inch, on stormy days this will be reduced to a much lower value of 0·5 candle per square inch.

If we consider the space all round a source of light, which is included by the total solid angle in space, namely, 4π, we see that the total flux of light in lumens is obtained by multiplying the average candle-power (mean spherical candle-power) by 4π.

A lamp giving one mean spherical candle-power gives a flux of 12·57 lumens and the total flux of light from any source is obtained by multiplying its mean spherical candle power by 12·57.

Intensity of Illumination :—The unit of intensity of illumination is called the foot-candle, and is the intensity of illumination produced on a surface at 1 foot distance from a standard candle upon which the light falls normally.

The intensity of illumination of a surface is directly proportional to the candle power of the source and inversely proportional to the square of the distance of the surface from the source.

From definition of unit of intensity, if a standard candle be situated at centre of sphere having a radius of 1 foot, the illumination of the interior of the sphere will be of unit intensity. The surface thus illuminated is 4π square feet.

When placed at centre of sphere having radius of r feet the same total light is emitted, but illuminates a surface of $4\pi r^2$ feet, hence the intensity is $\frac{4\pi}{4\pi r^2} = \frac{1}{r^2}$ foot-candles.

A source of c. p. (candle-power) will consequently produce an intensity of illumination of $\frac{c.\,p.}{r^2}$ foot-candles on a surface normal to the rays of light at a distance of r feet from the source.

If the rays fall obliquely on a surface, the intensity of illumination is $\frac{c.\,p.}{r^2} \cos\theta$ foot-candles, when θ is the angle of incidence of the light.

On the Continent, the illumination produced by one candle at a distance of 1 metre is the unit adopted, and is termed the **Lux.**

When the International Candle is used, the unit of illumination is the International Lux, which is 1. 11 times the Metre-Hefner Lux.

The INTENSITY (luminous intensity) in any given direction is measured by taking a small solid angle containing this direction dividing the luminous flux in this direction by the angle.

The usual unit of luminous flux is the SPHERICAL C.P. i.e. the total power emitted by a source giving one C.P. in every direction.

A better unit is the flux emitted in unit solid angle with one c.p. in every direction from the apex of the angle. This is called the luminous 1 s c.p. $= 4\pi$ lumens.

The Illumination—of a surface is the quantity of luminous flux received per unit area of the surface. The British unit is the illumination received by 1 sq. ft. of a surface placed 1 ft from 1 c.p. perpendicular to the rays of light. International distance is 1 metre.

British Standards of c.p.—The British standard of c.p. is one of pure spermaceti wax, of size 6 (6 to the pound) burning 120 grains per hour. It is no longer used as standard except in gas photometry. Its place has been taken by the pentane lamp. Standard lamps of 2 c.p. are sometimes used, but the official standard of the National Physical Laboratory is the Harcourt 10 c p. pentane lamp. It burns a mixture of air and pentane vapour (C_5H_{12}).

The c.p. is affected both by the atomspheric pressure and the humidity of the air and requires correction. The following equation has been found to apply within the range of variation of these experienced in practice.

$$c.p. = 10 + .066\ (10 - h) - .008\ (760 - b),$$

where

h = humidity in litres per cub. metre of dry air.

b = barometric height in mm. of mercury.

Standard is 760 mm and 10 litres of water per cub. metre of air.

Flux of light necessary for effective illumination :—The total flux of light required for the effective illumination of a room depends upon (1) the manner in which the light is distributed, (2) upon the composition (colour) of the light and (3) upon the mean coefficient of absorption or reflection of the illuminated surfaces. Ordinarily the interior of a room is to be illuminated by lamps which give a soft yellow light. The lamps are usually distributed overhead so as to be as much as possible out of the field of vision.

The **rating** of a lighting system depends on effective intensity of illumination on the work rather than the quantity of light produced by the lamps.

Illumination.—It denotes the density of the light flux falling upon a surface.

Luminosity.—It measures the density of the flux arising from a surface either as the result of light emission or light diffusion. Luminosity of a diffusingly reflecting surface is equal to the illumination multiplied by its reflection coefficient. But the luminosity of a diffusingly transmitting surface equals its received illumination multiplied by its coefficient of transmission.

Luminosity depends like Sound upon physiological relations of a certain form of energy and cannot be directly reduced to a mechanical equivalent.

The Intrinsic Brilliancy of a light source is expressed as the lumens emitted per square foot of radiating surface or as the candlepower per square inch of surface exposed to a given direction.

The c.g.s. unit of brightness is **Lambart** which is the brightness of a perfectly diffusing surface radiating or reflecting, one lumen per square centimeter.

Let ϕ = flux of light.

a = apparent luminous area of source (sq. in.)

A = area in sq. ft. on which it falls.

θ = angle of incidence of the rays, that is the angle between the beam and the normal to the surface at the point.

E = intensity of illumination in foot-candles.

I = light intensity of source (candle-power).

ω = solid angle subtended by A at source.

t = coefficient of diffuse transmission.

r = coefficient of diffuse reflection.

l = distance of A from sources.

e = brilliancy.

Concept.	Symbol.	Unit.	Defining Relation.
Intensity	I	Candle power.	$I = \frac{d\phi}{d\omega}$,
Quantity	ϕ	Lumen.	$\phi = I\omega = 4\pi$ Ims.
Quantity Mean Intensity	Ims	Spherical candle.	Ims. $= \frac{\phi}{4\pi}$,
Illumination	E	foot candle	$E = \frac{\phi}{A}$, $E = \frac{I \cos\theta}{l^2}$
Luminosity	L	...	$L = \frac{\Phi r}{A}$ or $L = \frac{\Phi t}{A}$,
Brilliancy	e	...	$e = \frac{I}{a}$,

From the law of inverse square and the law of cosine the illumination at any point may be expressed in terms of the intensity I acting in this direction, the distance l between the light source and the point illuminated and the angle θ between the beam and the normal to the surface at the point

$$E = \frac{I \cos \theta}{l^2}.$$

Mean horizontal candle power (m h.c.) of a lamp is the average candle power in the horizontal plane passing through the luminous centre of the lamp.

Mean spherical candle power (m. c. p.) of a lamp is the average candle power of a lamp in all directions in space. It is equal to the total luminous flux emitted by the lamp in lumens in that hemisphere divided by 4π.

Mean Spherical Candle Power.—The light intensity of lamps is far from uniform when the lamp is viewed from different directions; it varies with the shape of the filament, &c. Curves of candle-power may be obtained by observing the lamp from a succession of points situated on a horizontal plane through the centre of the lamp. From observations of this kind, the mean horizontal candle-power may be calculated. This has generally been the value used in stating the candle-power of incandescent lamps. Various reasons make it much preferable to use the mean spherical candle-power as the basis for comparing the value of various sources of light; (1) the lamp is generally fixed above the object to be illuminated, so that the rays directed downwards are more useful than those emitted horizontally; (2) different types of lamp give very different distribution of light in a vertical plane and cannot fairly be compared on a basis of horizontal illuminating power; (3) by the use of suitable reflectors, it is possible to direct the greater portion of the light rays in any desired direction, irrespective of their direction of emission in the lamp.

These reasons have led to the modern practice of rating lamps in watts per mean spherical candle-power, in place of the former method of statement in watts per mean horizontal candle-power. The ratio of the mean spherical candle-power to the mean horizontal candle-power for an ordinary incandescent lamp is about 0.8.

It is proposed that in future lamps should be rated in lumens (i.e., the total flux emitted) instead of candle power. Ordinary incandescent lamps with straight filaments emit a number of lumens which is approximately 10 times their mean horizontal candle-power. For any lamp, the total lumens = mean spherical candle power $\times$ 4 π.

'**Luminous efficiency** generally denotes the ratio of the luminious radiation of an illuminant to its total radiation. In Engineering practice efficiency is denoted by the ratio of the light produced to the total energy expended e. g. lumens per watt.

Note—

Illuminant	watts consumed.	Percent Power radiation as light.	M.S.C.P.	watts per M.S.C.P.	Lumens per watt.
Carbon filament	98·23	2 07	21·6	4·55	2·76
Kerosine lamp	508	·25	10·56	48·2	0·261
Acetylene flame	96	0·65	5·31	18·1	0.695
Osram Lamp	38.3	5·36	24·1	1·60	7·91
D. C. open Arc	435·0	5·6	461	0·95	13·3
D. C. enclosed arc	541·0	1·15	260	2·08	6·04
A. C carbon arc	180·6	1·84	66	1·88	6·67
Yellow flame arc	349·7	15 0	1010	0·343	36·3
White flame are	148	7·56	668	0·521	22·2

H. Lux Electrical world Vol 2 p. 929.

Mean Zonal Candle Power of a lamp is the average candle power of a lamp over a given Zone. It is equal to the total luminous flux emitted by the lamp in that zone divided by the solid angle of the zone.
Spherical reduction Factor of a lamp is the ratio of the mean spherical to the mean horizontal candle power of the lamp. For glow lamps its value is 0·8.

Let K = the reduction factor

$$= \frac{I_{ms}}{I_h}$$

Example :—A glow lamp has I_h =32 c. p. and K=0 8. what is the total flux of light
solution.

$$I_{ms} = KI_h = 32 \times 0{\cdot}8 = 25{\cdot}6$$

$$\phi = 4\pi I_{ms} = 4\pi \times 25{\cdot}6 = 322.$$

Absorption, Reflection and Transmission— The light which falls upon a surface is (1) partly absorbed and it disappears as light and appears as some other from of energy e. g. heat ; (2) partly reflected— as (a) regular or specular reflection or (b) irregular or diffuse reflection and (3) partly transmitted as (a) regular transmission or (b) diffused transmission e. g. when the emerging rays are scattered in all directions.

Influence of absorption upon Illumination :— An illuminated surface absorbs a definite fractional part of the light which falls upon it. The ratio of the light absorbed in the medium to that incident upon it is denoted by the coefficient of absorption of the illuminated surface. The intensity of illumination in a given room from a given source depends upon the coefficient of absorption of the illuminated surface. These coefficients may be affected very much by the colour composition of the incident light.

In general the total flux of light required to produce a given mean intensity of illumination in a room is proportional to the product of the combined area of all the surfaces to be illuminated and the mean coefficient of absorption of these surfaces. Furthur the illumination in an enclosure depends upon the colour of the surrounding surfaces.

Diffuse. irregular or Broken Reflection—In this, rays of light fall upon an irregular surface such as paper or lime, the rays are scattered in all directions, having their origin at the reflecting surface, which appears luminous but forms no image of the primary source. The rays advance in promiscuous directions after reflection.

Specular or Regular Reflection—In this, ray of light is reflected and continues to advance in the new direction from which the light has been received.

Both the reflections occur simultaneously but the proportion of each depends upon the degree or polish of the surface.

The ratio of light reflected by any source to that incident upon it is called COEFFICIENT OF REFLECTION.

REFLECTING POWER OF SURFACES

White Blotting Paper	82 %	Speculum metal	60–80 %
Yellow Wall Paper	40 %	Polished gold	50–55 %
Blue Paper	25 %	Burnished Copper	40–50 %
Deep Chocolate	4 %	Newspapers	50–70 %
Deal	30–50 %	Tissue Paper (one thickness)	40 %
Yellow Painted Wall	20–40 %	Tissue Paper (two thicknesses)	55 %
Black Cloth	1–2 %	Dark Brown Paper	13 %
Black Velvet	4 %	Plane Deal (dirty)	20 %
White Cartridge Paper	80 %	Yellow Cardboard	30 %
Tracing Cloth	35 %	Parchment (one thickness)	20 %
Tracing Paper	22 %	Parchment (two thicknesses	35 %
Ordinary Foolscape	70 %	Black paper	5 %
Highly polished Silver	92 %	Lime washes (ordinary Paleict)	50–66 %
Mirrors, Silvered on surface	70–85 %	„ „ umber	40 %
Highly Polished brass	70–75 %	Light orange paper	50 %
Highly Polished copper	60–70 %	„ cream paint	52 %
„ „ Steel	60 %		

Hygienic considerations demand, apart from avoidance of glare etc. that the light containing an excess of the chemically active ultraviolet rays should be avoided ; such rays, however, have great theraputical effects when used skilfully ; at the sametime, they are capable of doing great injury if wrongly applied. Even the ordinary coloured rays are said to effect cure and are utilized as healing agents in the art of chromopathy.

Aesthetic considerations would lead to prefer slightly reddish tinge rather than the cold and searching rays of pure white or white tinged with green. The colour values of dress goods for street wear should be determined with day light while goods for evening wear should be judged by artificial light like that in which they are to be worn.

Psychological considerations play a large part in determining the satisfaction derived from illumination. The principles of association and suggestion may be important considerations for the illumination Engineer. A person who is accustomed to one kind of lamp may complain of the supposed dimness of light when a lamp of a greater candle power but of a smaller dimension has been used.

Physiological Effect :—Colour seems to change in very dim light, the eye itself differs in its sensibility to different coloured lights. In very dim light, everything appears to be grey, red disappears first, violet and deep blue follow and so on, and hues of simple colours change.

The properties of the eye as a physical instrument are briefly stated as follows (Nutting in Bulletin Bureau of Standards Vol. 5, P. 265, 1908) :—

(1) Sensibility to Radiation of various wave lengths.

(2) Sensibility to Radiation of varying intensity.

(3) Sensibility to small differences in intensity.

(4) Sensibility to slight differences in wave lengths.

(5) Visual acuity or resolving power.

(e) The growth and decay of the visual responses with time.

The true criterion of effective and efficient lighting is the visual usefulness which takes into account the physiological factors in artificial lighting.

Let I = illumination in foot-candles.

Then the visual usefulness $= I\sigma$, where σ is proportional to the effective area of the pupil. It is an inverse function of the intrinsic brilliancy of the radiants used. Other physiological factors like adaptation also depend directly upon the intrinsic brilliancy to which the retina is exposed.

$\therefore$ the criterion is $i = \frac{I}{f(\beta)}$ where β is the intrinsic brilliancy of the radiant, i is the usual usefulness or the effective brilliancy of the illumination.

Heads of Illumination Considerations.

(1) Intensity of brilliancy.

(2) Distribution of light.

(3) Diffusion of light.

(4) Quality of light.

(Mr. E. L. Elliot quoted in Foster's Electrical Engineers Pocket-book p. 599. 7th Edition, 1918)

"**Intensity of Brilliancy**:—The average brilliancy of illumination required will depend on the use to which the light is put. "A dim light that would be very satisfactory for a church would be wholly inadequate for a library, and equally unsuitable for a ball room." In general, intensity of illumination should not be less than one candle-foot, rather double the brilliancy is often required. Generally it is found that two 16 candle-power lamps per 100 square feet of floor space give good illumination, three very bright, and four brilliant. The intensity depends upon the height of the ceiling, colour of walls and other local conditions. With the intense light of arc and incandescent lighting, there is danger of exceeding "the limits of effective illumination and producing a glaring intensity," which should be carefully avoided as much as too little intensity of illumination.

The sensation of vision—(Dr. Louis-Bell) comprises four elementary sensations of (1) contour involving boundaries, outlines and details assisting in recognising flat surfaces.

(2) Relief effected by light and shade due to different degree of luminosity.

(3) Perspective arising from the difference in the visual angles subtended by angles at different distances.

(4) **Colour**—The perception of surfaces in their true relations is dependent upon (1) colour and (2) contour.

The fundamental law respecting colour is "that every opaque object assumes a hue due to the sum of the colours which it reflects." The question of colour values is of great importance in the art of illumination e. g. in the illumination of stores, show-rooms, etc.

Lighting fixtures are primarily intended for providing light for utilitarian purpose, and the problem in designing lighting fixtures is, to combine beauty with utility or the artistic with the practical—if a sacrifice is needed let it be the sacrifice of efficiency in its narrow sense.

Attributes of Colour—The following are a few attributes which have been applied to some of the principal colours and which under many conditions appear to be appropriate.

Red—warm, exciting, passionate.

Orange—warm, exciting, suffocating, glowing, lively.

Yellow—warm, exciting, joyous, gay, merry.

Yellow-green—cheerful.

Green—neutral, tranquil, peaceful, soothing.

Blue-green—sober, sedate.

Blue—cold, grave, tranquil, serene.

Violet—solemn, melancholy, neutral, depressing.

Purple—neutral, solemn, stately, pompous, impressive.

Note that when colours are chosen for "colour's sake", generally pure colours are preferred to tints, and shades in pure colours, those having hues near the ends of the spectrum are liked more, *viz.*—blue and red, of these, men like blue, women red, and the least preferred colours are those near the middle of the spectrum, but the choice is contrary for decoration purposes.

The attention value of colours indicates that characters printed in red attract the attention much more than those in black when both are viewed together. But red has a low Luminosity value.

A colour may be agreeable under a given environment or attitude of mind and quite unpleasant under other conditions, and much depends upon the brightness saturation etc. upon the physiological effect, *e.g.* stimulating, soothing, heating; upon association, and upon "character" or expression of the colours. The appreciation of colour is essentially emotional and may be said to be aesthetic in the highest sense. The harmony and aesthetics of colour should be studied carefully in considering the problem of lighting.

(1) **The Colour Impression**—produced varies with the wave length and the brightness is proportional to the square of the amplitude of vibration.

(2) Hue is that property of colour by which various spectral regions are characteristically distinguished.

(3) Two hues are complementary if they may be mixed to produce white. Contrast in hue is the life of colour and the absence of it is practically fatal.

(4) Saturation of a colour is its degree of freedom from admixture with white.

(5) **Tints** are produced by the addition of white to pure colour. SHADES of a colour are produced by lowering its brightness.

THE ART OF ILLUMINATION consists of physical optics, physiological visual phenomena, and the psychological effects of light, shade and colour as well as engineering principles.

Distribution of Light—Distribution considers the arrangement of the various sources of light, and the determination of their candle-power to "secure a uniform brilliancy on a certain plane, or within a given space."

"A room uniformly lighted, even though comparatively dim, gives an effect of much better illumination than where there is great brilliancy at some points and comparative darkness at others. The darker parts, even though actually lighted enough, appear dark by contrast, while the lighter parts are dazzling. For this reason naked lights of any kind are to be avoided, since they must appear as dazzling points, in contrast with the general illumination."

The arrangement of the lamps depends upon the nature of individual case. In factories and shops, lamps should be placed over each machine or bench as to give the necessary light for each workman. In the lighting of halls, public buildings and large rooms, excellent effects are obtained by dividing the ceiling into squares and placing a lamp in the centre of each square. The size of square depends on the height of ceiling and the intensity of illumination desired. Another excellent method consists in placing the lamps in a border along the wall near the ceiling.

For the illumination of show windows and display effects, care must be taken to illuminate by reflected light. The lamps should be so placed as to throw their rays upon the display without casting any direct rays on the observer.

The relative value of high candle-power lamps in case of an equivalent number of 16 candle-power lamps is worthy of notice. Large lamps can be efficiently used for lighting large areas, but in general, a given area will be much less effectively lighted by high candle power lamps than by an equivalent number of 16 candle power lamps. For instance, sixteen 64 candle-power lamps distributed over a large area will not give as good general illumination as sixty-four 16 candle-power lamps distributed over the same area. High candle-power lamps are chiefly useful when a brilliant light is needed at one point, or where space is limited and an increase in illuminating effect is desired.

Distribution of Light by Incandescent Lamps

The best form of lighting interiors is to have single lamps uniformly distributed over the ceiling; unless the room has been especially designed with this in view, it is sometimes difficult to accomplish.

Another method giving most excellent results, but requiring more candle-power, is the arrangement of lamps around the sides of the room close to the ceiling. If the walls and ceiling are of a light colour, this method is quite satisfactory, and easier to wire.

If the chandeliers, or more correctly in this case, electroliers, are used, it is best to have but one main or large one in the room, balancing the light by side brackets.

All such suspended lights should be above the line of vision as far as convenient.

The most economical distribution, as far as candle-power necessary, is the first mentioned, where lights are evenly distributed over the ceiling. To obtain the same luminosity by using clusters of lamps more widely distributed instead of single ones, will require much more candle-power.

The 16 candle-power lamp is the universal standard when rating lamps or illumination, and following are given some ratings on which illumination of different classes of buildings is figured.

Ordinary illumination, 1 lamp, 8 feet from floor for 100 square feet, as in shade, depots, walks, etc.

In waiting-rooms, ferry-houses, etc. 1 lamp for 75 sq. feet.

In stores, offices, etc. 1 lamp for 60 sq. feet.

Of course the above must be varied to suit the circumstances such as dark walls or other surroundings requiring more light, as the walls reflect little of that furnished; and in rooms with dead white walls the reflection approaches 90 per cent. and less lamps would be required than in interiors having worse reflecting surfaces.

A very ingenious and satisfactory method of illuminating high arched and vaulted interiors is to place a number of lamps around the lower edge of the arch or dome, with reflectors under them, and so located behind the cornice as to be invisible to the eye from the floor.

The dome or arch will reflect a large part of the light so placed, giving a very fine even illumination to the whole interior, without shadows, and very restful to the eye.

Of course the arch must be of good colour for reflecting the light, or much of it will be wasted.

Diffusion of Light.—" Diffusion refers to the number of rays that cross each point. The amount of diffusion is shown by the character of the shadow. Daylight on a cloudy day may be considered perfectly diffused; produces no shadows whatever. The light from the electric arc is least diffused, since it emanates from a very small surface; the shadows cast by it have almost perfectly sharp outlines. It is largely due to its high state of diffusion that daylight, though vastly more intense than any artificial illumination is the easiest of all lights on the eyes. It is a common and serious mistake, in case of weak or overstrained eyes, to reduce the intensity of the light, instead of increasing the diffusion.

Quality of Light.—" Aside from difference in intensity, light produces many different effects upon the optic nerves and their centres in the brain. These different impressions we ascribe to difference in the quality of the light. Thus 'hard light,' 'cold light,' 'mellow light,' 'ambient light,' etc., designate various qualities. Quality in light is exactly analogous to timber or quality in sound, which is likewise independent of intensity. The most obvious differences in quality are plainly those called color. But color is by no means the element of quality. The proportion of invisible rays and the state of diffusion, are highly important factors, but on account of not being directly visible, they have been generally overlooked, and are but imperfectly understood."

CHAPTER II

Illumination Design.

POINTS FOR ARTIFICIAL ILLUMINATION

(1) Intensity of illumination.

(2) Sufficiency of illumination of unvarying intensity on all principal surfaces and to each person if working in a factory.

(3) The uniformity of illumination without regard to the location of the work.

(4) Reduction of glare, glaring reflections or blinding effect, to be minimised by (1) suitable arrangement of lamps, (2) using the proper size and (3) using a suitable reflector.

(5) Diffusion of illumination, and direction of light, avoiding objectionable shadows or contrasts of intensity

(6) Steadiness of the light secured by using constant voltage of supply.

(7) Colour value of the light and colour balance. Violet produces the maximum chemical effect, yellow the

maximum light effect. Red produces the maximum heat effect. The most luminous part of the spectrum is yellowish green.

(8) Appearance.

(9) Efficiency.

(10) The type of lamp must be suitable to (1) the class of work requiring light (2) the mounting height, (3) the physical surroundings.

(1) The Lighting effect appropriate for the location and lighting units which must be in harmony with their surroundings, whether lighted or unlighted.

(2) Simplicity, reliability, ease of maintainance, initial and operating condition and cost not out of proportion to the results attained.

Method of Illumination—There may be (1) GENERAL ILLUMINATION when the lamps are mounted overhead and SPECIFIC ILLUMINATION when individual lamps are provided close to the work.

Specific Illumination.—General lighting should be used as far as possible and supplemented by local illumination only where unavoidable. Since by the local illumination it is difficult to avoid glare either from the source directly or from the illuminated surface. For local illumination requiring bright light, every precaution should be taken to avoid glare. This is done by the use of diffusing media and care in locating the light course, and an ample general illumination supplementing the local illumination.

Estimates based upon cubic feet per mean s. c. p.

Bright illumination	requires	1 m s. c. p. to 30 c ft. or less.
Medium	,,	1 m. s. c. p. to 30 to 60 c ft.
Low	,,	1 m. s. c. p. to 60 to 100 c ft.

Estimates based upon square feet of floor space per mean spherical candle power.

Bright illumination	1 m. s. c. p.		to 20 sq. ft. or less
Medium	,,	,,	to 2 to 4 sq. ft.
Low	,,	,,	to 4 to 6 sq, fr.

For the proper design of a lighting system ascertain :—(1) the kind of work carried on, (2) the location of machines or furniture, (3) the height of ceiling and size of room, (4) the colour of walls and ceiling. An excess of ultra violet rays to be avoided for hygienic reason. In INDUSTRIAL LIGHTING, as in factory and warehouse, lighting efficiency of illumination is of greatest importance, and decorative effect and appearance of the lighting units is relatively unimportant.

In COMMERCIAL LIGHTING, e.g., the lighting of office buildings, stores, restaurants, hotels, libraries museums, railway stations, residences, etc. more attention must be paid to securing an installation which will harmonize with the decorations and furnishings of the rooms. Aesthetic considerations commend light of a faint reddish tint as warm and cheerful in comparison with the cold effects of green tint. Green colour is more effective in revealing hue detail. In such places, efficiency may be, to a certain extent, sacrificed for the sake of improved appearance. This is secured usually by careful attention to the proportion of the fixtures, and to the effect of the illumination upon the decorations of the room.

Then determine :—

1. Class of lighting, whether industrial or commercial.

2. Method of illumination, whether localized, general or a combination of the two.

3. System of illumination—whether direct, indirect or semi-indirect.

4. Type of lamp to be used, whether arc, incandescent or vapour tube.

5. Intensity of illumination, which depends upon item (1).

6. Power Required.

7. Size of light unit.
8. Location of light units.
9. Reflectors or Globes.

Avoid Harmful effects of light on the eyes—Very great contrast of light and shade in the field of vision impair visual perception. In very brilliant lights the details in the shadow are blotted out due to the glare. The effect is specially seen in bright unshaded lamps. Hence it is important, in arranging for the illumination of a room, to place the lamps outside of the field of vision. The bad effects of glare may be greatly reduced by enlarging the effective luminous surface of the lamp by means of a translucent globe which diminishes the glare owing to the amount of light coming from a larger area of the globe.

Excessive illumination and inadequate illumination both strain and fatigue the eye and are to be avoided.

Glare is due to the following principal causes—

(1) Intrinsic brilliancy of the lamp or source.

(2) The total candle-power from the sources directed towards the eye.

(3) Distance from the source to the eye.

(4) Contrast in brightness between the light source and the working surfaces and surroundings.

(5) Proximity of the light source to the line of vision.

(6) The length of the time during which the source of glare is present within the field of vision.

(1) Avoid the use of a single bright light in a poorly illuminated room or highly brilliant sources in the field of vision (2) Arrange for a general illumination of the room in addition to any necessary local light. In the ideal arrangement such a strong general illumination is provided that a pencil placed on the page of a book casts two shadows of nearly equal intensity—one coming from the general light and the other from the local light. (3) Prevent direct rays from striking the eye or improper direction of flux causing shadows, glares etc. The light that reaches the eye by day is always reflected. Avoid shadows in reading or writing by using the light which should come over the left shoulder. (4) Generally never use clear glass, unshaded lamps. Use frosted bulbs where soft light for reading is required In a frosted bulb the light is radiated from the whole surface of the bulb, and while the total illuminating effect is practically undiminished, the light is softened by diffusion, to the great comfort and relief of the eyes. (5) Never use old, dim, and blackened lamps giving but a small fraction of their proper light. Lamps should not be retained in use long after their efficient light giving power has gone. (6) Avoid faulty colour content, improper (1) proportioning of direct and of diffused light and of general and of concentrated light.

The eye works with normal efficiency upon surfaces possessing an effective luminosity of one lumen per square foot or more.

Intrinsic brilliancy of more than 5 candle power per square inch should be reduced by a diffusing medium when the rays enter the eye at an angle below 60° with the horizontal.

Remember that fluctuating, unsteady and streaky illumination strain the retina and as such should be avoided.

For the correct use of light.—(a) Allow only reflected light to reach the eye. Place the light in such a position that it throws the direct rays on the book or work, and not in the eye.

(b) Arrange for a general illumination in addition to the light near at hand.

(c) Place the light in such a manner that shadows will not fall on the work in hand.

(d) Use shades and frosted bulbs to soften the light.

(e) Renew the lamps frequently to keep the light up to full candle power.

Dim lamps *versus* **Bright Lamps**.—More satisfactory distribution of light is obtained by using several lamps of moderate brightness than by using one or two lamps of great brightness. Very bright lamps are not suitable for illuminating rooms excepting when indirect system of illumination is employed. For satisfactory distribution of light over the lower portion of a room, very bright lamps should be raised to a considerable height over head.

Proper Lighting conserves human resources and lessens the cost of maintaining order in the community, as such, it is a great element of safety.

The purpose to be served.—Lighting is necessary to make a store attractive to the prospective customer to promote the sale of goods; to illuminate the work on the machine and promote its prompt, accurate and safe accomplishment; to facilitate clerical work, promoting speed and accuracy without fatigue to the clerks; or to enhance the beauty and charm of a room in a residence. As a rule there are two or more principal objects to be attained in every installation.

Choice of Illuminant.—In a residence only incandescent lamps are suitable. In street lighting incandescent or arc lamps may be used. Reliability, simplicity, efficiency, colour of light, steadiness, cost (first, operating and maintenance) and size usually determine this choice.

Choice of auxiliary.—In choosing auxiliaries consider the cost, ease of cleaning, ruggedness, efficiency new and maintained, light-directing qualities, diffusion, colour, size and appearance. The importance of each qualification depends upon the nature of the installation.

Direct Lighting.—When the light is reflected toward the objects to be illuminated without the interposition of reflecting or transmitting media, the system is called "Direct Lighting" or in this the greater part of the light falls upon the reference plane as the direct rays of the illuminant. This facilitates the delivery of a maximum percentage of the total light upon the surfaces to be illuminated.

Advantage.—The ratio of utilization, or the per cent of light flux delivered upon a working plane, other things being equal, is greater when direct-lighting equipment is employed than under other methods. This system is the least expensive.

Disadvantage—The degree of diffusion of light which is essential to the avoidance of glare and the elimination of excessively deep shadows can scarcely be obtained. Hence the system does not always yield the most effective illumination obtainable from a given amount of light produced within a room.

Use—The Direct System is usually used for industrial lighting as it requires the least power to produce a given amount of illumination and in many commercial installations where efficiency is of great importance. Occasionally, however, an indirect system is used for work rooms with low ceilings, or where shadows must be eliminated, as in drafting rooms.

Indirect Lighting—"Indirect-lighting equipment. in which the light sources are entirely concealed from view and the light is directed upon a reflecting surface such as the ceiling, which reflects and diffuses it, avoids some of the worst difficulties of " Direct Lighting," The reflecting surface in this becomes the apparent light source, The illumination is accomplished entirely by reflected light directed from the ceiling and upper part of the wall and, having large area, its brightness is very much lower than that of the real source. As a result, the shadows are softened, immediate glare effect is much diminished, and glare due to reflection from specular surfaces is like wise very much reduced. It produces conditions much more conducive to comfortable vision than those usually attending the use of direct-lighting equipments. It eliminates all shadows, secures uniformity of light and low intrinsic brilliancy and vision is improved by shading the eyes.

Use—The indirect system used in drafting rooms, hotel bed rooms, etc. The semi-indirect system is in general preferable to the indirect system, both because of the efficiency slightly better and appearance of the installation. The ceiliug must be light in colour to make the systems effective.

Disadvantages—In this system it is difficult to control the light and the efficiency of light is very low and the method is very expensive.

Semi-indirect Lighting.—Systems intermediate between the two just described in respect to ieffectiveness of light direction, diffusion of light, softening of shadows and reduction of glare are classed as "Semi-Indirect Lighting" equipments. In these the translucent bowls are used, the translucency varying widely and brightness of bowl varying in a corresponding manner. There is very little difference between lighting effects obtained with some indirect-lighting equipments and some semi-indirect lighting equipments, as in both the cases large proportions of the light are directed toward the ceiling, whence they are diffused throughout the room. Sometimes enclosing globes are used to produce results of much the same order. These equipments are located, therefore, in (1) inverted bowls or caves, (2) totally enclosed glassware, (3) translucent bowls.

Use—The Semi-Indirect system is employed very extensively for commercial installations where a reasonably high efficiency such as better classes of stores, resturants, residences, hotels, etc. and harmony with the furnishings of the room are desired. These are effective in improving the appearance of the installation.

Harmony in Decoration—Lighting fixtures must not be conspicuous in themselves but should only contribute to the general scheme of decoration. "Artistic success results from the perfect blending of utility and beauty without the subordination of either." Attention should be given to the illuminants themselves as artistic motives without violation of their natural appearance and properties.

Spacing—In direct system the spacing of units depends principally upon the extent to which shadows must be eliminated and a good diffusion of the light secured. A wide spacing makes the illumination less uniform and gives stronger shadows and requires the use of larger units. A very close spacing gives a more uniform illumination and eliminates shadows to a considerable extent but results in a more expensive installation. Close spacing would be required where shadows should be practically eliminated. For high ceiling, wide spacings and large units are used. The mounting-height of the lamp determines the size of the rectangle which should be illuminated by one lamp.

Close spacing and small-size units should be used for low ceiling and large-size units and wide spacing should be used for high ceilings where the lamps can be mounted at a considerable distance above the floor. The exact spacing, and hence the size of the rectangle is fixed as soon as the watts per square foot and the most desirable size of unit are settled upon.

Example.—Required the spacing to allow 1·0 watt per sq. ft. in an office.

For	25 watt-units	...	5·0-ft. spacing.
„	40 „ ...	...	6·4 „
„	60 „ ...	...	7·8 „
„	100 „ ...	...	10·0 „

In industrial and commercial lighting the spacing should be about 50 per cent, greater than the vertical distance from the plane of illumination to the light source. In large rooms it is useful to divide the floor area into squares or approximate squares. Desirable sizes of these squares are given. One light source may be placed over the middle of each such square. Sometimes, however, the squares or rectangles which form the unit of space to be lighted are established by the confines of the room by the pillars. Deep girders often divide the ceiling into bays when the lamps should be located slightly below the bottom edge of the girders. In such cases it may be practicable to treat the space as a unit or it may be necessary to subdivide it into rectangles. For uniformity of illumination smaller rectangles should be adopted. Other things being equal, smaller rectangles should be used for direct lighting and larger ones for indirect lighting because in the latter case, the actual light source (ceiling) is higher and the diffusion is greater. In general, the adoption of smaller rectangles, which means more frequently spaced smaller light sources, results in greater uniformity less marked shadows and less glare, while larger rectangles and larger illuminants afford more pleasing appearance. Balance between these two depends upon local conditions. When, however, we use a reflector which directs the light in the proper direction, we can secure practically the same amount of light upon the working surface regardless of the height of the units. If we change the style of reflector when the mounting height changes, we can obtain the same illumination with the same expenditure of power.

LOCATION OF LIGHT UNIT.

TABLE—I

Desirable Spacing for Direct Lighting Units.

Class of Service.	Ceiling Height, Feet.	Spacing of Unit, Feet.
1. Armouries, auditoriums, churches, public halls, restuarants, ball rooms, theatres, etc. ...	12—16	12—16
	over 16	15—26
2. Factories :		
Ordinary work ...	8—11	8—11
	11—15	10—16
	over 15	14—22
3. Factories :		
Close work ...	8—11	6—10
	11—15	8—13
	over 15	11—17
4. Offices, libraries, school rooms : ...	10—20	12—18
(Where desk lamps are used) ...	9—12	7—11
(Where no desk lamps are used)	12—16	9—14
(Where no desk lamps are used)	over 16	11—18
5. Stores : ...	8—11	8—11
	11—15	10—16
	over 15	14—22
6. Drafting rooms :		
(Where desk lamps are used)	10—20	12—18
(Where no desk lamps are used)	9—12	6— 8
(Where no desk lamps are used)	12—16	8—10
(Where no desk lamps are used)	over 16	10—15

NOTE.—It is not desirable to use the widest spacing on the smallest ceiling height.

LOCATION OF LIGHT UNIT.

TABLE II

Desirable Spacing for Indirect and Semi-indirect Lighting Units.*

Class of Service.	Ceiling Height, Feet.	Spacing of Unit, Feet.	Hanging Height, Feet.†
1. Offices, libraries, school rooms, stores, banks ...	8	12	1.5
	10	15	2·0—2·5
	12	18	2·5—3·0
	14	24	3·5—4·0
	16	28	3·5—4·5
	18	36	4·0—5·0
	20	40	5·0—6
2. Drafting rooms, operating rooms, sewing machine rooms ...	8	6	1·5
	10	7·5	2·0—4
	12	9 0	3
	14	14·0	3·5—4·0
	16	16	4·0—5·0
	18	18	4·0—5·5
	20	20	5·5—6

* Values are maximum and should not be exceeded.

† Distance from ceiling to top of reflector.

Mounting Height.—This depends upon the system used for general purpose. The units must be mounted high enough to be out of the range of vision to avoid glare. In general, the lamps should be at least 8 ft. above the floor and higher if possible. For ceilings from 11 to 16 ft. high the lamps should be about 10 ft. above the floor. For higher ceilings, cranes or other obstructions usually fix the minimum mounting height.

TABLE III

Relation between Spacing and Mounting-height for approximately uniform Illumination on a Horizontal Plane.

Equipment		$\frac{\text{Spacing-distance}}{\text{Mounting-height}}$
Prismatic, mirrored, or aluminized reflectors ...	Focusing ...	$\frac{3}{4}$
	Intensive ...	$1\frac{1}{4}$
	Extensive...	2
Opal bowls ...	...	$1\frac{2}{3}$
Opal domes ...	...	,,
Enclosing glass units	...	,,
Semi-indirect units	...	$1\frac{1}{2}$
Indirect units ...	...	,,

TABLE IV

Maximum Spacings and Minimum Mounting Heights Recommended for Various Units.

(Mounting height equals distance of light source above plane of illumination).

Equipment*	Ratio = $\frac{\text{Spacing}}{\text{Mounting Height}}$	†Ratio = $\frac{\text{Mounting Height}}{\text{Spacing}}$
Prismatic or mirrored glass		
Intensive	$1 - \frac{1}{2}$	$\frac{2}{3}$
Focusing	$\frac{3}{4}$	$1 - \frac{1}{3}$
Extensive	2	$\frac{1}{2}$
Indirect or semi-indirect	$1 - \frac{1}{2}$‡	$\frac{2}{3}$‡
Opal or porcelain enamel: Bowl ..., Dome ...; Totally enclosing glass; Semi-enclosing	$1\frac{2}{3}$	$\frac{3}{5}$

* To get maximum spacing distance, multiply ratio by mounting height.

† To get minimum mounting height, multiply ratio by spacing distance.

‡ Height equals distance between ceiling and plane of illumination.

Preliminary Calculation of lamps for Given Illumination. The rough method of allowing so many candle-power per square foot of floor area is unsatisfactory and has been superseded by rules based on foot-candles of illumination on the working plane, when uniform illumination is desired. A uniform illumination is now more generally used than formerly, though for special purposes a concentrated light may be desirable. In all cases, it is most important to avoid unshaded lights in the direct range of vision and shadows due to columns or to incorrect spacing of the lamps.

In computing illumination in foot-candles, it is first decided what foot-candle intensity is desired upon the "Working Plane," i. e., usually 30″ to 42″ above the floor. Desks and tables are generally 30" high, while lathes and other machines may be 42". The value of the illumination due to any lamp at a given distance from it is given by.

$$E = \frac{I}{d^2} \qquad \dots \quad \text{(i)}$$

Where E = illumination in foot-candles,

I = candle-power of the lamp (in given direction).

d = distance of surface from lamp in feet,

This formula only applies when the light rays strike the plane of the surface at right angles,

If they fall on the working plane at some other angle, the formula becomes

$$E=\frac{I\cos^3\theta}{h^2} \quad \ldots \quad \text{(ii)}$$

Where θ = angle between light ray and a perpendicular dropped from the lamp,

h = height of lamp above working plane.

The value of candle-power at various angles can only be obtained from a photometric curve of the lamp with its shade. Such curves are supplied by makers of the modern types of lamp shades.

There are two simple methods of computing the lamps necessary for producing a given illumination : (1) watts per square foot and (2) the lumen method,

The first is satisfactory for rough approximation. With gas-filled lamps and suitable reflectors 0.6 watts per square foot, or 1 watt per square foot will give about 7 foot-candles. With vacuum lamps, one watt per square foot will give about 4.5 foot-candles, By dividing the total watts required for any desired illumination over a given area by the number of lamps decided upon, the necessary watts per lamp is obtained.

The lumen method should be used when more accurate results are desired. This is carried out as follows :—

(1) Decide upon the intensity of illumination at the working plane (in foot-candles)

(2) Calculate the quantity of light in lumens

required to give this illumination over the required area by the rule :—

$$\text{Total light in lumens} = \frac{\text{Area of room in sq. ft.} \times \text{ft. candle.}}{\text{efficiency.}}$$

For ordinary conditions, the reflector, ceiling and walls may absorb 55 °/ₒ of the light, giving an efficiency of 45 °/ₒ or 0.45 in the above formula.

(3) Assume suitable positions for the lamps by dividing the area into a number of approximately equal squares, with a lamp at the centre of each.

(4) Dividing the total number of lumens by the number of lamps, obtain the lumens per lamp. From a table of lamps select the correct size of lamp.

(5) From data supplied by the makers, determine the correct type and height of reflector to enable each lamp to light its portion of the area correctly.

Example.—(from particulars supplied by The Benjamin Electric Ltd.) To light a forge shop, area 60 × 120, with a 100 vols supply :

(1) Intensity of illumination suitable for this shop is 4 foot-candles.

(2) Lumens required $= \dfrac{60 \times 120 \times 4}{0.45} =$ 64,000 lumens.

(3) A suitable spacing for the lamps is here 30', obtained by dividing the whole area into 30 squares.

(4) This gives 8 squares, each lighted by a lamp of $\frac{64,000}{8}=8,000$ lumens. The nearest lamp is 500-watt gas-filled, giving 8,500 lumens.

(5) The makers recommend a R. L. M. dispersive reflector mounted at a height of 18 ft. above the working plane.

If, for some reason, it is desirable to install more units with smaller lamps and different reflectors, alternative arrangements can easily be worked out on similar lines.

Tables are frequently given of the correct intensity of illumination required for different purposes, or in different kinds of rooms, &c., but the effect of reflection from the objects illuminated and the general surroundings vary so much that these figures must be used with judgement.

CHAPTER III.

ILLUMINATION CALCULATION.

Chart of Important Factors in Illumination Design.

Choice of System ...	Glare and reflected glare. Shadow. Illumination of vertical surfaces. Colour. Wall brightness. Efficiency. Available units. Selection chart.
Choice of Intensity ...	Nature of work. Advertising value. The amount of Illumination depends upon the distribution and physical feature and on the area to be lighted. Table I Page 51.
Choice of size and number of lamps	Depends upon the distribution and the physical feature of the area to be lighted.
Depreciation Factor...	Depreciation of lamp service. Depreciation of equipment and lamp due to collection of dust.
Coefficient of Utilization.	Light absorbed by reflecting equipment Light absorbed by ceilling and walls. Size of room. Table II and III Page 57 and 58.

Location of Outlets ...	Relation of spacing distance to hanging height. Structural features of rooms or building. Tables I to IV pages 41 to 44 and VIII p. 69.
Calculation of Lumens per Outlet	Lumens required per outlet = $\frac{\text{Foot-candle} \times \text{Depreciation Factor} \times \text{Area in sq. ft.}}{\text{Coefficient of Utilization} \times N}$ where N = Number of Outlets.

Determine :—

(1) **The foot-candle illumination**—required for good illumination is obtained from the table which lays down generally good practice, subject to special consideration and personal equations.

Corridors, moving picture, theatres, store rooms, etc. require least illumination and 0·25 to 1·0 lumens per square foot.

Street lighting from 0·1 to 0·6 lumens per square foot depending upon the importance of the location.

(2) **Effective flux**—is next determined by the product of the total area of the working plane and the constant taken from the table and the total number of lumens output of the lamps. Then consider the kind of lamp used, the fixtures, the colour of the walls and ceilings and any other influencing agency.

(3) Then determine that part of the total output of the lamp which is effective, i.e., the flux which is

naturally directed downwards and falls on the working plane and the total power rating. In this connection remember that a celling is an effective reflector if it has a light tint and they contribute 70 to 80 per cent of the incident light if white, and 25 to 50 per cent if tinted. Similarly if the walls have light colour they are very beneficial and they contribute from 8 to 15 per cent of the incident light according to the angle of incidence.

4. The divisions of the total power supply among numerous units and the distribution of such units.

TABLE I—INTENSITIES OF ILLUMINATION RECOMMENDED FOR VARIOUS CLASSES OF WORK.

Armoury or drill hall	1·5-2·0
Art gallery walls	3·0-5·0
Assembly room	2-3·0
Auditorium	1·0-3·0
Automobile show-room	3·0-5·0
Ball-room	2·0-3·0
Bank	3·0-4·0
Barber shop	2·0-4·0
Billboard	4·0-6·0
Billiard room	0·5-1·0
Table	4·0-5·0
Book binding :-	
Cutting, punching, stitching	3·0-5·0
Embossing	4·0-6·0
Folding, assembling, pasting	2·0-4·0
Book keeping	3·0-5·0
Bowling:-	
Alley	1·0-1·5
Pins	4·0-5·0
Box factory	2·0-4·0
Building exterior	3-15
Cafe	2·0-4·0
Cabinet making	3-6
Candy factory	2·0-4·0
Canning plants.-	
Coffee roasting at tables	3·0-4·0
Filling tables	1·0-1·5
Packing tables	1·0-2·0
Packing (dried fruit)	1·5-2·5
Preserving cauldrons	2·0-2·5
Pressing tables	1·0-1·5
Shipping room	1·5-2·5

Carpenter shop :-	
Fine work	3·0-5 0
Rough work	2·0-4 0
Cars :-	
Baggage	1 0-1·5
Day coach	2·0-3·0
Dining	2 0-3 0
Mail	4·0-6·0
Pullman	2·0-3·0
Street	2·0-3·0
Cotton mill weaving	2·0-6 0
Courts :-	
Handball	5·0-8·0
Tennis	5 0-8 0
Court-room	2·0-3 0
Church	2·0-3 0
Diary or milk depot	2·0-4·0
Desk	2·0-5 0
Drafting room	5·0 10·
Electrotyping	3·0-8·0
Factory :-	
General illumination	4·0-5·0
Bench illumination	1·5-10·0
Assembling	4·0-7 0
Drills	2·0-4·0
Millers	3·0-6·0
Planers	3·0-5·0
Rough manufacturing	1·25-3 0
Fine manufacturing	3·5-10
Fine wood working and rough metal working	3-6
Rough wood working	2-4
Special cases of fine work	10·0-15·0
Fire station :-	
Times of alarm	2·0-3 0
Other times	1·0-1·5
Forge and blacksmithing:-	
Ordinary anvil work	2·0-4·
Machine forging	2·0-3·0
Forge and blacksmithing—	
Tempering ...	2·0-4·0
Tool forging ...	3·0-5·0
Foundry :—	
Bench moulding	1·0-3·0
Floor moulding	1·0-2 0
Garge ...	1·5-2 0
Garment industry :—	
Light goods ...	5·0
Dark goods ...	7 0
Glove factory	
Cutting ...	5·0 6 0
Sorting ...	6·0-10·0
Gymnasium ...	2·0-4·0
Hall, concert and entertainment	2·0-4 0
Hat factory:—	
Blacking ...	4·0-6 0
Forming ...	3·0-5·0
Stiffening ...	2·0-0·0
Hospital :—	
Corridor ...	0·5-1·5
Operating table	8·0-20·0
Wards, general	1·5-2·0
Wards with local illumination	0·5-1·0

Hotel :—	
Corridor	0·5-1·0
Dining room	2·0-3·0
Bedroom	1·0-2·0
Lobby	1·5-2.0
Parlor	2·0-3·0
Writing room	2·0-3·0
Jewelry manufacturing	3·0-10·0
Knitting mill	3·0-6·0
Laboratory	3·0-5·0
Laundry	3·0-5 0
Leather working :—	
Cutting	4 0-6·0
Grading	6·0-8·0
Library :—	
Art Gallery	3...4
Stack room	1·0 2·0
Reading room, no local illumination	3 0-4·0
Reading room, with local illumination	0·5-1·0
Lodge room	1·0 3·0
Lunch room	2·0 3 0
Machine shop :—	
General	1·0-1 5
Local	3·0 4·0
Market	2·0-3·0
Meat packing :—	
Cleaning	2·0-3-0
Packing	2·0-4·0
Moving Picture light	2-2·5
Museum	3·0-4·0
Offices :—	
Draughting	7·5-10
General	3·0
Private	1·0-3·0

Packing and shipping :	
Ordinary work	2·0-5·0
Fine work	2·0-5·0
Paint shop :	
Coarse work (first coat)	2·0-3·0
Fine work (finishing)	4·0-8·0
Paper industry	3-6
Passageways	0·25-0·5
Pattern shop	4·0-6·0
Pottery	2-4
Power House :—	
Boiler room	0·8-1·5
Engine room	2·0-3·5
Pottery :—	
Grinding	1·0-2·0
Pressing	2·0-4·0
Postal service	4·0-4·0
Preserving plant :—	
Cleaning	2·0-4·0
Cooking	2·0-4·0
Printing :—	
Presses	3·0-5·0
Type-setters	6·0-8·0
Public square	0·5-1·0
Reading :—	
Good print	2·0-3·0
Fine print	3·0-5·0
Residence :—	
Bath room	2·0-3·0
Bed room	1·0-2·0
Dining room	1·0-2·0
Furnace room	0·5-1·0
Hall	0·5-1·0

Kitchen ...	2·0-5·0
Laundry ...	2·0-3 0
Library ...	3 0-3·0
Living room ...	1-2·5
Music room ...	2 0-3 0
Night light ...	0·1-0.25
Pantry ...	2.0-3 0
Parlor ...	2·0-3,0
Porch ...	0.2-0.5
Reception room	1.0-2.0
Sitting room ...	2.0-3.0
Store room ...	0.5-1.0
Restaurant	
Generally ...	2 0-4·0
" Dining room	3·5-4·5
"Kitchen ...	2·5-3.
Rink, skating ...	2·0-3·0

School :—

Assembly room	2·0-4·0
Blackboards ...	3 0-5·0
Class room ...	3 0-5·0
Cloak room ...	0·5-1·0
Corridor ...	0.5-1 0
Drafting ...	5·0-10.0
Drawing ...	4·0-6·0
Gymnasium ...	1·0-5·0
Laboratory ...	3 0-5·0
Manual training	3·0-5·0
Office ...	2·0-3·0
Study room ...	2·0-3·0

Sheet metal shop :—

Assembling ...	2·0-4·0
Punching ...	3·0-6·0

Shoe shops :—

Bench work ...	2·0-5·0
Cutting ...	5·0-7·0

Show windows :—(Depending largely upon display and intensity of street illumination)

Light goods ...	5 0-20·0
Medium goods	20·0-30·0
Dark goods ...	20·0-50·0
Accurate colour Discremination	4 0 6·0
Sign ...	4·0-6·0

Silk Mill :—

Finishing ...	3·0-5 0
Weaving ...	3 0-5·0
Winding Forms	2 0-4·0
Spinning mills...	1 5-3·0
Stable ...	0·5-3·0
Stair ways ...	0 5-3·0

Station :—

Platform and trainshed ...	1·0-2·0
Waiting room...	2·0-5·0

Steel work :—

Blast furnace (cast house)...	0 3-0·5
Loading yards (inspection) ...	0·3-0 5
Mould, skull cracker and ore yards	0·1-0·3
Open hearth floors (soaking pits and cost house) ...	0 1-0·3
Rolling mills ...	1·0-2·0
Stamping and punching sheet metal	2·0-5·0
Stock room ...	1·0-2.0
Threading floor of	

pipe mills	...	1·0-2·0
Transfer and storage bays	...	0·5-1·0
Unloading yards		0·2-0·5
Warehouse	...	0·5-1·0
Stereotyping	...	3·0-5 0
Stock rooms :—		
Rough materials		1·0-3·0
Fine materials...		2·0-3·0
Storage	...	0·25-0·0
Store :—		
Art	...	4·0-5·0
Bakery	...	2·0-3·0
Book	...	2 0-4·0
Butcher	...	2·0-4·0
China	...	2·0-4·0
Cigar	...	2·0-4·0
Clothing	...	4·3-8·0
Cloak and suit		4·0-8·0
Confectionary...		2·0-4·0
Decorator	...	2·0-4·0
Drug	...	3·0-5·0
Dry goods	...	4·0-6·0
Florist	...	3·0-5·0
Store :—		
Furnishing	...	5-10
Furniture	...	4·0-6·0
Furrier	...	4·0-6·0
Grocery	...	2·0-4·0
Haberdasher	...	3·0-5·0
Hardwar	...	4·0-5·0
Hat	...	4·0-5·0
Jewelry	...	4·0-5·0
Lace	...	3·0-4·0
Leather	...	4·0-5·0
Meat	...	2·0-4·0
Men's furnishings		3 0-5·0
Millinery	...	4·0-8·0
Music	...	3·0-4·0
Notions	...	3·0-4·0
Piano	...	4·0-5.0
Post cards	...	3·0-4·0
Shoe	...	3·0-4 0
Stationary	...	3·0-4·0
Tailor	...	4·0-8·0
Tobacco	...	2.0-3.0
Street :—		
Business	...	0·4-0·6
Residence	...	0·1-0·2
Prominent residence	...	0·2-0·4
Studio	...	4·0-6·0
Telephone exchange	...	3·0-4·0
Theatre :—		
Auditorium	...	2 0-3·0
Lobby	...	2·0-3·0
Moving picture		0·25-0·5
Warehouse	...	1·0-1·5
Weaving :—		
Light colors	...	2·0-3·0
Dark colors	...	4·0-10·0
Wharf	...	2·0-3·0
Wire drawing:—		
Coarse	...	2.0-3.0
Fence machines		2.0-5 0
Fine	...	4·0-8·0
Woolen Mills :—		
Picking table	...	2·0-4·0
Twisting	...	2·0-5·0
Warping	...	3·0-5·0
Weaving	...	4·0-10·0

* The Lighting Art p. 204—by M. Luckiesh.

Coefficient of utilization :— This is the proportion of total light from the lamps which reach the plane of the work. For a given reflector; this is dependant upon the colour of the ceiling and walls and upon the room ratio which is the relative width of the room compared with the height of the light source above the level of the work.

For direct lighting, room ratio

$$= \frac{\text{width of room}}{2 \times \text{weight from plane of work to lamps.}}$$

For Indirect and Semi-indirect lighting

$$= \frac{\text{width of room}}{1{\cdot}13 \times \text{weight from plane of work to ceiling.}}$$

TABLE II.

APPROXIMATE COEFFICIENTS OF UTILIZATION.*

(MODERN LIGHTING EQUIPMENT WITH NO ALLOWANCE FOR DEPRECIATION).

	Ceiling-nearly white; walls-high reflection factor.	Ceiling nearly white; walls-medium reflection factor
Small Rooms (Offices, corridors, etc.)	Per cent.	Per cent.
Direct lighting; dense glass ...	40	36
Semi-indirect lighting; dense glass ...	25	22
Indirect lighting; mirrored glass ...	23	20
Medium room (Classrooms, laboratories, etc.) ...		
Direct lighting; dense glass ...	48	45
Semi-indirect lighting; dense glass ...	32	29
Indirect lighting; mirrored glass ...	29	26
Large rooms (Auditoriums, assembly rooms etc.		
Direct lighting; dense glass ...	60	58
Semi—indirect lighting; dense glass ...	43	41
Indirect lighting; mirrored glass ...	40	38

Note—That reflection Factors of ceilings can be ignored in industrial lighting as the reflector is opaque.

TABLE III—EFFICIENCY OF UTILIZATION.

Ceiling, reflection Coefficient.	Light, 70 per cent.			Medium 50 per cent.	
Walls, reflection coefficient	Light 50 %	Medium, 35 %	Dark 20 %	Medium, 35 %	Dark, 20 %
Lighting equipment :—					
Direct, prismatic ...	65 40	61 37	59 36	58 36	56 35
Direct, light opal ...	57 33	53 28	50 27	48 26	46 24
Direct, dense opal .	61 40	58 35	57 34	56 34	53 32
Direct, steel bowl, enamel or aluminum ...	57 39	55 36	54 35	54 35	53 34
Direct. steel dome, enamal...	70 46	67 42	65 39	67 42	65 39
Totally indirect, mirrored...	40 24	38 21	36 20	27 15	26 14
Semi-indirect, light opal ...	47 30	45 25	43 24	39 22	35 20
Semi-indirect, dense opal...	43 27	41 25	40 22	31 18	30 17
Totally enclosing ...	46	42	40	38	35
Light opal ...	25	19	18	18	15

TABLE IV—EFFICIENCY OF UTILIZATION.

Minimum dimension of room divided by ceiling height.	EFFICIECY OF UTILIZATINON.	
	Dark walls.	Light walls.
1·0	0·20	0·24
1·5	0·22	0·26
2·0	0·24	0·28
2·5	0·28	0·30
3·0	0·30	0·32
3·5	0·32	0·34

ABLE V.

USE REFLECTION.

cent. of incident flux.

	Color	With incident angle degree. 60	45	30	15	0	Avg.
		Per cent.					
Matt (smooth)	White ...	56	61	58	57	55	57
do ...	Light buff ...	46	47	46	44	43	45
do ...	Light Orange Yellow	43	44	43	43	42	43
emi-gloss ...	Orange Yellow ...	38	36	33	31	30	34
do ...	French gray ...	38	32	26	23	21	26
do ...	Light pea green ...	28	26	21	19	18	22

do ...	do ...	Dark pea green ...	23	19	14	11	9	15
do ...	do ...	Light brown ...	17	15	12	11	10	13
do ...	do ...	Light blue ...	15	13	10	9	8	11
do ...	do ...	Cherry red ...	14	12	9	7	6	10
Imported stock	Fibrous ...	**Tan**	19	19	17	16	16	17
do ...	do ...	Light blue ...	13	13	12	11	10	12
Duplex ...	Rough ...	do ...	13	12	11	9	8	10
do ...	do ...	Cherry ...	6	6	6	6	6	6
Plain ...	do ...	Yel. buff ...	31	34	36	36	35	34
do ...	do ...	Light pea green ...	21	20	20	19	18	20
do ...	do ...	Dark pea green ...	13	13	11	11	9	12
do ...	do ...	Deep red ...	7	7	6	5	5	6
Varnished tile	Glossy ...	Cream	66	71	73	72	71	71
Imported ...	Embossed glass	Gilt	54	50	44	38	27	42
White blotter	...	...	73	80	74	73	71	74

TABLE VI.

Desirable size of squares.

Kind of room.	Ceiling height.	Desirable length of side of square.
Armouries	12 to 16 ft. ...	12 to 16 ft.
Auditoriums	12 to 16 ft. ...	12 to 16 ft.
Public halls	Over 16 ft. ...	15 to 26 ft.
Rinks	Over 16 ft. ...	15 to 26 ft.
Stores	8 to 11 ft. ...	8 to 11 ft.
Stores	11 to 15 ft. ...	10 to 16 ft.
Stores	Over 15 ft. ...	14 to 22 ft.
Offices—with desk lights	10 to 20 ft. ...	12 to 18 ft.
Offices-without desk lights	9 to 12 ft. ...	7 to 11 ft.
Offices— do	12 to 16 ft. ...	9 to 14 ft.
Offices— do	Over 16 ft. ...	11 to 18 ft.

LIGHT LOSS.

It has been seen that an increase over the desired average intensity of 20 per cent. may be taken to cover both the decrease in lamp output and the dust depreciation under the best conditions. In a foundry an increase of 40 per cent. would not be excessive. Hence the value selected from the table should be multiplied by the depreciation factor from 1·20 to 1·40 depending upon the type of fixture and the existing conditions.

Hence lumens per outlet

$$= \frac{\text{Desired foot candles} \times \text{Depreciation factor} \times \text{Area in sq.ft.}}{\text{Coefficient of utilization} \times \text{Number of outlets.}}$$

TABLE VII.

DATA ON MAZDA B. (VAC[illegible]PE) LAMPS FOR CONSTANT POT[illegible]CIRCUITS.

Rated Watts.		Mean Spherical C. P.	Rating Watts per Candle.	Total Output, Lumens.	Lumens per watt.	AMPERES.	
						at 120 Volts.	at 240 Volts.
105—125 volts.	10	6·7	1·67	75	7·50	0·083	
	15	10·2	1·47	128	8·55	0·125	
	20	14·2	1·41	178	8·90	0·167	
	25	18·5	1·35	234	9·30	0·208	
	40	30·3	1·32	380	9·50	0·333	
	50	38·2	1·31	480	9·60	0·416	
	60	47·0	1·28	590	9·80	0·500	
	100	82·0	1·22	1030	10·30	0·833	
220—250 volts.	25	15·2	1·65	191	7·60	...	0·104
	40	28·2	1·42	354	8·85	...	0·167
	60	43·2	1·39	540	9·05	...	0·250
	100	78·7	1·27	990	9·90	...	0·417
	150	118·0	1·27	1480	9·90	...	0·625
	250	208·0	1·20	2620	10·50	...	1·042

*TABLE VIII
LUMEN VALUES OF VACUUM AND GAS-FILLED LAMPS.

Vaccum-Type Lamps.			Gas-Filed Lamps.		
Voltage.	Wattage	Lumen Value.	Voltage	Wattage	Lumen Value
50 to 130	20	158·5	25	15	168
	30	248·38	25	30	360
	40	332·47	25	60	750
	60	520·64	25	100	1,300
100 to 130	20	160·77	50/65	30	360
	30	251·65	50/65	160	750
	40	336·87	50/65	100	1,300
	60	527·56	50/65	150	2,100
			50/65	200	2,800
			50/65	300	[illegible]
			50/65	500	18 ft.)
120 to 250	20	145·18	100/130	40	[illegible]
	30	225·8	100/130	60	750
	40	324·44	100/130	100	1,300
	60	510·34	100/130	150	2,100
			100/130	200	2,800
			100/130	300	4,600
			100/130	500	8,500
			100/130	1000	18,000
			100/130	1500	28,000
			200/150	60	550
			200/250	100	1,200
			200/250	150	1,800
			200/250	200	2,500
			200/250	300	4,200
			200/250	500	7,300
			200/250	1000	16,500
			200/250	1500	26,000

*From Modern Electrical Illumination p. 62

Calculation of Illumination—Point-by-Point Method.—For determining the value of illumination consider (1) the candle-power of the units, and (2) the amount of reflected light for the given location of the lamps. For preliminary calculation the following formula based on the co-efficient of reflection of the walls of the room may be used :—

$$I = \frac{c.\,p.\ \frac{1}{1-r}}{d^2}$$

I = Illumination in foot-candles.

c. p. = Candle-power of the unit.

r = Coefficient of reflection of the walls. *(vide p. 14)*

d = Distance from the unit in feet.

Where several units of the same candle-power are used this formula becomes :—

$$I = c.\,p. \left(\frac{1}{d^2} + \frac{1}{d_1^2} + \frac{1}{d_2^2} + \ldots\ldots\ldots\ldots\right)\frac{1}{1-r}$$

$$\text{or, } c.p. = \frac{I}{\left(\frac{1}{d^2} + \frac{1}{d_1^2} + \frac{1}{d_2^2} + \ldots\ldots\ldots\ldots\right)\frac{1}{1-r}}$$

where d, d_1, d_2, etc., equal the distances from the point considered to the various light sources. For lamps of different candle-power, the illumination may be determined by combining the illumination from each source as calculated separately.

In general however, $I = \frac{c\,p. \times \text{cosine}\ a}{d^2}$.

The effect of reflected light from the ceilings is of more importance than that from the floor of a room. The value of r will vary from 60% to 10%, but for rooms with a fairly light finish 50% may be taken as a good average value.

The amount of illumination will depend on the use to be made of the room and may be found from the table I page 51 which gives good practice. An illumination of ·5 foot-candle on a plane 3 feet from the floor forms a sufficient ground illumination. The illumination from sunlight reflected from white clouds is from 20 foot-candles up, while that due to moonlight is in the neighbourhood of ·03 foot-candle.

The point-by-point method gives very accurate results if account is taken of the angle at which the light from each source strikes the plane of illumination and if the light distribution curves of the units, and the value of r, have been carefully determined.

Example 1—A room is 20 feet square and 12 feet high and has walls having a coefficient of reflection of 50%. Determine the illumination on a plane 3 feet above the floor when lighted by a single group of lights mounted at the centre of the room 3 feet below the ceiling.

$$L = \frac{AI}{R}$$

$$R = \frac{AI}{L}$$

Total watts = watts per square foot × area.

$$\text{Watts per unit} = \frac{\text{total watts} \times \text{coefficient of utilization}}{\text{Number of units}}$$

The Lumen method :—

$$\text{The effictive Lumens} = \frac{\text{Intensity} \times \text{area of Interior}}{0{\cdot}5}$$

Examples :—

(1) Required the power necessary to produce 4 foot-candles uniform illumination in a room having an area of 2000 square feet. Ceilings and walls light. Prismatic reflectors and vacuum type, 100-watt lamps used.

$$\text{Total lumens (L)} = \frac{4 \times 2000}{0{\cdot}53} = 1594 \text{ lumens,}$$

$$\text{Total watts (W)} = \frac{1594}{10{\cdot}30} = 1466 \text{ watts.}$$

(2) A room 30 by 20 feet is lighted with 20 vacuum-type tungsten lamps rated at 60 watts and equipped with translucent glass reflectors. The walls are a medium light buff, and the ceilings a vary light buff. The lamps are evenly spaced. Calculate the average intensity on the working surface. U = ·44.

Total power (W) = 20 × 60 = 1200 watts.

$$\text{The intensity } I = \frac{1200 \times 0{\cdot}44 \times 9{\cdot}8}{30 \times 20} = 8{\cdot}6 \text{ foot-candles.}$$

Estimating the Operating Cost.—The operating cost consists of three parts:—

(1) Fixed charges—Interest on the initial capital outlay, insurance, taxes, depreciation of permanent parts, regular attendance and other charges which are independent of the hours of use. Note that obsolescence rather than the wearing out of parts determines the life of a lighting system.

(2) Maintainance charges such as renewal of parts, labour and all costs except the cost of the energy supplied.

(3) The cost of energy—This depends upon the hours of burning and the rate of charge.

CHAPTER IV

THE INCANDESCENT LAMP.

Advantages and dis-advantages of electric lighting :—

1. Advantages :—

(i) Greater lighting power.

(ii) Consequent immunity from the many dangers which poor lighting gives rise to.

(iii) Little or no trouble with lamps.

(iv) Cheaper in cost of maintenance of light than oil lamps.

(v) Adaptability for fixing in almost any situation.

(vi) Suitability for use in sinking shafts, where its use is of great service.

(vii) Perfect safety in fiery mines, when open paraffin lamps would be a source of great danger, and where the poor light of hanging safety lamps is of itself a great argument in favour of the adoption of electric lighting.

(viii) Entire absence of any obnoxious smell or vitiating fumes.

(ix) Absolute cleanliness.

2. Disadvantages :—The disadvantages of electric lighting are practically confined to the following :—

(i) Necessity for generating plant. This is, of course, of little consequence where the electric current generated is used for pumping, hauling, or coal-cutting, as well as for lighting.

(ii) Laying and fixing of lighting cables.

(iii) Dynamo has often to be run for lights alone, when pumps, etc., are off, and this, of course, is expensive. This can be obviated by having a small plant for lights alone.

(iv) Cost of lamp renewals.

Forms of Lamps :—In electric lighting there are two distinct forms of lamps, the incandescent glow lamp, and the arc lamp, the former is almost universally used for colliery work, although for lighting railways, sidings, and pit heads, the arc lamp may be used with considerable advantage.

The incandescent or **glow lamp** is much less efficient than the arc lamp, but it is safer in fiery situations underground, and of greater adaptability for distribution. A number of glow lamps may be placed at short intervals apart, and fixed in any desirable situation at less expense and with more satisfactory results than can be had with even a very few arc lamps.

The light is obtained from the heated conductor of high resistance (called filament) and is transmitted by vibrations of ether. The current is sufficient to raise its temp, to luminosity. The filament is usually enclosed in a evacuated glass bulb.

Object of Vacuum :—

(a) to prevent the conductor burning away.

(b) to diminish the loss of heat by convection.

(a) can be secured by filling the bulb with some inert gas e.g. N.—but (b) cannot be helped, and in that case more power is to be spent to make good for the loss of heat by convection.

The property of the filament should be that it can withstand high temperature—a conductor of electricity but not a good one.

Only materials found to possess the above properties in conjunction with other qualities necessary for a commercial filament are carbon—tantalum and tungsten (wolfram). Osmium was used—molybdinum was suggested—and filament of silicon deposited on carbon is at the experimental stage.

Efficiency of Incandescent Lamps.—It is stated in watts per c.p. But this is inefficiency in the ordinary sense—because watt is the input and c.p. is proportional to the output. Even c.p. per watt when greater the more efficient the lamp is, is not the efficiency in the sense in which it is applied in the case of other electrical apparatus. For c.p., and watts are in different units.

The true, total or economic efficiency of a Glow lamp depends upon (1) the amount (2) the duration of its candle power and the energy supplied to the lamp. The life of the lamp or duration of time before it is smashed, being uncertain, is generally left out of account.

To obtain real efficiency the relation between one watt and one c.p. must be known and the duration of time before it reaches the smashing point which is not easy for accurate determination. The most recent experiments give .06 watts for 1 c.p. thus the real efficiency of a lamp whose efficiency is 1.5 watts per c.p. is

$$\frac{\cdot 06 \text{ watts}}{1\cdot 5 \text{ watts}} = 4\%.$$

The Immediate or watthour efficiency of a Lamp $= \dfrac{\text{watts}}{\text{candle power}}$

Relation between dimension of a filament and its c.p.—If the temperature of the filament and the efficiency remain constant then the following relations hold good.

The heat produced per sec Ht = heat got rid of by radiation (if vacuum is good).

$$Ht = I^2R, \text{ watts} = I^2 \frac{\rho L}{A} = I^2 \frac{\rho L}{\frac{\pi}{4} d^2} \text{ watts}$$

A = cross section of filament

L = length of Filament and d = diameter of filament.

ρ = specific resistance of the material at the working temperature.

Heat radiated per sec. varies as the surface and as the emissivity, which is nearly constant since the temp. is the same for all.

Heat radiated per sec. is proportional to.

$L \times d$ for circular filament.

and varies as the surface x emissivity

$$\therefore \quad \frac{4\, I^2\, \rho L}{\pi\, d^2} = L \times d \times \text{const.}$$

$$\text{or } \rho\, I^2 = d^3 \times \text{const.}$$

Compare Preeces, law for fuses (Vol I Elements of Applied Electricity by the Author). Again light (as heat) radiated per second is proportional to the surface $\therefore$ c.p. α $d \times L$ for a given material at a given efficiency.

Initially if the emissivity is high the diameter required is small for a given current—but with use the surface is made rough, emissivity becomes more i.e. it lowers the temperature necessary to radiate the heat produced, and so the efficiency is lowered.

Carbon and Metal Filaments :—Carbon can withstand a high temperature and has a high ρ which means a short and a thick filament. The working temperature is limited by the fact that in vacuum it is volatilised at a lower temperature than in ordinary conditions. Consequently the metalic filaments although their melting points are below the latter temperature, can be worked at a higher temperature (2200°) and therefore give a higher efficiency. than carbon (1800°).

The usual efficiencies are for c.p. 3·75 watts carbon.
,, 1·7 ,, tantalum
,, 1.1–1.4 ,, tungsten

Main disadvantages of metal filaments are—
(1) their greater cost, (2) low ρ—therefore long and thin filaments.

(3) They are much more fragile than carbon ones even inspite of their greater strength of material. Their higher efficiency increases their length and diminishes their diameter.

In consequence, earlier lamps were made for low voltages—improvements in manufacture has brought out lamps 250 volts etc.

These are made down to 15 or 16 c.p. The higher the c.p. of the lamp the less fragile it is because the filaments are thicker though longer.

Tantalum filaments are stronger than tungsten ones and the latter is therefore intermediate between Carbon and tungsten in strength and efficiency. They are employed for lighting electric trams and trains and the other places liable to vibrations.

Construction of the Lamps.

Carbon Lamps.—Preparation of the Filament :—Cotton wool is dissolved in zinc chloride to form a gelatine-like mass. This is then forced through (squirted) steel dies into alcohol, which hardens the soft transparent threads. The threads are then dried, cut to the required lengths, wound on forms.

Carbonisation.—This is effected by placing the threads and formers in plumbago crucibles, filled with powdered carbon and covered with air tight leads. These are steadily raised to about 550°C at which temperature carbonisation is finished and then are rapidly heated to the final temperature of 1700°C. The O and H in the cellulose being driven off leave a very hard pure carbon thread.

Mounting the Filament.—After carbonisation the filaments are mounted or joined to leading wires leading into the bulb. These are platinum wires, which have got the same coefficient. of expansion as glass—hence keeps the bulb air tight with variation of temperature. Sometimes German silver is used in cheap lamps, but is much less satisfactory.

Flashing.—The filament is then placed in a hydrocarbon gas or vapour, such as coal gas or benzene and heated to incandescence by passing a current through them. This decomposes the vapour and deposits carbon on the filament, rendering it uniform, since the thinner part gets hotter and gets a greater deposit. The resistance of the filament can be brought down to any desired value by continuing the flashing till the point is reached.

(1) This increases the diameter by the deposition of carbon and thus decreases the resistance, (2) changes the surface from a dull black and comparitively soft coating to a bright grey and much harder one.

(3) And the process lengthens the life and efficiency of the Filament.

The neck with the filament is then sealed to the glass-bulb which is exhausted, through a tube at its other end till the pressure falls to 0·002 m.m. of mercury by means of pumps. Exhaustion is necessary for (1) avoiding oxidation of the filament (2) to reduce the heat connected to the globe. The bulb is treated during the last stages so as to drive off the air which will otherwise cling to the glass.

The final exhaustion is done chemically. Phosphorus dissolved in alcohol is introduced into the tube before pumping starts. When the vacuum has been made as good as the pump can do, the tube is sealed a short way from the bulb. The phosphorus is then vaporised and combines with the oxygen and the bulb is then sealed off at the 'pip.'

The outer ends of the leading wire are connected by copper wires to two brass contact plates which are mounted in plaster of Paris or a vitreous enamel inside a brass collar with two projecting pins. Plaster of Paris has the disadvantage of absorbing moisture and so becoming a poor insulator.

Tantalum Lamps.—Powdered metallic tantalum is obtained by the reduction of potassium—tantalum—flouride. The powder is fused electrically in vacuum thus getting rid of the occluded gases. The metal can then be drawn into a wire of the required fineness through diamond dies, graphite being used as a lubricant.

In order to get the long filament into a bulb of ordinary size it is mounted on spiders of wire hooks each supported by a glass disc which is carried on a central glass stem. The hooks are insulated from each other by the glass.

Sp. R. = 37 microhms per cm. cube.

The life of tantalum lamp is very much less in alternating current than in direct current.

Tungsten Lamps.—A fragile bar is obtained by compressing tungsten powder in a steel mould. This bar is gradually heated in a current of hydrogen and then 'vitrified' by heating to 2 850° C. in an electric furnace. The metal contracts about 14% in this process,

It thus becomes stronger where reduced in diameter by hammering. This is done at 1300° C. by a special machine with rapid hammering. When the diam. comes to 30 mils. the wire can be drawn cold. It is preferable to use heated diamond dies and restrict cold drawing to the last stages. The final process is to reheat the filament in hydrogen to remove the oxide from the surface and then to mix it as for tantalum lamps.

Sp. R. = 28 microhms per cm. cube.

The tungsten filament has a positive temperature coefficient, it does not produce so great a change in candle-power hence in light out-put as in the case of carbon, further light from tungsten filament is whiter than that from other incandescent lamps.

Gas Filled Lamps.—These are tungsten lamps filled with N at atmospheric pressure or argon for its greater inertness. This lessens the evaporation which otherwise will blacken fhe lamp. The presence of the gas causes loss of heat by convection. But this is minimised by winding the filament in a close helix.

It will be noticed that the bulb has a long neck. The evaporated tungsten accumulates in the neck and the lower part of the bulb blackens very slowly and so the lamp has a useful life of 1000 hrs. These are very suitable for outside lighting such as pitheads, sidings etc.

Life of Lamps.—The c. p. of a carbon filament lamp falls off during use, with an initial rise. This is due partly to blackening of the inside of the bulb and partly to changes in the filament. Thus the lamp gives less c. p. or consumes more watts per c. p.—so it is useful to replace the lamp. The point at which this becomes true depends upon the conditions of use but it is usual to assume it to have been reached when the c. p. is 20 °/₀ less than its rated value. This is sometimes called SMASHING POINT.

Life of a lamp denotes the number of hours that a lamp could be used before falling to 80 per cent of its original and normal out put.

The rated normal life of the ordinary lamps is 1000 hours. Series lamps have a rated life of 1350 to 1700 hours. Head light lamps have a life of 300 to 500 hours, depending upon the size. The power consumption is about 0·74 watt per candle for multiple lamps and reaches 0·57 watt per candle for large series type lamps. The lamp will deteriorate until its efficiency as compared with a new lamp will warrant the expense of smashing it and installing a new one.

The useful life is the number of hours of use before this smashing point is reached.

The length of life depends upon the efficiency of the lamp. Rise of voltage shortens the life. B. O. T. allows 4 °/₀ variation from the declared pressures.

Matallic filaments fall off less rapidly in c. p. than carbon filament lamps.

Life tests to determine life performance of lamps are done by subjecting them to their rated voltage varying not more than 0·15 per cent and at stated intervals measuring their candle power and power consumption.

Rating of Lamps:—In rating of incandescent lamps it is necessary to recognise the voltage, candle-power efficiency and life. Show the voltage either in candle power or wattage. The old candle power rating of a lamp denotes the (M.H.C.P.) mean horizontal candle power and this is to be multiplied by the spherical reduction factor to get the mean spherical candle power. This reduction factor for standard carbon filament lamps is 0·78 and for 100 watt round bulb concentrated filament lamp is 0·955.

Frosted Lamps.—The frosting of bulb is done for decreasing the intrinsic brilliancy of lamps and so improving the softness and diffusion of other light. Frosted lamps are used where the clear lamp would be objectionable In such lamps the entire bulb becomes luminous and the filament is not visible, thus reducing the intensity of the light from 8 to 15 per cent. A frosted lamp declines in candle-power about twice as rapidly as a clear lamp. Often lamps are *bowl-frosted*, that is, only the lower half of the bulb is frosted. The reflectors are used with such lamps to shield the lower part of the filament from view. The rated life of a frosted lamp is the same as a clear lamp, but the candle-power falls off more rapidly. A bowl-frosted lamp absorbs about 5 per cent of the light.

Incandescent lamps and their holders—

(*a*) must not be placed in close proximity to inflammable materials; shades made of such materials must be kept free from contact with the lamps by suitable guards; celluloid and other highly inflammable material must not be used for shades;

(*b*) if placed in positions where they are exposed to inflammable vapour or gas, should be enclosed in air-tight fittings of thick glass and have not flexible cord connections.

Incandescent lamps of the Nerst type must comply with the regulations.

CHAPTER V

Arc lamp and Photometry.

Arc Lamp.—By the word "arc lamp" we generally mean carbon arcs—but also magnetite has been used for metallic arcs.

Sources of Luminisity in arc lamps.—Light is produced (1) by the incandescence of the electrodes owing to their high temperature as in ordinary carbon arc, (2) by the luminiscence of the salts derived from mineralized carbon electrodes as in flame arc.

The Arc.—If the two ends of a circuit having a sufficient P. D. be brought together and then they are separated a spark is produced. This vapourises a part of the conductor and if the distance of separation is small enough, an electric or voltaic arc will be kept up and a current will flow through the vapour. This is known as an arc and can be used for giving light. If the extremities are of metal a P. D. of at least 10 volts or less will suffice to maintain the arc, but if of carbon the P. D. must be at least 40 volts with direct current, and 30 volts with alternating current to maintain the arc.

ACTION OF A CARBON ARC.—If two core pieces in contact completes an electric circuit and then separated, the circuit will not break, if the distance be not great, the current passing through the arcs formed between the two tips. (1) The distance between tips may be from $\frac{1}{8}$ to 3/8 of an inch. (2) If the carbons are separated too far the arc will break and the current is stopped and it can be set up only temporarily connecting the ends of the carbon once more; this operation is served "striking the arcs." (3) by the luminescence of the arc of the conducting vapours from the cathode as in metallic arcs—the magnetite and mercury arcs. We find in a direct current arc that most of the light issues from the tip of the positive carbon with soft core which is hollowed in course of time and is known as the 'crater' or 'bowl' of the arc while the negative becomes pointed. The area of the crater varies approximately according to the law: $D = \cdot 128 \times \cdot 15\ I$ where $= D$ diameter in inches $I =$ the current expressed in ampere. It has a temparature of 3000°C—3500°C at which carbon vaporizes and gives about 80 to 85% of the total light furnished at the same time, as the positive is hollowed out and the crater is joined; and it is also incandescent but not to such a degree as the crater (temp. 2500°C). Between the electrodes there is a band of violet light, the arc proper; this is surrounded by a zone of orange red and outside it is again pale green. The arc proper does not furnish more than 5 % of the light emitted when pure carbon electrodes are used.

Elements of an Arc Lamp.—An arc lamp has got an arrangement (1) for holding the two carbon rods C.A end on to each other and passing current through them for the formation of the arc. When no current is passing or when the arc is extinguished while working, the carbon must be allowed by the mechanism to come near together, (2) for striking the arc, that is, the carbons if not already in contact, must be drawn together and then drawn apart, this is done by the striking mechanism of the lamp, (3) for feeding

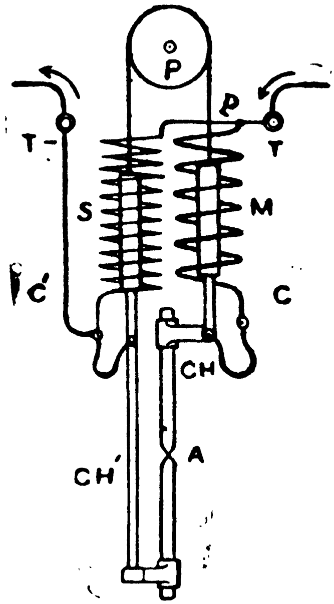


Fig. 1

forward the carbon rods, which are consumed while burning, to keep the distance between them constant. This is done by the feeding mechanism. This may be done by hand but in all arc lamps proper this is entirely automatic in action which means that when the current is sent through, the arc is struck, and the carbons fed forward by mechanisms within the lamp.

(4). If the lamp has to work in series with others it must be provided with a short circuiting cutout, by which the continuity of the service past the lamp is maintained even if the lamp is extinguished or have no carbons in it.

A.C lamp should not be used in DC circuits and vice versa.

Starting and feeding of arc lamps.—A solenoid or magnet wound with two windings—one a thick and the other a fine-wire coil—is placed inside the lamp box. One of the windings is placed in a reverse direction to the other.

The thick wire coil having the most magnetising effect is in series with the main circuit and the arc and the five wire coil is a shunt across the terminals of the lamp.

When the current is turned on, the armature is attracted and the upper carbon rod is lifted and the arc is formed, in other words, the rods are parted to start the arc. As the carbons are consumed during burning the arc becomes longer and its resistance increases, so that more current passes through the parallel path i.e. through the shunt coil and thus the magnet is weakened. Thus the armature is slightly dropped and the mechanism is so worked that the top carbon approaches the bottom one adjusting the arc to its proper length. Apparently the feeding of the arcs is in series of jerks but in reality the mechanism is so arranged that in actual practice a continual steady approach of the upper carbon to the lower one is obtained. If the arc is too long, it flames and the light becomes bluish and unsteady, if it is too short it hisses and the brilliancy of the light will be disminished.

Preparation of Carbons.—Carbons are either moulded or faced from a product known as 'petroleum coke' or from similar materials, such as lamp black. The material is thoroughly dried by heating to a high temperature, then it is ground to a fine powder and combined with some substance such as pitch which binds the fine particles of carbon together. After this the mixture is again ground and it is ready for moulds. For the forced carbon, the powder is formed into cylinders which are placed in machines that force the material through a die so arranged as to give the desired diameter. The forced carbons are usually made with a core of some special material, this core being added after the carbon proper has been finished. The moulded or forced carbon is carefully baked to drive away all volatile matter. The forced carbon is always more uniform in quality and cross section and is the type of carbon which should be used in carbon fed lamps. The adding of a core of different material seems to change the quality of light and being more readily volatile keeps the arc from wandering.

There are two kinds of carbon (1) Solid carbon and (2) cored carbon. The object of the core is (1) to decrease the Voltage for a given length of an arc (2) it tends to maintain a stable condition for the arc (3) also keeps the arc located in one spot (4) it may modify the colour of the light.

Hissing of arc.—If the distance between the two carbons is too small, the hissing arc is produced. This is so because there is a hissing sound in the arc. As the electrodes are brought nearer the current increases the area of the crater with it and E diminishes—the crater area extends to the sides of the carbon and the voltage suddenly becomes 10 volts and the I increases by 2 or 3 amps. and the arc begins to hiss. This is due to alternate sucking in and driving out of air from the arc.

The P. D. is generally kept at 50 volts.

CLASSIFICATION :—(i) A. C. or D. C. Systems where operated in series or in multiple system.

(ii) Open or closed arcs.

Classification of arc Lamps :—

Volts.

- Open Arc....
  - Constant pressure...
    - Direct...
      - Short arc...31-42
      - Long arc...42-43
    - Alternating...
      - Short arc...30-33
      - Long arc...33-47
  - Constant current...
    - Direct.
    - Alternating.
- Enclosed Arc...
  - Constant pressure...
    - Direct...
      - Short arc...50-60
      - Long arc...60-70
    - Alternating...
      - Short arc...45-50
      - Long arc...58-60
  - Constant current...
    - Direct.
    - Alternating.

Open arc is that in which the arc is exposed to the atmosphere, while in the enclosed arc it is surrounded by a globe and a cap which makes it nearly air-tight.

Approximately ·6 watt per candle power, is taken with clear Globe.

Open arc :—For D. C. were the first to be used in any great extent—they are always connected in series.

ADVANTAGES—high efficiency.

DISADVANTAGES—poor light distribution in street illumination due to the inclination of the arc, the cone being at 45° cutting away all light at the bottom. Carbons are consumed very quickly being exposed to air and require frequent 'trimming.' every 8 to 20 hours according to the type of lamp used.

Since they are used in series and each requires about 50 volts—the number to be connected in series is limited by the voltage capacity of the machine. As much as 125 lamps have been used in series. Open arc lamps consume 10 amperes at say about 45 volts per 1000 candle.

In open arc, carbons are consumed at the rate of one inch per hour. The rate depends upon whether the current is direct or alternating, on the diameter of the carbons, and on the current. In enclosed arc a pair of carbons about 20 inches will last from 50 to 150 hours or so.

Open arcs.—for direct current systems are connected in series and are run from some special arc machine. Each lamp requires about 50 volts and from 6 to 10 amperes.

Enclosed arcs ;—Construction same as of the former, Consumption less—$\frac{1}{16}$ inch per hour.

Enclosed Arc—In this lamp, the arc is formed in an enclosure from which the air is more or less excluded. The carbons are enclosed in a small cylindrical globe inside the outer one. When the arc is "struck," the carbon, combines with the air in the inner globe and forms carbon monoxide, which fills the globe and prevents further admission of air, and being placed in an atmosphere of carbon monoxide the carbons volatilise. This is the chief loss with the carbons. The carbons tend to assume a flat shape at the ends, instead of being pointed as in the open arc. This lamp emits light which is well diffused and steady when both outer and inner globes are opalescent. The arc is longer than the ordinary, a better distribution of light results, although the candle-power is sometimes 40 per cent. less. This better distribution of light is due to the inclination of arc, which forms a cone of 75°, while in the open arc the cone is 45°. The enclosed arc lamp works with a voltage of from 75 to 90, and with the resistance usually fitted inside the lamp it may be connected right away on a 100-volt circuit. As the carbons last from 120 to 200 hours, less trimming is required than in the open type. A nominal C. P. lamp takes about 7 amperes, but lamps are constructed to take 2·5 to 5 amperes. For inside work enclosed arcs are safer, there being less risk from fire due to falling carbon sparks.

Flame Arc Lamps :—These use **impregnated** carbons (as stated) and it depends upon the luminescence of salts impregnated in the carbon electrode for light production. It consists of a core of carbon which is impregnated with 50 % of Ca (yellow), Cerim (white) or Sr. (red) flouride together with silicates and a shell of hard carbon. These are consumed quicker than the ordinary carbon, hence they are made longer. The arc has a different light quality and most of the light comes from the arc than the crater, and its light penitrates in foggy weather. Consequently means are used (e. g. **economisers**, a saucer shaped piece of iron with a lining of refractory material or magnetic poles) to flatten the arc into a fan like form. It may be worked at 50 volts and it gives 10 candles per watt.

The advantage of the flame arc is an increased c. p. for a given power consumption e. g. 1/3 watt per M. S. C. P. These are made in sizes to emit as much as 3500 c. p. and is eminently suitable for lighting up open spaces.

Plating of carbons with copper is sometimes resorted to for moulded forms for the purpose of increasing the conductivity and protecting the near part of the arc thus prolonging its life.

The top Carbon is usually cored.

For D. C. the positive carbon is nearly twice in diameter of the negative carbon and it is usually put at the top, and the bottom carbon is smaller in diameter. In A. C. since the electrodes are alternatively positive and negative, they are consumed at an equal rate and the carbons are of the same size.

EFFICIENCY :—D. C.—1·4 watts per M.S. C.P.
A. C.—·3 watt per „ „

Distribution of Light ;—Most of the light is cut off by the negative C.

Relation of P. D. to length of arc and to current—If current is kept constant the arc sets up what is equivalent to an e. m. f. of its own which opposes the working e. m. f. and is regarded as the back or counter e, m. f. of the arc, its value is about 39 volts in D. C. and about 29 volts, in A. C. current system.

P. D. across the arc—back e. m. f. = const. × length of arc. + a constant

The back e. m. f, (39 volts there about) is due to thermo-e m. f. and also variation of the cross section and Sp. R. of the different parts of the arc particularly of a thin layer of carbon vapour in the crater.

With constant l and I varying.

$$E = c + \frac{d}{I}$$

Where I = not very large current through the arc,

c and d are constant for a given arc, i. e. the greater the current the less the P. D. across the arc.

THE PRESSURE REQUIRED FOR A LAMP DEPENDS ON :—

(1) Whether the current is direct or alternating,

(2) Whether the arc is open or enclosed,

(3) Whether the lamp is adjusted for a short arc or a long arc and the current depends upon (4) the size of the carbons and both depend upon the candle power of the lamp. Small arc lamps may take about 3 amperes while large ones for light-house and search light may take from 50 to 100 amps. The usual current for ordinary purpose is from 10 to 15 amperes.

Arc lamp Mechanisms have to perform the following duties :—

(*a*) To strike the arc i.e. to bring the carbons together and then to separate them by a given amount.

(*b*) To maintain the arc i.e. to feed them as they are consumed so that 'l' is kept constant. This may be done by hand but this is done usually by electro-magnetic actions, by means of solenoids acting against the force of gravity or against springs.

B.

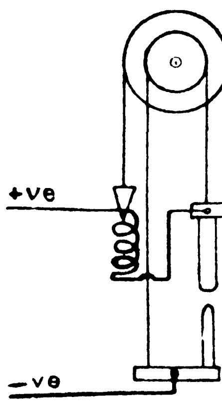
(*c*) The circuit should be open or closed when the carbons are entirely consumed, depending on the method of power distribution.

Electro-magnets :—used in arc lamp.

(1) Series wound.

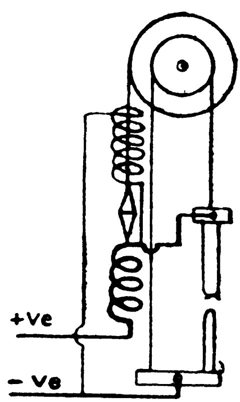
(2) Shunt wound.

(3) Differential wound, with both series and shunt winding.



Series arc lamp.

Fig. 2

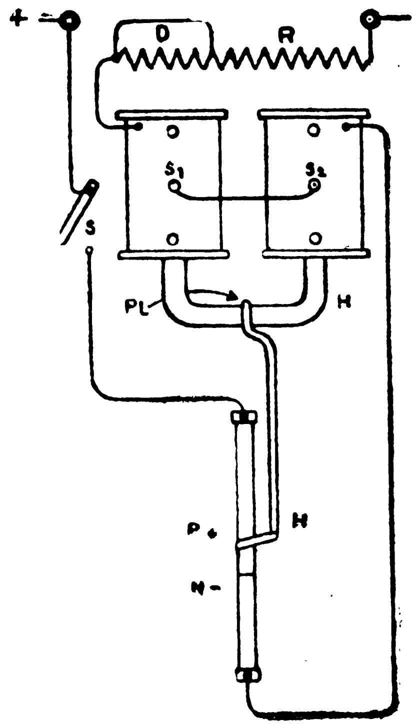


Shunt arc lamp.

Fig. 3

Series Arc Lamp :—In this, the weights of the parts are such that with no-current carbons are touching: with switching, large current flows through the series coil—attracts the core—rotates the pulley and therefore separates the carbons and strikes the arc, thus the carbons P and N are held together when the lamp is first started.

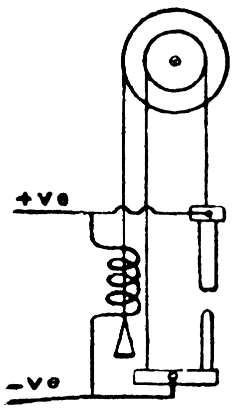
The current which flows in the series coil being excessive it draws up the plunger separates the electrodes by lifting the carbon P and strikes the arc. If the arc is too long, the resistance is increased and the current is lowered, so that the pull of the solenoid is weakened and the carbons feed together when the pull of the solenoid just counterbalances the weight of the plunger and carbon. This type of lamp is used only on constant potential circuit. D must be so adjusted that this point is reached when the arc is at its normal length. Thus I is kept constant and therefore it is suitable for arcs connected in parallel.



Series mechanism for DC Arc Lamp

Fig 4

Shunt :—In this the carbons are kept apart by gravity before the current is turned on, and the circuit is closed through a solenoid connected in parallel across the gap so formed. On switching the whole current passes through this coil, and the plunger of the solenoid is arranged to draw the carbons together and thus the arc is started. When in contact most of the current passes through the carbons and pull of the cores is mostly diminished and the carbons separate and the arc is struck as they move apart, Y_s the voltage across them increases, thus increases I and the core pull increases until balancing the weight of carbon and no further separation follows. As the carbons consume—pressure rises and so on. The pull of the solenoid and of the springs are so adjusted as to maintain the arc at its proper length.



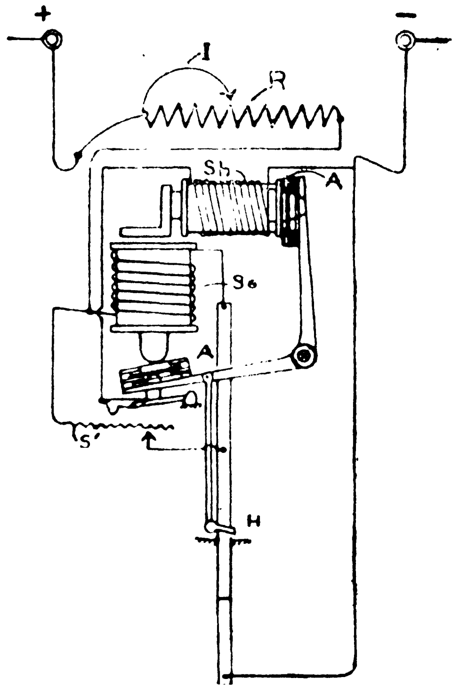
Differential arc lamp.
Fig. 5

Advantage—They tend to maintain a constant voltage at the arc.

Disadvantage—(1) It has a high resistance about 45o ohms or more. (2) Due to high voltage it is difficult to start on series circuit. (3) The arcs are a bit unsteady.

Differential Mechanism—In this the shunt and series mechanisms are combined. At first the carbons are held together. The series coil is arranged to separate them and the shunt coil Sh is connected across the arc preventing the carbons from being drawn too far apart. The armature of the two magnets are attached to a bell crank pivoted at B and attached to the carbon holder H. As the pull of Sh lowers the carbon that of Se raises it and the two are so adjusted that equilibrium is reached when the arc is of the proper length. All the lamps are fitted with an air dash-pot or some damping device to prevent too rapid movement of the working parts.

There is no pull when pulls due to Sh and Se coils are equal.



Differential mechanism for DC Arc Lamp

Fig. 6

The type is suitable for series-parallel, the most usual arrangement e. g. sets of 4 in series on 220 volt supply. Series lamps are sometimes used but they require careful adjustment to ensure equal division of V—so that they may be equally bright.

For good action there must be a brake wheel or a clutch in between the core and the carbons. For the pull on the core depends upon I and the position of core and as the carbons consume the core is pulled.

Advantage.—It tends to aid the generator in its regulation.

Disadvantage.—It operates only over a low current range.

Use of a choking coil and economy coil.—(1) The choking coil is usually used in series across the mains as an equivalent for a steadying resistance and for cutting down some pressure without causing much waste of energy.

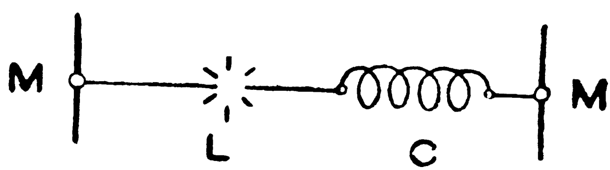


Fig. 7

(2) The choking coil may be joined up as a shunt to the lamp when it is called a compensating coil.

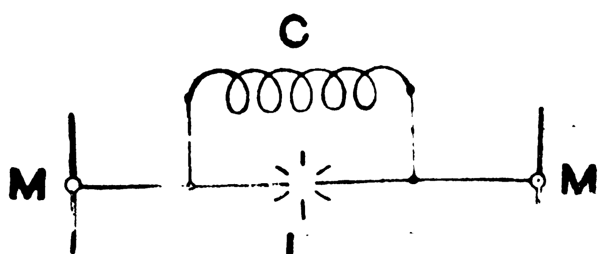


Fig. 8

This is adapted for running a large number of lamps in series of a constant current circuit.

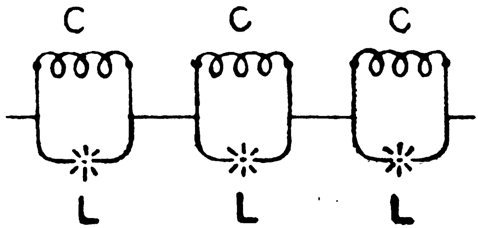


Fig. 9

An economy coil is a combination of a transformer, having two coils P and S wound in series in a laminated iron frame, and a choking coil. It is used with arc lamps in alternate current circuit. The function of P is to act as a reducer of pressure while S performs the duties of a conpensating coil.

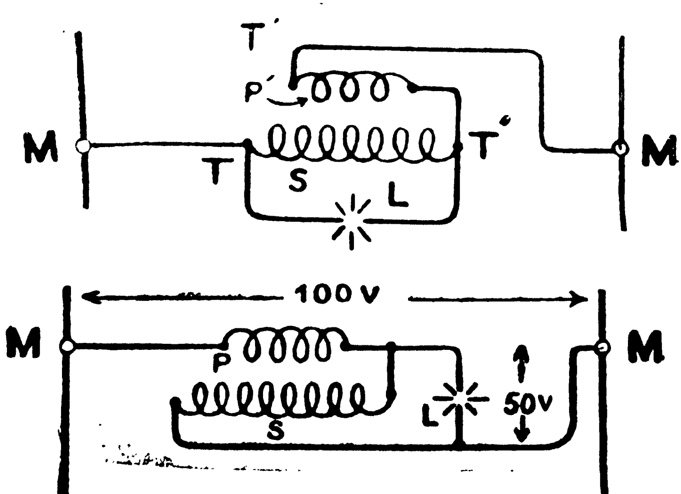


Fig. 10

Besides the above action there is the transformer action as follows—the current in P goes through the lamp but this induces a current in S which also flows through it or the lamp gets the current both from P and S. Any ordinary transformer can be connected into an economy coil by simply connecting the primary and secondary windings at one end.

Trimming and cleaning of arc lamp.—To trim first remove the old carbons and then wipe carefully and thoroughly the carbon rods, holders etc. with a clean rag. Do not, on any account, put oil or other lubricant on the carbon rods, or clean them with emery paper. After cleaning the rods wipe out the globe and get ready the fresh carbons. The coned carbon is placed in the top rod and fixed. See that it has been gripped firmly by the clamping screw in the holder. The bottom rod is fixed next and carefully observe that the two rods are in line and meet at points If not, unclamp the screws and turn the rods until they do. See that there are no loose connections etc. and replace the globe.

The manufacturers usually send a direction card with their lamps, study the card carefully and follow the instructions.

The terminals are generally marked positive and negative. If the light is projected upwards the connection is wrong and then change the lead.

Test for arc Light carbons (Fosters Electrical Engineers Pocket Book contributor J. H. Hallburg)—THE IMPORTANT POINTS to be determined are the range, including the hissing, jumping and flaming points, the resistance, and the life.

The RANGE is found by trimming a lamp with the carbons to be tested, allowing them to burn to good points and the lamps to become thoroughly heated; then connect a voltmeter across the lamp terminals, and very slowly and steadily depress the upper carbon until the lamp hisses, when the voltage will make a sudden drop. This is called the HISSING-POINT, and varies according to the temper of the carbon. It should be between 40 and 45 volts—preferably 42 volts. Then lengthen the arc somewhat, and allow it to become longer by the burning away of the carbons. Presently the arc will make small jumps or sputters out of the crater in the upper carbon. This is the JUMPING-POINT, and should be not less than 58 or 60 volts. Let the arc still increase in length, carefully watching the voltage, and in most carbons there will soon be a decided flaming. This is the FLAMING-POINT. This should not be less than 62 to 65 volts. Very impure carbons will commence to jump and flame almost as soon as the voltage is raised above the hissing-point, and even the hissing-point in such cases is very irregular and difficult to find. The Range is important as being a practical test of the purity of the material used in the manufacture of the carbon, an increase of a quarter of one per cent of impurity making a very decided reduction in the extent of the Range. The hissing-point should be 4 or 5 volts below the normal adjustment of the lamp to insure steady burning.

RESISTANCE.—The resistance is measured on an ordinary Wheatstone bridge. Care must be taken that the contact points go slightly into the carbon. A $\frac{7''}{16} \times 12''$ plain carbon should have a resistance of between .16 and .22 ohms, and $\frac{1}{2}'' \times 12''$ between .14 and .18 ohms. $\frac{7''}{16} \times 12''$ carbons coated with three pounds of copper per thousand, have a resistance between .06 and .05 ohms, and $\frac{1}{2} \times 12''$ with four pounds of copper between ·04 and .05 ohms.

LIFE.—The life of a carbon is most easily tested by consuming it entirely in the lamp, observing, of course, the current and average voltage during the entire time. A very quick and accurate comparative test of different carbons can be made, however, by burning the carbons to good points, then weighing them, and let them burn one hour, then weigh them again. The amount burned by both upper and lower carbons shows the rate of consumption which will accurately indicate the comparative merits of the carbons tested as to life.

To calculate the life from a burning test of one hour, both carbons should be first weighed, the upper carbon broken off to a 7 inch length, in order to make the test at the average point of burning, and with the lower carbon, burned to good points, weighed again, and after burning one hour in a lamp that has already been warmed up, taken out and weighed. The amount of two carbons 12 inches long consumed in a complete life-test is 63 per cent of the combined weight of both upper and lower carbons. Therefore 63 per cent of the weight of the two carbons, divided by the rate per hour obtained as above, will give the life approximately.

Methods of supply:—The two systems of running lamps are series and parallel.

Metallic filament lamps are generally run in parallel, but there is still the advantage of series running in this that a stronger filament can be obtained by running two or more lamps of lower voltage in series.

The disadvantages thereof are:—

(1) Two lamps should be 'off' or 'on' both.

(2) If one breaks the other goes out.

(3) They require to be 'paired'—i e. must be of the same type as far as possible.

Arc Lamp Circuits:—On ordinary lighting circuits they are two in series (on 110 volt circuit) or 4 to 5 on 200-250 volt circuit.

When an arc lamp or a set of them is supplied independently, a generator giving an approximately constant current is used. In this case the lamps are all connected in series—to put off a lamp short circuit it through switch—the generator voltage drops and the current in the remaining lamps rises very little. Economy coils are used where alternating current arc lamps are placed singly. These coils are combinations of transformers and choking coils.

Photometry :—Photometers are instruments used for the comparison of the c.p.'s of two sources in definite directions If one of these is a standard of known intensity, that of the other can be expressed in candles.

The theory :—The two sources illuminate similar surfaces and that too equally. The rays may be normal to the surfaces or equally inclined. Since the surfaces are similar and equally bright, they are equally illuminated. Hence

$$\frac{C.\ P_1}{C.\ P_2} = \frac{d_1^2}{d_2^2}$$

See that the two surfaces are adjacent or should appear so. Also the directions from which they are viewed should make the same angle to the normal to the surfaces.

Adjustment for equal illumination can be had either by moving the photometer or the light source keeping the former stationary.

N. B.—Inverse square law holds good for point sources. So, so long the dimension of sources are small, the above law is sufficiently accurate.

Photometers :—

(i) Shadow photometer.

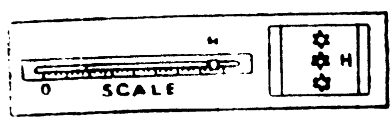
(ii) Wedge photometer.

(iii) Bunsen's grease spot photometer.

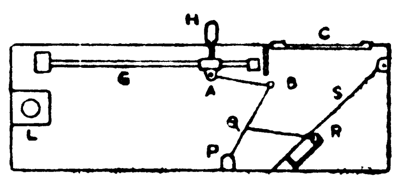
(iv) Lummer-Brodhun photometer.

Illumination Photometer.—It is used in determing the illumination on a surface. It is directly measured.

Principle.—To compare the brightness of a white matt. surface placed in the required position with brightness of a similar surface (S) with a variable known amount of illumination (from L).



Illumine by reflection an adjustable screen from a low voltage lamp and see the screen through 3 star shaped holes in a sheet of cardboard placed on the top of the instrument.



Trotter Illumination Photometer.

Figs. 11 and 12

C = card board diaphragm with 3 star shaped holes in it.

G = guide. H = handle. L = lamp.

AB = rod hinged at each end. BPQR = rigid rod hinged at B & P.

R = roller. S = screen.

Adjust the illumination of the screen by altering its inclination until it appears of the same brightness as the card-board. Read the illumination of the latter on the scale over which the actuating handle H moves. the lamp is lighted by a few small accumulators.

The whole thing is contained in a wooden case and is portable. The lamp is well aged and is reliably a standard one. This is generally used to varify the candle power of lamp used in street lighting e.g. at Howrah.

CHAPTER VI

Electric Lighting Accessories.

Switchboards are of two kinds.—Main and distributing. The main switchboard cuts off all communication with the outside mains, dynamos or other generators of electricity and controls the whole circuit. A distributing switchboard is placed at the point where the mains subdivide and each switch controls its particular portion of the circuit.

Essentials in Switchboard Design.—The designer must bear in mind the following essentials in a good switchboard layout :—

(1) Simplicity consistant with adequate protection.

(2) All the apparatus and the whole of the switch-board must be of incombustible materials.

(3) The apparatus must be so placed that there shall be no danger to life, whether from heat, fire, or mechanical force, during its normal or abnormal working.

(4) Every part, such as the conductors, switch contacts must be so calculated that it shall be free from over heating when used continuously.

(5) The board shall be so designed that the purpose of every portion of it shall be symmetrical and self-evident, without reference to diagram or description.

(6) The switch gear should be fool-proof, if possible.

(7) All parts must be readily accessible and must be so arranged that they can be handled safely.

(8) Portions subject to wear must be easily renewable.

(9) A breakdown on one section of the board should not cause any dislocation in another part, and should only affect the generator or feeder connected to it.

(10) The intruments, switch parts, straps, plugs relays, etc , should (as far as practicable) be standardized and interchangeable.

(11) In most cases the board should be so arranged that it can be readily extended to deal with increased output without alteration or disfigurement.

(12) The material of the panels shall be such as to afford the proper insulation between live metal parts mounted directly on the panel, for the voltage on which they are used.

(13) "All instruments shall be dead beat and protected from stray fields produced by adjacent connections or bus-bars."

(14) "Connection bars and wires shall have a cross section so that with maximum load, the temperature rise at no point will exceed 40°C. rise above the surrounding air, which may be based on 20°C."

"(16) A switchboard should consist as wholly of metal as possible. If for high pressure work, every particle of metal not forming part of the circuit should be connected efficiently to earth; and especially should all levers, and other parts that have to be handled, be most carefully kept at earth potential.

(17) Switchboards ought to be so placed that access can be had all round them; the back should be as open as the front. They should be placed in such a position that they are unlikely to be affected in the event of a disaster at the station, and hence should be well away from all running machinery, and quite clear of steam or water pipes.

Switchboards in an engine room should be placed in such a position that they command a view of the generators; and with this end in view, they are usually mounted on an elevated platform. This should preferably be of steel, with steel floor-plates for high pressure work, or with a concrete floor, tiled, for low pressure boards.

Distributing Switchboard.—Where the number of lamps is large it is convenient to supply them with power through a number of small circuits instead of putting them all in one. Thus there is better control and less heavy currents in one pair of mains.

It consists of several switches with cutout to each fixed on a board common to all the points. The current is taken to the board by one large pair of cables and after passing through the switches and cutouts leaves by several smaller ones.

The siwtches may be in both mains when two rows of switches with cutouts are fixed. One at the top and another along the bottom of the board. This arrangement is convenient, as it allows any one circuit being quickly and completely cut off from the supply mains in emergency cases.

Connections at the back of boards must be made accessible, but, unless protected from acid fumes, must not project into battery rooms. Circuits should be labelled for indentification.

The cases of instruments, if metallic, must be insulated from the circuits, or, if connected to one pole, they should be protected from the possibility of contact with the other.

Every voltmeter with its connecting wires should be protected by a fuse on each pole.

10. **Distribution boards.**—(1) Main distribution boards shall be of marble or slate, or iron skeleton frames for ironclad switchgear and shall be provided with a switch and fuse on each pole of each circuit.

(2) Branch distribution boards shall be provided with one fuse on each pole of each circuit. One spare circuit of the same carrying capacity shall be provided on each branch distribution board. No final fan sub-circuit radiating from a branch board shall carry more

than 4 fans. Incandescent lighting sub-circuits shall comply with the limits specified in I. E. E.

(3) Switches and fuses of opposite polarity shall be mounted on separate bases and the holes for the fixing bolts of the bases shall be bushed.

(4) In the construction and fixing of main and branch distribution boards the following requirements shall be fulfilled :—

(*a*) Connections of all circuits carrying more than 10 amperes shall be made by means of cable sockets.

(*b*) Two spare fuse carriers per main and branch board shall be supplied for replacements.

(*c*) All boards (other than those of "ironclad" pattern) shall have strongly made, well finished and approved teak cases with dovetailed corners and shall be painted, varnished or polished as directed by the Engineer, and shall be marked with conspicuous letters on labels, to correspond with the wiring plans.

SWITCH AND DISTRIBUTION BOARDS.

Position, Construction.—Main and distribution switch and fuse boards may be used under the following conditions :—

(*a*) They must be—

(*i*) Fixed in dry situations ;

(*ii*) So arranged that a fire thereon cannot spread whether occurring at the front or back.

(b) Their bases must be of incombustible and insulating material, and fitted with moisture-proof bushes at the points of support if the material is hygroscopic ;

(c) The possibility of a permanent arc must be prevented either by sufficient spacing of all live parts or by the use of separating partitions ;

Accessibility.—Switch and fuse boards must be so constructed and placed that all their parts which may have to be adjusted or handled are readily acessible.

Connections.—Connecting conductors on main boards must be—

(a) Permanently accessible from either the back or the front of the board ;

(b) Symmetrically placed and spaced apart ;

(c) So proportioned that there shall be no appreciable rise of temperature when the current flows through them ;

(d) So arranged that the course of every conductor may, where necessary, be readily traced ;

(e) So arranged as to prevent the access of acid fumes from batteries to the board

Labels.—Switchboard circuits should preferably be labelled for identification.

Open type Fuses.—No open-type fuses may be placed at the back of switchboards.

Metal Cases.—The cases of instruments, if metallic, must be insulated from the circuits, but they may be earthed if desired.

Fuses.—Every Voltmeter or pilot lamp with its connecting wires should be protected by a fuse on each pole.

Combination Boxes.—Combination switch and fuse boxes must be so arranged that it is possible to operate a switch without uncovering the fuses, if these are of the open type.

Fused Metal.—Where fuses are grouped together the case of the distribution board.

(*a*) will, if glass fronted, be a sufficient protection from the fused metal provided that the distance from cover to fuse exceeds 1 in.;

(*b*) must, if made of wood, be lined with fire-resisting material, and a minimum clearance of 1½ in. should be provided.

SWITCHING DEVICES.

Switching devices used in connection with switch-boards may be classified as follows.

(*a*) Circuit breakers, automatic.

(*b*) Relays.

(*c*) Lever switches (knife switches.)

(*d*) Quick-break switches.

(*e*) Plug switches.

(*f*) Disconnecting switches.

(*g*) Controlling switches.
(*h*) Oil-break switches (oil circuit breakers.)
(*i*) Fuses.

(*a*) CIRCUIT BREAKERS.

A circuit breaker automatically opens the circuit in event of abnormal electrical conditions in the circuit. Automatic circuit breakers are designed for alternating and direct-current circuits. Alternating-current circuit breakers [illegible] made to operate on overload or low volta[illegible]al conditions under which circuit [illegible]:

(1) Overload. (4) Overvoltage.
(2) Underload. (5) Undervoltage.
(3) Reverse current. (6) Electrically tripped from a distance (shunt trip.)

The sizes of the parts should be such as to carry the full current without over heating, current densities 800 amps per sq in for copper, 500 amps for brass or gun metal, 250 amps at the contact surfaces with laminated contact, 50 to 100 amps per sq. in for knife blade contact.

Switch :—The object is to open or close the circuit or to divert the current in a certain direction.

When the switch closes the circuit it is said to be on, and when it opens the circuit, it is in the off position.

Main switch is intended to cut off all connection with the outside main. They are designated by their current carrying capacity and are made in sizes from 10 upto 1000 amperes. Though the e.m f. of the system does not affect the current carrying capacity of the switch, it affects the design as the arc formed will vary with the e.m.f. The switch should be (1) opened quickly, (2) made of incombustible substance and well insulating and incombustible bases, s ch as marble or slate in large switches and porcelai switches. (3) fitted with an automatic thro ak and having long break action and qui (4) It should not be in an interme between full off and full on (5) The contacts sh be rubbing over and either the fixed or movable contact surfaces, should have a certain amount of spring in them so that they always bear well together, and shou be adjustable, and except for small currents the contact pieces should be.laminated or otherwise divided. It is best to have a double break switch even for small pressures and current. (6) It should have a good positive action.

Knife or chopper switches are used for 10 amperes and upwards.

For selection of a main switch, note :—

(1) Solidity of design and construction, this determines the life of the switch.

(2) Ample contact surfaces which automatically adjust themselves so as to take up in time.

(3) A quick break or automatic throw off action, some buffer arrangement should be made to deaden the shock to the contact bar when it flies off.

(4) A mechanical connection right through from terminal to terminal.

(5) Good attachment for the ends of the cables. The ends of the cables are soldered into cable connections or sweating sockets. The ends of the cables may be fastened to the main switch by (1) fastening to the contact pieces by clamping under a screw or nut, (2) soldered into a thimble or socket which is fastened to the contact piece by a bolt, (3) they may be soldered right into the contact piece itself.

(4) S**ll branch switches** :—SP. SB. switches are u low pressures and small current switches turned like a tap, are called **turn switches.**

Tumbler switches have tumbling movement of their working parts. There are two-way tumbler switch in which the movable portion is in two parts.

In all these switches the knob is turned to make contact.

The different types of switches are shown in Fig 11

The **pendant switches** are suitable, for a small current say for two or three ordinary lights. Use of metal covers in tumbler and other switches is not good practice as there is risk le contacts and shocks. g in t'

Plug Type of switch—In this the grinding of the contact is relied on, but split plugs are used for heavy currents.

Length of gap between switch terminals, 3 in up to 50 amp, 6 in up to 500 amps for SP. switches to 250 volts and DP switches up to 600 Volts. The two most important points to be secured in a lamp switch are that (1) it is impossible for the switch to be left in a position that it

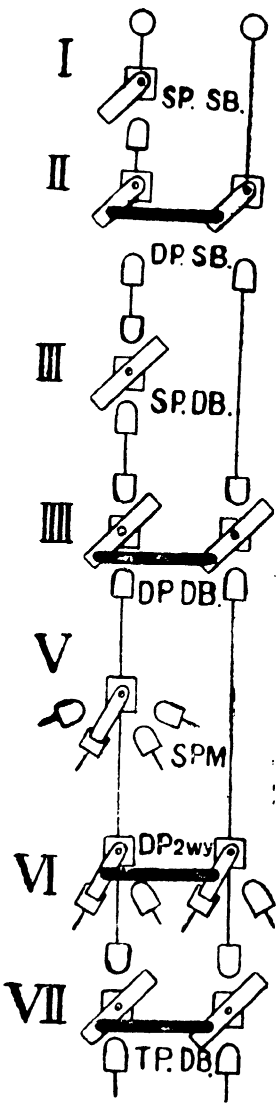


Fig. 13

can arc (2) It is composed of some non-combustible material.

Branch switch or a lamp switch :—This is used in each branch circuit to light or extinguish any one lamp independently of the rest. These are either single or double break. The tumbler switch is generally used for the purpose.

Points to be noted in selecting branch switch :—

(1) The switch should have good, quick break action, otherwise this will be the most fruitful source of fire.

(2) The base should be of non-combustible material.

(3) Construction must be solid.

(4) So far as possible mechanical connection must be made right through from terminal to terminal.

(5) No metal parts should be in touch with line wires at the back of the base.

Connectors and wall Plugs.

All connectors should be capable of withstanding a test at a pressure and current 50 per cent. in excess of that for which they are intended In damp places special watertight connectors must be used. In cases where the fixed part of the connector is attached to a floor it must be so arranged that no dust or water can accumulate in the cavity, and that all contacts are well below the floor level or covered to prevent any possibility of danger from contact with carpets.

No connector may contain a fuse.

Connectors must be constructed so that they cannot be readily short-circuited. Clearances should be such that an arc cannot be started if the connector is pulled out at the time that the current is flowing. The insulation used between opposite poles should be such that it will not readily break or chip.

Flexible cord conductors for portable fittings must end in a connector.

Every portable current-consuming device must be independently controlled by a switch on the live side of the connector.

WALL PLUGS :—This is used when a portable lamp or fan is to be given in a room. The lamp is connected with a flexible cord and is put in the circuit with the wires in the walls through the wall plug, the plug is inserted in the socket and thus the flexible cord is put into connection with the main wiring The fan is run or the lamp is lighted by inserting or withdrawing the plug without using the switches.

SWITCHES AND CIRCUIT-BREAKERS.

Switches and circuit-breakers, whether fixed separately or combined with lampholders or fittings, must comply with the following requirements.—

(*b*) **Construction.**—They must be so constructed or arranged that the contacts cannot accidentally close when left open ;

(*c*) **Size.**—They must be incapable of forming a permanent arc when breaking circuit, and they must be tested with pressures and currents 50 per cent in excess of those which will be used on the circuits for which they are intended;

(*e*) **Location.**—Circuit-breakers must be so arranged and placed that no combustible material is endangered by their action;

(*f*) **Covers.**—Unless placed in an engine room or in a compartment specially arranged for the purpose, they must have their live parts covered. The covers must be of incombustible material, and must be either non-conducting or of rigid metal and clear of all internal mechanism. For more than 6 amperes, at pressures exceeding 125 volts, metal covers must be lined with insulating material;

(*g*) **Boxes.**—In positions where they are liable to injury or to come into contact with goods they must be further protected by an open-fronted box or other suitable guard;

(*h*) **Handles.**—Handles must be insulated and so arranged that the hand cannot touch live metal or be injured through an adjacent fuse blowing;

(*j*) Switches having a handle projecting through an open slot in the cover must not be used.

Cutout or Safety Fuse—is a device inserted in a circuit so that the current cannot accidentaly increase beyond its normal strength.

In its most usual form it is a short length of tin or an alloy of lead-tin wire of much smaller cross section than the rest of the circuit so that the wires having their points of fusion very low are immediately fused as soon as a larger current than the normal rated current say by 50 °/₀ in the line flows through them, in main cutouts of very high tension circuits fine copper wire is frequently used.

Cutouts—are classified as (1) main cutout ıd (2) as branch cutouts, and these may be subdivided (1) single pole, and (2) double pole cutouts.

Main cutouts—are used in connection with the mains.

A Single pole cutout—has a fuse in one wire oniy.

In A Double pole cutout— a fuse is inserted in both negative and positive wires.

This is used in all circuits tapping directly into the mains as it completely protects the cirtuit. For lamp circuits a single pole cutout is generally used in both the mains.

There are various types of main cutouts available in the market.

Cutouts are generally designated by their current carrying capacity.

Points to be noted in Selecting a Good Cutout :—

(1) The base must be of non-combustible material.

(2) In high tension circuits extra long gaps must be provided between the fuse terminals.

(3) There must be easy access for renewing a melted fuse.

Branch Cutouts :—These are almost always single pole. It has no metal conducting parts at the back of the base. The different parts are fixed by screw from the front tapped into percelain base.

Fuse Board or Box.—When a number of circuits get their supply from one main circuit and it is not desired to use switches, a fuse box is usually used in which all the fuses are kept so that they can be easily renewed.

The main cable is connected to a horizontal bar and one wire of each of the other circuits is connected to the metal blocks above, between which blocks and the bar the fuses are fixed. The different metal parts of the board are fixed to a polished slate or marble base which is mounted in a teak wood case with hinged glass front. The clip type of fuse is quickly and easily renewed and in this, the fuse can be renewed without touching any metal parts in contact with the electric current.

Every fuse must be encased, except as specially provided and comply with the following requirements :—

(*a*) That no overheating can take place in any part when the full current flows continuously.

(*b*) That it shall effectually interrupt the current when a short-circuit occurs, and also when the current through it exceeds the working rate by 100 per cent., the current flowing under the normal pressure in both cases.

(*c*) The base of the fuse must be of incombustible, non-conducting, and moisture-proof material.

(*d*) The cover must be of incombustible material, and must either be non-conducting or of rigid metal lined with insulating incombustible material. It must be kept clear of all the internal machanism. When the fuses are of the open type and grouped together, the case of the distribution board will be a sufficient protection provided the distance from cover to fuse exceeds two inches.

(*e*) Fuses must not be placed in wall-sockets, ceiling roses, lampholders, or switch covers.

(*f*) The fusible metal must be of such size that no conductor protected by it can possibly exceed the specified temperature.

Separate single fuses, and not "double-pole" fuses, must be used on circuits on which the pressure exceeds 125 volts.

Fuses may be considered too large if they are not warm to the touch on full load, and too small if they hiss when moistened.

Note:—It is recommended that hard metal be used for fuses; and that if soft wire is used, it should be soldered to hard metal contacts.

Ceiling Roses:—This is a fitting fixed on the ceiling from which the flexible cord of a pendant is joined to the conducting wires in a decent manner and gives a finished appearance to the pendant. There are various types of ceiling roses in the market

Every ceiling rose must comply with the following requirements:—

(*a*) The base must be of incombustible, non-conducting and moisture-proof material;

(*b*) The cover must be of incombustible material, and must be either non-conducting or of rigid metal, and clear of all internal mechanism;

(*c*) Unless it, or its base, form part of the sheathing it must not be attached directly to a plastered surface, but must be mounted on a prepared block;

(*d*) Its terminals must be relieved of the direct pull of the attached conductor and fitting, and be so arranged that no short circuit can take place;

(*e*) It must not contain a fuse.

FITTING FOR SUPPORTING LAMPS.

Wherever brackets, electroliers, or standards, require to have the conductors threaded thr[illegible] tubes or channels formed in the metal work, the [illegible] be of ample size and have no sharp angles or p[illegible]g edges, which would be liable to damage the insula[illegible] material.

Where possible, the conductors should be carried without joints through the fittings to the lamps; but where connections at the fitting are unavoidable, special care must be taken to make the joints equal in conductivity and insulation to the rest of the work.

Combined gas and electric fittings must not be used.

When disused gas-fittings are adapted for electric light, they must be entirely disconnected from the gas-pipes.

Pendants :—The simplest one consists of a piece of flexible cord having at one end a lamp and a holder while its other end passes through a hole in the lid of the casing and is directly attached to the conducting wire.

Electroliers:—These are of various shapes and sizes. It consists of an upright stem through which the wires pass and two or more ornamental arms having holders which carry the shades and the lamps. The wires to the lamps are taken down the stem and through the arms to the holders to the lamps.

In the specification give the length of the centre tube.

Wall Brackets:—These are fixed against the wall for lighting the room from the side. It is made up of a plain tube fitted at one end with a back plate, and at the other, turned dow ight angles and fitted with a thread to suit the holde h may be with or without the shade carrier and lamp. These are very useful in bed rooms and other places where the light is to be manipulated. The use of side lights close to the wall, or on short brackets, is preferable to lighting from the ceiling in certain cases as when strong local illumination is needed.

HOLDERS.

Various types of HOLDERS are available :— such as (1) the bayonet joint form for brass capped lamps, (2) the screw socket for Edison screw lamps, (3) the spring for bottom loop lamps. The bayonet joint holder is the one most extensively used being the most efficient and reliable.

The points of a good holder should be :—

(*a*) Simplicity, fewness, strength, and interchangeability of parts.

(*b*) Interchangability of parts enabling a given holder to be used for the usual sizes of male or female attachments, or for flexible cord suspension.

(*c*) All non-metallic parts of porcelain, including the cord grip.

(*d*) Complete insulation and isolation of terminals and ends of wire on one pole from those on the other, and from the outer case.

(*e*) Ease of wiring.

(*f*) Secure and good contact-making terminals.

(*g*) Plungers with flat tops, thus making ample surface of contact on the plates of the lamp.

(*h*) An efficient shade carrier.

B.C. holders are of two chief varieties, (*a*) for fixing to the tube of a bracket, electrolier, &c., and (*b*) for suspending at the end of a flexible cord conductor.

Lampholder must—

(*a*) be entirely incumbustible ;

(*b*) be insulated from any continuously earthed conduit or sheath not forming part of the circuit ;

(*c*) be specially designed if for currents above 1½ amperes ;

(*d*) not be hung from flexible cord conductors where exposed to the weather, but be rigidly supported.

Switch lampholders should be controlled in groups of ten, or fewer, by a separate fixed wall switch.

Purpose of Reflectors.—The reflector serves to direct a larger proportion of the total light flux in a useful direction. It thus changes the distribution of the flux by redirecting it to a more needy zone. In indirect and semi-indirect systems the bowls are the reflectors. Metal reflectors are not to be used for lighting residences, stores, offices end similar places and glass reflectors are not in general suited for lighting factories The reflection may be (1) specular, e.g. in smooth glazed reflector a highly polished surface (2) diffuse e.g. when the surface is not polished as in mattsurfaced reflector (3) or spread, this lies between the last two extremes, as in glass having a sandblast surface etc.

Purpose of Diffusing Globes.—Diffusing globes or balls that entirely surround the light source although lower the efficiency of light are used to reduce the brilliancy of the light which affect the distribution of light, by changing the diffusion of the light, its colour and intensity, and in some cases globes are used to modify the colour of the light but are chiefly used for decorative purposes. Glass globes absorb a considerable amount of light. Ground-glass absorbs about 10 per cent. Translucent glass absorbs from 15 to 30 per cent.

Shades.—Shades are also used for decorative effect, they further generally enclose the lamp to a considerable extent and thus shield it form view or cut off all or apart of the light flux leaving the source in a certain direction. Glass shades are made in a large variety of shapes and kinds of glass, and can be used to produce very artistic effects. All shades are very inefficient in their distribution of light.

Determine the general type of reflector, whether glass or metal, before calculating the power required for illumination. The arrangement of the units decides the shape of the reflector, which determines the distribution of light. For uniform illumination the style of reflector selected will depend upon the mounting height and spacing of the units. Wide spacing and low mounting height reflector giving an extensive distribution, closer spacings require an intensive or a focussing distribution.

For reflectors spaced 10 ft. apart the following styles should be used :—

Extensive for a	height	above	the floor	of about	7 ft. 6 in.
Intensive	,,	,,	,,	,,	10 ft.
Focussing	,,	,,	,,	,,	13 ft.
,,	,,	,,	,,	,,	16 ft.

If the reflectors must be mounted about 15 ft. above the floor, the following styles should be used :—

Extensive	for a	spacing	of	about	25 ft.
Intensive	for a	spacing	of	about	25 ft.
Focussing	,,	,,	,,	,,	10 ft.

Choose the proper size of reflector for the lamp used, the proper shape to give the desired distribution of light and the proper style of shade holder so as to centre the lamp in the reflector. Otherwise, the distribution of light will not be as designed, and uniform illumination will not be secured. The size of bowl used for indirect and semi-indirect systems depends principally upon the ceiling height.

CHAPTER VII.

WIRING RULES AND REGULATIONS.

Current in Circuits and Sub-circuits for Lighting and Heating. Conductors must radiate from distributing centres, and in large systems, feeders will be necessary between centres and sub-centres. For lighting purposes in any final sub-circuit which supplies more than a single point, the current must not exceed 6 amperes for pressures up to 125 volts, nor the power 600 watts from 125 to 250 volts, and the maximum number of points on any sub-circuit must not exceed 10. Every sub-ciruit must be protected on each pole by a fuse Mains and feeders must be protected on each pole by a switch and fuse or circuit-breaker or fuse switch, except with earthed concentric wiring.

Earthing.—Earthing conductors (earth wires) must be of copper of a cross-sectional area not less than that of a No.14 S.W.G. When the cross-sectional area of portable or other leads is less than that of a No. 14 S.W.G., the earthing conductor may be equal in cross-sectional area to the live conductor. The earth wires must be suitably protected from mechanical injury, and they must be efficiently and permanently earthed. One such No. 14 S.W.G. conductor for every 50 amperes of working current or part thereof, or a conductor of equivalent cross-sectional area, must be provided.

Where an efficient earth or earths cannot otherwise be obtained, earth plate 18 in, square, surrounded by about 12 in. of broken coke, free from sulphur, should be placed preferably in an upright position in the ground. The place selected should be permanently wet, or at least damp.

Mounting of Switches, etc.—All switches, etc. and outlet points must be so arranged that the external conductor is interposed betwe n the internal conductor and the surface, upon which the fitting is mounted.

Fuse Boards.—The fuse board must be provided with—

(*a*) A metal case to which the internal conductors, leaving the board must be connected ; or

(*b*) A metal bar or wires connected to the external conductors, the whole being connected to a sheet of metal of the same size as the board interposed between the board and the wall or surface on which it is to be mounted.

JOINTS AND CONNECTIONS.

Junction Boxes.—Junction boxes must be so Constructed that—

(*a*) The conductors cannot be readily short-circuited ;

(*b*) The insulation between opposite poles is rigid and durable ;

(*c*) The connections do not heat ;

(*d*) If used in damp places they are of watertight pattern.

Connection at Terminals.—Where conductors are connected to switches, fuses or other appliances—

(*a*) The whole of the separate wires forming the stranded or flexible conductor must be contained within the terminal, but the dielectric must not be bared back further than to allow the conductor to enter the terminals properly;

(*b*) The braid, lead or other covering must be cut back from the end of the dielectric;

(*c*) The exposed end of dielectries of Class B must be protected from moisture which might creep along the insulating material within the sheath;

(*d*) In damp places the strands should be soldered until solid

Precautions at Points of connection where conductors are connected to switches, fuses, junction-boxes, or other appliances, the whole of the separate wires forming the stranded or flexible conductor must make contact with the terminal so that no loose wire or strand can project. The dielectric must not be bared back further than to allow the conductor to enter the terminals properly, and the ends of the insulation Class (b) should be sealed.

The braiding, lead, or other covering to the dielectric must be cut back from the end of the insulating material, and waterproofed. In damp places the strands of conductors, Class (b), should be soldered to prevent moisture creeping along the copper beneath the insulation.

Conductors of larger section than 7/18 must be soldered to proper lugs for connection. Where there is any possibility of strain on the lugs they must be mechanically attached in addition to the soldering.

The installation generally shall be carried out in conformity with the latest edition of the Wiring Rules of the Institution of Electrical Engineers (London), hereinafter referred to as the " I. E. E. Wiring Rules " but, where this Specification or the attached Special Conditions of Contract differ from those rules, the Specification and Special Conditions shall be followed.

Definitions and conventional symbols.—A "point" shall consist of the branch wiring from the branch distribution board, together with a switch if required as far as and including the ceiling rose or wall plug, etc.

System of Wiring.—" Power " wiring will be kept separate and distinct from lighting wiring. The wiring must be done on the distribution system, with main and branch distribution boards at convenient centres and without isolated fuses. All conductors shall be run as far as possible along the walls, and ceiling, so as to be easily accessible and capable of being thoroughly inspected. The balancing of circuits in 3-wire or 3-phase installations shall be arranged beforehand by the Engineer. Circuits on opposite sides of a 3-wire system or on different phases of a 3-phase system should be kept as far as possible apart, where bringing them into the same room is unavoidable.

Conductors—Except as provided in clause dealing with fittings no insulated conductor shall have a cross-section less than that of one no. 18 S. W. G. and every such conductor of greater cross-section shall be stranded.

Fall of potential —The cross-sectional area of all conductors inside buildings shall be so proportioned to their length that the drop in pressure between the main fuses and the furtherest or any lamp shall not exceed 2 per cent. with all the consuming devices in use.

Rating of lamps and fans.—In estimating the current to be carried by any conductors, glow lamps are to be rated as of 4 and 1.25 watts per candle-power for carbon and metallic filament lamps respectively where the conditions are known, and otherwise at 60 watts, except in the case of gas-filled lamps. Ceiling fans ar to be rated at 140 watts; table fans at 80 wa..s, mless actual values are known and specified.

Tests — 'he installation with fittings complete shall, before current is switched on satisfactorily, pass the following test:- –

The whole of the lamps and appliances having been connected to the conductors, and all switches and fuses being "on," a pressure not less than twice the intended working pressure (subject to a limit of 500 volts) shall be applied and the insulation resistance of the whole or any part of the installation to earth must not be less in megohms than 25 divided by the number of points as defined above. With all lamps and appliances removed from the circuits a similar test between poles may be demanded: Provided that during the rainy season, or in new buildings at any season, half the above test value will be accepted. Where any appliance referred to is a motor larger than one-half B. H. P. the insulation resistance of that particular circuit must be greater than 1 megohm.

Joints and looping back.—Unless with the sanction of the Engineer all joints in conductors shall be made by means of approved mechanical connectors in suitable and approved joint boxes; but "looping back" is preferable.

Control at point of entry of supply.—There shall be one main switch and one main fuse on each pole of each main circuit (other than the neutral conductor of a 3-wire circuit) at the point of entry of the supply. The switches must be linked unless otherwise specified in the Special Conditions of Contract.

CURRENT IN CIRCUITS AND SUB CIRCUITS.

(Part only)—For lighting purposes, in any final sub-circuit which supplies more than a single point, the current must not exceed 6 amperes for pressures up to 125 volts, nor the power 600 watts from 125 to 250 volts and the maximum number of points on any sub-circuit must not exceed 10.

BUNCHING.

Bunching.—Where protected from mechanical injury by metal conduit or by a covering of tough rubber compound conductors of opposite polarity may be bunched. Where the protecting tubing or casing is non-metallic, lengths of conductors of the same polarity and free from joints, carrying small currents for incandescent lighting, from sub-centres may be bunched. If the supply is alternating and the protection iron or steel, the lead and return conductors must be bunched.

FLEXIBLE CONDUCTORS.

Size—Flexibles must be made up so that the total cross-sectional area is not less than equivalent to no. 22-S. W. G., and they must be composed of wires twisted together on a short lay, no wire being smaller than a no. 36-S.W.G.

Dielectric and tests.—Each coil of pure rubber flexible must be tested in air for 15 minutes with a pressure of 1,500 volts alternating between the conductors at a frequency of 50 to 100.

(1) **Passing through walls.**—Except as laid down specially where conductors pass through walls one of the following alternative methods shall be used:—

(a) A hole of suitable area shall be made in the wall, through which the casing shall be carried so as to allow of an air space of not less than 1 inch on three sides of the casing

(b) Where cleated wiring is used, conductors shall be carried in an approved heavy gauge solid drawn or lapwelded, insulated conduit of tube, the mouth of each tube shall be bushed with a snapheaded bush and the internal diameter of the tube shall be such that when all the wires have been drawn through it there shall remain a free air space to accommodate twice the number of similar wires.

Where the supply is alternating current the conductors of the circuit must be bunched.

Where casing is led up to a wall tube which passes to the outside of a building, the casing must not be entered by the wall tube, but must be clear of it, the mains leading from the wall tube shall enter the casing by a junction box with mechanical connectors.

(2) Where a wall tube passes outside a building so as to be exposed to the weather, the outer end shall be bell mouthed and turned downwards.

Wall Pluggs.—Plugs for ordinary walls or ceilings shall be of well-seasoned teak or other approved hard wood not less than 2 inches long by 1 inch square on the inner end and $\frac{3}{4}$ inch square on the outer end, except for use with metal-sheathed wiring. They shall be cemented into the walls, to within $\frac{1}{4}$ inch of the surface, the remainder being finished according to the nature of the surface, used, with plaster or lime punning; and to give the cement a hold on the plug, there must be on each of two opposite sides two counterbores not less than $\frac{1}{2}$ inch diameter + $\frac{1}{8}$ inch deep. Unless otherwise similarly specified, iron screws may be used for attaching casing to the plugs. Where owing to irregular coursing or other reasons the plugging of the walls or ceiling presents difficulties, the casing, conduit or cleats (as the case may be) shall be attached to the wall or ceiling in a manner approved by the Engineer.

Branch switches.—In installations supplied from a 3-wire system all branch switches shall be placed on the "outer." Switches (other than those for multiple control) controlling not more than 10 amperes shall be of the tumbler type, and the switch shall be "on" when the handle or knob is down. Where the specified position of branches is altered, any such alteration of position, after fixing, will be paid for.

Ceiling roses and wall sockets.—Ceiling roses and wall sockets shall not contain fuse terminals. Wall sockets shall comply with the requirements of the British Engineering Standards Committee.

Fitting.—Where conductors require to be threaded through tubes or channels formed in the metal-work of fittings, these must be free from sharp angles or projecting edges and of such a size as will enable them to be wired with the conductors used for the final sub-circuits with-out removing the braiding or taping. As fas as possible all tubes or channels should be of sufficient size to permit of "looping backs." Where, with the approval of the Engineer, "electrolier wire" is used for wiring fittings the sub-circuit leads must terminate in a ceiling rose or connector, from which this will be carried into the fittings. Flexible wire must not be used for wiring fittings, except portable fittings. All fittings must not have less than a ½-inch male nipple. Fitting and lamp-holders for gas-filled lamps shall be adequately ventilated.

Lamps-holder—Lamp-holders for use on brackets, ect., shall have not less than a ½-inch female nipple, and all those for use with flexible pendants shall be provided with cord grips. All lamp-holders shall be provided with shade-carrirs. All cases must be solid and substantial, thin-cased export type not being admissible. Edison screw-holders will not be accepted for lamps below 100 watts.

External and Road Lamps :—External and road lamps shall have weather-proof fittings of approved design so as effectually to prevent the admission of moisture. An insulating distance piece of moisture-proof material must be inserted between the lamp-holders-nipple and that of the fitting. Flexible cord conductors and cord-grip lamp-holders must not be used where exposed to the weather. In verandahs and similar exposed situations rod pendants shall be used.

Lamps :—All glow lamps, unless otherwise specified in the Special Conditions of Contract, shall be hung at a height of 8 feet above the floor level, and shall be separately switched, metal filament lamps shall be made of drawn wire only.

(2) When carbon filament lamps are used, they shall comply with the Engineering Standerds Committee's specification for carbon filament glow lamps.

Fans and Regulators :

(1) (*a*) All ceiling fans shall be wired to a ceiling-rose and suspended from a hook or shackle, and insulated from the same. All joints in the suspension rod shall be screwed and all joints or bolts in connection therewith shall be additionally secured by means of split pins.

(*b*) The canopy at the top of the suspension rod shall effectually hide the suspension.

(*c*) The leading in wires shall be not smaller than 3-22 S.W.G. and shall be protected from being cut.

(*d*) All fans shall be free from sparking, noise, oil-throwing and excessive heating

(2) Unless otherwise stated in the Special conditions of Contract.

(a) All fans shall be hung 9 feet above the floor.

(b) All fans shall be capable of running continuously at full speed for one month without additional oiling.

(c) Each fan shall have a separate switch.

(d) Each fan shall have a speed regulator, which shall have a cover and an "off" position, and shall be so designed as to be capable of reducing the normal speed of the fan by not less than 60 per cent, with all resistance in circuit. The regulator shall be capable of continuous use on any contact without burning or overheating.

Attachment of fittings and accessories:—

(1) In other than conduit wiring, all ceiling-roses, wall-sockets, switches, regulators, brackets, pendants, and accessories attached to walls or ceiling shall be mounted on substantial teak wood blocks twice varnished after all fixing holes are made in them. Brass screws only to be used for attaching fittings and accessories to their base blocks.

(2) Unless otherwise specified in the Special Conditions of Contract all attachment blocks shall be spaced from the wall or ceiling by means of moisture-proof distance piece not less than $\frac{1}{8}$ of an inch think. The blocks must consist of a hollow base and a back cover.

CHAPTER VIII.

SYSTEMS OF WIRING.

The "Times of India" Engineering Supplement, dated the 16th September 1921, made the following *remarks with reference to the different systems of Electric Wiring* :—

"Owing to the number of different systems of wiring which have been put on the market in recent years, and the varied claims which have been made by the partisans of each, there is a good deal of confusion at the present time as to which is the best method to adopt when buildings have to be wired or re-wired. IN INDIA the question is one of special importance, as the CLIMATIC CONDITIONS MAKE THE LIFE OF AN INSTALLATION SHORT unless due care is taken, firstly, in the choice of system, secondly, in the quality of the materials employed and, thirdly, in the selection of a contractor to carry out the work. A few notes on the subject based upon actual experience may therefore not be out of place."

The specification is from the rules for wiring government Buildings. The remarks on each system, except the enamelled wiring system, have been taken from the above paper.

WOOD CASING SYSTEM.

1. **Material and pattern of casing.**—All casing shall be of teak or other approved hard wood, free from knots, shakes, sap or other defects and shall have a smooth finish. The casing shall have a grooved body with a simple reeded or plain moulded cover.

2. **Dimensions of casing and capping, etc.**—The scantling of casing and capping shall be to the satisfaction of the Engineer. The grooves shall be rounded and in no case shall the width of the fillet between the grooves be less than $\frac{1}{2}$ inch, or the thickness of the back under the grooves or capping over the grooves be less than $\frac{1}{4}$ inch. Dimensions of grooves shall be such that the wires will not require any force to put them in place. Where capping is attached to casing by screws at the sides, the thickness of the outer wall of the casing shall not be less than $\frac{3}{8}$ inch.

3. **Bunching of circuits.**—Wires of opposite polarity shall not be bunched, but wires of the same polarity may, with the permission of the Engineer, be bunched in accordance with I. E E. Wiring Rule.

4. **Attachment of casing to walls and ceiling.**—Ordinarily all casing shall be fixed, by means of screws, to plugs at intervals not exceeding 3 feet, arranged as provided for in clause 12. Unless otherwise specified in the Special Conditions of Contract, all casing shall be spaced from the walls or ceilings by means of moisture-

proof distance pieces not less than $\frac{1}{8}$ inch thick. All screws shall be so spaced as not to break the wall of the grooves. Casing shall not be buried in walls When it is ordered that casing shall be partially sunk in a chase, in a permanently dry wall, it must be painted externally with at least two coats of oil-paint, and be allowed to dry thoroughly before being fixed in position.

5. **Passing through floors.**—Where conductors pass through floors, the conductor shall be carried in an approved heavy gauge insulated conduit or tube. The floor tubes shall be carried 12 inches above floor line and an inch below ceiling line and neatly entered into the casing which shall, if required by the Engineer, be suitably protected at the floor line. Where the supply is alternating current the conductors of the circuit must be bunched in the tube.

6. **Joints in casing and capping.**—Casing and capping shall be run in lengths as long as possible. All joints shall be scarfed, or cut diagonally in longitudinal section. Capping shall be secured at the joint with two or more screws as may be necessary. Joints in capping must break joint with those in the casing.

7. **Conductors carried round moulding and angles.**—In order to avoid carrying casing round wood mouldings or beams, holes should, where practicable, be pierced through the same, provided that the piercing of such holes does not appreciably weaken the structure. A separate hole should be pierced for each

groove in the casing. Where casing forms an angle on a wall or ceiling the corners of the grooves must be properly rounded. In all other cases corner pieces with front grooving shall be used at all inside angles, where casing attached to a wall is united to casing attached to a ceiling.

8. **Casing to harmonize with decorations.**—When wiring is to be carried over ornamental work, with which it is required to harmonize, the design of any special casing which may be necessary shall be submitted to the Engineer for approval. Casing attached to the ceilings shall be carried completely across the ceiling whenever required by the Engineer, instead of being stopped at the fittings ; and in all cases where it is required by the Engineer, dummy casing must be used.

9. **Attachment of Capping.**—Capping shall be attached to casing by round-headed brass screws placed in each edge at intervals not exceeding 12 inches in all sizes of and above $1\frac{3}{4}$ inch in width, and along the centre in smaller sizes. In casing having more than two grooves, screws for fixing the capping. shall be placed in the fillets between the conductors as well as in the outer walls of the casing if so required by the Engineer.

10. **Painting and Varnishing.**—All casing and capping shall be served before erection, internally and on the back with two coats of varnish made up of

not less than 3 lbs. of pure shellack per gallon of spirit. In addition, all casing together with capping after erection shall be finished, painted or varnished, in such manner as may be ordered by the Engineer.

11. Inspection—Unless with the sanction of the Engineer, capping shall not be put on until the work has been inspected with the wires in position, and approved by the Engineer. This inspection will be done from time to time as the work progresses, on the application of the Contractor.

"In this system, which comes next to the Cleat System in point of age, the RUBBER INSULATED WIRES are run in wood casing having two grooves, wood capping of more or less ornamental design being fixed with screws over the casing after the wires have been inserted into the groves. The casing can be fixed on the surface of walls, etc., or embedded in the plaster, and in either case it is usually coated with an insulating varnish, such as Shellac, or preferably. "Ohmaline," before fixing. At first sight, it is a simple system, requiring little skill or supervision in its installation, beyond a certain amount of skill in carpentering, but actually this is not the case. The casing, as mentioned above, has two grooves and the intention of the originators of the system, in the early days of electricity, was obviously that the two grooves were for wires of opposite polarity. In actual practice, where installations are left to the MERCY OF IGNORANT MISTRIES, this fact is more often than not entirely lost sight of, and it is no uncommon thing to find a number of wires crowded into a groove quite irrespective of their polarities. If there is plenty of room for the wires to lie loosely in the groove, no trouble occurs as long as the rubber insulation remains good, but it is not effectively guarded against atmospheric conditions and there is always a lurking danger of trouble in the future.

It may, in fact, be definitely asserted that the majority of FIRES ATTRIBUTED TO "THE FUSING OF AN ELECTRIC WIRE" are caused by this crowding together of wires of opposite polarity in one groove of a HIGHLY INFLAMABLE VERNISHED WOOD CASING. More often than not the wires have been forced into the groove, thereby squeezing and damaging their insulation, and the writer has actually seen the bunch of wires being hammered with an iron hammer to force them sufficiently into the groove to enable the capping to be fixed. The casing system, therefore, contrary to general opinion, requires great care and considerable supervision in its installation. IT IS THE MOST FRUITFUL SOURCE OF FIRES DUE TO ELECTRICAL CAUSES. If properly installed, however, it makes a good job, but is UNSIGHTLY ON THE SURFACE, especially where a number of wires have to be run and large casing, or a number of lines of casing, have to be used. As regards cost, owing to the high price of teak,—the only suitable timber to use in India—THE COST OF THE SYSTEM IS CONSIDERABLY HIGHER than that of the Cleat System."

CONDUIT SYSTEM.

1. **Conduit to be continuous.**—Conduit shall be heavy gauge solid-drawn or lapwelded, of approved pattern and manufacture, and in accordance with the specification of the British Engineering Standards Committee. It shall be supplied with or without an insulating lining as may be specified in the Special Conditions of Contract. The conduit shall be electrically continuous from distribution board to outlet boxes for fittings, switches and other appliances. No conduit tube less than six-tenths inch in diameter, measured inside the metal tube or insulating lining shall be used.

2. **Bunching of wires.**—The wires of a circuit may be bunched together in a conduit and, if the supply is alternating current, they shall be bunched.

3. **Junctions in conduit** —The lenghts of conduit shall be joined by means of screwed sockets. Threads shall be free from grease or oil and no material of this nature shall be allowed to come in contact with the conductors. The greatest care shall be taken in preparing the conduit that no sharp edges or burrs are left which may damage the insulation. The Engineer, with a view to ensuring that the above proviso has been carried out, may require (if he should consider it necessary) that the separate lengths of conduit, etc., after they have been prepared, shall be submitted for inspection before being fixed.

4. **Precaution against insects and damp.**—In order to minimise condensation or sweating inside the tubes, all outlets of conduit systems shall be properly drained and ventilated but in such a manner as to prevent the entry of insects.

5. **Insulating lining of tubes.**—Where insulating conduit is to be used the lining shall be firmly secured to the tube and shall not be less than one-sixteenth inch in thickness. The insulating material must not soften injuriously at any temperature below 312° Fahrenheit and must be composed of such materials as will not have a deteriorating effect on the dielectric of the conductor; it must be sufficiently tough and tenacious to withstand the abrasion test of drawing in and out long lengths of conductor from a length of tube. All bends and fittings shall be made so that neither the conduit nor the lining of the same will be injured when drawing in wires.

6. **Protection of conduit against rust.**—The outer surfaces of conduits including all bends, unions, tees, junction boxes, etc., forming part of the conduit system shall be protected from rust by being galvanized or enamelled, or by two coats of iron oxide paint, applied before they are fixed. If so required by the Engineer, all conduits shall be painted after fixing, in such manner as may be directed.

7. **Fixing of conduit.**—The conduit shall be fixed to the surface of walls, secured to plugs, arranged as

in clause 12, by saddles and round-headed screws. No conduit shall be buried beneath the surface of masonry unless so specified in the Special Conditions of Contract or approved by the Engineer.

8. **Bends in conduit.**—The conduit shall be brought round angles of walls by means of bends or inspection elbows as may be directed. Angles on the face of the wall shall be arranged for by means of cast-iron inspection boxes, with suitable inlet and outlet sockets and screwed joints. Each box shall be provided with a cover, properly secured, by means of which access to the conductor may be obtained. The radius on the inner side of any bend shall not be less than 3 inches and no length of conduit shall have more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

9. **Outlets**—All outlets for fittings, switches, etc., shall be equipped with an approved let box.

10. **Conductors.**—All conductors used in conduit wiring shall be stranded.

11. **Erection and earthing of conduit.**—The whole system of conduit shall be erected and completed before the conductors are drawn in. The whole metal system of the conduit shall be electrically continuous throughout and shall be permanently and efficiently connected to earth in general conformity with approved methods, gas or water pipes must not be used to obtain an earth connection. Not less than the equivalent

(solid or stranded) of one No. 8-S. W. G. copper wire shall be used for making an earth connection. In a conduit system the pipe must be continuous when passing through walls or floors, and no other form of insulating or protecting tube is required.

CLEATED WIRING SYSTEM.

1. **Accessibility.**—All cleated wiring shall be run as far as practicable so as to be visible and accessible.

2. **Cleat.**—All cleats shall be of porcelain of approved design and must consist of two parts, a base piece and a cap. A special pattern of cleat should be used, if necessary, where conductors pass round corners, so that there may be no risk of the conductors touching the walls owing to sagging or stretching. Cleats shall be fixed at distances not greater than 3 feet apart and at regular intervals. There must be no apparent sag on the condutors.

3. **Fixing of cleats**.—(a) In ordinary cases, cleats shall be attached to plugs arranged as provided for.

(b) Where practicable the same method shall be adopted in the case of stone walls, but when, owing to irregular coursing or other reasons, it is impracticable to fix the cleats in a regular and workmanlike manner, a wood batten shall be provided and fixed with not less than one plug per 4 foot run. The batten shall be of teak or other suitable hard wood, $\frac{3}{4}$ inch thick, and

1 inch wider than the cleat used; it shall be chamfered on the edges, wrought all over and varnished with two coats of varnish (prepared as specified in clause), or painted, as may be ordered by the Engineer.

(c) Where reasons exist which prevent the use of either plugs or battens, cleats must be attached to the wall or ceiling in a manner approved by the Engineer.

4. **Distance apart of wires.**—(a) For pressures up to 250 volts cleats shall be of such dimensions that, in the case of branch leads, conductors shall not be less than 1 inch apart, centre to centre; in the case of submains, not less than 1½ inches apart, centre to centre; in the case of mains, not less than 2⅜ inches apart, centre to centre:

Provided that this sub clause shall not apply to twin conductors used with the approval of the Engineer.

(b) Where the pressure exceeds 250 volts cleated wiring shall only be used under such conditions as may be laid down by the Engineer in the Special Conditions of Contract.

5. **Crossing of Conductors.**—Where cleated conductors cross each other they may be either looped over to maintain the prescribed distance or fixed to an insulating bridging piece, which will rigidly maintain separation of at least ½ inch between the poles. If the point of crossing be within 10 feet of the ground or floor level, an insulating bridging piece must be used.

Provided that this clause shall not apply to twin conductors used with the approval of the Engineer.

6. **Protection near floors.**—No cleat wiring shall be left unprotected within 5 feet of a floor. When brought through the floor it shall be enclosed in conduit in the manner specified in clause.

" In this, the simplest and cheapest system, RUBBER INSULATED AND BRAIDED WIRES are supported on porcelain insulators fixed at intervals of a foot or so upon walls, ceilings, etc. Owing to UNSIGHTLINESS this system can only be used where appearances may be entirely neglected, whilst, the wires being quite unprotected from atmospheric conditions, their RUBBER INSULATION QUICKLY PERISHES SPECIALLY IN INDIA, where the conditions are so severe. From an electrical standpoint this does not matter to any great extent, as long as the insulators remain dry and clean, but IN DAPM CLIMATES SUCH AS THOSE OF BOMBAY AND CALCUTTA ESPECIALLY DURING THE MONSOON, LEAKAGE OCCURS WHEN THE RUBBER INSULATION BECOMES DEFECTIVE. The system, on the whole, can only be looked upon as a make-shift–an easy method of running wires from point to point, regardless of any considerations beyond ease and cheapness of installation. It requires little or no skill to install it and therefore lends itself to SHODDY WORK. If care is taken, and wires made by a reputable manufacturer are used, however, the system is useful under certain conditions."

METAL SHEATHED WIRING SYSTEM.

1. **Plain or Braided wire**—Plain or braided metal sheathed wiring shall be used according to which is specified in the Special Conditions of Contract.

2. **Attachment to walls and ceilings**—All conductors shall be supported on walls and ceilings at intervals not exceeding 9 inches horizontally and 1 foot vertically, and special clips, fixed by screws or suitable pins to the plugs, shall be used for their attachment The heads of such screws or pins shall be set level with the surface of the clips, so as not to injure the metal sheathing, The clips shall be of such character as not to lead to corrosion or electrolytic action, from contact. Saddles may only be used if specified in the Special Conditions of Contract, No bend shall have a radius of less than 3 inches.

3. **Plugs.**—Wooden plugs used for metal sheathed wiring under the above conditions shall not be less than $1\frac{1}{2}$ inches long, and $\frac{1}{4}$ inch in diameter on the outer end. With the Engineer's permission, Rawl or other special plugs may be used. In other respects clause 12 shall apply.

4. **Wiring on Rolled Steel Joists.**—Where wiring is to be carried along the face of rolled-steel joists a wooden backing, preferably the full width of the joist, shall first be laid on the joist, and clipped to it as inconspicuously as possible. The wiring shall be fixed to this backing in the ordinary way.

5. **Spacing off walls.**—Unless otherwise stated in the Special Conditions of Contract all metal-sheathed wiring run on plastered walls shall be spaced $\frac{1}{8}$ inch off the plaster.

6. **Joints.**—Joints shall be made by means of connections of porcelain, or other approved material, enclosed in joint boxes approved by the Engineer. The joint boxes shall be so constructed as to prevent insects entering them, and to allow of the whitewashing of the walls without water having access to the connectors. All wires shall be bored through or across these boxes Bonding connections shall be so arranged as not to come in contact with plaster.

7. **Stripping of Insulation**—(a) When V.I.R. insulation has to be stripped for joints, etc., the metal sheathing must be nicked only, not cut, and the insulation between the metal sheath and the conductor shall be of rubber only. All tape shall be stripped off.

(b) Where paper insulated, metal-sheathed cable is used all openings in the same shall be efficiently sealed.

8. **Protection of wiring.**—(a) When so required by the Special Conditions of Contract, metal-sheathed wiring must be covered with a sheet metal protective covering, to protect it from damage, and the base of the protective covering shall be flush with the plaster or brickwork, as the case may be.

(b) Such protective covering shall in all cases be fitted on all down drops within such distance from the floor as may be specified in the Special Conditions of Contract.

9. **Passing through floors.**—All wires taken through floors shall be enclosed in an insulated heavy gauge steel conduit, extending 6 inches above the floor and flush with the ceiling below, or protected in such other manner as the Engineer shall approve. The ends of all conduits or pipes shall be neatly bushed with porcelain, wood or other approved material

10. **Passing through walls.**—The method to be adopted shall be either that laid down in clause 11 (1) (a) or shall be similar to that in clause 9 the conduit to extend 1 inch beyond the wall on either side, if the wire is taken through the wall straight; and to be flush with the wall if the course of the wire is at right angles to the wall.

11. **Buried wires.**—Metal sheathed wire shall in no case be buried directly in plaster.

12. **Metal sheathing to be bonded and earthed.**—All metal sheathing shall be well bonded throughout the whole of its length and efficiently connected with earth and shall pass the test specified in clause 15 The earthing shall extend to the metal frames of all main and branch switch and distribution boards.

13. **Earth wire and plates.**—(a) The earthing wire and the connection with earth shall be of the same

metal, whether iron or copper, and shall be so constructed and laid as to avoid the formation of any electrolytic couple.

(b) The size of the earthing wire shall be not less than No. 8 S. W. G., or equivalent stranded cable.

(c) Copper earthing wires, where underground, shall be insulated, and all earthing wires shall be protected in the manner laid down in the Special Conditions of Contract.

(d) The connection with earth shall have a total contact area not less than is specified in the Special Conditions of Contract. It shall be buried to a depth of not less than 6 feet below ground and shall not be less than 6 feet from any building.

14. **Painting.**—All metal-sheathed wiring, or the protective covering of the same, when fitted, shall be neatly painted, after erection, with two coats of zinc paint, to the satisfaction of the Engineer.

15. **Testing.**—Every circuit of metal sheathing shall be tested to earth by the contractor with a pressure not exceeding 4 volts, which shall ring a bell requiring not less than half an ampere to actuate it. Alternatively a low reading ammeter may be used.

METAL SHEATHED SYSTEMS.

"To get over some of the disadvantages of the older methods of wiring buildings, some of the leading firms of electric Wire and Cable Manufacturers have devised systems of their own from time to time, most of these systems embodying *the use of metal sheathing* to protect the insulating material of the wires from atmospheric conditions, in place of the cotton or jute braiding over the rubber as used in the Cleat and Casing Systems. One of the earliest of these systems was the "Stannos" System, brought out by Messrs. Siemens Bros. and Co., Ltd. In this system the wires are single as distinguished from some later twin wire systems, the metal sheathing is of tinned copper and the *wires are therefore expensive and somewhat difficult to install* owing to their stiffness, whilst *soldered joints are required at all joint boxes etc.*, to ensure continuity of the metallic sheathing. For these reasons, mainly, the system has not been used to any large extent in India.

Another early system was that of the British Insulated and Helsby Cables Ltd., who used twin semi-circular conductors, insulated with impregnated paper made up circular, and sheathed with lead. The difficulty with this system was that owing to the use of paper, which ABSORBS MOISTURE READILY, GREAT CARE WAS REQUIRED IN SEALING THE ENDS OF ALL THE WIRES AT JOINT-BOXES, SWITCHES, ETC. and this system also has not been used in India, as far as the writer is aware"

THE TWIN WIRING SYSTEM.

"About ten years ago, Messrs. Henley's Telegraph Works Co., Ltd. introduced their patent Twin Wiring

System into India, and the success of this system has certainly been phenomenal, as is indicated by the long list of important buildings already wired on their system in India which the firm have issued. The two wires of a circuit are in this System, laid side by side after the insulation, WHICH IS OF PURE AND VULCANIZED INDIA RUBBERS, has been supplied and then sheathed with a special alloy which appears to contain a considerable proportion of lead, but which the makers claim is harder and tougher than lead, being therefore less liable to mechanical damage. At the same time it appears to be perfectly pliable and the wires can be very easly run round cornices, etc., without appearing obstrusive.

Critics of the Henley System suggest trouble owing to IMPROPER BONDING and EARTHING OF THE METALLIC SHEATHING, and the writer knows of a few cases of trouble having been experienced due to this cause, but such trouble is always due to faulty installation and WANT OF PROPER SUPERVISION when the work is in progress, and the remedy is to employ GOOD AND RELIABLE CONTRACTORS FOR the work. The same applies to all systems, as electric WIRING IS OBVIOUSLY SKILLED WORK and should be treated as such, and in this connection reference should be made to the remarks in connection with the Casing System above. If properly installed a metal-sheathed system is essentially the best for use in India, if only because the RUBBER INSULATION IS PROTECTED BY

THE SHEATHING FROM THE DELETERIOUS EFFECTS OF THE ATMOSPHERE AND WILL THEREFORE LAST FOR AN INDEFINITE PERIOD. AS REGARDS COST, it compares very favourably with the Casing System, the tenders of contractors being usually less for the Henley Wiring System.

The undoubted success of the "Henley" System has led the other leading cable manufacturers to introduce generally similar systems of their own, but they differ only in small details from the Henley System, further reference to them is unnecessary here."

THE "CAB-TYRE SHEATHED" SYSTEM.

"Cab Tyre Sheathed" Wires and Cables were introduced some few years ago by the St. Helens Cable Co., Ltd.. and have been very much advertised as being suitable for use for all and every purpose, and under all sorts of conditions. Their use for house-wiring purposes is of more recent date, but they are now being pushed for this purpose and not only by the orginal manufacturers. In these cables the protective sheathing instead of being of metal, is of a HARD RUBBER COMPOSITION, as use of tyres. At first sight this appears to be a very good protection, as it is hard and flexible it is a partial insulator but not a good one and will stand a lot of knocking about. A point, however, which its champions overlook is the fact that it possesses these characteristics only when it is new or comparatively new.

It should be obvious that NO RUBBER COMPOSITION WILL STAND THE INDIAN CLIMATE FOR LONG, and one has only to consider the condition of motor tyres if left standing for a year or two exposed to the atmosphere, to realise this, THE TROUBLE WILL COME WITH THE ADVENT OF THE MONSOON, after the wires have been installed for a few years, and a word of warning, therefore really appears to be necessary. It is not suggested that "Cab-Tyre Sheathed" Cables are of no use for any purpose, as they certainly have their uses, and for certain purposes, with which this article is not concerned, this type of sheathing is probably the best that has been devised—but not for house-wiring of a permanent nature.

Note.—In the above article all reference to the CONDUIT SYSTEM has been omitted, probably because it is not used very largely in India OWING TO ITS EXPENSE, the condensation troubles to which it is liable and to the facilities which it provides for the harbouring of insects."

THE ENAMELLED WIRING SYSTEM.

A perusal of the above statement clearly shows the defects of the various systems of wiring with reference to their comparative (1) RELIABILITY, (2) LIFE–the climatic conditions making the life of the Installation short, (3) ECONOMY, (4) SOURCES OF TROUBLE (5) Unsightly appearance and (6) Unsuitability to stand exposed to atmosphere e.g. where it is exposed to moisture, rain, etc. The defect is fundamentally DUE TO THE RUBBER INSULATION which more or less quickly perishes owing to the climatic conditions. All the systems of wiring so far invented—the Cleat, the Casing, the Metal Sheathed, the Twin Wiring and the Cab-tyre Sheathed Systems— depend for their insulation on this rubber coating.

The Twin Wiring System which is pointed out to be the best is also unfortunately not free from the defect of rubber insulation, because when the wire is taken out of the metal sheath at all joints and ends of points, the rubber insulation is exposed to all "the effects of climatic condition," and that no "rubber composition will stand the Indian climate for long."

Further, the Twin Wiring System is (1) more costly than Wood Casing System and (2) very seriously damaged by the exposure to moisture, as a consequence, this system is altogether unsatisfactory in moist places and during the rainy season. As the "ignorant mistries" of India cannot carry out the casing work to the satisfaction of an expert, it is too much to expect from them a proper execution of all (*a*) the bonding, (*b*) earthing and (*c*) the careful handling and protecting of the rubber insulation when the wire is taken out of the metal sheath in the Twin Wiring System. In this system of Messrs. Henley & Co. the bare wire when it comes out from the rubber insulation, is almost always in electric contact with the metal sheathing which is so near to it, in moist atmosphere. This is aggravated by the rubber coating having hygroscopic properties to a certain extent. Very often a leakage current is at work to corrode out the metal sheathing and finally to affect the rubber insulation of the wiring.

Thus the whole of the interior wiring installed according to any system including the Twin Wiring System, used so far, must be changed entirely after a few years' use. This causes very severe loss to the public.

All the prevailing systems in use up to the present time require expert hands to detect the faults. This means money and annoyance to the uninitiated public.

TO REMEDY THESE DEFECTS of the different systems of interior wiring the author has devised and experimented upon the "ENAMELLED SYSTEM OF WIRING" which has none of the above defects.

Thus :—

(1) The Enamelled System of Wiring has no rubber insulation which deteriorates in time or which is affected by climatic conditions.

(2) It has no "*highly inflamable varnished wood casing*" to be "*the most fruitful source of fire* due to electrical contact."

(3) It DOES NOT DAMAGE THE WALLS by having so many plugs at "a distance of 9 inches or a foot."

(4) IT HAS NO "LEAKAGE" to occur when the rubber insulation is defective as it has no rubber insulation.

It is thoroughly protected by enamel and suitable porcelain insulators mounted on varnished wood.

(5) It has no "improper bonding and earthing of the metallic sheathing" which requires good and reliable contractors to treat the wiring as "obviously skilled work."

(6) It is the only system which may be used equally well inside or outside a building as it is altogether unaffected by climatic conditions such as rain and the extremes of temperature. This point is exceedingly important.

(7) It is absolutely free from the attack of vermins.

(8) It causes a great saving of copper, for the safe current carrying capacity of the conductors, which are exposed to atmosphere is much greater than that of rubber coated wires.

Thus the Enamelled System of Wiring has:—(*a*) INDEFINITELY LONG LIFE, (*b*) ECONOMY, (*c*) EASE OF INSPECTION, and (*d*) appearance, absolutly in its favour, (*e*) It can be used in moist and exposed places (f) It is entirely free from attack of insects e. g., white ants.

The system is thoroughly protected by proper insulators and fuses, Enamelled insulation it may be remarked, is very successfully used for manufacturing the field coils for dynamos and motors working at a much higher voltage than that used for interior wiring.

In the Enamelled System of Wiring the investment is practically on the copper-wire, the intrinsic value of which cannot depreciate, whereas in any other system much larger sum is required for the composite or rubber insulation which has doubtfully lasting insulating property and which loses all its value after a few years' use.

APPENDIX

SPECIAL TRADE PRICE LIST, MARCH, 1928.

Adaptors Standard size 1 way English at Rs. 5-4-0. German best quality at Rs. 2-3-0; miniature D. C. Cocus at Rs. 2-4-0; S. C. at Rs. 2-8-0 per doz. with China head at Rs. 1-8-0 per doz D C. Parallel Holder Adaptor Cocus wood with plugs and one holder English at Rs. 16-8-0; per doz.

Alabaster (real marble) bowl shades for indirect lighting. Prices ranging from 25/- to 75/- aocording to to sizes and qualities, sizes 13¾ in. to 19¾ in; Plain and Decorated. Chains and ceiling plates, for small size 4-8, large 6-0 each.

Batteries Leclanche complete English but without salamoniac No. 1 at Rs. 24-0-0; No. 2 at Rs. 16-8-0 per doz. Spare Porous pots No. 2 English at Rs 7-4-0; No. 1 at Rs. 10-8-0; glass jars No. 2 English at Rs. 6-12-0; No 1 at Rs. 12-0-0 per doz. Zinc Rod English No. 1 at Rs. 3-6-0; No. 2 at Rs. 2-2-0 per doz. Salamoniac Voltoid at Rs. 37-8-0 per cwt. and in pound at Re. 0-6-0 per lb.

Ball Fittings German good quality 2 lights at Rs. 6-12-0; 3 lights at Rs. 7-8-0; 4 lights at Rs. 9-0-0; 5 Lights at Rs. 12-0-0 per doz. Spider fitting

3 lights at Rs. 18-0-0 ; 4 lights at Rs. 19-8-0 ; 5 lights at Rs. 21-0-0 per doz.

Bells. In teak cases 3 in. superior at Rs.16-8-0 per doz. 220 Volt Bell best quality A. C. and D.C. 3 in. flat steel gong at Rs 2-8-0 each. Bell Transformer A. C. or D. C. 3 to 5 Volts at Rs. 4-8-0 each ; Bell Pushes English 2½ in. at Rs. 6-0-0 ; 2″ at Rs. 4-8-0. Pear shape English at Rs. 6-0-0. 220 and 110 volt Mining Type Bell 6″ Gong at Rs. 22-8-0 each. Brass Switch Type for 220 volt English at Rs. 11-4-0 ; German at Rs. 6-12-0 per doz.

Bell Wires. English D. C. C. 1/20 at Rs. 2-4-0 ; 1/22 at Rs. 2-2-0 per coil of 100 yards.

Bracket Fancy real cut glass crystal 1 Light with Shades and Holders Nos. 560 & 515 at Rs 18-0 0 ; No. 561 at Rs. 15-12 0 ; 2 Light No. 587 at Rs 3-0-0 each.

Brackets. P. B. Japanese plain ½ in. tube good quality ; 9 in at Rs. 3-12-0 ; 12in. at Rs. 4-8-0 per doz. German with Nurl Heavy Pattern 9 in. at Rs. 5-8-0 per English with nipple Latest Improved 6 in. at Rs 5-6-0 ; 9 in. at Rs. 5-12-0 ; 12 in. at Rs. 6-2-0 ; 9 in. × 5/8 in. Heavy Pattern at Rs. 15-0-0 per doz. Fancy 1 light English very nice design Brass and Bronze from Rs. 1-14-0 to Rs. 8-4-0 each. Fancy 2 light Bronze English at Rs. 9-0-0 to Rs. 13-0-0 each.

Blocks and Boards. Teakwood. 4 in. × 1 in. round at Re. 0-11-0; 5 in. at Rs. 1-4-0; 6 in. at Rs 2-5-0; 7 in. × 4 in. at Re. 1-0-0 per doz. Recessed 4 in. × 1 in. round at Re. 0-14-0, 7 in. × 4 in. at Rs. 1-2-0; 8 in. × 8 in. at Rs. 4-4-0; 8 in. × 10 in. at Rs. 4-10-0; 8 in. × 12 in at Rs. 5-12-0; 10 in. × 12 in. at Rs. 6-12-0; 10 in. × 18 in. at Rs. 9-0-0 per doz. Fancy board for two switches and regulator at Rs 10-8; wooden pins ordinary Re 0-7-0 per 100. Government specification at Rs. 3-12-0 per gross.

Iron Screws Flat Head English Nettle Fold ½ in. × 4 at Re. 0-4-0; ¾ in. × 5 at Re. 0-5-3; 1 in. × 6 at Re. 0-6-9; 1 in. × 7 at Re. 0-7-0; 1¼ in. × 7 at Re. 0-8-3; 1¼ in. × 8 at Re. 0-9-3; 2 in. × 10 at Re. 0-14-0 and 2½ in. × 10 at Rs. 1-2-0 per gross.

Brass Screw. Nettle-fold round head ⅝ in. 4 No. English at Rs. 1-10-0 per gross.

Carriers for Table Lamps P. B. Double arm tilting shade carrier good quality at Rs. 7-8-0 per doz.

Casings and Capping's. Burmah teakwood 6 ft. and up good quality 1¼ in. × ½ at Rs. 4-6-0; 1¼ in. at Rs. 5-3-0; 2 in. at Rs 5-10-0; Government specification 1⅞ in. Casing and Capping ¼ in. at Rs. 7-8-0. 1¾ × 5/8 and 2 × 5/8 at Rs. 7-0-0. Teakwood corner of any size at Rs. 1-8-0 per doz.

Ceiling Roses H. V. 2 loops English cream Vitrous at Rs. 3-10-0 per doz.: German cream good quality

Heavy at Rs. 2-0-0; ordinary at Rs. 1-14-0; 3 Loops at Rs. 3-0-0 per doz. Japanese white at Rs. 1-1-0 per doz. In Gross Lot at Rs. 12-0-0 per gross.

Cut Outs 5 Amp. round English Vitrous at Rs.3 10: German cream superior at Rs. 2-0-0; Japanese cream superior at Rs. 1-2; In Gross Lot at Rs. 2-12 per Gross. Joint cut-outs small at Rs. 1-2-0 per doz. 10 Amp. round cream at Rs. 3-0-0 per doz. Oblong cream 5 Amp. at Rs. 2-12-0; 10 Amp. at Rs. 5-10-0 per doz.; English 5 Amp. at Rs. 5-4-0; 10 Amp. at Rs. 6-0-0 per doz. 20 amp. at Rs. 9-12-0 per doz.

Counter weights with ring pulley cream good quality at Rs. 4-2-0 per doz.

Cleats Porcelain for 2 wires $1\frac{5}{8}$ in. at Rs. 1-2-0; German or Pottery at Rs. 1-5-0; 2 in. at Rs. 2-12-0; $2\frac{1}{2}$ in. at Rs. 4-4-0; 4 in. at Rs. 12-0-0 per gross pairs. For 3 wire $1\frac{3}{4}$ in. at Rs. 2-4-0; $2\frac{1}{2}$ in. at Rs. 8-4-0: 4 in. at Rs. 12-0-0 per gross pairs.

Perfecta English Plain Conduits close joint $\frac{1}{2}$ in. @ 5, $\frac{3}{4}$ in. @ 7-14 %, R. ft. Sockets $\frac{1}{2}$ in. @ 1, $\frac{3}{4}$ in 1-6, Elbows $\frac{1}{2}$ in. @ 1-8. $\frac{3}{4}$ in. @ 2-4, Bends $\frac{1}{2}$ in. @ 2-6, $\frac{3}{4}$ in. @ 3-0, Tees $\frac{1}{2}$ in. @ 3-0, $\frac{3}{4}$ in. @ 3-12 doz.

Distribution fuse Boards in teak boxes Highly polished with glass front English Channel type for 3—12 way S. P. and D. P. at Re. 0-10-0 per S. P. way; for 2 way S. P. and D. P. at Re. 0-11-0 S. P. way.

Interior only from 1—12 way complete with bus-bars and terminals but without teak boxes at Re. 0 9-0 per S. P. way ; 1 way fuses English complete at Rs. 5-12-0 per doz. Japanese Fuses 2, 3, 4, 6 way Interior only at Re. 0-7-0 with Box at Re, 0-8-0 per S. P. way,

Electroliers Brass and Bronze fancy 3 lts. at Rs. 19-8-0 ; 4 Light at Rs. 27-0-0 each.

Ceiling Fans D. C. 220/225 Volt 4 Wooden Bladed in Black and Gold complete with Blade Rod Canopy and Hanger Dayton Midget 48 in. Sweep at Rs. 56-0-0 Selco 57 in. sweep with 4 wooden blade black at Rs. 72-8-0 ; Skidoo 57 in. Sweep at Rs. 70-0-0 each Nett.

Ceiling Fans each British made 220 volts 60 inch sweep with 4 wooden blade at Rs. 75-0-0.

Ceiling Fan Met-Vick British D. C. 220 or 110 volts 54 in. sweep with 3 metal blade down rod, Canopy and Insulator white at Rs. 95-0-0 ; A. C. White at Rs. 97-8 0 each.

Ceiling Fan G, E. American 220 volt. D. C. white complete with 3 aluminium Bladed 48 in. sweep at Rs. 82-8-0 each.

Ceiling Fan Osler Lundell "Senior" 225 volts D. C. with three aluminium blades finished in white and gold, complete with down rod and canopy at Rs. 106-4-0 each. JUNIOR type 225 volts D. C.

with three aluminium blades white and gold finished at Rs. 84 each.

Ceiling Fan Osler " Maestralino " 220 volts 50 Cycles A. C. with 3 aluminium blades white finish complete with Regulator at Rs. 105 ; " Maestrale " at Rs. 115 each.

Fans Ceiling D. C. 220 & 225 volts Revo British made with 3 aluminium blades black finish 54 in. sweep at Rs. 85 each.

Fans Ceiling A. C. 220 & 22; volts Revo British made 50 cycles single phase with 3 aluminium blades black finish 54 in. at Rs. 97-8-0 ; 36 in. at Rs. 85 each.

Marelli's Ceiling Fan 220 or 110 volts D. C. fitted with three curved aluminium blades white or black super-export 83 in. at Rs. 117 ; 60 in. at Rs. 105-8-0 ; export-senior 56 in. at Rs. 95 ; 54 in. at Rs. 83 ; export-junior 48 in. at Rs. 65 ; export-minor 36 in. at Rs. 51 each. Less 2½% discount.

Marelli's Ceilling Fan 220 or 110 volts A. C. Single phase frequency 50 and 60 cycles fitted with 3 curved aluminium blades white and black complete with down rod and suitable speed regulator " Maestralino senior " 63 in. at Rs. 115 ; " Masstralino " 60 in. at Rs. 107 ; Maestralinojunior at Rs. 78 ; Maestralino minor at Rs. 72 each.

Fans Ceiling D. C 220 & 225 volts Verity's Raisian with 3 aluminium blades black finish 48 in. sweep at Rs. 75 each.

Siemens Schuckert Ceiling Fan G. M. D. 56 in. sweep 220 volts D. C. complete with 3 aluminium blades, Down Rod and Canopy White body at Rs. 69-6-0; Black body at Rs. 64-12-0 each.

Siemens Schuckert Ceiling Fan 25 in. sweep 220 volts D. C. complete with 3 aluminium blades, Down Rod and Canopy White body at Rs. 50-14-0 each

Siemens Schuckert Ceiling Fan MED 73/24, 56 in. sweep 220 volts A. C. 60 cycles complete with 3 aluminium blades, Down Rod and Canopy White body at Rs. 111; Black body at Rs. 106-6; 33/24 White 52 in. at Rs. 89-12 each.

Siemens Schuckert Ceiling Fan MED. 73/24, 56 in. sweep 220 volts A. C. 50 cycles complete with 3 aluminium blades, Down Rod and Canopy White body at Rs. 101-12-0; Black body at Rs. 97-2-0, 71/24 White at Rs. 92-8-0; Black at Rs. 89-12-0 each.

Siemens Schuckert Ceiling Fan 33/24 52 in. sweep A. C. 220 volts 50 cycles complete with 3 aluminium blades White body at Rs. 80-8-0; Black at Rs. 77-11-0; 48 in. sweep White at Rs. 75-14-0 : 48 in. sweep Black at Rs. 74; 31/24 48 in. sweep White at Rs. 75-14-0 each.

Siemens Schuckerts Ceiling Fan 220 volt 50 cycle D. C. black 56 in. sweep complete with down rod blades regulator at Rs. 75 each.

Fans-Ceiling country made with 4 wooden blade 48 in. sweep clyde at Rs 47-8-0 each. White Body with 3 aluminium blades at Rs. 54 each; Osler type at Rs. 75 each.

Fans-Table D. C. Osler or Revo British made latest improved pattern complete with brass blades guards 220 volts 16 in. fixed at Rs. 47-8-0; Oscillating at Rs. 67-8-0 each. 12 in. fixed at Rs. 50 each.

Marelli's Table Fan Italian Swivel and Trunnion Table or Wall bracket type fans black complete with four brass blades and guardes and 3 speed off regulators incorporated in the base 220 or 110 volts A. C. Single phase 50 and 60 cycles. 10 in. Universal "Yankee" fixed at Rs. 22-8-0; 10 in. Oscillating Delio at Rs. 32-8-0 Nimbo 12 in. fixed at Rs. 37-8-0; Bisa 12 in. Oscillating at Rs. 40; Noto 14 in. fixed at Rs. 42; Bisa 14 in. Oscillating at Rs. 45; 46 in. fixed Pompero at Rs. 47-8-0: Ghibli 16 in. Oscillating at Rs. 62-8-0 each.

Marelli's Table Fan Italian Swivel and Trunion Table or Wall bracket type fans black complete with four brass blades and guards and 3 speed off regulator incorporated in the base 220 or 110 volts D. C. 10 in. Universal Yankee fixed at Rs. 22-8-0; Delio 10 in. Oscillatiug at Rs. 32-8-0; Nimbo 12 in. fixed type at Rs. 30-0-0; Bisa 12 in. Oscillating at Rs. 40-0-0;

Nimbo 14 in. fixed at Rs. 33-0-0 ; Verno 14 in. Oscillating at Rs. 42-0-0 ; Pompero 16 in. fixed at Rs.41-0-0 Ghibli 16 in. Oscillating Rs. 51-0-0 each.

Fans-Table by Siemens Schuckert D. C. 220 volts with nickle blades and guards fixed type black finish with regulators 14 in. at Rs. 29-0-0 ; 16 in. fixed at Rs. 40-12-0 ; Oscillating 14 in. at Rs. 37-15 0 ; 16 in. at Rs. 51-13 0 each.

Fans-Table by Seimens Schuckert A. C. 220 volts single phase 50 cycles fixed type 14 in. at Rs. 34 4-0 ; 16 in. at Rs. 44-6-0 ; each ; Oscillating 14 in. at Rs. 41-10-0 ; 16 in Oscillating at Rs. 49-15-0 each.

Fans-Table A. E. G. 220 volts D. C. or A. C. Universal type with 4 blades and guard 12 in. at Rs. 24-0-0 ; 16 in. Oscillating at Rs. 45-0 0 each.

Fans-Table Westing House Railway coach 24 9 in. at Rs. 25-0-0 and 12 in. at Rs. 27 each.

Fan Regulator D. C. 225 Volts, Veritys Aston covered type, black at Rs. 8-4-0 each, Armour covered type, New Improved Pattern, Bakelite Cover, at Rs 8-8-0 each. G. E. Fan Regulators at Rs. 7-0-0 each. Donovan Cornwallis Tropical, at Rs. 6-0-0 each. Fan Regulators A. C. Revo, British made 220 volts at Rs. 15-0-0; Leach A. C. British at Rs. 10-8-0 each.

Seimens Schuckert Fan Regulator 220 volts D. C. type A, 112, 1 at Rs. 7-6-0 ; A. 117 W 1 at Rs. 12-15-0 each.

Siemens Sehuckert Fan Regulator 220 volts A. C. Type A. 113 13 step at Rs. 8-1; Type A. 115 15 step at Rs. 13-4; Type A. 117 W. 1 at Rs. 13-14-0; Type 117 W. A. at Rs. 13-14 each.

Fan Carbons best Morganite quality from English carbon block 1½ in. × $\frac{5}{16}$ in. round square at Rs. 1 per doz. in lot of 5 gross at Rs. 10-8 per gross Ebonite Caps for any Fan at Rs. 3-12; Lubricator at Rs. 18 per doz. Spare Shanke for any Fan at Rs. 13-8 per doz

Lamp Holder P. B. British made heavy pattern good quality with shade carrier pendent at Rs. 3-12 Bracket ½ or 5/8 in. at Rs. 3-10, Batten at Rs. 4-2 per doz. Shell reflector for 50 C. P. nickled deep at Rs. 12-12 per doz. Brass Galleries for cut glass shade at Rs. 6-12-8 per dozen. Dimalite holder 220 volt 40 and 60 watt at Rs. 4-4 each.

Lamp Holder P. B. German best quality Heavy Pattern pendant S. C and C. G. at Rs. 2-10. ½ in. at Rs. 2-10. Batten at Rs. 2-14 Key Holder Bracket or Pendent Best quality at Rs. 6-12. Goliath holder ½ in. or 5/8 in. at Rs. 9 Edison screw Holder ½ in. and 5/8 at Rs. 5-4 per dozon.

Lamp Holders P. B. Japanese superior with solid ring and free interior terminals English type pendant S. C. C. G. at Rs. 2-2; ½ bracket S. C. Rs. 2-1; $\frac{5}{8}$ or $\frac{2}{8}$ in. at Rs. 2-6 batten with S. C. at Rs. 2-2 Key holder bracket or pendant with shade carrier best quality at Rs. 5-10 ; miniature batten at Rs. 3 ; pendant at Rs. 2-12 ; bracket $\frac{1}{8}$ in. at Rs. 2-12 per doz.

Insulated Eye Hook $1\frac{1}{2}$ and 2 in English at Rs. 1-12 per doz.

Hand Lamps With wire Guard and well glass Brass with holder superior quality at Rs. 3-12 each Ordinary at Rs. 2-4 each.

Heating and Cooking Appliances Electric Iron Germans 5 lbs. good quality at Rs. 6-8 each ; English Best quality at Rs 11-4 each. Electric kettle copper finish insulated handle best English make 225 Volts 3 pint ordinary at Rs. 15-12 each Electric Sold ring Iron at Rs. 15-12 each Immerson Heater at Rs. 5-4

Insulators spacing Disc 1 in. × $\frac{1}{4}$ in. at Re. 0-9 per gross ; 1 in. × $\frac{1}{2}$ in. at Rs. 2-4 ; Wheel type at Rs. 2-4 per gross ; Bobbin 1 in. × 1 in. at Rs. 3 ; $1\frac{1}{2} \times 1\frac{1}{2}$ at Rs. 6-12 per gross. Reel Insulators $\frac{5}{8}$ in. $\frac{8}{8}$ in. at Rs. 2 : $\frac{1}{8}$ in. × $\frac{5}{8}$ in. at Rs. 6 per gross. Shackle complete with thick straps, bolts and nuts ; 2 in. × $2\frac{1}{2}$ in. at Rs. 3 ; 3in × $3\frac{1}{2}$ in. at Rs. 4 : $4\frac{1}{2}$ in. × $3\frac{1}{4}$ in. at Rs. 9 per doz. Insulators only 2 in. × $2\frac{1}{2}$ in. at Rs. 1-12 ; 3 in. × $3\frac{1}{2}$ in. at Rs. 2-12 per doz. Sinclair 4 in. × $2\frac{1}{2}$ in. complete with $\frac{5}{8}$ in. galvd. bolts at Rs. 3-12 ; Insulators only at Rs. 2-4 Spare $\frac{5}{8}$ galvd. iron bolts and nuts at Rs. 2-6 per doz. Swan Neck 2 in. × $2\frac{1}{2}$ in. with G. I. Bracket at Rs. 1-6 per doz. Cordeaux size $4\frac{1}{2}$ in. × 3 in. with $\frac{5}{8}$ in. iron bolt and nuts at Rs. 5 per doz.

Insulating Materials English Red fibre sheet 72 in. × 42 in. 1/64 in. 1/32 in. 1/16 in. $\frac{1}{8}$ in. $\frac{1}{4}$ in at Re. 1 per ℔. Red fibre rod $\frac{1}{2}$ in at Rs. 5-4 ; Ebonite Sheet and Rod of any size at Rs. 2-12 per ℔. Empire Cloth 10 miles at Rs. 1-1 per yard. Leatheroid 10 mils and 20 mils thick at Rs. 1-5-6 per ℔. Pressphan sheets 32 in. × 24 in. 1/100 at Re. 0-7 ; 1/64 at Re. 0-9 ; 1/32 in. at Rs. 1-2 ; 1/16 in. at Rs. 1-8 ; 1/8 at Rs 1-12 per sheet. Cotton Tubing at Rs.. 5.

Insulating Tapes, Egyptian cotton tape English superfine, $\frac{1}{2}$ in. at Rs. 1-14 ; $\frac{3}{4}$ in. at Rs. 2-6 ; 1 in. at Rs. 3 per gross yards. Pure rubber tape Henley's English $\frac{1}{2}$ in $\frac{3}{4}$ in. at Rs. 3-2 per lb. Empirs Tape British $\frac{1}{2}$ in. at Rs. 3-12 ; $\frac{3}{4}$ in. at Rs. 3-7 , 1 in. at Rs. 5-4 per gross yard. Black sticky tape $\frac{1}{2}$ in. $\frac{3}{4}$ in, 1 in. Henley's English best quality at Rs. 2 9 ; Japan Toma Best quality $\frac{1}{2}$ in. and $\frac{3}{4}$ in. and 1 in. Rs 0 9 per lb, Chatterton Compound at Rs. 2 5 per lb.

Semi-Indiret Fittings with 14 in. bowl and 3 chains claws at Rs. 21 each. Luzzet Semi Direct Fitting complete suitable for 200 watt Lamp at Rs. 11 each. Big size at Rs. 15 each. Drop Shaped Fitting with opalesent Globe very nice looking at Rs. 12 each.

Drawn Wire Metal Filament Lamps B C. Clear :—

Hollanel make Arax Lamp 220 and 110 volt 10, 16, 25, 32 and 50 C. P. at Rs. 6-12. Spiral small Round shape B. C. 220 volt 10 to 50 C. P. at Rs. 9-12 per doz. Sunlight Conlor without shade 220 volts 25, 32 & 50 C. P. at Rs. 11-4; 100 C. P. with opal shades at Rs. 22-8. Halfwatt Gas filled clear glass 220 & 110 volt 30 40 watt at Rs. 7-4; 60 watt at Rs. 9-12; 75 watt at Rs. 10-4 per doz.; 100 watts at Rs. 12-12; 150 watts at Rs. 18; 200 watts at Rs. 24; 500 watt at Rs, 78. Show Window Lamp 220 volts at Rs. 3-8 each. Non-Shock Holder for save at Rs. 12 per doz.

Siemens' Wotan by Osram Works Berlin 220 volts 32 and 50 C. P. at Rs. 6-12 per doz.

Austrian Metalum 225 volts, 10, 16, 25, 32 & 50 C. P. at Rs. 5-13. Superla or Bijli or any other make 220 volts 10 to 50 C. P. at Rs. 5; 5 C. P. at Rs. 5-8. Spiral Round Shape 220 Volts 10 and 16 C. P. at Rs. 8-4 per doz. 110/115 volts 10 to 50 C. P. at Rs. 5-8 per doz. Fancy Natural Coloured Lamp Red, Blue, Green opal and clear 220 volts 10 C. P. at Rs. 6 per doz.

Fancy Artistic Lamp 220 volts standard bayonet cap "Metalum" Street Lantern 25 watt at Rs. 18; Jap. Lantern big 40 watt at Rs. 19-8; Oblong small 20; watt at Rs. 13-8; Rouud shape 25 watt at Rs. 13-8; Candle lamp 25 watt at Rs. 13-8; Snn-flower 25 watt at Rs. 13-8; Rose lamp 25 watt at Rs. 18-8; Tulip 25 watt at 13-8; Acorn 25 watt at Rs. 13-8; Orange 25 at Rs. 13-8; Cherry big size 25 watt at Rs 15; Cherry small 25 watt at Rs. 13-8; Grape 25 watt at

Rs. 16 8; Candle twisted big 25 watt at Rs. 13-8; Flame lamp small 25 watt at Rs. 13-8 per doz.

Raymour Beloian good quality 220 and 110 volt 16 to 50 C. P. at Rs. 4-14 per doz.

Joint Boxes round German large 3-8. German small 1-4 per doz. Jap. @ 1-3 doz.

Special Brand Lamp without any mark Superior quality 220 or 110 volts 5 to 50 C. P. at Rs. 4-8-0 per doz. In quantity at Rs. 4-6-0.

Illumination Lamp consisting 16 lamps Monkey, Bird and Flower at Rs. 4 per set.

English make Osram Cosmos or Pop 110 & 225 volts 20, 30, 40 & 60 watts at Rs. 10-8 per doz. British made ½ watt lamp, Osram Cosmos or any other make 110 or 220 volts, 30 and 40 watt at Rs. 16-8-0; 60 watt at Rs. 21; 75 watt at Rs. 22-8; 100 watt at Rs. 31-8; 200 watt at Rs. 51-0-0 per doz. Radiator Heating Lamp 220 volts 250 watt English at Rs. 3-8 each; German good quality at Rs. 2-2; Low voltage 24, 32, 50 65, 80, 100, 180 volt 16 to 50 C. P. Cosmos and Dutch Make Lamp at Rs. 6-12 per doz.

Phillips Lamps (*a*) One watt 10 to 50 C. P., 110 & 220 volts at Rs. 10-2 per doz.; 100 C. P. Round Shape Full Watt at Rs. 2-4 each; Fancy Real Coloured Lamp Green, Blue and Red 220 Volts 16 to 50 C. P. at Rs. 13-8 per doz. Tubular candle shape

220/110 volts 16 & 32 C. P. at Rs. 15 per doz. Candle Shape Twisted 220/110 volts 16 & 32 C. P. at Rs. 15 per doz. Candle Shape Twisted 220/110 volts 10 to 50 C.P. at Rs. 15-12 per doz. (*b*) Halfwatt (Gas-filled) Lamps—(1) Argenta Opal Glass 110—220 volts, 25 & 40 watt at Rs. 16-12 ; 60 watt at Rs. 22-8 ; 75 watt at Rs. 24 ; 100 watt at Rs. 33 ; 200 watt at Rs. 57 per doz. Arga clear glass Gas-filled Philips, 110—220 volts, 25, 30, 40 watts at Rs. 15-12 ; 60 watt at Rs. 19-8 75 watt at Rs. 21-12 ; 100 watt at Rs. 28-4 ; 150 watt at Rs. 39 ; 200 watt at Rs. 51 ; 300 watt at Rs. 67-8 per doz. 500 watt at Rs. 6-8 ; 750 watt at Rs. 10-8 ; 1000 watt at Rs. 12 ; 1500 watt at Rs. 19-8 each. Daylight 220/110 40 watt at Rs. 18-12 ; volts 60 watt at Rs. 25-8 ; 75 watt at Rs. 27 ; 100 watt at Rs. 37-8 per doz.

Half Watt Lamp Austrian Metalum 110 and 220 Volts 40 watt at Rs. 7-8 ; 60 watt at Rs. 9-12 ; 75 watts at Rs 10-12 ; 100 watts at Rs. 13-8 ; 150 watts at Rs. 17-4 ; 200 watts at Rs. 22-8 per doz. 300 watts at Rs. 5-4-0 each 500 watt at Rs. 6-8 each. Opalite lamps 220 volts 30 & 40 watt at Rs. 12 ; 60 watt at Rs. 14-4 ; 75 watt at Rs. 18 per doz. Special metalum Daylight lamp 220 volts 30 & 40 watt at Rs. 12 ; 60 watt at Rs. 14-4 ; 75 watt at Rs. 16-8 ; 100 watt at Rs. 18 ; 200 watt at Rs. 36 per doz.

Carbon Filament Lamps. Dutch make good quality

225 and 110 Volts 16 C. P. at Rs. 6 ; 32 C. P. at Rs. 6-12 ; 50 C. P. at Rs. 9-12. Austrian 110 & 220 Volts 16 C. P. at Rs. 5-4 ; 32 C. P. at Rs. 6 per doz.

Motor Car Lamps Miniature Cap Japanese without mark superior quality 4, 6, 8, & 12 volts 2 to 12 C. P. D. C. & S. C. at Rs. 1-10 Higher Size at Rs. 2-10 per dozen. Austrian 3, 4, 6, 8 & 12 volts 2 to 6 C. P. D. C. & S. C. at Rs. 4-8 ; 24 C. P. S. C. & D. C. at Rs. 5-4 per doz.

Motor Car Accessories Pendent Holder S. C. Nickel Finish at Rs. 5-4 ; 2 way Holder Nickel Finish S. C. at Rs. 6-12 Nickel Finish Tumbler Switches at Rs. 6-12. Switches Push Nickel Finish at Rs. 12 per doz.

Meters House Service by Ferranti or Chamberlain Hukcham English make continuous current 225 volts 2½ & 5 amp at Rs. 36 ; 10 amp at Rs. 37-8 ; 20 amp at Rs. 42 ; 50 amp at Rs. 50 each. 220 volt A. C. 2½ 5 and 10 amp at Rs. 18. German make best quality by Siemens Schuckert continuous current 225 volts D. C. 3, 5 and 10 amp at Rs. 17 ; A. C. 3, 5, 6 and 10 amp at Rs. 15

Megger. Evershed and Vignoles No. 3 patt Megger Testing set reading up to 100 Megohms 500 volts at Rs. 495 each. Insulation Tester 500 volts 100 Meg. variable pressure weight under 7 lbs. at Rs. 265 each. German Meg. at Rs. 195 each.

Hand Grip Fuses Bobin type Sperrynwood unmounted 15 amp at Rs. 13-8; 30 amp at Rs. 15-12; 26-4 ; 100 amp. at Rs. 54 per dozen ; 200 amp at Rs. 9-12 each. Japanese 30 amp at Re. 1 each.

Iron Clad House Service Cutout S. P. 250 English Henley or Revo. 10 amp at Rs. 1-3 ; 30 amp 500 volt at Rs. 2-10 each.

Iron Clad Switch & Fuse Triple pole English 10/15 amp at Rs. 7-12 ; 20 amp at Rs. 29 ; 120 amp at Rs. 67-8 & 200 watt at Rs. 115 each.

Iron Clad Switches and Fuses Combined D. P. English Revo or Vincent 10/15 amp at Rs. 3-8 ; 20 amp at Rs. 6 ; 30 amp 500 volts at Rs. 10 ; 60 amp. 500 Volts at Rs. 19-8. 20 amp at Rs. 45 each.

Porcelain Pipes Inside Glazed 1 in. Hole Latest Improved Pattern 6 ins. at Rs. 1-12 ; 9 ins. at Rs. 1-14 ; 12 ins at Rs. 2-6 ; 15 ins at Rs. 3-12 ; 18 ins. at Rs. 4-8 ; 24 ins. at Rs. 6 per dozen. Composition Lead pipe ½ in at Rs. 45 per cwt.

Pipes Insulated Brazed ¾ in. ext. dia. at Rs. 21- ; 1 in. at Rs. 30- per °/o ft. Perfecta Normal Bends ¾ in. at Rs. 7 8- ; Couplings at Rs. 3- per dozen.

Insulated Pliers. 7 in. @ 15, 8 in. @ 19-8 per doz.

Wallshall Heavy Gauge Screwed Enamel Insulated ¾ ins at Rs. 19-8 ; 1 in. at Rs. 27- ; 1¼ ins. at Rs. 37-8; 1½ ins. at Rs 40 per cent ft.

Shades Enamelled Iron German 6 ins. at Rs. 2-2; 8 ins at Rs. 2-6; 9 ins. at Rs. 2 10; 10 ins. at Rs. 3; 12 ins. at Rs. 6; 15 ins. at Rs 9-12; 18 ins. at Rs. 15 per doz. Opal Conical Shades 8 ins. at Rs. 3-8 & 9 ins at Rs. 3-12 & 10 ins. at Rs. 4 per dozen. Opal Langham German 6 ins. × 8 ins. at Rs. 3-4; 9 ins. at Rs. 3-6; 10 ins at Rs. 3-12 per dozen. Green and White Opal Shades 10 ins × 5 ins. Deep at Rs. 10-8 per dozen. Fancy Langham Shades with Blue, Red and White border at Rs. 6-8 per doz.

Shades Fancy Glass different kind frosted cloured itched opalescent and flowered rose prices from Rs. 5-8 to Rs. 18 per doz. Fancy Golden about 18 designs from Rs. 9-12 to Rs. 13-8 per dozen.

Fancy Glass Globe Flambeau type satin finish red, green and blue at Rs. 13-8 Grape Type red, blue and green globe at Rs. 13-8 per doz. Galleries for same at Rs. 6-12 per doz.

Shell-Reflector—Rs. 13 8 per doz. SHELL-LAC, best quality Rs. 2 per lb.

Switches S. P. English by Messrs. Sperryn E91 5 amp. improved type with fluted brass cover E. H. at Rs. 9-8; E90 China cover at Rs. 10-12; E96 10 amp. fluted brass cover E. H. at Rs. 14-4; E99 or E100 12 to 15 amp Brass and China cover Rs. 24 per dozen. English by G. A. G. Vitrious 5 amp. plain brass cover No. 62, flat with E. H. at Rs. 6; and B. H. at Rs. 5-4; 10 amp. plain brass cover with E. H. at Rs. 13-8; 10 amp. Brass cover B.H. Superior English at Rs. 11-4 per doz. 2 way plain brass cover with E. H. or B. H. at Rs. 12-12 per doz. Switch and Wall plugs combined cover brass at Rs. 21.

Switches S. P. German 5 amp. plain brass cover flat good quality with E. H. at Rs. 3-15: ordinary quality at Rs. 3-14 and B. H. superior quality Cream Bass at Rs. 3-10 per doz.; Switch and Wall Plug Pattern 5 amp But without Plug at Rs. 3-4 per doz. Zeta Switch China cover at Rs. 3-10 per dozen. 3 amp Brass cover B. H. superior quality at Rs. 5 4 per doz. 10 amp. brass cover E. H. at Rs. 9 and B. H. at Rs. 84 per doz. Switch and Wall Plug Combined at Rs. 9-12 per doz. Switch with separate key 5 amp. Brass cover good quality at Rs. 7-8 per doz. 2 way Brass Cover at Rs. 6-12 per doz. Japanese Cheap type 5 amp. with China cover E. H. at Rs. 1-8; Fluted Brass cover Spares at Rs. 1-8; per dozen. Spare Knob for 5 amp at as. 14; 10 amp. at Rs. 1-4 per dozen. Cover Brass for 5 & 10 amp at Rs. 2-4; China Rs. 3 per dozen.

Switches D. P. tumbler English 5 amp. Vitreous Brass at Rs. 15; 10 amp Brass at Rs. 30; English Sperrynwood 5 amp. E91 at Rs. 25 8; 10 amp. E95 at Rs. 36; 15 amp. E100 at Rs. 60 per dozen. German 5 amp. plain brass cover at Rs. 12; and 10 amp. superior quality at Rs. 24-12 per dozen.

Bed Switches Cocus imitation wood best English at Rs. 12 ; German best quality at Rs. 5-13 per dozen. Pear Pushes good quality at Rs. 7-8 per doz.

Sperryn Knife Switch unmounted 15 amp. S. P. at Rs. 3 ; D. P. at Rs. 6 ; 30 amp. S. P. at Rs. 3-12 ; D. P. at Rs. 7-8 ; 60 amp. S. P. at Rs. 5-4 ; D. P. at Rs. 10-8 ; 100 amp. S. P. at Rs. 7 ; D. P. at 14 200 amp. S. P. at Rs. 13-8 ; D. P. at Rs. 32 each. Sperryn mounted on slate 15 amp, at Rs. 3-12 ; D. P. at Rs. 7-8 ; 30 amp. S. P. at Rs. 4-4 ; D. P. at Rs. 9 ; 60 amp. S. P. at Rs. 5-4 ; D. P. at Rs. 11-4 each.

Knife Switches Change Over Sperryn unmounted 60 amp S. P. at Rs. 12 ; D P. at Rs. 24 100 amp. S. P. at Rs. 25 ; 200 amp S. P. at Rs. 30 each. Mounted 60 amp. S. P. at Rs. 11.

Table Standard English Sherwood No. 2591 10 ins. high Pilla type Brass at Rs. 3-4 each. Bronze at Rs. 3-12 each. No. E147 Polished Brass very good quality at Rs. 2-8 each.

Table Standard Fancy Flexible No. E155 Polished Brass 16 ins height, 6 ins. base at Rs 7-8 ; No. 2535E Oxidised copper 12 ins high, Pillar type at Rs 6-12 ; No. 2159 Oxidised copper adjustable type 24 ins. high very good qulity at Rs. 9-12.

Wall-Plugs and Sockets English Vitreous 5 amp 2 pin Cocus best at Rs. 9-8. Hand Shieled Type at Rs. 11 per doz. ; 10/15 amp Cocus best at Rs. 17-4 ; 20 amp. at Rs. 27 per dozen. Concentric Wall

Plugs English Cocus at Rs. 24 per dozen. Spare pin Cocus at Rs. 3 per doz. China cover 5 amp all cream China best quality at Rs. 4-8 per dozen. German Cocus 2 pin 5 amp good quality No. 1 at Rs. 4-12; ordinary at Rs 4-8 per dozen 10 lamp cocus ordinary pattern at Rs. 8-4; Hand Shield good quality at Rs. 9 per doz.

Water Tight Fittings Latest Improved Qnality Highly Polished with 7½ in. Reflector and well glass rubber ring and 12 in. C. I. Bracket suitable for 50 C.P lamp at Rs. 1-2. In quantity of 6 dozen at Rs. 12 per dozen at Spare C. I. Bracket with back plate 9 in. or 12 in. at Re. 0-12 each; spare Reflector only a Re. 0-14 each; for 100 C. P. complete at Rs. 2-12 each. Spare well glass for 50 C. P. at Rs. 5-4 per doz.

German Half Watt Enamelled Fitting Ditmar with China holder No. 333 suitable for 200 watt lamps at Rs. 5-4; No. 555 with brass holder suitable for 200 watt lamp at Rs. 5 each. No. 312 suitable for 600 C. P. Lamp with Opal Shade at Rs. 6-12 each. Cargo Cluster Fitting 6 Light at Rs. 35 each.

Wires English C. M. A., 600 meg. Association; Henleys 1/·044 at Rs. 4 6 6 nett; 3/·29 at Rs. 7; 1/.064 at Rs. 7/12; 3/.036 at Rs. 9; 7/·029 at Rs. 12 12; 7/·036 at Rs. 16; 7/·044 at Rs. 21-3; 7/.064 at Rs. 34-4 per coil of %₀ yards. All Henley's less 5%₀ except 1/044.

Wires English C. M. A. 600 Meg. Callenders any other make 1/18 at Rs. 4-7; 1/16 at Rs. 7-6; 3/22 at Rs. 6-8 ; 3/20 at Rs. at 8-4 ; 7/20 at Rs. 14 ; 7/18 at Rs. 19-4 ; 7/16 at Rs. 29-12 per coil of 100 yards. Glover 1/18 at Rs. 4-12 per coil.

Wires English C. M. A. 600 Meg. Johnson and Philip 1/18 at Rs. 4-6 ; 1/16 at Rs. 7 ; 3/22 at Rs. 6-8 ; 7/20 at Rs. 8 ; 7/22 at Rs. 12 ; 7/20 at Rs. 14-4 ; 7/18 at Rs. 19-8 ; 7/16 at Rs. 28 ; 19/18 at Rs. 45 per coil.

V. I. R. Wires King Brand 600 meg. grade 1/18 at Rs. 3-8 per coil of 100 yds. German Deka or Siemens 1/18 in 600 meg. good quality at Rs. 3-1. Siemens 300 megh at Rs. 3-50 per coil. 1/18 Twin Lead covered at Rs. 19-8 per 100 yards.

Wires By Messrs. Indian Cable Co., 600 megh. 1/18 at Rs. 3-12 ; 3/22 at Rs. 5 12 ; 1/16 at Rs. 6-4 3/20 at Rs. 6-12 ; 7/22 at Rs. 9-12 ; 7/20 at Rs. 12-8 ; 7/18 at Rs. 15 ; 7/16 at Rs 26-8 per coil of 100 yds. 1/18 Twin Lead Cover 1/18 at Rs. 21 ; 3/20 at Rs. 25 ; 3/20 at Rs. 31. Single lead cover 1/18 at Rs. 18-8 ; 3/22 at Rs. 14-8 ; 3/20 at Rs. 17-8 per coil of 100 yds.

Flexible Wires German best quality 35/40 or 14 36 Cotton extra D. V. at Rs. 9-12 ; S. V. at Rs. 9-12 ; S. V. at Rs. 8 ; Silk S. V. at Rs. 13-8 ; Silk D. V. at Rs. 15 per gross yards. Workshop Flexible Wire D. V. at Rs. 10-12 per gross yards. Twin white silk Electrollier fitting wire at Rs. 12-12 per gross yards,

Henley's Lead Covered Wires Twin Class *ZZ*MF Standard 1/18 at Rs. 24-10 ; 3/22 at Rs. 30 : 1/16 at Rs. 37-7 ; 3/20 at Rs. 40 ; 7/22 at Rs. 60-0 ; 7/22 at Rs. 72-8 ; 7/18 at Rs. 89 ; 7/16 at Rs. 130 ; Tropical 1/18 at Rs. 23-12 ; 3/22 at Rs. 29 ; 3/20 at Rs. 39 ; 7/20 at Rs. 70-8 ; 7/18 at Rs. 86 per coil of 100 yards. Single Core QM 1/18 at Rs. 17-5 ; 3/22 at Rs. 22 5 ; 3/20 at Rs. 25 8 ; 3 Core TQMF Standard 1/18 at Rs. 45 ; 3/22 at Rs. 53 3/20 at Rs. 70. All less 5°/o Discount.

Henley's Wiring System Accessories Link Clips No. 125 at Re. 0-11-6 ; No. 150 at Re. 0-12 ; No. 175 at Re. 0-14 ; No. 200—225 at Re. 0-15 6 ; No. 250 at Rs. 1-1 ; No. 275 at Rs. 1-2 ; No. 300 at Rs. 1-4 ; No. 325 at Rs. 1-2 ; No. 350 at Rs. 1-2 per box of 100. Joint Box T. T. 1 at Rs. 45-2 ; T. T. 2 at Rs. 75 ; T. S. 1, at Rs. 28-6 : T. S. 2, at Rs. 42-8 per hundred. T. C. Tape at Re. 0-2 per yard. Porcelain connectors 1 way at Rs. 10-8 ; 2 way at Rs. 15-0 ; 3 way at Rs. 18 per gross. For all other Accessories prices as per Henley's List less 5°/o discount.

Double Cotton Covered Wire English No. 6, 9, 10, 12 and 13, at Re. 0-12 ; No. 14, 15 at Re. 0-13 ; No. 16 at Re. 0-13-6 : No. 17 at Re. 0-14-3 ; No. 18 at Re. 0-15 ; No. 19 at Rs. 1-1 ; No. 20 at Rs. 1-2 and 21 at Rs. 1-3 ; No. 22 at Rs. 1-7 No. 24 at Rs, 1-14 ; No, 26 at Rs, 2 ; No, 27 at Rs, 2-2 ; No. 28 at Rs 2-5 No, 30 at Rs, 3-8 ; No, 32 at Rs, 4-2 per lb German good quality No, 26 at Rs, 1-14 ; No. 28 at Rs. 2 ; No. 30 at Rs. 2-8 ; No. 32 at Rs. 3 : No. 33 at Rs 3-4 No. 34 at Rs. 3-8 ; No. 36 at Rs. 3-12 per lb.

Double Silk Covered Wire German best quality without any mark No. 26 at Rs. 3-4 ; No. 28 at Rs. 3-12 ; No. 30 at Rs. 4-4 ; No. 31 at Rs. 4-8 ; No. 32 at Rs. 4-12; No, 33 at Rs 5-4 No, 34 at Rs. 5-8 No. 36 at Rs. 6-12 ; No. 38 at Rs. 9-4 ; No. 40 at Rs. 12 8 per lb.

Double Silk Covered Wire English No, 22 at Rs. 2-10 ; No, 24 at Rs, 3 ; No, 26 at Rs, 3-10 ; No 27 at Rs, 4-2 ; No, 28 at Rs, 4 ; No, 30 at Rs, 4 12 No 31 at Rs, 5-4 ; No, 32 at Rs, 5-6 ; No, 33 at Rs, 6 ; No 34 at Rs, 6 6 : No. 36 at Rs. 8-12 : No. 38 at Rs. 9-12 ; No 40 at Rs. 13-8 per lb.

Single Cotton Covered Wire English No. 19 at Re. 1 ; No 2- at Rs. 1-2 ; No. 22 at Rs 1-8 ; No. 24 at Rs. 1-14 ; No, 26 at Rs. 1-14 ; No. 27 at Rs. 2-6 ; No. 28 at Rs. 2 2 ; No. 30 at Rs. 3 4 per lb.

Enamel Insulated Copper Wire English No. 16 and 18 and 19 and 20 at Rs. 1-2 ; No, 22 at Rs, 0-3 ; No 21 at Rs. 1-7 ; No. 26 at Rs. 1-8 ; No. 27 at Rs. 1-9 ; No. 28 at Rs. 1-10 ; No. 3o at Rs. 1-14 ; No. 32 and 33 at Rs. 2-4 ; No. 34 and 35 at Rs. 2-8 ; No. 36 and 37 at Rs. 3 ; No. 38 at Rs. 3-8 ; No. 40 at Rs. 4 per lb.

Fuse Wires Tin Lean English No. 14 and 16 at Re. 1-15 ; No. 18 and 20 at Rs. 2-4 ; No. 22 at Rs. 2-6 ; No. 24 Rs. 2-10 ; No 26 Rs. 3 ; No. 28 at Rs. 3-12 ; per lb. German Nos. 10, 12, 13, 14 and 16 at Re. 0-11 ; No, 18, 19, 20 at Re.0-12 ; No, 22, 24 and 26 at Rs. 0-14 ; No. 27, 28, 29 and 30 at Rs. 0-15 ;

No. 31, 32, 33 at Rs. 1 2 per ℔. Japanese 14, 16, 18 and 20 at Re. 0-9 ; 22, 24, 26 at Re. 0-10 per ℔,

Fuse Wire Tinned Copper English No. 14 and 16 at Re. 0-12 ; No. 18, 20 and 22 at Re. 0-15 ; No, 24, 26 and 28 at Rs. 1 2 per lb.

Eureka Resistance Wire English No. 14 at Rs. 2 ; No. 16 at Rs, 2-2 ; No, 18 at Rs, 2-6 ; No, 20 at Rs, 2-8 ; No, 22 at Rs, 2-10 ; No, 24 at Rs, 3 ; No, 26 Rs 3-4 ; No, 28 at Rs. 3-10 ; No. 30 at Rs, 4 ; No, 32 at Rs, 4-10 ; No, 33 and 34 at Rs, 5, No, 36 at Rs. 6 No, 38 at Rs, 7-2 No, 40 at Rs 8 8 per lb,

Hard Drawn Bare Copper Wire English, S. W. G. No. 4, 6, 8, 10, at Re. 0-8-6. In quantity at Re. 0-8 per lb. No. 12, at Re. 0-11-6 ; 14, 16, 18 at Re. 0-13 per lb. For other sizes prices may be had on application.

High Tension Wire For Motor Car 7 m/m at As. 5 ; and 9 m/m at As. per yard.

Instruments Wire Gauze 0 to 36 S. W. G. at Rs. 8-4 ; 0 to 40 at Rs. 9 each. Electrician Pliers Insulated English 6 ins., 7 ins. and 8 ins. at Rs. 13-8 per doz. Electricion Pocket Screw Driver 4 ins. at Rs. 10-8 ; 5 ins. at Rs. 12 ; 6 ins. Rs. 15 ; 8 ins. at Rs. 18 ; and 10 ins. at Rs. 21 per dozen. Lamp Tester 220 volts 5 amp at Rs. 15 each. Ammeter 0/25 amp midget type at Rs. 9 ; watch type at Rs. 10. Voltmeter 0/3 Volt quantity Gauze type at Rs. 7-8 ; 0/15 & 0/25 Volt Flush type at Rs. 9 ; each.

Shaydolite Colouring Lacquer for Lamp3 Green, Amber, Yellow, Blue (Emerald) at Rs. 21-12 ; Red at Rs. 22-8 per gallon. Less than ½ gallon of each are not supplied.

Insulating Varnish Ohmalne Air Drying Black at Rs. 7-6 armacell (air Drying) Golden at Rs. 9 ; Pakyderm (for Finishing) Black and Golden at Rs. 12-8 per gross. Ante Sulphuric Enamel Black at Rs. 14-8. White at Rs. 15-12 Vermilion at Rs. 23 per gallon. Insulating Varnish Best Shellac at Rs. 8-4 per gallon. Copal Varnish at Rs. 6-12 gallon.

This price list is from,

MESSRS DEVA DATTA SARAOGI, & SONS,

41 Ezra Street, a reliable firm of Calcutta.

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