Electric Shock:

When a person comes in contact with a live conductor, directly or indirectly, he gets a shock. The shock may be minor or severe. The severity of shock depends upon the following:

1) Nature of the current whether AC or DC: Since DC flows continuously and does not pass through zero current value as in AC, DC is considered more dangerous than AC supply.
2) Duration of flow of current: Shock will be more severe if duration of contact with the live wire of a person is more. However, the severity of shock can be reduced by disengaging the person from live wire contact immediately.
3) Path of current through human body: Severity of shock also depends upon the path of the electric current through human body. A person gets severe shock if the current path involves his heart.

The effect of electric current when it passes through human body is given in the table 1.1 below:

Table 1.1: Effect of electric current through human body

1-10 mA	Prickling sensations
10 mA	Muscle contraction: The person remains 'stuck' to the conductor
20-30 mA	Muscles contraction can cause respiratory paralysis
70-100 mA	Cardiac fibrillation: The heart begins to vibrate and no longer beats at a steady rate. This situation is dangerous since it is irreversible.
500 mA	Immediate cardiac arrest resulting in death

Electric Shock Treatment:

The victim of electric shock should be immediately treated as suggested below:

1) The victim should be removed immediately from the contact of live conductor.
2) Artificial respiration should be given immediately.
3) Treat the burns, if any, on recovery of the victim.
4) Finally, give a call to the doctor.

For removing the victim from the contact of L.T. (Low Tension) live wire, any one of the following procedures can be followed:

1) Immediately 'Switch OFF' the supply. If the switch is far away, then pull out the plug top.
2) Pull the victim by using wooden stick, dry clothes, dry rope, etc.

3) One can pull the victim directly by standing on well-insulated footing such as rubber mat, dry board, dry wooden chair, electrician rubber gloves or even pull directly (to some extent) if wearing rubber sole shoes.
4) Cut the conductor with an axe, or axe like device having a large wooden handle.

For removing the victim from the contact of HT (high tension) live conductor, any one of the following procedures can be followed:

1) 'Switch OFF' the circuit breaker, if it is nearby.
2) Short the live conductors by throwing a bare wire or chain upon them. This will result in tripping of the circuit breaker, at the substation or power station.

Methods of Artificial Respiration:

Once the victim has been removed from the contact of the live wire, the next step is to give him artificial respiration. There are various methods of giving artificial respiration as given below:

a) **Schafer's Method:**

   Schafer's method is the best method to give artificial respiration to the victim of electric shock. The various steps of this method are as follows:

   1) The victim is laid on the stomach, with his face on one side and pull the arms forward as shown in Figure 1.1 (a).
   2) To allow proper breathing, victim's neck is cleared from clothing.
   3) Clear the mouth of the victim from pan, tobacco, artificial teeth, etc.
   4) Kneel over the victim as shown in figure 1.1 (b) and place both your hands flat on his back. Place your hand in such a manner that both of your thumbs nearly touch each other, and fingers are spread on each side of the victim's lower ribs.
   5) Lean forward over the victim gradually and gently by putting your weight on the victim for a moment as shown in figure 1.1(b).
   6) Now slowly release the pressure and come to original position.
   7) Repeat the process at least 12 to 15 times in one minute, till the victim starts natural breathing.

Schafer's method of artificial respiration is better method as compared with other two methods to be followed. Hence, this method should be adopted as and when required. However, this method cannot be used if it is not possible due to burns to lay the victim on his stomach.

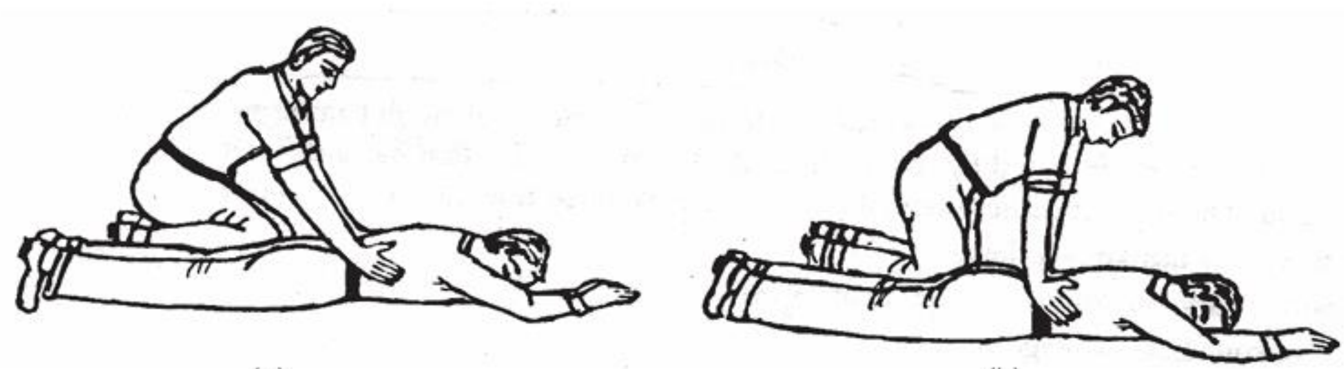


Fig. 1.1 Schafer's method of artificial respiration (a) Lay the victim on stomach (b) Kneeling over the victim

b) Silvestre's Method:

Schafer's method is the best method of artificial respiration; however, if the victim got some burns on the chest or anywhere on the front side of the body, only then this method is adopted. The various steps of this method are as follows:

1) Lay the victim on his back, as shown in Figure 1.2(a).
2) Remove the victim's clothes around his neck.
3) Clear the mouth of the victim from pan, tobacco, artificial teeth, etc.
4) Use a pillow or rolled coat or any other cloth under the shoulders of the victim, so that his head falls backwards.
5) Tilt the head a little back. It will keep the tongue out of the throat allowing passage to air for breathing.
6) Now kneel in the position near the head of the victim as shown in Figure 1.2(b).
7) Stretch both arms of the victim backward by holding them below the elbows.
8) Keep the arms in this position for about 2 to 3 seconds.
9) Now bring the arms of the victim on each side of his chest as shown in figure 1.2 (b), so as to compress his chest. Keep the victim's arms in the same position also for 2 to 3 seconds.
10) Repeat the process for about 12 to 15 times in a minute, till the victim starts natural breathing.

It should be assured that this method is to be adopted only when it is not convenient to make the victim lie on his stomach due to burns.

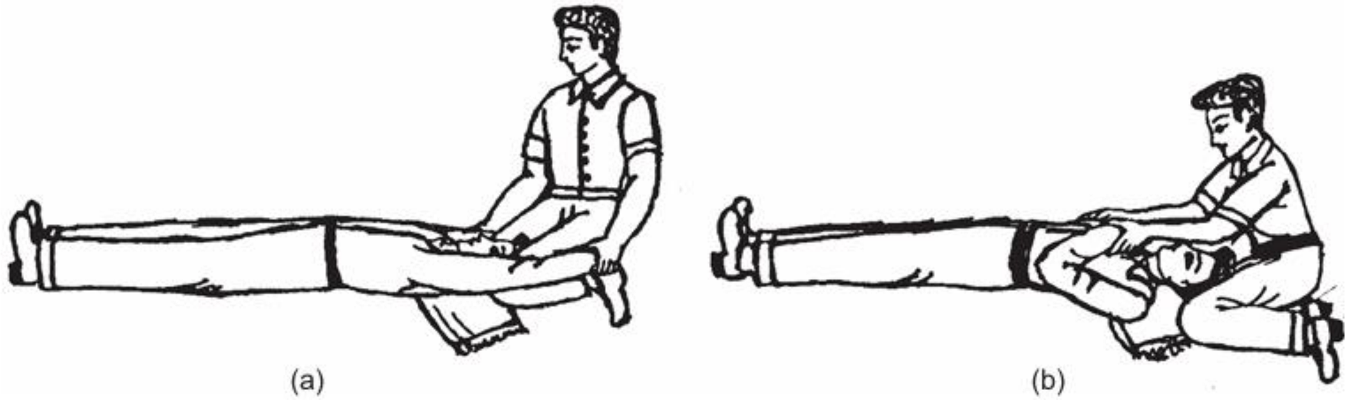


Fig. 1.2 Silvestre's method of artificial respiration (a) Lay the victim on back (b) Kneeling near the victim's head

c) Artificial Respirator Method:

It is the easiest and most hygienic method of artificial respiration, if the apparatus is available. When the victim has suffered an electric shock and is unconscious, an artificial respirator may be used. An artificial respirator consists of a rubber bulb mask and an air filter along with a transparent celluloid valve arrangement as shown in Figure 1.3(b). The air enters through the holes of rubber bulb and goes out through the outlet valve. The mask is placed on the mouth and nose of the patient as shown in Figure 1.3(a). The rubber bulb is pressed at the rate of 12 to 15 times per minute to bring his respiration back. This process should be continued regularly till the doctor advises to stop.

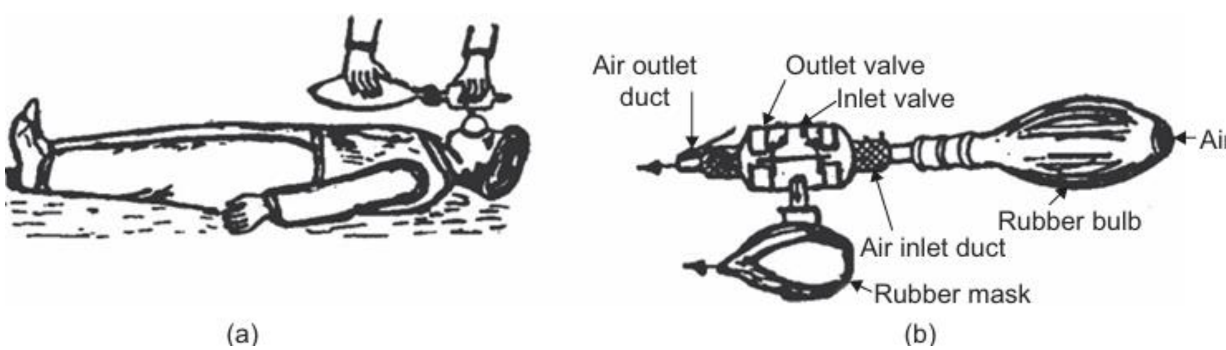


Fig. 1.3: (a) Artificial respiration (b) Respirator

Special Instructions for electric shock treatment are as follows:

1) Never give any drink to the unconscious man.
2) Violent operation of the process must be avoided because an internal injury in the affected organ may be harmed due to quick and excessive pressure.
3) If there is a burn on the body, it should be properly dressed after the recovery of the patient.
4) The patient should be kept warm.
5) No medicine should be given without the consent of the doctor.
6) The owner of the factory must provide and fix a chart explaining the methods of artificial respiration. The chart should carry the name of the nearest doctor and his telephone number. Preferably, the address of the hospital and residential address of the doctor to be contacted should be given in the chart.

Precautions against electric shock:

The following precautions should be taken as preventive measures while dealing with electrical equipment fittings or appliances:

1) Never work on live circuit.
2) Always stand on the insulating material, such as rubber mat, wooden board, etc., while switching on the main switch, motor switch, etc.
3) While switching ON the circuit, equipment, etc., ensure that your hands and feet are dry.
4) Avoid working at all those places where your head is liable to touch the live parts.
5) While working with electrical circuits/equipment, never come in contact with the metallic casing, earth conductor, cross arms, etc.
6) While working on the high-voltage circuit, avoid your direct contact with concrete flooring.
7) Never touch the person directly, while rescuing him from electric shock.
8) Consider all conductors as live, till you are not sure.

Electric safety measures:

The following common safety measures should be followed while dealing with the electricity:

1) Always follow IE (Indian Electricity) rules while dealing with electrical equipment and installations.

2) Consider all conductors (insulted or bare) as live conductors. So do not touch them till you are not sure.
3) Switch OFF the main switch and keep the fuse carriers with you while working on an electrical installation.
4) Single-way switches should be always connected in a live wire.
5) Fuse should only be provided in a live wire.
6) Before replacing the blown fuse or switching ON the tripped MCB (miniature circuit breaker), be sure that the defect has been rectified.
7) Do not work on live circuits. However, wherever the energized circuits are to be handled, then always use rubber mats, rubber sole shoes, rubber gloves, etc.
8) Never disconnect the appliance from the plug point by pulling the connecting cord.
9) Always use proper size of wire of proper voltage grade for all electrical appliances, equipment, wiring installation, etc.
10) Always use standard cable for connecting portable equipment, appliances, pendant holders, etc. Since standard conductor cable provides flexibility, equipment can be handled conveniently.
11) All electrical connections should be made tight, and these should be checked periodically, so as to avoid fire due to loose connections.
12) Always use waterproof cables and fittings for all our door installations except distribution and transmission lines.
13) All non-current carrying metal parts of the equipment and of installation should be properly earthed.
14) All portable electrical equipment should be properly earthed. Therefore, for such equipment, always use a three-core cable.
15) Always keep the earthing in good condition, that is, earth resistance should be kept very low all the time, since safety depends upon perfect earthing.
16) As far as possible, switch off the main switch (or controlling switch), when a person is still in contact with a live conductor.
17) Do not disengage a person, who is still in contact with live circuit, by touching him directly. Push him only with a piece of dry wood or other such insulating material.

18) In case a person is electrocuted, immediately apply artificial respiration and call the doctor.
19) Never use water for extinguishing fire due to electric current. Use only carbon tetrachloride, liquid carbon dioxide fire extinguishers. Sand can also be used for extinguishing electric fire.

Earthing:

The process of connecting metallic bodies of all the electrical apparatus and equipment to the huge mass of earth by a wire of negligible resistance is called earthing.

When a body is earthed, it is basically connected to the huge mass of earth by a wire having negligible resistance. Therefore, the body attains zero potential, that is, the potential of earth. This ensures that whenever a live conductor comes in contact with the outer body, the charge is released to the earth immediately.

Necessity of Earthing:

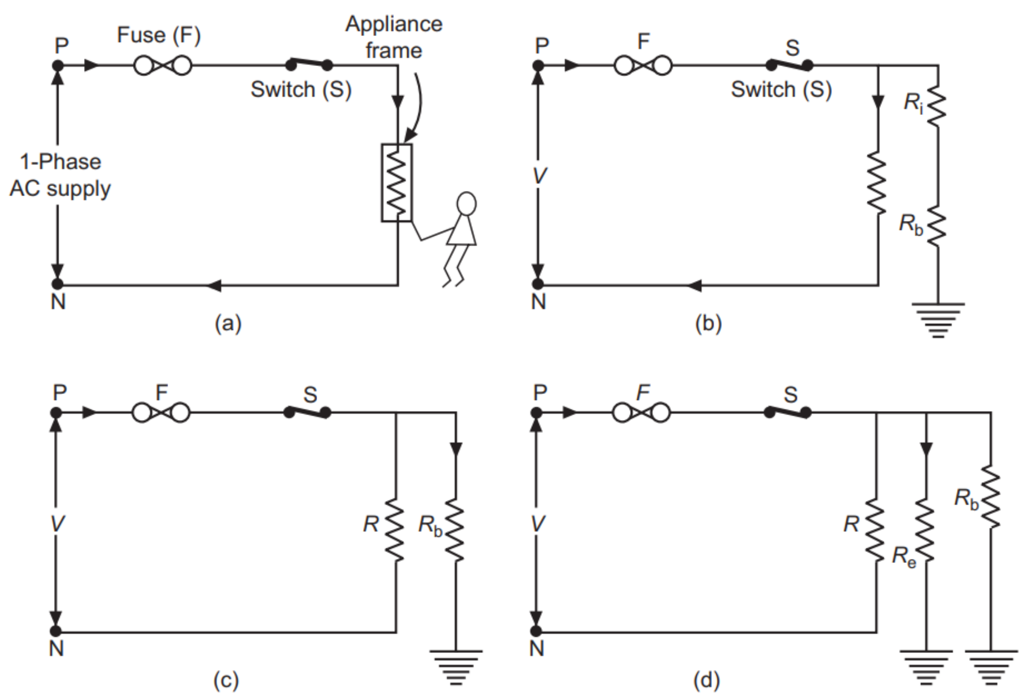


Fig. 1.4: (a) Operator touching the metallic body of the apparatus (b) Under normal condition insulation resistance R_i and body resistance R_b come in series (c) When frame comes in contact with live wire, the insulation resistance R_i vanishes (d) When earthing is provided, low earth resistance R_e comes in parallel with body resistance.

The basic purpose of earthing is to protect the human body (operator) from electric shock. To illustrate the purpose of earthing, consider an electrical circuit shown in Figure 1.4 where an electrical appliance of resistance R is connected to the supply through a fuse and a switch. When an operator touches the metallic body of the apparatus [Fig. 1.4 (a)] having perfect insulation, the equivalent circuit is shown in Figure 1.4 (b), where two parallel paths are formed. Since the insulation resistance R_i is very high as compared with appliance resistance R, whole current flows through appliance resistance and no current flows through human body (operator's body).

When an earth fault occurs, the live (phase) wire directly comes in contact with the outer body and the insulation resistance reduces to zero as shown in Figure 1.4 (c). Now, the body resistance is just in parallel with the appliance resistance. A heavy current flows through the human body and the operator gets a severe shock.

However, if the metallic body or outer frame of the appliance is properly earthed, then under earth fault condition, the circuit will be as shown in Figure 1.4 (d), where earth resistance R_e is just in parallel with the appliance resistance R and body resistance R_b. Since earth resistance is very small as compared with body resistance, almost whole of the fault current flows through the earth resistance and no current flows through the human body. Therefore, the operator is protected from electric shock. Moreover, the fault current is much more than the full-load current of the circuit that melts the fuse. Hence, the appliance is disconnected automatically from the supply mains.

Purpose/Objectives of earthing:

The primary objective of earthing is to protect the operator from electric shock.

The other objective is to circulate the heavy earth fault current which operates the protective device (i.e., fuse or miniature circuit breaker) to disconnect the faulty circuit.

Methods of earthing:

As discussed earlier, earthing means to connect metallic bodies of the apparatus with the general mass of earth by a wire of negligible resistance. There are various methods of achieving this connection, some of them are given below:

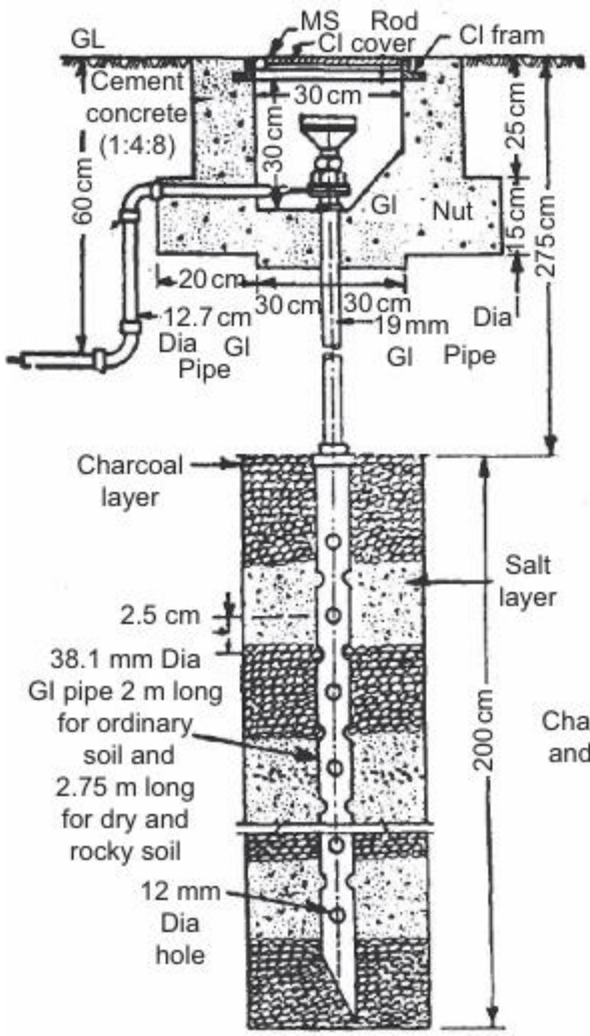
1) Strip earthing: This system of earthing employs the use of 5 SWG (standard wire gauge) copper wire or strip of cross section not less than 25 mm × 1.6 mm. The strips or wires are buried in

horizontal trenches. This type of earthing is used where the earth bed has rocky soil and excavation work is difficult.

2) Earthing through water mains: In this type of earthing, a stranded copper lead is used that is rounded on the pipe with the help of a steel binding wire and a properly designed earthing clip. The copper lead is soldered to make it solid. Before making connection to the water main, it should be ensured that G.I. pipe is used throughout.
3) Rod earthing: It is the cheapest method of earthing and is employed in sandy areas. In this method, a copper rod is hammered directly into the ground, and no excavation work is required. The earthing lead is joined to this rod with the help of nuts and bolts.
4) Pipe earthing: Taking into consideration, the factors such as initial cost, inspection, resistance measurement, etc., G.I. pipe earthing is best form of ground connection. Iron is the cheapest material and remains serviceable even if put in salty mass of earth. The pipe used as earth electrode is galvanized and perforated. Its diameter is 38.1 mm and length is 2 m. The length may be increased to 2.75 m in case of dry soil. The diameter of the pipe has very little effect on the resistance of the earth connection. To facilitate the driving in of the pipe into ground, it is provided with tapered casting at the lower end. Another pipe of 19.05 mm diameter and of length 2.45 m is connected at the top of the above-mentioned pipe. The connection between these pipes is made through a reducing socket as shown in Figure 1.5.

   The earthing lead should be soldered and connected to the pipe. Alternate layers of charcoal and salt are provided around the G.I. pipe to keep the surroundings moist enough. The salt is poured at the bottom and thereafter alternate layers of charcoal and salt are arranged.
5) Plate earthing: In this type of earthing, a copper or G.I. plate of dimensions not less than 60 cm × 60 cm × 3.18 mm or 60 cm × 60 cm × 6.35 mm is used as earth electrode instead of G.I. pipe. The plate is buried into the ground in such a way that its face is vertical and the top is not less than 3 m below the ground level. The G.I. wire is used for G.I. plate and copper wire for copper plate earthing. The size of wire is selected according to the installation and fault current. The earthing lead is suitably protected by placing it underground in a pipe as shown in Figure 1.6. Alternate layers of charcoal and salt are used around the plate. The layers of charcoal shall be placed

immediately over the plate, and thereafter, successive layers of salt and charcoal are laid to keep the surroundings sufficiently moist.



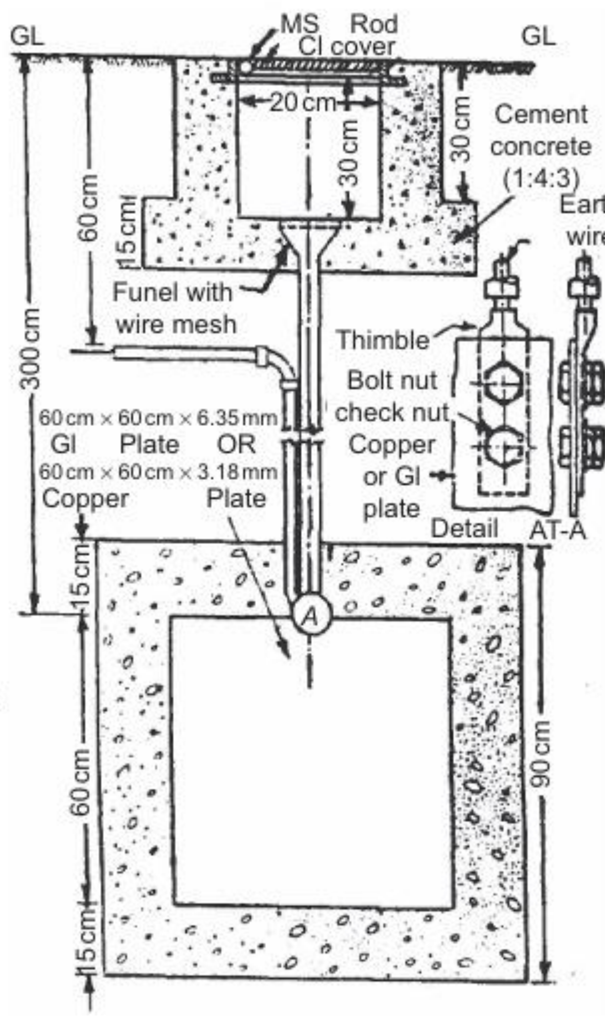


Fig. 1.5: Pipe earthing

Fig. 1.6: Plate earthing

Fuse:

A short piece of metal wire, inserted in series with the circuit, which melts when predetermined value of current flows through it and breaks the circuit is called a fuse. A fuse is connected in series (Fig. 1.7) with the circuit to be protected and carries the load current without overheating itself under normal conditions. However, when abnormal conditions occur, an excessive current (more or equal to the predetermined value for which the fuse is designed) flows through it. This raises the temperature of the fuse wire to the extent that it melts and opens the circuit. This protects the machines or apparatus from damage that can be caused by the excessive current.

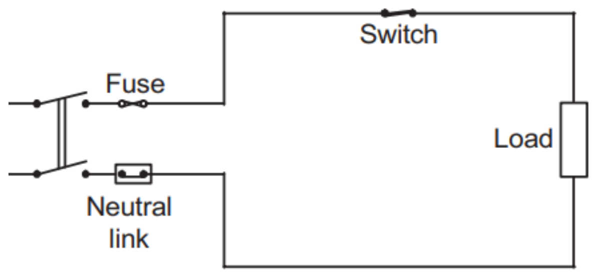


Fig. 1.7: Electric circuit with fuse and switch

Time-current characteristics:

The time required to blow out a fuse depends upon the magnitude of excessive current. The larger the current, smaller is the time taken by the fuse to blow out. Hence, a fuse has inverse time current characteristic as shown in Figure 1.8, which is desirable for a protective device.

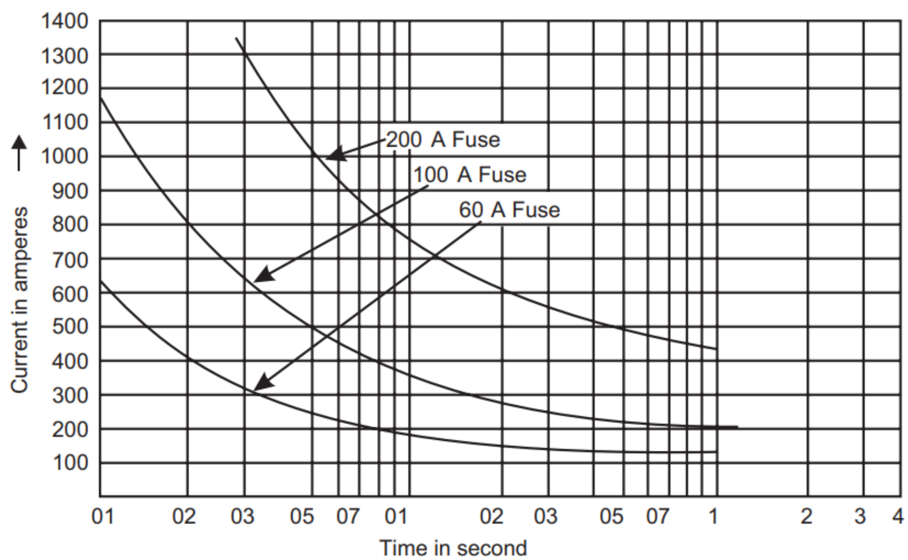


Fig. 1.8: Characteristics of fuse

Advantages of fuse:

1) The cost of this protective device is very low.
2) It requires no maintenance.
3) It interrupts heavy current without noise or smoke.
4) The minimum time of operation can be predetermined by selecting proper material for the fuse wire.
5) The inverse time–current characteristic makes it suitable for overcurrent protection.

Disadvantages of Fuse:

1) Considerable time is lost in rewiring or replacing fuses after every operation.
2) On short circuit, discrimination between fuses in series can only be obtained if there is considerable difference in the relative sizes of the fuse concerned.

Miniature Circuit Breaker (MCB):

Miniature circuit breaker (MCB) is a device that ensures definite protection of wiring system and sophisticated equipment against over current and short circuit faults. The outer view and the internal details of a MCB are shown in Figures 1.9 (a) and 1.9 (b), respectively.

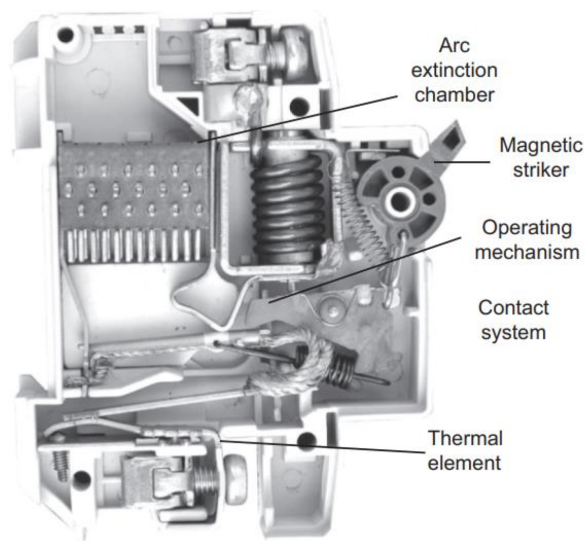


Fig. 1.9 (a): Outer view of MCS   Fig. 1.9 (b): Internal details of MCB

Construction of an MCB can be explained by considering the following main parts:

1) Outer body or housing: The outer body or housing of an MCB is moulded from a special grade glass fiber-reinforced polyester with the help of an injection-moulding machine. The outer body and other polyester components of MCB are fire-retardant, anti-tracking and non-hygroscopic. These polyester parts and housing have the ability to withstand high-temperature and mechanical impacts.
2) Contacts: The contacts of an MCB are made of pure silver. This provides definite advantages such as long contact life, low contact resistance, ensures quick arc removal, and low-heat generation.
3) Operating mechanism: All the components of the operating mechanism are made of special plastic so that they are self-lubricating that eliminates wear and tear, rust, and corrosion. These

components are very light in weight and have low inertia, thereby ensure snap make and break ability. The reliability and ruggedness of the operating mechanism is, thus, maintained.

4) Arc extinguishing chamber: The arc produced during breaking of circuit is extinguished abruptly by providing a special arc chute chamber.
5) Fixing arrangement: The MCB-mounting clip gets easily snapped on to the Din-bar and can be removed easily by a simple operation with a screwdriver. This saves the time that would have been required for fixing it with screws.
6) Mechanical interlocking of multiple MCBs: The levers of all the (3 or 4) multiple MCBs are connected internally. This ensures simultaneous tripping of all poles even if the fault develops in any one of the phases.

Working:

MCB may operate under the following two different conditions:

1) Moderate overload condition: Detection of moderate overload conditions is achieved by the use of a bimetallic strip that deflects in response to the current passing through it. The strip moves against the trip lever, releasing the trip mechanism.
2) Short circuit conditions: When the current flowing through the MCB reaches a predetermined level (as per its setting or rating), it pushes the solenoid plunger that releases the trip mechanism and simultaneously separates the contacts. Under short circuit conditions, the current-limiting action is achieved by the use of a high speed, direct acting electromagnetic mechanism. This mechanism forcibly separates the contacts and simultaneously releases the trip mechanism.

Applications:

MCBs are available with different current ratings of 0.5, 1.6, 2, 2.5, 3, 4, 5, 6, 7.5, 10, 16, 20, 25, 32, 35, 40, and 63 A and voltage ratings of 240/415 V AC and up to 220 V DC. Moreover, they have very small breaking time (5 millisecond), and therefore, these are generally employed to protect the important and sophisticated appliances used commercially and for domestic purposes, such as computers, air conditioners, compressors, refrigerators, and many others.

Earth Leakage Circuit Breaker (ELCB):

In the industrial, commercial, and domestic buildings, sometimes (usually in rainy season) leakage to earth occurs. This leakage may cause electric shock or fire. Hence, the leakage to earth is very dangerous and needs protection. ELCB is a device that provides protection against earth leakage faults.

Construction and internal circuit details:

The enclosure of the ELCB is moulded from high-quality insulating material. The materials are fire-retardant, anti-tracking, non-hygroscopic, impact resistant and can withstand high temperatures. The body contains spring-loaded mounting arrangement on din-channel that ensures snap fitting of ELCB into position. However, these also have the facility to screw-on directly to any surface with the help of two screws. A two-pole ELCB is used for single-phase supply and a four-pole ELCB is used for three-phase, four-wire supply. A four-pole ELCB is shown in Figure 1.10.

Fig. 1.10: Outer body of an ELCB

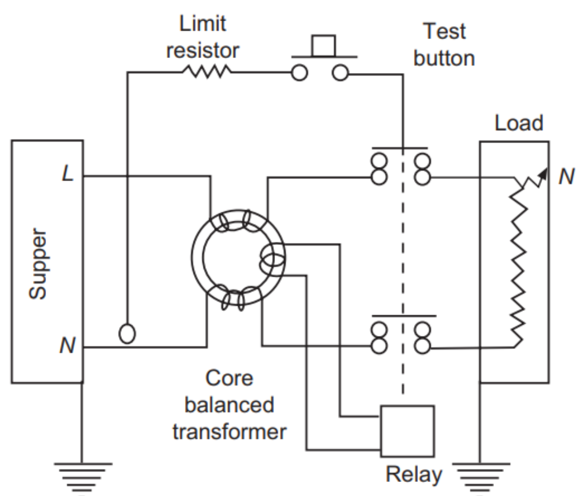


Fig. 1.11: Electrical circuit of an ELCB

Internal wiring diagram of a two-pole ELCB is shown in Figure 1.11. As shown in Figure 1.11, an ELCB contains a core-balanced transformer (ferrite ring on which one or two turns of phase and neutral wire, and a few turns of operating coil of relay are wound) and a relay. A test button is placed between phase and neutral in series with a limiting resistor.

Principle of Operation: Under normal conditions, the magnitude of currents flowing through the phase wire and neutral are the same and core of the core-balanced transformer does not carry any flux (i.e., two windings neutralize the flux). Therefore, no emf is induced in the operating coil of the relay wound on the same core.

However, when the earth fault (earth leakage) occurs, the current in the phase wire becomes more than the neutral wire. This unbalancing sets up flux in the core of the core-balanced transformer, which in turn induces an emf in the operating coil of the relay. Hence, the relay is energized and the plunger of the ELCB goes to the off position or disconnects the load from the supply. Therefore, ELCB protects the system against leakage.

Use of test knob:

A test knob is provided for the periodic checking of the mechanism and function of ELCB.

Types of Wires/Cables:

A solid or stranded conductor covered with insulation is known as a cable. The cable may be a single core or multicore depending upon the number of conductors. Aluminium or Copper core cables or wires can be used. Selection of correct size of wire or cable depends on the load current and voltage drop. Therefore, to find out the correct size of wire to be used, it is necessary to determine the load current in amperes to be carried by the wire or cable.

Various types of insulating materials are employed for covering the conductors. Accordingly, the cables (wiring conductors) may be classified as follows:

1) Vulcanized Indian Rubber (VIR) cables
2) Polyvinyl chloride (PVC) cables
3) Tough rubber sheathed (TRS) or Cab tire sheathed (CTS) cables
4) Lead sheathed cables
5) Weather-proof cables