1

Tools

1. Introduction. 2. Screw Drivers. 3. Pliers. 4.Pocket Knife. 5. Hammers. 6. Wooden Saw. 7. Chisels. 8. Scratch Awl. 9. Hand Drill. 10. Ratchet Bit Brace. 11. Auger Bits. 12. Rawl Plug Tool. 13. Hacksaw. 14. Centre Punch. 15. Twist Drill. 16. Putty Knife. 17. Blow Lamp. 18. Files. 19. Plumb Bob. 20. Conduit Wiring Tools. 21. Pipe Vices. 22. Conduit Pipes Cutter. 23. Conduit cutting by Hacksaw. 24. Reamer. 25. Die and Die Stock. 26. Conduit Bending tools. 27. Taps. 28. Wrenches. 29. Precautions in handling the Tools.

1.Introduction. It is said that among the tool kits of engineers, electrical engineer's kit is the most simple and brief. He can do much work with a screw driver and a plier, but as electric lighting and wiring is a specialized job, so it requires a special kit. Some of the tools used for lighting and wiring are common with other trades. These tools are not expensive and are available at all leading hardware stores. While purchasing tools, it should be remembered that better grade tools should be preferred to cheap type tools. As estimating the cost of any installation and executing the same are related, it is imperative to know about the tools which form the essential part of the execution. The following are the most common types of tools.

2. Screw Drivers. As mentioned earlier, it is the most important tool and is used more often than any other tool. The screw drivers are available in different blade sizes, but commonly a 25 cms. screw driver with 15 cms. blade is a standard one which can be used to meet different types of jobs. Such a screw driver is shown in Fig. 1.1 (*a*). In addition to this, a similar screw driver with thin blade is useful for screwing or unscrewing the small screws of switches, lamp holders etc. In some cases a square blade screw driver may be required to augment handpressure. Such a screw driver is shown in Fig. 1.1 (*c*).

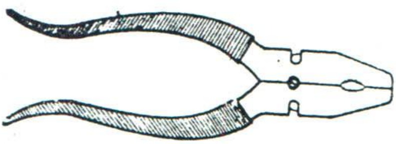
Standard Screw Driver
(*a*)

Thin Blade Screw Driver
(*b*)

Square blade Screw Driver
(*c*)
Fig. 1.1

3. Pliers. It is also one of the mostly used tools in wiring. The various types of pliers in use are :

(*a*) *Side Cutting Pliers.*

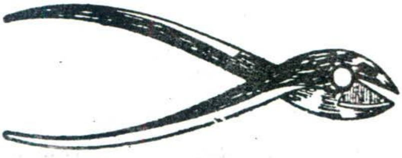


Side cutting pliers
Fig. 1.2

Such a pliers is used for cutting wires, gripping operation by hand, twisting wires and a number of other operations required in electrical work. It is usually provided with snub-nosed jaws and have a cutting edge only on one side as shown in Fig. 1.2. Usually 15 cms. or 22.5 cms. pliers is used. An insulated pliers is always preferred.

(*b*) *Diagonal Cutting Pliers.*

It is usually very difficult to cut the conductor of the wires terminating into holders, switches etc. with the side cutting pliers.

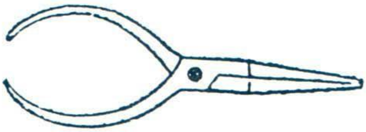


Diagonal cutting pliers.
Fig. 1.3

So under such odd circumstances diagonal pliers as shown in Fig. 1.3 is much useful.

(c) *Long Nose Pliers.*

The efficient tool kit must also include a long nose pliers.

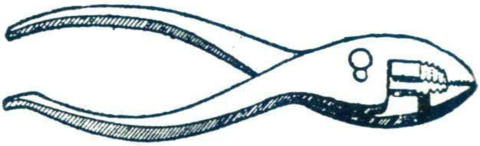


Long Nose Pliers.
Fig. 1.4.

It is useful for forming eyes of the wires which are to be used where they are held fast under the screw. Long nose pliers is shown in Fig. 1.4.

(d) *Slip Joint Pliers.*

This type of pliers is useful for conduit wiring, where its application is in the making up locknuts and bushings and holding conduits. Such a plier has a slip joint so that its jaws can be opened to a greater width.

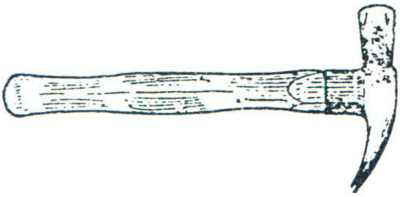


Slip Joint Pliers.
Fig. 1.5.

4. Pocket Knife. The pocket knife is also one of the most important tools in the worker's tool kit. It is generally used for removing insulation from the wires. The knife must be made from high grade cutlery steel. The closing type of knife should always be preferred, although a knife made from a broken hacksaw blade can serve the purpose well.

Pocket Knife
Fig. 1.6.

5. Hammers. For electrical work, generally two types of hammers are used : (*i*) Claw Hammer. (*ii*) Ball-Peen Hammer. The claw hammers are available in two types, *i.e.*, with a straight claw or a curved claw. Usually a straight claw hammer is preferred by electricians because the straight claw can be inserted behind, beneath or between wooden boards to be removed. It is shown in Fig. 1.7 (*a*).



(*a*) Straight claw hammer

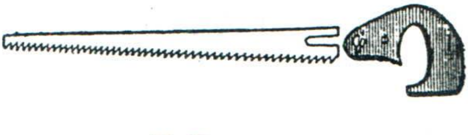
(*b*) Ball-peen hammer

Fig. 1.7.

The ball-peen hammer is required for driving nails into wooden batten or for cutting wall plaster and bricks when it is necessary to take the wiring from one room to another. Fig. 1.7 (*b*) shows a ball-peen hammer.

6. Wooden Saw. The house wiring is also done with wooden casing capping or batten and it is necessary to make use of a carpenter's saw for making joints or for cutting the casing or capping.

(*a*) Wood Saw



(*b*) Key-hole Saw

Fig. 1.8.

In addition to carpenter's saw, a small keyhole saw is also useful which is used for cutting small holes. Such type of saw has a thin and narrow blade, and the blade is usually attached with a fly wing nut to the handle, so that the blade may be replaced when it breaks.

7. Chisels. In house wiring, chisels are required for cutting wood and for cutting brick or concrete work. In wood work, the use of chisel is made in making various connections of casing capping, or for cutting the side of the wooden board from the centre in order to allow the wires to be connected to switches etc. The wood chisel is made from tool steel. It has a bevel at the cutting edge.

For plaster cutting or for brick cutting, cold chisels forged from alloy steel are used. Before use, these chisels are tempered. The cold chisels are generally available upto 25 mm. size.

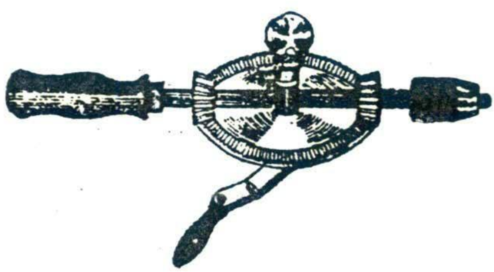
(*a*) Wood Chisel (*b*) Cold Chisel

Fig. 1.9.

8. Scratch Awl. It is generally difficult to insert a wooden screw into wood, unless there is a small hole. With a scratch awl, an impression is made into the wood before starting. Generally it is made from forged tool steel and has a very sharp point as shown in Fig. 1.10. As the tool is quite sharp, much care should be taken to handle such a tool, it should never be taken in hand or pocket.

Scratch Awl
Fig. 1.10.

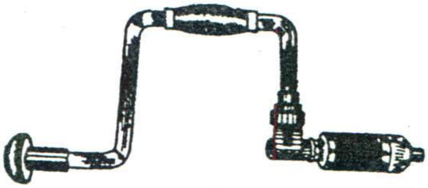
9. Hand Drill. In house wiring, it is often required to drill a hole in wooden blocks and wooden boards to facilitate the passage of insulated V.I.R. wires which terminate into switches or other fittings. For such purposes, a hand drill is much useful. It consists of a chuck with hardened steel jaws into which is placed the twist drill. A crank and gear is used for increasing the speed of drill. For opening the jaws, hold the chuck in left hand and turn the handle in an anti-clockwise direction with chuck pointing downward, and



Hand drill
Fig. 1.11.

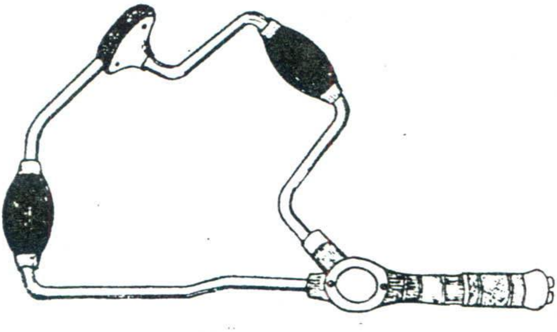
for tightening the twist drill, place the drill into the jaws, hold the chuck firmly and turn the handle in a clockwise direction with the drill pointing down, *i.e.*, in the direction of operation of the drill, and the drill will be firmly secured. Fig. 1.11 shows the hand drill.

10. Ratchet Bit Brace. Sometimes it is required to drill holes in heavy materials such as beams and joists. For such jobs, a ratchet bit brace, as shown in Fig 1.12 may be used. A ratchet bit brace with interlocking jaws ball bearing head and with 25 cm. sweep is best suitable for electrical jobs.



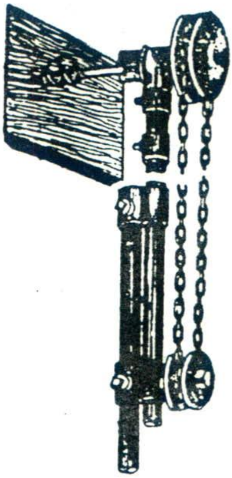
Ratchet bit brace
Fig. 1.12.

But for drilling holes near the corners, corner bit or angle brace is used as shown in Fig. 1.13. With such an arrangements, the hole will be slanting. The degree of slant depends upon the place where a hole is to be made.



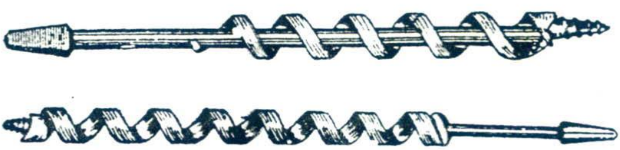
Corner bit
Fig. 1.13.

An alternative arrangement of drilling a horizontal hole in a joist is by means of a joist boring machine. With such a machine, it is possible to drill a hole from floor level.



Joist Boring Machine
Fig. 1.14

11. Auger Bits. In the above-mentioned boring tools, auger bits are used for drilling. Fig. 1.14 (*a*) shows different types of auger bits, while Fig. 1.14 (*b*) represents auger bit extension.



Auger bits
Fig. 1.14 (*a*)

Auger bit extension
Fig. 1.14 (*b*)

For new constructional work, a bit with coarse pitch of thread is to be preferred for which single spiral single cutter bit or double spiral double cutter bit may be used, but si. gle spiral single cutter bit is used for easy cuttings. The clip auger or spur ear bit is used for providing holes in old house wiring, since in old houses there might be nails etc. driven into the wood and more-over there is not much to choose for drilling hole for wiring. The clip auger is not easily damaged by such work as compared to other types of bits.

12. Rawlplug Tool. In case of wiring, whether it is casing capping, wooden batten or conduit pipe, they are all to be fixed to walls, for which purpose holes must be drilled into them. One of the methods of making holes in the wall is by means of a drilling bit fixed to a holder, and into the hole so made in the wall, a rawlplug is inserted. The rawlplug consists of a tube of hard fibre with a central hole. The rawlplug and the bit are selected to suit the job.

Rawlplug Tool
Fig. 1.15

There are two types of bit in use ; one is called a bullet bit and the other drilling bit. The bullet bit has a blunt nose and is of smooth surface which is used in soft plaster. Such a bit is driven straight without turning. It compresses the sides of the hole and drills out the material. The pointed bit is used for making hole into cement brick or stone. While drilling, care should be taken to tap it slightly with a rotary motion so that with each stroke, it goes forward and throws out the dust.

13. Hacksaw. For cutting metals such as conduits, cables etc., the wooden saw is not suitable and for such purposes a hacksaw as shown in Fig. 1.16 is used. The hacksaw frame is adjustable and carries a blade of tool steel. The blade is usually gripped into the frame by means of wing nuts. The blade is usually 30 cm. long with 18, 24 or 32 teeth to an inch. The less numbered ones are used for coarse jobs while more numbered ones are used for fine cuts.

Hacksaw
Fig. 1.16

When cutting with a hacksaw, make full strokes while pushing the saw away from you and no pressure should be applied on return stroke. For starting, an accurate cut should be made with a blade having 32 teeth an inch and later on, cut should be continued with a coarse blade. No doubt the coarse blade will cut faster ; but if the cut is started with a coarse blade, the back strokes try to jump, thus spoiling the accuracy.

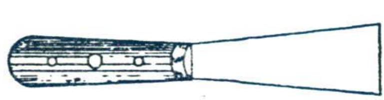
14. Centre Punch. When a hole is to be drilled in metals, the centre punch is usually used for making a starting hole. It is usually made of high grade tool steel hardened at both ends as shown in Fig. 1.17.

Centre Punch
Fig. 1.17

15. Twist Drill. For drilling holes into metals, the twist drill is used. It is held into the jaws of the hand drill and the drill is rotated at a high speed. Such a drill can also well be used for drilling holes into wooden boards etc. Fig. 1.18 represents the twist drill. It is available in different sizes.

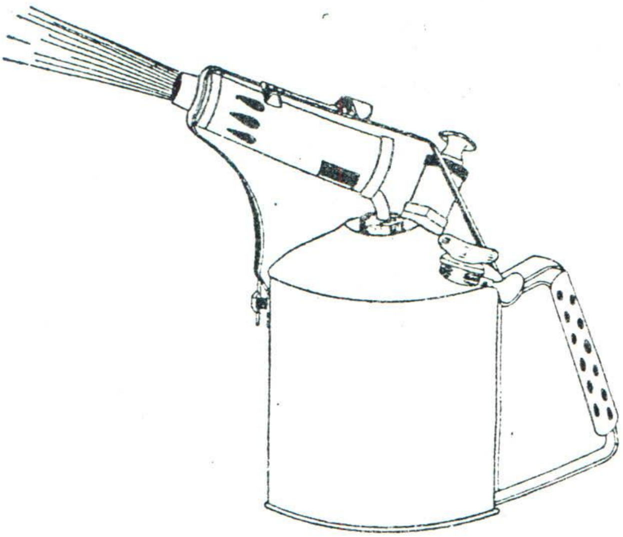
Twist Drill
Fig. 1.18

16. Putty Knife. The putty knife is used to replaster the holes on the wall and ceiling after inserting wooden gutties into them. It has a broad blade as shown in Fig. 1.19.



Putty Knife
Fig. 1.19

17. Blow Lamp. The blow lamp is used for soldering and cable jointing purposes. It is capable of producing very high temperatures. Usually kerosene oil is burnt into it. If its flame is projected directly on a job, the temperature of the job will increase to a very high degree. Blow lamp as shown in Fig. 1.20.

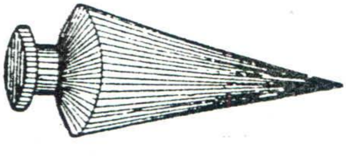


Blow Lamp
Fig. 1.20

18. Files. For wiring purposes, often we require a file for removing burrs etc. For such purposes, usually a smooth half round file of length 30 cm. size can be used. Since its use is limited, so only one file will serve the purpose.

File
Fig. 1.21

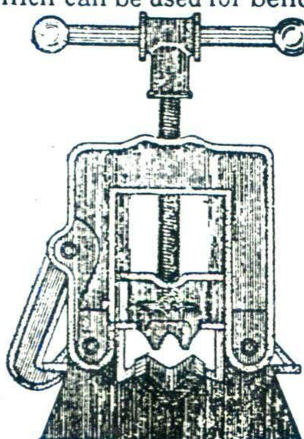
19. Plumb Bob. The plumb bob is shown in Fig. 1.22. It has a pointed end with a hole at the top for attaching a string. It is generally used to establish a true vertical line.



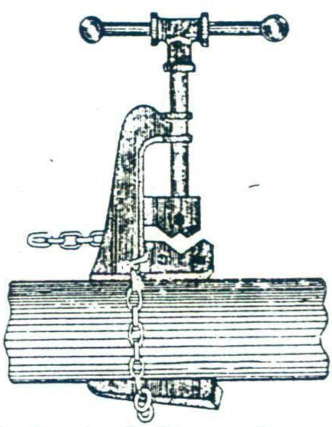
Plumb Bob
Fig. 1.22

20. Conduit Wiring Tools. The conduit wiring is a specialized job and requires highly skilled labour. There are special tools for such works which are described in the following articles.

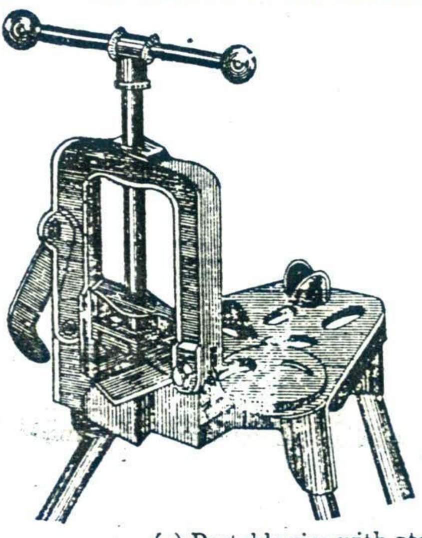
21. Pipe Vice. For cutting conduits or for cutting threads on the conduits or for bending conduits, they must be held securely. For holding such conduits firmly, the pipe vice is used. There are three types of vices which are generally used. Fig. 1.23 (*a*) shows a self-locking vice which is bolted to work bench at the site, while Fig. 1.23 (*b*) shows a portable vice which can be attached to a wooden post at the site, and Fig. 1.23 (*c*) represents a portable vice and stand which can be used for bending conduits also.



(*a*) Self-locking vice



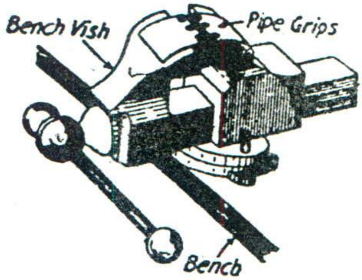
(*b*) Portable vice attached to wooden post



(*c*) Portable vice with stand

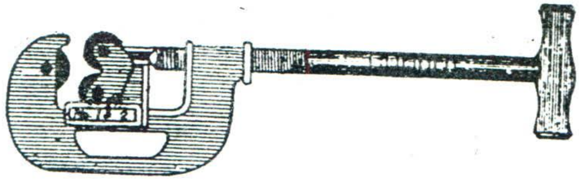
Fig. 1.23.

The bench vice can also be used for holding the conduit pipe securely, by using pipe grip with the vice as shown in Fig. 1.24.



Bench Vice
Fig. 1.24.

22. Conduit Pipe Cutter. The conduit can be cut by means of an ordinary pipe cutter as shown in Fig. 1.25. The conduit pipe is held securely by the pipe cutter which is rotated round the conduit and after few round rotations the cutter is again tightened against the conduit wall and further rotations are given to the cutter. But the only draw-back is that it leaves with a bulge and a sharp edge at the cut as represented in Fig. 1.26. Usually it is difficult to get rid of such a bulge and sharp edge and if it is left, it strongly affects the wires by spoiling their insulation and putting them out of action.



Conduit pipe cutter
Fig. 1.25

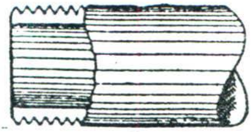


Illustration of a bulge
Fig. 1.26

Although such sharp edges are difficult to remove totally, an improvement can be made by reaming the edges by means of a *Reamer*.

23. Conduit Cutting by Hacksaw. The conduits can better be cut with a hacksaw, the construction of which has already been explained earlier. Fig. 1.27 shows a cut which has been made with the half of hacksaw. The cuts made by a hacksaw must also be reamed.

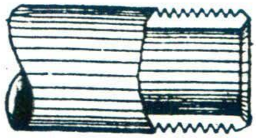
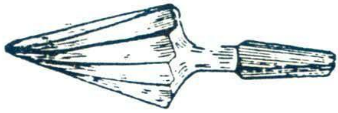


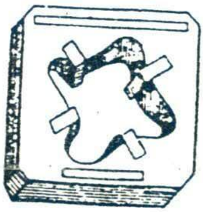
Illustration of a cut made by Hacksaw
Fig. 1.27

24. Reamer. It has already been said earlier that when the cut is made whether with a pipe cutter or with a hacksaw burr or sharp edge is formed on the conduit. If these burrs or sharp edges are not removed they damage the insulation of the wires. These burrs are removed by means of a reamer as shown in Fig. 1.28. Instead of reamer a half-inch round file can also be used.



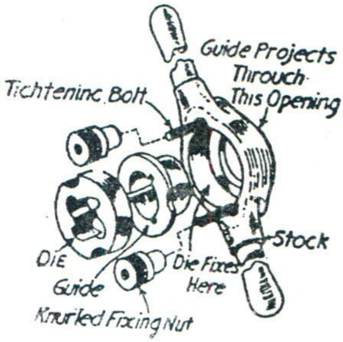
Reamer
Fig. 1.28

25. Die and Die-Stock. The conduits used in wiring must have a continuous connection for which purpose the conduits must be joined properly. The general method adopted is by jointing the two lengths of conduits which are threaded and a socket is provided over them.



Taps or Dies
Fig. 1.29

For cutting threads over the conduits, two types of die-stocks are used : the solid die-stock and the adjustable die-stock. In a solid die-stock, there is a single block of steel having two handles which can carry dies or taps shown in Fig. 1.29 of different sizes. Fig. 1.30 represents the die and die-stock. The guide is placed first in the stock, the purpose of which is to ensure that the threads are kept absolutely square in respect to the conduit. The die is fixed in position by two knurled fixing nuts. For cutting threads of different sizes, the guide and the die must be changed. But in a stock with adjustable guide, the lever adjusts the tool to any size of conduit. A triplex die can also be used for this purpose.

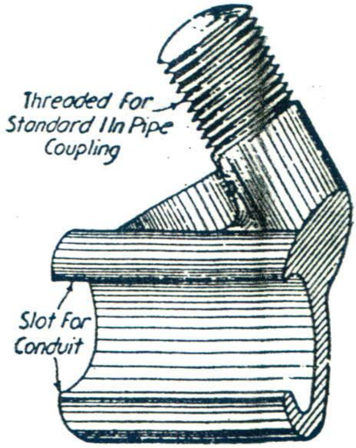


Die and Die-stock
Fig. 1.30

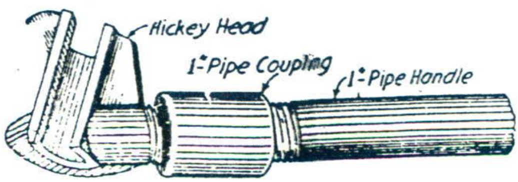
26. Conduit Bending Tools. There are four types of conduit bending tools. They are :

(*a*) Hickeys.
(*b*) Bending racks.
(*c*) Pressure benders.
(*d*) Roller benders.

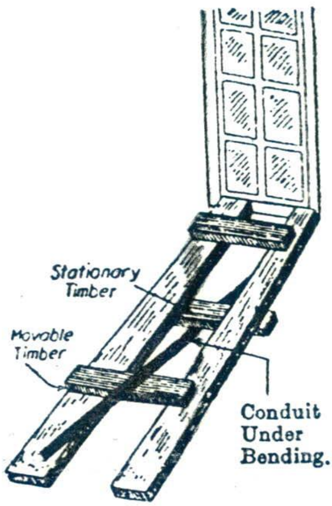
(*a*) *Hickey.* It is a practical tool that is used so commonly by the electrician for bending the conduits without spoiling the true round shape of the conduit. It is a hand bender based upon the principle of levers. It consists of a slot into which the conduit to be bent is engaged and has a threaded end with which is attached a handle by means of a pipe coupling. Fig. 1.31 (*a*) shows a Lakin hickey, while Fig. 1.31 (*b*) shows the hickey with a handle. The size of the Lakin hickey depends upon the size of the conduit to be bent, but there is another type of hickey which has a movable jaw and when the operator pulls the handle, it automatically grips the conduit and prevents the tool from slipping.



Lakin Hickey
Fig. 1.31 (a)



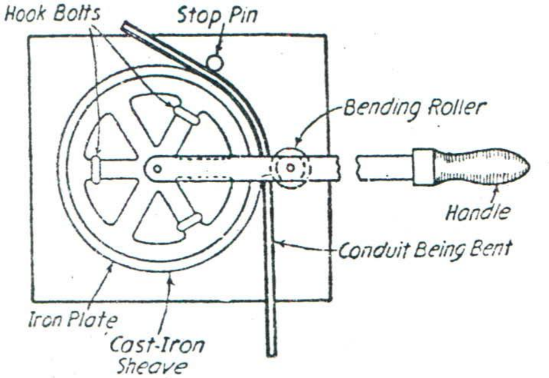
Hickey with handle
Fig. 1.31 (b)



Bending Rack
Fig. 1.32

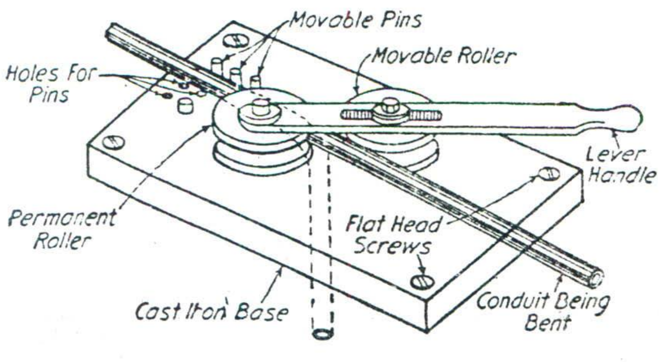
(*b*) *Bending Racks.* It has an arrangement of 'A' shape made from wood as shown in Fig. 1.32. In such an arrangement on end of the conduit is fixed and a force is applied to the other end of the conduit. The leverage of the bending conduit can be changed.

(*c*) *Pressure benders.* For pressure bending of the conduits, the conduit is laid as a beam and the pressure is applied at the centre. Such a bender is shown in Fig 1.33.



Pressure Benders
Fig. 1.33

(*d*) *Roller benders.* There are many types of roller benders. Fig. 1.34 shows an arrangement of roller bending in which system, a roller is used at the top and bottom of the conduit.



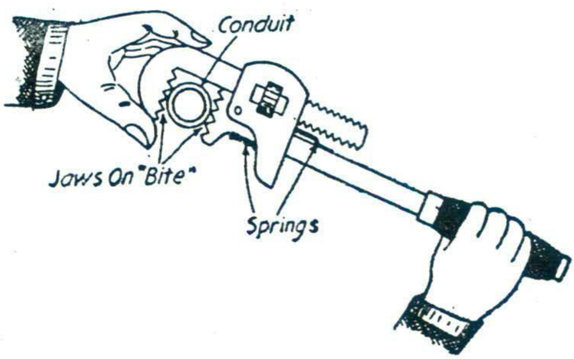
Roller Bender
Fig. 1.34

27. Taps. For screwing a bolt into the holes made in metal, it is necessary to thread the holes. The taps shown in Fig. 1.35 is generally utilised

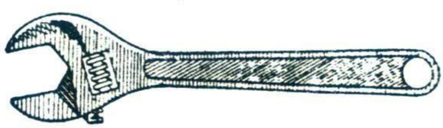
Taps
Fig. 1.35

for such purposes. For cutting threads the tap is held into a tap wrenches and is pressed downward with clockwise rotation.

28. Wrenches. For connecting or disconnecting the rigid conduits pipe wrenches are required. A pipe wrench which can handle a conduit upto dia. of 35 mm is sufficient.



Pipe Wrenches
Fig. 1.36



Adjustable wrench
Fig. 1.37

In addition to this an adjustable wrench is also used for handling square or octagonal head bolts. Such a wrench is shown in Fig. 1.37.

29. Precautions in handling the Tools. Great caution and care are acquired in handling tools. A worker is liable to injure himself in addition to the damage caused to the tools, if he, at any time is slacked in handling them. The following are the safety precautions in the handling of tools :

(1) The sharp edged tools such as pocket knife, chisels, scratching awl should never be put in pocket without shield, and while working with such tools, care should be taken not to place hand or finger in the path of motions of the cutting tool. Also care should be taken not to hand over the sharp-edged tools with its sharp edge first.

(2) When cutting with a chisel, always cut away from you rather than towards yourself.

(3) Before using a hammer, its handle must be examined, whether it is properly secured or not.

(4) When making a cut with a saw, the cut must be guided with a finger and thumb of one hand, otherwise the blade is liable to brake which may cause serious injuries.

(5) After using tools, they should never be left at the top of the ladder or any other place since they may fall accidentally and cause injury.

(6) Only a suitable tool should be used for the proper purpose and if a particular tool does not suit the purpose, *do not abuse the tool*, try to have a new tool matching the need.

(7) All injuries must be attended to immediately, since delay may cause infection.

2

Wires, Wire Splicing and Termination

1. Introduction. For estimating the cost of internal wiring, it is necessary to know the type of wires in use. The wires should be specified and size of conductor according to the type of conductor or the type of insulation and size of conductor.

As far as the type of conductor is concerned, the subject has been explained in chapter 8. With the adoption of use of aluminium as conductor, the use of copper as conducting material has been stopped and therefore the usual way to specify the wire is with the reference to the insulation, size and number of cores.

Knowing only the type of wire will not help the executive. For this purpose it is imperative for him to know the splicing termination and jointing which has also been illustrated in this chapter.

2. Sizes of wires. It has been mentioned earlier that for conduction of electrical power, insulated aluminium conductors are used. There is a limit to the current carrying capacity of the aluminium conductor. The current flowing through a wire causes heat which is proportional to the square of the current. Again there is a limit to the degree of heat which a particular insulation can withstand safely. According to the standards laid down, there is ...icular value of maximum current which can be safely carried ...e wires of different sizes with different insulations ; and if the ...are not adhered to, there is a possibility of damage to insulation ...h may cause fire.

The sizes to the wires are assigned much intelligently. Aluminium wires are referred according to the areas, but in case of copper conductor (which is not generally used), numbers have been assigned to the wire sizes. The gauge commonly used is the British Standard Wire Gauge.

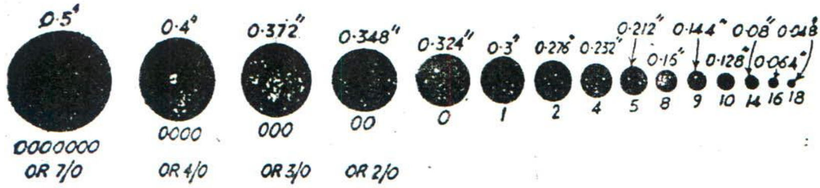
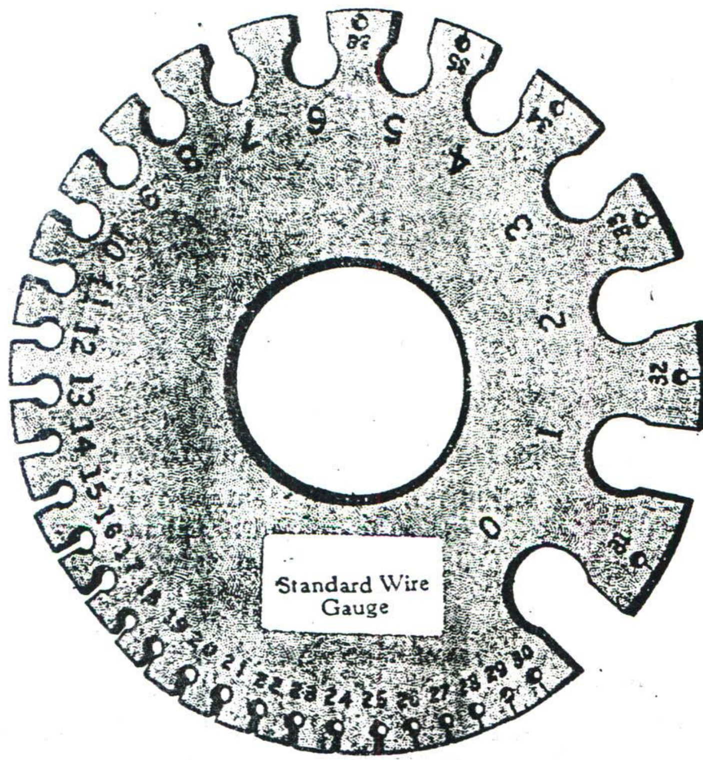


Illustration of sizes of various notches of wire gauge
Fig. 2.1

The smallest wire gauge is of No. 40 having a diameter of 0.0048 inch ; while the largest No. of wire is 0,000,000 (named as seven



Wire Gauge
Fig. 2.2

zero) or written as 7/0 having a diameter of 0.5". *It should be noted that the higher the number of wire gauge, the smaller is the diameter.* Table 2.1 gives the diameters of the British Standard wire gauge. Fig. 2.2 shows the wire gauge used for measuring the size of wire.

The American Wire Gauge is different from that of British Standard. The American way of representation of diameter is *miles* and not in *inches. A mils is one-thousandth part of an inch.*

Table 2.1

British Standard Wire Gauge (S.W.G.)					
Gauge No.	*Diameter*		*Area*		
	Inch	*mm*	*CIRC-Mils*	*SQ. Inch*	*mm²*
7/0	.500	12.7000	250000	.19635	126.6769
6/0	.464	11.7856	215296	.16909	109.0921
5/0	.432	10.9728	186624	.14657	94.5638
4/0	.400	10.1600	160000	.12566	81.0732
3/0	.372	9.4488	138384	.10869	70.1202
2/0	.348	8.8392	121104	.09511	61.3643
0	.324	8.2296	104976	.08245	53.1921
1	.300	7.6200	90000	.07069	45.6037
2	.276	7.0104	76176	.05983	38.5990
3	.252	6.4008	63504	.04988	32.1780
4	.232	5.8928	53824	.04227	22.2730
5	.212	5.3848	44944	.03530	22.7734
6	.192	4.8768	36864	.02895	18.6792
7	.176	4.4704	30976	.02433	15.6958
8	.160	4.0640	25600	.02011	12.9717
9	.144	3.6576	20736	.016286	10.5071
10	.128	3.2512	16384	.012868	8.3019
11	.116	2.9464	13456	.010568	6.8183
12	.104	2.6416	10816	.008495	5.4805
13	.092	2.3368	8464	.006648	4.2888
14	.080	2.0320	6400	.005027	3.2429
15	.072	1.8288	5184	.004072	2.6268

(Contd.)

British Standard Wire Gauge (S.W.G.)					
Gauge No.	*Diameter*		*Area*		
	Inch	*mm*	*CIRC-Mils*	*SQ. Inch*	*mm^2*
16	.064	1.6256	4096	.003217	2.0755
17	.056	1.4224	3136	.002463	1.5890
18	.048	1.2192	2304	.0018096	1.1675
19	.040	1.0160	1600	.0012566	.8107
20	.036	.9144	1296	.0010179	.6567
21	.032	.8128	1024	.0008042	.5189
22	.028	.7112	784	.0006158	.3973
23	.024	.6096	576	.0004524	.2919
24	.022	.5588	484	.0003801	.2453
25	.020	.5080	400	.0003142	.2027
26	.018	.4572	324	.0002545	.16417
27	.0164	.4166	269	.0002112	.13628
28	.0148	.3759	219	.00017203	.11099
29	.0136	.3454	185	.00014527	.09372
30	.0124	.3150	154	.00012076	.07791
31	.0016	.2946	135	.00010568	.06818
32	.0108	.2743	117	.00009161	.05910
33	.0100	.2540	100	.00007854	.05067
34	.0092	.2337	85	.00006648	.04289
35	.0084	.2134	71	.00005542	.03575
36	.0076	.1930	58	.00004536	.02927
37	.0068	.1727	46	.00003632	.02343
38	.0060	.1524	36	.00002827	.018241
39	.0052	.1321	27	.00002124	.013701
40	.0048	.1219	23	000018096	.011675

Similarly the American way of representing an area is not square inches, but it is *circular mils*. A circular mil is the area of a circle of one mil in diameter. *A wire having a diameter of one mil is said to have an area of one circular mil.*

Since the areas of two circles are proportional to the square of their diameters, so the cross-sectional area of the wire of diameter 2 mils is 4 circular mils. The areas are also sometimes measured in square mils. This is measured by multiplying the two dimensions in mils. Say the area of a strip $2'' \times \frac{1}{2}''$ is given as :

$$2'' = 2000 \text{ mils}$$

$$\frac{1}{2}'' = 500 \text{ mils}$$

$$\text{Area} = 2000 \times 500$$

$$= 1,000,000 \text{ square mils.}$$

Circular mils can be changed into square mils.

Square mils = circular mils × 0.7854.

Table 2.2 gives the American Wire Gauge for comparison only.

After the adoption of metric system in India the sizes of the wires are being usually denoted by cross-sectional area in sq. mm. *viz.* 1.5 sq. mm., 2.5 sq. mm., 4 sq. mm. etc. The industry has also started manufacturing the wires in accordance with the new trend.

3. Stranded wires. The wires used for ordinary wiring purposes are of single solid conductors ; but when the wires are required for greater flexibility, such as for a pendant lamp, wires of single conductors are not suitable. The flexible wire or cord may have number of wires of dia. 0.0076 inch, or 0.1930 mm. (36 S.W.G.) stranded together. The number of conductors stranded together depends upon the current-carrying capacity of the wire. For example, a flexible cord of 40/0.0076 has a current-carrying capacity of 7 A and possesses 40 conductors of 36 S.W.G. stranded together to give a cross-sectional area of 1.171 sq. mm. The wire having largest number of strands is 162/0.0076 with a cross-sectional area of 14.742 sq. mm. and has a maximum current capacity of 28 Amps.

4. Types of wires. The wires used for general electrical purposes can be divided into the following :

(*i*) Rubber covered, taped, braided and compounded or V.I.R. wires.

(*ii*) Lead alloy sheathed wires.

(*iii*) Tough rubber sheathed (T.R.S.)/or C.T.S. (Cab. Tyre Sheathed).

(*iv*) Weather-proof wires.

(*v*) Flexible wires.

Table 2.2

Brown And Sharp's Gauge (B.S./AWG)					
Gauge No.	Diameter		Area		
	Inches	mm	CIRC-Mils	SQ. Inch	mm²
7/0	—	—	—	—	—
6/0	—	—	—	—	—
5/0	—	—	—	—	—
4/0	.46000	11.7	211600	.1662	107.2
3/0	.40964	10.4	167805	.1318	85.03
2/0	.36480	9.27	133080	.1045	67.43
0	.32495	8.25	105592	.0829	53.48
1	.28930	7.35	83694	.0657	42.41
2	.25763	6.54	66373	.0521	33.63
3	.22942	5.83	52634	.04133	26.67
4	.20431	5.19	41742	.03278	21.15
5	.18194	4.62	33102	.02599	16.77
6	.16202	4.11	26250	.02061	13.30
7	.14428	3.66	20816	.01635	10.55
8	.12849	3.26	16509	.01297	8.366
9	.11443	2.91	13094	.01028	6.634
10	.10189	2.59	10381	.00815	5.261
11	.09074	2.30	8234	.00646	4.168
12	.08081	2.05	6530	.00513	3.308
13	.07196	1.83	5178	.00407	2.627
14	.06408	1.63	4107	.00323	2.082
15	.05707	1.45	3257	.00256	1.651
16	.05082	1.29	2583	.00203	1.308
17	.04526	1.15	2048	.00161	1.039
18	.04030	1.02	1624	.001276	.8258
19	.03589	.912	1288	.001012	.6516
20	.03196	.813	1021	.000804	.5189
21	.02846	.724	812	.000608	.4116
22	.02535	.643	640	.000503	.3243
23	.02260	.574	511	.000401	.2588
24	.02010	.511	404	.000317	.2047
25	.01790	.455	320	.000252	.1658
26	.01594	.404	254	.0001985	.1281
27	.01420	.361	202	.0001584	.10217

(Contd.)

Brown And Sharp'S Gauge (B.S./AWG)					
Gauge No.	*Diameter*		*Area*		
	Inches	*mm*	*CIRC-Mils*	*SQ. Inch*	*mm²*
28	.01264	.320	160	.0001247	.08064
29	.01130	.287	127	.0001003	.06452
30	.01003	.254	100	.00007854	.05067
31	.00893	.226	792	.0000622	.04014
32	.00795	.203	64	.0000496	.03243
33	.00708	.180	50.4	.0000396	.02554
34	.00630	.160	39.7	.00003116	.02011
35	.00561	.142	31.4	.00002463	.01589
36	.00500	.127	25	.00001963	.01267
37	.00445	.114	20	.0000159	.01026
38	.00400	.102	16	.0000126	.008107
39	.00353	.090	12	.00000962	.006207
40	.00314	.079	10	.00000755	.004869

The rubber covered, taped, braided and compounded wires are always single core ; but can be subdivided into two classes *i.e.*, whether meant up to 600 V or 250 V. All other types of wires are either single core, or double core or 3 core or twin core with E.C.C. (Earth continuity conductor).

5. Rubber covered, Taped, Braided, Compounded wires.

(*i*) *Single braid 250 V.* Such type of wire is also called simply as V.I.R. wire. These are used generally for ordinary electrical wiring in casing, capping or conduit wiring.

Rubber covered, Taped, Braided, Compounded Wires
Fig. 2.3

The general construction of the wire is as shown in Fig. 2.3. It consists of a tinned (to prevent the rubber sticking to the conductor) copper or aluminium conductor covered with a layer of rubber insulation. Over this rubber insulation is put up a cotton protective braid which is usually saturated with flame retarding and moisture-resistant compound. Finally it is finished with a wax for cleanliness and for helping the pulling action of it into the conduits. Such type of wire is also called as S.B.R.C. wire (single-braid rubber-covered). The thickness of the rubber insulation depends upon the voltage for which the wire is required, *i.e.*, whether it is for 250 V or 600 V.

The wires required for higher values of current are usually stranded, in case, copper is used as conductor. Stranded wires with aluminium conductor are not manufactured. These wires are provided with two protective cotton braids and are usually called as D. B. R. C. Std. (double-braid rubber-covered stranded) wires as shown in Fig. 2.4.

Double Braid
Fig. 2.4.

6. Lead Alloy Sheathed Wires. Such types are recommended where the climatic condition is not dry, but has a little bit of the moisture. Ordinary S.B.R.C. wires are specified for reasonably dry locations, so in order to use rubber insulated wires in damp conditions, the ordinary wires are covered with a continuous sheath of lead.

The lead covering is usually thin, about 1.25 mm. thick.

Lead Alloy Sheathed Wires
Fig. 2.5

The lead alloy sheathed cables are usually available in the following types :

(1) Single core lead-sheathed.

(2) Flat twin lead alloy sheathed (as shown in Fig. 2.5).

(3) Flat lead alloy sheathed 3-core.

(4) Flat twin lead alloy sheathed with E. C. C. (earth continuity conductor).

These types of lead sheathed wires provide only a little mechanical protection. The more stronger and mechanically protected cables are used for laying under the ground.

7. Tough Rubber Sheathed (T.R.S.) or Cab Tyre Sheathed (C.T.S.) Wires.

The lead sheathed cables are costlier and are quite heavy in weight. The T.R.S. cables have properties similar to that of lead sheathed cable, but is much cheaper.

The ordinary wire is provided with rubber insulation which is not water resistant; but the T.R.S. wires are provided with a tough rubber compound which does not deteriorate even after long exposure to moisture. So it can well be used in wet locations. Such wires are also available in single core, twin core, 3-core and twin with an earth continuity conductor. Fig. 2.6 (*a*) shows a single core cable while Fig. 2.6 (*b*) shows a twin core cable.

(*a*)

(*b*)

Tough Rubber Sheathed (T.R.S.) or Cab Tyre Sheathed (C.T.S.) wires
Fig. 2.6

8. Weather-Proof Wire. The weather-proof wires are for outdoor purposes, *i.e.*, they are run between buildings. Such wires when used are suspended at higher distances from the ground and moreover there is no possibility that anyone will touch them. Also the wires used must be cheap and resistant to atmospheric varying conditions. Hence the insulation provided over it is not the same as that for indoor wiring. Although the T.R.S. wires can be used, yet the T. R. S. wires are not much cheaper.

Such type of wires consists of 3 braids of fibrous yarn provided over the copper conductors. The copper conductors are not usually tinned. Before these braids are applied they are thoroughly saturated with a water-proof compound.

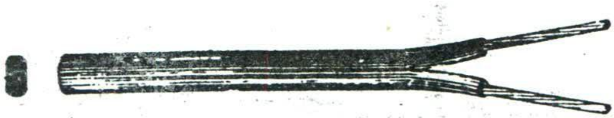
Weather-proof Wires
Fig 2.7

9. Flexible Wires. The wires used for household appliances such as heaters, irons, refrigerators, lamps etc., must be durable and very flexible. The flexibility is required firstly from the point of view of handling the equipment, secondly to prevent the wires from break. These flexible wires are also called as *lamp cords*. The flexible cord usually consists of two separately insulated flexible stranded conductors. The flexible wires are called as 14/0.0076 or 162/0.0076 which means that there are 14 or 162 strands of copper wire each having a diameter 0.0076 inch or 0.1930 mm. which is equivalent to 36 S.W.G. wire. There are different types of flexible wires. They are :

(*a*) **Twin Silk Cord.** It consists of two cores but each of these consists of a number of fine copper conductors stranded together. Over each conductor is given a layer of cotton, which prevents the sticking of rubber to the copper conductor. After cotton layer covering the layer of rubber insulation is followed up by a loose braid of cotton and finally the conductors are laid side by side and silk insulation is provided over them as shown in Fig. 2.8.

Twin core flexible wire
Fig. 2.8

(*b*) **Twin Rubber insulated Cord.** It is also similar to that of twin silk cord wire and consists of two stranded conductors each covered with cotton in order to prevent rubber sticking to the conductor. Then the two conductors are embedded in a solid mass of rubber insulation which is built up to a full size of finished wire and there is no further provision of any other insulation. The two conductors in the rubber insulation are so laid as to form a depression in the middle of them which facilitates in separating the two conductors at the termination of the wire in receptacles etc. The rubber provided for such insulation must be of much higher grade than is used for ordinary wire insulation.



Twin Rubber insulated Cord
Fig. 2.9

(*c*) **Twin Twisted Cotton Braided Flexible Wire.** In this case each of the conductor is insulated as in the silk flexible cord, *i.e.*, each conductor is cotton covered, followed up with a layer of rubber insulation and after this comes a braid of cotton thus completing the insulation of the single conductor. Then two such conductors are twisted together. Usually the two insulated conductors twisted together have rubber insulation of two colours, *i.e.*, red and black.

Twin Twisted Cotton Braided Flexible Wire
Fig. 2.10

(*d*) **Twin T.R.S. Flexible Wire.** The flexible lamp cords mentioned earlier are not much resistant to moisture and also they cannot withstand much wear and tear. The T.R.S. flexible wire consists of two or more insulated conductors twisted together as in case of twin twisted flexible wire. The open space in between the twisted conductors is filled up with cotton or jute threads, so as to form a round assembly. Over this assembly is provided a loose cotton braid and then a final layer of high grade of tough rubber.

Twin T.R.S. Flexible Wire
Fig. 2.11

In case of a wire better resistant to moisture, rubber filler is used to make the twin twisted conductors assembly round and the wire is finished off with an outer jacket of cotton which is impregnated with a moisture-resistant compound. Such a wire is called as reinforced wire and is shown in Fig. 2.11.

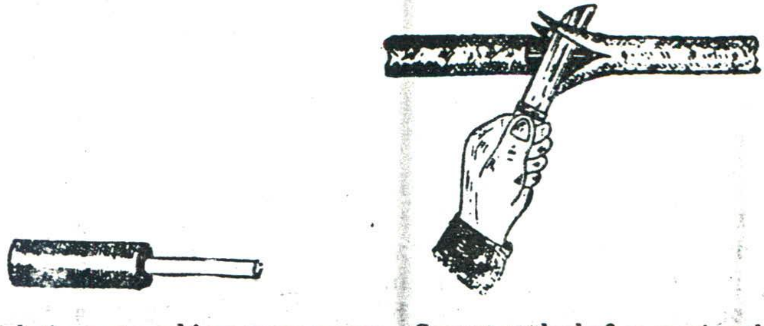
10. Wire splicing and termination. In all jobs of wiring, splicing (jointing) and termination is a necessity. The jointing is required since the wires are manufactured in 100-metre lengths and the total length of wire used for house wiring may be more than 100 metres. The termination of wires is needed, as the wires are to be connected to switches, holders, receptacles etc. *It is important to note that all joints made must be mechanically and electrically sound.*

The jointing conductors and wires should always be carried out at outlets, *i.e.*, in switches, ceiling roses using the looping in system or in junction boxes used specially for this purpose. Splicing should never be done in conduit runs. But sometimes when repairing old works, jointing becomes a necessity.

11. Western Union Splice or Twist Splice. The western union splice can be completed in four steps which are :

(*a*) Removing insulation.
(*b*) Mechanically jointing the conductors.
(*c*) Soldering the joint.
(*d*) Tapping the soldered joint.

(*a*) *Removing insulation.* For joining two conductors together, first their insulation is removed. The insulation of the wire should not be cut by holding the knife at right angles to the conductor which cuts the insulation as shown in Fig. 2.12 (*a*); but it should be removed by holding the knife at an angle just as in the case of sharpening a pencil, as represented in Fig. 2.12 (*b*) taking care not to injure the copper conductor. The removing of insulation in a tapered fashion is a necessity since it facilitates better jointing and insulating the joint. After the insulation is removed in a tapered fashion from a certain portion of a wire, the insulation from the remaining portion of wire can be removed with one pull of pliers up to the end of the wire as shown in Fig. 2.13. For joining insulated conductors it is necessary to remove braid only for a required length *i.e.*, 2.5 cm. approximately as shown in Fig. 2.14 (*a*). Then the bare conductors of the two wires to be joined together are gently cleaned with sand paper.



Insulation removed in a wrong way (*a*)

Correct method of removing the insulation (*b*)

Fig. 2.12

Pulling insulation with a Pliers
Fig. 2.13

Fig. 2.14 (*a*)

(*b*) *Mechanically jointing the conductors.* For making the joint, cross the two bare wires at ends at a distance of about 2 cm. from insulation of either of the wire, the wires are crossed or neck turned as shown in Fig. 2.14 (*b*). The crossing or neck turn of the conductors prevents the two wires being separated out under a pressure. Now with the help of the forefinger and thumb or with pliers, make five to eight turns, as shown. The remaining excess of the conductor should be cut away with the pliers and the turns should be tightened with it. Now a similar process is repeated with the other conductor and is finished off in a similar manner. The finished joint is as shown in Fig. 2.14 (*d*).

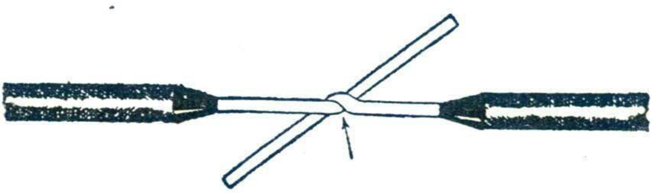


Fig. showing neckturn of the wires
(*b*)

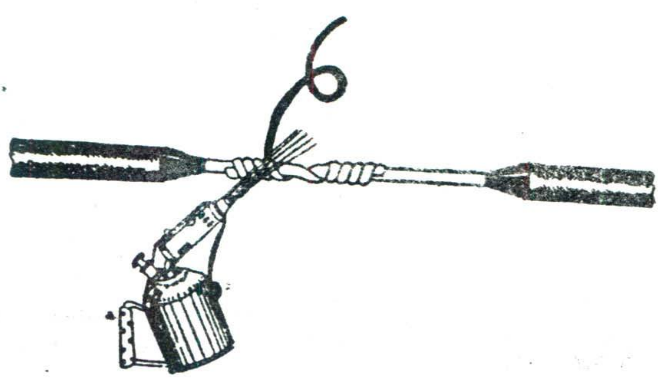
Fig. showing one of the conductor bent around the other
(*c*)

Finished joint
(*d*)

Fig. 2.14

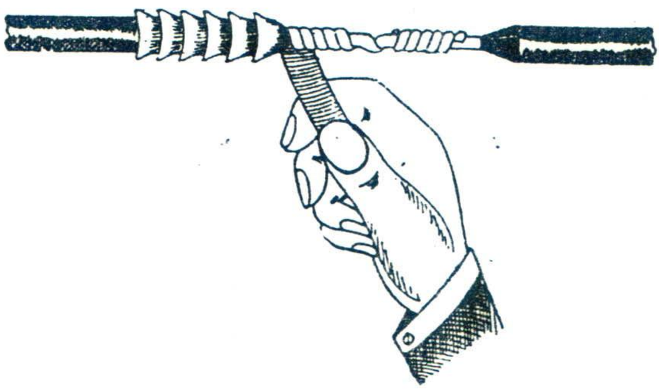
(*c*) *Soldering the Joint.* The mechanically bound joint made earlier cannot be said to be mechanically secure. In order to make the mechanical joint as strong as continuous length of the wire, it is necessary to solder the joint.

The soldering can be done either with the help of a soldering iron or by means of a blow lamp. Before soldering it is essential to clean the surface and to make it free from dirt, grease etc. Now apply soldering paste around the joint both at the top and bottom of it. The application of soldering paste is not necessary if resin-core solder is used which acts as a flux. Now heat the joint with the help of a blow lamp heating it with the tip of the flame. It is essential to heat the joint up to a proper temperature ; if it is not properly heated, proper soldering cannot be done, and if the joint is over-heated the conductor is weakened and becomes brittle. The proper temperature is tested with a piece of solder wire, which when placed over the joint should melt. At that instant, apply solder over whole of the joint as shown in Fig. 2.15. The solder should be applied several times until the solder floats or runs completely through the splice.



Soldering the joint
Fig. 2.15

(*d*) *Taping the splice.* The soldered joint must now be provided with an insulation, the thickness of which must be equal to that on the wire. For the wires generally used for house-wiring purpose rubber tape, friction tapes and black tape should be used. The method of applying the rubber tape is shown in Fig. 2.15. The tape should half overlap the previous turn, and the type should be stretched a bit until whole of the joint is covered and a bit of the insulation of the other wire is also covered. Now apply friction tape in a similar fashion to that of rubber tape.



Method of applying tape
Fig. 2.16

12. Married Joint. For a wire having one strand only, the joint made is called **twisted joint**, but for wires having a number of strands, the joint made is called as **married joint.** The following points show how the joint is made :

(1) Remove the insulation about 10 cm. on each wire with the help of knife in a tapered fashion as explained in Twist Splice.

(2) Remove braid for about 2.5 cm. on each wire.

(3) Separate the strands of each wire by twisting the stranded conductors in opposite direction to that of winding.

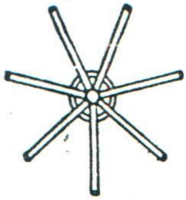
(4) Clean each of the strand gently with sand paper.

(5) Retwist the strands for a length of about 0.5 cm.

(6) Bind the twisted wire with a binding wire.

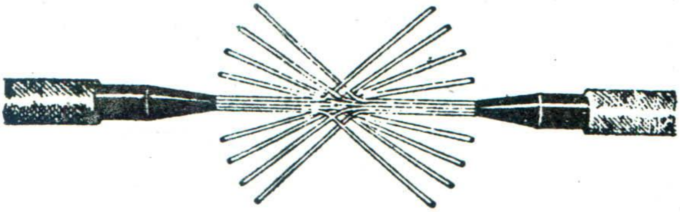
(7) Cut off the middle strand with the help of a pliers.

(8) Spread the individual strand as shown in Fig. 2.17 (*a*).



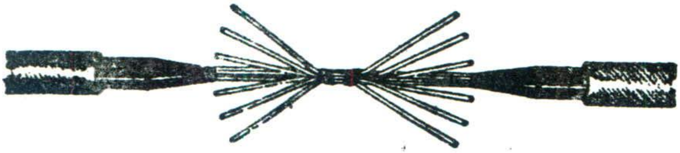
Spreading of Strands
(*a*)

(9) Bring the two wires end to end with all the strands intersecting as shown in Fig. 2.17 (*b*).



Intersecting of strands of two wires
(*b*)

(10) Hold one of the wires in the left hand and wrap one of the strands of the other wire around the twisted conductor in opposite direction as shown in Fig. 2.17 (*c*). Repeat the process with the other strand and so on.



Twisting of strands
(*c*)

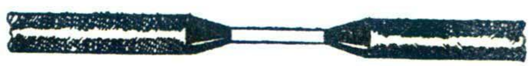
Finished joint
(*d*)
Fig. 2.17

(11) Round off the ends with mallet or pliers.

(12) Repeat the process with the other side of the wire.

The joint is then soldered and insulated as explained in article 11.

13. Single Branch Splice or a Tap Joint. Sometimes it is necessary to tap the electrical energy from a running line. In that case, only one free end of the wire is available and thus the twist joint or western union joint is not possible which necessarily requires two free ends. So in such circumstances a T joint is necessarily made. The following steps explain the process of joining.

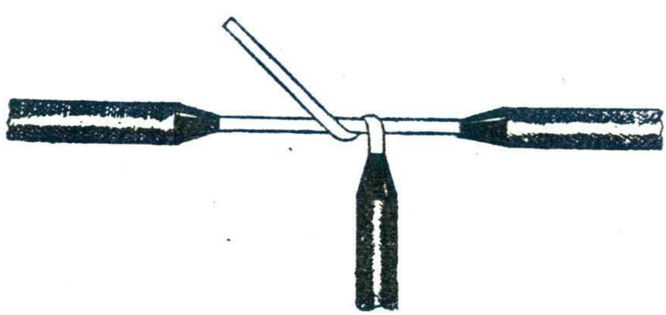


Removing insulation of a running wire for T-Joint
(*a*)

Removing insulation of a branch wire
(*b*)
Fig. 2.18

(*a*) Remove the insulation of the running wire as shown in Fig. 2.18 (*a*) for a length of about 2.5 cm. with care and precautions as explained earlier.

(*b*) Remove the insulation of the branch wire for a length of about 7.5 cm. as shown in Fig. 2.18 (*b*).

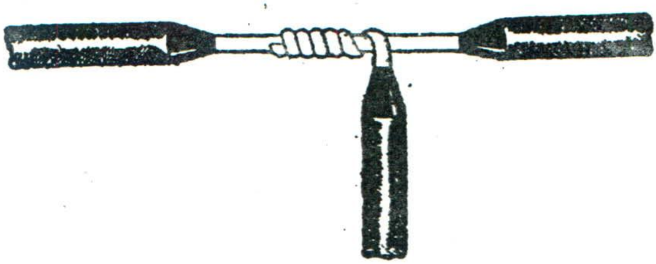


Neck turn for making T-Joint
(*c*)
Fig. 2.18

(*c*) Gently clean the conductors with the help of a double zero sand paper.

(*d*) Now keeping the branch wire at 90° to the running wire and with insulation of both wires near to each other make a neck turn as shown in Fig. 2.18 (*c*) which guards against the slipping of the joint under pressure.

(*e*) With the branch wire now give 5 to 8 turns as in the case of western union splice.

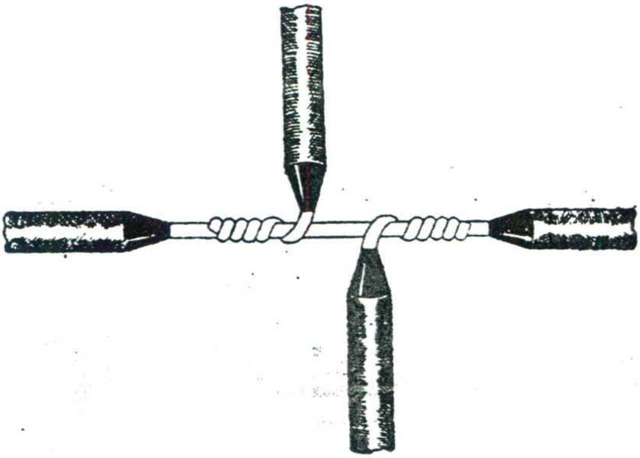


Finished T-Joint
(*d*)
Fig. 2.18

(*f*) Cut off the excees of the conductor.

(*g*) Now round off the conductor end with the help of a pliers or mallet. The finished joint is shown in Fig. 2.18 (*d*).

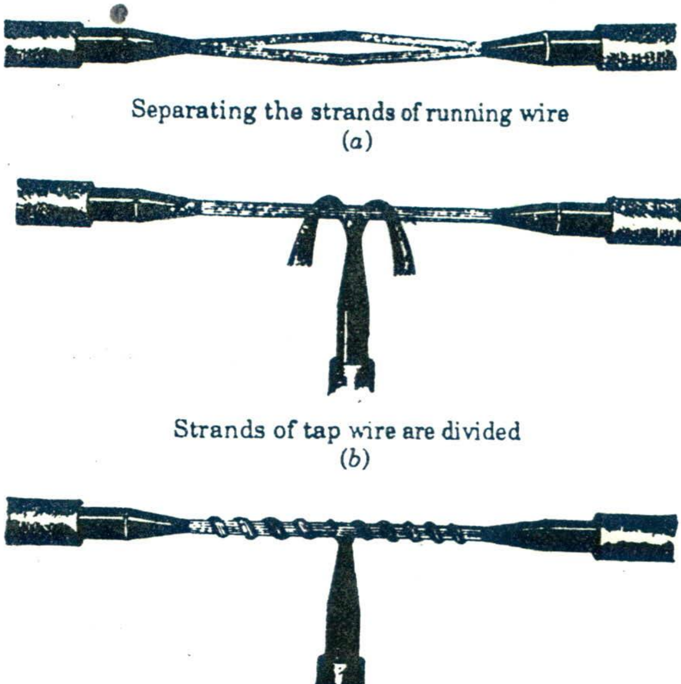
The splice is then soldered and insulated with a tape as already explained in article 11.



Double branch splice
Fig. 2.19

14. Double Branch Splice. The double branch splice is used when the electrical energy is required to be sent in two directions at right angles to each other. Such a splice is nothing more than that of two single branch splices in opposite direction, so the method of obtaining such a joint is the same as that of a single branch splice. Fig. 2.19 represents the double branch splice.

15. Tap Joint for Stranded Wires. For stranded wires the single branch splice or the tap joint is made as explained in steps indicated in Fig. 2.20 (*a*), (*b*) and (*c*).



Separating the strands of running wire
(*a*)

Strands of tap wire are divided
(*b*)

Finished Tap-Joint
(*c*)
Fig. 2.20

(*a*) Remove insulation of the running wire for a length of about 5 cm.

(*b*) Similarly remove insulation of the tapping wire for a length of about 7.5 cm.

(*c*) Clean the conductors gently with sand paper.

(*d*) Separate the strands of the running wire into two groups as shown in Fig. 2.20 (*a*).

(*e*) Insert the tap wire into the opening made in the running wire.

(*f*) Divide the strands of the tap wire into two groups, shown in Fig. 2.20 (*b*).

(*g*) Wrap one of the strands around the running wire, then wrap the second strand and so on.

(*h*) Wrap one of the strands around the running wire in the opposite direction to the previous one as shown in Fig. 2.20 (*c*).

(*i*) Round off the ends of the conductor with a pliers or mallet.

(*j*) Solder the joint as explained earlier and provide tape.

16. Flexible Cord Splicing. Sometimes it is necessary to provide a joint in a twin core cord. In such cases the two joints of the cores must be staggered as represented in Fig. 2.21. Such a splice has double advantages. Firstly it avoids the accidental short circuit between the two cores, secondly it does not make the splice bulky.

Joint in flexible twin core cord
Fig. 2.21

17. Pigtail Joint. The pig tail joint is the most important joint, since it is often required for termination of the wires in switches, holders etc. Moreover it can easily be made and unmade. For making such a joint :

Pigtail joint
Fig. 2.22

(*a*) Remove insulation from the two wires as shown earlier in Fig. 2.14 for a length of about 5 cm.

(*b*) Gently clean both the conductors.

(*c*) Keep the two wires with their insulation parallel.

(*d*) With a pliers make a number of twists as shown in Fig. 2.21.

(*e*) Keep the length of the twists about 2.5 cm. and cut off the excess wire.

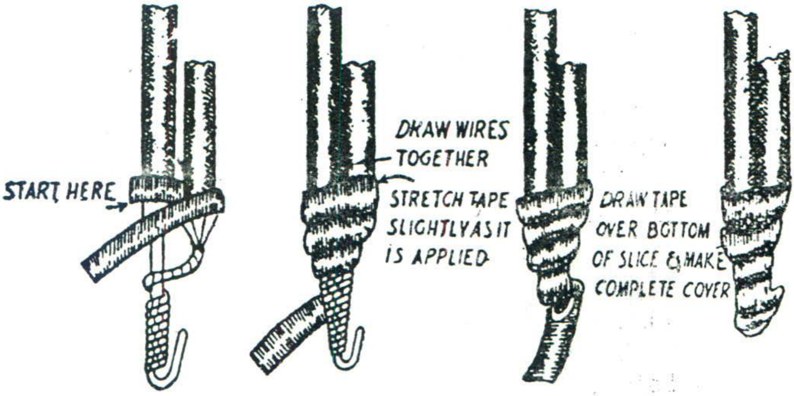
(*f*) Round off the corners with a mallet.

Now solder the splice and provide a tape. Similarly more than two wires can also be spliced together to form a pigtail joint.

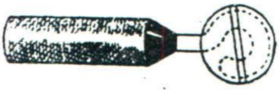
18. Pigtail joint of a solid conductor and a flexible wire. Such a joint is made in a manner similar to that of an ordinary pigtail joint, except that after wrapping the stranded wire, round the solid conductor for a length of about 2.5 cm., the solid conductor is bent back parallel to the wire as shown in Fig. 2.23. and then the joint is soldered and provided with a tape as shown in Fig. 2.24 (*a*). For providing tape, care should be taken to know that no end of the joint is left without a tape, so for this purpose, the tape is started between the wires as in Fig. 2.24 (*a*). The wires are brought together tightly and provided a layer of tapes as in Fig. 2.24 (*b*). Then wrap the tape half overlap. At bottom, the tape is provided without stretch as shown in Fig. 2.24 (*c*). Complete the tape as in Fig. 2.24 (*d*). Over this rubber tape is provided and then a friction tape.

Finished pigtail joint of a solid conductor and a flexible wire
Fig. 2.23.

19. Termination of wires at terminal screws. When it is required to terminate an 18 S.W.G. wire or lighter wire to a screw, the insulation from the wire is removed with the care to remove it in a tapered fashion. The conductor is bent in the form of a loop as shown in Fig. 2.25 (*a*). *It should be remembered that the loop of the wire must be made in the same direction in which the terminal screw is to be turned for lighting ;* such an action closes the loop in the process. Fig. 2.25 (*a*) represents the correct termination. While making a termination, the insulation of the wire is brought near to the screw ; it is a wrong method to keep it away as shown in Fig. 2.25 (*b*) as such a termination causes short circuit. Also the excess wire as shown in Fig. 2.25 (*c*) should be cut off and the wire end is tucked inward to avoid exposing bare portion of the conductor.

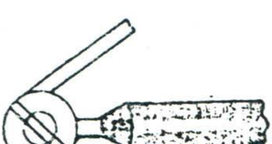


Method of employing tape on a pigtail joint of a solid conductor and flexible wire
Fig. 2.24.



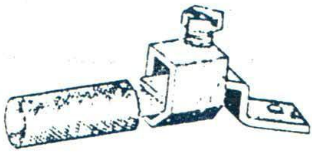
Bending of conductor in the form of loop
(*a*)

Wrong method of forming the loop.
(*b*)

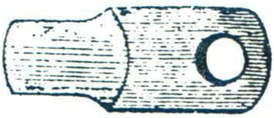


Excess wire needs cutting.
(*c*)

Fig. 2.25



Solderless connection for heavier wire
(a)



Soldering lug
(b)

Fig. 2.26

For heavier wire either a solderless connection is made as shown in Fig. 2.26 (a) or a soldering lug as shown in Fig. 2.26 (b) is used for connection. The heavier conductors are soldered to this lug which is terminated with a bolt.

3

Type and Installation of Wiring Systems

1. Introduction. The type of wiring to be adopted is dependent on various factors *viz.* durability, safety, appearance, cost and consumers budget etc. Each factor is explained below.

(*a*) *Durability.* The type of wiring selected for incorporation in a consumer's premises should be durable, *i.e.*, it should be of proper specification and as well as in accordance with the assessed life and type of building. Cleat wiring suitable for a temporary building will definitely be unsuitable for permanent factory building.

(*b*) *Safety.* While selecting the type of wiring, one has to look into the safety aspect. In a factory, where lot of fumes are produced, the cleat or capping casing wiring will be unsuitable.

(*c*) *Appearance.* It must be taken into consideration that the wiring do not spoil the beauty of the premises. In a beautiful banglow, if one resort to cleat or capping casing type of wiring, the whole outlook of the building will deteriorate which will create a bad impression on the capability of the designer.

(*d*) *Cost.* This is the most important factor. The executive or the designer has to see the funds available for the job and thereby arriving at the conclusion for the type of wiring to be adopted for meeting the consumer's requirement within the available resources.

(e) *Accessibility.* The extension, renewal of the wiring should be suitable.

(f) *Maintenance Cost.* As far as possible the maintenance cost should be low.

2. Methods of Installing Wiring. There are a number of methods of installing a wiring system. They are :

(i) *Cleat Wiring* (Vulcanized India Rubber wire known as V.I.R. wire in porcelain cleats).

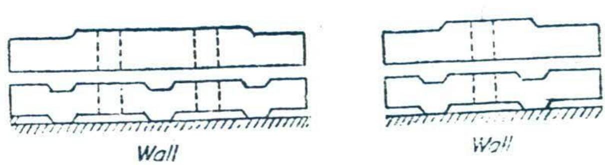
(ii) *Casing Capping* (V.I.R. wires in Wooden casings).

(iii) *T.R.S. Wiring* (Tough, rubber sheath wires run over wooden battens).

(iv) *Metal Sheathed Wiring* (V.I.R. wires covered with lead, run over wooden battens).

(v) *Conduit Wiring* (V.I.R. Conductors run in metallic conduits).

3. Cleat Wiring. In this system the V.I.R. conductors are supported in porcelain cleats. These cleats are made in two halves one of which is grooved to receive the wire and the other half is put over it and the whole of it is fixed on the wall by means of screws which further tightens the grip of the wire between the two halves of the cleat. The cleats are of three types, having one, two or three grooves, so as to receive one, two or three wires. Two types of cleats are shown in Fig. 3.1.



Two and three grooves cleats
Fig. 3.1

It is one of the cheapest methods of wiring. The wires are exposed to view. This system is most suitable for temporary wiring as it can be quickly installed and the recovery of the material can be made when the wiring is no longer required. Inspection, alterations and additions can easily be made.

This type of wiring is not permitted for permanent jobs, as the wiring system, though it appears very neat and clean at the time of erection, it gives a shabby look after some time. It sags at some places, after a certain period, dust and dirt collect over them, moreover a *the time of white washing or distempering the lime falls over the conductor, which erodes it and eventually the wire may break. Thus the maintenance cost in increased.* Further oil and smoke are much injurious to V.I.R. So this type of wiring should not be used in blacksmith's shops or similar places. In order to ensure longer life to such a wiring system, cleats should be used at intervals of 30 cm.

While installing cleat wiring system the following points should be borne in mind :

1. The cleats used should not be more than 60 cm. apart horizontally or vertically.

2. The wires must be laid stretched between the cleats, so as to avoid contact with the wall.

3. Only proper type of cleats should be used, *i.e.* a three-groove cleat should not be used for 2 wires or a two-groove cleat for a single wire. *For a pressure up to 250 V, the distance between the cleat grooves should not be less than 2.5 cm. for branch circuits, but for sub-mains it should not be less than 4 cm.*

4. Sharp bends should be avoided and the spacing between the cleats under the bends should be reduced.

5. *With 2 metres above the floor, the wires must be run in wooden casing or conduits and the end of these conduits must be filed to round off the corners etc.* so that it may not spoil the insulation when the wire is drawn in through them.

6. Wooden bushings are preferred at each end of the conduit.

7. A *cleat* must be placed close to each end of the conduit, similarly a cleat must also be placed at each end of a fitting.

8. When the wires are to pass through walls, they must be taken through conduits.

9. When the wires cross or superimpose, they must be separated by an insulating bridge piece which will maintain at least 1.3 cm. distance between the conductors.

10. *The wires should not be run near water and gas pipes and structural work.*

11. *This system of wiring should not be used for damp places.*

4. **Wooden Casing Capping.** This system of wiring is most commonly adopted for residential buildings. It consists of rectangular wooden blocks made from first class seasoned teak wood or any other wood free from knots, shakes or shaps etc. called **casing**. It has usually two grooves into which the wires are laid. The casing at the top is covered by means of a rectangular strip of wood of the

same width as that of casing known as capping and is screwed to it. A double bed is cut in the capping to show the position of wires so that the screws may not be driven through wrong position. Two or three wires of the same polarity may be run in one groove and in no case the wires of the opposite polaritiy may be run in one groove. Such a system of wiring is suitable for low pressure installations, where vulcanized insulated rubber cables or plastic insulated cables are used in grooves. The two main **disadvantages** which go against this system are :

1. *Highly skilled carpenters are required to make the job cleaner which will naturally be costlier.*

2. *There is every risk of fire.*

According to Indian Standards, the size of the casing capping and the size of the wire it can accommodate is given in Tables 3.1 and 3.2.

The capping and casing is available in pieces of lengths varying between 3.0 metre to 6.0 metre.

The casing is so fixed on the wall that it does not come in direct contact with but is supported by round porcelain disc insulators The fixing is done with the help of wooden counter-sunk screws into the wooden plugs or gutties. The gutties are fitted into the wall at intervals not exceeding 90 cm. (3 ft.) for sizes up to 63.5 mm. (2.5 in.) and not exceeding 60 cm. (2 ft.) for sizes above 63.5 mm. (2.5 in.). In the casing, the wooden screws are passed into the dividing wall.

5. Joints in casing capping. Since the standards casing and capping is available in maximum lengths of 3 m. and 6 m., so their jointing will be required. All joints made must be smooth and close fit and they are secured with wooden screws. The following are the various joints generally required.

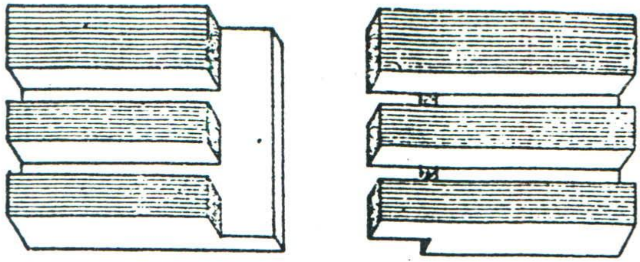
1. *Straight Joint.* Such a joint is required when two pieces of casing are to be joined Straight joints are necessary, since casing and capping is available in lengths of 3 m. and 6 m. For such a joint, the walls of one of the casings is removed for a length of about 2.5 cm. so that only thickness of the wood under the grooves is left there and in the other piece of casing the wooden piece under grooves is removed for a length of about 2.5 cm. and the two casings properly made are shown in Fig. 3.2. The joint is made permanent by providing one or more wooden screws. The completed joint is shown in Fig. 3.3. If instead of this type of straight joint, it is made by placing two casings side by side, it will leave a gap between the two pieces through which white ants etc. can enter and can spoil the insulation.

Table 3.1

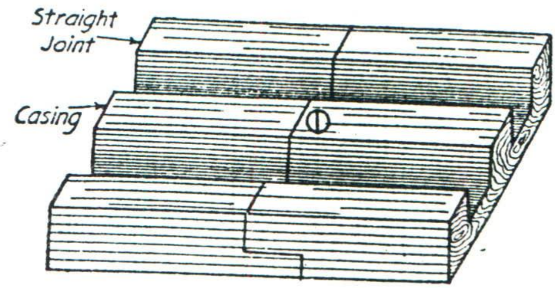
Width of casing or capping		*No. of grooves*	*Width of groove*		*Thickness of casing*		*Thickness at the back under the groove of casing*		*Thickness of outer wall*		*Thickness of capping*	
mm.	*in.*		*mm.*	*in.*	*mm.*	*in.*	*mm.*	*in.*	*mm.*	*in.*	*mm.*	*in.*
38	$1\frac{1}{2}$	2	6	1/4	16	5/8	6	1/4	6	1/4	6	1/4
44	$1\frac{3}{4}$	2	6	1/4	16	5/8	6	1/4	10	3/8	6	1/4
51	2	2	10	3/8	19	3/4	6	1/4	10	3/8	10	3/8
64	$2\frac{1}{2}$	2	10	3/8	19	3/4	10	3/8	10	3/8	10	3/8
76	3	2	13	$\frac{1}{2}$	25	1	10	3/8	10	3/8	13	1/2
89	$3\frac{1}{2}$	2	16	5/8	32	$\frac{1}{4}$	10	3/8	10	3/8	13	1/2
102	4	2	19	3/4	32	$1\frac{1}{4}$	13	$\frac{1}{2}$	13	1/2	13	1/2

Table 3.2

Width of casing or capping		Nos of conductors which can be drawn in one groove																
mm.	in.	1.0 sq. mm.	1.25 sq. mm.	1.5 sq. mm.	2.0 sq. mm.	2.5 sq. mm.	3.0 sq. mm.	4.0 sq. mm.	4.5 sq. mm.	6.0 sq. mm.	10 sq. mm.	14 sq. mm.	16 sq. mm.	25 sq. mm.	35 sq. mm.	40 sq. mm.	50 sq. mm.	Conductors sizes
38	$1\frac{1}{2}$	2	1	1	1	1	–	–	–	–	–	–	–	–	–	–	–	
44	$1\frac{3}{4}$	2	1	1	1	1	–	–	–	–	–	–	–	–	–	–	–	
51	2	3	2	2	2	2	2	1	1	1	1	–	–	–	-	–	–	
64	$2\frac{1}{2}$	3	2	2	2	2	2	1	1	1	1	–	–	–	–	–	–	
76	3	9	6	8	5	5	5	4	4	4	2	1	1	1	1	1	1	
89	$3\frac{1}{2}$	12	11	0.12	9	9	8	6	6	6	3	2	2	1	1	1	1	
102	4	12	10	0.10	9	9	9	6	6	6	4	2	2	1	1	1	1	

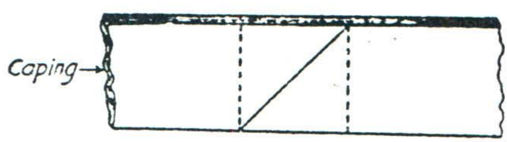


The figure represents two shaped casings to be joined together
Fig. 3.2



The figure represents the finished joints
Fig. 3.3

The capping joints do not overlap, but the two pieces of capping are cut at an angle of 45° and are joined, as is shown in Fig. 3.4.



Jointing of Capping
Fig. 3.4

(*ii*) *Tee Joint*. Such a joint is required where the wiring is to be carried out at right angles to the normal run of the casing, since the shape of this joint is a T, it is called as *Tee Joint*. In this joint, for the piece of casing to be joined at right angles to the normal run the flat portion of the wood at the bottom of the casing is removed for a length equal to the outer distance between the middle and outer walls of the casing (*i.e.* two wall thickness and a cavity). Such a piece is called as *tenon*, which is further shaped as in Fig. 3.5 *i.e.* the other two walls of the tenon are made shorter than the middle wall by a length equal to one of the cavity plus one thickness of the wall.

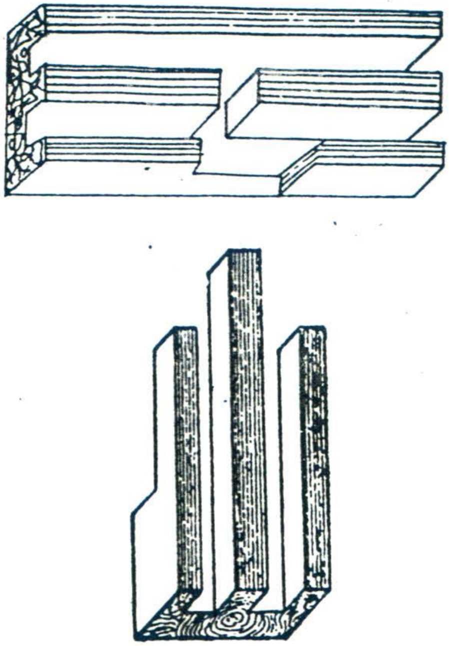


Figure representing Tenon and Mortise.
(a)

The other piece in which this tenon will be fixed is called *mortise*, the outer wall (not the flat position) is removed for a width equal to the width of the casing, also some portion of the middle wall of

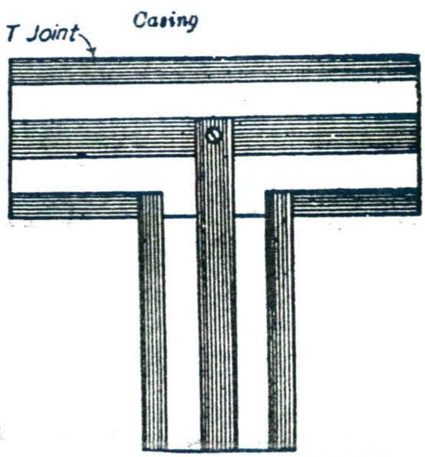


Figure representing finished T-Joint.
(b)
Fig. 3.5

mortise of width equal to the thickness of the middle wall is removed. Under such conditions the tenon can be made tight fit into mortise and a Tee Joint is obtained.

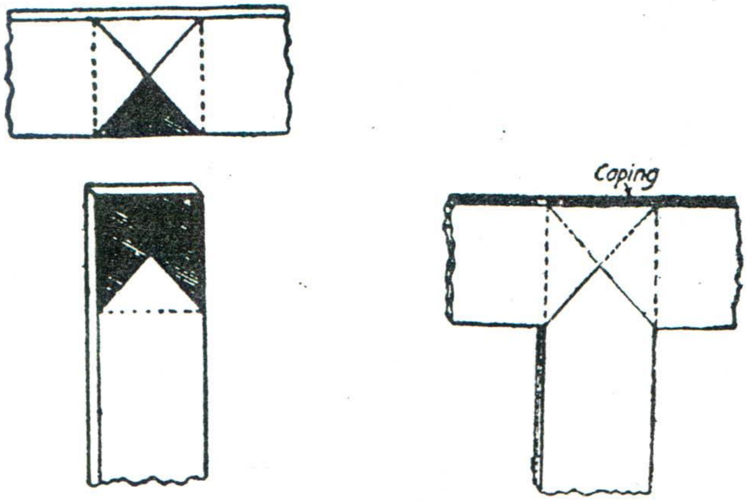


Figure representing top and bottom pieces of capping with the shaded portions marked for removing
(c)

Figure representing finished T-Joint.
(d)

Fig. 3.5.

For the joint of the capping, the squares are made on the top and right angle bottom cappings as shown. From the top capping,

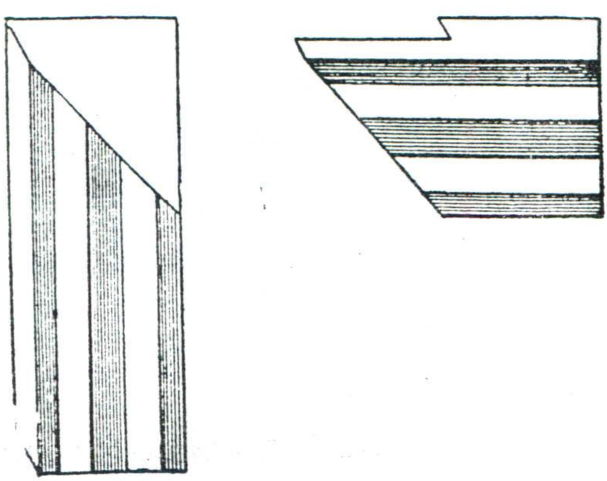
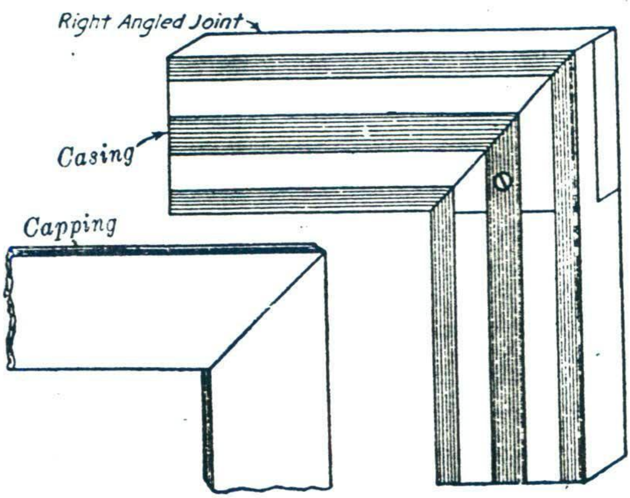


Figure representing the two portions prepared to the right angled joint.
Fig. 3.6

one quarter of the square is removed, while from the right-angled capping, $\frac{3}{4}$ of the square is removed so that the joint is shaped as shown in Fig. 3.6.

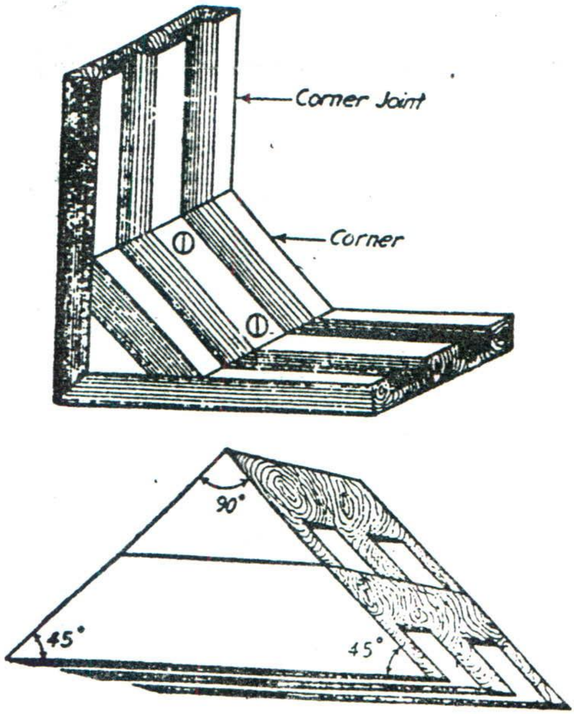
(*iii*) *Right-angled Joint.* When a right-angled turn is to be given to the run of the casing, a right-angled joint is required. For this joint, the squares are made on the two pieces of the casing to be joined for a right-angled joint, the piece acting as a tenon is cut along the diagonal of the square and thus half of the square is removed, for the half of the square, the bottom flat portion of the casing is removed. For the piece acting as mortise, the walls of the casing are removed along the diagonal of the square made as earlier. The joint is made permanent by providing a screw in middle wall as shown in Fig. 3.7.



Finish right angled joint
Fig. 3.7

For the capping joint, the squares are made at the ends of the two pieces and they are cut along the diagonals of these squares.

Corner Joint. To avoid sharp bends in the insulating wire, a corner joint is required. The corner joint is a right-angled triangular prism made by joining two casings and screwing them. For making such a joint, two pieces of casing are screwed together by placing one at the back of the other, and this composite casing is then cut at an angle of 45° depth wise so as to form a right-angular prism. Such a corner joint is fixed in the corner as shown in Fig. 3.8.



Finished corner joint
Fig. 3.8

The points to be noted for installing such a wiring system are :

1. Only seasoned teak wood should be used for casing and capping to avoid trouble from white ants.

2. The casing should be well fixed to the walls and in no case it should be supported by the wires themselves.

3. Proper measurement should be taken to avoid gaps.

4. In no case the casing should be buried under plaster or masonry work.

5. When the wiring is to cross a wall, it must pass through conduits.

6. At bends, the grooves must be well rounded off to avoid the insulation being damaged.

7. While fixing capping to the casing with the help of wooden screws, care should be taken that they go into dividing wall of the casing, otherwise they will damage the insulation of the wires.

5. Tough Rubber sheathed Wiring (T.R.S). The type of cables are sometimes also called as cable-tyer sheathed wiring (C.T.S.). The T.R.S. cables are available in single, twin or three cores with a circular or oval shape. The cable is quite flexible and has an insulation which resist rough usage, moisture, climatic variations, acids, alkalis, but is slightly affected by lubricating oils. So T.R.S. cables may be run on the surface of the walls or buried in plaster, but usually the cable is laid over wooden batten which is fixed on the wall, lead strips or fibre brackets as shown. For permanent neat appearance, the cable should be secured at a distance of 30 cm.

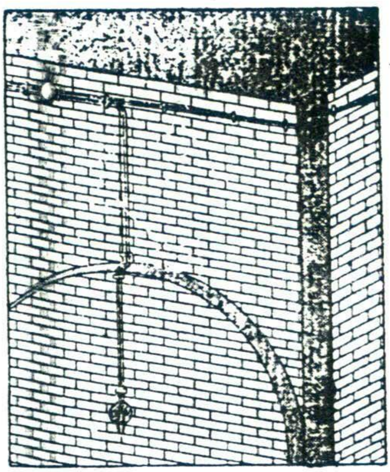


Illustration of surface conduit wiring
Fig. 3.9.

The following are the specific points which should be noted when installing T.R.S. wiring system :

1. For damp places, a wooden batten or beading must be used over which the cable should be laid.

2. In damp places, care must be taken to earth switches, lamp holders and other metal fittings.

3. Fibre clips should not be used in damp places as these are hygroscopic.

4. If the cable is concealed under plaster, care must be taken to provide a layer of neat cement over it to avoid danger from nails.

5. The cable should not in any case be put under stress either due to lead clips or due to bends etc.

6. In damp places the ends of the cable must be sealed with compounds.

7. While taking through walls conduit must be used and at both ends of the conduit, rubber bushing should be inserted.

8 The wire should be properly tightened and to achieve this, the distance between the clips should not be more than 6 cm.

9 Bends should be provided with longer radius to avoid cracks.

6. Metal Sheathed or Lead sheathed Wiring. This type of wiring consists of rubber insulated conductor covered with an outer sheath of lead alloy containing about 95% lead which provides a protection to the cable from mechanical injury. These cables can also be run on wooden beading or batten in residential buildings. The lead sheath must be earthed. *If the lead sheath is not earthed there will be an electrolytic action due to the leakage current which will deteriorate the lead covering, also earthing provides a safety against the metal sheath becoming alive.* Metal sheath cables are costlier than the T.R.S, ones. The following points should be kept in mind for installation of metal-sheathed wiring :

(1) The cables should be supported by proper metal clips, saddles etc; which must not be more than 30 cm. apart both horizontally as well as vertically.

(2) The supports used must not be of such a material that it set up chemical action with the sheath.

(3) Sharp bends should be avoided and for a change of direction, a round bend should be made of not less than 10 cm. (approximate) radius.

(4) The lead sheath must be earthed and it must have a continuous electrical contact.

(5) The cable should not be run over a damp place.

(6) When crossing a wall, the cable must be run in conduits with bushings at both ends.

(7) The ends of the conduits used must be filed to remove burrs, and bushes may also be provided at both ends.

7. Metal Conduit Wiring. In this system of wiring, the V.I.R. Conductors are run in metallic tubes called conduits. It is indisputably the best system of wiring which provides mechanical protection, safety against fire and shock if bonding and earthing are well done ; and this is most desirable for workshops and public buildings.

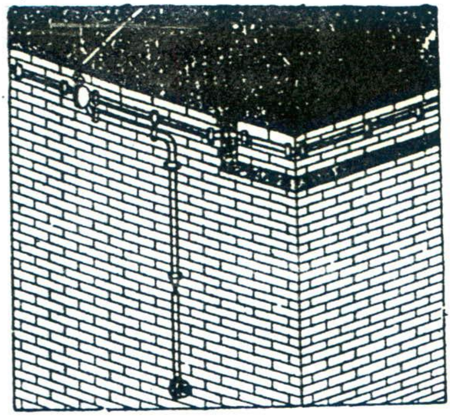


Illustration of surface conduit wiring
Fig. 3.10

There are two types of conduits used for wiring. *One is known as close joint or open seam conduits or brazed conduits and the second type of conduits are solid drawn seamless or welded.*

The conduits can either be buried under plaster or can be supported over the wall by means of saddles or pipe hooks. *The wiring with conduit on the surface of the wall is known as surface conduit wiring and whereas wiring with conduit buried under plaster is known as recessed conduit wiring.* **The main advantages of conduit wiring are :**

(1) It provides protection against fire due to short circuits etc.

(2) It provides protection against mechanical injury to the V.I.R. wires used.

(3) It provides protection against moisture of the atmosphere since the conduits can be made water-tight.

(4) It provides an easy way of replacing the damaged wires.

(5) Such a system is most suitable for workshops.

The conduits are generally erected first and wiring is done later. There are three methods by means of which the wiring of the conduits can be done. They are :

(*a*) Threading through.
(*b*) Pushing in.
(*c*) Drawing in.

The first method of threading through is suitable when the wiring is done before the conduits are erected which is somewhat laborious and takes more time. This is useful only for making extensions.

The method of pushing in is possible only when the erected lengths of the conduit are small and straight.

The drawing in method of wiring the conduit is most commonly adopted. First the wires are inserted in the conduits and later V.I.R. conductors are pulled through by means of steel wires. In order that the wires may be easily pulled they are sometimes rubbed with French Chalk. Inspection boxes and bends are provided at frequent intervals to facilitate drawing in of the wires. While drawing, care must be taken that wires are in no case to be twisted round one another. It will reduce the capacity of the conduit and it will become difficult to change the wire if necessity arises some time later. *The following are the chief points which should be cared for in the adoption of conduit wiring :*

(1) The main drawback for conduit wiring is that there is a considerable condensation in the conduits in places where there occurs appreciable change in temperature. In order to avoid condensation of water, the conduits must be well ventilated to allow free air circulation. When a conduit is run horizontally, it should be given a fall and care should be taken that no pocket is formed where the condensation may rest.

(2) Much care should be taken in cutting the conduit lengths so that burns etc. may not be formed which will tear off the insulation from the wires when drawing in. It is always advisable to cut the conduits with a fine blade having 32 teeth per inch.

(3) Correct measurements should be taken to make satisfactory joints.

(4) The oil used for threading the conduits must be wiped off as it is injurious to the rubber insulation.

(5) The threads should be coated with aluminium paint and not with red lead as it may act as an insulator

(6) For change of direction, the conduit must be bent round cold in a press and the radius of the bend should not be less than 8 cm.

(7) Whenever the conduits are buried under plaster, the conduits must be screwed to the wall behind first so that it may not become loose later.

(8) The conduit must be well painted even if it is galvanized before burying it under plaster.

(9) Wooden or ebonite bushes should be used whenever the wires enter or leave the conduit, while brass bushings may be used when leading into the building from overhead lines.

(10) If the current is alternating, conductors of opposite polarity should be bunched together so that the sum of current through that length of the conduit will be zero at any instant, otherwise eddy currents may be induced in the conduits which will heat them up.

(11) It is always advisable to use only one size of conduits even if the parts of run of conduits be duplicated or if the conduit is to carry much less number of wires than its carrying capacity.

(12) The conduit must be electrically continues and effectively connected to earth.

(13) Contact of the conduits with the metal work should be avoided and conduits should be kept away from gas and water pipes.

8. Installation of Conduit Wiring. The conduit wiring is undoubtedly the best wiring system. It has attained much importance for interior wiring installations. The conduits used may either be non-metallic (such a fibre, plastic or alkathine etc.) or metallic. The metallic conduits may further be subdivided into ferrous or non-ferrous. The non-ferrous conduits may either be of aluminium or of copper. The ferrous conduits are made of mild steel ; in its appearance it is similar to that of a water pipe, but they differ from it, in the sense that conduits are annealed to permit easy bending. They are specially treated during manufacture so as to have high degree of corrosion resistance. In general the conduits can be classified as :

(*a*) *Thin wall conduits.*
(*b*) *Rigid conduits.*
(*c*) *Flexible conduits.*

9. Thin Wall Conduits. Such conduits are further subdivided into :

(*a*) *Close joint conduits.* These are made out of light gauge steel strips, bent so as to form a tube. There is no mechanical adhesion between its two edges. It is the cheapest form of conduit, and provides only mechanical protection and covers risk against fire. Such conduits are not recommended for quality work.

(*b*) *Brazed conduits.* Such conduits are also made similar to that of close-joint conduits, but the ends of the steel tubing are brazed together which makes the conduits damp-proof. If has the greatest disadvantages that the brazing material is left projecting inside the tube which makes drawing in of the wires impossible.

10. Rigid Conduits. Such conduits are made out of a heavy gauge steel and the tube edges are electrically welded, so they are named as *heavy gauge welded conduits.*

There is another form of rigid conduit called as *Solid drawn conduit.* Such conduits are drawn from solids and have no joint throughout its section. They are the heaviest and the best, although a bit costlier.

These are available in about 3-metre lengths and are threaded at the two ends. The threads are usually tapered and are provided with a coupling on one side similar to that of plumbing pipe coupling. They can be joined together to form one continuous run. The rigid conduit is shown in Fig. 3.11.

Rigid Conduit
Fig. 3.11

While manufacturing conduits, care is taken to remove all burrs, scale and other rough spots from inside of the conduit to avoid damage to the insulation on the wires. This also makes pulling in of the wires and cables easier.

There are two general types of finishes in which conduits are available. They are :

(*a*) black enamelled.

(*b*) galvanized.

The black enamelled conduits have a coating of black enamel, baked in a heating furnace, so that it may not peal off easily. The "galvanized conduits" have a coating of zinc which is usually applied by hot dipping process.

The black enamelled conduits should be used only in doors. Their use should be avoided where the location is damp and where they are liable to face acid fumes, and salt sea water atmosphere. *Table 3.3 gives the maximum number of wires which can be accommodated in different sizes of conduits.*

11. Flexible Conduits. The flexible conduits are made from galvanized steel strips, specially wound upon each other.

There are three types of flexible conduit :

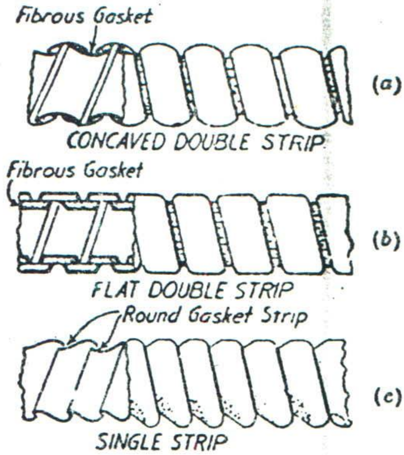
(*a*) *Concaved double strip.* It consists of concave-shaped steel strips spirally wound one upon the other as shown in Fig. 3.12 (*a*). To make the conduit moisture-proof a gasket is provided in between the strips.

(*b*) *Flat double strip.* The construction of this type of flexible conduit is similar to that in (*a*) except that the strips are flat as shown in Fig. 3.12 (*b*).

Table 3.3

Maximum Capacity of Conduits for the Drawing in of V.I.R. Cables

Size of Conduits		$\frac{3}{4}$ in. 19.0 mm.		1 in. 25.4 mm.		$1\frac{1}{4}$ in 31.8 mm.		$1\frac{1}{2}$ in 38.1 mm.		2 in. 50.4 mm.		$2\frac{1}{2}$ in. 63.5 mm.	
		Maximum Number of Cables											
Size of Cable													
No. and dia in mm.	Normal cross-sectional area in sq. mm.	250 V	660 V	250 V	660 V	250 V	660 V	250 V	600 V	250 V	660 V	250 V	660 V
1/1.12	1.0	6	4	10	9	14	12	...	...	...	...	...	...
3/0.736	1.25	6	4	10	9	14	10	...	...	...	...	...	...
1/1.40	1.5	5	4	10	8	14	9	...	...	...	...	...	...
3/0.925	2.0	5	3	10	6	14	8	...	...	...	...	...	...
1/1.80	2.50	4	2	6	5	10	7	...	8	...	...	...	...
7/0.736	4.5	4	...	6	4	10	6	...	7	...	...	...	...
1/2.80	6.0	2	...	4	3	8	5	...	6	...	...	...	...
1/3.55	10.0	...	...	3	2	5	4	6	4	...	8	...	...
7/1.70	16.0	...	...	2	2	4	3	5	3	...	7	8	...
19/1.32	25.0	...	...	...	...	3	2	4	2	...	6	7	...
7/2.24	25.0	...	...	...	...	2	...	3	...	5	5	6	...
19/1.60	4.0	...	...	...	...	...	...	...	...	3	3	...	4
7/3.0, 19/1.80	5.0	...	...	...	...	...	...	...	...	2	2	...	2



Flexible Conduits
Fig. 3.12

(c) *Single strip.* This type of flexible conduit is made from a single galvanized steel strip. Such strips are interlocked as shown in Fig. 3.12 (c). These conduits may also be gasketed.

Usually the double strip conduits are preferred to single strip conduits since :

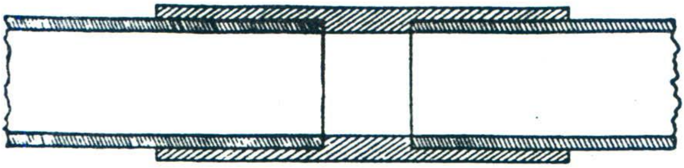
(1) they are more flexible ;
(2) they are smoother from inside.

The flexible conduits are available in lengths up to 250 metres, so no couplings are required and hence no threading. Since the conduits are flexible and are easily bent, no elbows are required. The flexible conduits have advantageous application in installations where a certain amount of flexibility is required, *i.e.* with motors having sliding bases. However, the flexible conduit is costlier than the rigid conduit. Moreover it is not satisfactory in damp places as the moisture is liable to enter into the conduit. So embedding of such conduits into the concrete is avoided.

12. The Conduit Accessories. The general accessories required for the conduit installations are given in the following articles.

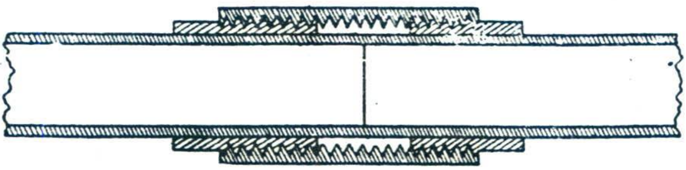
13. Couplings. Since the conduits are available in smaller lengths, so to obtain a continuous length of the conduit the two are coupled together by means of coupling. For the three types of conduit (thin, rigid and flexible) different type of couplings are required.

(*i*) **Thin wall conduit coupling.** The thin wall conduits cannot have threads, so coupling cannot be done in an ordinary way. There are two methods by which two conduit lengths can be joined together. The first method is by means of a *slip socket joint* in which case the two ends of the conduits are slipped inside a socket which is provided with collars against which the two ends butt. But this form of joint is not recommended as it does not provide a better electrically continuous joint. The joint is shown in Fig. 3.13.



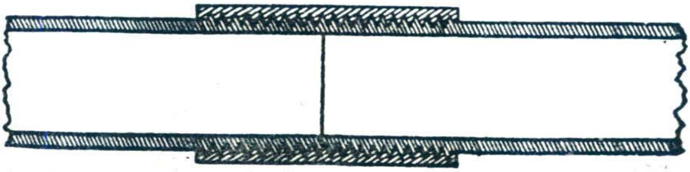
Slip socket joint
Fig. 3.13

The second type of thin wall conduit coupling is the *watertight coupling*. It consists of a slip socket similar to that of the previous method, but each end of this socket is provided with male threads and possess compression rings as shown in Fig. 3.14. A gland nut is screwed at the top of this socket which compresses the compression ring, thus tightly clamping the two ends of the conduit.



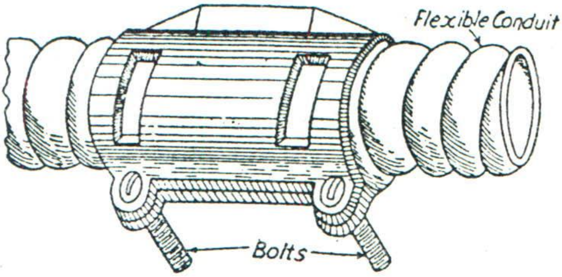
Slip socket with a gland nut at the top
Fig. 3.14

(*ii*) **Coupling for rigid conduits.** The rigid seamless or welded conduits can be joined by means of a screwed socket as shown in Fig. 3.15. Such coupling is similar to that of water-pipe couplings.

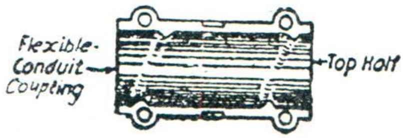


Rigid conduit coupling
Fig. 3.15

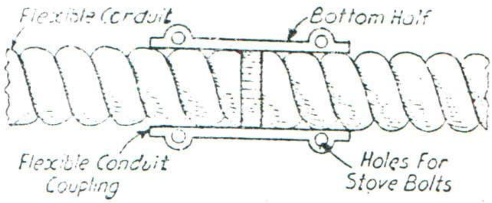
(*iii*) **Flexible conduit coupling.** Usually for such types of conduits slip couplings are used. The split coupling may have two or four screws. Fig. 3.16 (*a*) shows a two-screw coupling, while Figs. 3.16 (*b*) and (*c*) show the upper and lower parts of the fourscrew type flexible conduit coupling.



Two screw flexible coupling
(*a*)



Top half of the flexible coupling
(*b*)



Bottom half of the flexible coupling
Fig. 3.16 (*c*)

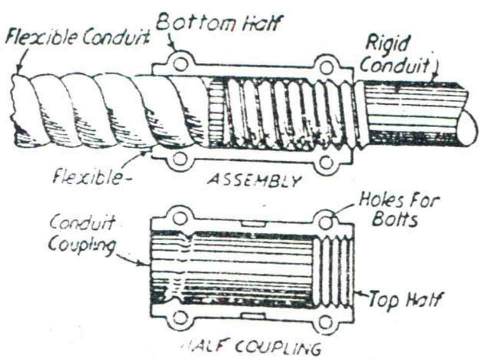


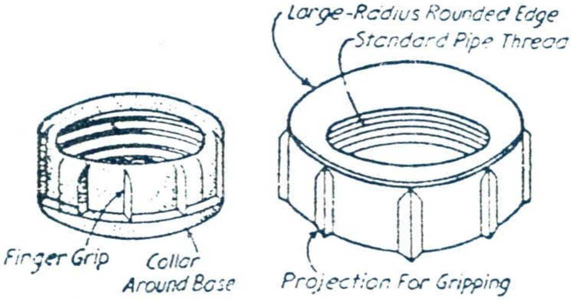
Fig. representing a joint between a rigid conduit and a flexible conduit
Fig. 3.17

When a flexible conduit is to be connected to a rigid conduit, a combination coupling is used. The combination coupling is similar to that of a split coupling with 4 screws, but one end of such a coupling is provided with threads for rigid conduit coupling, Fig: 3.17 represents such type of coupling.

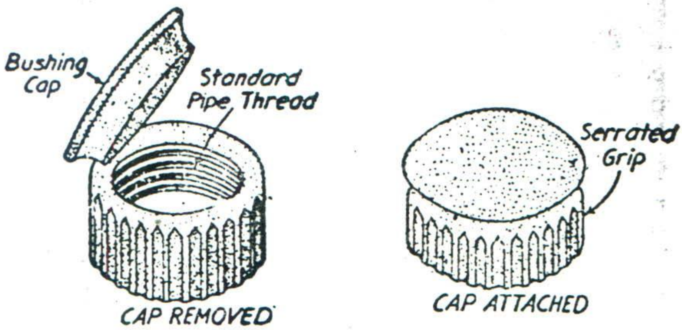
14. Elbows. The change of direction in conduit wiring is always made by means of an elbow which provides a 90° bend. Since the wires are to be pulled through the conduits after installation, it is necessary that the radius of the bend must be about 6 times the internal diameter of the conduit. Usually the standard L's are available in the market, but it is always a practice to bend the conduit at the site by means of hickey or by hand in pipe vice. The offset due to ells is always more than the radius as shown in Fig. 3.18. While cutting conduits, care must be taken to allow for this offset. Since this offset is not the same for all sizes of conduit L's, the usual practice adopted is not to cut the conduit until the L is fixed to the job.

Elbow
Fig. 3.18

15. Conduit Bushings. These are used when the rigid conduit enters the conduit box or when the conduit enter a hole which is not threaded. It is either made from a malleable iron or from a formed sheet steel. The bushings serve a double purpose. Firstly it prevents the insulation on the cables from being peeled off due to rubbing against the sharp edges of the conduit when they are pulled in ; secondly it helps in securing the rigid conduit to conduit box when no locknut is placed on the inside of the box. Fig. 3.19 shows the two types of bushings used. Generally the collarded bushing is used since it covers the hole in the board.



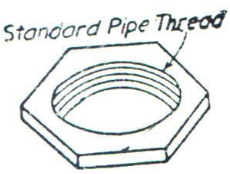
Bushings
Fig. 3.19



(a) Collarded Bushing (b) Bushing with cap

Fig. 3.20

There is another closed type of bushing which is used during the construction of the building. Such type of bushing is provided with a cap as shown in Fig. 3.20. It prevents the moisture entering the conduit system during construction.

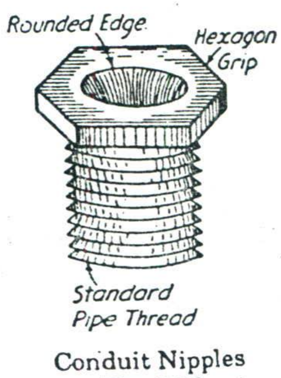


Locknut
Fig. 3.21

16. Locknuts. When the conduit enters a box, it is necessary that the locknut should be screwed on the conduit as it makes the connection to the box rigid and electrically continuous. The locknuts are punched out of thin steel sheets shown in Fig. 3.21. The locknuts are either hexagonal or octagonal.

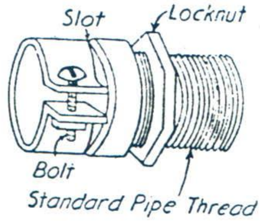
17. Conduit Nipples. The nipples serve the same purpose as that of conduit bushing.

Similar to the bushing, it has a smooth inner surface and are used for providing a coupling to the conduit bore. Conduit nipple is shown in Fig. 3.22. The nipples are rarely provided because the system becomes costlier.



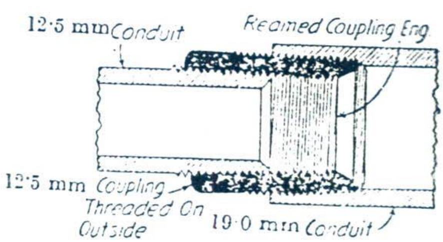
Conduit Nipples
Fig. 3.22

18. Box Connector Bushings for Flexible Conduits. Fig. 3.23 represents the bushing to be used when the flexible conduit enters the box. The connectors so used are usually made of cast iron, one end of it clamps the flexible conduit while the other threaded end enters the bore where it is fixed to the box with the locknut.



Box connector bushings for flexible conduits
Fig. 3.23

19. Conduit Reducers. The reducers are used when the size of the conduit is changed in between the wiring system. The conduit reducers are similar to that of steam and water-pipe reducer. Fig. 3.24 shows a reducer changing a 19.0 mm conduit pipe to 12.5 mm conduit pipe. In practice the size of the conduit used in one building is not changed.

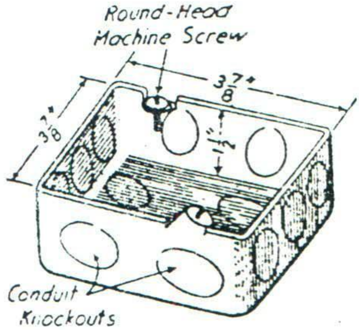


Conduit reducer
Fig. 3.24

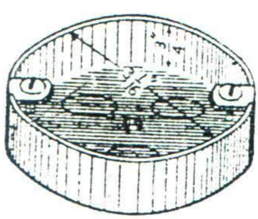
20. Conduit Box. The rigid conduits are always terminated at outlets into a box. There are different types of boxes ; it may be round, square or octagonal. The depth of the box may be $\frac{3}{4}$" to $1\frac{1}{2}$".

The boxes always have knockouts punch out at the time of manufacture as shown in Fig. 3.25 and are held there by small sections of knockouts : these knockouts are removed by hammering, or with the twist motion of the pliers or a blunt tool. The conduit boxes are also called as outlet boxes since they are usually used for outlets. The boxes are provided with a cover held by screw on it.

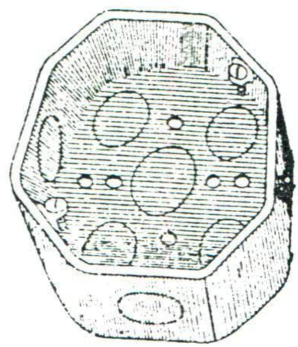
After removing the knockout the conduit is attached to it by means of the locknut and bushing. Care should always be taken not to remove the knockout until and unless it is to be used; if the knockout is removed, it must be sealed. The purposes for which the boxes are used are underlined :



Square conduit box
(*a*)



Round conduit box
(*b*)



Octagonal conduit box
(*c*)

Fig. 3.25

(*i*) to provide connections for lights, fan, heaters etc. in which case they are called as outlet boxes ;

(*ii*) to facilitate the pulling of conductors in the conduits and are known as inspection boxes ;

(*iii*) to house the junctions of the conductors and are known as junction boxes ;

(*iv*) to provide snap switches.

Figs. 3.26 (*a*), (*b*), (*c*) represent the method of fixing the rigid conduit to the outlet box.

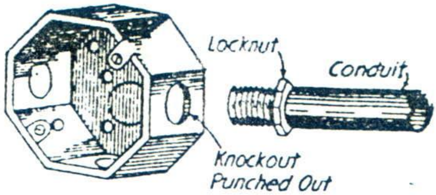


Fig. representing the conduit box and the conduit
(a)

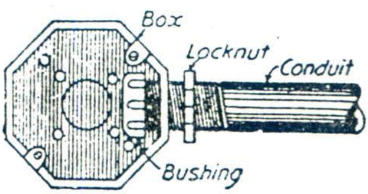


Fig. representing the conduit fixed to the box with the bushing in position
(b)

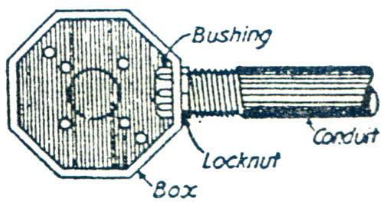


Fig. representing the locknut tightened with the box.
(c)

Fig. 3.26

It should be noted that if the conduit to be fixed to the box is cut too long, two locknuts are provided, one inside the box and the other out.

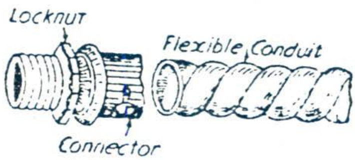
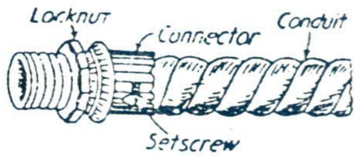


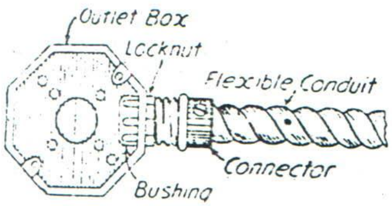
Fig. representing the connector and the flexible conduit
(a)



Conduit fixed to be connector with the help of screw
(b)

Fig. 3.27

Figs. 3.27 (a), (b), (c) represent the method of connecting flexible conduit to the outlet box with the help of a conductor.



The connector and conduit assembly is inserted into the box and the lock-nut inside the box is provided

(c)

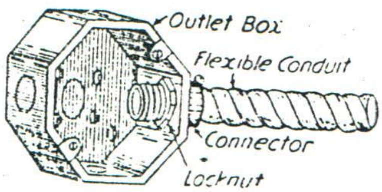
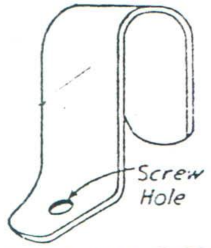


Fig. representing the complete assembly with the bushing

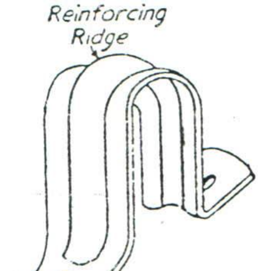
(d)

Fig. 3.27

21. **Conduit Saddles or Conduit Clamps or Conduit Straps.** The conduit straps or saddles are used to fix the conduit to the wooden plugs in the wall. The conduit saddle may have one or two holes as shown in Fig. 3.28. All such saddles are made from sheet steel.



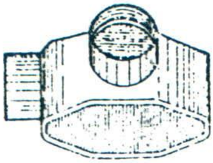
(a)



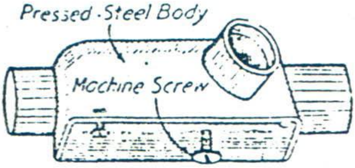
(b)

Conduit saddles
Fig. 3.28

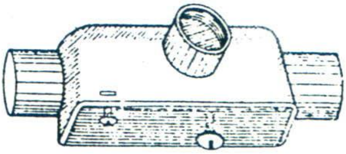
22. **Conduit Fittings.** The conduit fittings are similar to that of a box ; but the difference lies only in the method of fixing the conduit to these. The conduit fittings have productions as shown in Fig. 3.29 and have female threads. The use of boxes are generally limited to the concealed type wiring as the conduit fittings are rarely used for that, but for the surface work both fittings and boxes can be used.



Octagonal outlet fitting
(*a*)



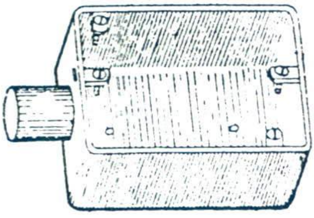
Rectangular outlet fitting
(*b*)



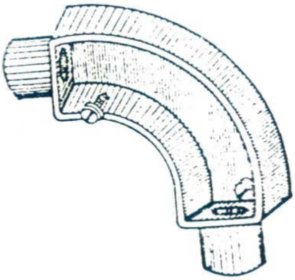
Another type of rectangular fitting
(*c*)

Fig. 3.29

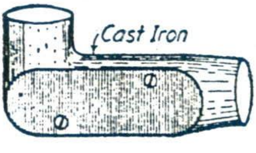
Long pull-out fitting
(*d*)



Switch outlet fitting
(*e*)



Pull-out rectangular bend fitting
(*f*)



Another type of rectangular pull-out fitting.
(*g*)
Fig. 3.29

For pulling the conductors into the conduits special fittings called 'pull outlet fittings' are used.

23. Finishing Wires Through Rigid Conduits. Before discussing the method of wiring rigid conduits, it should be remembered that the conductors or wires should not be run into them until and unless the whole of the mechanical works in the building are completed. The drawback in running of wires before such works completed is that there is a possibility of any nail etc. being driven into the conduit which would spoil the insulation.

Thus no conduit is wired until the complete running of the conduit is completed and the building has reached the water-tight stage.

There are two methods of installing conductors in the conduit runs, namely,

(1) Pushing. (2) Drawing.

In the *pushing method* the wires are pushed into the conduits from one end of the outlet by exerting manual pressure on them but this method is practicable only when the conduit runs are small and straight. In the *drawing* method the wires are pulled through the conduit with the help of a wire. Such a method of drawing the wires is also called "*fishing*".

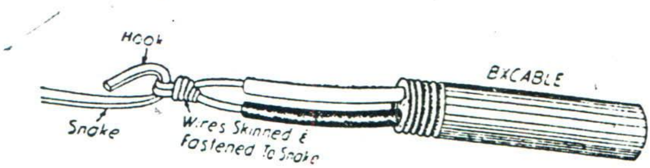


Fig. 3.30

The wire snake consists of a flat steel wire $\frac{1}{8}$" or $\frac{3}{16}$" thick which is rounded off at one end to form a hook as shown in Fig. 3.31. For making the hook, the snake wire is heated at one end by means of blow lamp and is bend into shape with the help of pliers. For drawings in, the wires are skinned and fastened to the snake hook as shown in Fig. 3.31. It is advantageous to provide a friction tape over the connection.

There are two methods of fishing the wire in conduits :

(*i*) One-way fishing. (*ii*) Two-way fishing.

In case of one-way fishing, only one snake wire is used for pulling the wires ; but where the conduit runs are very long and have a number of bends close together, those require two-way fishing *i.e.* two snake wires are pushed in, one from each end of the conduit. The wires in the conduit are so manipulated that their hooked ends engage each other. Then one of the wires is pulled through the conduit. Usually it is a job of two men, in order that the wires may engage easily, one of the workers shakes and rattles it while the other worker tries to get it engaged with the other snake wire.

In fishing operation care must be taken that :

(*i*) there should not be any kink or bend in the wire entering the conduit.

(*ii*) the wires in the conduit should not cross.

24. Conduit Cutting, Threading and Bending. The methods have already been explained in Chapter I while dealing with the Tools.

25. Comparison of Various Wiring Systems. To decide which type of wiring should be used for a particular job much depend upon the experience of the designer and the prevailing circumstances. There are no hard and fast rules regarding the best wiring system. Comparative statement given in Table 3.4 can well guide one in the selection of proper type of wiring to be adopted,

Table 3.4

S. No.	*Particulars*	*Cleat wiring*	*Wooden casing capping*	*T.R.S.*	*Lead sheathed*	*Conduit wiring*	*Remarks*
1.	Life	Short	Fairly long	Long	Long	Very long	
2.	Cost	Low	Medium	Medium	Medium	High	
3.	Mechanical protection	None	Fair	Good	Poor	Very good	
4.	Possibility of fire	Nil	Good	Fire resisting	Fair	Nil	
5.	Protection from dampness provided	None	Slight	Good	Good	Poor	
6.	Type of labour required	Semi-skilled	Highly skilled	Skilled	Skilled	Highly skilled	
7.	No. of points which can be installed per day by an electrician with a male	4	3	3	3	2	Average

TYPICAL QUESTIONS

1. What are the various types of conduit used ?
2. How is the conduit cut and threaded ?
3. What is the use of offset and how is it obtained ?
4. How is the flexible conduit fixed to the conduit box ?
5. What do you understand by fishing wires through rigid conduit ?
6. What is the difference between a conduit box and a conduit fitting?

4

Lighting Accessories

1. Introduction. 2. Switches. 3. Surface Switches. 4. Flush-Switches. 5. Pull Switches or Ceiling Switches. 6. Grid Switch. 7. Architrave Switch. 8. Rotary Snap Switch. 9. Push button Switch. 10. Iron-clad Water-tight Switch. 11. Industrial Iron-clad Switch. 12. Quick Break Knife Switch. 13. Lamp Holders. 14. Switch Bayonet Cap Lamp Holder. 15. Small Bayonet Cap Holder. 16. Goliath Edison Screw Lamp Holder. 17. Medium Edison Screw Lamp Holder. 18. Porcelain Lamp Holders. 19. Swivel Lamp Holder. 20. Fluorescent Lamp holders and Starter Holders. 21. Ceiling Roses. 22. Mounting Blocks. 23. Socket Outlet. 24. Plugs. 25. Terminal Block. 26. Appliance Connection. 27. Main Switch. 28. Splitter Units. 29. Distribution Fuse Boards. 30. Neutral Link.

1. Introducticn. Under the heading of Lighting Accessories, come the switches, lamp-holders, ceiling roses, socket outlets, plugs etc. ; their different types will be discussed here.

2. Switches. A switch is used to make or break the electric circuit. It should so operate that it must make the circuit firmly, and under some abnormal conditions, it must retain its rigidity and keep its alignment between switch blades and contacts correct to a fraction of a cm. At the instant of breaking the switch, it should break the current so that there is no formation of an arc between the switch blades and contact terminals. The disadvantage of formation of an arc is that it burns or damages the switch contacts. Such an arc is avoided usually by means of providing a spring to movable blade so as to have a quick action. Further the switch used must have a base mechanically strong, capable of holding the parts together and must have high insulation resistance.

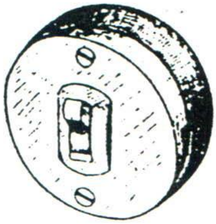
The following are the various types of switches which can be classified as :

(*a*) Surface switches or Tumbler switch.
(*b*) Flush switches.
(*c*) Pull switches or Ceiling switches.
(*d*) Grid switches.
(*e*) Architrave switch.
(*f*) Rotary snap switch.

(*g*) Push button switch.
(*h*) Iron-clad water-tight switch.
(*i*) Industrial iron-clad switch.
(*j*) Quick break knife switch.

3. Surface Switch or Tumbler Switch. The surface switches are those which are mounted on the mounting block directly fixed over the surface of the wall, *i.e.*, such types of switches project out of the surface of the wall. The surface switches can be classified as :

Fig. representing 5 Amp single-way surface switch without cap with moulded box
(*b*)



5 Amp single-way switch with cap
(*a*)

Fig. 4.1.

(*i*) *Single-way Switch.* Fig. 4.1 (*a*) represents the single-way switch while the adjoining Fig. 4.1 (*b*) shows the switch with cover removed while Fig. 4.2 (*a*) and (*b*) represent switches with metal cap porcelain base. The cover when fixed with two screws does not

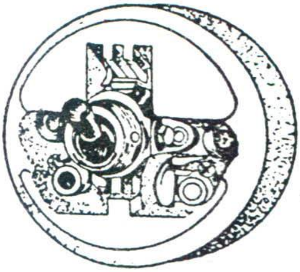
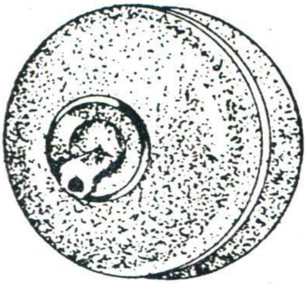


Fig. representing 5 Amp single-way surface switch with porcelain base
(*a*)



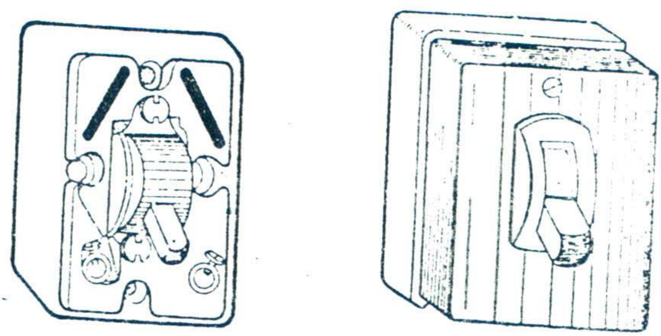
The porcelain based switch with a metal cap
(*b*)

Fig. 4.2

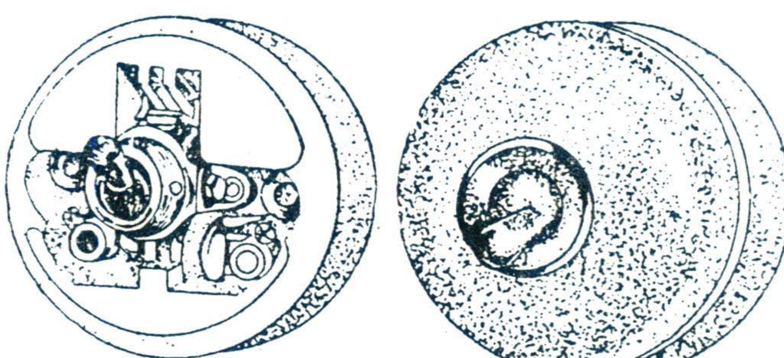
rotate. Such a switch is usually provided with a single pole, with robust contacts having a quick make and wipe action and has a wide separation. Each switch movement is mechanically linked to the dolly. Fig. 4.3 represent an oblong switch which again has a porcelain base and moulded dolly and cover.

Fig. 4.4 represents a single-way heavy duty 15 Amp switch. Such switches are required for power circuits, where more than 5 Amp current flows.

(*ii*) *Two-way Switch.* The two-way switches are used for wiring circuits which are to be controlled from two points independently. Such switches are represented in Fig. 4.2 (*a*) and (*b*).



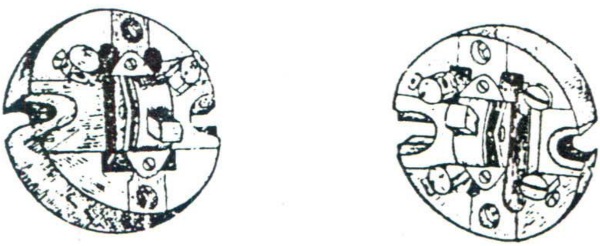
5 Amp Oblong switch
Fig. 4.3



Single-way 15 Amp heavy duty switch
Fig. 4.4

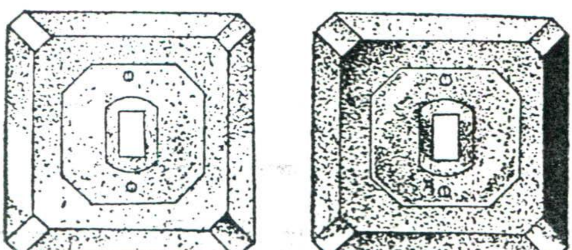
Two-way Switch
Fig. 4.5

4. Flush Switches. The flush switch as is clear from its name is fixed in flush with the wall and it does not project out. Such type of switches is used where high quality performance and appearance are desired. In it, all current carrying parts are mounted on high grade vitreous porcelain enclosed in an iron box recessed into the wall. Figs. 4.6 (*a*) and 4.7 (*a*) represent 5 Amp single way switch and its cover. Figs. 4.6 (*b*) and 4.7 (*b*) represent 5 Amp two-way switch.



(*a*) Single way (*b*) Two way

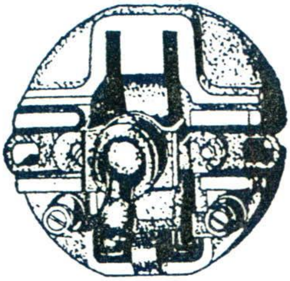
5 Amp Flush Switch
Fig. 4.6



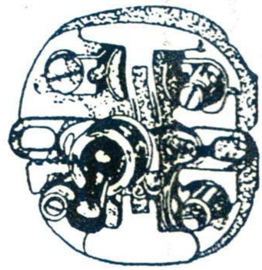
5 Amp Two-way Flush Switch cap (*a*) 5 Amp Two-way switch cap (*b*)

Fig. 4.7

Figs. 4.8 (*a*) and (*b*) represent 15 Amp single-way and two-way switches.

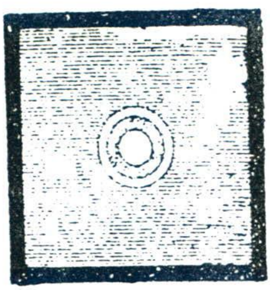


Single-way 15 Amp switch
(*a*)

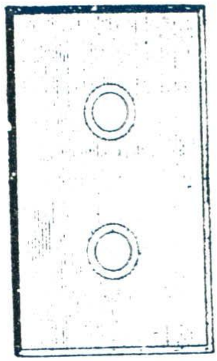


15 Amp Two-way switch
(*b*)

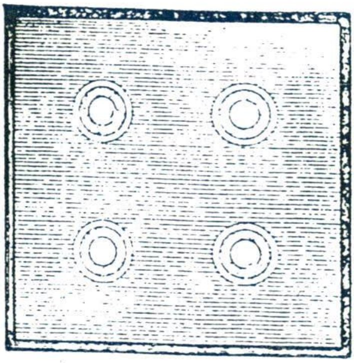
Fig. 4.8



Single-switch plate
(*a*)



Two-switch plate
(*b*)

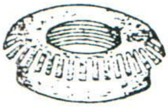


For-switch plate
(*c*)
Fig. 4.9

Figs. 4.9 (*a*), (*b*) and (*c*) represent the flush switch plate for a single-switch, two switches and 4 switches. All switch plates are supplied with suitable switch fixing rings which may either be shallow insulated rings or deep rings as shown in Fig. 4.10. The deep rings designated for use with their appropriate plates will ensure proper fixing in those cases where excessive plaster depths prevent the shallow ring being threaded on to the switches.

Shallow insulated ring (*a*)

Deep insulated ring (*b*)



Standard insulated ring (*c*)

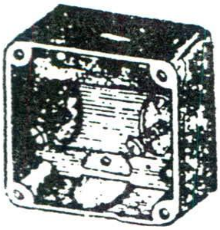
Fig. 4.10

Fig. 4.11 shows the metal backing rings which should be used in those cases where the switches are to be secured to a plate or a panel and is dependent on the fixing ring for support. A metal backing ring placed between switch and back of plate or panel will ensure secure fixing.

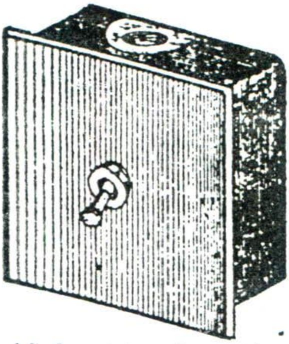
Backing rings

Fig. 4.11

Fig. 4.12 (*a*) shows a cast iron box into which the flush switch is fixed ; while Fig. 4.12 (*b*) represents an assembled view of the switch.



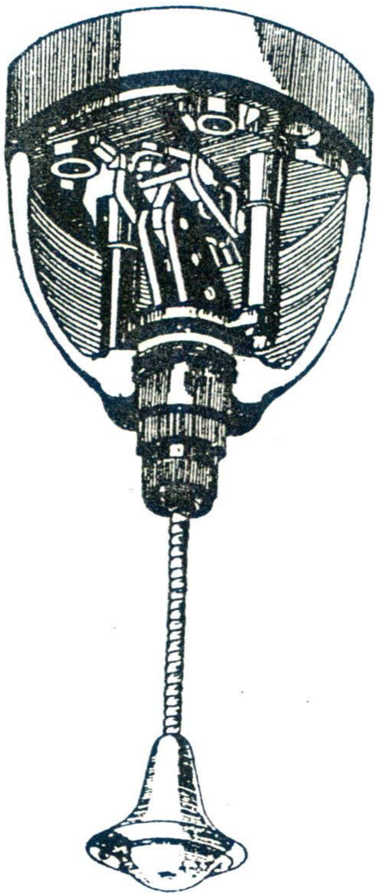
Cast Iron Box (*a*)



Assembled cast iron box with a switch (*b*)

Fig. 4.12

5. Pull switches or Ceiling switches. The pull switches are fixed on the ceiling and all the alive parts are out off reach of the operator. The switch has a strong mechanical action and is usually operated with a single pull on the cord for the on and off position.

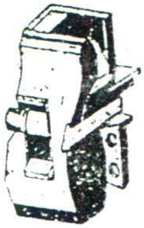


Pull Switch
Fig. 4.13

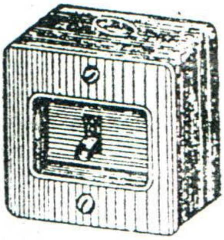
Such switches are most conveniently used in bath rooms (where water heaters are used), bed rooms (where the pull cord is provided near the pillow and restaurants). The only drawback in such a switch is that there is a considerable wear and tear at the point where the cord enters the switch. Such a switch is shown in Fig. 4.13.

6. Grid Switches. The grid switches are similar to that of tumbler switches, except that they are lighter and are portable so for that reason they are quite useful for the portable machines such as hand-drill, portable grinder etc. Such switches have all insulated moulded base and dolly and have a smooth and silent action. They are manufactured either in a single-way or a two-way pattern both for 5 and 15 amperes.

This type of switch can also be used for house wiring as a flush switch for which an iron box is required with an insulated plate. Such an assembly is shown in Fig. 4.14.



Grid switch for grinders etc.
(*a*)

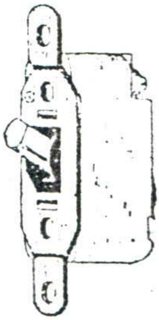


Grid switch for house wiring
(*b*)

Fig. 4.14

7. Architrave Switch. This type of switch is designed for flush mounting on architraves. The switch movement is enclosed in a compact porcelain base to which is fitted a metal mounting plate with 102.5 mm fixing centres. An ivory plate is secured to switch mount by two fixing screws as is represented in Fig. 4.15. Such

Cover plate.

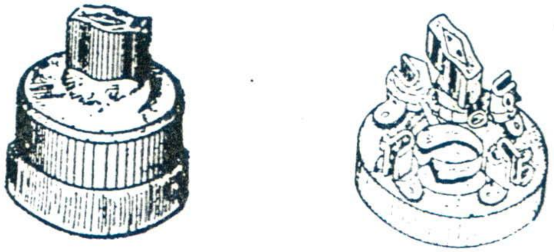


Architrave Switch.

Fig. 4.15

switches are available in one and two-way patterns and they cannot be used without the cover plate.

8. Rotary Snap Switches. The rotary switches are much different from that of ordinary tumbler switch. It consists of an insulated handle to which are fixed the blades. These blades move in steps by the movement of the handle and make contact with the terminals to which are connected the wires in the electric circuits. The handle motion is controlled by a cam or a spring as the handle is moved through a quarter turn, the blade is released and moves over quickly (with the help of spring) to make or break the circuit. Such switches are available in a single or two-way patterns and a two-way switch is shown in Fig. 4.16.

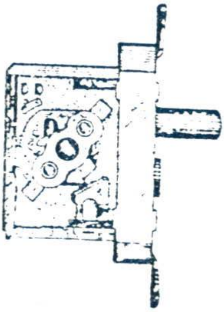


(a) (b)

Rotary switches.
Fig. 4.16

This type of switch is not used for ordinary lighting purpose ; but they are specially used for reversal of small motors, speed controls and for control of circuits or electric ranges of heaters etc.

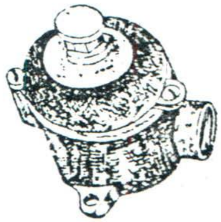
9. Push Button Switch. The construction of push button switch is similar to that of a rotary switch, instead of a number of blades it consists of only one blade. The operation of this switch is



Push botton switch.
Fig. 4.17

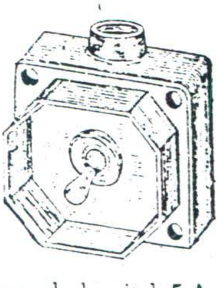
not due to rotary motion; but the blade is given a rocking action by press buttons and its movement is controlled by a cam and a spring thus they open or close with quick motion. Such switches have a special application for starting motors and they can also be used for controlling the lighting circuits such as a light provided in a refrigerator which lights automatically when the door is opened and goes off when its door is closed. This type of switch is shown in Fig. 4.17.

10. Iron-clad Water-tight Switches. Such switches are of cast iron and have very robust construction. A cork gasket is fitted between the case and the cover which makes it water-tight. The switch spindle operates through a packed gland. Its construction is much similar to that of a rotary switch and is represented in Fig. 4.18. Another type of water-tight switch has a similar construction to that of a tumbler switch. Such switches are directly mounted on to conduits.

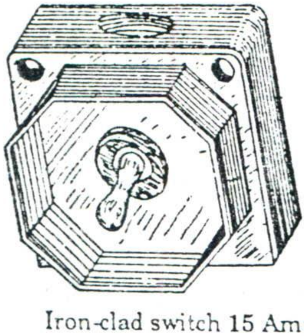


Iron-clad water-tight switch
Fig. 4.18

11. Industrial Iron-clad Switches. The switches to be used in industry must be of heavy duty and they require a robust construction. The ordinary switch is provided with a cast iron cover



Iron-clad switch 5 Amp
(a)

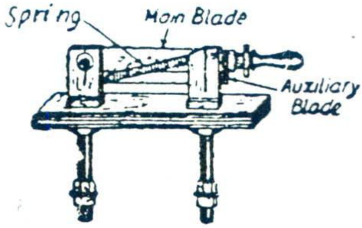


Iron-clad switch 15 Amp
(b)

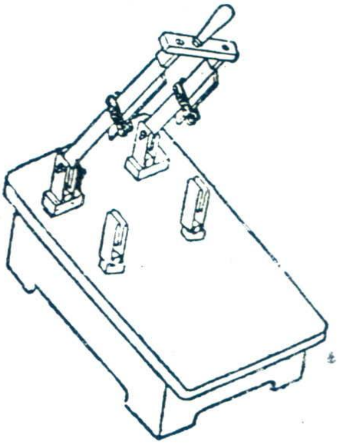
Fig. 4.19

designed to give protection to the nickel plated switch dollies against possibility of damage. This cover is secured to the iron box with the help of four corner screws. Fig. 4.19 (*a*) and (*b*) represent a 5 ampere and 15 ampere, Iron clad-switches respectively.

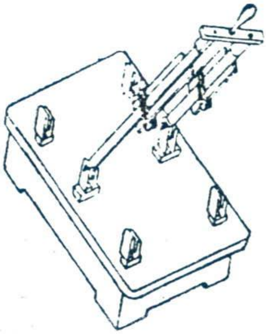
12. Quick-break Knife Switch. The knife switch consists of blades hinged at one end and are arranged to go into forked terminals or jaws at the other end. Each blade consists of one or two or more hard rolled copper bars, the cross-section of which is dependent upon the current to be handled. The hard rolled copper used makes a better contact. At the hinged end spring washers are used. The knife switch assembly is either fixed over an insulating



Single pole knife switch.
(*a*)



2-pole knife switch.
(*b*)

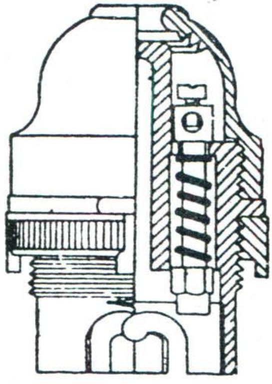


2-pole double throw knife switch.
(*c*)
Fig. 4.20

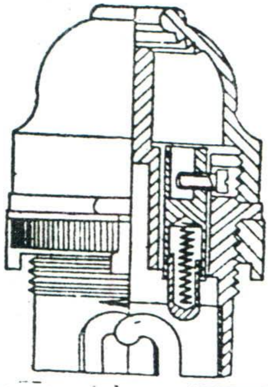
board or on switch board panel. For making connection to the external circuit, the hinged ends and the jaws are connected to the threaded studs at the back as shown.

For making the switch a quick break, the main blade is provided with an auxiliary blade independent of the handle and both these blades are connected by means of a spring. For breaking the circuit, as the handle is moved out, the main blade comes out while the auxiliary blade remains in the clip and maintains connection, but as the handle is moved further out, its puts a tension in the spring which brings out the auxiliary blade out of the clip quickly. Thus the spring provides a quick break action. Knife switches are available as single throw switches or double throw switches. Fig. 4.20 represents the single throw switch. In case of a double throw knife switch, 2 more clips are provided on the other side of the hinged side of the switch as in Fig. 4.20 (*c*).

13. Lamp holders. As is clear from its name a lamp-holder is used to hold the lamp required for lighting purposes. Earlier, brass lamp-holders were quite popular, but now-a-days these have been superseded by the all insulated pattern. A lamp-holder has either moulded or porcelain interior with a solid or spring plunger and easily wired terminals. In case of a solid plunger holder, solid plunger is a one piece construction and the wiring terminal forms an integral part of plunger and thus the current flows directly through this plunger to the lamp. The plunger has an external spring as shown in Fig. 4.21 (*a*). As the wire terminal moves in and out as the lamp is moved out or inserted in, so only flexible wire should be used for wiring.



Sectional view of a solid plunger lamp-holder
(*a*)



Sectional view of a spring plunger lamp-holder
(*b*)

Fig. 4.21

The spring plunger is necessary a two part construction. The spring is inside a barrel to one end of which is a wire terminal and on the other end is a solid contact making contact with the lamp. There is no movement of the wiring terminal as the lamp is inserted into the holder to any suitable V.I.R. wire or flexible wire can be used for wiring. Such a holder is shown in Fig. 4.21 (*b*) Each holder carries a threaded shade carrier ring or holder may be of Home Office pattern ventilated and provided with safety shields. The Home Office pattern lamp-holders are required in bath rooms and places where contact with live parts cause additional risks. The lamp holders can be classified as :

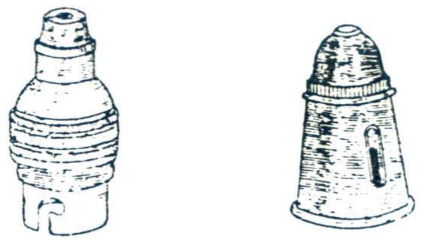
(*i*) *Bayonet Cap Lampholders* which can further be subdivided into

(*a*) Pendant holder or Cord Grip pattern.

(*b*) Batten holder

(*c*) Screwed holder which when used with a bracket is called as bracket holder

(*d*) Water-tight pattern provided with T.R.S. Gland.



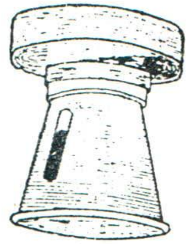
Pendant holders
Fig. 4.22

Standard 3-hole batten holder
(*a*)

Strap two hole batten holder
(*b*)

Fig. 4.23

Angle batten holder
(*c*)



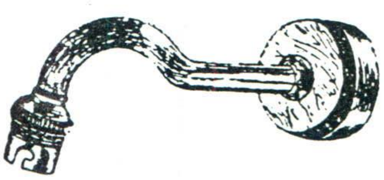
Home office type batten holder
(*d*)

Different types of batten holders
Fig. 4.23

(*a*)

(*b*)

Two types of screwed entry bracket holders
Fig. 4.24



Bracket holder with bracket
Fig. 4.25

Water-tight lamp-holder has got a gland at the top. The gland is moulded with a bush and a rubber grounment which firmly grips the T.R.S. flexible wire.

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*According to Indian Standard 732 clause 5.5 "all lamp-holders to be used on bracket and the like shall have not less than a 1.13 mm nipple and all those for use with flexible pendants shall be provided with corded cord grips. All lamp-holders shall be provided with shade carriers. Where centre contact Edison Screw Lamp-holders are used, the outer or screwed contact shall be connected to the earthed conductor of the circuit.

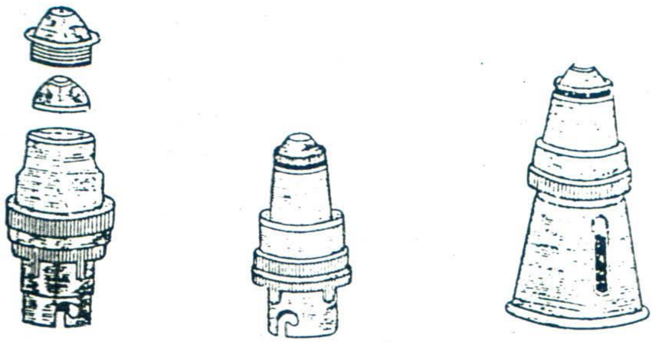


Fig. showing the gland (a) Assembled view of the holder (b) Home office pattern (c)

Fig. 4.26

14. Switched Bayonet Cap Lampholder. The switched bayonet bayonet cap lamp-holder has a bush bar switch and is used only to carry an electric load not exceeding 2 amp. These push bars are non-detachable. The usual types of switch holders are :

(*i*) Pendant holder or cord grip holder.

(*ii*) Screwed lamp-holder.

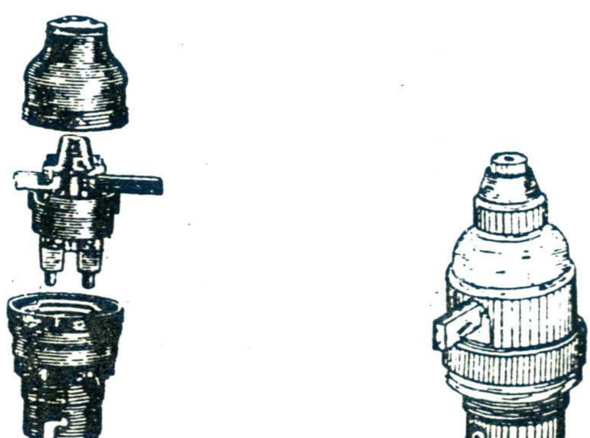
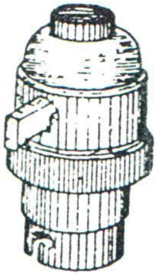
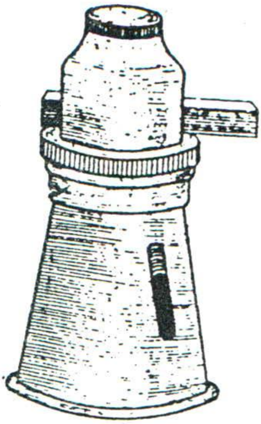


Fig. represents the sectional view of switched bayonet holder. (a) Assembled view of the cord grip type Pendant holder. (b)

Fig. 4.27



Screwed lamp-holder
(*c*)



Screwed lamp-holder Home office pattern
(*d*)

Fig. 4.27

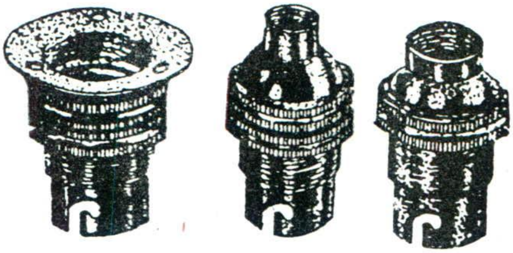
15. Small Bayonet Cap Holder. The small bayonet cap holders possess all the features of larger patterns. They are again of :

(*i*) Cord grip type.

(*ii*) Batten type.

(*iii*) Screwed pattern.

They are designed for carrying small sizes of lamps.



Small bayonet cap holders
Fig. 4.28

16. Goliath Edison Screw Lampholders (Brass). Such holders are useful for the lamps having wattage beyond 300 W, the maximum range the lamps with which they can be used is 1,500 W Fig. 4.29 (*a*) and (*b*) represent cord grip type and screwed entry type Screwed Lamp-holders respectively.

(a)

(b)

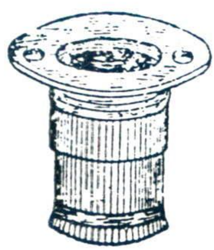
Goliath Edison Screw Lamp-holders
Fig. 4.29

17. Medium Edisbon Screw Lamp holders (Brass). Such holders are used with the screwed type lamps upto 200 watts, 250 volts. The different types of such holders are shown in Fig. 4.30.

They are :

(*a*) Cord grip type.
(*b*) Batten type and
(*c*) Screwed Entry Pattern.

Cord Grip type
(*a*)



Batten type
(*b*)

Screwed entry type
(*c*)

Fig. 4.30

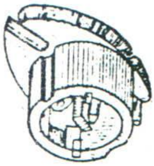
It will be quite to the point to mention that :

According to Indian Standard 732, clause 5.8, all incandescent lamps unless otherwise required shall be hung at a high of 2.5 m (8 ft.), above the floor level. They shall be provided with a cap holder of the following patterns upto and including 200 watts–Standard Bayonet.

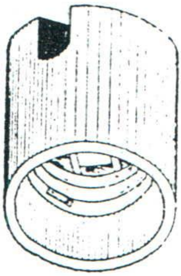
Above 200 watts and exceeding 200 watts–Edison Screw.

Above 300 watts–Goliath Screw.

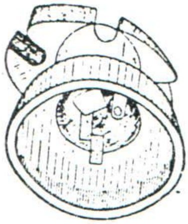
18. Porcelain Lampholders. The porcelain lamp-holders are designed for batten lampholders in Bayonet Cap Edison Screw



Bayonet cap holder without skirt
(*a*)

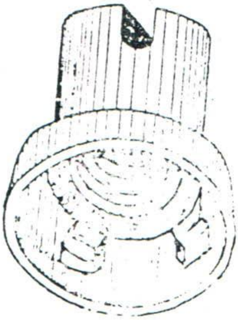


Bayonet cap holder with skirt
(*b*)



Goliath Edison screw lamp holder without skirt
(*c*)

Goliath Edison screw lamp-holder with skirt
(*d*)



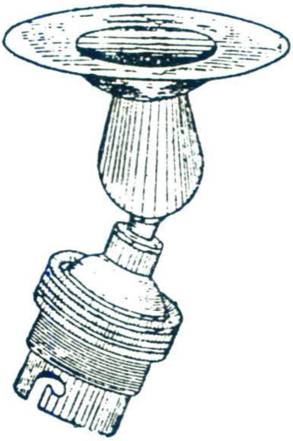
Edison screw lamp-holder without skirt
(*e*)

Edison screw lamp-holder with skirt
(*f*)

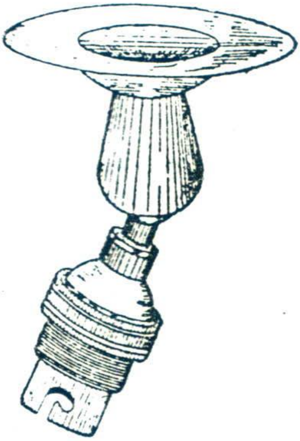
Fig. 4.31

patterns with or without skirts. The bayonet cap lamp-holders are fitted with spring loaded brass plungers while the Edison Screw lamp-holders have spring loaded central contacts to ensure efficient contact pressure. Figs. 4.30 and 4.31 represent the different types of lamp-holders.

19. Swivel Lamp-holders. The swivel lamp holders are designed for controlled wide angle directional lighting which are used for lighting of shop windows, show cases etc. It consists of a ball and socket joint fitted between back plate and lamp-holder. Such a joint is separately shown in Fig. 4.32 (*c*). The swivel lamp-holders are available in bayonet cap type, small bayonet cap type and Edison screw type. All the three types of holders are further available for wall fixing pattern or ceiling pattern.



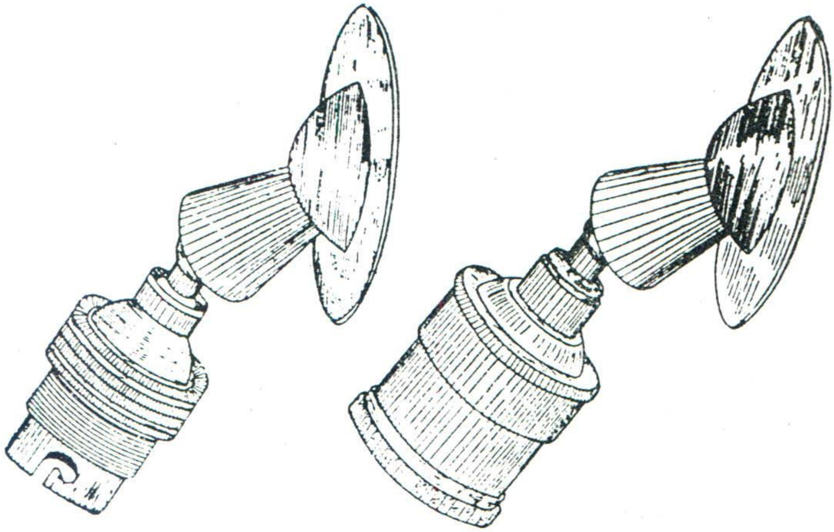
Swivel lamp batten holder
(*a*)



Miniature swivel lamp-holder
(*b*)

Ball and socket joint
(*c*)

Fig. 4.32

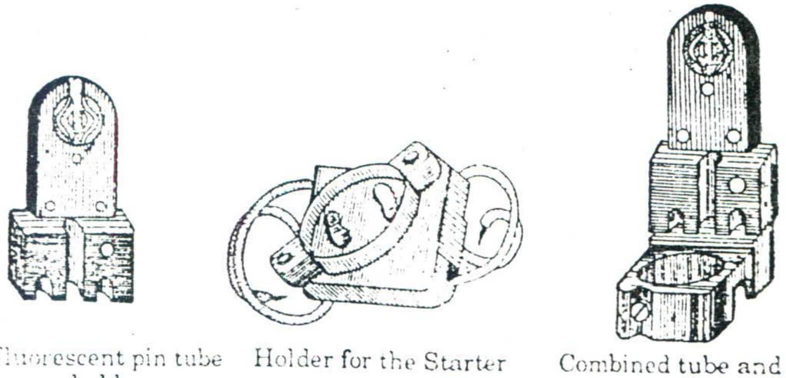


Angle swivel lamp-holder
(*d*)

Edison screw swivel holder
(*e*)

Fig. 4.32

20. Fluorescent Lamp-holders and Starter holders. The fluorescent holders are either of bi-pin type or of bayonet cap type, but pin type holders are generally used for ordinary fluorescent tubes, Fig. 4.33 represents a holder for the starter and the twist turn contact holder of the tube, while Fig. 4.33 (*c*) represents a combined holder for the tube as well as for the starter.



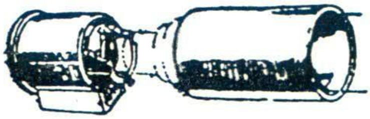
Fluorescent pin tube holder
(*a*)

Holder for the Starter
(*b*)

Combined tube and Starter holder
(*c*)

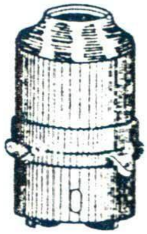
Fig. 4.33

The holder for bayonet caped tube is shown in Fig. 4.34 for easy fitting of the tube, the holder is provided with a lead in guide.



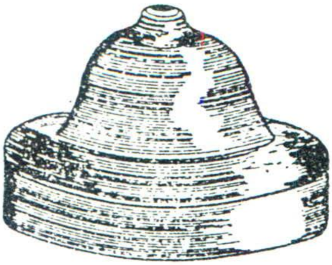
Bayonet caped tube
Fig. 4.34

21. Lamp-holder Adopter. The lamp-holder adopters are used for tapping temporary power for small portable electric appliances from lamp-holders. Although such a practice is not advised. In no case the electric appliance energized by this method is permitted in bathroom or other damp places. A bayonet lamp-holder adopter with oval contacts similar to that of an electric lamp is as shown in Fig. 4.35.

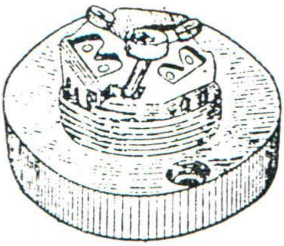


Adopter
Fig. 4.35

22. Ceiling Roses. The ceiling roses are used to provide a tapping to the pendant lamp-holder through the flexible wire or a connection to a fluorescent tube. The ceiling rose consists of a circular porcelain or bakelite base provided with 2 or 3 terminal plates (according to the type of ceiling rose whether it is a 2-way or a 3-way), which are separated from each other by a porcelain or bakelite bridge. Each of the terminal plate is provided with metallic sleeve and a binding screw on one side through which circuit wire from the back via mounting block enters the ceiling roses, on the other side of the terminal plate is provided with a washer and a clamping screw for making connection to the flexible wire. The insulating bridge is provided with holders through which the flexible wire is passed through first before making connection to the terminal plate. Such a construction avoids the supporting of the load of the lamp-holder flexible wire and lamp by the connecting terminal plate. To the threaded base is fixed a porcelain or bakelite cover as shown in Fig. 4.36.



Cover
(*a*)



Base
(*b*)

(*c*)
Fig. 4.36

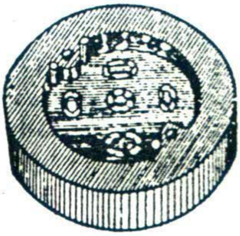
According to Indian standard 732-5.1.

(a) A ceiling rose of any other similar attachment shall not be used on a circuit, the voltage of which normally exceeds 250 volts.

(b) Normally only one flexible cord shall be attached to a ceiling rose. Specially designed ceiling roses shall be used for multiple pendants.

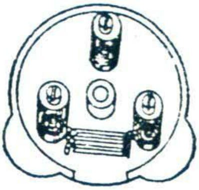
(c) A ceiling rose shall not embody fuse terminal as integral part of it.

23. Mounting Blocks. According to I.S. 732 clause 5.10, all the surface mounting accessories such as ceiling roses, batten lamp holders, surface switches, ceiling switches etc., are used in conjunction with wooden mounting block. For fixing the accessory on the mounting block, it is placed centrally over the block, its binding screws used to connect accessory with the main circuit wire are slacked and through these metallic sleeves pricks are made into the wooden block. Then the accessory is removed and holes of 6 mm or more are drilled into the block for the entry of the wire. The rough edges of the holes made are cleaned with a file. For fixing the block over the wall or ceiling two holes are so drilled and made countersunk so as to over these with the base of the accessory fixed over it. The cable is drawn in for a sufficient length through these holes made earlier, which can again be pushed in after making connection to the accessory. Then the wooden block is fixed to the wall with the help of the two countersunk wooden screws.

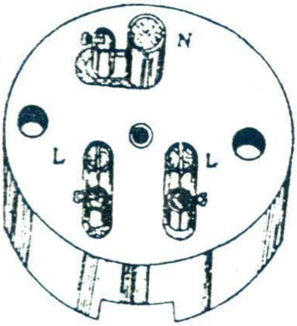


Wooden mounting Block
Fig. 4.37

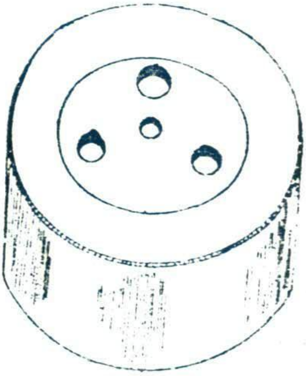
24. Socket Outlets. The socket outlets have all-insulated base with moulded or socket base having 3 terminal sleeves. *The two thin terminal sleeves are meant for making connection to the cable, with the third terminal sleeve, thicker in cross-section is used for an earth connection.*



5 Amps Socket base
(*a*)



Cover
(*b*)



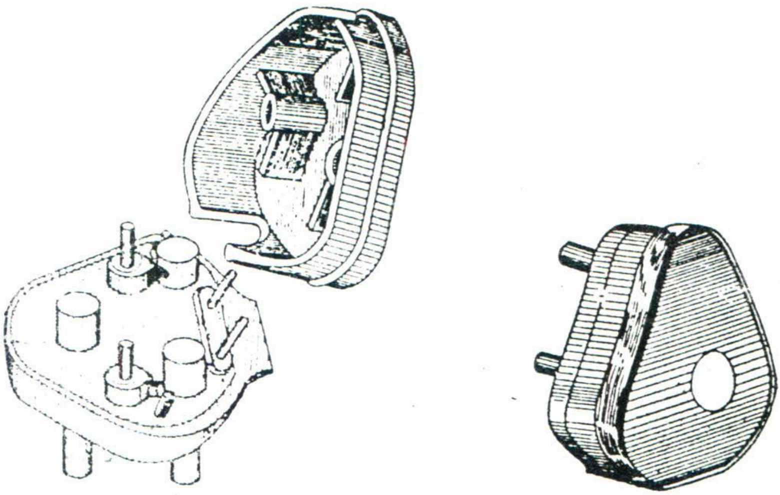
3-pin 15 Amp socket with top cover
(*c*)

Fig. 4.38

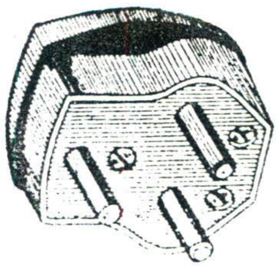
The cover is again moulded and has corresponding 3 holes. Earlier 2-pin sockets were used for 5 ampere rouge, but now these are obsolete and only 3-pin sockets are used. These sockets are shown in Fig. 4.38 (*a*), (*b*) and (*c*) and are available either in flush pattern or surface mounting.

The heavy duty 15 A is used for power circuits and is shown in Fig. 4.38 (*c*).

25. Plugs. For tapping power from socket outlets, 3-pin plugs are used. The thicker pin is used for an earth connection to the portable appliance. Fig. 4.39 represents a 3-pin 5 Amp plug while Fig. 4.40 represents a heavy duty power plug.



5 Amp plug.
Fig. 4.39



Heavy duty power plug.
Fig. 4.40

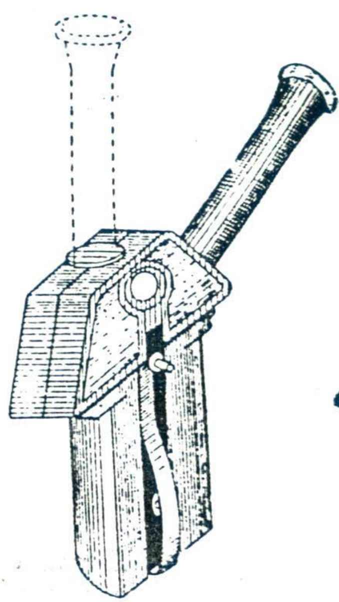
26. Terminal Block. Fig. 4.41 (*a*) and (*b*) represent 5 Amp and 15 Amp 12-way terminal blocks used for termination and connection to the other. A single-way terminal block is used for differentiating the live line from the neutral when the domestic connection is given and is called as *Connector*.

(*a*) 5 Amp, 12-way terminal block.

(b) 15 Amp, 12-way terminal block.

Fig. 4.41

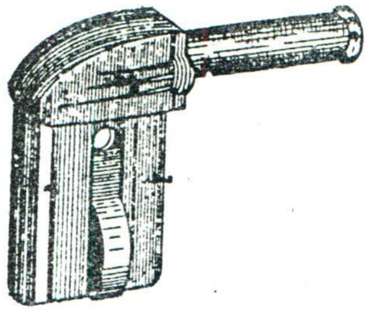
27. Appliance Connector. Making connection to the domestic appliances such as electric kettle, electric press, percolator, etc. with the supply mains *appliance connectors* are used. The connector is provided with a 2-pin socket and the earth connection is provided with a twin nickel spring. The cable entry has a rubber protection tube. The connectors are either flat or round with a side entry or straight entry as shown in Fig. 4.42.



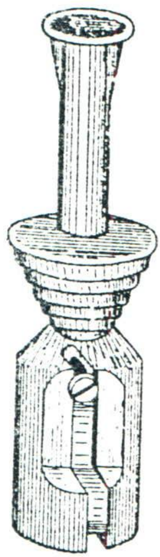
Flat connector with a top or side entry

(*a*)

Fig. 4.42



Flat connector with side entry
(b)

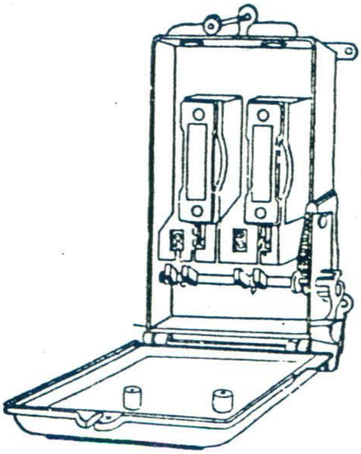


Round connector.
(c)

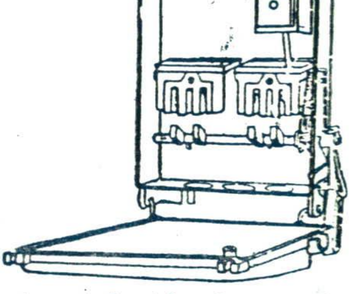
Fig. 4.42.

28. **Main Switch.** In order that the consumer may have self control of the electric circuit, he must have a main switch. Fig. 4.43 represents a 15 ampere main switch. The switch is a double-poled one and is combined with fuses. The base of the switch is high grade vitreous porcelain possessing perfect insulating properties and it has moulded slots for the entry of cables. The blades of the double pole switch are made of two links mounted on an insulating bar, to which is also connected the handle for the operation of the switch. It is provided with a moulded cover attached to the base with a

captive nut. The movement of the insulated bar is controlled by a spring, which locks up the movement of the handle when the switch is without the cover and thus avoids the accidental switching on the circuit. When the cover is placed in position, it releases a catch which in turn unlocks the handle. Such main switches are designed for maximum safe volts of 250, or 400 and they are available in 30 amperes range too, so they are suitable for domestic installations

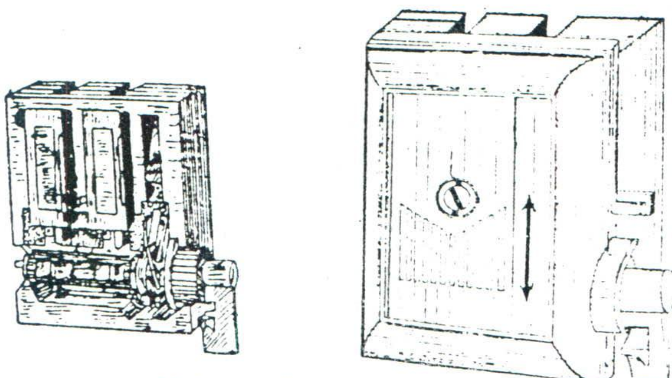


Main switch having fuse grips in both the lines, and generally when it is used for single phase the ends of one of the fuse are connected permanently with a wire.
(a)

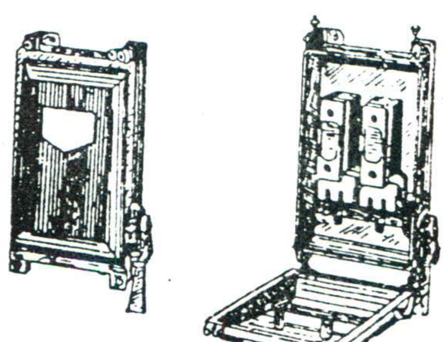


Single phase main switch with a fuse grip for neutral
(b)
Fig. 4.43

where ideal conditions prevail. But for control and isolation of motors and machine tools etc. where oil and suds are prevalent, it requires weather-proof, dust-proof and robust construction of the switch. So for heavy duty, cast iron switches are used, *i.e.*, in factories, mills, chemical plants etc. The covers of such switches are provided with a gasket to ensure that they are weather-proof. Fig. 4.44 represents a closed and open view of a single-phase bakelite top main switch while Fig. 4.45 represents open and closed view of ironclad switch. Fig. 4.46 (*a*) represents triple pole main switch, while Fig. 4.46 (*b*) represents a triple pole main switch with a neutral.

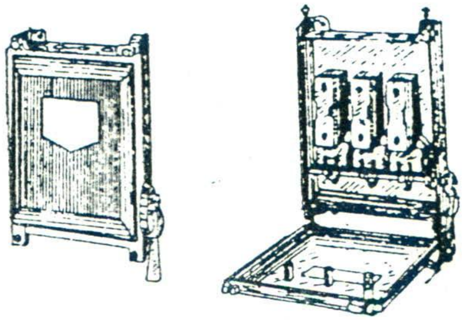


Main switch with Bakelite cover
Fig. 4.44

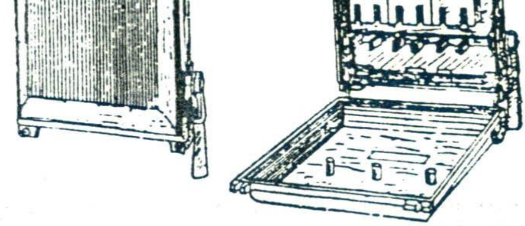


Open and closed view of iron clad switch
Fig. 4.45

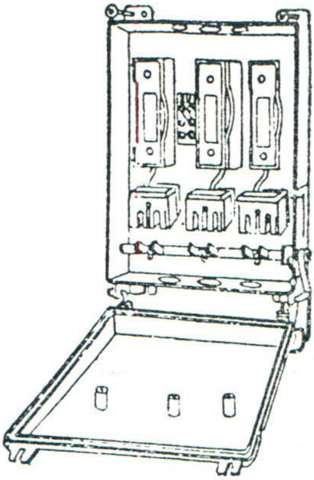
29. Splitter Units. There are fixed number of lamps which can be connected across the mains circuit depending on the voltage which is received at the last point and according to Indian Electricity Rules it must not be less than 5 per cent of the declared voltage given by the supplier. If in a building, there are a number of outlets, the wiring of all of the points is divided into a number of circuits. For having a number of circuits from a single supply line, a splitter unit is required. Fig. 4.47 represents a splitter unit, splitting the supply into three circuits. It consists of main switch and a fuse board in cast iron box similar to that for main switch. Such a unit does not control the individual circuits, for which purpose, separate main switch, one in each circuit is required. For the splitter unit, to be weather-proof, a gasket is provided on the cover. They are available either for 5 A range or 15 A range.



Triple pole 15 Amp iron-clad 400 V switch
(a)

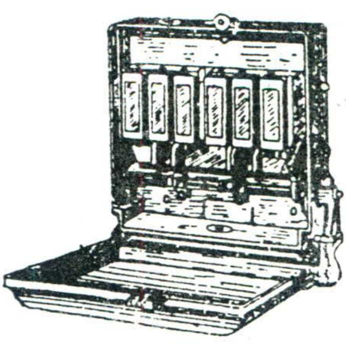


30 Amp switch.
(b)
Fig. 4.46

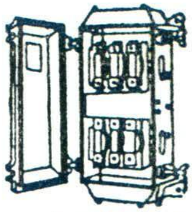


Three-phase four-wire main switch.
Fig. 4.47

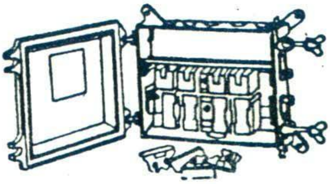
30. Distribution Fuse Boards. In the Industries or in very big buildings, where a number of circuits are to be wired, the distribution fuse boards become a necessity. They are usually ironclad and are designed to provide a large space for wiring and splitting the circuits. The fuse bank in the distribution board can easily be removed. Since there are a number of wires making connection to the various fuse at top and bottom, to facilitate this, the fuse bank can be tilted. Moreover, for further convenience of wiring, the cover plate, top and bottom plates can be removed easily. In the top place, knockouts are provided for fixing the conduits. Fig. 4.49 represents 300 V, water-tight fuse boards.



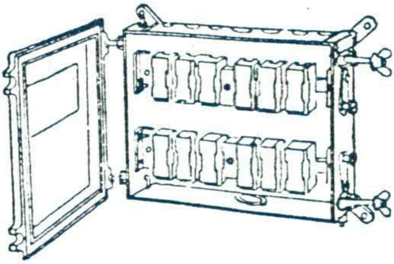
Six-way distribution board
Fig. 4.48



Six-way distribution board
(a)

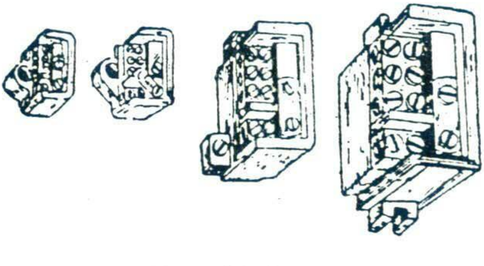


(b)



12-way distribution board
(c)
Fig. 4.49

31. Neutral Links. With the help of a neutral link, the normal three-phase fuse board can be converted into 3-phase 4-wire circuits. Such neutral terminal consists of a terminal for incoming neutral



Neutral links
Fig. 4.50

main and a three-way outgoing circuit terminal, both are connected by a link which can be detached for test purposes. The metal components are mounted on high grade vitreous porcelain base. Fig. 4.50 represents 100 Amp, 60 Amp, 30 Amp, 15 Amp neutral links.

32. Miniature Circuit Breaker. The modern day practical is to use miniature circuit Breakers which are available in sailings varying from 0.5 Amps to 100 Amps. These can be single pole, double poles or three poles.

Miniature circuit Breaker Commanly known as **MCB** are final sub circuit protective device as it comprises of thermal overload and magnetic short circuit tripping devices. The MCB can carry rated circuit continuously but sustained overloading of 150% or above. Can be detected by thermal overload device which will trip the M.C.B. The thermal elevate prevents rapid relosing of a circuit while the overload still persists.

Magnetic short circuit device will trip M.C.B on fault. The trip free mechanism incorporated in the breaker do not permit closing of the contacts and in addition the thermal element also prevents rapid closing of the circuit.

33. Specifications of some Electrical Accessories.

(1) **A.C. Energy meter :**

Supply : Single phase/three phase 3 wire/4 wire

Rated voltage	: 230 Volts/440 Volts.
Frequency	: 50 Hertz.
Current Rating	: 5, 10, 20, 25 and 100 amps.
Revelution/KWH	: 450/900/1200 etc.

(2) **Main switch, Lighting/Power** (I.C.D.P./I.C.T.P.)

Material	: I.C. (Iron clad)
Poles	: Double pole/Triple pole. 32A, 250/500V
Rating	: 16 amps 250/500; 60A, 500V; 100A, 500V

(3) **Tumbler Switch :**

Rating	: 5 Amp. 250V, one way/Two way, 15 A 250V one way.
Material	: Bakelite or bakelite with porcelain base.
Type	: Surface/flush.

(4) **Aerial Fuse :**

Rating	: 16A, 250V, or 16/32/60A, 500V
Material	: Tinned copper or tin lead alloy (63 % tin, 37 % lead)

Size of fuse wire : Tinned copper : 24 SWG to 40 SWG
Lead : 10 SWG TO 32 SWG

(5) The complete specification of cable will give the following data :

(*a*) Size in metric system (19/2.34, 7/1.70, 7/2.24)-the numer ator giving the number of strands and the denominator dia. of each strand in mm.

(*b*) Type of conductor material used in cables (copper or aluminium)

(*c*) Number of cores that cable consists of e.g. Single core, Twin core, Three core etc.

(*d*) Voltage grade 250/500 volts or 600/1100 volts or HV or EHV grade.

(*e*) Type of cable with clear description regarding insulation, taping, braiding and compounding etc.

(*f*) **Type Designation :**

The type designation is as per IS : 7098–1977 (Part - I)
Ex. YY, AYA, YFA, AYMfl. etc.
In these codes, the **FIRST** letter indicates the material of conductor, viz Al. or copper.
The **SECOND** letter indicates the type of insulation.
The letter **A** indicates Aluminium. If the code does NOT start with **A**, then it is copper.
The letter **Y** in the Second place indicates, the insulation is PVC
The letter **2X** in the second place indicates the insulation is **FINVUL-X**
The letter **Y** in the last place indicates it is PVC sheathed.
The letter **M** indicates, the conductor is in round construction.
The letter **W** or **R** indicates, it is Round Steel Wire armouring.
The letter **F** indicates, it is Flat Steel Wire (strip) armouring.

Example :

AYA → Aluminium Conductor, PVC insulted

AYY → Aluminium Conductor, PVC insulated, and PVC sheathed, (unarmoured)

YY → Copper Conductor, PVC insulated and PVC sheathed, unarmoured

YFY → Copper conductor, PVC insulated Flat steel wire armouring and PVC sheathed.

AYWY → Aluminium Conductor PVC insulated, Round steel wire armouring and PVC sheathed.

Also note :

1) AYRY → 2 core upto 10 sq.mm. available.
3 core upto 6. sq.mm. available
4 core upto 4. sq.mm. available
2) AYFY → All other types available
3) YRY → upto 7 cores available
4) YFY → from 10 cores available

(6) **For House wiring, the cable size upto 1.50 KW load (Lighting only)**

Copper = SWG 1/18. = $1mm^2$	14/0.3	multistrand, single core or
	1/1.12	single strand, single core
	OR	
Alum. = SWG 1/18. = $1.5\ mm^2$	3/0.80	multistrand, single core or
	1/1.40	single strand, single core

(7) For House wiring the cable size for loads more than 1.5KW and upto 3KW

(Plugs, and other House - hold appliances - Wet Grinders, Refrigerators etc.)

Copper : SWG 3/20, = $2.0\ mm^2$	28/0.3	multi-strand, single core or
	3/0.925	multistrand, single core
	OR	
Alum. : SWG 3/20, = $2.5mm^2$	3/1.0	multistrand, single core or
	1/1.80	single strand, single core

(8) **For power loads more than 3KW and less than 10KW**

Alum. SWG 7/20, = $4.0mm^2$	7/0.85multistrand, single core or
	1/2.24single stand
Copper SWG 7/20, = $4.5mm^2$	65/0.3multistrand or
	7/0.925single core

(9) **Socket outlet :**

Rating	: 5 Amps/250V grade
Type	: Flush/surface
Socket	: 3 pin/2 pin.

(10) **Adhesive black insulating tape.**

The tape contains insulating adhesive material pasted on one side of it. Its adhesive properties should retain for a considerable period. It is available in rolls of 2, 5, 10, 20, 25 meters length. It can withstand 250 volts per layer.

(11) Electric Heater.

Wattage	:	450W/ 1000/1500/2000 watts.
Voltage	:	230 volts.
Type	:	AC/DC
Make	:	BAJAJ/Klertone/Crompton, Vijay, Recold, etc

(12) Electric press (for domestic use)

Wattage	:	500/1000 watts, 230 volts.
Weight	:	2 to 3 kg. System : Automatic / Non-automatic.

Name of manufacturing firm:Bajaj, Klertone, Vijay, Maurya etc.

(13) Ceiling Fan :

Name of the manufacturing firm	:	Usha, Orient, Crompton, Rally, Kaiton etc.
Number of blades	:	two or three or four
Size of blade sweep	:	900 mm (36"); 60W; 1200 mm (48"), 100W 1400 mm (56"), 100W; 1500 mm (60"), 100W
Type of fan	:	AC or DC
Rated voltage	:	230 V/1 Φ, 50Hz.

(14) Fluorescent tube :

Standard size	:	2 ft/60 cm; 4 ft/120 cm and 1 inch/2.5 cm dia;
Name of the manufacturing firm	:	Crompton, Philips, Electron, Sylvinia, Anchor etc.
Power consumed	:	20 watts/40 watts; 230 volt; 0.6 lag.

(15) Choke for fluorescent tube :

Rating	:	40 watts/20 watts at 230 volts
Power factor	:	0.6
Name of Manufacturers	:	Crompton, Philps, Sylvinia, Anchor etc.

(16) Starter for Flourecent tube :

Rating	:	40 watts/20 watts at 230 volts
Type	:	Glow type.
Name of Manufacturer	:	Crompton, Philips, Usha etc.

(17) Incandescent lamp :

Rating	: 230 volts, 25/40/60/100/200 watts.
Type	: Pin/Screw.
Make	: Osram/Crompton, Philips, Surya, Sylvinia Bajaj etc.

TYPICAL QUESTIONS

1. How many types of switches are there ?

2. What are the various lighting accessories ? Illustrate two types of switches in use.

3. Why iron-clad water-tight switches are used ? Illustrate with diagram its various parts.

4. Why lamp-holders and ceiling roses are used ?

5. How many types of lamp-holders are there, explain the constructional parts of any two of them with sketches.

6. Illustrate with a sketch the various parts of main switch.

7. Write short notes and specifications for the following :

(*a*) Quick break knife switch

(*b*) Tumbler switch

(*c*) Push Button switch

(*d*) Medium Edison Screw lamp-holder

(*e*) Mounting Blocks

(*f*) Distribution fuse boards

(*g*) Plugs

(*h*) Socket outlet

(*i*) Fluorescent lamp-holder and starter holders

(*j*) A holder for holding 60 watts, 230 volts lamps and suitable for fixing to a brass bracket

[*S.B.T.E. Pb.* (*Elect. Engg. 1967*)]

(*k*) A switch for controlling 100 watts, 230 V lamp in cleat wiring.

[*S.B.T.E. Pb.* (*Elect. Engg., 1963*)]

(*l*) A single phase energy meter.

(*m*) Ceiling Fan.

(*n*) Main Switch ; lighting/power

5

Protection Devices

1. Attracted Armature Type Relay. 2. Solenoid Type Relay. 3. Thermal Relay. 4. Induction Type over Current Relay. 5. Induction Type Reverse Power Relay. 6. Induction Type Directional over Current Relay. 7. Impedance or Distance Relay (Induction Type). 8. Impedance Time Relay.

Introduction. In an electrical power station, when anything becomes abnormal, it becomes necessary to isolate the abnormal condition instantaneously or in some cases after a predetermined time delay. The action may be automatic and selective *i.e.* it must segregate the faulty section or piece of apparatus leaving the correct apparatus in the circuit in the normal position. The function can be fulfilled by using the protective devices like fuses or relays in the circuit to isolate the circuit from the damages to be occured due to short circuit or over-loads etc.

The use of fuse in the circuit is limited for the protection of low voltage circuits. For higher voltages say from 3300 V upwards, the protection of the circuit is achieved by providing the protective relays at proper selected points. At the time of occurring the faults in the circuit, the relay operates to complete the circuit of trip coil, thereby resulting in opening the circuit breaker and isolating the faulty section from the rest of the system. The relay thus ensures the safety of the equipments from being damaged and normal working of healthy portion of the system.

Main Features of Good Protective Devices

(*i*) **Sensitivity :** The protective system should be so sensitive that it should operate for low values of fault current.

(*ii*) **Selectivity :** The protective system should select correctly the faulty part of the power system and disconnect the same without disturbing the rest of the system.

(*iii*) **Reliability :** The protective system should operate definitely under predetermined condition.

(*iv*) **Quickness :** The protective system should be such that it should respond quickly in order to improve quality of service, increase safety of life of equipment and increase stability of operation.

(v) **Non-interference with Future Extension** : There should be scope for future extension without interfering the original installation.

Protective Relays : The protective relay may be defined as an electrical device connected between the main circuit and the circuit breaker in such a way that if any abnormality acts on the relay in the circuit, it causes the breaker to open and the faulty element is isolated. Thus the circuit equipments are saved from any damage being caused by the fault.

The types of a relays may be classified as under :

(a) **According to Construction and Principle of operation.**

(i) *Attracted Armature type* : The operation of this type of relay depends upon the movement of an armature under the influence of attractive force due to magnetic field set up by current flowing through the relay winding.

(ii) *Solenoid type* : The operation of this type of relay depends upon the movement of an iron plunger core along the axis of a solenoid.

(iii) *Electro dynamic type* : In this type of relay, the moving part consists of a coil, free to rotate in an electromagnetic field.

(iv) *Induction type* : The operation of this type of relay depends upon the movement of a metallic disc or cylinder, free to rotate by the inter action of induced eddy currents and the alternating magnetic field producing them.

(v) *Thermal type* : The operation of this type of relay depends upon the action of heat produced by the current flowing through the element of the relay.

(vi) *Moving Coil Type* : In this type of relay, the moving part consists of a coil, free to rotate in the air gap of a permanent magnet.

(b) **According to Applications**

(i) *Over Voltage/over Current/over Power Relay* : When the voltage/current/power increases in any circuit above a specified value, then the relay operates.

(ii) *Under Voltage/under Current/under Power relay* : When the voltage/current/power falls below a specified value, then the relay operates.

(*iii*) *Directional or Reverse Power Relay* : When the applied current and voltage assume specified phase displacement, then the relay operates.

(*iv*) *Directional or Reverse Current Relay* : When the applied current assumes a specified phase displacement with respect to applied voltage, then the relay operates.

(*v*) *Differential Relay* : When some specified phase or magnitude difference occurs between two or more electrical quantities, then the relay operates.

(*vi*) *Distance Relay* : In this type, the operation of relay depends upon the ratio of voltage to the current.

(*c*) **According to timing characteristics**

(*i*) *Instantaneous Relay* : In these types, the operation of relays takes place after a very short duration from the incidence of the current or other quantity resulting in operation.

(*ii*) *Definite Time Lag Relay* : The time of operation is sensibly independent of the magnitude of the current or of other quantity causing operation in these relays.

(*iii*) *Inverse Time Lag Relay* : In these types of relays, the time of operation is approx. inversely proportional to the magnitude of the current or other quantity causing operation.

Description of Relays

1. **Attracted Armature Type Relay.** One of the most common type of instantaneous electro-magnetic relays (attracted armature type) is shown in the fig. below.

The system of an attracted Armature type Relay
Fig. 5.1

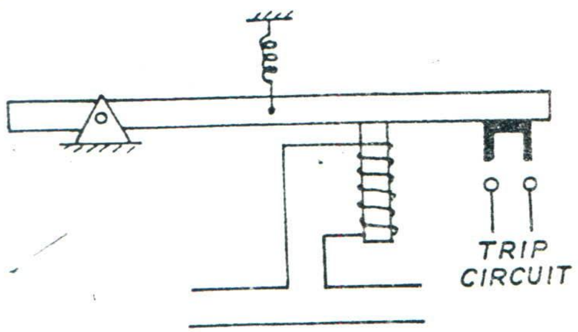
The relay described here consists of an electro-magnet and a pivoted armature. The armature is balanced by a counter weight and carries a pair of spring contact at its free end. The armature of the relay is attracted as soon as the fault or abnormal condition takes place, so the stationary contacts attached to the relay frame are bridged and trip circuit is completed. The magnet coil is tapped at intervals and the tapping points are brought out to a number of terminals or contacts on a plug section bridge, so the number of turns in use and consequently the setting value at which the relay operates may be varied.

A definite time lag can be obtained by using an oil dash pot, an air escapement chamber or a clock work mechanism.

An instantaneous or definite time lag relay works as an inverse time lag relay when a fuse is placed in parallel to it.

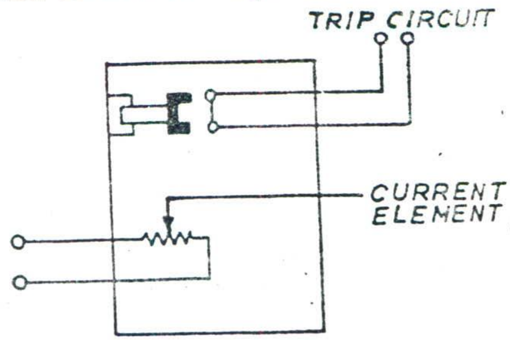
2. Solenoid Type Relay. This type of relay is used for over current protection. It consists of a lever which is attracted by the solenoid, when any fault occurs, the trip circuit is completed.

This type of relay is also an instantaneous type but it can be converted into a definite time lag or inverse time lag by using an oil dash pot, an air escapement chamber, a clock work mechanism or by placing a fuse in parallel with the relay.



System of a Solenoid Type Relay
Fig. 5.2

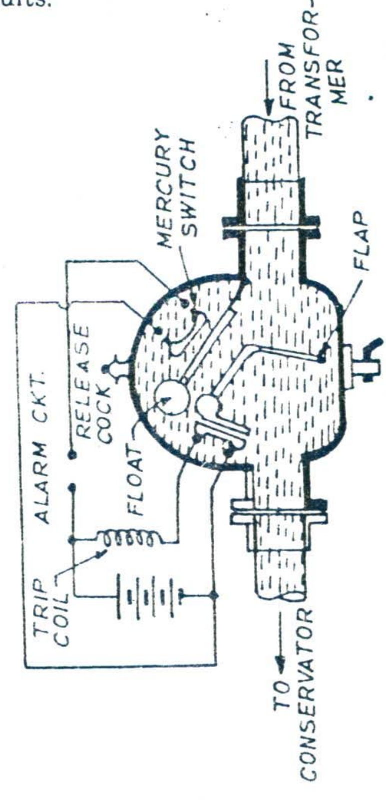
3. Thermal Relay. It consists of a metallic strip, which is heated by the flow of current through the filament. Due to heat, the



System of a Thermal Relay
Fig. 5.3

strip expands and it closes the trip circuit for the operation of circuit breaker. Due to the availability of magnetic relays, the use of thermal relays have become outdated.

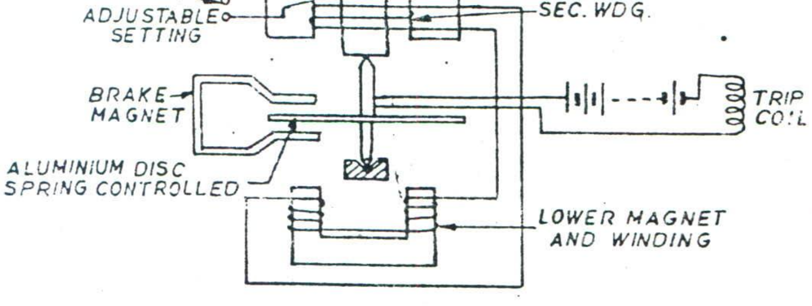
The other type of thermal relay is Buchholz relay. It is used on all oil immersed transformers having rating more than 750 KVA. It is used in conjunction with some forms of electrically operated protective gear between the transformer and conservator to give warning in case of less severe internal faults in oil immersed transformer and to disconnect the transformer from main supply in case of severe internal faults. It only protects the transformer from internal faults and does not respond to external bushing or cable connection faults.



Construction of Buchholz Relay
5.4

The construction of Buchholz Relay is described below and shown in the Fig. 5.4. It contains two elements mounted in a small chamber located in the pipe connection between the conservator and the transformer oil tank. When any minor fault occurs, current leaks and heat is produced. Due to this heat, some of the oil evaporates in the transformer tank and some vapours are collected in the top of the chamber while passing to the conservator. When a sufficient amount of vapour is a accumulated in the top of the chamber, the oil level falls, the mercury type switch, attached to a float is tilted, thereby closing the alarm circuit and the bell rings. A release cock is installed at the top of the chamber so that after operation, the pressure in the chamber can be released and the gas emitted to allow the chamber to refill with oil. When any severe fault occurs, large volume of gas is evolved so that the lower element containing a mercury switch, fitted on a hinged type flap is tilted and the trip coil is energized. A test cock is installed at the bottom of the chamber to allow air to be pumped into the chamber for test purposes.

4. **Induction type over Current Relay.** It gives an inverse time operation with definite minimum time characteristics. As shown in the Fig. it consists of modified mechanism of an a.c. watt hour meter to give required characteristics. There are two windings on the upper electromagnet, one of these is primary and is connected to the secondary of a current transformer in the line to be protected and is tapped at intervals. The tappings are connected to a plug setting bridge by which the number of turns in use can be adjusted, thereby giving the desired current setting. The second winding is connected in series with the winding on the lower magnet and is energized by induction from the primary winding.

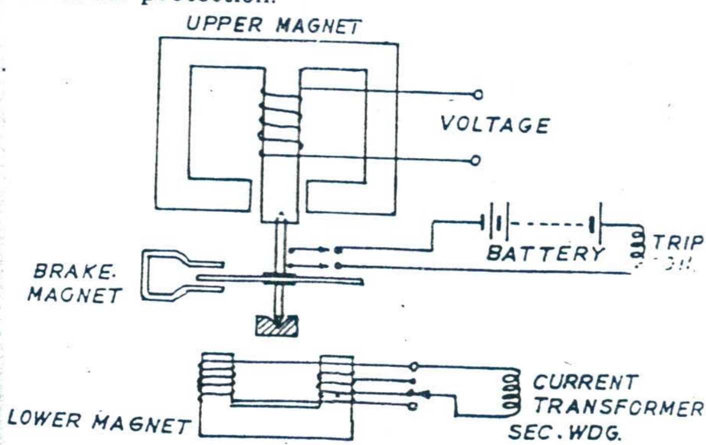


Internal structure of Induction Type Over Current Relay
Fig. 5.5

The fluxes produced by the primary and secondary windings are separated in phase and space and a rotational torque is set up on the aluminium disc suspended between the two magnets. This torque is controlled by a special spring and also by a permanent magnet brake on the disc. The disc spindle carries a moving contact which bridges two fixed contacts when the disc has rotated through an angle which can be adjusted to any value between 0 and 360 degrees. The relay can be given any desired time setting by the adjustment of angle. Since the torque increases with the current, therefore, the relay has an inverse time characteristic.

In recent designs, the definite minimum time characteristic is obtained by saturating the iron in the upper electromagnet so that there is practically no increase in flux after the current has reached a certain value.

5. Induction Type Reverse Power Relay. As shown in the Fig., a reverse power relay can be obtained by having a winding on the middle limb of the upper magnet, energising it from a potential transformer (P.T.), a separate winding on the two limbs of lower magnet and energising it from current transformer (C.T.). The system is just like an energy meter and direction of torque depends on the direction of flow of energy. When the power flows in a circuit in the reversed direction, the relay can be used to close trip circuit contacts. The relay can be made more sensitive by introducing a very light control spring so that a very small reversal of power should cause the relay to operate. This relay is very suitable for parallel feeder protection.



Internal structure of Induction Type Reverse Power Relay.
Fig. 5.6

6. Induction Type Directional Over Current Relay. This type of relay consists of induction type relays, one of which is simple over current relay and the other is reverse power relay, both fitted in one case. Their contacts are connected in series sc that the trip circuit is not energized unless both operate *i.e.* when the current is more than the set limit and at the same time direction of power flow is also reversed.

7. Impedance or Distance Relay (Induction Type). This relay is similar to induction type over current relay in construction except that there are two magnet systems, one on each side of the disc. The over current relay operates only due to current but in induction type impedance relay, one additional magnet system, operated by voltage is provided such that under normal working conditions, torque exerted by voltage operated magnet system is grater than that exerted by current operated magnet system and the trip circuit remains open. In case of occuring any fault, current becomes excessive and hence the torque exerted by the current operated system overcome that of the voltage operated system and thus the trip circuit is closed.

8. Impedance Time Relay. In this type of relay, the current drives a disc round by induction and a spring is wound up. This spring tends to close the trip circuit contacts but is opposed by an armature attached to the spindle and attracted by a coil carrying current due to line voltage. Under normal working conditions, the force exerted by armature is more than that of the induction element and thus the trip circuit contacts remain open. When any fault occurs, the induction element, operated by current exerts greater torque than that of the armature and thus there is a tendency of closing of trip circuit contacts. When the disc starts rotating, spring is wound up and when the spring is sufficiently wound up, the armature leaves the voltage coil and the trip circuit is closed at once.

FUSES

Introduction and Importance

Fuse is the safety valve and the weakest part of the electrical system. It consists of a small link of soft metal which melts when excessive current passes through it. The fuse wires are usually bare wires and are made of lead and tin. Lead alloy for small current and tinned copper wire issued for large current. Upto 3 amperes load, lead fuse wires are used, upto 15 amperes alloy of lead and tin is used and above 15 amperes, tinned copper wires are used.

If a short circuit occurs anywhere in the wiring system, an excessive current flows through the wires and fuse and if the fuse operates properly, it will melt, cutting off the current before any harm can be done. If the fuse fails to operate, the wire may become hot enough to ignite the insulation, possibly causing a fire and it may harm the appliances and fittings connected in the circuit.

Fuses have a second function. Besides protecting in the case of short circuit, they protect in the case of overload. If too many appliances are connected to one circuit, more current will flow through the supply wires than the wires were meant to carry and will cause the wires to be burnt and appliances, accessories connected to circuits will be also damaged. In such case, the fuse, if properly selected, will melt or blow, thus protecting the wires, appliances, accessories etc.

Principle of Operation of Fuse. The operation of fuse depends upon the heating effect of an electric current. When the electric current is increased in a circuit due to short circuits or over loads, it increases the rate of heat generation which will increase the temperature of the fuse wire and thereby the rate of heat dissipation increases from the exposed surface of the fuse wire. The final temperature reaches to such stage that the heat generation will be equal to the rate of heat dissipation. If this temperature happens to be above the melting point of the material of fuse wire, fuse must have operated.

Selection of Fuse Wire. To select the proper fuse wire to be inserted in a circuit two factors *viz* (*a*) maximum current rating of the circuit and (*b*) current rating of the smallest size of wire or accessories is to be seen, the fuse wire inserted should be of size so that when the current with reference to factors (*a*) and (*b*) is increased, it should blow out.

The type of wire to be selected to use as a fuse wire depends upon the type of load connected to the circuits *i.e.* steady load and fluctuating loads. The stead load covers the heating loads and the fluctuating load consists of motor, capacitor and transformer loads, all of which take transient over current when they are switched into the circuit. In steady load circuits, the fuse forms only the protection part of the circuit. Therefore, the fuse rating should be equal to or next greater than the ratings of the smallest cable used in the circuit. But if a number of fuse wires are run in parallel to augment the rating of fuse, total rating should not be equal to the product of rating of one strand and number of strands used. In fluctuating load circuits, fuse should have current time characteristics such as to allow the short time over current to flow without blowing. For this, it is necessary to select fuses of rated current greater than that of the cable of the circuit. In motor circuit, fuse is rated for short circuit and not for over current protection which is looked after by over current protection provided in the starter. On the other hand, the over current protection is not suitable for clearing heavy short circuit current. As at the time of starting the motors, very heavy current is to be handled, so the fuse must be of sufficient size to carry these current, over long period and as such these are rated at twice the full load current of motor. The three phase motors which have protracted starting period or are driving heavy inertia loads, it is necessary to select fuses of required current time characteristics. In three phase motors, all the fuses used on the three phases should be the same rating otherwise it would have single phasing trouble.

For other type of fluctuating load circuit using capacitors, fluorescent lighting, battery charger, transformers etc., the fuses to be used must be of 50% more than rated current.

The fuse wire should always be inserted in live wire or phase of the circuit, or otherwise even if the fuse blows out, the faulty circuit will be fed and would cause considerable damage in case of leakage fault.

Melting Points of Various Metals.

Table 5.1 gives melting point of various metals.

Table 5.1

Metal		*Melting Point in Centigrade*
Aluminium	...	671.5
Antimony	...	428.5
Copper	...	1092.5
Lead	...	329
Silver	...	999
Tin	...	239.5
Zinc	...	419.20

Silver as a Fusing Element. It has been determined practically that silver is quite satisfactory material for fuse wires as it is not subjected to oxidization since its oxide is unstable. There is no deterioration of the material when used in dry air, and it remains bright. But when the air is moist and contains hydrogen sulphide, the silver surface is attacked ; a layer of silver sulphide is formed at the top which shields the metal from further attack. The only drawback in its use as a fuse wire is that it is costlier.

Either copper or lead-tin alloy is mostly used as an ordinary fuse wire.

Copper as Fuse Wire. Table 5.2 gives the fusing current of copper in air.

Table 5.2

Diameter of Wire in mm	*Equivalent S.W.G. Size*	*Fusing Current Amps.*	*Maximum Safe Working Current Amps.*	*Remarks*
0.2336	34	8.6	4.3	The length of fuse wire up to 0.4572 mm dia. must be between 63.5 mm to 90.0 mm but for large dia. wires the length must not be less than 100 mm.
0.254	33	9.8	4.9	
0.2736	32	11.0	5.5	
0.3149	30	13.5	6.8	
0.3759	28	17	8.6	
0.4572	26	22	11	
0.5588	24	30	15	
0.7112	22	41	21	
0.9143	20	62	31	
1.016	19	73	37	
1.219	18	98	49	
1.422	17	125	63	
1.828	15	191	96	
2.032	14	229	115	

Lead-tin Alloy as Fuse Wire. Mostly for small value of currents lead-tin alloy has been used in the past. The tin content varies from 2 per cent and above. The main objection for the lead-tin alloys is that these alloys being soft, they are apt to spread under pressure. The most preferred lead-tin alloy for a fuse element contains 37 per cent lead and 63 per cent tin. Such an alloy is known as euectic alloy and is preferred due to the following reasons :

1. It has the highest brinnel hardness in all the lead-tin alloy series and hence there is less tendency to spread over.

2. The material is quite homogeneous.

3. If the fusing characteristic of eutectic alloy and other composition of alloys is studied, there is only one arrest point in eutectic alloy as compared to two in other type of alloys.

Table 5.3

Diameter of Wire mm	*Equivalent size S.W.G.*	*Fusing Current Amps.*	*Maximum Safe Current Amps.*	*Remarks*
0.508	25		2.0	The maximum length of wire used must be 63.5 mm to 90.0 mm
0.5588	24	3.5	2.3	
0.6095	23	4	2.6	
0.7112	22	5	3.3	
0.8128	21	6	4.1	
0.9143	20	7	4.8	
1.219	18	10	7.0	
1.626	16	16	11.0	

Table 5.3 gives the approximate fusing currents of lead-tin alloy in air (lead 75 per cent, tin 25 per cent).

The values of current given in the above tables will be true only when the fuse wire passes through asbestos tube and does not come in contact with it. When the fuse wire comes in contact with porcelain, the value of fusing current increases.

Generally for rupturing small values of current, the fuse wire used is of lead-tin alloy, because the fusing current for such a type of fuse wire is about 50 per cent over load. For heavy currents lead-tin alloy is not used since the diameter of the wire used will be large and after fusing the metal, released will be excessive. Lead-tin alloy fuse wires are not used beyond 10 ampere range, for which copper wires are suitable.

Note : When a fuse blows, something is wrong, either a cord or an appliance is defective or there are too many appliances connected at the same time on one circuit. Find the trouble and correct it, otherwise when the blown fuse is replaced, the new one will also blow out immediately. Before replacing a blown fuse, remove the appliances from the circuit involved. It is usually advisable to open the main switch before changing fuses. Never, at any time insert a fuse of greater current carrying capacity than the wires of the circuit can safely carry.

Types of Fuses and Their Description

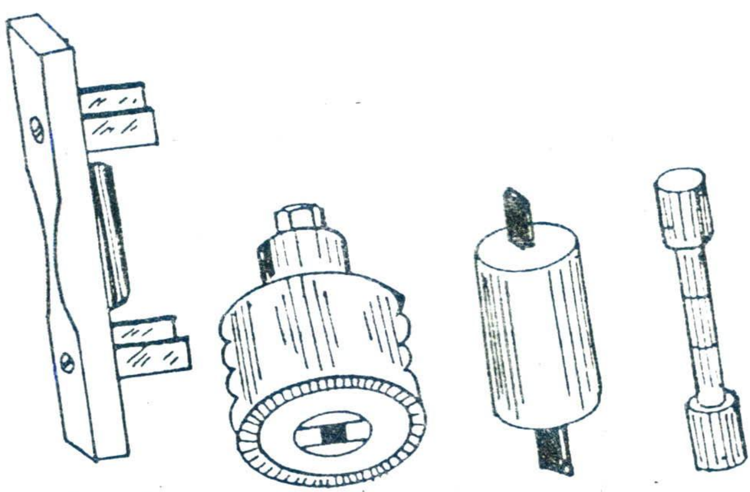
Fuses can be built in various forms but the most common types are described below :

1. The Ordinary Fuse. The ordinary or single link fuse is simply a strip of metal, usually lead. The strip of metal, called the fuse link, is the part of the fuse through which electricity flows. This metals when more electricity flows and breaks the connection and stops the flow of electricity.

2. The Screw-Plug-Type Fuse. It is used on electric machinery circuits of 220 volts. This type of fuse can be had in sizes from 3 to 30 amperes and is constructed with either a porcelain or glass body which encloses the fuse link.

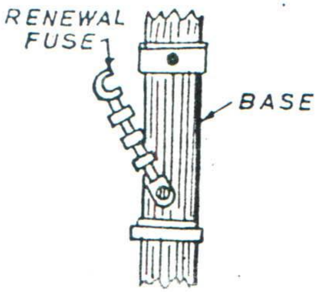
3. A Knife Blade Cartridge Fuse. This type of fuse is used mostly on heavy power lines of 60 to 600 amperes and 250 volts and more. They are constructed with a heavy fibre body, fitted with brass ferrules at each end and a heavy copper blade for making contact with the circuit. The fuse link can easily be renewed by removing the end ferrules and inserting the new link.

4. The Ferrule Type Cartridge Fuse. This type of fuses are of two types—the renewal or non-renewal. The renewal type has a small screw plug in each end which can be renewed and the new link is inserted. The body part of this fuse is made of fibre with brass ferrules fastened to each end and can be had in sizes up to 100 amperes and 250 volts.

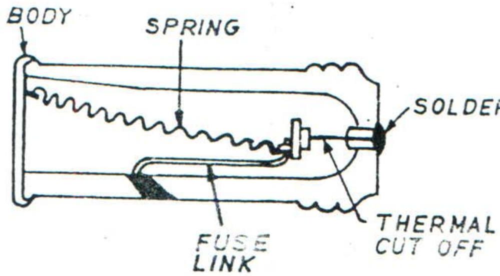


1. Ordinary Fuse 2. Screw Plug Type Fuse 3. Knife blade Cartridge Fuse with Fuse Link 4. Ferrule-Type Cartridge Fuse with Fuse Link

Fig. 5.7. Types of Fuses.



5. The Renewal Type Cartridge Fuse



6. Time Delay Fuse

Fig. 5.7. Types of Fuses.

5. H.R.C. (High Rupturing Capacity) **Cartridge Fuses.** These are used where the high power is supplied. These have a definite known breaking capacity and a high value.

6. Time Delay Fuse. It is a fuse which has the ability to carry overload currents of short duration without melting. The heavier the overload, the less is the time required for the fuse to "Blow". In most circuits where the starting currents are high but of short duration, this type of fuse need not have as high rating as an ordinary fuse to permit the motor to be started. Like the common fuse the time delay fuse is also made in plug and cartridge types.

Disadvantages of Ordinary Fuses

Rewirable /ordinary fuses suffer from the following disadvantages :

(*a*) *Unreliable operation.* It is due to :

(*i*) Oxidation of fuse wire and consequent thinning of wire section with lapse of time.

(*ii*) Loose connection causes the local heating.

(*iii*) Heat radiating devices used in the circuit.

(*iv*) Single phasing of three phase induction motors when one of the fuse in blown off.

(*b*) *Lack of discrimination.* : On account of unreliable operation, discrimination can not be ensured always.

(*c*) *Small Time.Lag :* On account of small time lag, these type of fuses can blow will large transient currents when three phase motors, transformers, capacitors and fluorescent lights etc. are used in the circuit.

(*d*) *Misuse* : Sometimes the proper rated wire for the fuse element is not available and any other piece of wire is used for the fuse element to solve the purpose which is against the I.S. rules of electricity.

(*e*) *Low Rupturing Capacity* : The use of rewirable fuse is limited to 4 KA in faulty circuit.

Advantages of Rewirable Fuse

Advantages

1. It is the cheapest form of operation.
2. It affords current limiting effect under short circuit conditions due to cut off.
3. It requires minimum time to replace.
4. It requires no maintenance.
5. It has current limiting effect.

Advantages of H.R.C. Fuses

1. They are simple and have easy installation.
2. They are cheaper as compared with other type of circuit interrupter of the same breaking capacity. They have high breaking capacity.
3. They do not require any maintenance.
4. Their operation is quick and sure.
5. They have inverse time current characteristic.
6. They do not deteriorate with time.
7. They are quite reliable and can be selected for proper discrimination.
8. They are capable of clearing high as well as low currents.
9. They have closer control on sustained overloads due to low fusing factor and the time lag feature.
10. They have current limitation by 'cut off' property.

Disadvantages of H.R.C. Fuses

1. After each operation, its replacement is required.
2. Interlocking is not possible in these types of fuses.
3. They lack relays in complete discrimination.

TABLE 5.4

Fuse Wire Table for Tinned Copper Wires

S.W.G.	*Current Rating in Amperes*	*App. Fusing Current in Amperes*
40	1.5	3
39	2.5	4
38	3.0	5
37	3.5	6
36	4.5	7
35	5.0	8
34	5.5	9
33	6.0	10
32	7.0	11
31	8.0	12
30	8.5	13
29	10.0	16
28	12.0	18
27	13.0	23
26	14.0	28
25	15.0	30
24	17.0	33
23	20.0	38
22	24.0	48
21	29.0	58
20	34.0	70
19	38.0	81
18	45.0	106
17	65.0	135
16	73.0	166
15	78.0	197
14	102.0	230

Fuse Holders. The fuse holders are designed, keeping in view the following points :

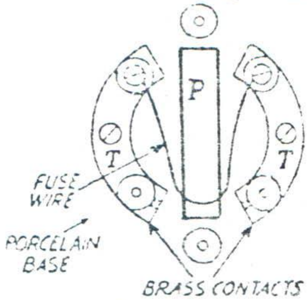


Fig. 5.8.

(*i*) Insulation and separation of the terminals;

(*ii*) Security against fire;

(*iii*) Ease of replacement—This requirement is not so important when the working voltage does not exceed 100 Volts.

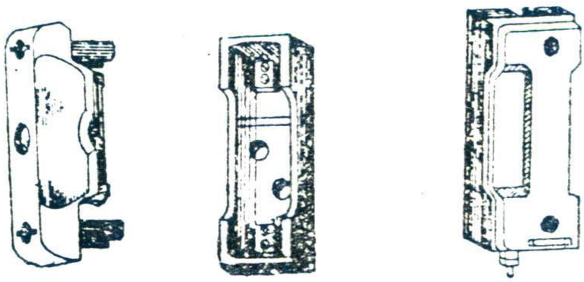
Formerly fuse holders used to be made in a variety of pattern Fig. 5.8 shows a type of fuse holder which was being used in the plate. It consists of a porcelain base with two brass connecting plates. Between the two brass contacts is connected a fuse wire, and also in between them is a porcelain portion *P* which helps in suppression of forming an arc between the two contacts.

This type of fuse holder is, although useful from the protection point of view, has the following disadvantages :

(*i*) For replacement of fuse wire, the worker has to touch the live mains or the main switch must be opened for such replacements.

(*ii*) On occasions when the fuse is blown off there is an appreciable arcing which will take place on the screws, holding the fuse wire, thus damaging it. After two or three such arcing, the fuse unit will become unusable and will have to be replaced.

In order to overcome this difficulty, fuse holders were designed across two knife contact and these contacts clip into fixed contacts on a porcelain base. Fig. 5.9 shows such an arrangement which is its simplest form and was used in early days. The greatest advantage of such an arrangement is that the holder can be isolated from the fuse base for replacement of fuse wire or to interrupt the circuit. By continuous use, if the holder is damaged, it can immediately be replaced without handling the wires etc.



Fuse holders
Fig. 5.9.

Many useful designs of fuse have been now developed whose uses depend upon the nature of work. In practice two types of fuses mostly used are :

(*i*) Semi-enclosed fuse.

(*ii*) Totally enclosed or cartridge fuse.

(*i*) *Semi-enclosed fuse.* In this type of fuses the fuse element is neither kept in free air nor it is totally enclosed. For household installations mostly such type of fuses are used. Fig. 5.9 shows the semi-enclosed fuse. The advantage of semi-enclosed fuse is that the fuse wire used is of shorter length. The shorter length increases the minimum fusing current. The short length of fuse wire may be enclosed in an asbestos tube. The added advantage of such enclosure is that the temperature distribution along the length of the fuse wire becomes quite uniform in the centre.

The following terms are mostly used in connection with fuse holders :

(*a*) *Fuse Link.* It is that part of a fuse which consists of a fuse element and cartridge or other container and is capable of either being attached to contacts or is fitted with contacts as an integral part of it.

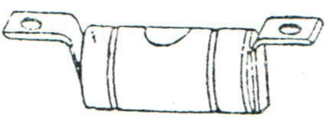
(*b*) *Fuse Carrier.* It is a removable holder which carries the fuse links.

(*c*) *Carrier Contact.* It is a contact which engages with fixed contacts and is capable of having a fuse link attached to it.

(*d*) *Fuse Base.* It is that part of a fuse which carries the fixed contacts.

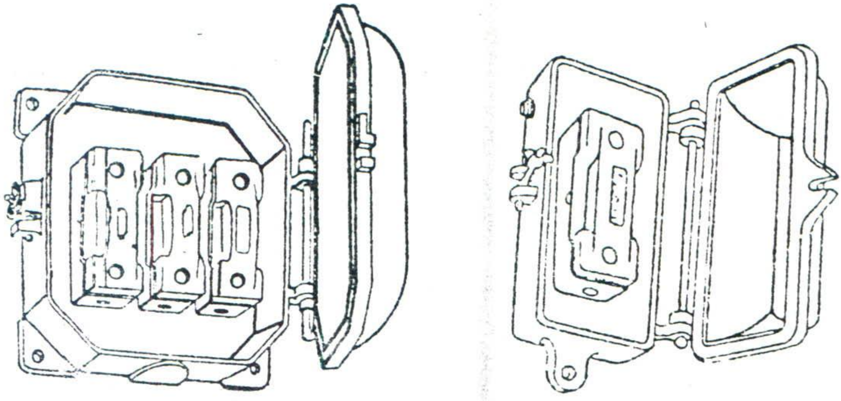
(*e*) *Fixed Contacts.* These contacts engage with carrier contact and are connected to fixed terminal.

(*ii*) *Totally enclosed fuse.* It is a totally enclosed form of fuse. In this, the fuse element is placed in an insulating container called the cartridge. Generally the cartridge is in the form of a tube and its ends are enclosed with metallic caps as shown in Fig. 5.10.



Totally enclosed fuse
Fig. 5.10

Generally the cartridge fuse containing the fuse element is filled with the powder or granular material called the filler. The filler used



Tripple pole iron clad switch showing semi enclosed knife carrier and holder fuse.
(*a*)

Iron clad cutout showing semi enclosed knife fuse carrier and holder.
(*b*)

Fig. 5.11.

expresses the connection and radiation loss from the fuse element. There are various types of materials used as filler. Formerly sand was used, because sand is useful for quenching etc. but the main drawback in its use of its thermal expansion which causes cracks in cartridge. The other material used as filler may be calcium carbonate ; but it evolves gas when heated. Generally quartz is used as filler as it is chemically stable. The use of filler increases the minimum fusing current.

In practice the open fuse holders are not used ; unless they are provided with some protection. Usually iron clad knife fuse as shown in Fig. 5.11 is used. The porcelain fuses are fitted into the iron box.

Terms generally used.

The following are the definitions of a few terms mostly used in the study of fuses :

1. **Fuse,** as defined earlier, is a device used for protecting the cable in a circuit against damage from an excessive current. Fuse is a term used in general to represent all parts of the device.

2. **Fuse element or fuse wire.** It is that part of the fuse which melts when an excessive current flows in the circuit and thus isolates the device from the supply mains.

3. **Minimum fusing current.** It is that minimum value of current of which the fuse element melts.

4. **Current rating of fusing element.** It is that value of current which the fusing element can normally carry without melting. Its value is less than the minimum fusing current.

5. **Fusing factor.** The ratio of minimum fusing current and the current rating of fusing element.

or $$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Current rating of fusing element}}$$

Its value is always more than 1.

TYPICAL QUESTIONS

1. What is the importance of protective devices in an electrical circuit ?

2. What are the main features of good protective devices and explain about them ?

3. How would you define a protective relay ?

4. What are the types of relays according to construction and principle of operation and explain about them ?

5. State the types of relays according to applications and timing characteristics.

6. Describe the attracted armature type relay and draw the diagram.

7. Explain about the solenoid type relay and draw the figure.

8. Describe about two types of thermal relays and draw the figures.

9. Explain about the Induction type over current relay and draw the figure.

10. Describe about the Induction type Reverse Power relay and draw the figure.

11. Explain about the following :

(*a*) Induction type directional over current relay.
(*b*) Distance Relay.
(*c*) Impedance time relay.

12. What is the importance of a fuse in an electrical circuit ?

13. Explain about the principle of operation of fuse.

14. What the factors on which selection of a fuse wire depends ?

15. What are types of fuses ? Explain about them and draw the figures.

16. What are the advantages and disadvantages of an ordinary rewirable fuse and H.R.C. fuses ?

17. Write short notes on (*a*) Fuse, (*b*) Fuse element, (*c*) Minimum fusing current, (*d*) fusing factor.

18. What are the various types of metals used for making fuse elements ?

19. What is the difference between fusing current and maximum safe current or the current rating ?

20. Explain with diagram the construction and function of fuse holder.

21. According to the I.E. Rules a cut-out (fuse) shall not be placed in the earthed netural conductor of two-wire system. Discuss the reason to justify the rule.

6

Illumination-(Lamps, Discharge Lamps and Fluorescent Lamps)

1. Introduction. 2. Nature of Light. 3. Colour. 4. Relative Sensitivity. 5. Radiant efficiency. 6. Definitions. 7. Laws of Illumination. 8. Lamberts' cosine Law. 9. Design of Lighting Scheme. 10. Illumination Required for Various Purposes. 11. Lighting Schemes. 12. Types of Electric Lamp. 13. Incandescent Vacuum Lamp. 14. Gas-filled incandescent Lamp. 15. Characteristics of Incandescent Lamp. 16. Working Principle of Electric Discharge Lamp. 17. Sodium Discharge Lamp. 18. Low Pressure Mercury Discharge Lamp. 19. Mercury Fluoresent I.amp (Low Pressure). 20. Neon Lamp. 21. High Pressure Mercury Vāpour Lamp.

Introduction. In the beginning of the nineteenth century, it was not possible to do daytime work after sunset, due to lack of adequate light. During those days, crude system of lighting was used but during the middle of the 19th century, a gas mantle was used as source of light. In the year 1900, the electric filament lamps came into the field as a source of light and they proved to be the best competitor to gas as a source of light. The electric lamps are preferred to other sources of illumination for reasons of cleanliness, convenience, steady light output and reliability.

Due to proper sources of good illumination much advancement has been made in the sphere of industrialization of countries as it has reduced the differences between day and night. Every work which can be done in daylight, can equally be done during night time with same efficiency. Too bright lights may not be confused as good illumination because it may cause viewing a bit painful. *The best illumination is that which produces no strain on the eyes.*

2. Nature of Light. Light is a form of energy which is radiated by bodies whose temperatures are increased. The main source of light is sun which gives out energy in the form of heat and light at a very high rate (of the order fifty thousand million billion horse power); but only a fraction of it reaches the earth (250 billion h.p.). Of the total energy received on earth only 40 per cent is in the form a light. The energy reaches earth in a very peculiar way. The energy transmitted by the sun is received without heating or lighting the space in between and without an obvious transmitting agency such as copper conductors in case of electrical energy. The energy is released only when it strikes solid object. *The energy radiated in such a fashion is called as radiant energy. An example of it is a room heater, in which case the heat is felt at a distance from the radiator.* The radiant energy is necessarily a wave motion propagated in an other medium in a manner similar to that of an electromagnetic wave. The velocity of propagation in a medium is 2.99776×10^8 m/sec. or say 3×10^8 m/sec. which is constant, but the wavelength is different. If some obstacle comes in the way of radiant energy, either the energy is reflected or observed by it. If the energy is absorbed then the light energy is converted into heat.

All this has been said about natural source ; but for the treatment of the subject are concerned with the light which is obtained from the incandescent body which is at a higher temperature than the surrounding medium radiates out energy into the medium. At low temperatures the radiation is only in the form of heat waves : but as it becomes red hot it emits light waves in addition to heat waves. At low temperatures, the wavelength is comparatively larger than the wavelengths at high temperatures.

At about 300°C the energy emitted has wavelength of 85×10^{-6}m; at about 800°C (when it is said to be red hot) the wavelength of radiation is of the order of 0.9×10^{-6}m; at temperatures about 3000°C (temperature at which incandescent lamps work) the wavelength of radiation is of the order of 0.4×10^{-6} to 0.7×10^{-6} m. Actually the radiation is a mixture of different wavelengths. The whole of the energy radiated out is not useful for illumination purpose. Radiations of very short wavelengths of range of 0.000015×10^{-6} m to 0.001×10^{-6} m are not in the visible range and are called as Rontgen or X-rays which have the very useful property of penetrating opaque bodies.

There is a definite relation between wavelength (λ) and the frequency (f).

i.e., Wavelength × Frequency = Velocity of propagation

$$f \times \lambda = 3 \times 10^8 \text{m/sec.} \quad \ldots(6.1)$$

The wavelength is not usually represented in cm/sec., but is usually represented in the following two units :

(1) Micron : (2) Angstrom (A°) so that

$$1 \text{ micron} = 10^{-6} \text{ metres} \quad \ldots(6.2)$$

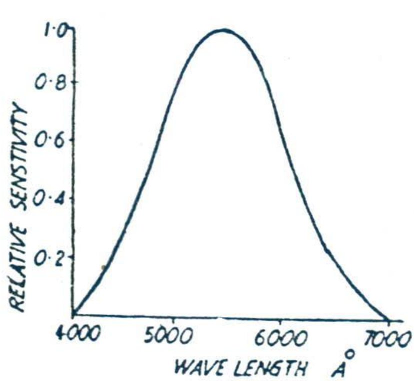
$$1 \text{ A°} = 10^{-8} \text{ cm} \quad \ldots(6.3)$$

3. Colour. Let the energy radiated by the heated body be monochromatic *i.e.* radiation of only one wavelength, then the colour of the radiation is as shown in the Table 6.1.

Table 6.1
Colours of Radiation

Wavelength in A°	*Colour*
4000	Violet
4750	Blue
5500	Green
6000	Yellow
7000	Red

4. Relative Sensitivity. The wavelength which can produce the sensation of sight lies between 4000 A^0 and 7500 A^0. The sensitivity of the eye to lights of different wavelengths varies from person to person and according to age. Fig. 6.1 shows an average relative sensitivity according to which sensitivity decreases for lesser and more wavelengths. The eye is most sensitive for a wavelength of 5500 A° and relative sensitivity according to this wavelength is taken as unity. The ratio of visual sensation at any wavelength to sensation at 5500 A° is called as relative sensitivity, the colour corresponding to wavelength 5500 A° is yellowish green, which is not suitable for most purposes. The relative sensitivity for any wavelength is also called as **Relative Luminosity Factor (Kλ).**



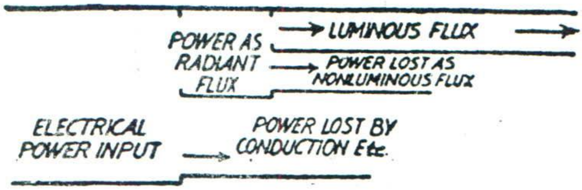
Relative Sensitivity
Fig. 6.1

5. Radiant Efficiency. It has been said that when a body is heated, its temperature increases, and it radiates out energy. The whole of the energy radiated is not in the form of light, *i.e.* producing sensation of vision ; but it radiates out energy in the form of waves too.

$$\text{Radiant efficiency} = \frac{\text{Energy radiated in the form of light}}{\text{Total energy radiated by the body}}$$

Definitions. (*i*) ***Light.*** It may be defined as that radiant energy which produces a sensation of vision upon the human eye.

(*ii*) **Luminous Flux.** It is defined as the light energy radiated per second from a luminous body. Say for example, the luminous body is an incandescent lamp. The whole of the electrical power supplied to the lamp is not changed into luminous flux ; some of the power is lost by heat conduction, heat convection and absorption. Of the remaining radiant flux, only a fraction of it lies in between the visual range of wavelength, *i.e.* between 4000 A° and 7000 A°.Fig. 6.2 shows the representation by a flux diagram.



Flux diagram
Fig. 6.2

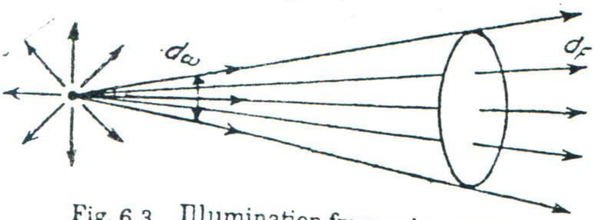


Fig. 6.3 Illumination from point source

Table 6.2

Tungsten Lamps			*Fluorescent Lamps*			
Power input in watts	*Luminous Flux in Lumens, app.*	*Efficiency Lumens per watt*	*Input in watts*	*Length in cm.*	*Luminous Flux in Lumens. app.*	*Efficiency Lumens app.*
10	80	8	4	15.25	75	18.75
40	460	11.5	8	30.5	325	40.53
60	840	14.0	20	61.0	950	47.5
100	1630	16.3	30	91.5	1500	50.0
200	3660	18.3	40	122.0	2300	57.5
500	9950	19.9	100	152.5	4400	44.0

Table 6.2 gives the approximate overhaul efficiency of incandescent tungsten filament lamp and fluorescent lamps.

(*iii*) **Luminous Intensity.** Consider a point source of light *O*. Let *dF* be the luminous flux crossing any section of a narrow cone of solid angle* *dω* steradians. The apex of the cone so formed is at the source. Then the Luminous intensity in the direction of the cone is the ratio of flux *dF* to the solid angle, *dω* or it may be defined as the flux emitted by the source per unit solid angle. If luminous intensity is represented by *I*

$$I = \frac{dF}{d\omega} \qquad \ldots(6.5)$$

(*iv*) **Lumen.** It is a unit of flux and *is defined as the luminous flux per unit solid angle from a source of* 1 *candle power.*

Therefore total flux emitted by the source of 1 C.P. is 4π lumens.

(*v*) **Illuminance or illumination or degree of illumination.** When the light falls on a surface it is illuminated, the illuminance is defined as the luminous flux received per unit area. Let the incident luminous flux on a small area *dA* be *dF*, then

$$\text{Illumination} = \frac{dF}{dA} \qquad \ldots(6.6)$$

If the area is in square feet, then the unit of illumination is *lumens per sq. foot or foot-candle.* If the area is in metres the unit is lumens per square metre.

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*The point source radiates out energy in all directions. With this point source as centre, and with any distance R as radius, imagine a spherical surface to be constructed. The lines of flux will cross an area A forming a cone. The steradian is a measure of solid angle ω which is defined as the ratio

$$\omega = \frac{A}{R^2}$$

Since surface area of the sphere is $4\pi R^2$, the total solid angle subtended by the point is

$$4\pi\frac{R^2}{R^2} = 4\pi$$

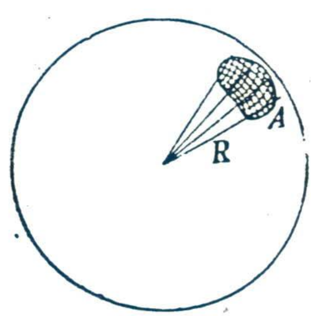
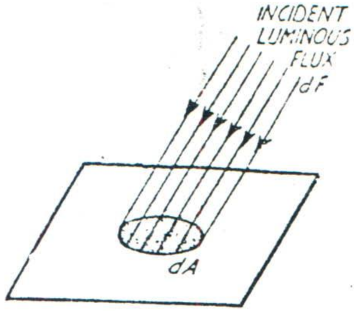


Fig. 6.4



Representation of luminous flux on an area
Fig. 6.5

(*vi*) **Mean Horizontal Candle Power.** The mean horizontal candle power of a source of light is the mean of the candle power in a horizontal plane in all directions.

(*vii*) **Mean Spherical Candle Power.** It is the mean of C.P. of a source of light in all directions within the hemisphere either above the horizontal plane or below the horizontal plane

(*viii*) **Reduction Factor.**

$$\text{Reduction factor} = \frac{\text{Mean spherical candle power}}{\text{Mean horizontal candle power}} \qquad \ldots(6.7)$$

is called as the reduction factor of the source of light.

(*ix*) **Foot candle.** It is a unit of illumination and may be defined as the illumination of the inside of a sphere of radius 1 ft. at the centre of which there is a source of I.C.P.

(*x*) **Lux.** It is mere candle and is defined as the illumination of the inside of the sphere of radius 1 metre at the centre of which there is a source of I.C.P.

$$1 \text{ metre} = 3.28 \text{ ft.} \qquad \ldots(6.8)$$

$$1 \text{ ft.-c} = (3.28)^2 \times 1 \text{ lux}^{*}$$

$$= 10.76 \text{ lux} \qquad \ldots(6.9)$$

or

$$1 \text{ lux} = \frac{1}{10.76} \text{ f.t.-c.}$$

$$= 0.093 \text{ ft.-c.} \qquad \ldots(6.10)$$

*Since the illumination is inversely proportional to the square of the distance.

(*xi*) **Nit.** It is an M.K.S. unit of illuminance as of degree of illumination at the surface and is defined as illumination of one candle per square metre.

(*xii*) **Stilb.** It is a bigger M.K.S. unit of illuminance and is equal to illumination of one candle per square centimetre.

(*xiii*) **Brightness.** It is defined as the flux emitted per unit area of the source in a direction perpendicular to the surface.

Brightness is a term which may be applied either for emission of light directly from the source of light covering a large area such as an incandescent lamp in a globe or for an installation used for production of a certain illumination on the object to be seen, in which case actually the light reflected by the object reaches our eyes, such as the light from a cinema screen.

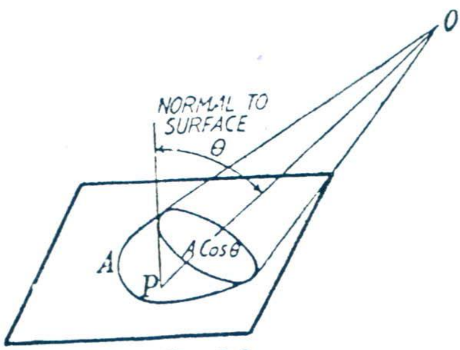


Fig. 6.6

Let the illuminous intensity in direction *OP* be 1 lumens per steradian on an area *A*, the projected area will then be A cos θ.

$$\text{or brightness } B = \frac{1}{A \cos .\theta} \qquad ...(6.11)$$

The unit of brightness is candles per sq. metre or candles/ft² *since 1 candle gives 1 unit solid angle.*

Another unit of brightness known as **foot lambert** (ft.-L) and is defined as brightness of an area emitting or reflecting light at the rate of 1 lumen per sq. foot.

$$\text{one candle/ft}^2 \ldots \pi \text{ ft.L.} \qquad ...(6.12)$$

Law of Illumination. It is defined as :

The illumination of a surface is inversely proportional to the square of the distance of the surface from the source of light. It is true only if the source is a point source.

6. Quantity of Light to be Obtained from Various Devices.

Luminous flux—lumen (unit)

Bicycle Lamp		10 lm.
Incandescent lamp of	150 w	1940 lm.
Flouresent lamp of	40 w	3000 lm.
Sodium Lamp of	200 w	30000 lm.
Mercury Vapour lamp	100 w	52000 lm.

Luminous Intensiy—candela (unit)

Bicycle lamp, straight ahead (without reflector)	—1 cd.
Bicycle lamp, straight ahead (with reflector)	—250 cd.
Light House light, centre of beam	20,00,000 cd.

Illumination—Lux (unit)

Summer, midday (Cloudless sky)	—100,000 lux.
Winter, midday	10,000 lux.
Summer, midday under balcony	2000—5000 lux.
Summer, behind a window	1000—3000 lux.
Sun rise & Sun set	500 lux.
Full moon & bright sky	0.25 lux.
Living room table under good artificial lighting	200 lux.
Office with good artificial lighting	1000 lux.

Luminance—cd/m² (unit)

Sun	—	16.5 cd/m^2
Moon	—	0.25×10^{-4} cd/m^2
Incandescent lamp	—	0.7 cd/m^2
Flourescent Lamp (lateral direction)		8.0 cd/m^2
Flourescent Lamp (longitudinal dirction)		0.5 cd/m^2

7. Lambert's Cosine Law. According to this law the illumination of a surface at any point is dependent upon the cosine of the angle between the line of flux and the normal at that point.

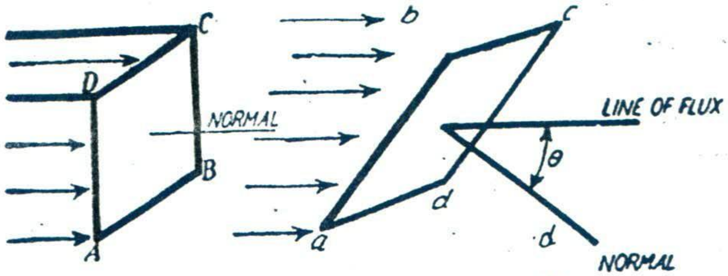
Let F be the total light flux falling on the area.

Thus in Fig. 6.7 (a) the angle between normal to the surface and line of flux is zero.

$$\text{Intensity of illumination} = \frac{F}{\text{Area } ABCD}$$

in Fig. 6.7 (b), the angle between them is θ.

$$\therefore \quad \text{Intensity of illumination} = \frac{F}{\text{Area } abcd} \cos\theta. \qquad \ldots(6.13)$$



(a) (b)

Lambert's cosine law
Fig. 6.7

In view of article 7 Eq.6.12 can be rewritten as

$$\text{intensity of illumination} = \frac{F \cos\theta}{d^2} \qquad \ldots(6.13)$$

8. Design of Lighting Scheme. For designing a lighting scheme the following factors should be taken into account :

(*i*) **Space-height ratio.** It is defined as the ratio of horizontal distance between lamps and the mounting height of the lamps, or

Space-height ratio

$$= \frac{\text{The horizontal distance between lamps}}{\text{Mounting height of lamps}} \qquad \ldots(6.14)$$

In order to have a uniform illumination which can be only with reflectors, it is necessary that the value of this should be properly chosen. When reflectors are used, the value of this ratio is given as between 1 and 2. The height of the source should be between 2.2 m to 2.45 m from the ground level.

(*ii*) **Utilization factor.** The total light flux radiated out by the source is not utilized on the working planes and its value is given as

Utilization factor

$$= \frac{\text{Total lumens utilised on working planes}}{\text{Total lumens radiated by lamp}} \qquad \ldots(6.15)$$

The value of this co-efficient depends upon the following conditions :

(*a*) the area to be illuminated;

(*b*) height at which the lamps are fitted;

(*c*) the colour of surrounding walls, ceiling fittings etc.;

(*d*) the type of lighting–direct or indirect.

The value for direct light varies from 0.25 to 0.5 while its value for indirect light varies from 0.1 to 0.3.

(*iii*) **Depreciation factor.** When the lamps are covered with dust, dirt and smoke, they do not radiate out same amount of flux as when they do at the time of fitting new lamps.

Similarly, after some time the walls and surrounding in which lamps are fitted are covered with dirt and dust, so they do not reflect the same amount of light as compared with the initial conditions. The depreciation factor takes into account all such loss of flux.

Thus depreciation factor

$$= \frac{\text{Illumination under normal working conditions}}{\text{Illumination when everything is clean}} \quad \ldots(6.16)$$

Its average value is 0.8.

The depreciation factor is also given as

$$= \frac{\text{Illumination when everything is clean}}{\text{Illumination under normal working conditions}} \quad \ldots(6.17)$$

In this case, the value of depreciation factor is more than 1 and its value is 1.3 to 1.4. Table 6.3 indicates the light reflected from various coloured surroundings.

Table 6.3

Colour of surface	*Light reflected in percentage*
Light White	81%
Light Cream	69% to 75%
Light Green	65%
Light Grey	58%
Medium Gray	55%
Dark Tan	46%
Dark Grey	25%
Dark Olive Green	15%
Dark Red	12%
Natural	23%

Total lumens required. The total gross lumens output

$$= \frac{\text{Area (sq. ft.)} \times \text{illumination (ft. candles)}}{\text{Co-efficient of utilization} \times \text{Depreciation (for values less than 1)}} \quad \ldots(6.18)$$

Also

$$= \text{Area (sq. ft).} \times \text{Illum. (ft. candle)} \times \frac{\text{Dep. factor (for values more than 1)}}{\text{Co-efficient of utilization}} \quad \ldots(6.19)$$

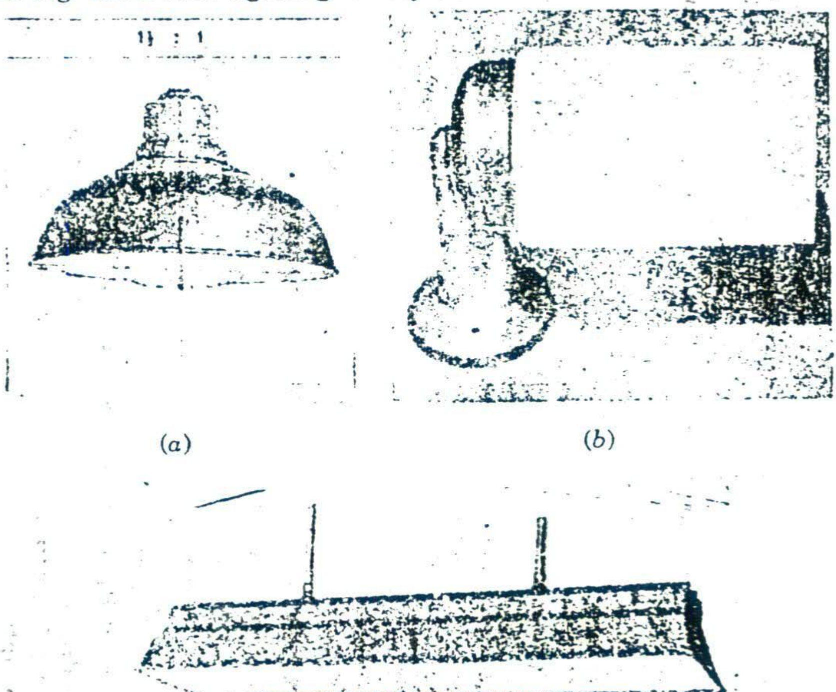
9. Illumination required for various purposes :

The illumination required is given in Table 6.4 and 6.5

10. **Lighting Schemes.** If the light from the source falls on polished or metallic surfaces, the light is reflected back. According to laws of reflection, the angle of reflection is equal to angle of incidence. This is very good as far as illumination is concerned but only drawback is that it produces glare on the eyes.

If the light from the source falls on coarse surface like painted ceilings, frosted glass and paper, the light is diffused in all directions and no glare or image is formed. This method is used for internal or external lighting. Following types of lighting schemes can be incorporated in any construction:

(1) *Direct lighting.* In this type, the light directly falls from the source *i.e.* lamps. The shades or globes are provided to cover the source from the line of vision. Such type of arrangement is shown in Fig. 6.8. Direct lighting is very efficient but it causes shadows



(*a*) (*b*)

(*c*)

Direct lighting schemes

Fig. 6.8

Table 6.4

0.1 to 5 Ft. Candle	*10 Ft. Candles*	*15 Ft. Candles*	*20 Ft. Candles*	*30 Ft.-50 Ft. Candles*	*Above 50 Ft.Candles*
Corridors, Stair case, Storage Toilets, Auditoriums, Cinemas, Dancing Halls, Night clubs and Bars, Railway platforms and Hospital wards.	Restaurants, Lunch Rooms, Cafetaria, Dinning Halls, Conference Room, Reception Room, Waiting Room, Lobby and Museum etc.	Bank's Lobby, Railway Compartment, Street Lights.	For intermittent reading or writing, Filing clerk or Daftry's room, Store room of an industry offices, Class room, Library, Showrooms, Kitchen and operating room.	Steno-Typist room, Design Cabins, Drawing rooms, Office, Bank Counter and desks.	Used for person work where minute adjustment and rapid discrimination is required.

Table 6.5

If the light requirement for reading a good print at 10 years of age is 1 unit, then

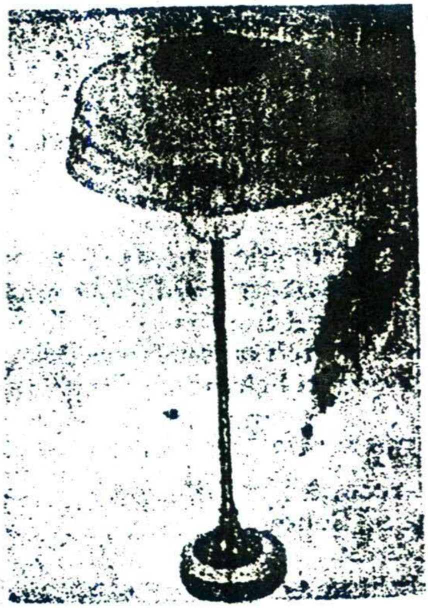
For	20 years of age	... ...	1.5
"	30 years of age	... ...	2.0
"	40 years of age	... ...	3.0
"	50 years of age	... ...	6:0
"	60 years of age	... ...	15.0

Level of Illumination required for

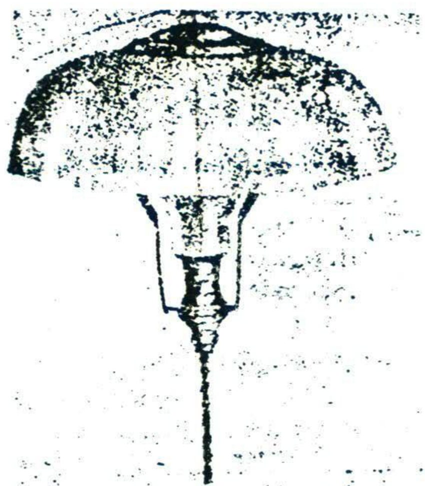
Children upto	10 years of age	— 200 lux.
Men & Women upto	40 years of age	— 600 lux.
-do- upto	60 years of age	— 3000 lux

and glare. *The correct and uniform light in a room is obtained by correctly locating the lamps at different places.*

(2) *Indirect lighting.* As the name implies, in this case the light does not reach the surface directly. In this case maximum light is thrown towards the ceiling from where it is diverted to the room through diffuse reflection. The indirect lighting is suitable specially for drawing offices, workshops where shadowless light is preferred. However there is one drawback in this system that the illumination will be depressive to the eye. Fig. 6.9 (*a*) shows an arrangement which can provide indirect lighting.



Indirect lighting
(*a*)

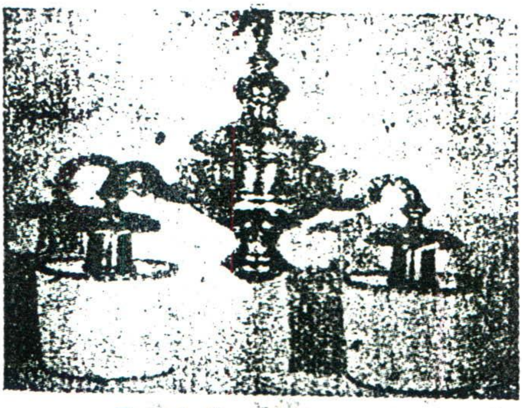


Semi-direct lighting
(*b*)

(c)
Fig. 6.9

(3) *Semidirect lighting.* In this system about 50% of the light is

sent from the source directly on the reading plane and about 30% is sent upward. Diffused globes are preferred in this case, which avoids glare. Such schemes provide uniform distributed light in a room. Fig. 6.9 (*b*) shows an arrangement which can provide semi-direct lighting.



Semi-indirect lighting
Fig. 6.10

(4) *Semi-indirect lighting.* In this system 40% light is sent upward for diffused reflection and 40% is sent directly on the surface. Fig. 6.10 shows an arrangement for such a scheme semi translucent plastic bawls are used. The defect of indirect lighting as given above does not exist in this scheme.

Table 6.6
Amount of Light to be received in different System of Lighting Scheme.

Systems	*Down wards*	*Up wards*
1. Direct	90—100%	0—10%
2. Semi direct	60—90%	10—40%
3. General Diffuse	approx. 50%	approx. 50%
4. Mixed Diffuse	40—60%	60—40%
5. Semi-indirect	10—40%	60—90%
6. Indirect	0—10%	90—100%

Example 1. *A lamp having mean spherical candle power of 800 is suspended at a height of 10 ft. Calculate (a) the total flux of light. (b) the illumination just below the lamp.*

Solution.

(*a*) Total lines of flux = M.S.S.P. × 4π = 800 × π.

= 10,048 lumens. Ans.

(*b*) The illumination just below the lamp

$$= \frac{C.P.}{d^2} = \frac{800}{(10)^2}$$

= **8 ft.-candle. Ans.**

Example 2. *A room 50 ft. × 20 ft. is illuminated by twenty 200 watt lamps. The M.S.C.P. of each lamp is 250. Assuming a depreciation factor of 1.2 and utilization factor 0.6, find the average illumination produced on the floor.*

Solution. Area of the room = 50 × 20 = 1000 sq. ft.

M.S.C.P. of each lamp = 250

Total number of lumens given by each lamp

$$= 250 \times 4\pi = 3,140 \text{ lumens}$$

Total number of lumens given by all lamps

$$= 3,140 \times 20 = 62,800$$

$$\text{Lumens utilized} = \frac{62,800 \times 0.6}{1.2} = 31,400$$

From Eq. (6.18)

$$\text{Average illumination on floor} = \frac{\text{Lumens utilized}}{\text{Area of the floor}}$$

$$= \frac{31,400}{1,400} = \textbf{31.4 ft. candle. Ans.}$$

Example 3. *A workshop measures 20 × 40 ft. and is lighted by 10 lamps which are each rated at 200 watts and have an efficiency of 15 lumens/watts. Assuming a depreciation factor of 1.5 and a coefficient of utilisation of 0.5 find the illumination at workshop plane.*

[A.M.I.E. Sec. B, 1955 (Elect. Engg.)]

Solution.

Total luminous output

$$= 10 \times 200 \times 15 = 30,000 \text{ lumens}$$

In view of Eqn. (6.19),

$$\text{illumination} = \frac{30,000 \times 0.5}{1.5 \times 20 \times 40}$$

$$= 12.5 \text{ lumens/ft}^2 \quad \textbf{Ans.}$$

Example 4. *A workshop size 40 × 60 ft. by 12 ft. height is to be illuminated to 45 lumens per sq. ft. on the working plane. If the coefficient of utilization is 0.5 and the source gives out 10 lumens per watt, find the total wattage required and number of lamps assuming depreciation factor as 0.8.*

Solution.

In view of Eqn. (6.18),

$$\text{Total lumens required} = \frac{40 \times 60 \times 45}{0.5 \times 0.8} = 2,70,000 \text{ lumens}$$

$$\text{Power required} = \frac{2,70,000}{10} = 27,000 \text{ watts.} \quad \textbf{Ans.}$$

If each lamp of 200 watts is to be fixed, then

$$\text{No. of lamps} = \frac{27,000}{200} = 135 \text{ lamps.} \quad \textbf{Ans.}$$

Example 5. *An illumination on the working plane of 3 ft. candle is required on a room 270′ × 50′. The lamps are required to be hung 15 ft. above the work benches. Assuming space/height ratio of 1.25, a utilisation factor of 0.5 and a candle power depreciation of 20%, estimate the number, rating and disposition of suitable lamps. Efficiency of a lamp may be taken as 0.5 watt per candle power.*

Solution.

In view of Eqn. (6.19),

$$\text{Total lumens required} = \frac{3 \times 270 \times 50 \times 1.2}{0.5}$$

$$= 97,200 \text{ lumens}$$

Output of the lamp for 0.5 watt = 1 C.P.

$$= 4\pi \text{ lumens}$$

Output of the lamp for each watt = 8π lumens

$$\text{Total wattage} = \frac{97,200}{8\pi}$$

$$= 3,866 \text{ watts}$$

$$\frac{\text{Spacing of the lamps}}{\text{Height}} = 1.25$$

$$\text{Spacing of the lamps} = 18.75 \text{ ft.}$$

Now if 2 lamps are provided widthwise, the space height ratio will be too more; and if 3 lamps are provided, the ratio will be 1:10 approx. which will be acceptable.

Similarly 14 lamps can be placed lengthwise, bringing the number of lamps as 42.

$$\text{Wattage of each lamp} = \frac{\text{Total wattage}}{\text{No. of lamps}}$$

$$= \frac{3,866}{42} = 92.05 \text{ or say } 100 \text{ watts. Ans.}$$

11. Methods of Lighting Calculations

Some of the common methods of lighting calculations are given below :

(*a*) Watts per square metre method.
(*b*) Lumen or light flux method.
(*c*) Point to Point or Inverse square law method.

Description

(*a*) *Watts per square metre method*. Basically it is a 'Thumb Rule' method. It is very handy for rough calculation or checking. While applying this method, an allowance of watts per square metre of area to be illuminated is taken according to the illumination desired on an average figure of overall efficiency of the system.

(*b*) *Lumens or light flux method*. This method is applied to those cases where the sources of light have to produce an approximate uniform illumination over the working plane or where an average value is required. Total lumens output is calculated from the efficiency of each lamp and the number of lamps used in the circuit. To calculate the lumens received on the working plane, the total lumens already calculated are multiplied by the co-efficient of utilisation. When the lamps and surroundings are not perfectly clean then while calculating the Lumens received on working plane, the depreciation factor or maintenance factor is taken into consideration.

Thus Lumens received on working plane

= No. of lamps × Wattage of each lamp × efficiency of each lamp in terms of lumens/watt × $\frac{\text{Coefficient of utilisation}}{\text{depreciation factor}}$

or = No. of lamps × Wattage of each lamp × Efficiency of each lamp in terms of lumens/watt × coefficient of utilisation × maintenance factor.

Coefficient of Utilisation or Utilisation factor

The light which is radiated by all lamps does not reach the working plane. When the installation is new, the ratio of lumens reaching the working plane to the total lumens given out by the lamp/lamps is known as utilisation factor or coefficient of utilisation. If the utilisation factor is on higher side, then more lumens will reach the working plane for the given lumens output of the lamps. The value of utilisation factor depend upon :

(*i*) The mounting height of lamps *i.e.* it decreases with the increase in mounting height of lamps.

(*ii*) Area to be illuminated *i.e.* utilisation factor increases with the increase in area to be illuminated.

(*iii*) Type of lighting *i.e.*, it is more for direct lighting and less for indirect lighting.

(*iv*) Colours of surroundings *i.e.* it is more for light colours and less for dark colours.

Its value varies from 0.25 to 0.5 and from 0.1 to 0.25 for direct and indirect lighting schemes respectively.

Maintenance factor. The illumination produced by a lighting installation decreases considerably after a year or two partly due to the aging of lamps and partly due to the accumulation of dust on the lamps, on the transmitting and reflecting fixtures and on the ceilings and walls. So at the time of calculation of lumens received on the working plane, this fact is taken into account by including the maintenance factor which may be defined as *the ratio of the ultimate maintained metre candles on the working plane to the initial metre candles.* If the lamps and fixtures and surroundings are cleaned regularly, its value is more say 0.8 and if there is more dust then its value decreases to 0.6.

Depreciation Factor. This is merely the reverse of maintenance factor. Its value in more than unity.

(*c*) *Point to point or Inverse-square law method.* This method is applied where the illumination is required at a point due to one or more sources of light.

The illumination at any point within the range of the lamp can be calculated from the Inverse square law, if a polar curve of lamp and candle power of lamp reflected by its reflector in different directions is known. If two and more than two lamps are illuminating the same working plane, illumination due to each can be calculated and added. This method is not commonly used due to more complications involved in its calculations. However, it is used in some special problems such as flood lighting and yard lighting etc.

12. Types of Electric Lamps. Following types of lamps are being used :

(1) *Incandescent lamp.* This type can further be divided into the following :

(*a*) Incandescent vacuum lamp.
(*b*) Incandescent gas filled lamp.

(2) *Discharge lamp.* Following types of discharge lamps are being used :

(*a*) Sodium discharge lamp.
(*b*) Low pressure mercury discharge lamp.
(*c*) Neon lamp.
(*d*) High pressure mercury discharge lamp.

13. Incandescent Vacuum Lamps. When an electric current is passed through a fine metallic wire, it raises the temperature of the wire, and heat energy will be radiated at low temperatures. At high temperatures heat as well as light energy will be radiated : the higher the temperature of the wire, higher is the amount of light energy radiated.

The incandescent lamp consists of an evacuated* glass bulb having a fine metallic wire within it. The metal which can be used as a filament must have the following properties :

(1) It must be capable of being worked at very high temperatures, *i.e.* its melting point must be high.

(2) It should have low temperature co-efficient.

(3) It must be ductile.

(4) It must be very strong mechanically to withstand vibration during normal use.

(5) It must have low vapour pressure.

*The lamps are evacuated (*i*) to prevent the oxidization of the filament, (*ii*) to prevent the temperature lowered by radiation.

The different types of materials which can be used for the production of light in incandescent lamps are carbon, tantalum and tungsten. Carbon has a melting point of about 3500 but the main drawback is that it cannot be worked at higher temperatures as at high temperatures it starts disintegrating and blackens the inside of the bulb : moreover its temperature co-efficient is negative and thus its resistance decreases at higher temperatures and so it takes more current from mains. The efficiency of this lamp is low and is of the order of 4 lumens per watt. When tantalum metal is used as a filament of the incandescent lamp, the drawback of negative temperature co-efficient is compensated since its temperature co-efficient is positive and is of the order of .00235. But the greatest drawback in such types of filament is that its melting point is only 2580°C, thus it cannot be worked at higher temperatures to give more efficiency. The efficiency of tantalum lamps is about 5 lumens per watt.

Tungsten is the most common material used as filament in modern lamps. It is being preferred to carbon and tantalum due to the following reasons :

(*i*) Its melting point is high, of the order of 3400°C, (no doubt it is less than that of carbon, but it can be worked at higher temperatures).

(*ii*) Its vapour pressure is low.

(*iii*) It is very strong and can be made ductile.

(*iv*) Its temperature co-efficient is 0.0051.

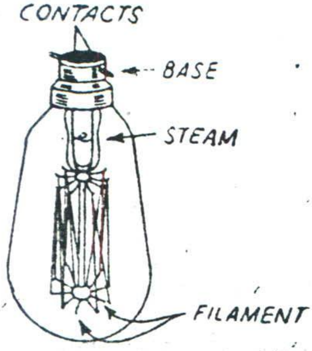


Fig. 6.11

The chemically pure tungsten is very strong and fragile. In order to make it ductile, the pure tungsten oxide is first reduced in the form of a grey powder in an atmosphere of hydrogen. The powder then is pressed under hydraulic presses into small bars. These bars are again heated in an atmosphere of hydrogen at about 1100°C. Further in order to make these bars strong mechanically, they are raised to melting point by passing an electric current through them, but still the bars are not ductile. In order to make them ductile, they are heated and resolved and then they are drawn into wires. Fig. 6.11 represents a vacuum lamp with a large barrel-shaped filament.

14. Gass-filled Incandescent lamp. It has been said earlier that in order to prevent the oxidization of the filament the lamps are evacuated. The minimum temperature at which the filament can be worked without oxidization is 2000°C. It has been observed that when the tungsten lamp is worked beyond 2000°C it blackens the inside of the lamp. Now in order to make the lamp more efficient it must be worked at the highest temperature possible. In tungsten lamps, it can be attained by inserting a small quantity of inert gas (nitrogen with small quantity of argon). In the barrel type of construction of the lamp, the filament is quite distributed over whole of the lamp surface, and in this type of construction, if gas is added, the heat of the lamp is conducted away and it reduces the efficiency of the lamp. To reduce the dissipation of heat, the surface area of filament lamp is reduced. So the filament is so wound that it takes very little space, *i.e.* they have coiled filament or a coiled coil filament as shown in Fig. 6.12. The gas prevents the arching between two consecutive coils of the spiral filament. As the lamps are always hung vertically, any disintegrated part of the filament is convected to the top of the lamp and so the efficiency of the lamp is not affected.

In case of low wattage lamps the heat loss due to introduction gas is more than in the medium wattage lamp, so for low wattage lamps vacuum type is used. For wattage up to 100, coiled coil lamps, are used and for still lighter wattage lamps single coil filament are used.

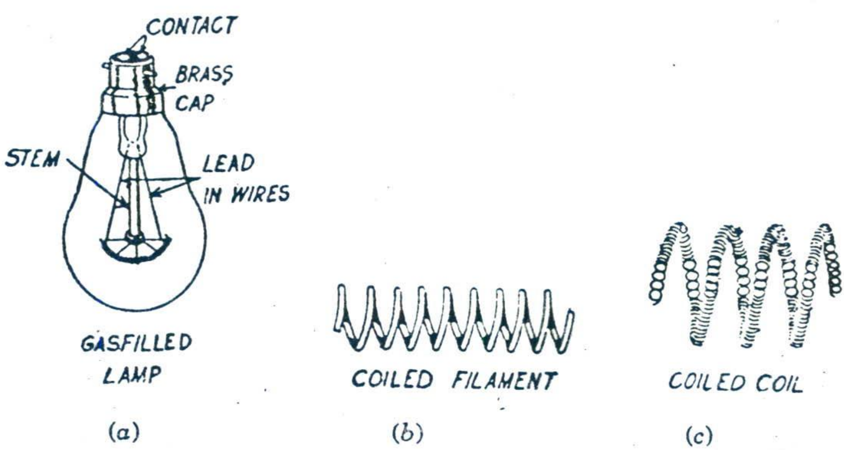


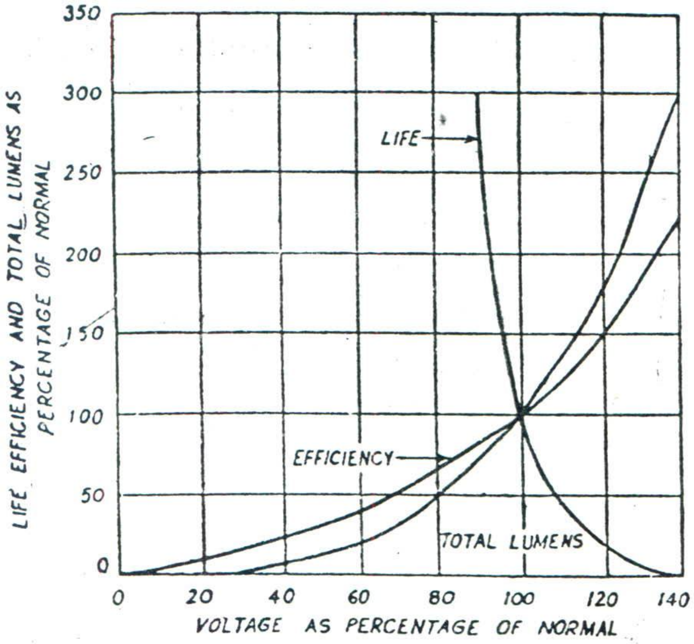
Fig. 6.12

15. Characteristics of Incandescent Lamps. The candle power or the total number of lumens given out by the lamp depends much upon the applied voltage and the relation between them is given as :

$$C.P. \propto E n \quad \ldots(6.20)$$

where n = Constant and varies from 4 to 5 for tungsten filament lamps, and from 8 to 7 for carbon filament lamps.

The efficiency of the lamp is given in lumens/watt, the efficiency or the total number of lumens given out by the lamp increases with the increase of temperature or voltage. The life of the lamp in number of hours decreases with the increase of voltage. Fig. 6.13 represents the curves for life, efficiency and total lumens.



Curves for life efficiency and total lumens
Fig. 6.13

16. Halogen Lamp. This is one of types of incandescent lamps, possessing number of advantages over the ordinary incandescent lamp. The life and efficiency of an incandescent lamps are affected by the gradual evaporation of tungsten and also its operating temperature, But the addition of a small amount of halogen vapour to the filling gas restores part of the evaporated tungsten vapour back to the filament by means of a chemical reaction and the cycle goes on. Halogens are a group consisting of the elements fluorine, chlorine, bromine and iodine.

As a result, halogen lamps possess the following advantages :

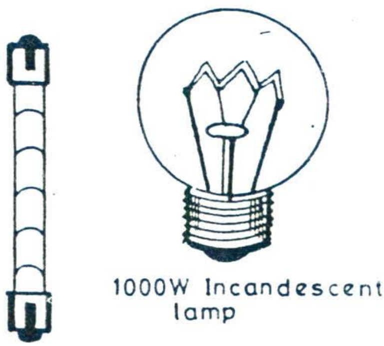
(*a*) The blackening of the bulb is not caused, so there is no depreciation of light output.

(*b*) It has 50% more efficiency than that of an ordinary incandescent lamp.

(*c*) It is smaller in size than that of incandescent lamp.

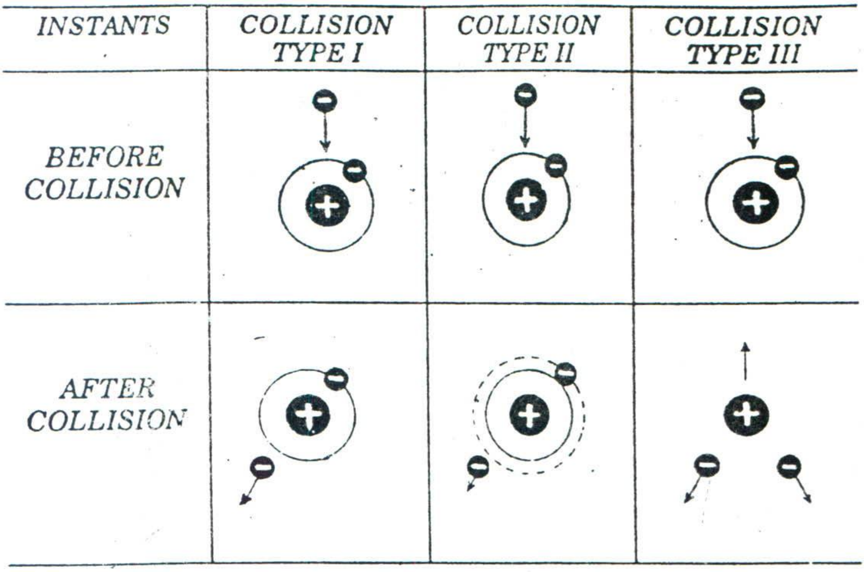
(*d*) It gives better colour radiation.

Halogen lamps are manufactured upto 5 kW and are suitable for outdoor illumination of building, sports grounds, parks, airports etc. These are also used for lighting of halls, factories, sport halls and marriages' shamianas etc.



The Comparison of Halogen Lamp of 1000 W
and 1000 W incandescent lamp.
Fig. 6.14

17. Working Principle of Electric discharge Lamp. Such lamps have a transparent enclosure and contain a gas or vapour at low pressure (sometimes the pressure is several atmospheres). At the two ends of the lamp electrodes are provided for connecting the lamp to the mains. The principle of such lamp is that the light is obtained from the excited atom of the gas. In the discharge space, there are three kinds of particles such as neutral atoms or molecules of gas or vapour, positive ions and electrons. When the potential is applied to the electrodes, the neutral atoms will not respond to potential gradient but will have a motion at random depending upon thermal conditions ; *but the positive ions and electrons will have an axial drift towards the cathode and anode respectively*. The movement of the electrons is accelerated by the potential gradient and thus obtain a very high velocity and so possess high kinetic energy. During the passage of the movement of the electrons toward anode, they collide with the neutral atoms or molecules of the gas or vapour. The collisions are of three types which are detailed below and as well as shown in Fig. 6.15.



Types of collision in discharge lamp
Fig. 6.15

(*i*) The collision may be elastic in which case the electron simply bounces off the neutral atom without any physical change. Such a collision results in the change of direction and change of velocity of both electron and neutral atom.

(*ii*) The collision may be so severe that the neutral atom may receive sufficient energy to displace the valency electron from normal orbit to the outer orbit. The energy received by the neutral atom for such displacement is equal to the work done against the gravitational attraction of the molecules. The loss in the kinetic energy of the colliding electron is equal to the energy gained by the neutral atom with which the electron has collided. When the structure of the atom is thus changed, the atom is said to be in an excited state. The excited state of the atom is an unstable state for about 10^{-8} secs, after which the atom attains its original state and in doing so, it *gives out energy exactly equal to that received by it in the form of light waves.*

(*iii*) The collision of the electron with the neutral atom may be so violent as to detach the electrons from it. The atom after losing electron becomes positive and starts moving towards the cathode.

All these effects of collisions have been given in Table 6.7.

Table 6.7

Instants	*Collision Type I*	*Collision Type II*	*Collision Type III*
Result	(*i*) No physical change.	(*i*) The structure of the atom is changed.	(*i*) The electron is detached from the neutral atom.
	(*ii*) Change in the direction of electrons.	(*ii*) Loss in kinetic energy of the colliding electrons and is equal to the energy received by the atom.	(*ii*) The neutral atom attains positive charge.
	(*iii*) Change in velocity.	(*iii*) The structure of the atom is changed and the atom is said to be excited.	
		(*iv*) After about 10^{-8} secs, the atom reverts to its original state and gives out energy in the form of light waves.	

The gas discharge lamps are preferred to filament lamps due to the following reasons :

(*a*) It has been seen that the efficiency of the filament lamp is dependent upon the temperature at which it is worked but there is a limit to which its temperature can be increased which is much less than the melting point of the filament. Even if the working temperature of the filament is high only a small portion of the total energy radiated is in the form of light energy, while in the case of a discharge lamp the light energy is obtained from a gas column which is not heated but is excited electrically.

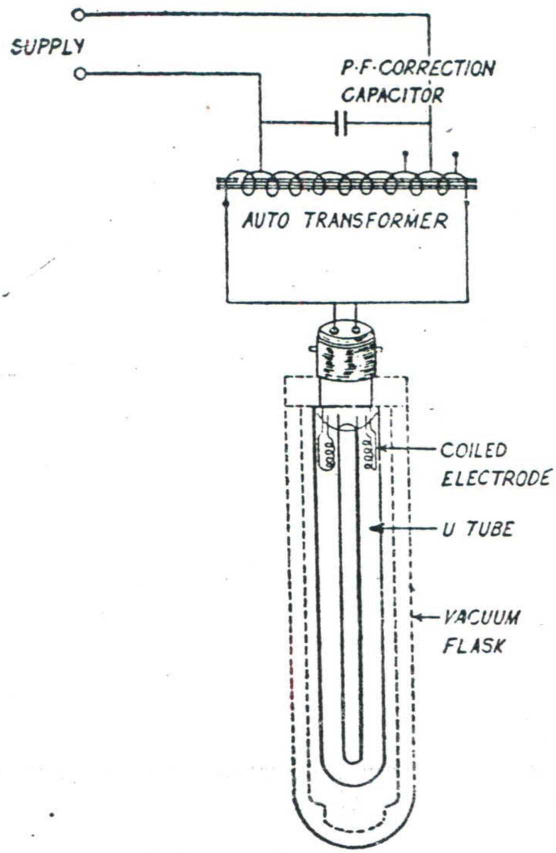
(*b*) The gas discharge lamps are capable of giving only one particular type of wavelength of electrical energy while the incandescent lamps give light energy of all wavelengths. It is due to the fact that the atoms in a solid filament are closely packed and are not capable of radiating energy of one frequency, while in gas discharge lamps, the atoms are widely separated and so can radiate out energy without interference from any other atom.

The luminance of the discharge lamps is dependent upon—

(*a*) composition of the gas ;

(*b*) the gas or vapour pressure.

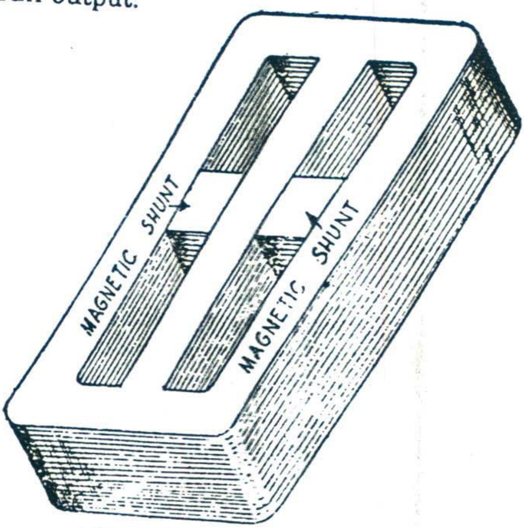
18. Sodium Discharge Lamp. It is in the form of U-tube as shown in Fig. 6.16. The glass of this tube is also special since sodium vapour blackens the ordinary glass. Usually a thin coating of special glass is made by fusing it on inner surface of the ordinary glass tube.



Sodium discharge lamp
Fig. 6.16

The lamp is quite sensitive to temperatures, as when the temperature increases over the normal working temperature, the velocity attained by the colliding electrons becomes excessive and they excite the electrons to 2nd energy level and since the radiation from 2nd energy level of 3.61 V is of wavelength which lies in the ultraviolet region ; also if its temperature lowers below the normal working temperature, the sodium does not remain in the vapour form. So to keep the temperature of the lamp within the working range, it is enclosed in a double-walled flask as shown. In addition to sodium a small quantity of inert neon gas is also inserted.

Operation. Before the lamp starts working the sodium is usually in the form of a solid deposited on the sides of the tube walls. So in the initial state when the potential is applied to the lamp, it operates as a low pressure neon lamp with pink colour (characteristic of the neon gas); but as the lamp warms up it vaporizes sodium and slowly, it radiates out yellow light and after about twenty minutes, the lamp starts giving its full output.



Transformer core

Fig. 6.17

At the time of starting the discharge lamp, a voltage higher than the normal supply voltage is required which is 350 V for the 45 watts lamp and 410 volts for 100-watt lamp. Such voltages are obtained from an auto-transformer. The auto-transformer used has a very poor regulation, *i.e.* at no load when no current is taken from the transformer, the voltage is very much higher than when the transformer is loaded. Thus when the discharge starts, the output voltage of the transformer falls. The regulation of the transformer is made poor by increasing the leakage reactance which in turn is obtained by means of providing magnetic shunts in the core as shown in Fig. 6.17. Hence the transformer acts as a blast.

The colour of the sodium discharge lamp is *bright yellow and is recommended only for street lighting.* The life of such a lamp ends when :

(*a*) the filament breaks or burns out ;

(*b*) when the cathode fails to emit electrons ;

(*c*) when the sodium particles may concentrate to one side of the tube ;

(*d*) when the lamp tube is blackened due to sodium vapour action on the glas,, in which case the output will be reduced.

Advantages. (1) First excitation level is achieved at law potential and thus requires less energy in excitation as compared to other vapours.

(2) Most of the radiation is on visible region and therefore more economical.

Disadvantages. (1) Its luminous intensity is low which is approx. 9 candle-cm^2 and to evercome this, U-tube of larger size as shown in Fig. 6.16 is used.

(2) The colour of the light is bright yellow and thereby its use is restricted to street lights or advertisement.

19. Low Pressure Mercury Discharge Lamp. The mercury discharge is quite complicated since the atom of mercury has eighty electrons and they are of two valency. These two valency electrons are excited in a number of ways and in the visible spectrum, the colours radiated are yellow, green, blue and violet. From this visible radiation, the effect of variation of wavelength 5461 A^0, which produces green colour, on the human eye is maximum and as the radiations depart from this wavelength, the visual effect decreases.

Therefore the radiations from the low pressure mercury discharge give a spectrum of few lines resulting in a colour which is very objectionable from practical point of view. The gaps in the mercury discharge spectrum must be filled in. Such filling is obtained by the following methods :

(*i*) By using fluorescent materials in the tube.

(*ii*) By increasing the vapour pressure in the tube.

(*iii*) By using mixed vapours.

(*iv*) By using low mercury discharge lamps in conjunction with temperature radiations.

20. Mercury Fluorescent Lamps. *(Low pressure)*

It has been pointed out earlier that the low pressure mercury discharge lamps produce an objectionable colour and have a low efficiency. Such drawbacks can be overcome by coating the inside of the tube with a fluorescent material. Before the discharge lamps are explained, it is necessary to have some knowledge of fluorescence which is explained as :

All bodies except perfect absorbers reflect most of the light falling on it ; the difference may be due to the absorption of certain wavelengths of incident light by the colour of the body. There are certain bodies which do not observe the general law of reflection but radiate out light energy in a different wavelength if the incident radiation is in the ultraviolet region. Usually the radiated wavelength is longer than the incident wavelength. The phenomenon of re-emission is called as *luminescence*. The luminescence can be classified as :

(*a*) *Fluorescence,* in which case the excitation lasts only for the excited period.

(*b*) *Phosphorescence,* in which case the excitation persists even after the exciting source is removed.

In case of discharge lamp, the radiation of light energy is due to the collision of electrons. Again, for luminescence the radiation is due to the collision process but of *photons*. The photon is an excited atom as a whole and possesses an energy equivalent to the energy level acquired by the excited valency electron of the atom, for example the energy of photon of resonance radiation is exactly equal to the first excitation of the electrons. When the photon, say of resonance radiation, collides with a neutral atom of fluorescent material, it transfers its whole energy to the neutral atom and it disappears itself. The part of the energy received by the neutral atom reappears in the form of light energy of longer wavelengths. Let E by the energy received by the fluorescent material.

So wavelength of photon giving incident radiation to the fluorescent material is $= \dfrac{12,378}{E}$

$$\text{Let the energy re-emitted} = \alpha E \qquad \ldots(6.21)$$

where α is always less than 1, since the energy re-emitted is always less than the incident energy.

$$\therefore \text{ Wavelength of re-emitted radiation} = \frac{12,378}{\propto E} \qquad \ldots(6.22)$$

The fluorescent powders used in case of low pressure lamps are solids and are usually called as *phosphors*. The phosphors used are shown in Table 6.8. They are excited by resonance mercury radiation. By the use of suitable mixtures of phosphors a variety of colours can be obtained.

Table 6.8

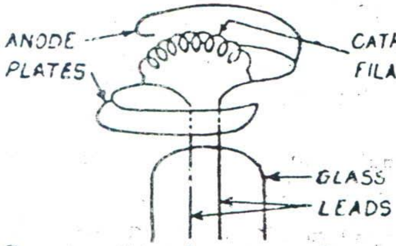
Phosphor	*Wavelength in A° of emitted radiation*	*Colour of Fluorescence*
Calcium tungstate	3800–7000	Blue
Magnesium tungstate	3800–7200	Blue-white
Cadmium borate	4000–7000	Pink
Cadmium silicate	4300–7200	Yellow-pink
Zinc silicate	4500–6200	Green
Zinc-beryllium silicate	4500–7200	Yellow-white

For commercial use the phosphors usually contain a heavy impurity called activator. such an impurity is introduced in order to have the required spectral distribution in the re-emitted radiation. The materials used as activators are shown in Table 6.9.

Table 6.9

Activator	*Colour of Fluorescence*
Silver	Blue
Copper	Green
Bismuth	Green
Gold	Blue-white
Manganese	Deep-yellow
Copper plus silver	Bluish or greenish white

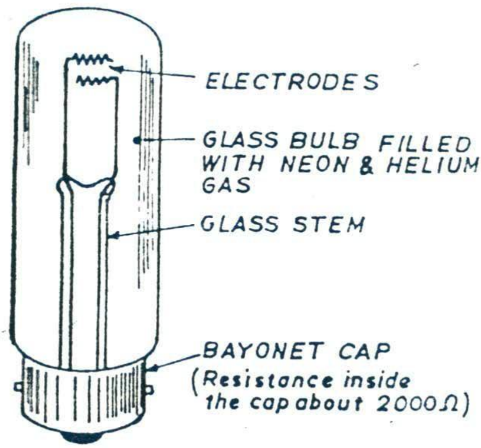
Construction of the Lamp. The low pressure mercury lamp is essentially a long tube, the inside of which is coated with phosphor. The tube contains a small amount of mercury and a small quantity of argon gas at a pressure of 2.5 mm. of mercury. The presence of the gas is justified as at starting the mercury is in the form of globules, so in the beginning the lamp starts



Construction of mercury fluorescent lamp (low pressure)
Fig. 6.18.

conducting with argon gas and as the temperature increases, the mercury changes into vapour form and takes over the conduction of current. Both the electrodes of the lamp are of tungsten and are coated with an electron-emitting material (usually an alkaline earth). Each of the filament alternatively acts as a cathode and emits electrons and so also each of them alternatively acts as an anode. But since during each half of a cycle it is almost an insulator, it does not attract electrons. So for collection of electrons, each end is provided with metallic fins called as anodes as shown in Fig. 6.18. The starter filaments of the tube and the choke all form one series circuit. The series choke acts as a ballast when the lamp is running and it also provides a voltage impulse for starting. The starter used is a small cathode glow tube with bimetal strips as support to the electrodes and when starter is cold, the electrodes of the starter are open.

21. Neon Lamp. It is a cold cathode lamp. It consists of a glass bulb filled with neon gas with a small percentage of helium. Such types of lamps give orange pink coloured light. The electrodes used in the lamp are of pure iron and are spaced only few mm apart so that lamps may be made for the voltages as low as 110 volts a.c. or 150 volts d.c. When the lamps are to be used an a.c. supply,



Neon lamp
Fig. 6.19

the electrodes used in the lamp should of equal size. when the lamps are used on d.c. supply, the gas glows near the negative electrode. Therefore negative electrode is made larger in size owing to discharge of the gas between the electrodes in the form of an arc, it may cause the current drawn by the lamp to increase indefinitely.

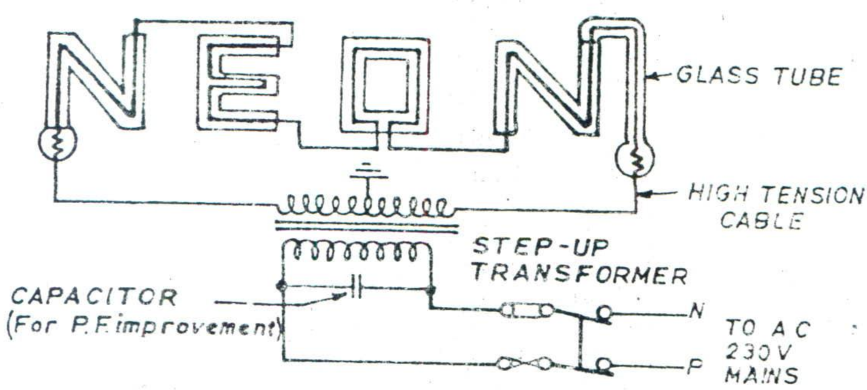
This can be prevented by inserting a high resistance of few thousand ohms in series of the electrode and mounted in the cap of the lamp. The size of this lamp is of an ordinary incandescent lamp. The efficiency of the lamp lies between 15 lumens/watt to 40 lumens/watt. The power consumption of the lamp is 5 watt.

22. Neon Tubes. The high voltage neon tubes or neon signs are used for advertising; for signs ; for the decoration of buildings etc. The neon tubes are used in varying lengths upto 8 m and are bent into almost any desired shape during manufacturing. The neon tubes contain two electrodes, one at each end of the tube, made of iron, steel or copper.

The neon tubes are manufactured in different colours by varying the composition of glass and adding different substances to neon gas.

Colour Production

1. Orange-Red → Neon gas
2. Blue → Mercury neon and argon gas
3. Green → Yellow glass and mixture of neon and mercury.
4. Yellow → Yellow glass and helium gas.



Arrangement of Neon Signs
Fig. 6.20

The tubes are manufactured in different diameters like 10, 15, 20 and 30 mm which may carry currents of 25, 35, 60 and 150 m A respectively. The voltage required per metre of tube length is 300

V to 1000 V and for starting the discharge, a striking voltage of about $1\frac{1}{2}$ times this value is required. The high voltage is obtained with the help of step up transformer, having a high leakage reactance so that it may give drooping characteristics.

The neon tubes are installed either on a wooden frame or a metal base. Nickel wires are used for the connection of letters in the neon signs which are covered with glass tubings and these are matched with step up transformer by connecting suitable tappings for the rated current. Since the power factor of the neon tubes is quite low which is improved by using capacitors on the low voltage of transformers in the circuit. When the neon tubes are installed in open, they require frequent cleaning, say 4 times per annum. Sometimes flickering is noticed in the lighting which can be rectified by adjustment of the transformer tappings. Flickering may be due to low gas pressure in the tube on account of absorption of the gas in the electrodes. The gas can be got filled by the manufacturers.

23. High Pressure Mercury Vapour Lamp. There are different types of high pressure mercury vapour lamps. They are :

(*a*) M.A. Type made in 250 and 400 watt sizes for 200–250V A.C. mains.

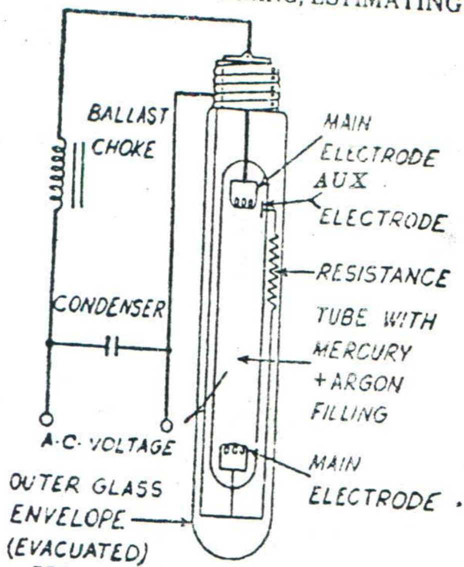
(*b*) M.A.T. Type made in 300 and 500 watt sizes for 200–250V A.C. mains.

(*c*) M.B. Type working at very high pressure and is available in 80 and 125 watt sizes.

The high pressure lamps are used either for street lighting or for industrial purposes where there is no objection to the greenish light.

(*a*) **M.A. Type Lamp.** It consists of a glass tube of borosilicatewhich is quite hard. At the two ends in the tube are provided two electrodes of specially coated wire. Near the upper electrode is another auxiliary starting electrode which is connected to the bottom electrode through a high resistance as shown. The tube is sealed with an inside pressure of one and a half atmosphere. This tube is further enveloped by another tube, the advantage of which is that the heat of inner tube may not be dissipated and the tube may not be caused to come in contact with sudden changes in temperature. The lamp has a screwed cap and is connected to the mains supply through a choke. To improve the power factor of the tube, a condenser is connected across the mains as shown.

The inner tube, in addition to mercury, also contains a small quantity of argon gas since at the time of starting, the tube is cold



H.P.M.V. lamp (M.A. Type)
Fig. 6.21

and the mercury is in the condensed form. When the tube is switched on, an arc starts between an auxiliary electrode to the main electrode and at this instant the discharge is in argon gas controlled by high resistance and due to this discharge, the whole of the argon gas becomes conducting and a discharge starts between the two main electrodes. Due to the high resistance in the auxiliary anode circuit, the discharge shifts in between the main electrodes. The discharge is of a pale blue glow and is now controlled by the choke. Due to the heat produced during discharge, the tube warms up and the mercury is evaporated and the pressure inside develops. The discharge later takes up the shape of an intense are. After about 5 minutes the lamp starts giving full output.

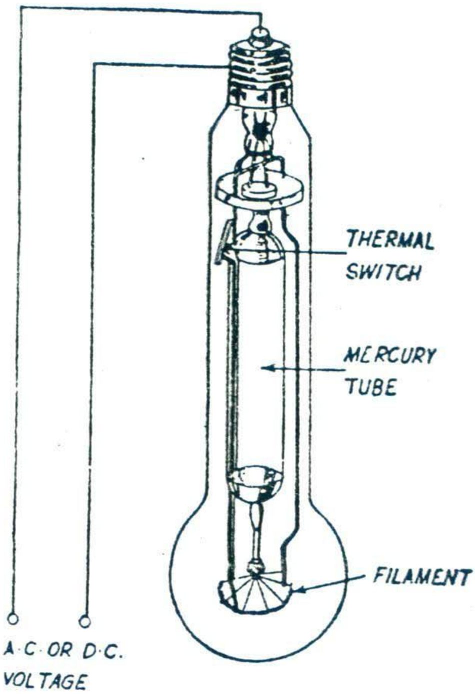
In such lamps it should be noted that–

(*i*) As the lamp is not operative when cold, its running up takes some time, about six minutes.

(*ii*) Once the lamp is switched off, it will not restart again until and unless the pressure is developed inside the tube subsides but there is no harm in keeping the switches on.

(*iii*) The lamp should always be hung vertically, otherwise the arc will burn the inner tube.

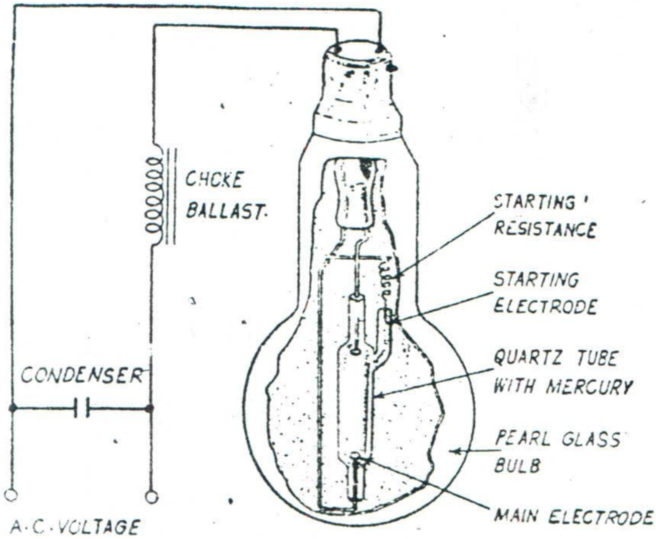
(*b*) **M.A.T. Type Lamp.** This type of lamp is almost similar to that of M.A. type, but the outer tube, instead of being empty, consists of a tungsten filament similar to that of an ordinary lamp in series with the discharge tube, so that it acts as a blast. Since the lamp does not require a blast of choke, it can be used for a.c. as well d.c. mains. When the lamp is switched on, it works as a filament lamp and its full output is given by the outer tube, at the same time the discharge tube starts warming up and when a particular temperature is attained, a thermal switch operates and coils of a part of the filament is cut off so that the voltage across the discharge tube increases.



H.P.M.V. Lamp (M.A.T. Type)
Fig. 6.22

The advantage of the type of lamp is that the colour given out by the M.A. type lamp is of poor appearance since it is short of red colour while light given by this lamp consists of a mixture of lights due to discharge lamp (short of red colour) and that due to filament lamp (excess of red colour). The colour so obtained is more something.

(c) **M.B. Type Lamp.** This lamp operates at an extra high pressure of 5 to 10 atmosphere. The discharge tube in this type of lamp is of quartz about 5 cm. long has three electrodes, two main and one auxiliary. This tube is in a pearl glass bulb, similar to that of 100 watt lamp. There is a high starting resistance in series with the auxiliary starting electrode. This lamp generally has 3 pin bayonet cap so that it may not be put in an ordinary holder since it requires a choke and a condenser.



H.P.M.V. lamp (M.B. type)
Fig. 6.23

The function of the tube is similar to that of M.A. Type lamp. Since quartz tube can withstand high temperature due to arc etc., it can be used in any position.

24. Minimum Mounting Height of Lamps.

S.No.	*Type of Lamps and Wattage*			*Min. Ht. of mounting in*	
	Tungsten	*Mercury*	*Sodium*	*Feet*	*Metre*
1.	60	–	–	8	2.5
2.	100	–	–	9	2.75
3.	150	–	45	9	2.75
4.	200	80	60	10.5	3.2
5.	300	125	85	12	3.6
6.	500	250	140	14	4.2
7.	750	–	–	17	5.1
8.	1000	400	–	20	6.0
9.	1500	–	–	24	7.2

Notes. In order to avoid the feeling of inconvenience or discomfort and disability, the light should be installed at the proper height so that there should be no strain on the eyes and direct type of fixtures should be avoided.

25. Street Lighting

(*i*) To make the road clearly visible is order to promote safety and convenience to the traffic and any other obstructions, if any.

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

(*iii*) To increase the community value of the street.

26. Lighting Schemes. In this system of lighting, since there are no walls and ceiling which reflect or diffuse light, hence only direct lighting scheme is used. As the areas to be illuminated being large, the value of illumination for economic reasons is very low as compared to that of indoor lighting and the question of colour rendering is also of minor importance. Owing to the low illumination, the eye is in its most sensitive state and therefore glare must be avoided.

27. Principle of designing of street lighting installations. Generally two principles are employed in the design of street lighting installations *i.e.*

(*i*) The Diffusion Principle (*ii*) The Specular Reflection Principle

(*i*) **The Diffusion Principle**. In this case the lamps are fitted with suitable reflectors. The reflectors are designed in such a way that they may direct the light downwards and spread over the road surface uniformly. To avoid glare, the reflectors are made to have a cut-off off between 30° to 45° so that the filament is not visible. The diffusing nature of the road surface causes the reflection of a certain proportion of the incident light in the direction of the observer and therefore the road surface appears bright to the observer. The illumination at any point on the road surface is calculated by applying point to point or inverse square law method.

(*ii*) **The Specular Reflection Principle.** In this case, the reflectors are curved up in such a way that the light is thrown on the road at a very large angle of incidence. It has been observed that a motorist requires to see objects about 30 m away, which is fulfilled by the method of the using the type of reflectors in this principle. The object will appear against the bright road surface due to lamps at a long distance. The requirement of a pedestarians is to see objects nearby which is also fulfilled in this method as some light falls directly downwards from the lamps. This method of lighting is more economical than the diffusion method but there is one drawback that it produces glares for the motorist. This method is more suitable for straight sections of the road.

28. Illumination level for street lighting and mounting height of lamps. The illumination required depends upon the class of installation of street lighting. The class A installation is used for shopping centres and road junctions and level of illumination required is 20 lumens/m^2. The class H installation is used for poorly lighted suburban streets and the illumination level of 1 lumen/m^2 in sufficient. The level of illumination required for an average well lighted street is between 2 to 5 lumens/m^2.

Lamps posts should be fixed at the junction of roads and they should be avoided from large trees. Normal spacing for standard lamps is 50 metres with a mounting height of 8 metres.

29. Spacing of Street Lighting. The spacing should be uniform between luminaries *i.e.* about 29.31 metres in case of cut off type fittings and in case of 'non cut off' type fittings, it should be 31.46 metres. Maximum spacing is recommended 37 metres only for 'non-cut off fittings. Light seurces may be installed on one or both sides of the road, in parallel or in staggered way or in the middle depending upon the width of road and the intensity of lighting required. Staggered arrangement is more preferred as it gives more uniform lighting than other systems of lighting arrangement.

30. Types of lamps used for street lighting. Due to lower efficiency, high glare and high recurring cost, incandescent lamps are used only in the streets having less traffic. The streets where there is medium and heavy intensity of traffic is observed, the types of lamps used there are fluorescent tubes, mercury lamps and sodium lamps. Fluorescent lamps fitted one above other gives better light distribution for street lighting.

31. Control of street lights. Two types of connections are used for street lighting *i.e.*

(*i*) Lamps in Parallel connections (Constant Voltage Control)

(*ii*) Lamps in Series connections (Constant Current Control)

The constant voltage control is not preferred due to the variation of voltage from lamp to lamp and conductors of more cross sectional are required. But there is no such drawback in constant current control and is thus preferred more for street lighting system. For this purpose, special high voltage transformers are used. Series type connections are used for sodium vapour lamps and parallel connections are used for mercury vapour lamp but for incandescent lamps either connection can be used. Special cutout is provided with each lamp in series arrangement to maintain the continuity of the circuits.

32. Flood Lighting. This type of lighting is obtained by using a powerful projectors on any line. This type of lighting Is mostly employed for decoration of buildings (ancient or religious), public places, monuments, on important occasions / festivals at night. These are also used for illuminating railway yards, parking areas, recreation and sports grounds, shipping yards, Air ports, construction sites, advertisement boards and show cases etc.

For flood lighting, it is necessary to concentrate the light from the light source into a relatively narrow beam. For this purpose a flood light projector is used which is robust in nature and weather proof in construction as it is to be used in remote positions. Since the reflecting surface is the most important part in a projector, so it should be made of silvered glass or chromium plate or stainless steel. Metal reflectors are preferred more being robust in nature.

The casing and mounting of the projector are arranged in such a way so that the beam can be varied in both a vertical and a horizontal direction as per requirement on any site. Use of cast-metal cases is made for the robustness and protection against weather for permanent installations. For temporary installations or those in sheltered situations, the use of sheet metal casing is made.

At the time of using 500 or 100 watt lamps in the projectors, ventilation is provided for adequate cooling by providing sufficient radiating surface.

Projectors are classified according to spreading of beam :

(*a*) *Narrow beam projectors,* the beam of which is spreaded between 12 to 25°and are used for above than 70 metres range.

(*b*) *Medium angle projectors,* the beam of which is spreaded between 25 to 40° and are used between 30 to 70 metres range.

(*c*) *Wide angle Projectors,* the beam of which is spreaded between 40 to 90° are used for distance below 30 metres.

For economic reasons, the use of wide angle projectors with high wattage lamp are more preferred than that of narrow beam projectors with low wattage lamp. High wattage lamps prove more efficient in narrow beam projectors. Medium and wide angle projectors make use of standard gas filled tungsten filament lamps of 250, 500 or 1000 watts or special lamps having bunched filaments, known as projector lamps.

33. Location and Mounting of Projectors. There are two possible locations of projectors in practice *i.e.* symmetrical and unsymmetrical. Symmetric projectors are kept 20 to 35 metres away from the surface to be flooded and provide approximately parallel beam having beam spread of 25° to 30°. Sometimes when the projector cannot be located away from the building, in such a case an unsymmetric reflector mounted in a basement area or on a bracket attached to the building is used which directs more intense light towards the tip of the building.

34. Flood Lighting Calculations. Flood-lighting calculations may be considered into three steps :

First Step : *Illumination level required.*

The level of illumination *i.e.* lumens/m^2 to be required depends upon the type of building, the purpose of the flood lighting ; the amount of conflicting light in the vicinity etc.

Second Step : *Type of Projector*

Beam size and light output are taken into consideration to select the type of projector. The former calculates the area to be covered by the beam and the latter is for providing illumination. While deciding the beam angle of the projector, the distance of projector from the surface is kept in view.

Third Step : *Number of projectors*

The number of projectors for any desired intensity of light over a definite surface is obtained from the following relation :

$$N = \frac{A \times E \times \text{depreciation factor} \times \text{waste light factor}}{\text{Utilisation factor} \times \text{wattage of lamp} \times \text{Luminous efficiency of lamp}}$$

where N = Number of projectors

A = Area of surface to be illuminated in square metres

E = Illumination level required in lumens/m^2

Description of terms used in the above relation

(*i*) *Waste light factor.* When a surface is illuminated by a number of light sources, there is always a certain amount of waste light on account of over lapping and falling of light beyond the edges of the area to be illuminated.

This is known as waste light factor which may be taken into account as 1.2 per rectanguler areas and 1.5 for irregular areas and objects like states and monuments etc.

(*ii*) *Depreciation factor.* Depreciation factor may be defined as the ratio of illumination under ideal conditions to the illumination under normal conditions. The need of taking this factor into consideration arises when dirt and dust depositing on the reflector surface and on the source of light reduces the effectiveness of the projector.

(*iii*) *Utilisation Factor.* It is also known as beam factor and is defined as the ratio of beam lumens to lamp lumens. Its value is taken as 0.3 to 0.5. This factor is taken into account because all the light emitted by the projector is not along the direction of the beam but some of it is absorbed by the reflector and by front glass when the losses increases, the utilisation factor becomes low.

35. Brief Description of Various Lamps

1. Vaccuum Lamps ; — single coil, rating upto 25W

2. Gas filled lamps ; — Coiled-Coil - rating 25W to 300W.

3. Single Coil Gas filled lmaps ; — rating 300 to 1000W

All the above are available with clear inside - frosted or opalised bulbs (milky white upto 200W). For ratings 300W and above, the bulbs are practically clear.

4. Bulbs upto 200W :

Special characteristics are (*a*) Pleasant & warm light (*b*) Soft shadow effect (*c*) Perfect diffused light.

5. Super lux Lamps :

These are partially satin-frosted bulbs. These have increased luminous intensity (upto 30%) in the direction of the working plane. Hence most suitable for all applications where brighter local illumination levels are required.

6. Three-Light Lamps :

These have 3 contacts. One for the lower wattage, the second for higher wattage and the thrid being the combined contact.

7. Bowl Reflector Lamps :

These are normal, inside-frosted incandescent lamps (60 – 200W). The bulb is provided with a silvered bowl, such that the filament is completely shielded from the viewer. This bowl eliminates the glare, with suitable fittings, and these bulbs can give diffused lighting.

For usage for displays and in shop windows. Clear glass bulb with bowl reflector bulbs (24V) are also available.

8. Re-inforced - Construction Lamps :

These bulbs are available with an inside - frosted finish (25 to 200W). These bulbs have strong, special filament wire which enable them to be used in places where shocks, jumps and vibrations occur frequencly.

9. K - Lamps :

These bulbs are smaller in dimension & the bulb's shape is pleasing. In smaller size rooms, these can be used.

10. Show - Window Lamps :

These are ordinary incandescent bulbs but have tubular envelope with a cap at each end. These two caps are clamped between straight contacts in single - pole lamp holders, since the dia. of the tube is smaller, the lamps can be concealed behind small covers in shop windows, show cases, acquiria, pictures and mirrors. The filament practically extends over the entire length of the bulb, & hence gives a uniform strip of light.

11. Philinea Lamps :

Another type of tubular incandescent lamp, with the bulb of diffusing glass, having low luminance is available.

These have caps at one side of the bulb and a continuous line of light can be got by arranging these bulbs end - to - end or in patterns of one's choice.

12. "Fantasie" Lamps :

These are new-style lamps for decorative and general interior lighting of living rooms, halls, restaurants, shops, recreation rooms, canteens etc. Ordinary lamp holders can be used and eliminates additional glass outer globe.

13. Decorative Lamps :

Decorative lamps like candle lamps, colorenta lamps, festoon lighting sets, christmas tree illumination sets are available.

14. Coloured Lamps :

These lamps can be used for illumination of streets, gardens, fairgrounds etc. The colour coating is flushed inside & hence it can not chip, scratch or fade & can not be affected by weather. Two different shapes are available for voltage 110 to 230V. These are low wattage rating only, less than 10W to avoid glare & hence not suitable for illuminating specific work task.

15. Reflector Lamps :

These have a light quality internal mirror. An extensive range of lamps giving beams of various widths & luminous intensities are available. Two clases of reflector lamps are available

(*i*) Pressed - Glass Lamps & (*ii*) Blown - bulb Lamps.

Pressed glass lamp have higher luminous efficiency & can be used for indoor & outdoor lighting. These have longer burning hours (200Hrs.). These are made from pressed hard glass, the bulb wall is thick & strong, water proof at all times and can be placed even in water.

Available wattage	100W	&150W
Operating voltage	24 V,	250V

Narrow beam (2 × 7.5)

Illuminating smaller surfaces or objects placed at longer distance

Wide beam (2 × 18°).

Illuminating large surfaces or objects placed at shorter distances.

16. Halogen Lamps :

Halogen gas in smaller quantity is added in an ordinary incandescent lamp. The chief advantages are blackening of bulb is avoided, light depreciation is greatly reduced, size becomes smaller and the filament efficiency is increased. (22 lm/w to 33 lm/w). These are most suitable for lighting of film studios, 8mm line photography, narrow-guage film projection & for use in motor car head lights. For flood lighting tubular quartz halogen lamps are avaiable. Halogen lamps can also be used for outdoor illumination of buildings, sports grounds, playing fields, parks, large gardens, fountains, car parks, lighting of Air port runways etc.

100W, 150W bulbs give symmetrical cone shaped beams.

300W bulbs give elliptical or oval shaped beams.

300W Wide flood beam spread	2 × 19° (horizontal)
	2 × 8° (vertical)
Medium flood beam spread	2 × 12.5° (horizontal)
	2 × 6° (vertical)
Narrow spot, beam spread	2 × 7° (horizontal)
	2 × 5° (vertical)

Flood Colour Lamps :

100W pressed - glass reflector lamps are available with red, green, yellow or blue front. These are heat & weather resistant & hence most useful for indoor & outdoor uses.

Blown - Bulb Reflector Lamps ;

These are used for indoor lighting. These have low luminous flux. These have a narrow beam (2 × 9°) and a wide beam (2 × 25°)

17. Neon Tubes :

These tubes have a maximum length of 25 feet (750 cm) and dia. ranging from 1/2" to 1" (12.5 mm to 25 mm) & can be bent in all shapes. The current intensity is low (50 - 200mA). Luminous efficiency 5 - 101m watt. For advertising signs, the length is distributed over a few letters, which are connected in series. The gases introduced in the bulb, Neon (red) Helium (pink). Nitrogen (golden yellow), Sodium (yellow), xenon (pale blue), kypton, carbaric acid and mercury vapour (blue), argon (violet). These colours are also varied by using either coloured glass or internally coating the glass wall with a filtering or colour powder.

18. Glow Lamps :

Glow lamps or neon indicator lamps have very low currents and have lower gas pressure & hence the radiation of light remains limited to a faint glow. The gas in the lamp is normally neon or helium or argon. These are available in a great variety of sizes and voltages with or without series resistor. These are smaller in sizes & suitable for mains tension. These have high brightness and never affected by mains fluctuations. these are shock and vibration proof to a large extent, develope minimum heat & serve for a longer period.

These can be used in all kinds of electric appliances such as irons, grills, domestic heaters, boilers, frying pans, electric ovens, washing machines, dish washers hair dryers, coffee percolators, freezers, refrigerators, blankets etc.

19. Night Lamps :

These lamps also belong to the large family of discharge lamps. The neon gas filling, acts as the current - carrying medium. These have no filaments, these can withstand vibration & shock. These are fitted with a flourescent bulb & give a greenish light.

These have low wattage rating (0.8W) & serve for a long life. These are suitable for children's bed rooms. hospitals, nurseries, passages, staircases etc.

20. Sodium Vapour Lamps :

Available in 85W, 140W & 200W

Average life time 6000 Hrs.
(for 3 or more burning hours per switching)

Power factor : 0.25 to 0.35 without a capacitor
: 0.8 to 0.9 with a paralled capacitor

Luminous Efficiency : High (110 lm/W)

The light is monochromatic (single colour)

These are most suitable for lighting of motor ways, storage yards, & for flood lighting of high buildings.

21. Mercury Vapour Lamps :

Lamp	Min. starting Voltage	Ballast losses	Nominal luminous flux. lm.
50W	200V	9W	1700
80W	200V	9W	3100
125W	300V	11W	5400
250W	200V	17W	11500
300W	200V	25W	20500
700W	200V	32W	36000
1000W	200V	43W	52000
2000W	340V	68W	125000

Application : Factory lighting, quarries, paper mills, Iron foundaries & advertisement flood lighting.

22. Mercury Iodide Lamps :

These are lamps with a mercury - discharge tube made of quartz. In this tube, apart from Mercury, there are a no. of iodides — like sodium iodide (pinkish - yellow light), thallium iodide (green light), indium iodide (blue light). These lamps are available with high efficiency 75 lm/watt.

They are also available with 400W, 2000W, 30,000 lms. and 1,90,000 lms. These are mostly used in the field of flood lighting, industrial lighting & public lighting.

23. Blended Light Lamps :

The Construction of these lamps is similar to that of mercury vapour lamps, but, with addition of a filament which is connected in series with the vapour tube. i.e. apart from mercury light, the same quantity of incandescent lamp light is also produced i.e. the ballast is incorporated in the lamp itself. Operating voltage should not be lower than 200V.

Average life time	—	600 burning Hrs.
Light Depreciation	—	20%
Available wattages	—	160, 250, & 500 watts

Note : 160W bulb has to be used in vertical position only.

24. Low Pressure Mercury Vapour Lamps : Flourescent Tube Lights

These are subject to ageing. After 3000 burning Hours, the depreciation of luminous flux is about 15 to 20% of normal value. These give the best efficiency when the ambient temp. is around 25°C to 30°C. When used in cold and draughty places, tightly closed fittings are to be used. When used in warm surroundings open type fittings or fittings with ventilating holes are to be used. When there is a variation in the frequency of supply mains, the lamps have to be switched OFF.

These are slightly sensitive to vibration & hence can be mounted on machines, in trains, ships. For violent vibrations, spring loaded suspensions have to be used.

25. Special Gas Discharged Lamps :

(1) Low pressure Pulsed Xenon Lamps

These are used in the printing industry for reproduction & copying. The wattage rating will be 1500, 3000, 4000W. These are instant start and Restart - max efficiency immediately after starting. Colour, temperature, and light out put remain constant throughout its life period. Long life period, uniform burning during exposure and high efficiency are their advantages. So they are excellent for colour reproduction.

Applications :

1. Copy - Board lighting
   Small size horizontal copy - boards, as well as large vertical ones can be lit very evenly with 2 or 4 lamps.
2. Stop and Repeat copying machines.
3. Light source in photo and film studios.
4. Plate making : The concentrated beam from the lamp is used for plate - making, wattages required ; 4000W.
5. Light printing Lamps : In Photo.copying equipments

Super Actinic Lamps :

These are flourescent lamps used in various photo - chemical processes such as light printing (Diazo), copying and reproductions. These are tubular, low pressure lamps coated with a flourescent layer that transforms the short - wave ultra - violet radiation of the arc into useful actinic radiation. For a higher light printing speed, several lamps are used together. No complicated cooling systems are required.

Mercury - Vapour Lamps 125W

In this, the discharge tube is fitted in a bulb of hard glass provided with an internal mirror reflector. This reflector allows the transmission of long - wave ultra violet radiation. This is particularly suitable for black white reproduction and copying process. Also used for flood light.

Sun Lamp :

The sun lamp 300W is a tungsten mercury lamp, constructed in the same principle of Blended - light lamps. No ballast is necessary. The bulb is made of hard glass which filters out radiations of lower values.

Applications :

Used for pre - heating and drying processes of plastics.

Black Light Flourescent Lamps :

These are tubular low pressure mercury vapour lamps. The tube is of dark blue glass transparent to ultra violet and opeque to visible radiation. A minimum of visible light is produced by the lamp.

Applications :

Analysis in chemical, suger, food and textile industries.

Detection in philately, mineralogy, bauring, criminology and medicine and in the field of entertainment.

GERMICIDAL Lamps :

Power rating 6W, 220/230V. No ballast is necessary. This gives ultra - violet radiation.

Applications :

Used in refrigerators and in all vending machines for liquids.

Tubular Germicidal Lamps :

These are low pressure mercury vapour lamps without a phosphor coating. These lamps radiate energy at 2537 Armstrong line, which is very near the wavelength that destroys bacteria & moulds.

Applications :

Used in Hospitals, cold storage rooms, cheese ware - houses, pharmaceutical industries, dairies, breweries etc.

Warning :

Do not have long exposures. This will affect the skin and eyes.

Compact Sources Mercury Lamps :

These are super - high pressure mercury lamps. These have high energy concentration with in a small dimension. Hence high brightness is possible.

Applications :

Micro film enlargers, recording and measuring instruments, photochemistry.

Compact Source Xenon Lamps :

These are super - high pressure xenon lamps. Chief advantages is that optical adjustment remains constant, when once set and perfect in operation. This is to be used only on D.C. supply.

Applications :

Cinema projection (900 - 2500 W), colour matching scientific purposes (microscope), Small spot lights, Spot lights in films studios, Back ground projectors, Beacons Zone melting.

36. Light Sources and Light Fittings. The three main groups of light sources available for industrial lighting and their main characteristics are tabulated below :

Type of Sources	*Characteristics*	*Applications*
1. Incandescent lamps	Low initial outlay Rather high-running costs owing to the limited luminous efficiency and relatively short life	For lighting areas or rooms of restricted extent or where traffic or occupation density is low and hours of burning is limited.
2. Discharge lamps	High Luminous efficiency	For residence and Factory lighting
a) Mercury vapour	Low running costs	All factory premises with high ceilings
b) Sodium vapour	Long life	All premises with a smoky or dust laden atmosphere.
3. Flouresent Lamps	High luminous efficiency (5 times more light than incandescent lamps for the same power consumption). Long life. Low running costs, (compensating the higher initial outlay). Pleasant diffuse light. No shadows.	In circumstances where colour appraisal is important.

Once the light source is selected, the next step is to select the type of fitting to be used. For big factory halls, high bay fittings are used; for mercury vapour lamps, fittings with slots in the reflector can be utilised, to present excessive contrasts between fittings and background. Where atmospheric conditions warrant, specially designed fittings such as water tight, dust proof, explosion proof and corrosion resistant fittings have to be used.

37. Recommended Values of Illumination.

S.No.	Visual Tasks	Illumination lux
	A. Industrial Buildings and Processes	
1.	*General Factory Areas :*	
	a) Canteens b) Cloak-rooms and c) Entrances, corridors, stairs	100
2.	*Factory Outdoor Areas :*	
	Stockyards, main entrances and exit roads, car parks, internal factory roads	20
3.	*Assembly Shops :*	
	a) Rough work, for example, frame assembly and assembly of heavy machinery.	150
	b) Medium work for example, machined parts, engine assembly, vehicle body assembly.	300
	c) Fine work, for example, radio and telephone equipment, typewriter and office machinery assembly.	700
	d) Very fine work, for example, assembly of very small precision mechanisms and instruments	1500
4.	*Boot and Shoe Factories*	900(ave)
5.	*Canning and Preserving Factories*	300(ave)
6.	*Carpet Factories*	300(ave)
7.	*Chemical Works*	200(ave)
8.	*Engraving*	1000
9.	*Flour Mills*	200
10.	*Forges*	150
11.	*Foundries*	250(ave)
12.	*Gas work*	50(ave)
13.	*Gauge and Tool Room*	700
14.	*Glass works and Processes*	300(ave)
15.	*Inspection shops (Engineering)*	
	a) Rough work for example counting and rough checking of stock parts, etc.	150
	b) Medium work for example 'go' and no 'go' gauges and sub-assemblies	300
	c) Fine work for example radio and telecommunication equipment, calibrated scales, precision mechanisms and instruments.	700
	d) Very fine work for example, gauging and inspection of small interior parts.	1500
	e) Minute work for example, very small instruments.	3000
16.	*Iron and Steel Works*	150-200

(Contd.)

S.No.	*Visual Tasks*	*Illumination lux*
17.	*Laboratories and Test Rooms :*	
	a) General laboratories and balance rooms	300
	b) Electrical and instrument laboratories	450
18.	*Machine and Fitting shops :*	
	a) Rough bench and machine work	150
	b) Medium bench and machine work, ordinary, automatic machines, rough grinding, medium buffing and polishing.	300
	c) Fine bench and machine work, fine automatic machines medium grinding, fine buffing and polishing.	750
19.	*Motor vehicle plants*	400(ave)
20.	*Pharmaceutial and Fine Chemisal works*	300(ave)
21.	*Plastic works*	200(ave)
22.	*Plating shops*	
	a) Vat bath, buffing polishing and burnishing	150
	b) Final buffing and polishing	Special lighting
23.	*Sheet Metal Work :*	
	a) Bench work scribing, pressing, punching, shearing stamping spining and folding	200
	b) sheet inspection	Special lighting
24.	*Textile Mills (Cotton Linen) :*	500(ave)
25.	*Textile Mills (Silk or Synthetics) :*	400(ave)
26.	*Textile Mills (Woolen) :*	500(ave)
27.	*Textile Mills (Jute) :*	150(ave)
28.	*Welding and soldering :*	250(ave)
	B. Office, Schools and Public Buildings	
29.	*Cinemas*	120(ave)
30.	*Libraries :*	
	a) Shelves (stacks)	71 to 150
	b) Reading room (newspaper and magazines)	150 to 300
	c) Reading tables	300 to 730
31.	*Office :*	400(ave)
32.	*School and Collages*	
	a) Assembly halls	
	1) General	150
	2) When used for examinations,	300
	3) platform	300

(Contd.)

S.No.	Visual Tasks		Illumination lux
	b)	class and lecture room (1) Desks (2) chalk boards	300
33.	*Homes :*	a) Kitchen	200
		b) Bathrooms, Stairs	100
		c) Garazes	70
		d) Reading (casual)	150
		e) Homework and sustained readings	300

POWER REQUIREMENT OF THE MOST IMPORTANT HOUSEHOLD APPLIANCE

Electric iron ...400 - 1000 W
Immersion heater ...500 - 1000 W
Rapaid.action cooker ...700 - 1200 W
Electric heater ...1000 - 2000 W
Hair-drier ...500 W
Heating pad ...90 W
Vaccuum cleaner ...150 - 300 W
Cooker ...1200 - 1500 W

Oven ...700 - 1500 W

Kettles & Jugs :

1.13 litre 450 - 650 W
1.7 litre 800 - 1000 W
2.3-3.4 litre 1000 - 1400 W

Hot-water tanks & Wash boilers
36-45 litre 3 k W
54 litre 4.5 k W

Small Kitchen range ... 2200 - 3500 W
Large Kitchen range ... 3700 - 7300 W
Water heater ... 1200 - 6000 W
Washing machine ... 300 W
Washing with heating ... 1 - 6 k.W
Refrigerator ... 100 - 200 W
Radio ... 50 - 100 W
Wet Grinder ... 0.25 HP - 0.5 HP
180 W - 400 W
Mixies 40 W - 60 W (small)
250 W - 450 W (big)
Grills : 20.3 × 15.2 cm 750 - 1000 W
46 × 30.5 cm 3000 - 4500 W
Ovens : 36 × 36 × 30 cm - 1.5 kW
30 × 30 × 41 cm - 1.5 kW
36 × 36 × 41 cm - 2 kW

Irons (Laundry and tailoring) :

1.36 kg	250 W
181 kg	280 - 300 W
2.27 kg	350 - 450 W
3.17 kg	500 - 600 W
5.44 kg	600 - 750 W
9.10 kg	800 - 1500 W

TYPICAL QUESTIONS

1. Explain coefficient of utilization and depreciation factor in connection with the lighting schemes.

2. Define the terms (*a*) brightness (*b*) illumination (*c*) luminous intensity (*d*) luminous flux.

3. Explain (*a*) Relative sensitivity (*b*) Radiant efficiency (*c*) Foot-candles and (*d*) luminous flux.

4. Explain the (*a*) Sodium discharge lamp (*b*) Mercury vapour lamp.

5. Explain the various lighting system employed in interior lighting.

6. What do you understand by discharge lamp ? Explain the construction and working principle of sodium vapour lamps.

7. What do you understand by incandescent lamp? Explain the construction of vacuum incandescent lamp.

8. Why high pressure mercury vapour is used in H.P.M.V lamp ? Explain its construction and working.

9. A class room size 20′ × 30′ by 12 ft. high, is to be illuminated to 15 lumens per sq. ft on the working plane. If the coefficient of utilization is 0.45 and the source gives 12 lumens per watt. Calculate the total wattage required and the number of lamps. **Ans.** 10 lamps 200 watts

10. An illumination on the working plane of 0.33 ft. candles is required in a room 270′ × 50′. The lamps are required to be hung 15 ft. above the working benches. Assuming a suitable space ratio and utilisation factor 0.5 and candle power depreciation as 80%, estimate the number of lamps required. *(A.M.I.E. Sec. B, Nov. 1958)*

Ans. 22

11. A certain incandescent lamp has an MSCP of 250. It is suspended at a bright of 16 ft. above the working plane and is provided with a reflector which gives an approximate uniform light distribution over an area of 16 ft. in diameter on the working plane. If the efficiency of such reflector is such that 45% of the total light emitted by the lamp is directed on to this circular area, calculate the average illumination would you expect at the outer part of the circular area if the reflector is removed from the lamp. *(A.M.I.E. Nov. 1957, Elect. Engg.)*

Ans. 0.7 lumens/ft^2

12. What are methods of lighting calculations ? Explain about them.

13. Explain about the Halogen lamp and draw the figure.

14. What is the difference between neon lamp and neon tubes ? Explain about them with figures.

15. What is the necessity and lighting scheme of street lighting ?

16. On what principles the designing of installations of street lighting depend ?

17. Explain about the illumination level and mounting height of lamps for street lighting.

18. What do you know about spacing of street lighting ?

19. What types of lamps are used for street lighting and how are street lights controlled ?

20. What types of projectors are used for flood lighting ?

21. Explain about the flood lighting calculations.