Electrical safety precaution and first aid

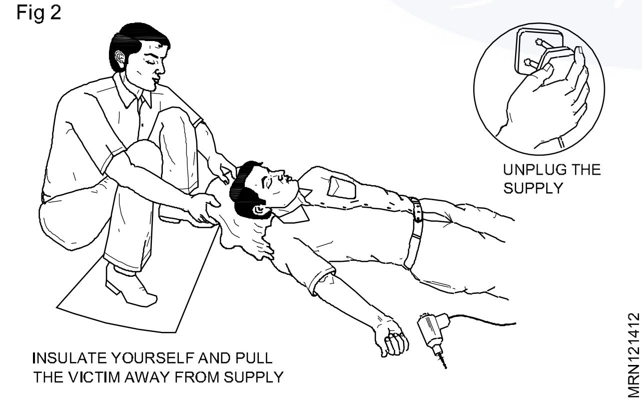
Objectives: At the end of this lesson you shall be able to
- **rescuse a person who is in contact with a live wire**
- **safety practice-first aid for electric shock and injury.**

The severity of an electric shock will depend on the level of current which passes through the body and the length of time of contact. Do not delay, act at once. Make sure that the electric current has been disconnected.

If the casualty is still in contact with the supply - break the contact either by switching off the power, removing the plug or wrenching the cable free. If not, stand on some insulating material such as dry wood, rubber or plastic, or using whatever is at hand to insulate yourself and break the contact by pushing or pulling the person free. (Figs 1 & 2)

Fig 1

Fig 2



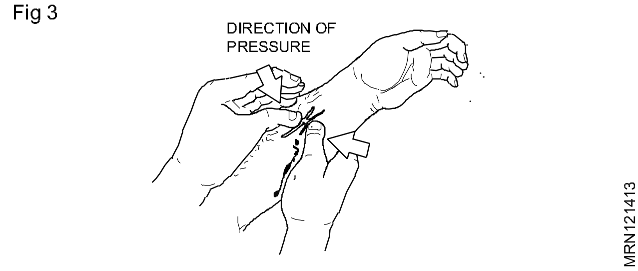
If you remain un-insulated, do not touch the victim with your bare hands until the circuit is made dead or person is moved away from the equipment.

If the victim is aloft, measures must be taken to prevent him from falling or atleast make him fall safe.

Electric burns on the victim may not cover a big area but may be deep seated. All you can do is to cover the area with a clean, sterile dressing and treat for shock. Get expert help as quickly as possible.

If the casualty is unconscious but is breathing, loosen the clothing about the neck, chest and waist and place the casualty in the recovery position.(Fig 3)

Fig 3



Keep a constant check on the breathing and pulse rate.

Keep the casualty warm and comfortable. (Fig 4)

Send for help.

> **Do not give an unconscious person anything by mouth.**
>
> **Do not leave an unconscious person unattended.**

If the casualty is not breathing - Act at once - don't waste time!

Fig 4

Safety practice- first aid

Objectives: At the end of this lesson you shall be able to
- **explain how to treat a person affected due to electric shock/injury.**

Electric shock: The severity of an electric shock will depend on the level of the current which passes through the body and the length of time of the contact.

Other factors that contribute to the severity of shock are:

- age of the person

- not wearnig insulating footwear or wearing wet foot-wear
- weather condition
- floor is wet or dry
- mains voltage etc.

Effects of electric shock: The effect of current at very low levels may only be an unpleasant tingling sensation, but this by itself may be sufficient to cause one to lose his balance and fall.

At higher levels of current, the person receiving the shock may be thrown off his feet and will experience severe pain, and possibly minor burns at the point of contact.

At an excessive level of current flow, the muscles may contract and the person unable to release his grip on the conductor. He may lose consciousness and the muscles of the heart may contract spasmodically (fibrillation). This may be fatal.

Electric shock can also cause burning of the skin at the point of contact.

Treatment of electric shock

Prompt treatment is essential.

If assistance is close at hand, send for medical aid, then carry on with emergency treatment.

If you are alone, proceed with treatment at once.

Switch off the current, if this can be done without undue delay. Otherwise, remove the victim from contact with the live conductor, using dry non-conducting materials such as a wooden bar, rope, a scarf, the victim's coat-tails, any dry article of clothing, a belt, rolled-up newspaper, non-metallic hose, PVC tubing, bakelised paper, tube etc. (Fig 1)

Fig 1

Avoid direct contact with the victim. Wrap your hands in dry material if rubber gloves are not available.

Electrical burns: A person receiving an electric shock may also sustain burns when the current passes through his body. Do not waste time by applying first aid to the burns until breathing has been restored and the patient can breathe normally - unaided.

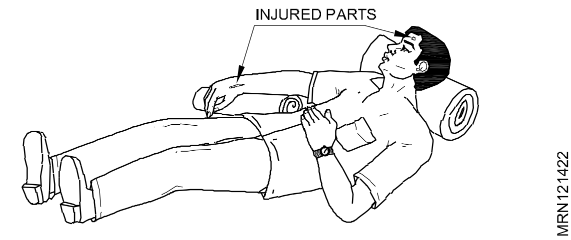
Burns and scalds: Burns are very painful. If a large area of the body is burnt, give no treatment, except to exclude the air, eg.by covering with water, clean paper, or a clean shirt. This relieves the pain.

Severe bleeding: Any wound which is bleeding profusely, especially in the wrist, hand or fingers must be considered serious and must receive professional attention. As an immediate first aid measure, pressure on the wound itself is the best means of stopping the bleeding and avoiding infection.

Immediate action: Always in cases of severe bleeding:

- make the patient lie down and rest
- if possible, raise the injured part above the level of the body (Fig 2)

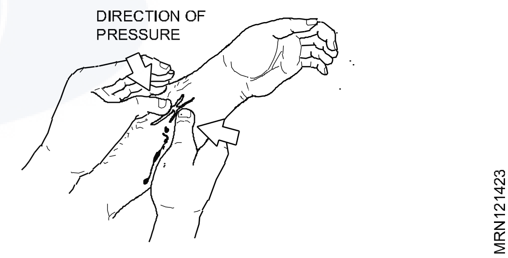
Fig 2



- apply pressure to the wound
- summon assistance.

To control severe bleeding: Squeeze together the sides of the wound. Apply pressure as long as it is necessary to stop the bleeding. When the bleeding has stopped, put a dressing over the wound, and cover it with a pad of soft material. (Fig 3)

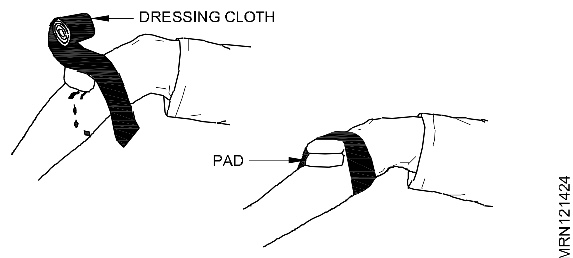
Fig 3



For an abdominal stab wound, such as may be caused by falling on a sharp tool, keep the patient bending over the wound to stop internal bleeding.

Large wound: Apply a clean pad (preferably an individual dressing) and bandage firmly in place. If bleeding is very severe apply more than one dressing. (Fig 4)

Fig 4



Follow the right methods of artificial respiration.

Electrical tools

Objectives: At the end of this lesson you shall be able to
- **list the tools necessary for R&AC**
- **identify and specify the tools**
- **identify the use of each tool**
- **explain the care and maintenance of a R&AC.**

It is important that the R&AC uses proper tools for his work. The accuracy of workmanship and speed of work depend upon the use of correct tools. If the tools are properly used, and maintained, the wireman will find the working efficiency increases and the skills becomes a work habit.

Listed below are the most commonly used tools by R&AC.

Their specifications and BIS number are given for your reference. Proper method of care and maintenance will result in prolonged tool life and improved working efficiency.

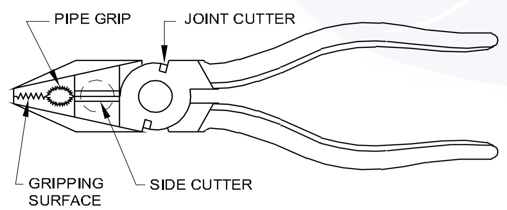
PLIERS

They are specified with their overall dimensions of length in mm. The pliers used for electrical work will be of insulated grip.

1 **Combination pliers with pipe grip, side cutter and insulated handle**. BIS 3650 (Fig 1)

Size 150 mm, 200 mm etc.

Fig 1



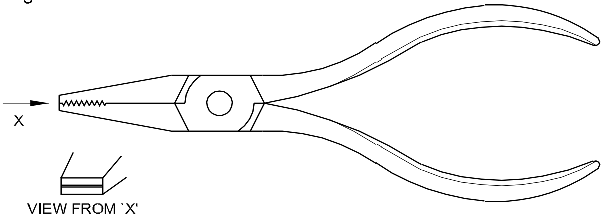
COMBINATION SIDE CUTTING PLIERS (ENGINEER'S PLIERS, COMBINATION PLIERS)

It is made of forged steel. It is used for cutting, twisting, pulling, holding and gripping small jobs in wiring assembly and repairing work. A non-insulated type is also available. Insulated pliers are used for work on live lines.

2 **Flat nose pliers** BIS 3552 (Fig 2)

Size 100 mm, 150 mm, 200 mm etc.

Fig 2



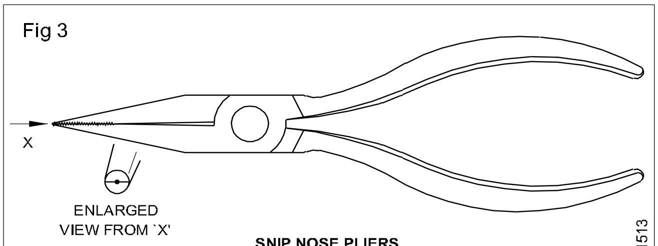
FLAT NOSE PLIERS

Flat nose pliers are used for holding flat objects like thin plates etc.

3 **Long nose pliers** or (snip nose pliers) with side cutter.BIS 5658 (Fig 3)

Size 100 mm, 150 mm etc.

Fig 3

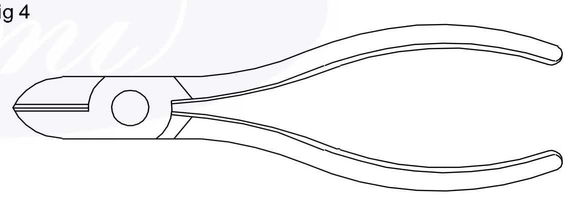


SNIP NOSE PLIERS

Long nose pliers are used for holding small objects in places where fingers cannot reach.

4 **Side cutting pliers** (Diagonal cutting pliers) BIS 4378 (Fig 4) Size 100 mm, 150 mm etc.

Fig 4



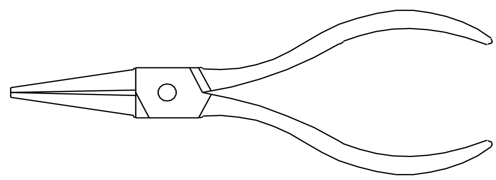
DIAGONAL CUTTING PLIERS/NIPPER

It is used for cutting copper and aluminium wires of smaller diameter (less than 4mm dia).

5 **Round nose pliers** BIS 3568 (Fig 5)

Size 100 mm, 150 mm etc.

Fig 5



ROUND NOSE PLIERS

Wire hooks and loops could be made using the round nose pliers.

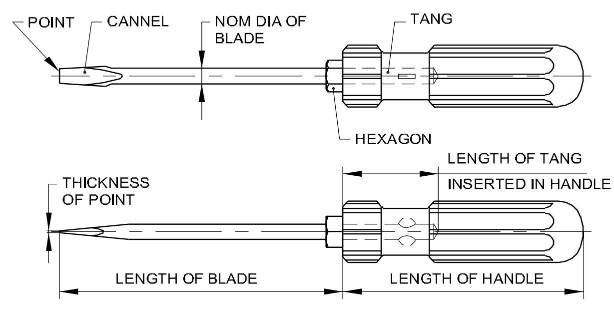
Care and maintenance of pliers

- Do not use pliers as hammers.
- Do not use pliers to cut large sized copper or aluminium wires and hard steel wires of any size.

- While using the pliers avoid damages to the insulation of hand grips.
- Lubricate hinged portions.

6 **Screwdriver BIS 844** (Fig 6)

Fig 6



NOMENCLATURE FOR SCREWDRIVERS

The screwdrivers used for electrical works generally have plastic handles and the stem is covered with insulating sleeves. The size of the screw driver is specified by its blade length in mm and nominal screwdriver's point size (thickness of tip of blade) and by the diameter of the stem.

eg. 75 mm x 0.4 mm x 2.5 mm
150 mm x 0.6 mm x 4 mm
200 mm x 0.8 mm x 5.5 mm etc.

The handle of screwdrivers is either made of wood or cellulose acetate.

Screwdrivers are used for tightening or loosening screws. The screwdriver tip should snugly fit the grooves of the screw to have maximum efficiency and to avoid damage to the screw heads.

As the length of the screw driver is proportional to the turning force, for small work choose a suitable small sized screwdriver and vice versa.

Screwdriver - Philips

It is used for driving star headed screws.

Care and maintenance

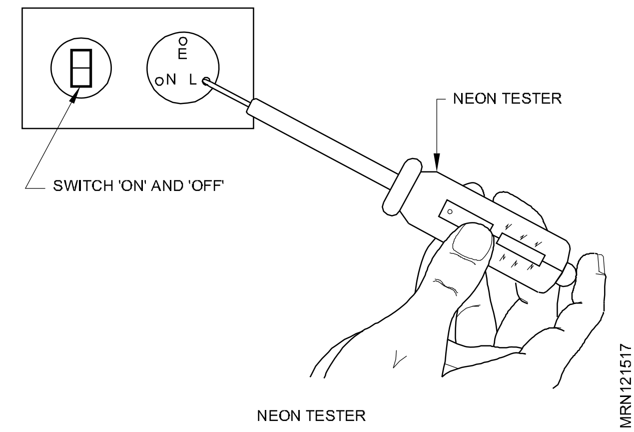
- Never use a screwdriver as a lever to apply force as this action will make the stem to bend and the use of the screw driver will be lost.
- Keep the tip in correct shape and in rare cases it could be grinded to shape.

7 **Neon tester** BIS 5579 - 1985 (Fig 7)

It is specified with its working voltage range 100 to 250 volts but rated to 500 V.

It consists of a glass tube filled with neon gas, and electrodes at the ends. To limit the current within 300 micro-amps at the maximum voltage, a high value resistance is connected in series with one of the electrodes. It may have a tip like a probe or screwdriver at one end. The presence of supply is indicated by the glow of the lamp when the tip is touched on the live supply and the brass contact in the other end of neon tester is touched by hand.

Fig 7



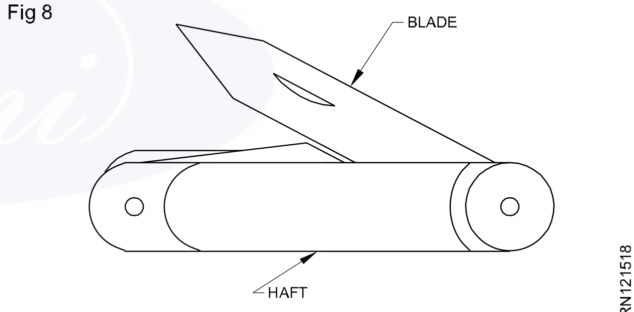
NEON TESTER

Care and maintenance

- Never use the neon tester for voltage higher than the specified range.
- While testing see the circuit is completed through the body. In case if you are using rubber soled shoes, the earthing of the body could be provided by touching the wall by one hand.
- Use the screwdriver tipped neon tester for light duty work only.

8 **Electrician's knife** (Double blade) (Fig 8)

Fig 8



ELECTRICIAN'S KNIFE

The size of the knife is specified by its largest blade length eg. 50 mm, 75 mm.

It is used for skinning the insulation of cables and cleaning the wire surface. One of the blades which is sharp is used for skinning the cable and the rough edged blade is used for cleaning the surface of the wires.

Care and maintenance

- Do not use the knife for cutting wires.
- Keep it free from rust.
- Keep one of the blades in a sharp condition.
- Fold the knife blade when not in use.

Joints in electrical conductors

Objectives: At the end of this lesson you shall be able to
- **state the necessity of joints, their types and uses.**

Joints in electrical conductors are necessary to extend the cables, overhead lines and also to tap the electricity to other branch loads wherever required.

Definition

Joints in electrical conductor mean connecting/tying or interlaying together of two or more conductors such that the union/junction becomes secured both electrically and mechanically.

Types of joints

In electrical work, different types of joints are used based on the requirement. The service to be performed by a joint determines the type to be used.

Some joints may require to have good electrical conductivity. They need not necessarily be mechanically strong. For example: the joints made in junction boxes and conduit accessories.

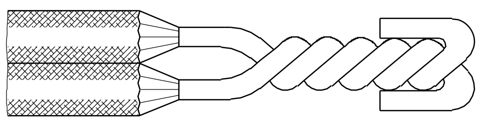
On the otherhand, the joints made in overhead conductors, need to be not only electrically conductive but also to be mechanically strong to withstand the tensile stress due to the weight of the suspended conductor and wind pressure.

Some of the commonly used joints are listed below.

- Pig-tail or rat-tail or twisted joints.
- Married joint
- Tee joint
- Britannia straight joint
- Western union joint
- Scarfed joint
- Tap joint in single stranded conductor.

Pig-tail / rat-tail / twisted joint (Fig 1)

Fig 1



RAT TAIL JOINT

MRN121611

This joint made in either single or multi-strand conductors is suitable for places where there is no mechanical stress on the conductors as found in junction boxes or conduit accessories boxes. However, the joint should maintain good electrical conductivity.

Married joint (Fig 2)

Fig 2

MARRIED JOINT

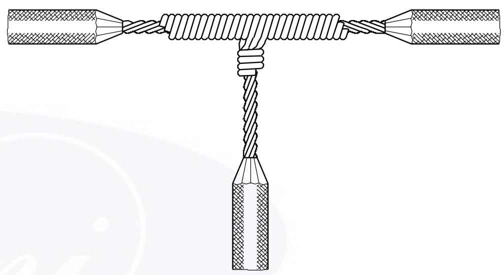
MRN121612

A married joint made with stranded conductors is used in places where appreciable electrical conductivity is required along with compactness.

As the mechanical strength is less, this joint could be used at places where the tensile stress is not too great.

Tee joint (Fig 3)

Fig 3



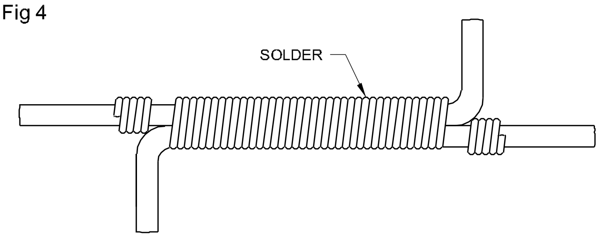
TEE JOINT

MRN121613

This joint in the stranded conductors could be used in overhead distribution lines where the electrical energy is to be tapped for the service connections.

Britannia joint (Fig 4)

Fig 4



BRITANNIA JOINT

MRN121614

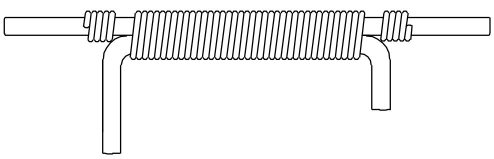
This joint made in a single strand conductor of 4 mm dia. or more is used in overhead lines where considerable tensile strength is required.

It is also used both for inside and outside wiring.

Britannia Tee joint (Fig 5)

This joint made in single strand conductors of 4 mm dia. or more is used for overhead lines for tapping the electrical energy perpendicular to the service lines.

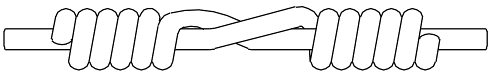
Fig 5



BRITANNIA TEE JOINT

Western union joint (Fig 6)

Fig 6

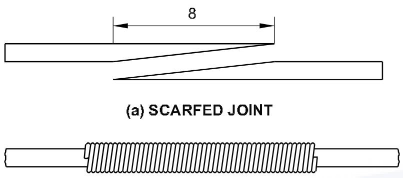


WESTERN UNION JOINT

This joint made in single strand conductors of 4 mm dia. or more is used in overhead lines for extending the length of the wire where the joint is subjected to considerable tensile stress.

Scarfed joint (Fig 7)

Fig 7



(a) SCARFED JOINT

(b) SCARFED JOINT

This joint made in single strand conductors is used in large single conductors where good appearance and compactness are the main considerations, and where the joint is not subjected to appreciable tensile stress as in earth conductors used in indoor wiring. It is preferable to solder this joint to increase the reliability.

Tap joint in single stranded conductors of diameter 2 mm or less.

By definition, a tap is the connection of the end of one wire to some point along the run of another wire.

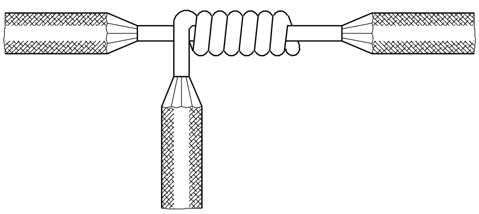
The following types of taps are commonly used.

- Plain
- Aerial
- Knotted
- Cross - Double - Duplex

Plain tap joint (Fig 8)

This joint is the most frequently used and is quickly made. Soldering makes the joint more dependable.

Fig 8

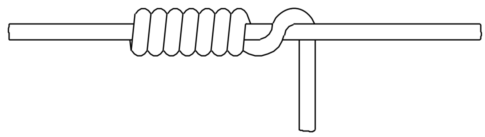


PLAIN TAP JOINT

Aerial tap joint (Fig 9)

This joint is intended for wires subjected to considerable movement and it is left without soldering for this purpose. This joint is suitable for low current circuits only. It is similar to the plain tap except that it has a long or easy twist to permit the movement of the tap wire over the main wire.

Fig 9

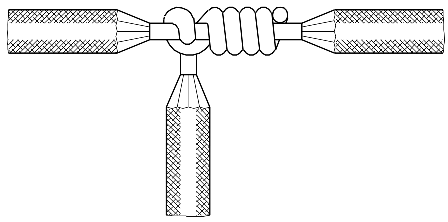


AERIAL TAP JOINT

Knotted tap joint (Fig 10)

A knotted tap joint is designed to take considerable tensile stress.

Fig 10

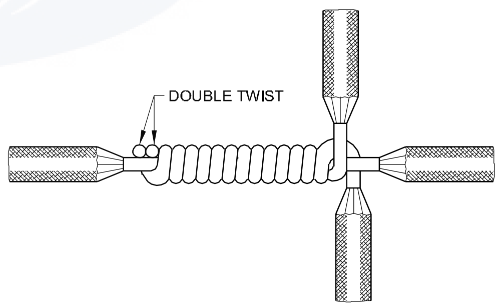


KNOTTED TAP JOINT

Duplex-cross tap joint (Fig 11)

This joint is used where two wires are to be tapped at the same time. This joint could be made quickly.

Fig 11

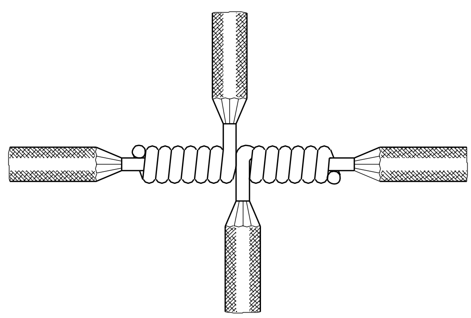


DUPLEX-CROSS TAP JOINT

Double-cross tap joint (Fig 12)

This joint is simply a combination of two plain taps.

Fig 12



DOUBLE-CROSS TAP JOINT

Simple electrical circuit and its elements

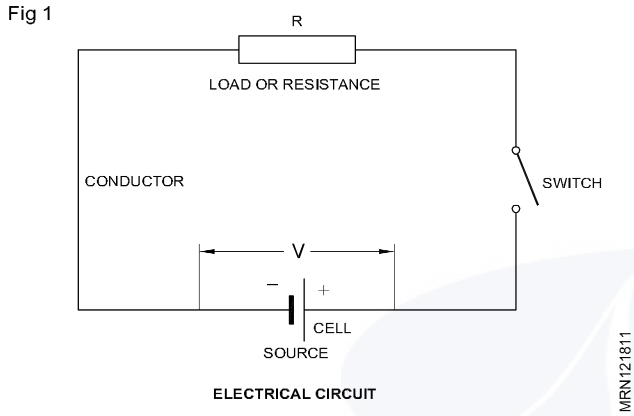
Objectives: At the end of this lesson you shall be able to
- **describe a simple electric circuit**
- **explain the current, its units and method of measurement (Ammeter)**
- **explain the emf, potential difference, their units and method of measurement (Voltmeter)**
- **explain resistance and its unit, and quantity of electricity.**

Simple electric circuit

A simple electrical circuit is one in which the current flows from the source to a load and reaches back the source to complete the path.

As shown in Fig 1, the electrical circuit should consist of the following.

Fig 1



- An energy source (cell) to provide the voltage needed to force the current through the circuit.
- Conductors through which the current can flow.
- A load (resistor) to control the amount of current and to convert the electrical energy to other forms.
- A control device (switch) to start or stop the flow of current.

In addition to the above, the circuit may have insulators (PVC or rubber) to confine the current to the desired path, and a protection device (fuse) to interrupt the circuit in case of malfunction of the circuit (excess current).

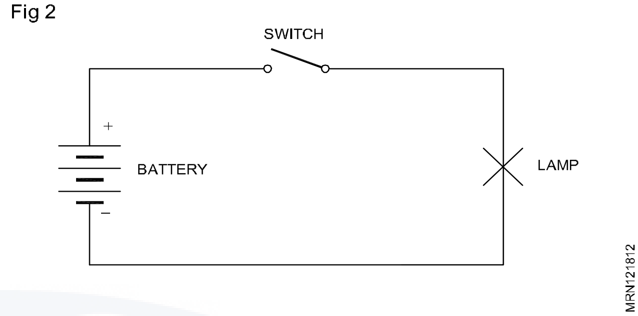
Electric current

Fig 2 shows a simple circuit which consists of a battery as the energy source and a lamp as the resistance. In this circuit, when the switch is closed, the lamp glows because of the electric current flows from the +ve terminal of the source (battery) via the lamp and reaches back the –ve terminal of the source.

Flow of electric current is nothing but the flow of electrons. Actually the electrons flow is from the negative terminal of the battery to the lamp and reaches back to the positive terminal of the battery.

However direction of current flow is taken conventionally from the +ve terminal of the battery to the lamp and back to the –ve terminal of the battery. Hence, we can conclude that conventional flow of current is opposite to the direction of the flow of electrons. Throughout the Trade Theory book, the current flow is taken from the +ve terminal of source to the load and then back to the –ve terminal of the source.

Fig 2



Ampere

The unit of current (abbreviated as I) is an ampere (symbol A). If 6.24×10^{18} electrons pass through a conductor per second, then we can say one ampere current has passed through the conductor.

Ammeter

We know the electrons cannot be seen and no human being can count the electrons. As such an instrument called ammeter is used to measure the current in a circuit.

As an ammeter measures the flow of current in amperes it should be connected in series with the resistance (Load)as shown in Fig 3. For the decimal and decimal sub-multiples of the ampere we use the following expressions.

1 kilo-ampere = 1 kA = 1000 A = 1×10^3A

1 milli-ampere = 1 mA = 1/1000 A = 1×10^{-3}A

1 micro-ampere = 1 μA = 1/1000000 A = 1×10^{-6}A

- Measuring the current drawn by the circuit.
- Testing capacitors, diodes and transistors to know their condition.

Transformer

Tranformers change the voltage in AC circuits. A transformer has two coils of wire close enough to each other for the magnetic filed of one coil to affect the other coil.

Electromotive force

In order to move the electrons in a circuit- that is to make the current to flow, a source of electrical energy is required.

Fig 3

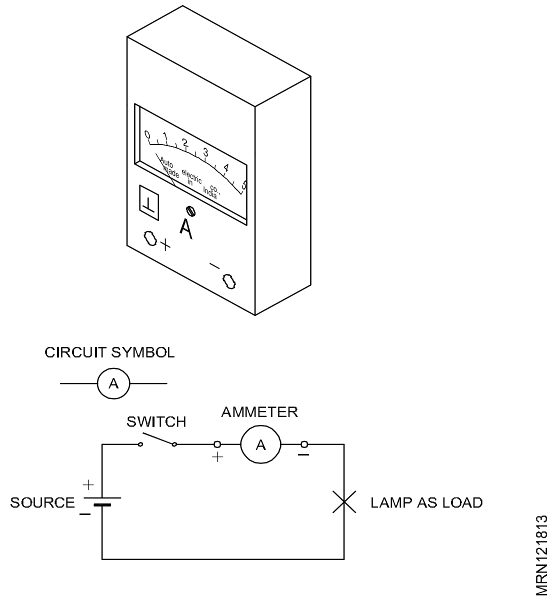
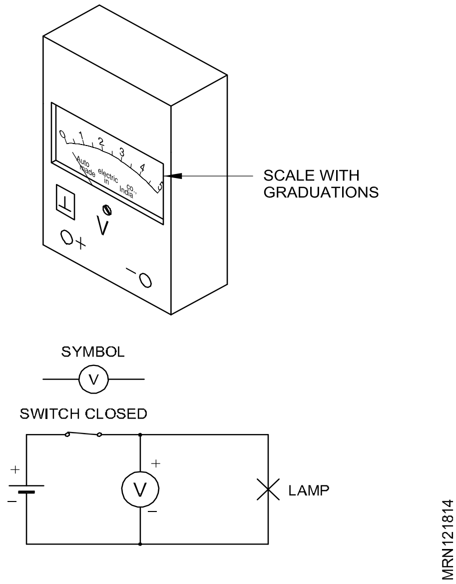


Fig 4



In a torch light, the battery is the source of electrical energy.

The terminals of the battery are indicated in the circuit symbol by two lines, the longer line for the *positive* and the shorter for the *negative* terminal.

Within the battery the negative terminal contains an excess of electrons whereas the positive terminal has a deficit of electrons. The battery is said to have an electromotive force (emf) which is available to drive the free electrons in the closed path of the electrical circuit. The difference in the distribution of electrons between the two terminals of the battery produces this emf.

Potential difference (PD)

The unit of electromotive force is the volt (symbol V) and the emf is commonly referred as 'voltage'. When the battery is connected to any load, the voltage measured across the terminals is called potential difference (PD) and this will be slightly less than the value of emf.

Voltmeter

Electrical voltage is measured with a voltmeter. In order to measure the voltage of a source, the terminals of the voltmeter must be connected to the terminals of the source. Positive to the positive terminal and negative to the negative terminal, as shown in Fig 4. The voltmeter connection is across or it is a parallel connection.

For the decimal or decimal sub-multiples of the volt, we use the following expressions.

1 kilo-volt = 1 kV = 1000 V
= 1×10^3V

1 milli-volt = 1 mV = 1/1000 V
= 1×10^{-3}V

1 micro-volt = 1 μV = 1/1000000 V = 1×10^{-6}V

Resistance

In addition to the current and voltage there is a third quantity which plays a role in a circuit, called the electrical resistance. Resistance is the property of a material by which it opposes the flow of electric current.

Ohm

The unit of electrical resistance (abbreviated as R) is ohm (symbol W).

For the decimal multiples or decimal sub-multiples of the ohm we use the following expressions:

1 megohm = 1 MΩ = 1000000Ω = $1 \times 10^6\Omega$

1 kilo-ohm = 1 kΩ = 1000Ω = $1 \times 10^3\Omega$

1 milli-ohm = 1 mΩ = 1/1000Ω = $1 \times 10^{-3}\Omega$

1 micro-ohm = 1 μΩ = 1/1000000Ω = $1 \times 10^{-6}\Omega$

Types of electrical supply

Objectives: At the end of this lesson you shall be able to
- **explain the different types of electrical supply**
- **differentiate between alternating current and direct current**
- **differentiate between alternating voltage and direct voltage, and their sources**
- **identify AC and DC supply by the terminal markings.**

Working with electricity requires making accurate measurements. Measurements are done by using instruments (meters).

There are various types of instruments working on different principles. Each instrument is designed to measure a particular electrical quantity or more than one quantity with suitable modification and necessary instruction. Further they may be designed to measure AC or DC supply quantities or can be used in either supply.

To enable proper use of the instruments, the wireman should be able to identify the type of supply with the help of the details given below.

Type of electrical supply (Voltage)

There are two types of electrical supply in use for various technical requirements. The alternating current supply (AC) and the direct current supply (DC).

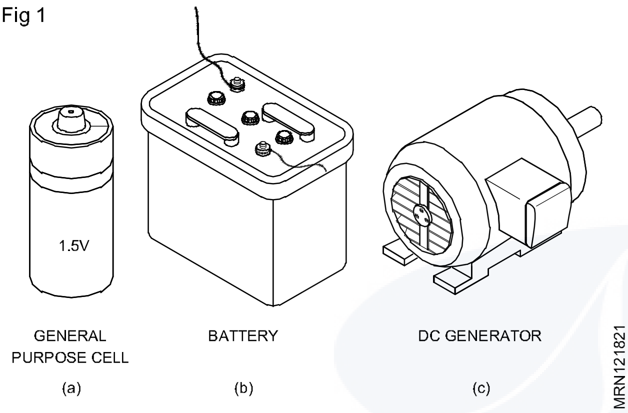
– DC is represented by this symbol.

– AC is represented by this symbol.

DC Supply

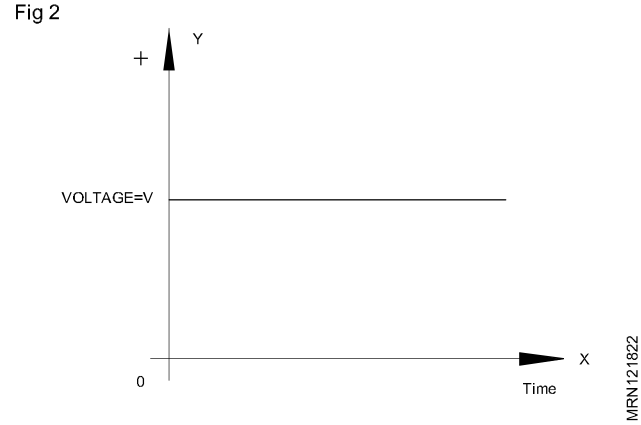
The most common sources of DC supply are the cells/ batteries (Figs 1a and 1b) and DC generators (dynamos). (Fig 1C)

Fig 1



Direct voltage is of constant magnitude (amplitude). It remains at the same amplitude from the moment of switching on to the moment of switching off. The polarity of the voltage source does not change. (Fig 2)

Fig 2



The polarity of direct voltage (commonly known as DC voltage) is positive (+ve) and negative (–ve). The direction of conventional flow of current is taken as from the positive to the negative terminal outside the source. (Fig 3)

AC Supply

The source of AC supply is AC generators (alternators). (Fig 4a) The supply from a transformer (Fig 4b) is also AC.

Fig 3

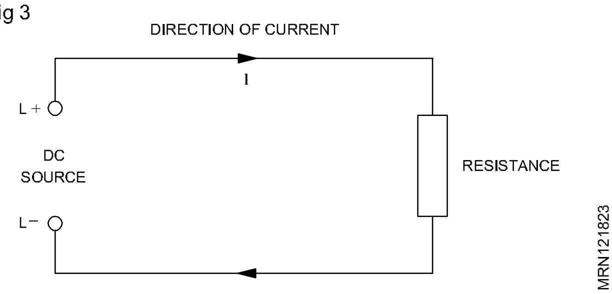
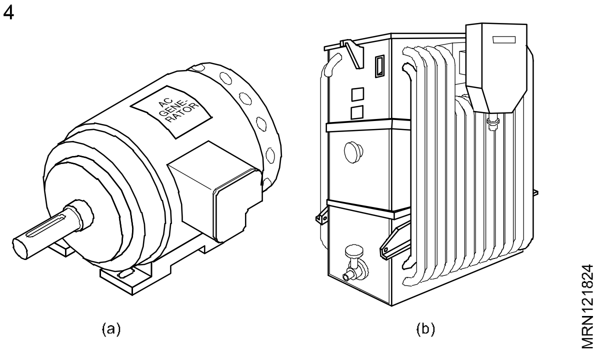


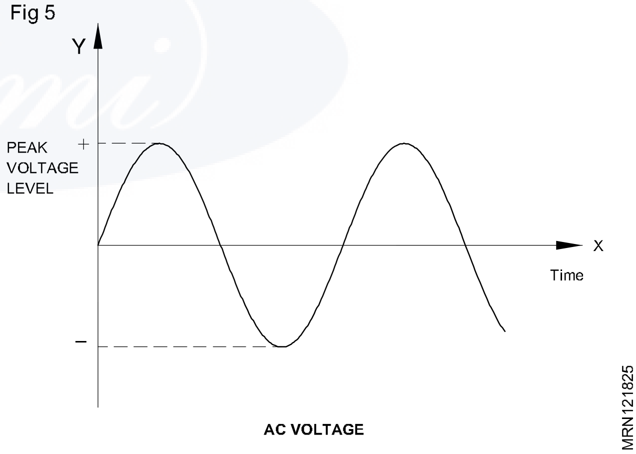
Fig 4



Alternating voltage

AC supply sources change their polarity constantly, and consequently the direction of voltage. The voltage supplied to our homes by power plants is alternating. Fig 5 shows a sinusoidal alternating voltage over time (wave-form).

Fig 5



AC supply is expressed by the effective value of the voltage, and the number of times it changes in one second is known as frequency. Frequency is represented by 'F' and its unit is in Hertz(Hz).

For example, the AC supply used for lighting is 240V 50 Hz. (Alternating voltage in common use is known as AC voltage.) AC supply terminals are marked as phase/line(L) and neutral(N).

Current is caused in an electric circuit due to the application of voltage. If an alternating voltage is applied to an electrical circuit, an alternating current (commonly known as AC current) will flow. (Figs 6 and 7)

Fig 6

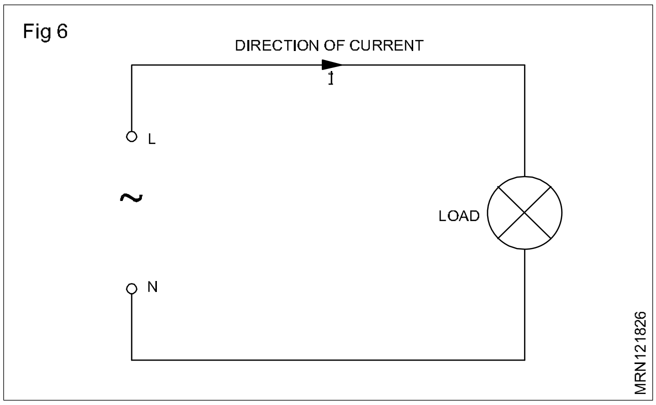
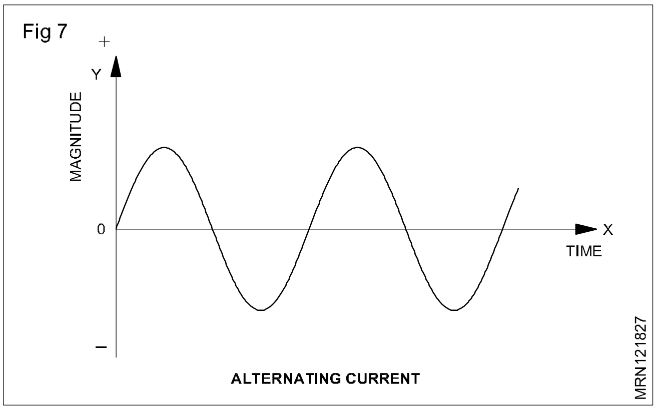


Fig 7



Polarity test in DC

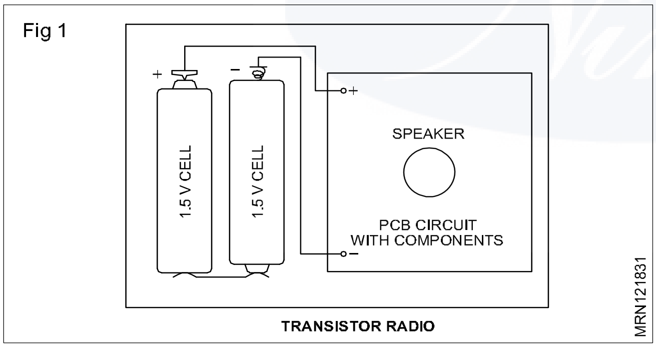
Objectives: At the end of this lesson you shall be able to

- **state the importance of polarity**
- **explain the method of identifying the polarity of DC sources by MC voltmeter**
- **explain how to use a neon lamp/indicator for testing polarity.**
- **state the effects of electric current.**

Polarity

The polarity of a DC supply source should be identified as positive or negative. We can also use the term to indicate how an electric device is to be connected to the supply. For example, when putting new cells in a transistor radio we must put the cells correctly such that the positive terminal of one cell connects to the positive terminal of the radio and the negative terminal of the other cell connects to the negative terminal of the radio as shown in Fig 1.

Fig 1



Importance of the polarity

Direct current supply has fixed polarity, positive and negative marked as + and –. Electric devices which have positive and negative identifications on their terminals are said to be polarised. When connecting such devices to a source of voltage (such as a battery or DC supply) we must observe the correct polarity markings. That is the positive terminal of the device must be connected to the positive terminal of the source, and the negative to the negative. If the polarity is not observed correctly (that is, if +ve is connected to –ve) the device will not function and may be damaged.

To get more voltage, current and power, the voltage sources like cells, batteries and generator are often connected in series, or in parallel or in series/parallel combination circuit. To connect them in such a manner we must know the correct polarity of the source. Fig 2 shows the method of connecting 3 cells in series to get more voltage. Fig 3 shows connection of 3 cells in parallel for getting more current.

Fig 2

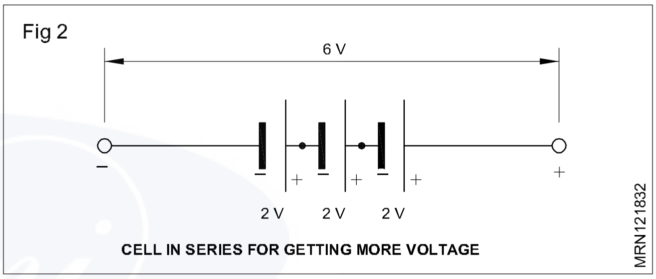
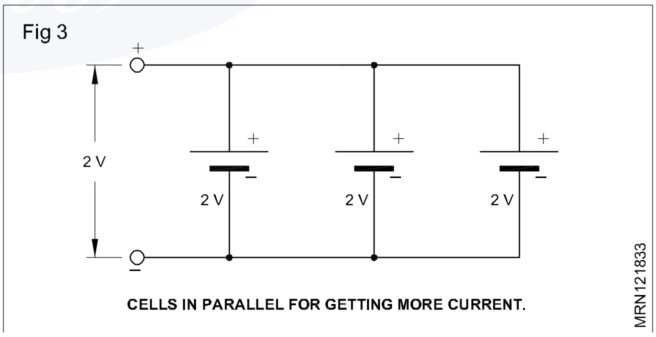


Fig 3



Testing polarity by MC meter

The polarity of a cell is determined by the use of a moving coil volt-meter. The terminals of the MC meter are marked as +ve and –ve. MC meters are called as polarised as they have to be connected as per the polarity marking. By using a low range (0-3V) MC voltmeter we can find out the voltage of a cell. The connections are made as per Fig 4 the voltmeter reads 1.5 volts. The polarity of the cell is correct as per the marked polarity on the meter terminals. If the pointer of the voltmeter deflects as in Fig 5, below zero, the polarity is not correct. From this we conclude that the meter reads in forward direction only if the instrument is connected with correct polarity as per the markings on the instrument terminals.

Fig 4

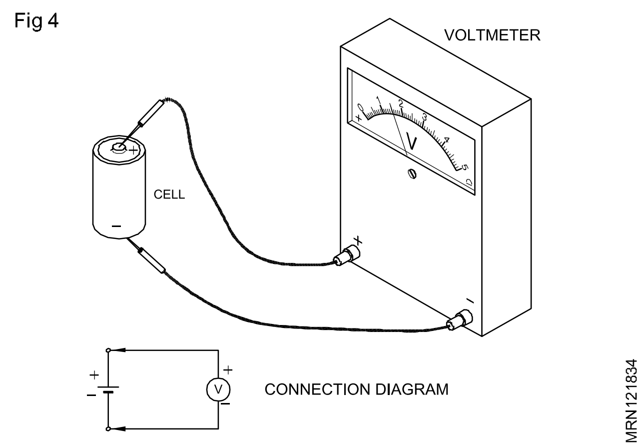
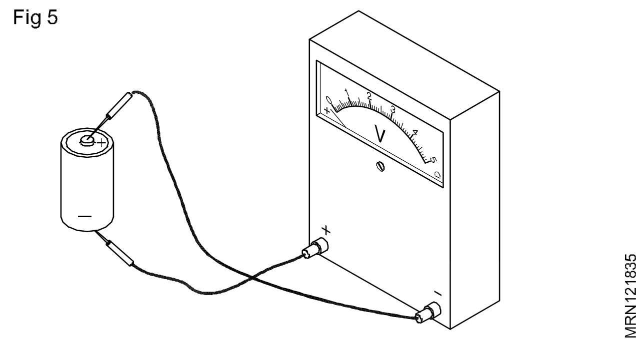


Fig 5



Polarity of the battery

To determine the polarity of the terminals of an unmarked battery, that is +ve and –ve we can use a low range MC voltmeter. If the voltmeter reads positive reading, say 10 or 12 volts then the polarity of the terminals are correct as per the markings on the meter terminals. If the meter reading is negative, that is below zero, the battery polarity is not correct with respect to the meter.

Polarity of DC supply

In the same way to find out the polarity of DC generator or a DC source it is advisable to use a moving coil type voltmeter with a suitable range, of say 0-300 volts. To protect the meters, always use higher range meters above the rated voltage of the generator or DC source supply.

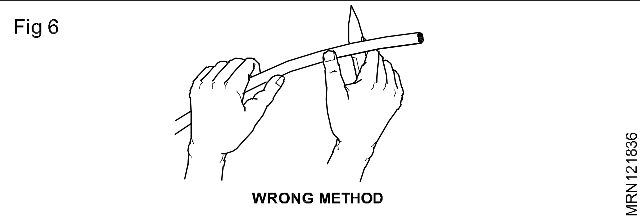
Accordingly, while, using aluminium cables proper care is to be taken regarding the following.

- Handling
- Skinning of the cables
- Connecting the cable ends

Handling: Remember that aluminium conductors when compared to copper conductors have less tensile strength and less resistance to fatigue. As such, bending or twisting of aluminium conductors while laying the cables should be avoided as far as possible.

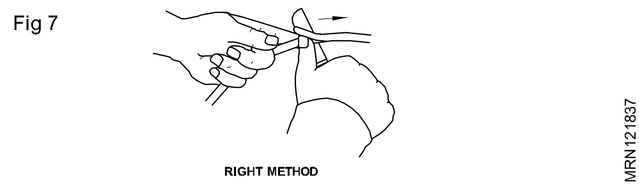
Skinning of cables: While skinning the insulation from the cables, knicks and scratches should be avoided. As shown in Fig 6, the insulation should not be ringed as there is a danger of nicking the aluminium conductor while ringing the insulation with a knife.

Fig 6



Using the knife as shown in Fig 7 at an angle of 20^0 to the axis of the core will avoid knicking of the conductor.

Fig 7



Connecting the cable ends

The following problems are encountered while connecting aluminium cables to the accessories.

The termination holes in the accessories may be undersized.

This normally happens in old accessories as they are designed for copper cable ends. Hence, while selecting accessories, a thorough check is necessary of all accessories to ensure whether the holes in the terminating connectors as shown in Fig 9 are suitable to accommodate the specified aluminium conductors. In any case, the strands should not be cut or the conductor filed as shown in Fig 8 to enable insertion in the undersized hole as this operation results in the heating of the cable end on load condition.

Joints in electrical conductors are necessary to extend the cables, overhead lines, and also to tap the electricity to other branch loads wherever required.

Fig 8

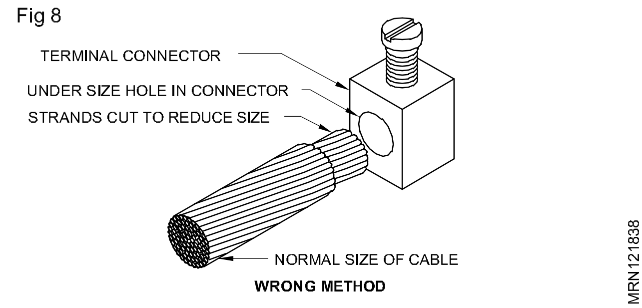
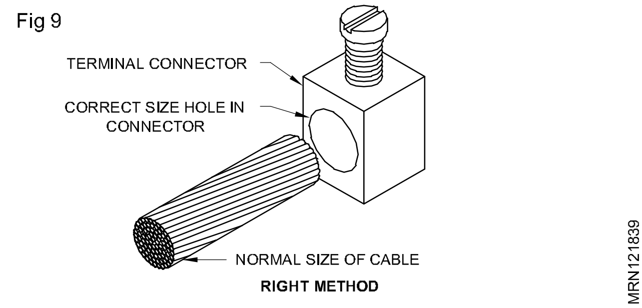


Fig 9



Measurement of energy in single phase circuit

Objectives: At the end of this lesson you shall be able to
- **describe the construction and working principle of a single phase energy meter**
- **name the different dial systems for recording and the method of reading dials**
- **name the different errors in the energy meter**
- **identify and use the meter constant of a kWH meter**
- **state the modification required of the induction type energy meter to read as wattmeters**
- **identify the different dial systems of reading.**

Necessity of energy meter

The electrical energy supplied to different consumers by the electrical supply companies should be billed, based on the actual amount of energy utilised. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt-hour in practice. The meter used for this is the energy meter. Symbolically it is represented as Wh.

In AC, an induction type of energy meter is universally used for measurement of energy in domestic and industrial circuits.

Principle of a single phase induction type energy meter

The operation of this meter depends on the induction principle. Two alternating magnetic field produced by two coils induce current in the disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries load current (Fig 1). Torque is proportional to the power as in a wattmeter. The watt-hour meter must take both power and time into consideration. The instantaneous speed of the disc is proportional to the power passing through it. The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that time.

Parts and function of energy meter

The parts of the induction type single phase energy meter are as shown in Fig 1.

Fig 1

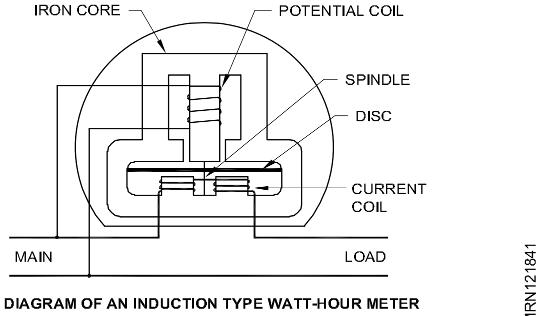


DIAGRAM OF AN INDUCTION TYPE WATT-HOUR METER

Iron core

It is specially shaped to direct the magnetic flux in the desired path. It gives path for magnetic lines of force, reduces leakage flux and also magnetic reluctance.

Potential coil (voltage coil)

The potential coil is connected across the main and is wound with many turns of fine wire. When alternating current passes through the potential coil, it produces an alternating magnetic flux, which, in turn, induces eddy current in the aluminium disc.

Current coil

The current coils, connected in series with load, are wound with a few turns of heavy wire, since they must carry the full line current.

Disc

The disc is made of aluminium and it is the rotating element in the meter. This is mounted on a vertical spindle. The disc is positioned in the air gap between the potential and current coil magnets.

Spindle

The spindle has a hardened steel pivot, at both ends. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. The gear turns the dials that indicate the amount of energy passing through the meter.

Permanent magnet/braking magnet

The permanent magnets restrain the aluminium disk from racing at a high speed. This produces an opposing torque that acts against the turning torque of the aluminium disc. It also acts as a brake to the disc when the load is off. Fig 2 shows the arrangement of parts in an energy meter.

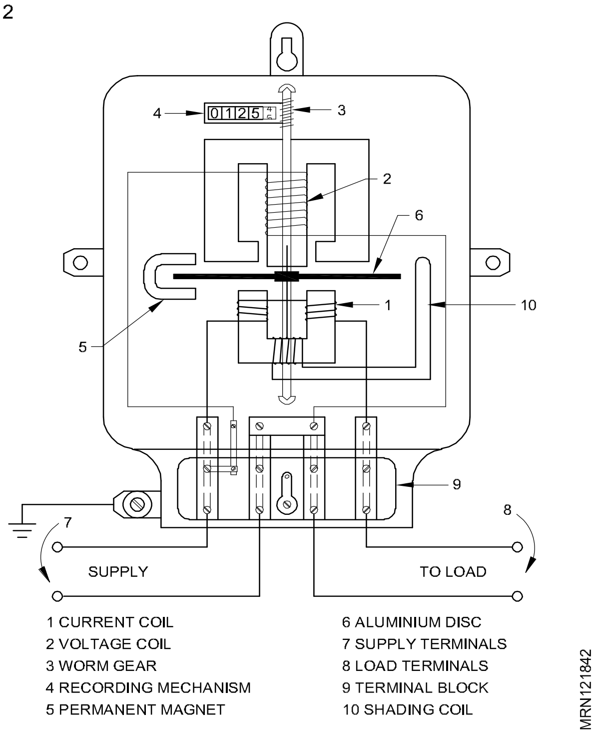
Functioning of energy meter

The rotation of the aluminium disc is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the rotating aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given time period.

A small copper coil (shading coil) called friction compensator is placed in the core to produce a forward torque large enough to counteract any friction produced against the rotating aluminium disc.

Fig 2



Meter constant

It is the number of revolutions the disc makes for one kWh of energy consumed.

Number of revolutions per kWh = 3600 x 1000 watt sec.

$$\text{One rev.} = \frac{3600 \times 1000}{\text{Meter constant}}.$$

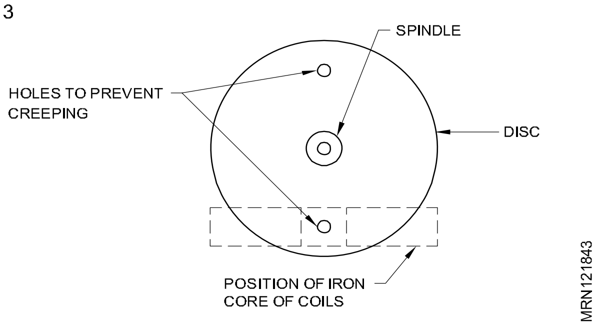
Creeping error and adjustment

In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only pressure coil is energised. This is called creeping.

The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diametrically opposite holes are drilled in the disc (Fig 3). The disc will come to rest with one of the holes under the poles of the brake magnet, the rotation being thus limited to a maximum of half a revolution.

Fig 3



CAUSES OF ERRORS IN METERS

Incorrect magnitude of fluxes

The shunt magnet flux may be in error due to changes in the resistance of the coil or due to abnormal frequencies.

Incorrect phase angles

There may be phase difference between voltage and current, though they may be actually in phase. This may be due to improper power factor adjustment, abnormal frequencies, change in resistance with temperature etc.

Lack of symmetry in magnetic circuits

If the magnetic circuit is not symmetrical, a driving torque is produced which makes the meter to creep.

ERRORS CAUSED BY THE BRAKING SYSTEM

They are:

– changes in the strength of the brake magnet

– improper positioning of the brake magnet in the disc edge

– abnormal friction of the moving parts.

Adjustments are provided for correcting the errors in the energy meters so that they read correctly and their errors are within acceptable limits.

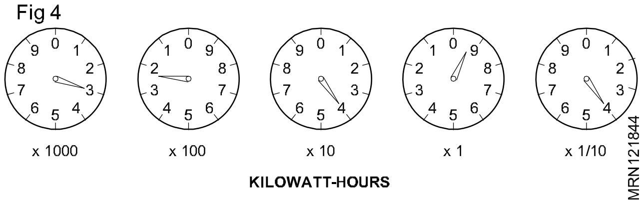
Induction type meter as wattmeter

In the induction type energy meter, the disc is made to rotate and the train of gears attached to the spindle registers the energy consumed. When the induction type meter is used as a wattmeter, the spindle movement is controlled by two phosphor bronze springs and the train of gears is removed. With this arrangement and an addition of a pointer in the spindle, the pointer indicates the power consumed in an AC circuit over a graduated scale of watts or kilowatts.

Types of energy meter dials

In earlier energy meters, the reading of energy had to be done by cyclometer type dials as shown in Fig 4.

Fig 4



In this type there are five dials each having its own pointer. Initially all the pointers will be at zero. The first dial in the left registers in 1000, 2nd dial in 100s, 3rd dial in 10s, 4th dial in ones and the fifth dial in 1/10th of the KWH. When the fifth dial pointer completes one revolution, the fourth dial (one's dial) pointer moves from zero to one, further if the fourth dial (one's dial) completes one revolution, the third dial (10's dial) pointer moves from zero to one and so on.

While reading start from right to left being careful to note the direction of rotation.

Read the right hand dial. If the pointer has moved away from one figure, read the figure behind the pointer in the direction of rotation.

Read the remaining dials in order, taking care to read the figures behind the pointer on these dials. When one of the pointers is directly on a number, the procedure is to look back at the dial on the right. Has it passed the zero? If it has not passed the zero, the correct figure to read is the one behind the pointer.

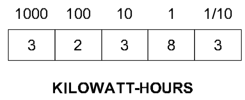
Meters are read once each month or once in two months. The earlier reading is subtracted from the present reading to know the consumption in kWH.

Example

The reading shown by the energy meter as per Fig 4 will be 3239.3 KWH

In the latest type of energy meters these scales have been changed from cyclometer type to direct reading system as shown in Fig 5.

Fig 5



MRN121845

Frequency meter

The digital frequency meter is commonly called a counter since it determines the frequency by electronically counting the number of cycles of an unknown signal in a standard time interval usually second.

Earthing – Terms and methods

Objectives: At the end of this lesson you shall be able to
- **describe the necessity of earthing**
- **explain the reasons for system and equipment earthing**
- **explain the various terms used in earthing electrical system**
- **differentiate between an earthed and non-earthed electrical equipment towards human safety**
- **state and explain the methods of preparing pipe earthing and plate earthing according to BIS recommendations**
- **explain the procedure of reducing the resistance of earth electrodes to an acceptable value.**

Necessity of earthing

While working in electrical circuits, the most important consideration for a wireman is the safety factor - safety not only for himself but also for the consumer who uses the electricity.

Earthing the metal frames/casing of the electrical equipment is done to ensure that the surface of the equipment under faulty conditions does not hold dangerous potential which may lead to shock hazards. However, earthing the electrical equipment needs further consideration as to ensure that the earth electrode resistance is reasonably low to activate the safety devices like earth circuit leakage breaker, fuses and circuit breakers to open the faulty circuit, and thereby, protect men and material.

Earthing of an electrical installation can be brought under the following three categories.

System earthing

Equipment earthing

Special requirement earthing

System earthing

Earthing associated with current-carrying conductors is normally essential to the security of the system and is generally known as system earthing.

System earthing is done at generating stations and substations. The following are the purposes of system earthing.

– Maintain the ground as zero reference potential, thereby ensuring that the voltage on each live conductor is restricted to such a value with respect to the potential of the general mass of the earth as is consistent with the level of the insulation applied.

– Protect the system when any fault occurs against which earthing is designed to give protection, by making the protective gear to operate and make the faulty portion of the plant harmless.

In most cases, such operation involves isolation of the faulty main or plant by circuit breakers or fuses. Earthing may not give protection against faults which are not essentially earth faults.

For example, if a phase conductor on an overhead spur line breaks, and a part remote from the supply falls to the ground, it is unlikely that any protective gear relying on earthing, other than current balance protection at the substation will operate since the earth fault current circuit includes the impedance of the load that would be high relative to the rest of the circuit which will not allow the earth's protective gear to operate and cut off the supply.

Equipment earthing

This is a permanent and continuous bonding together (i.e. connecting together) of all non-current carrying metal parts of the electrical equipment to the system earthing electrode.

'Equipment earthing' is provided to ensure that the exposed metallic parts in the installation do not become dangerous by attaining a high touch potential under conditions of faults. It should also carry the earth fault currents, till clearance by protective devices, without creating a fire hazard.

Special requirements earthing

Static earthing' is provided to prevent building up of static charges, by connections to earth at appropriate locations. Example, operation theatres in hospitals. (For details, please refer to BIS 7689 - 1974 and the National Electrical Code.)

'Clean earth' may be needed for some of the computer data processing equipments. These are to be independent of any other earthing in the building. (For details, please refer to BIS: 10422 - 1982 and BIS: 3043 - 1987.)

Earthing is essentially required for the protection of buildings against lightning.

TERMINOLOGY

The following terms are to be understood, which are often used while referring to earthing in electrical installations.

Apparatus

Electrical apparatus including all machines, appliances and fittings in which conductors are used or of which they form a part.

Bonding

Bonding is a method to connect together electrically two or more conductors or metal parts.

Dead

'Dead' means at or about earth potential and disconnected from any live system.

Earth

A connection to the general mass of earth by means of an earth electrode. An object is said to be 'earthed' when it is electrically connected to an earth electrode and a conductor is said to be 'solidly earthed' when it is electrically connected to an earth electrode without intentional addition of resistance or impedance in the earth connection.

Earth continuity conductor (ECC)

The conductor, including any clamp, connecting to the earthing lead or to each other parts of an installation which are required to be earthed. It may be in whole or in part the metal conduit or the metal sheath or armour of the cables, or a special continuity conductor, cable or flexible cord incorporating such a conductor.

Earth current

A current flowing to earth.

Earth electrode

A metal plate, pipe or other conductor or an array of conductors electrically connected to the general mass of the earth.

Earth fault

Live portion of a system getting accidentally connected to earth.

Earth wire

A conductor connected to earth and usually situated in proximity to the associated line conductors.

Earthed circuit

A circuit having one or more points which are intentionally connected to earth.

Earthed system

A system in which the neutral or any one conductor is deliberately connected to earth directly or through an impedance.

Earthing lead

The conductor by which the connection to the earth electrode is made.

Earthing ring (or earth bus)

A ring or bus formed by connecting earth electrodes.

Fault

Any defect in plant, apparatus or conductor, which impairs normal operation or safety.

Fault current

A current flowing from a conductor to earth, or to another conductor, owing to a fault in the insulation.

Double insulation

Denotes insulation comprising both functional insulation and supplementary insulation.

Functional insulation

Denotes the insulation necessary for the proper functioning of equipment and for basic protection against electric shock.

Supplementary insulation (Protective insulation)

Denotes an independent insulation provided in addition to the functional insulation in order to ensure protection against electric shock in case of failure of the functional insulation.

Leakage

The passage of electricity in a path, other than that desired, due to imperfect insulation.

Leakage current

A fault current of relatively small value, as distinguished from that due to a short circuit.

Live

An object is said to be 'live' when a difference of potential exists between it and earth.

Multiple earthed neutral system

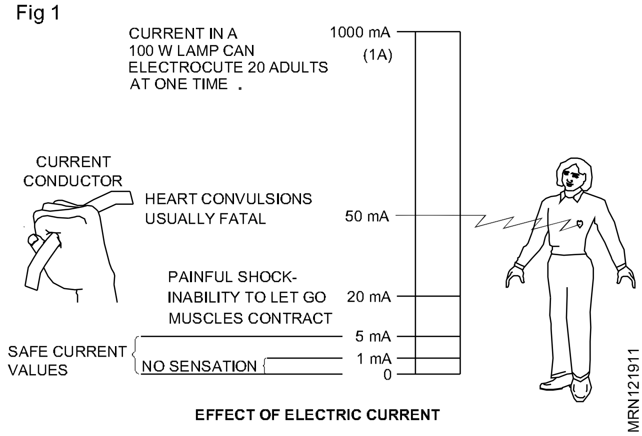
A system of earthing in which the parts of an installation specified to be earthed are connected to the general mass of earth, and in addition, are connected within the installation to the neutral conductor of the supply system.

Reasons for earthing

The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock. The reason for having a properly earthed metal part in an electrical installation is to provide a low resistance discharge path for earth leakage currents which would otherwise prove injurious or fatal to any person touching the metal part.

An electric shock is dangerous only when the current through the body exceeds beyond certain milliampere value. In general any current flowing through the body beyond 5 milliamperes is considered dangerous. Fig 1 shows the magnitude of current and its effect.

Fig 1



EFFECT OF ELECTRIC CURRENT

However, the degree of danger is dependent not only on the current through the body but also on the duration of time it flows. The applied voltage is in itself only important in producing this minimum current through the resistance of the body. In human beings, the resistance between hand and hand or between hand and foot, can easily be as low as 400 ohms under certain conditions. Table 1 shows the body resistance at specified area of contact.

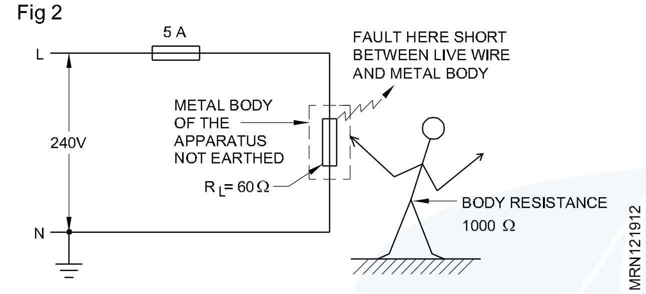
Let us consider the effect of earthing of the body of the apparatus through two extreme cases.

CASE 1 Metal body of apparatus when not earthed

Let us consider a 240 V AC circuit connected to an apparatus having a load resistance of 60 ohms. Assume that the defective insulation of the cable makes the metal body to be live and the metal body is not earthed.

As shown in Fig 2, when a person whose body resistance is 1000 ohms comes in contact with the metal body of the apparatus which is at 240 V, a leakage current may pass through the body of the person.

Fig 2



The value of current through the body =

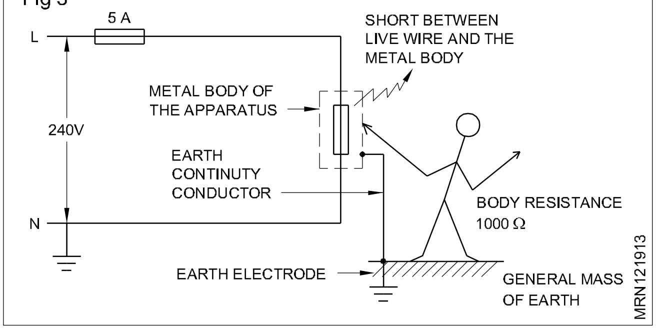
$$\frac{V}{R_{BODY}} = \frac{240}{1000} = 0.24 \text{ amps or } 240 \text{ milliamps.}$$

This current according to Table 1 is highly dangerous and will prove to be fatal. On the other hand, the 5 amps fuse in the circuit will not blow for this additional leakage current of 240 milliamperes. As such the metal body will have 240 V supply and may electrocute any person touching it.

CASE 2 Metal body of apparatus when earthed

In case the metal body of the apparatus is earthed as shown in Fig 3 the moment the metal body comes in contact with the live wire, a higher amount of leakage current will flow through the metal body to earth.

Fig 3



Assuming that the sum of the resistance of the main cable, metal body, earth continuity conductor and the general mass of earth to a tune of 10 ohms.

The leakage current =

$$\frac{V}{R_{Total}} = \frac{240}{10} = 24 \text{ amps.}$$

This leakage current is 4.8 times higher than the fuse rating, and hence, the fuse will blow and disconnect the supply from the mains. The person touching will not get any shock due to two reasons. Firstly, before the fuse operates, the metal body and earth are in the same zero potential, and across the person there is no difference of potential. Secondly within a short (milli-seconds) time the fuse blows to open the defective circuit.

By studying the above two cases, it is clear that a properly earthed metal body eliminates shock hazards to persons and also prevents fire hazards in the system by blowing the fuse quickly in case of ground faults.

General

In general all parts of the apparatus, other than the live parts shall be at earth potential. For this purpose, earth electrodes are used. These earth electrodes shall be provided at generating stations, substations and consumer premises. Sometimes a number of earth electrodes in parallel is necessary to bring down the earth resistance to acceptable low value such that the system's protective devices like earth fault relays and fuses operate properly in case of fault. As far as possible these earth electrodes shall be visible.

Earth resistance tester

Objectives: At the end of this lesson you shall be able to
- **state the meaning of earth system resistance**
- **analyse low and high values of earth system resistance**
- **state the minimum size of the earth continuity conductor**
- **state the method of measuring the resistance of the earth continuity conductor**
- **state the necessity of measuring of earth electrode resistance**
- **explain the principle of an earth resistance tester (earth Megger)**
- **explain the construction and working of the earth resistance tester (earth Megger)**
- **explain the method of measuring earth resistance**
- **state the other uses of an earth resistance tester.**

Earth system resistance

This is the sum of the resistance of the general mass of earth and the resistance of the earth continuity conductor. (E C C)

If the resistance of the general mass of earth is high it can be brought to a low value by the methods suggested in Ex.3.10 Related Theory of Wireman 1st year.

The resistance of the earth continuity conductor also can be lowered by using a larger area of cross-section conductor or by replacing the existing conductor to a higher conductivity metal wire of the same cross-section.

Protection by lower earth resistance

In accordance with the recommendations of B.I.S: 3043-1966, the earthing arrangement of the consumer's installation shall be such that, on the occurrence of a fault of negligible impedance from a phase or non-earthed conductor to adjacent exposed metal, a current corresponding to not less than three and a half times the rating of the fuse or one and a half times the setting of the overload leakage earth circuit breaker will flow (except where voltage operated earth leakage circuit breakers are used) and make the faulty circuit dead.

To facilitate easy flow of faulty current through the earth and, thereby, to blow the fuse or activate the circuit breakers, the sum of the resistance of the general mass of earth and earth continuity conductor (ECC) resistance should be of low value such that the faulty current is atleast $3\frac{1}{2}$ times or more than the fuse rating to blow the fuses. (Fig 1)

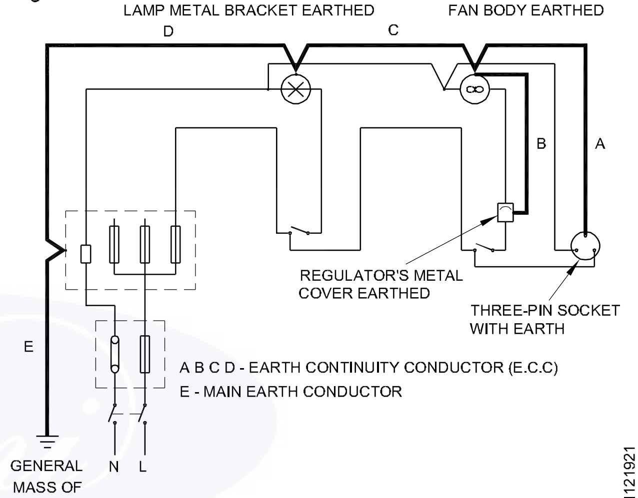
Let us say that the general mass of earth has a resistance (impedance) of 30 ohms and the earth continuity conductor (Route A,B,C,D and E) has a resistance of 20 ohms. Then the faulty current in a 240 V supply system will be

$$= \frac{\text{Supply volts}}{\text{Earth resistance} + \text{ECC resistance}}$$

$$= \frac{240}{30 + 20} = \frac{240}{50} = 4.8 \text{ amps}$$

If the circuit fuse is of 5 amps, this faulty current of 4.8 amps will not blow the fuse. As such if anybody touches the regulator or fan or lamp bracket or appliance connected to the 3-pin socket he will get a shock.

Fig 1



METHOD OF EARTHING AN INSTALLATION

The earth tester, has to be placed horizontally and is rotated at a rated speed (normally 160 r.p.m.). The resistance of the electrode under test is directly read on the calibrated dial. To ensure correct measurement, the spikes are placed at a different position around the electrode under test, keeping the distance the same as in the first reading. The average of these readings is the earth resistance of the electrodes.

Effectiveness of earth resistance

To ensure whether the earth electrode resistance is below the safe value please refer to the earlier part of this lesson.

Applications

There are several uses of the earth Megger as listed below.

1 Earth electrode resistance measurement
2 Soil resistivity
3 Earth continuity testing
4 Neutral earth test
5 Direct resistance measurement.

Resistance of earth electrode to earth at generating stations, substations etc. - soil resistivity measurements to find optimum sitting for new earth electrodes - positioning and testing of ground beds of cathodic protection systems - geophysical surveying - bedrock depth assessment for dam foundations.

Single phase motors- types- resistance/induction-start, induction-run motor

Objectives: At the end of this lesson you shall be able to
- **explain briefly the types of AC single phase motors**
- **explain the necessity and methods of split-phasing the single phase to obtain a rotating magnetic field**
- **explain the principle, construction, operation characteristic and application of single phase resistance / induction-start / induction-run motors.**

Single phase motors perform a great variety of useful services at home, office, farm, factory, and in business establishments. These motors are generally referred to as fractional horsepower motors with a rating of less than 1 H.P. Most single phase motors fall into this category. Single phase motors are also manufactured in 1.5,2,3 and up to 10 H.P. as a special requirement.

Single phase motors may be broadly classified as split-phase induction motors and commutator motors according to their construction and method of starting.

Split-phase induction motors can be further classified as:

- resistance-start, induction-run motors
- induction-start, induction-run motors
- permanent capacitor motors
- capacitor-start, induction-run motors
- capacitor-start, capacitor-run motors
- shaded pole motors.

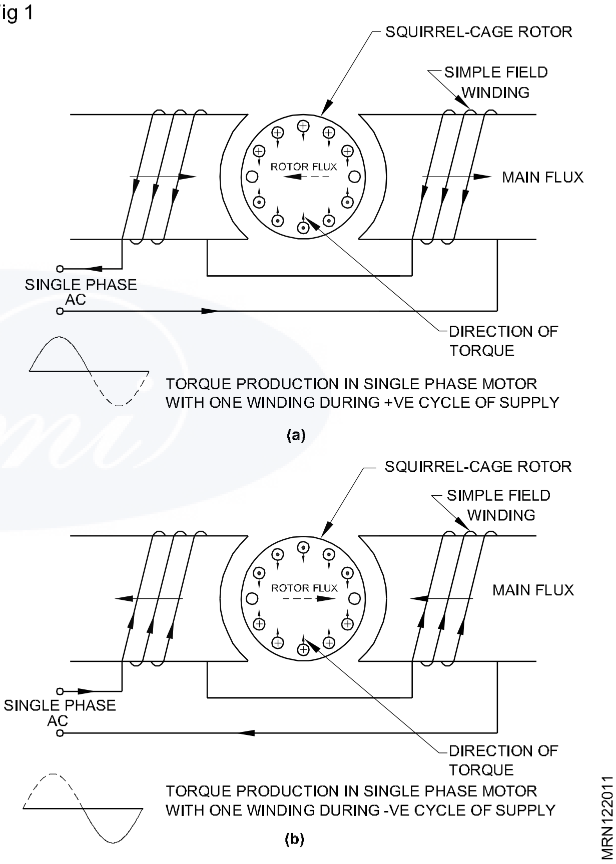
Commutator motors can be classified as:

- repulsion motors
- series motors.

The basic principle of operation of a split-phase induction motor is similar to that of a polyphase induction motor. The main difference is that the single phase motor does not produce a rotating magnetic field but produces only a pulsating field. Hence to produce the rotating magnetic field, phase-spliting is to be done to make the motor to work as a two-phase motor for starting.

First, let us examine the behaviour of the magnetic field as set up by an AC current in a sinlge-phase field winding. With reference to Fig 1, at a particular instant, the current flowing in the field winding produces the magnetic field as shown in Fig 1a. Since the produced magnetic field is varying, it will induce currents in the rotor bars which in turn will create a rotor flux. This stator-induced flux, according to Lenz's law, opposes that of the main field. By applying this principle, the current direction in the rotor bars can be determined as shown in Fig 1a, as well as the torque created between the field and rotor currents. It is apparent that the downward torque produced by the upper rotor conductors is counteracted by the upward torque produced by the lower rotor conductors; hence no rotation results. In the next instant, as shown in Fig 1b, the voltage in the input supply changes its polarity, creating a main field with a change in direction. This main field produces a torque, downward in upper conductors, and upwards in bottom conductors resulting in the cancellation of torque with no movement of the rotor, in this case also. Since the field is pulsating, the torque is pulsating although no net torque is produced over a full cycle.

Fig 1



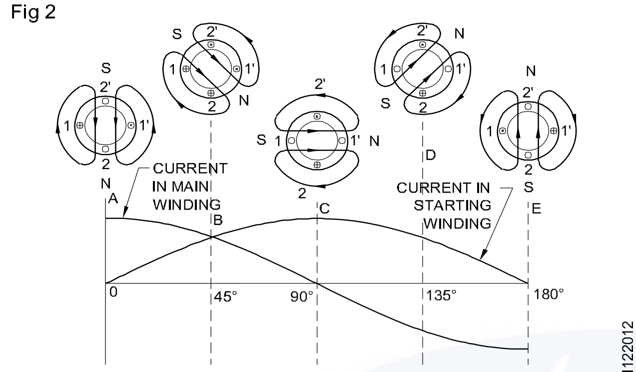
If the rotor is given a small jerk in any direction in the above mentioned cases, it will go on revolving, and will develop a torque in that particular direction due to interaction between the rotor and stator fluxes. Because of this effect, the split-phase motor, once started, needs only one winding to be connected to the supply for running. It is clear that a single phase induction motor, when having only one winding, is not self-starting. If the main field is made revolving instead of pulsating, a rotational torque could be produced in the rotor.

Producing a rotating field from two 90° out-of-phase fields: One of the methods of producing a rotating magnetic field is by split-phasing. This could be done by providing a second set of winding in the stator called the starting winding. This winding should be kept physically at 90 electrical degrees from the main winding, and should carry a current out of phase from the main winding. This, out of phase current, could be achieved by making the reactance of the starting winding being different from that of the main winding. In case both the windings have similar reactance and impedance, the resulting field, created by the main and starting windings, will alternate but will not revolve and the motor will not start.

By split-phasing, the two (main and starting) fields would combine to produce a rotating magnetic field as stated below.

Fig 2 shows that the main (1,1') and starting (2,2') windings are kept in the stator at 90° to each other. For consideration, only, one half cycle is shown with the effects at 45^0 increments.

Fig 2



PRODUCING ROTATING FIELD FROM TWO 90° OUT-OF-PHASE FIELDS

At position `A', only the main winding is producing flux, and the net flux will be in a vertical direction, as shown in the stator diagram. At instant `B', 45° later, both windings are producing flux, and the net flux direction will also have rotated 45°. At position `C', the maximum flux is now in a horizontal direction because only the starting winding is producing flux. At instant `D', the current from the main winding is building up again, but in a new direction, while that from starting winding is now decreasing. Therefore, the net flux at this instant will be as shown in position D. At position `E', the maximum flux is just the opposite of what it was at instant `A'. It should now be evident that the two out-of-phase fields are combining to produce a net rotating field effect.

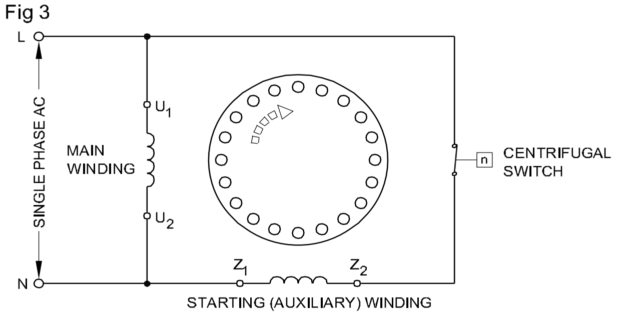
Working of split-phase motor: At the time of starting, both the main and starting windings should be connected across the supply to produce the rotating magnetic field. The rotor is of a squirrel cage type, and the revolving magnetic field sweeps past the stationary rotor, inducing an emf in the rotor. As the rotor bars are short-circuited, a current flows through them producing a magnetic field. This magnetic field opposes the revolving magnetic field and will combine with the main field to produce a revolving field. By this action, the rotor starts revolving in the same direction of the rotating magnetic field as in the case of a squirrel cage induction motor, which was explained earlier.

Hence, once the rotor starts rotating, the starting winding can be disconnected from the supply by some mechanical means as the rotor and stator fields form a revolving magnetic field.

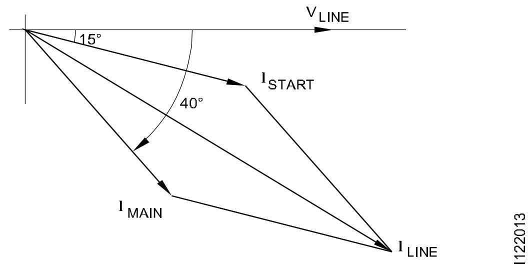
Resistance-start, induction-run motor: As the starting torque of this type of motor is relatively small and its starting current is high, these motors are most commonly used for rating up to 0.5 HP where the load could be started easily.

The essential parts are as shown in Fig 3a.

Fig 3



(a) RESISTANCE START INDUCTION RUN MOTOR



(b) PHASOR DIAGRAM AT THE INSTANT OF STARTING

– Main winding or running winding
– Auxiliary winding or starting winding
– Squirrel cage type rotor
– Centrifugal switch

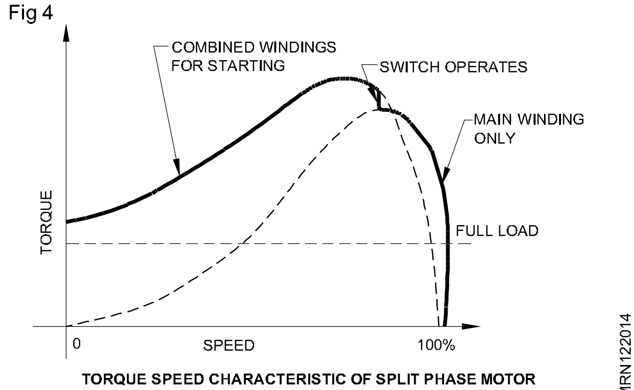
The starting winding is designed to have a higher resistance and lower reactance than the main winding. This is achieved by using smaller conductors in the auxiliary winding than in the main winding. The main winding will have higher inductance when surrounded by more iron, which could be made possible by placing it deeper into the stator slots. It is obvious that the current would split as shown in Fig 3b. The starting current `I start' will lag the main supply voltage `V' line' by 15° and the main winding current. `I main' lags the main voltage by about 40°. Therefore, these currents will differ in time phase and their magnetic fields will combine to produce a rotating magnetic field.

When the motor has come up to about 75 to 80% of synchronous speed, the starting winding is opened by a centrifugal switch, and the motor will continue to operate as a single phase motor. At the point where the starting winding is disconnected, the motor develops nearly as much torque with the main winding alone as with both windings connected.

This can be onserved from the typical torque-speed characteristics of this motor, as shown in Fig 4.

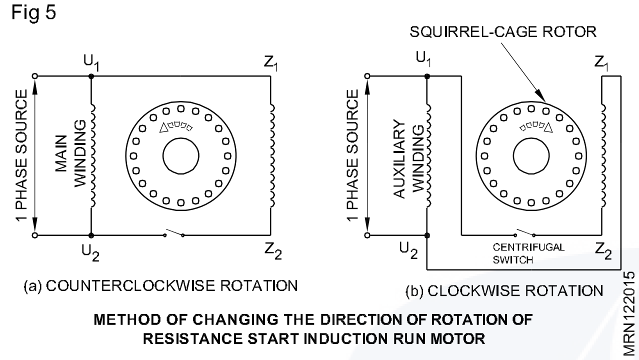
The direction of rotation of a split-phase motor is determined by the way the main and auxiliary windings are connected. Hence, either by changing the main winding terminals or by changing the starting winding terminals, the reversal of direction of rotation could be obtained. Rotation will be, say counter-clockwise, if Z_1 is joined to U_1 and Z_2 is joined to U_2 as per Fig 5a. If Z_1 is joined to U_2 and Z_2 is joined to U_1, then the rotation will be clockwise, as shown in Fig 5b.

Fig 4



TORQUE SPEED CHARACTERISTIC OF SPLIT PHASE MOTOR

Fig 5



METHOD OF CHANGING THE DIRECTION OF ROTATION OF RESISTANCE START INDUCTION RUN MOTOR

Application of resistance-start, induction-run motor: As the starting torque of this type of motors is relatively small and its starting current is high, these are manufactured for a rating up to 0.5 HP where the starting load is light. These motors are used for driving fans, grinders, washing machines and wood working tools.

Induction-start, induction-run motor: Instead of resistance start, inductance can be used to start the motor through a highly inductive starting winding. In such a case, the starting winding will have more number of turns, and will be imbedded in the inner areas of the stator slots so as to have high inductance due to more number of turns, and the area will be surrounded by more iron. As the starting and main windings in most of the cases are made from the same gauge winding wire, resistance measurement has to be done to identify the windings. This motor will have a low starting torque, higher starting current and lower power factor.

Centrifugal switch

Objectives: At the end of this lesson you shall be able to
- **explain the working, the method of maintenance and testing of a centrifugal switch**
- **explain the necessity of a manual D.O.L. starter and its working.**

The centrifugal switch: The centrifugal switch is located inside the motor and is connected in series with the starting winding in the case of capacitor-start, induction-run motors, and for disconnecting the starting capacitor in the case of a two value, capacitor-start, capacitor-run motor. Its function is to disconnect the starting winding after the rotor has reached 75 to 80% of the rated speed. The usual type consists of two main parts. Namely, a stationary part as shown in Fig 1, and a rotating part as shown in Fig 2. The stationary part is usually located on the front-end plate of the motor and has two contacts, so that it is similar in action to a single-pole, single-throw switch. When the rotating part is fitted in the rotor, it rotates along with it. When the rotor is stationary, the insulator ring of the rotating part is in an inward position due to spring tension. This inward movement of the insulator ring allows the stationary switch contacts to be closed which is due to the movable lever pressure against the leaf-spring tension in the switch.

Fig 1

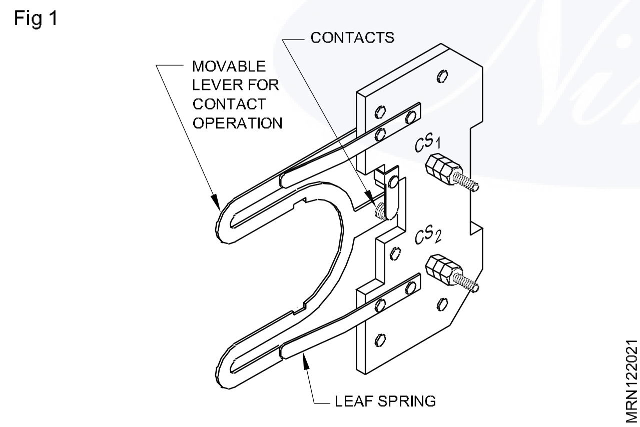
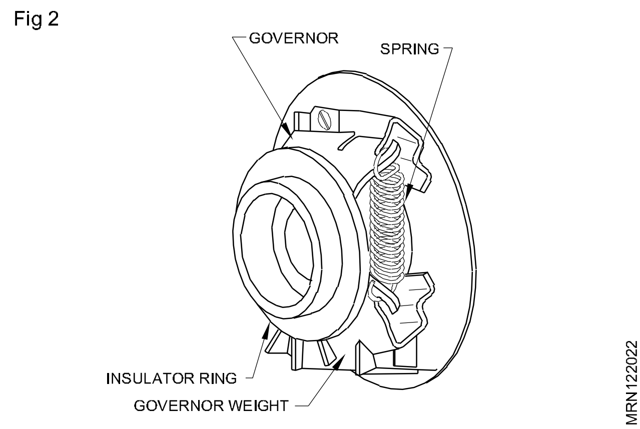


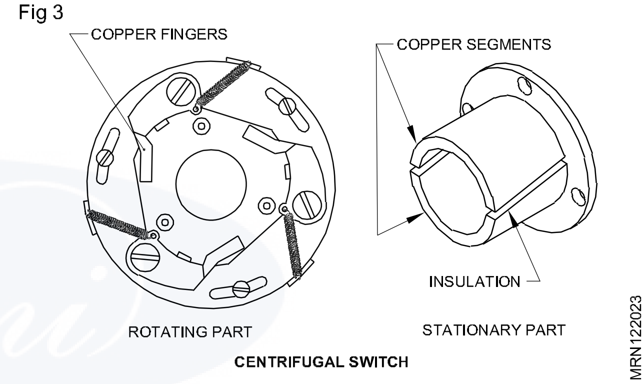
Fig 2



When the rotor attains about 75% of the rated speed, due to centrifugal force, the governor weights fly out, and this makes the insulator ring to come outward. Due to this forward movement of the insulated ring, it presses the movable lever, and the contacts connected through terminals CS_1 and CS_2 open the starting winding.

In older types of centrifugal switches, the stationary part consists of two copper, semicircular segments. These are insulated from each other and mounted inside the front-end plate. The centrifugal switch connections are given to these segments. The rotating part is composed of three copper fingers that ride around the stationary segments, while the motor is at rest or running at lower than 75% of the rated speed. These parts are illustrated in Fig 3.

Fig 3

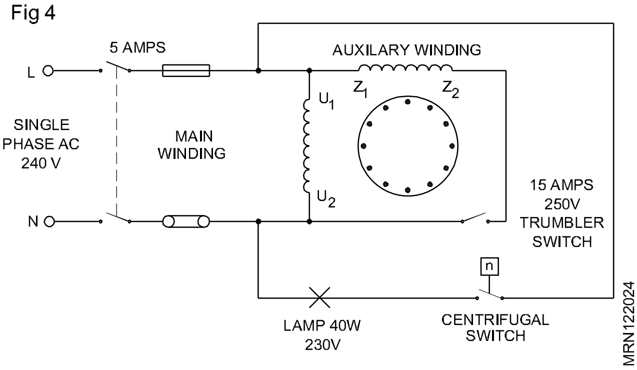


At the time of starting, the segments are shorted by the copper fingers, thus causing the starting winding to be included in the motor circuit. At approximately 75 percent of the full speed, the centrifugal force causes the fingers to be lifted from the segments, thereby disconnecting the starting winding from the circuit.

Maintenance of centrifugal switch: Access to the centrifugal switch could be had by removing the inspection plate, located in the end covers of the motor. In very many cases, the switch is accessible only when the end plate is removed. These switches need to be checked atleast once in six months to ensure their proper operation. Look for broken or weak springs, for improper movement, for dirt or corrosion or pittings in the contact points. Make sure all parts work freely without binding. Replace the switch, if found defective.

Testing the operation of a centrifugal switch: Though the centrifugal switch could be tested in a static condition, it will be very difficult to assess its operation at dynamic condition. As most of these switches cannot be checked without opening the end plate, the procedure becomes lengthy and cumbersome. To check the dynamic operation of the switch the following method is suggested. Disconnect the interconnecting terminals of the centrifugal switch from the supply and the starting winding. Connect the starting (auxiliary) winding through a 15 amps, single-pole, tumbler switch to the rated supply as shown in Fig 4, and keep the trumbler switch in the `ON' position.

Fig 4



Connect the terminals of the centrifugal switch, through a lamp as shown in Fig 4. Switch `ON' the motor. When the centrifugal switch is in the closed position, the lamp will light. As the motor picks up speed, say in about 20 seconds, open the tumbler switch to disconnect the starting winding. When the speed of the motor attains about 75% of the rated value, the centrifugal switch, if it operates correctly, will open its contacts which could be observed from the lamp going `off'. Soon after switching `on' the main supply, if the lamp is not lighted, or if it lights up but does not go out after 30-40 seconds (75 % of the rated speed) then the centrifugal switch is deemed to be not working, and should be repaired or replaced.

Manual D.O.L. starter: A starter is necessary for starting and stopping the motor, and for providing overload protection.

A manual starter, as it appears, is shown in Fig 5, an open view of the starter is shown in Fig 6, and the internal parts are shown in Fig 7, as a schematic diagram. A manual starter is a motor controller with a contact mechanism operated by hand. A push-button operates the mechanism through a mechanical linkage. As shown in Figs 6 & 7, the starter may have both a thermal overload relay and a magnetic overload relay for overload protection and short circuit protection respectively. Both the relays are made to operate independently, in case of overload or short circuit, to release the start-button for disconnecting the motor from supply. Most of the present day, manual starters have either of the two relays only. Basically, a manual starter is an ON-OFF switch with overload relay only.

Fig 5

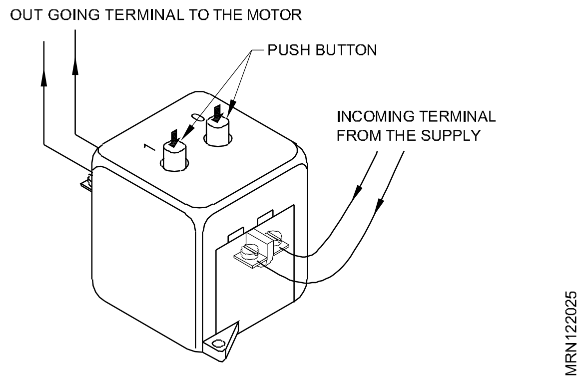
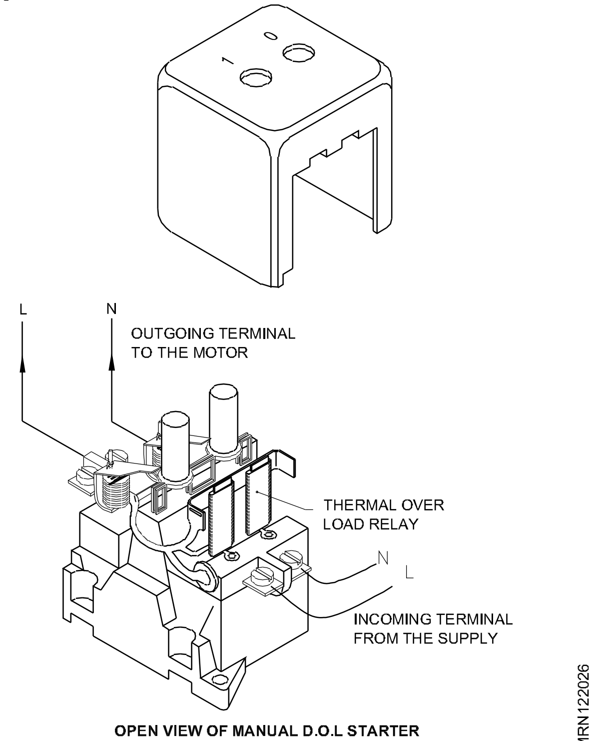
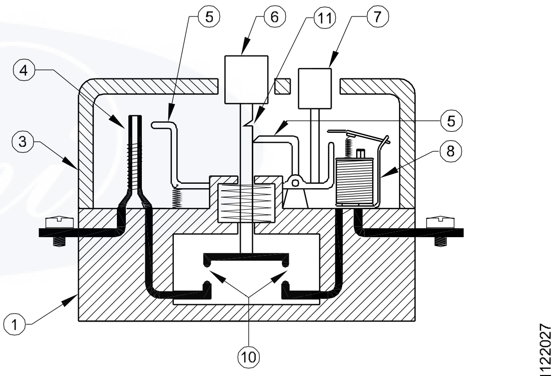


Fig 6



OPEN VIEW OF MANUAL D.O.L STARTER

Fig 7



SCHEMATIC DIAGRAM OF A MANUAL D.O.L STARTER

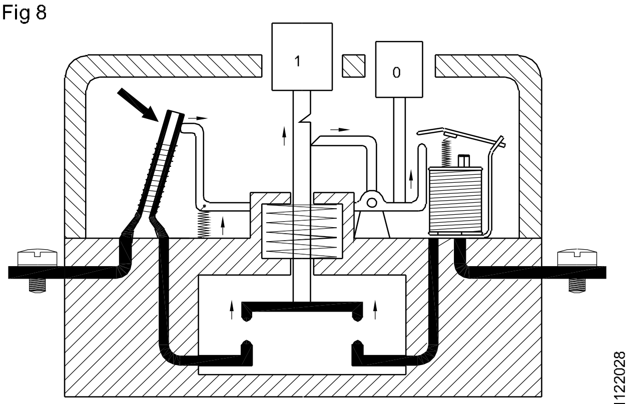
Manual starters are simple and they provide quiet operation

Operation: Pushing the `ON' button closes the contacts. The contacts remain closed until the STOP button is pushed or the overload relay or the short circuit relay trips the starter.

As shown in Fig 7, when the `ON' push-button (6) is pressed, the switching contact (10) gets closed, and remains in a closed position, as the mechanical lever system (5) holds the stem of the `ON' button by the cavity (11) against the spring tension. By operating the stop button (7), the mechanical lever system (5) gets disengaged from the stem cavity, making the stem of the `ON' button to spring back, thereby opening the switching contacts (10).

Operation of overload relay: In the case of sustained overloads, the heavy currents passing through the heating element of the thermal overload relay heats up the bimetallic strip, making it to bend as shown by the arrow in Fig 8, thereby activating the mechanical lever system to open the switching contacts.

Fig 8



OPERATION OF O/L RELAY IN A MANUAL D.O.L. STARTER

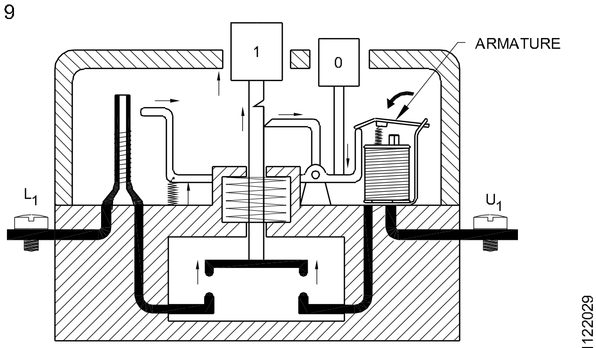
The current setting of the thermal overload relay can be changed by adjusting the setting screw, provided for this purpose (not shown in the figure.)

Operation of short-circuit relay:In the case of a short circuit in the motor circuit, the short circuit current will be very high in value. Though the thermal overload relay is also in series with such a short circuit current, it is sluggish in operation and takes considerable time to operate. On the other hand, the short circuit current within such time of delayed operation, will sufficiently damage the motor winding, power cables or the connected supply line.

The magnetic relay will operate faster than the thermal overload relay in such cases.

During normal load current the magnetic field produced by the coil will not have sufficient pull to attract the armature. But in case of short circuit, the current will be very high and the coil produces sufficient magnetism to attract the armature. Downward movement of the armature activates the mechacnical lever mechanism as shown by the arrow in Fig 9 and the switching contact opens. These contacts cannot be reclosed until the starter mechanism has been reset by pressing the Stop button.

Fig 9

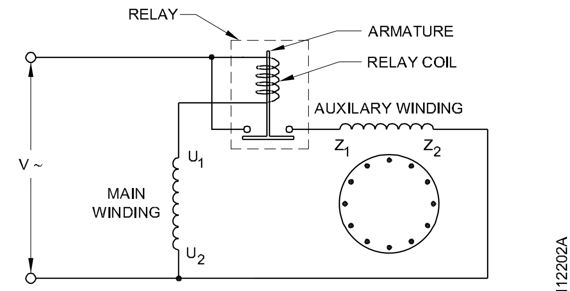


OPERATING OF MAGNETIC RELAY DURING SHORT CIRCUIT

Manual starters are used for fractional horsepower motors. They usually provide across-the-line starting. Manual starters cannot provide low-voltage protection or no-volt release. If power fails, the contacts remain closed, and the motor will restart when the power returns. This may be an advantage for pumps, fans, compressors, and oil burners. But in the case of machinery it can be dangerous to people operating the equipment, and hence, such manual starters are not recommended to be used in these places.

Electromagnetic relay: Single phase induction motors, like poly phase induction motors takes heavy current from the time during starting when started direct on line Advantage of this high starting current is taken to operate electromagnetic type relay which performs the same function as the centrifugal device. Connection diagram for such a relay is shown in Fig 10.

Fig 10



WIRING DIAGRAM FOR AN ELECTROMAGNETIC RELAY

The relay has a coil which is connected in series with the main winding. The auxiliary winding is connected across the supply through a normally open contact of the relay. Since split-phase motors are usually started direct on line, the initial current inrush may be as high a five to six times the rated current. During the starting period, when the main winding current is high, the armature of the relay will be drawn upwards, thereby closing the relay contacts. The auxiliary winding will, therefore, get connected across the supply, thus helping the motor to start rotating. As the rotor starts rotating, the line current gradually goes on decreasing. After the motor reaches proper speed, the main winding current drops to a low value and causes the armature of the relay to fall downwards and open the contacts, thereby cutting out the auxiliary winding from the supply. Such relays are located outside the motor so that they can be easily serviced or replaced. As centrifugal switches are mounted internally, their servicing or replacement is not as simple as an externally mounted over-current relay.