IVC Course Code : 321

ELECTRICAL TECHNICIAN

SECOND YEAR

(w.e.f.2019 – 20)

Intermediate Vocational Course

Paper I : Electrical Machines & Power Systems

Paper II : Domestic Appliances & Rewinding

Paper III : Electrical Estimation & Utilization

STATE INSTITUTE OF VOCATIONAL EDUCATION

BOARD OF INTERMEDIATE EDUCATION, A.P.

Text Book Development Committee

Paper -I ELECTRICAL MACHINES & POWER SYSTEMS

AUTHOR

Sri.D.Ajai Raj M.Tech.
Junior Lecturer in E.T
SRR & CRR Govt. Junior College
Vijayawada-520 004
Krishna (Dt.)

Paper-II DOMESTIC APPLIANCES AND REWINDING

AUTHOR

Sri.B.Simhadri Rao
Junior Lecturer in E.T
Govt Junior College
Kothapeta, EAST GODAVARI (DT)

Paper-III PELECTRICAL ESTIMATION & UTILIZATION

AUTHOR

B.Madhu Kiran
Associate Professor,
Department of Electrical & Electronics Engineering
Gudlavalleru Engineering College
Gudlavalleru.
Krishna (Dt.)

EDITOR

Dr. G.Srinivasa Rao M.Tech., Ph.D., MIE,LMISTE
Associate Professor,
Department of Electrical & Electronics Engineering
V.R.Siddhartha Engineering College, Kanuru
Vijayawada.

ELECTRICAL TECHNICIAN

TEXT BOOK DEVELOPMENT COMMITTEE

S.No	Name	Designation	Signature
1	**Dr. G.Srinivasa Rao M.Tech., Ph.D., MIE,LMISTE** Associate Professor, Department of Electrical & Electronics Engineering V.R.Siddhartha Engineering College, Kanuru Vijayawada.	Editor	
2	**Sri.D.Ajai Raj** M.Tech. Junior Lecturer in E.T SRR & CRR Govt. Junior College Vijayawada-520 004 Krishna (Dt.)	Author	
3	**Sri.B.Simhadri Rao** Junior Lecturer in E.T Govt Junior College Kothapeta, EAST GODAVARI (DT)	Author	
4.	**B.Madhu Kiran** Associate Professor, Department of Electrical & Electronics Engineering Gudlavalleru Engineering College Gudlavalleru. Krishna (Dt.)	Author	

Smt. B.UDAYA LAKSHMI, I.A.S.

Commissioner & Secretary

Intermediate Education

ANDHRA PRADESH

GUNTUR

S.I.V.E Co – Ordinating Committee

Sri. Podili Yerraiah, **M.Sc., B.Ed.**
Professor
State Institute of Vocational Education
Commissioner of Intermediate Education, Guntur

Sri. B. Nageswara **B.Com, B.L.,**
Joint Secretary (Vocational)
Board of Intermediate Education, Vijayawada

Sri. Dr.G.V.S.R. Murthy, **M.SC., Ph.D.**
Lecturer
State Institute of Vocational Education
Commissioner of Intermediate Education, Guntur

DTP

Thuraka Ravi Kumar ***BA,B.Ed., PGDCA***

ELECTRICAL TECHNICIAN

SECOND YEAR

PART – B

Theory Paper – I

ELECTRICAL MACHINES & POWER SYSTEMS

UNIT – 1

DC GENERATORS

OBJECTIVE

- To learn the working principle of a simple loop Generator.
- To learn the various types of DC Generators.
- To learn the applications of a different types of DC Generators.

1.0. INTRODUCTION

A Dynamo is a machine which converts either mechanical energy into electrical energy or electrical energy to mechanical energy. When a Dynamo is driven mechanically by a prime mover such as a steam turbine, water turbine, gas turbine or a diesel engine and supplies electrical energy, it is called a Generator.

1.1. SIMPLE LOOP GENERATOR

1.1.1. Working principle. A Generator works on the principle of Faradays laws of Electromagnetic induction which states that "whenever a conductor is placed in a varying magnetic field, EMF is induced and this induced EMF is equal to the rate of change of flux linkages". Hence, the basic essential components of an electrical generator are (i) a magnetic field (ii) a conductor or conductors which can so move as to cut the flux and (iii) motion of conductor with respect to magnetic field.

1.1.2. Simple loop Generator. A single turn rectangular copper coil rotating about its own axis in a magnetic field provided by either permanent magnet or an electromagnet is shown in the figure 1.1.

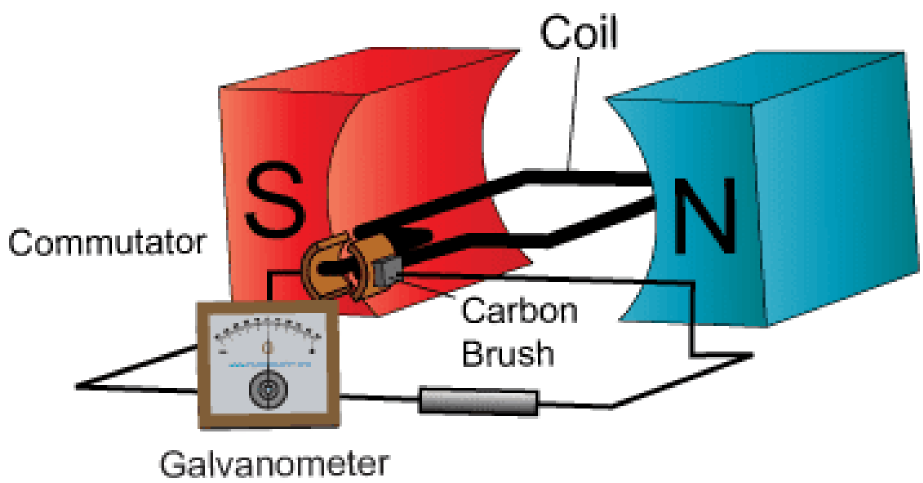


Figure.1.1. Simple loop Generator.

The two ends of the coil are joined to two slip-rings which are insulated from each other and from the central shaft. Two collecting brushes (carbon or copper) press against these slip-rings. Their function is to collect the current induced in the coil and convey it to the external load resistance. The rotating coil may be called 'armature' and the magnets as 'field magnets'.

1.2. PRODUCTION OF INDUCED EMF

1.2.1. Faradays laws of Electromagnetic Induction. A Generator works on the principle of Faradays laws of Electromagnetic induction.

Faradays first law. It states that any change in the magnetic field of a coil of wire will cause an emf to be induced in the coil. This emf induced is called induced emf and if the conductor circuit is closed, the current will also circulate through the circuit and this current is called induced current.

Faradays second law. It states that the magnitude of emf induced in the coil is equal to the rate of change of flux linkages with the coil. The flux linkage of the coil is the product of the number of turns in the coil and flux associated with the coil.

Consider, a magnet is approaching towards a coil. Here we consider two instants at time T_1 and time T_2.

Flux linkage with the coil at time,

$$T_1 = N\phi_1 \ wb$$

Flux linkage with the coil at time,

$$T_2 = N\phi_2 \ wb$$

Change in flux linkage,

$$N(\phi_2 - \phi_1)$$

Let this change in flux linkage be,

$$\phi = (\phi_2 - \phi_1)$$

So, the Change in flux linkage

$$N\phi$$

Now the rate of change of flux linkage

$$\frac{N\phi}{t}$$

The rate of change of flux linkage

$$E = N\frac{d\phi}{dt}$$

But according to Faraday's law of electromagnetic induction, the rate of change of flux linkages is equal to induced emf.

$$E = -\,N\frac{d\phi}{dt}$$

Various methods to change the magnetic field are:

(i) by moving a magnet towards or away from the coil
(ii) by moving the coil into or out of the magnetic field
(iii) by changing the area of a coil placed in the magnetic field
(iv) by rotating the coil relative to the magnet.

1.2.2. Production of Induced emf by simple loop DC generator. A single turn rectangular copper coil ABCD rotating about its own axis in a magnetic field provided by either permanent magnet or an electromagnet is shown in the figure 1.1. The two ends of the coil are joined to two slip-rings 'a' and 'b' are insulated from each other and from the central shaft. Two collecting brushes (carbon or copper) press against these slip-rings. Their function is to collect the current induced in the coil and convey it to the external load resistance 'R'.

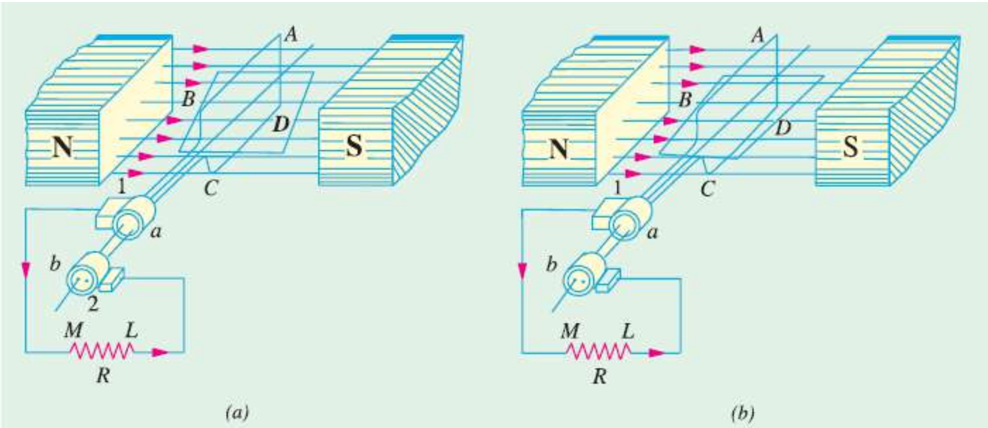


Figure.1.2. Current direction in external circuit with slip-rings.

Imagine the coil to be rotating in clock-wise direction. As the coil assumes successive positions in the field, the flux linked with it changes. Hence, an emf is induced in it which is proportional to rate of change of flux linkages. When the plane of the coil is at right angles to lines of flux i.e. in position 1, the flux linked with the coil is maximum but rate of change of flux linkages is minimum as the coil sides AB and CD do not cut or shear the flux, rather they slide along them i.e. they move parallel to them. Hence, there is no induced emf in the coil. Consider this no-emf or vertical position of the coil as the starting position. As the coil continues rotating further, the rate of change of flux linkages increases, till position 3 is reached where θ = 90º. Here, the coil plane is horizontal i.e. parallel to the lines of flux. The flux linked with the coil is minimum but rate of change of flux linkages is maximum.

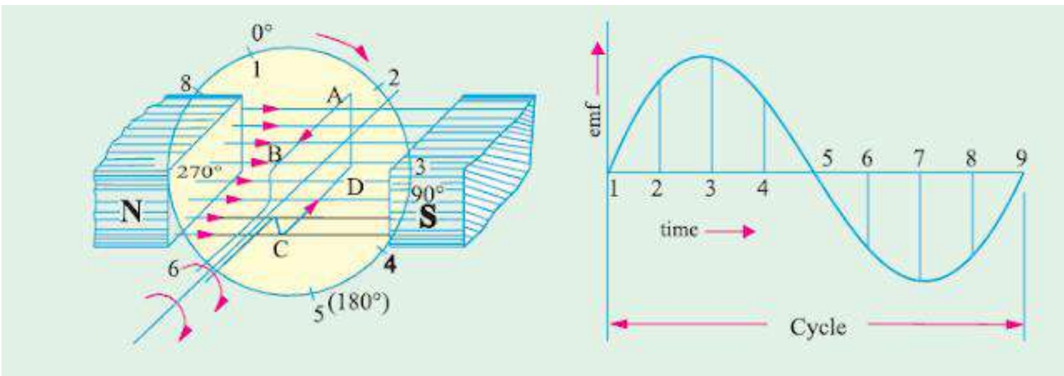


Figure.1.3. Coil position and induced emf.

In the next quarter revolution i.e. from 90º to 180º, the flux linked with the coil gradually increases but the rate of change of flux linkages decreases. Hence, the induced emf decreases gradually till position 5 of the coil and is reduced to zero value. So, we find that in the first half of the revolution, no emf is induced in position 1, maximum in position 3 and no emf in position 5. The direction of this induced emf is from A to B and C to D. Hence, the direction of current flow is ABMLCD. The current through the load resistance R flows from M to L during the first half revolution of the coil.

In the next half revolution i.e. from 180º to 360º, the variations in the magnitude of emf are similar to those in the first half revolution. Its value is maximum when coil is in position 7 and minimum in position 1. But it is found that the direction of the induced current is from D to C and B to A. Hence, the path of current flow is along DCLMBA which is just the reverse of the previous direction of flow. Therefore, we find that the current obtained from such a simple generator reverses its direction after every half revolution. Such a current undergoing periodic reversals is known as alternating current. Alternating current not only reverses its direction, it does not even keep its magnitude constant while flowing in any one direction. The two half-cycles may be called positive and negative half-cycles respectively.

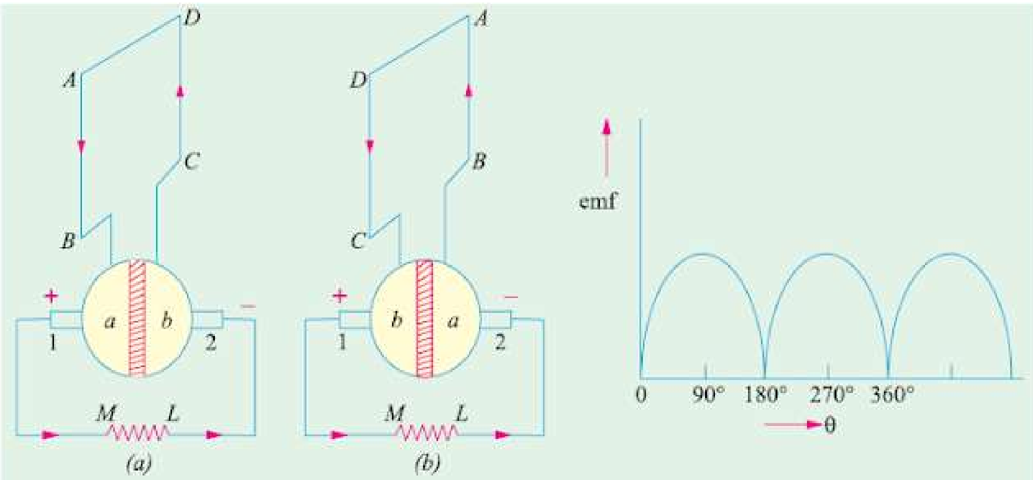


Figure.1.4. Current direction in external circuit with Split-rings.

For making the current flow unidirectional in the external circuit, the slip-rings are replaced by split-rings. The split-rings are made out of a conducting cylinder which is cut into two halves or segments insulated from each other by a thin sheet of mica or some other insulating material. The coil ends are joined to these segments on which rest the carbon or copper brushes. It is seen that in the first half revolution current flows along ABMLCD i.e. the brush No. 1 in contact with segment 'a' acts as the positive end of the supply and 'b' as the negative end. In the next half revolution, the direction of the induced current in the coil has reversed. But at the same time, the positions of segments 'a' and 'b' have also reversed with the result that brush No. 1 comes in touch with the segment which is positive i.e. segment 'b' in this case. Hence, current in the load resistance again flows from M to L.

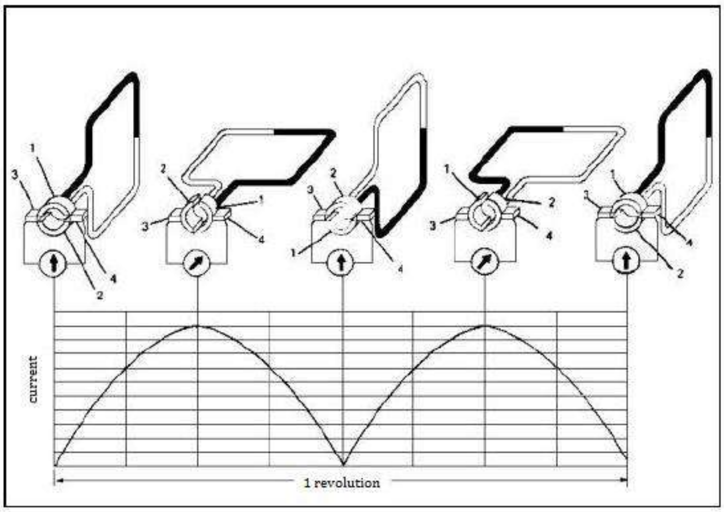


Figure.1.5. Waveform of current through the external circuit.

The waveform of the current through the external circuit is shown in the figure 1.5. This current is unidirectional but not continuous like pure direct current. It should be noted that the position of brushes is so arranged that the changeover of segments ‘a’ and ‘b’ from one brush to the other takes place when the plane of the rotating coil is at right angles to the plane of the lines of flux. It is so because in that position, the induced emf in the coil is zero. It is only due to the rectifying action of the split-rings (also called commutator) that it becomes unidirectional in the external circuit. Hence, it should be clearly understood that even in the armature of a DC generator, the induced voltage is alternating.

1.3. CONSTRUCTION DETAILS OF DC GENERATOR

A DC Generator mainly consists of three main parts i.e. Magnetic field system, Armature, Commutator and Brush gear arrangement. The other parts of a DC Generator are Magnetic frame and Yoke, Pole Core and Pole Shoes, Field or Exciting coils, Armature Core and Windings, Brushes, End housings, Bearings and Shafts. The main parts of a 4 pole DC Generator is shown in the figure 1.6.

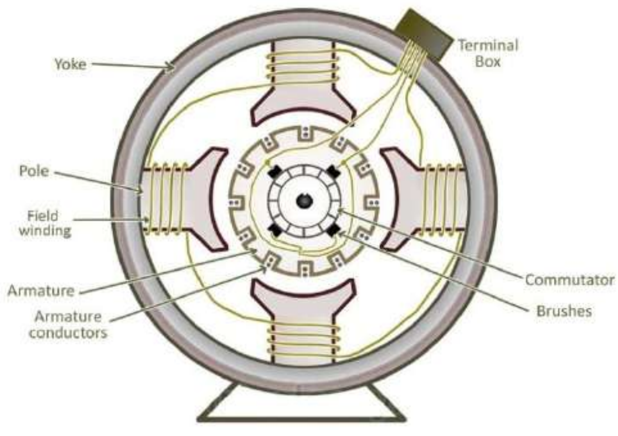


Figure.1.6. Construction of a DC Generator.

1.3.1. Magnetic Field System of DC Generator. The magnetic field system is the stationary or fixed part of the machine. It produces the main magnetic flux. The magnetic field system consists of Mainframe or Yoke, Pole core and Pole shoes and Field or Exciting coils.

1.3.1.1. Magnetic Frame and Yoke. The outer hollow cylindrical frame to which main poles and inter-poles are fixed and by means of which the machine is fixed to the foundation is known as Yoke. It is made of cast steel or rolled steel for the large machines and for the smaller size machine the yoke is generally made of cast iron. The yoke supports the pole cores and provides mechanical protection to the inner parts of the machines. It also provides a low reluctance path for the magnetic flux. The magnetic frame and yoke are shown in the figure 1.7.

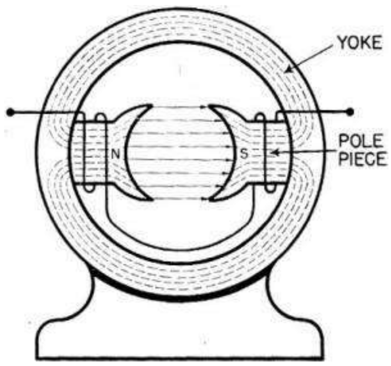


Figure.1.7. Construction of Magnetic frame and Yoke.

1.3.1.2. Pole Core and Pole Shoe. The Pole Core and Pole Shoes are fixed to the magnetic frame or yoke by bolts. Since the poles, project inwards they are called salient poles. Each pole core has a curved surface. Usually, the pole core and shoes are made of thin cast steel or wrought iron laminations which are riveted together under hydraulic pressure. The poles are laminated to reduce the Eddy Current loss. The pole core and pole shoe are shown in the figure 1.8.

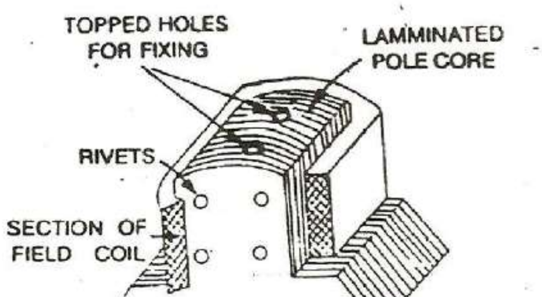


Figure.1.8. Construction of Pole core and Pole Shoe.

The poles core supports the field or exciting coils. They spread out the magnetic flux over the armature periphery more uniformly. It increases the cross-sectional area of the magnetic circuit which reduces the reluctance of the magnetic path.

1.3.1.3. Field or Exciting Coils. Each pole core has one or more field coils placed over it to produce a magnetic field. The enamelled copper wire is used for the construction of field or exciting coils. These are wound on former and then placed around the pole core. The field or exciting coils are shown in the figure 1.9.

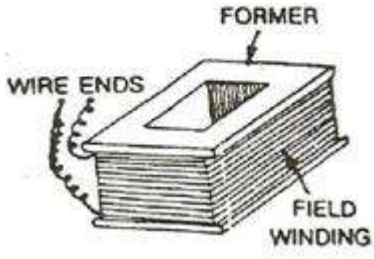


Figure.1.9. Construction of Field or Exciting Coils.

When DC passes through the field winding, it magnetizes the poles, which in turns produces the flux. The field coils of all the poles are connected in series in such a way that when current flows through them, the adjacent poles attain opposite polarity.

1.3.2. Armature of DC Generator. The rotating part of the DC Generator is called the Armature. The armature consists of a shaft upon which a laminated cylinder, called armature core is placed.

1.3.2.1. Armature Core. The armature core of DC Generator is cylindrical in shape and keyed to the rotating shaft. The outer periphery of the armature has grooves or slots which accommodate the armature winding. The armature core of a DC generator houses the conductors in the slots. It also provides an easy path for the magnetic flux as shown in the figure 1.10.

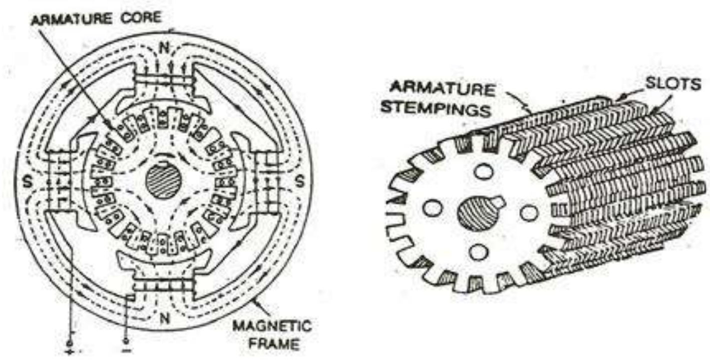


Figure.1.10. Construction of Armature Core.

As the armature is a rotating part of the DC Generator, the reversal of flux takes place in the core, hence results in hysteresis losses. The silicon steel material is used for the construction of the core to reduce the hysteresis losses. The rotating armature cuts the magnetic field, due to which an emf is induced in it. This emf circulates the eddy current which results in Eddy Current loss. Thus to reduce the loss the armature core is laminated with a stamping of about 0.3 to 0.5 mm thickness. Each lamination is insulated from the other by a coating of varnish.

1.3.2.2. Armature Winding. The insulated conductors are placed in the slots of the armature core. The conductors are wedged, and bands of steel wire wound around the core and are suitably connected. This arrangement of conductors is called Armature winding. On the basis of connections, the windings are classified into two types named as Lap winding and Wave winding.

1.3.3. Commutator and Brush gear arrangement in DC Generator. The Commutator and Brush gear arrangement consists of commutator, brushes, end housings, bearings and shaft etc.

1.3.3.1. Commutator. The commutator, which rotates with the armature, is cylindrical in shape and is made from a number of wedge-shaped hard drawn copper bars or segments insulated from each other and from the shaft. The segments form a ring around the shaft of the armature. Each commutator segment is connected to the ends of the armature coils. The commutator construction is shown in the figure 1.10.

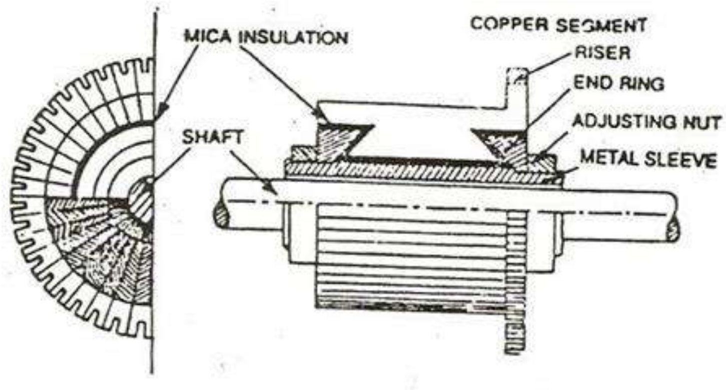


Figure.1.11. Construction of Commutator.

It connects the rotating armature conductors to the stationary external circuit through brushes. It converts the induced alternating current in the armature conductor into unidirectional current in the external load circuit.

1.3.3.2. Brush Gear. Carbon brushes are mounted on the commutator and with the help of two or more carbon brushes, current is collected from the armature winding. Each brush is supported in a metal box called a brush box. The brushes are pressed upon the commutator and form the connecting link between the armature winding and the external circuit. A typical Pigtail brush and holder is shown in the figure 1.12.

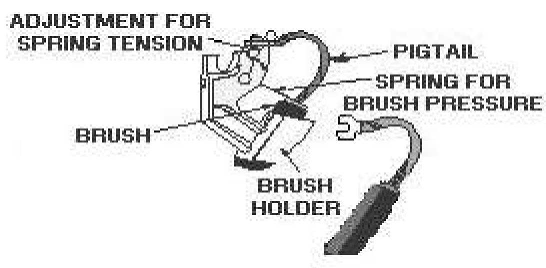


Figure.1.12. Construction of Pigtail brush and holder.

The pressure exerted by the brushes on the commutator can be adjusted and is maintained at a constant value by means of springs. With the help of the brushes the current which is produced on the windings, is passed on to the commutator and then to the external circuit. They are usually made of high-grade carbon because carbon is conducting material and at the same time in powdered form provides a lubricating effect on the commutator surface.

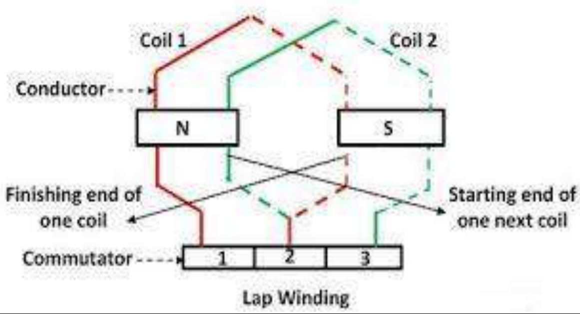
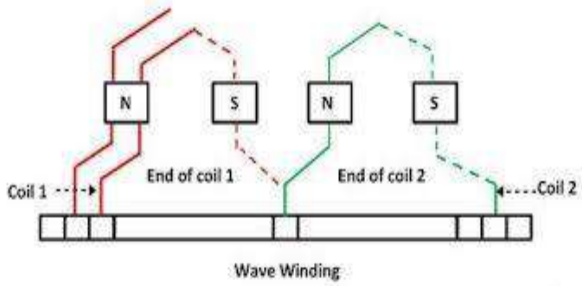
1.3.3.3. End Housings. End housings are attached to the ends of the Mainframe and provide support to the bearings. The front housings support the bearing and the brush assemblies where as the rear housings usually support the bearings only.

1.3.3.4. Bearings. The ball or roller bearings are fitted in the end housings. The function of the bearings is to reduce friction between the rotating and stationary parts of the machine. Mostly high carbon steel is used for the construction of bearings as it is very hard material.

1.3.3.4. Shaft. The shaft is made of mild steel with a maximum breaking strength. The shaft is used to transfer mechanical power from or to the machine. The rotating parts like armature core, commutator, cooling fans, etc. are keyed to the shaft

1.4. COMPARISON BETWEEN LAP WINDING AND WAVE WINDING

Table.1.1. Comparison between Lap winding and Wave winding

<table>
<tr><th>LAP WINDING</th><th>WAVE WINDING</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>The end of the armature coil is connected to an adjacent segment on the commutator</td><td>The end of the armature coil is connected to commutator segments some distance apart</td></tr>
<tr><td>The number of parallel paths is equal to the number of poles</td><td>The number of parallel paths is always equal to 2(two)</td></tr>
<tr><td>The number of carbon brushes is equal to the number of poles</td><td>The number of carbon brushes is equal to 2 due to 2 parallel paths</td></tr>
<tr><td>The conductor current in each parallel path is equal to (I/a)</td><td>The conductor current in each parallel path is equal to (I/2)</td></tr>
<tr><td>For same EMF generation, more number of conductors are required</td><td>For same EMF generation, less number of conductors are required</td></tr>
<tr><td>Equaliser ring is required for better commutation</td><td>Equaliser ring is not required.</td></tr>
<tr><td>This is used for Low voltage and High current rating machines</td><td>This is used for High voltage and Low current rating machines</td></tr>
</table>

1.5. EMF EQUATION

As the armature rotates, voltage is generated in its coils. In the case of a generator, the emf of rotation is called the **Generated emf** or **Armature emf** and is denoted as $\mathbf{E_r = E_g}$.

Let,
P – Number of poles of the machine
ϕ – Flux per pole in Weber.
Z – Total number of armature conductors.
N – Speed of armature in revolution per minute.
A – Number of parallel paths in the armature winding.

In one revolution of the armature, the flux cut by one conductor is given as

$$\text{Flux cut by one conductor} = P\varphi \quad \text{wb} \ldots \ldots (1)$$

Time taken to complete one revolution is given as

$$t = \frac{60}{N} \quad \text{seconds} \quad \ldots \ldots (2)$$

Therefore, the average induced emf in one conductor will be

$$e = \frac{P\varphi}{t} \quad \ldots \ldots (3)$$

Putting the value of (t) from Equation (2) in the equation (3) we will get

$$e = \frac{P\varphi}{60/N} = \frac{P\varphi N}{60} \quad \text{volts} \quad \ldots \ldots (4)$$

The number of conductors connected in series in each parallel path = Z/A.

Therefore, the average induced emf across each parallel path or the armature terminals is given by the equation shown below.

$$E = \frac{P\varphi N}{60} \times \frac{Z}{A} = \frac{PZ\varphi N}{60\,A} \quad \text{volts} \quad \text{or}$$

$$E = \frac{PZ\varphi n}{A} \quad \ldots \ldots (5)$$

Where n is the speed in revolution per second and given as

$$n = \frac{N}{60}$$

For a given machine, the number of poles and the number of conductors per parallel path (Z/A) are constant. Hence, the equation (5) can be written as

$$E = K\varphi n$$

Where, K is a constant and given as

$$K = \frac{PZ}{A}$$

Therefore, the average induced emf equation can also be written as

$$E \propto \varphi n \quad \text{or}$$

$$E = K_1 \varphi N$$

Where K_1 is another constant and hence induced emf equation can be written as

$$E \propto \varphi N \quad \text{or}$$

$$E \propto \varphi \omega$$

Where ω is the angular velocity in radians/second is represented as

$$\omega = \frac{2\pi N}{60}$$

Thus, it is clear that the induced emf is directly proportional to the speed and flux per pole. The polarity of induced emf depends upon the direction of the magnetic field and the direction of rotation. If either of the two is reverse the polarity changes, but if two are reversed the polarity remains unchanged.

If the machine DC Machine is working as a Generator, the induced emf is given by the equation shown below.

$$E_g = \frac{PZ\varphi N}{60\,A} \quad \text{volts}$$

1.6. TYPES OF GENERATORS

DC generators are classified based on how their fields are excited. There are three methods of excitation, and thus three main types of DC generators:
Permanent Magnet DC Generators – Field coils excited by permanent magnets.
Separately Excited DC Generators – Field coils excited by some external source.
Self Excited DC Generators – Field coils excited by the generator itself.
Self-excited DC generators can further be classified depending on the position of their field coils such as Series Wound Generators, Shunt Wound Generators and Compound Wound Generators.

1.6.1. Permanent Magnet DC Generator. When the flux in the magnetic circuit is created through the use of permanent magnets, then it is known as a Permanent magnet DC generator. The construction of a Permanent Magnet DC generator is shown in the figure1.13.

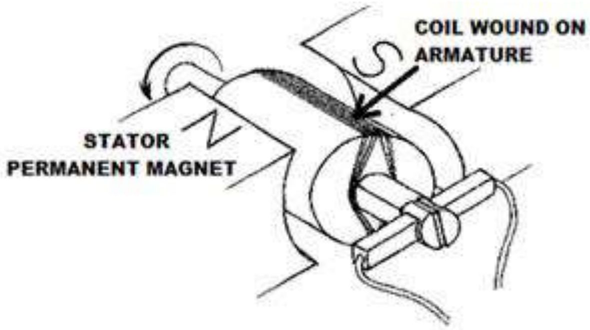


Figure.1.13. Construction of Permanent magnet DC generator.

It consists of an armature and one or several permanent magnets situated around the armature. This type of DC generator generates does not generate much power. They are normally used in small application like dynamos in motorcycles. They are rarely found in industrial applications.

1.6.2. Separately excited DC Generator. When the flux in the magnetic circuit is created through the use of permanent magnets, then it is known as a Permanent magnet DC generator. These are the generators whose field magnets are energized by some external DC source, such as a battery. A circuit diagram of separately excited DC generator is shown in the figure 1.14.

Here,
I_a = Armature current
I_f = Field current
I_L = Load current
V = Terminal voltage
E_g = Generated EMF (Electromagnetic force)

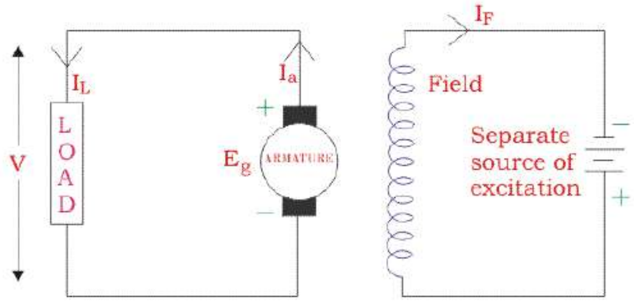


Figure.1.14. separately excited DC generator.

Voltage drop in the armature = $I_a \times R_a$.
Let,

$$I_a = I_L = I \ (say)$$

Voltage across the load is equal to,

$$V = IR_a$$

Power generated is equal to

$$P_g = E_g \times I$$

Power delivered to the external load is equal to

$$P_L = V \times I$$

1.6.3. Self excited DC Generator. Self-excited DC generators are generators whose field magnets are energized by the current supplied by them. In these types of machines, field coils are internally connected with the armature. Due to residual magnetism, some flux is always present in the poles. When the armature is rotated, EMF is induced. Hence induced current is produced. This small current flows through the field coil as well as the load thereby strengthening the pole flux. As the pole flux gets strengthened, it produces more armatures EMF, which causes the increase of current through the field. This increased field current further raises armature EMF, and this cumulative phenomenon continues until the excitation reaches the rated value.

1.6.3.1. Series wound Generator. In this type of generator, the field windings are connected in series with armature conductors, as shown in the figure 1.15. The whole current flows through the field coils as well as the load. As series field winding carries full load current it is designed with relatively few turns of thick wire. The electrical resistance of series field winding is therefore very low (nearly 0.5Ω).

Here,
R_{sc} = Series winding resistance
I_{sc} = Current flowing through the series field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_g = Generated EMF

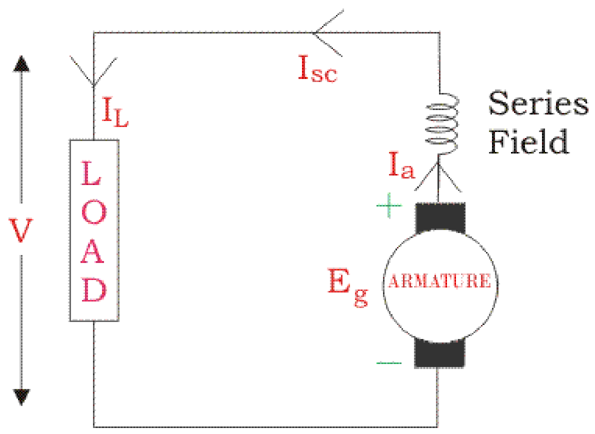


Figure.1.15. Self excited DC generator – Series wound.

Let,

$$I_a = I_{sc} = I_L = I\ (say)$$

Voltage across the load is equal to,

$$V = E_g - I(I_a \times R_a)$$

Power generated is equal to,

$$P_g = E_g \times I$$

Power delivered to the load is equal to,

$$P_L = V \times I$$

In series wound generators, output voltage is directly proportional with load current.

1.6.3.2. Shunt wound Generator. In this type of DC generator, the field windings are connected in parallel with armature conductors, as shown in the figure 1.16. In shunt wound generators voltage in the field winding is same as the voltage across terminal.

Here,
R_{sh} = Shunt winding resistance
I_{sh} = Current flowing through the shunt field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_g = Generated EMF

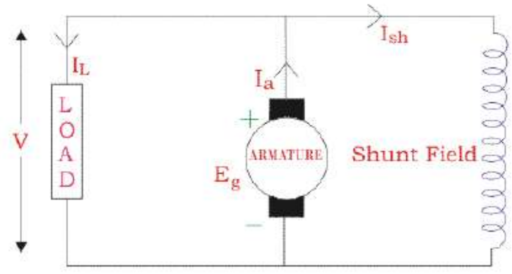


Figure.1.16. Self excited DC generator – Shunt wound.

Here armature current I_a is divided in two parts – one is shunt field current I_{sh}, and another is load current I_L. So,

$$I_a = I_{sh} + I_L$$

The effective power across the load will be maximum when I_L is maximum. So, it is required to keep the shunt field current as small as possible. So the resistance of shunt field winding is generally kept high (100 Ω) and large no of turns are used for the desired EMF.

Shunt field current is equal to,

$$I_{sh} = \frac{V}{R_{sh}}$$

Voltage across the load is equal to,

$$V = E_g - I_a R_a$$

Power generated is equal to,

$$P_g = E_g \times I_a$$

Power delivered to the load is equal to,

$$P_L = V \times I_L$$

In shunt wound generators, output voltage is inversely proportional with load current.

1.6.3.3. Compound wound Generator. The combination of series and shunt wound generators can overcome the disadvantages of both. Compound wound generators have both series field winding and shunt field winding. One winding is placed in series with the armature, and the other is placed in parallel with the armature. This type of DC generators may be of two types namely short shunt compound-wound generator and long shunt compound-wound generator.

1.6.3.3.1. Short Shunt Compound Wound DC Generator. Short Shunt Compound Wound DC Generators are generators where only the shunt field winding is in parallel with the armature winding, as shown in the figure 1.17.

Here,
R_{sh} = Shunt winding resistance
I_{sh} = Current flowing through the shunt field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_g = Generated EMF

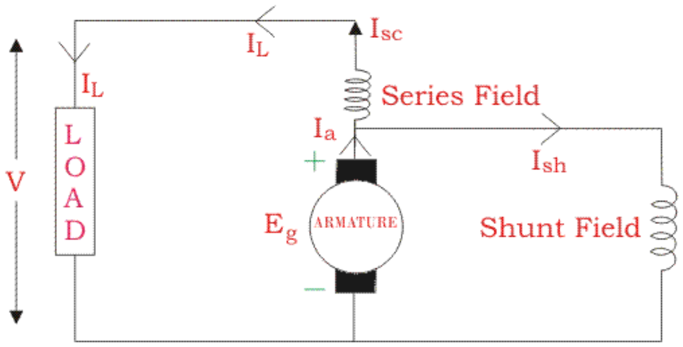


Figure.1.17. Short shunt DC generator – Compound wound.

Series field current is equal to,

$$I_{sc} = I_L$$

Shunt field current is equal to,

$$I_{sh} = \frac{(V + I_{sc}R_{sc})}{R_{sh}}$$

Armature current is equal to,

$$I_a = I_{sh} + I_L$$

Voltage across the load is equal to,

$$V = E_g - I_aR_a - I_{sc}R_{sc}$$

Power generated is equal to,

$$P_g = E_g \times I_a$$

Power delivered to the load is equal to,

$$P_L = V \times I_L$$

1.6.3.3.2. Long Shunt Compound Wound DC Generator. Long Shunt Compound Wound DC Generators are generators where the shunt field winding is in parallel with both series field and armature winding, as shown in the figure 1.18.

Here,
R_{sh} = Shunt winding resistance
I_{sh} = Current flowing through the shunt field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_g = Generated EMF

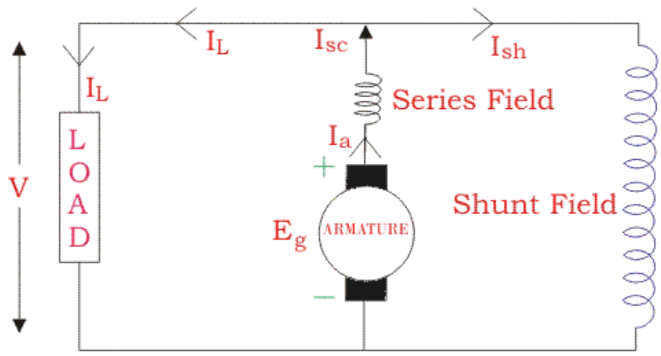


Figure.1.18. Long shunt DC generator – Compound wound.

Shunt field current is equal to,

$$I_{sh} = \frac{V}{R_{sh}}$$

Armature current, I_a = series field current,

$$I_{sc} = I_L + I_{sh}$$

Voltage across the load is equal to,

$$V = E_g - I_a R_a - I_{sc} R_{sc} = E_g - I_a(R_a + R_{sc})$$

Power generated is equal to,

$$P_g = E_g \times I_a$$

Power delivered to the load is equal to,

$$P_L = V \times I_L$$

In a compound wound generator, the shunt field is stronger than the series field. When the series field assists the shunt field, generator is said to be **commutatively compound wound**.

$$Ø_{total} = Ø_{series} + Ø_{shunt}$$

The cumulative and differential compounding methods are as shown in the figure 1.19.

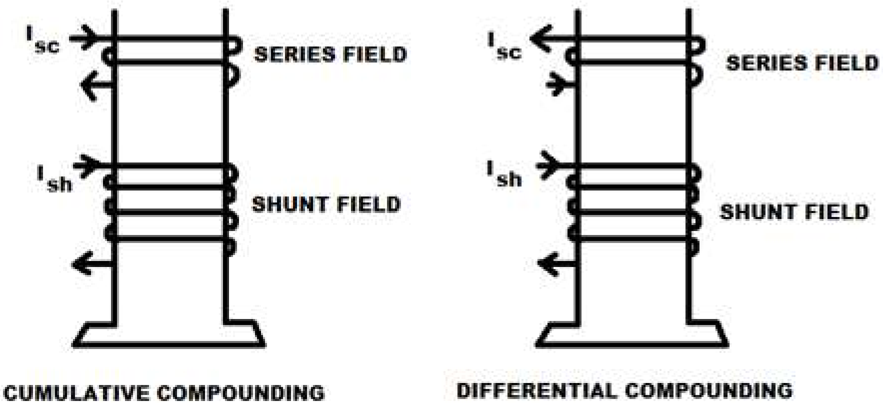


Figure.1.19. Cumulative and Differential Compounding.

On the other hand, if the series field opposes the shunt field, the generator is said to be **differentially compound wound**.

$$\text{Ø}_{\text{total}} = \text{Ø}_{\text{series}} - \text{Ø}_{\text{shunt}}$$

1.7. FAILURE OF BUILDING VOLTAGE

The various reasons due to which a self excited generator may fail to build up voltage are as follows:

1. No residual magnetism: The start of the build up process needs some residual magnetism in the magnetic circuit of the generator. If there is little or no residual magnetism, because of inactivity or jarring in shipment, no voltage will be induced that can produce field current.

2. Reversal of Field Connections: The voltage induced owing to residual magnetism acts across the field and results in flow or current in the field coils in such a direction as to produce magnetic flux in the same direction as the residual flux. Reversal of connections of the field winding destroys the residual magnetism which causes the generator failure to build up voltage.

3. In case of DC series wound generators: The resistance in the load circuit may be more than its critical resistance, which may be due to (i) open-circuit (ii) high resistance of load circuit (iii) faulty contact between brushes and commutator and (iv) commutator surface dirty or greasy.

4. In case of DC shunt wound generators
(a) The resistance of the shunt field circuit may be greater than the critical resistance; (b) the resistance in the load circuit may be lower than the critical resistance; (c) the speed of rotation may not be equal to rated one.

Remedy: In the above cases, the field coils must be connected to a dc source (a storage battery) for a short while to magnetise the poles to build up voltage. The application of external source of direct current to the field is called flashing of the field.

1.8. LOSSES, EFFICIENCY AND ARMATURE REACTION

The various types of losses that occur in a dc generator are as follows:

1. Copper losses
   (i) Armature Cu loss
   (ii) Field Cu loss
   (iii) Loss due to brush contact resistance
2. Iron Losses
   (i) Hysteresis loss
   (ii) Eddy current loss
3. Mechanical losses
   (i) Friction loss
   (ii) Windage loss
4. Stray Losses

1.8.1. Copper losses. These losses occur in armature and field copper windings. Copper losses consist of Armature copper loss, Field copper loss and loss due to brush contact resistance.

1.8.1.1. Armature copper loss. This loss contributes about 30 to 40% to full load losses. The armature copper loss is variable and depends upon the amount of loading of the machine.

Armature copper loss = $I_a^2R_a$

where, I_a = Armature current and R_a= Armature resistance.

1.8.1.2. Field copper loss. In the case of a shunt wounded field, field copper loss is practically constant. It contributes about 20 to 30% to full load losses.

Field copper loss = $I_f^2R_f$

where, I_f = field current and R_f = field resistance.

18.1.3. Brush contact resistance loss. Brush contact resistance also contributes to the copper losses. Generally, this loss is included into armature copper loss.

1.8.2. Iron losses. As the armature core is made of iron and it rotates in a magnetic field, a small current gets induced in the core itself too. Due to this current, eddy current loss and hysteresis loss occur in the armature iron core. Iron losses are also called as Core losses or magnetic losses.

1.8.2.1. Hysteresis loss. It is due to the reversal of magnetization of the armature core. When the core passes under one pair of poles, it undergoes one complete cycle of magnetic reversal.

The frequency of magnetic reversal is given by, f = (P.N)/120.

where, P = no. of poles and N = Speed in rpm.

Hysteresis loss is given by,

Steinmetz formula: $W_h=\eta B_{max}^{1.6}fV$ (watts)

where, η = Steinmetz hysteresis constant

V = volume of the core in m^3.

The loss depends upon the volume and grade of the iron, frequency of magnetic reversals and value of flux density.

1.8.2.2. Eddy current loss. When the armature core rotates in the magnetic field, an emf is also induced in the core, according to the Faraday's law of electromagnetic induction. Though this induced emf is small, it causes a large current to flow in the body due to the low resistance of the core. This current is known as eddy current. The power loss due to this current is known as eddy current loss.

1.8.3. Mechanical losses. Mechanical losses consist of the losses due to friction in bearings and commutator. Air friction loss of rotating armature also contributes to these. These losses are about 10 to 20% of full load losses.

1.8.3. Stray losses. In addition to the losses stated above, there may be small losses present which are called as stray losses or miscellaneous losses. They are usually due to inaccuracies in the designing and modelling of the machine. Stray losses are assumed to be 1% of the full load mostly.

1.8.4. Efficiency. For a DC machine, its overall efficiency is given by,

$$\%\,\eta = \frac{\text{total output}}{\text{total input}} \times 100$$

Let
P_{out} = total output of a machine
P_{in} = total input of a machine
P_{cu} = variable losses
P_i = constant losses

Then, $P_{in} = P_{out} + P_{cu} + P_i$

$$\%\,\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{P_{out}}{P_{out} + \text{losses}} \times 100$$

In case of a d.c. generator the output is given by, $P_{out} = VI$
Where,
P_{cu} = variable losses = $I^2 R_a = I^2 R_a$
$I_a = I$ (neglecting shunt field current)

$$\therefore \quad \%\,\eta = \frac{VI}{VI + I^2 R_a + P_i} \times 100 = \frac{1}{1 + \left(\frac{I R_a}{V} + \frac{P_i}{VI}\right)} \times 100$$

The efficiency is maximum, when the denominator is minimum in the above equation. According to maxima-minima theorem, the derivative of denominator gives,

$$I^2R_a - P_i = 0$$

Therefore, $I^2R_a = P_i$

Thus for the maximum efficiency, the condition is **Variable losses = Constant losses.**

1.8.5. Armature Reaction. Armature reaction is effect of armature flux over main field flux. When we excite the field winding, it produces a flux which links with the armature. This causes an emf and hence a current in the armature. This current in

armature produces another flux which lags the main flux. This is referred to as armature reaction. It has two effects on the machine:
1. Demagnetising effect: It reduces the strength of the main flux.
2. Cross magnetising effect: It bends/distorts the main flux line along the conductor.

Due to this, the output voltage is reduced and more sparking occurs at brushes. This effect of armature reaction can be reduced by using interpoles in between the main field poles and compensating windings placed in pole faces.

1.9. APPLICATIONS OF DC GENERATORS.

The applications of various types of DC generators are as follows.

1.9.1. Shunt wound Generators. The terminal voltage of DC shunt generator is more or less constant from no load to full load. Therefore these generators are used where constant voltage is required.
(i) Electroplating
(ii) Battery charging
(iii) Excitation of alternators
(iv) Ordinary lighting loads

1.9.2. Series wound Generators. The terminal voltage of DC series generator increases with load current from no load to full load. Therefore these generators are used where rise in voltage is required.
(i) Boosters in Electric distribution system
(ii) Arc lamps lighting

1.9.3. Cumulative compound wound Generators. The external characteristics of cumulative compound generator can be adjusted for compensating the voltage drop in the line resistance. Therefore these generators are used for motors which require DC supply at constant voltage.
(i) For lamp loads
(ii) For supplying power loads such as hotels, offices etc..

1.9.4. Differential compound wound Generators. The external characteristics of differential compound generator are similar to that of a shunt generator but with large demagnetization armature reaction. Therefore these generators are used for
(i) Arc Welding
(ii) Compensators in feeders/electric traction.

1.9.5. Separately excited Generators. The terminal voltage of separately excited generator gives a wide range of voltage output. Therefore these generators are used for
(i) Electroplating
(ii) Lighting loads with field regulators
(iii) Used in Laboratories for testing.

UNIT – 2

DC MOTORS

OBJECTIVE

- To learn the working principle of a DC motor.
- To learn the various types of DC motors.
- To learn the various types of starters used for DC motors.
- To learn the applications of a different types of DC motors.

2.0. INTRODUCTION

A Motor is a machine which converts electrical energy into mechanical energy. It is similar to a generator in construction. Therefore a DC machine can be used as generator or a motor. The DC motor's speed can be controlled over a wide range.

2.1. CONSTRUCTION OF MOTOR

2.1.1. Working principle. A motor works on the principle of Fleming's left-hand rule which states that "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force". When armature windings are connected to a DC supply, an electric current sets up in the winding. Magnetic field may be provided by field winding or by using permanent magnets. The direction of force would have reversed every time when the direction of movement of conductor is reversed in the magnetic field. Hence, commutator is made segmented to achieve unidirectional torque as shown in the figure 2.1.

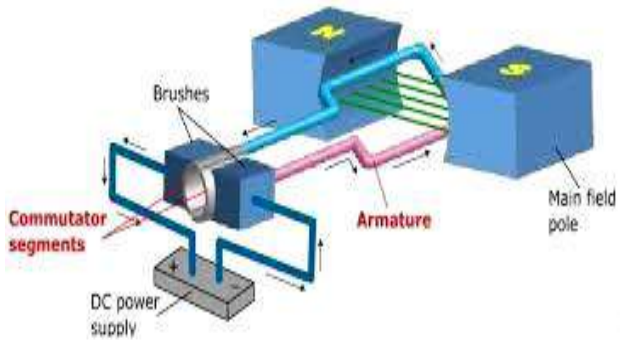


Figure.2.1. Simple loop Motor.

In this case, current carrying armature conductors experience a force due to the magnetic field, according to the principle stated above. The direction of this force is given by Fleming's left-hand rule. DC motor is used in many applications where constant or low-speed torque is required.

2.1.2. Fleming's left hand rule. If we stretch the first finger, second finger and thumb of our left hand to be perpendicular to each other, the direction of magnetic field is represented by the first finger, direction of the current is represented by the second finger, and the thumb represents direction of the force experienced by the current carrying conductor is as shown in the figure 2.2.

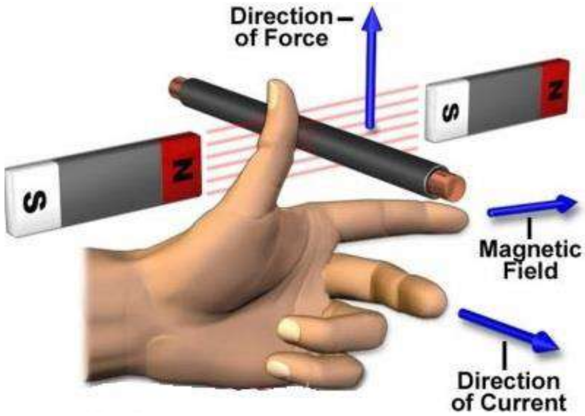


Figure.2.2. Flemings left hand rule.

The magnitude of the force is given by F = BIL newtons. Where, B = magnetic flux density, I = current and L = length of the conductor within the magnetic field.

2.1.3. BACK EMF. When the armature of a DC motor rotates under the influence of the driving torque, the armature conductors move through the magnetic field and emf is induced in them as in a generator. This induced emf acts in opposite direction to the applied voltage V according to Lenz's law and is known as Back emf or Counter emf (E_b). The equation to find out back emf in a DC motor is given below,

$$E_b = \frac{P\phi ZN}{60A}$$

The back emf, (E_b) is always less than the applied voltage V, although this difference is small when the motor is running under normal conditions. The magnitude of back emf is directly proportional to speed of the motor.

2.1.4. Significance of Back EMF. When the motor is running on no load, small torque is required to overcome the friction and windage losses. Therefore, the armature current I_a is small and the back emf is nearly equal to the applied voltage. The presence of back emf E_b makes a dc motor self-regulating.

Consider a shunt wound DC motor, equation of armature current is given below,

$$I_a = \frac{V - E_b}{R_a}$$

Suppose if the load on the motor is suddenly decreased, the driving torque is momentarily in excess of the requirement so that armature gets accelerated. As the armature speed increases, the back emf E_b also increases and causes the armature current I_a to decrease. The motor will stop accelerating when the armature current is just sufficient to produce the reduced torque required by the load.

On the other hand, if the load on the motor is suddenly increased, the speed at which the armature conductors move through the field is reduced and hence the back emf E_b falls. The decreased back emf allows a larger current to flow through the armature I_a which increase driving torque. Thus, the driving torque increases as the motor slows down. The motor will stop decelerating down when the armature current is just sufficient to produce the increased torque required by the load. Thus, speed of the motor will regulate in both conditions.

2.2. TYPES OF MOTORS

DC motors are classified based on the connection of the field winding with armature. Mainly there are two types of DC Motors, Separately excited DC Motor and Self-excited DC Motor. The self-excited DC motors are further classified as Shunt wound motor, Series wound motor and Compound wound motor.

2.2.1. Separately excited DC Motor. The field coils or field windings are energised by a separate DC source as shown in the circuit diagram shown in figure 2.3. Here,

I_a = Armature current
I_f = Field current
R_a = Armature resistance
V = Load voltage
E_b = Back EMF

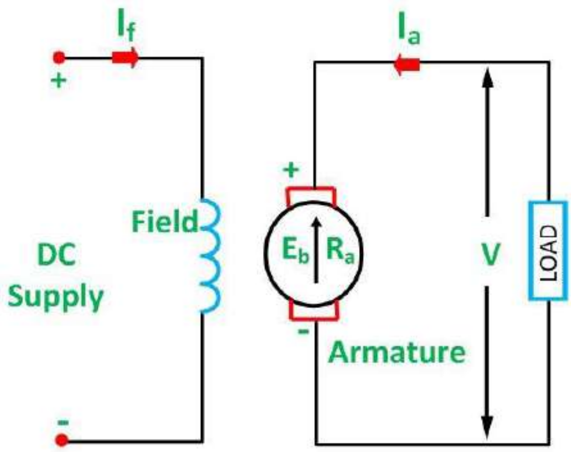


Figure.2.3. separately excited DC motor.

Voltage equation of a DC motor
Input Voltage provided to the motor armature can control Back emf, E_b of the Motor and provide supply to the ohmic drop, I_aR_a.

$$V = E_b + I_aR_a \text{ ....}(1)$$

Power equation of a DC Motor
Multiply both sides of Equation (1) by I_a , we get,

$$V I_a = E_b I_a + I_a^2 R_a \text{ .... } (2)$$

VI_a = Input Power supply (Armature Input)
E_bI_a = Mechanical Power developed in Armature (Armature Output)
$I_a^2R_a$= Power loss in armature (Armature Copper Loss)

2.2.2. Self excited DC Motor. Self-excited DC motors are motors where the current to the windings is supplied by the motor itself. Self-excited DC Motor is further divided into shunt wound, and series wound and compound wound.

2.2.2.1. Series wound motor. In the series motor, the field winding is connected in series with the armature winding. The connection diagram of a series motor is as shown in figure 2.4.

Here,
R_{se} = Series winding resistance
I_{se} = Current flowing through the series field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_b = Back EMF

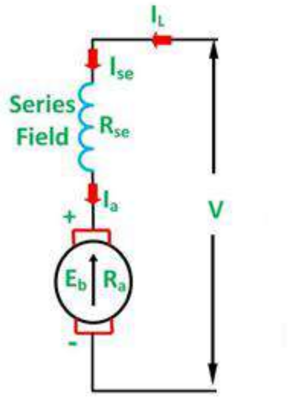


Figure.2.4. Self excited DC generator – Series wound.

By applying the KCL in the above figure
$$I_L = I_a = I_{se} \ldots \ldots \ldots (1)$$

The voltage equation can be obtained by applying KVL in the above figure
$$V = E + I_a (R_a + R_{se}) \ldots \ldots \ldots (2)$$

The power equation is obtained by multiplying equation (2) by I we get
$$V I = E I + I_a^2 (R_a + R_{se}) \ldots \ldots \ldots (3)$$

The power equation is given as
Power input = mechanical power developed + losses in the armature + losses in the field
$$V I = P_m + I^2 R_a + I^2 R_{se} \ldots \ldots \ldots (4)$$

Comparing the equation (3) and (4), we will get the equation shown below.
$$P_m = E I_a \ldots \ldots \ldots (5)$$

Where, VI is the electrical power supplied to the armature of the motor.

2.2.2.2. Shunt wound Motor. In this type of DC motor, the field windings are connected in parallel with armature conductors, as shown in the figure 2.5. In shunt wound motors voltage in the field winding is same as the voltage across terminal.

Here,
R_{sh} = Shunt winding resistance
I_{sh} = Current flowing through the shunt field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_b = Back EMF

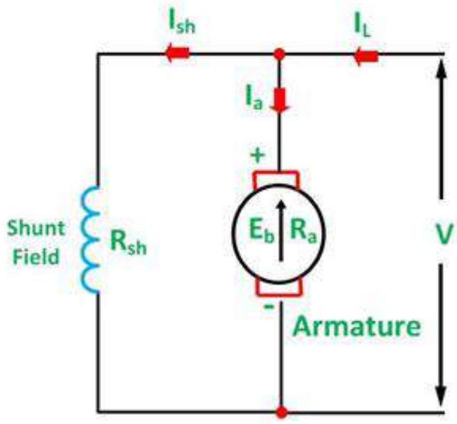


Figure.2.5. self excited DC Motor – Shunt wound.

By applying the KCL in the above figure

$I_L = I_a + I_{sh}$ … … … (1)

The voltage equation can be obtained by applying KVL for the field winding circuit.

$V = I_{sh} R_{sh}$ … … … (2)

For armature winding circuit the equation will be given as

$V = E + I_a R_a$ … … … (3)

The power equation is given as
Power input = mechanical power developed + losses in the armature + loss in the field.

$V I_L = P_m + I_a^2 R_a + I_{sh}^2 R_{sh}$ … … … (4)
$V I_L = P_m + I_a^2 R_a + V I_{sh}$
$P_m = V I_L - V I_{sh} - I_a^2 R_a = V (I_L - I_{sh}) - I_a^2 R_a$
$P_m = V I_a - I_a^2 R_a = (V - I_a R_a) I_a = (V - (V - E)) I_a$
$P_m = E I_a$ … … … (5)

Multiplying equation (3) by I_a we get the following equations.

$V\ I_a = E\ I_a + I_a^2\ R_a$ … … … (6)
$V\ I_a = P_m + I_a^2\ R_a$ … … … (7)

Where, VI_a is the electrical power supplied to the armature of the motor.

2.2.2.3. Compound Wound DC Motor. The combination of the series and shunt wound motors can overcome the disadvantages of both. Compound wound motors have both series field winding and shunt field winding. One winding is placed in series with the armature, and the other is placed in parallel with the armature. This type of DC generators may be of two types namely short shunt compound-wound generator and long shunt compound-wound generator.

2.2.2.3.1. Short Shunt Compound Wound DC Motor. Short Shunt Compound Wound DC Motors are motors where only the shunt field winding is in parallel with the armature winding, as shown in the figure 1.17.

Here:
R_{sh} = Shunt winding resistance
I_{sh} = Current flowing through the shunt field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_g = Generated EMF

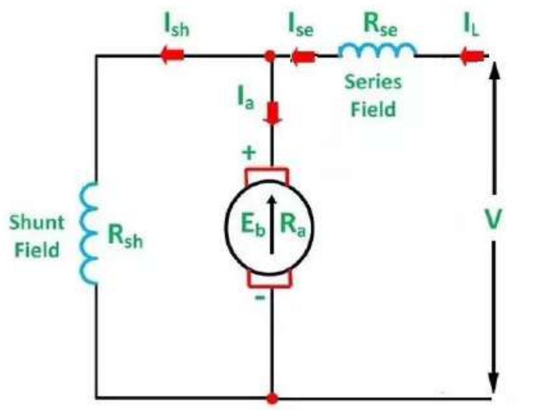


Figure.2.6. Short shunt DC motor – Compound wound.

By applying the KCL in the above figure
$I_{se} = I_L = I_a + I_{sh}$ … … … (1)

The voltage equation can be obtained by applying KVL for the field winding circuit.
$V = I_{sh}\ R_{sh}$ … … … (2)

For armature winding circuit the equation will be given as
$V = E + I_a\ R_a + I_{se}\ R_{se}$ … … … (3)

The power equation is given as
Power input = mechanical power developed + losses in the armature + loss in the field.

$$V I_{se} = P_m + I_a^2 R_a + I_{sh}^2 R_{sh}$$

$$V I_{se} = P_m + I_a^2 R_a + V I_{sh}$$

$$V (I_{se} - I_{sh}) = P_m + I_a^2 R_a$$

$$P_m = I_a^2 R_a - V I_a = Ia (I_a R_a - I_{sh} R_{sh}) \ldots \ldots \ldots (4)$$

Therefore, $VI_a = P_m + I_a^2 R_a \ldots \ldots \ldots (5)$
Where, VI_a is the electrical power supplied to the armature of the motor.

2.2.2.3.2. Long Shunt Compound Wound DC Motor. Long Shunt Compound Wound DC motors are generators where the shunt field winding is in parallel with both series field and armature winding, as shown in the figure 1.18.

Here:
R_{sh} = Shunt winding resistance
I_{sh} = Current flowing through the shunt field
R_a = Armature resistance
I_a = Armature current
I_L = Load current
V = Terminal voltage
E_g = Generated EMF

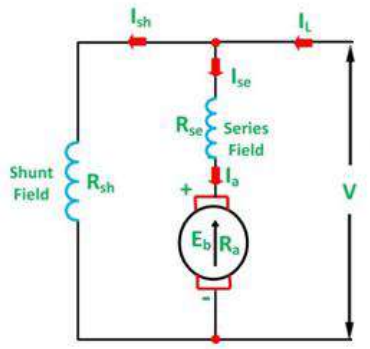


Figure.2.7. Long shunt DC motor – Compound wound.

By applying the KCL in the above figure

$$I_L = I_a + I_{sh} = I_{se} + I_{sh} \ldots \ldots \ldots (1)$$

The voltage equation can be obtained by applying KVL for the field winding circuit.

$$V = I_{sh} R_{sh} \ldots \ldots \ldots (2)$$

For armature winding circuit the equation will be given as

$$V = E + I_a R_a + I_{se} R_{se} = E + I_a(R_a + R_{se}) \ldots \ldots \ldots (3)$$

The power equation is given as
Power input = mechanical power developed + losses in the armature + loss in the field.

$$V I_L = P_m + I_a^2 R_a + I_{sh}^2 R_{sh}$$

$V\ (I_L - I_{sh}) = P_m + I_a^2\ R_a$

$P_m = V\ I_a\ - I_a^2\ R_a\ = Ia(I_{sh}\ R_{sh} - Ia\ R_a)\ \ldots\ \ldots\ \ldots\ (4)$

Therefore, $VI_a = P_m + I_a^2\ R_a \ldots\ \ldots\ \ldots\ (5)$

Where, VI_a is the electrical power supplied to the armature of the motor.

The cumulative and differential compounding methods are as shown in the figure 2.8. In a compound wound motor, the shunt field is stronger than the series field. When the series field assists the shunt field, motor is said to be commutatively compound wound.

$$\text{Ø}_{\ total} = \text{Ø}_{\ series} + \text{Ø}_{\ shunt}$$

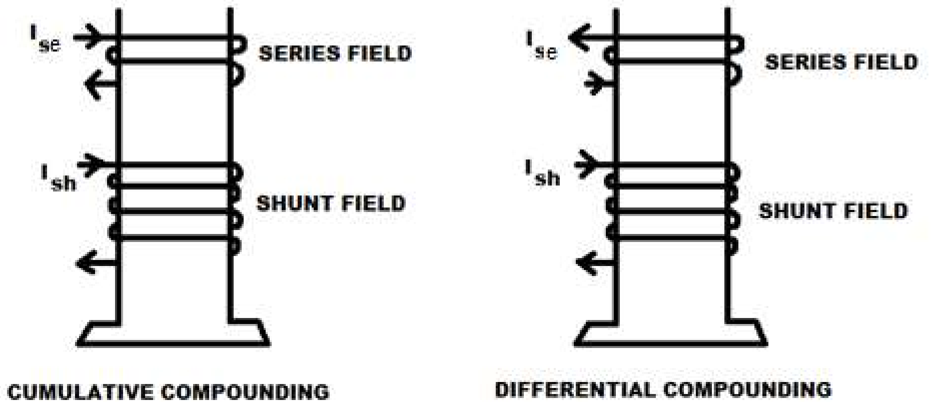


Figure.2.8. Cumulative and Differential Compounding.

On the other hand, if the series field opposes the shunt field, the motor is said to be differentially compound wound.

$$\text{Ø}_{\ total} = \text{Ø}_{\ series} - \text{Ø}_{\ shunt}$$

2.3. LOSSES AND EFFICIENCY

The losses taking place in the motor are the same as in generators. These are (i) copper losses (ii) magnetic losses and (iii) mechanical losses. The condition for maximum power developed by the motor is

$$I_a\ R_a = V/2 = E_b$$

The condition for maximum efficiency is that armature Copper losses are equal to constant losses. The various stages of energy transformation and also various losses occurring in a motor are shown in the flow diagram 2.9.

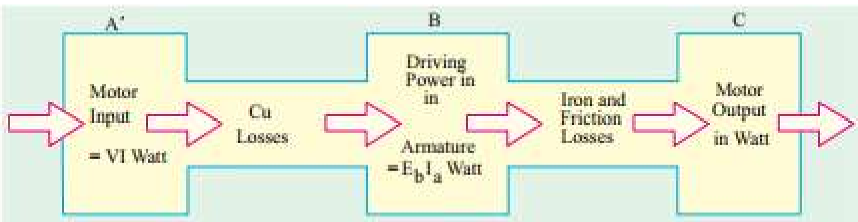


Figure.2.9. Stages of energy transformation and losses occur in a DC motor.

Copper losses = $A - B = (V\,I - E_b\,I_a)$
Iron and Friction losses = $B - C = (E_b\,I_a - T_a\,\omega)$
Overall or commercial efficiency $\eta_c = C/A$
Electrical efficiency $\eta_e = B/A$
Mechanical efficiency $\eta_m = C/B$

2.4. SPEED AND TORQUE

Torque is the turning or twisting moment of a force about an axis. It is measured by the product of force, F newtons and the radius, r metres at which the force acts.

Then, torque,

$$T = F \times r \text{ (N-m)}$$

Work done by this force in one revolution

$= F \times \text{distance} = F \times 2\pi r$ joules.

Therefore, Power developed

$= F \times 2\pi r \times N$ joules/sec or watt

$= (F \times r) \times 2\pi N = T \times \omega$ watts, If N is in rpm, then $\omega = 2\pi N/60$

$= (2\pi N/60) \times T = NT/9.55$

Therefore, Power developed, $P = NT/9.55$

2.4.1. Armature torque of a DC Motor. Let Ta be the torque developed at armature of a motor running at N rps.

Then Power developed, $P = (F \times r) \times 2\pi N = T_a \times \omega$ watts … … … (1)

The electrical power converted into mechanical power in the armature

$P = E_b \times I_a$ watts … … … (2)

$$E_b = \frac{P\phi ZN}{60A}$$

Equating (1) and (2), we get, $T_a = 0.159\,N$ Newton-metre
Therefore, Armature torque, $T_a = 0.159\,\phi\,Z\,I_a \times (P/A)$ N-m

From the above equation, $T_a \propto \phi I_a$
In case of series motors, ϕ is directly proportional to I_a, Therefore $T_a \propto I_a^2$.
In case of shunt motors, ϕ is practically constant, Therefore $T_a \propto I_a$.

2.4.2. Shaft torque of a DC Motor. Let T_{sh} be the torque available at the shaft for doing useful working at N rps.

The motor output is given by, Output = T_{sh} x 2π N watts

$$T_{sh} = \text{Output}/(2\pi N/60)$$
$$= (60/2\pi) \times (\text{Output}/N)$$
$$= 9.55\ (\text{Output}/N)\ \text{N-m}$$

Therefore, Shaft Torque, $T_{sh} = 9.55 \times (\text{Output}/N)$ N-m

The difference ($T_a - T_{sh}$) is known as Lost torque and is due to iron and friction losses of the motor.

2.4.3. Speed regulation of a DC Motor. The change in speed when the load on the motor is reduced to zero from its rated value, expressed as percent of the rated load speed.

% speed regulation = {(N.L. speed – F.L. speed)/ F.L. speed} x 100

2.5. SPEED CONTROL OF DC MOTORS.

The series DC motors are used where high starting torque is required, and variations in speed are possible. The shunt motors are used where constant speed is required and starting conditions are not severe.

2.5.1. Speed Control of DC Series Motor. Speed control methods for a DC series motor can be classified as:
1. Armature Control Method
2. Flux control Method

2.5.1.1. Armature Controlled Method. The controlling resistance is connected directly in series with the supply of the motor as shown in the figure 2.10. By increasing the resistance in series with the armature the voltage applied across the armature terminals can be decreased. With reduced voltage across the armature, the speed is reduced.

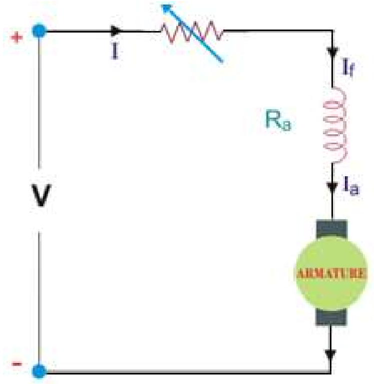


Figure.2.10. Armature controlled method for DC Series motor.

2.5.1.2. Flux Control Method. Speed adjustment of a DC series motor by field control may be done by:
1. Armature Diverter method
2. Field Diverter Method
3. Tapped Field Control Method

2.5.1.2.1. Armature Diverter Method. A Diverter across the armature can be used for obtaining speeds lower than the normal speed is as shown in the figure 2.11. The variation in speed can be controlled by varying the diverter resistance.

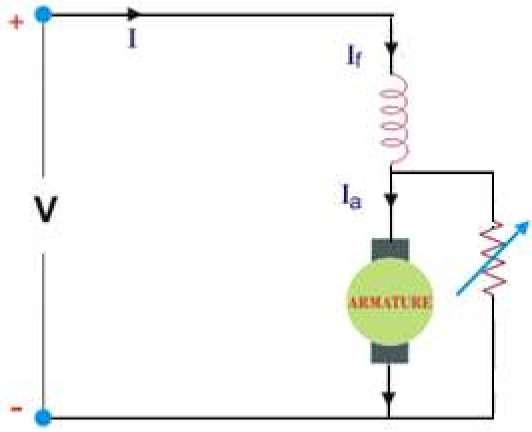


Figure.2.11. Flux control – Armature Diverter method for DC Series motor.

The power loss in the control resistance of DC series motor can be neglected because this control method is utilized for a large portion of time for reducing the speed under light load condition. This method of speed control is most economical for constant torque. This method of speed control is employed for DC series motor driving cranes, hoists, trains etc.

2.5.1.2.2. Field Diverter Method. This method uses a diverter. Here the field flux can be reduced by shunting a portion of motor current around the series field. Lesser the diverter resistance less is the field current, less flux therefore more speed. This method gives speed above normal and the method is used in electric drives in which speed should rise sharply as soon as load is decreased.

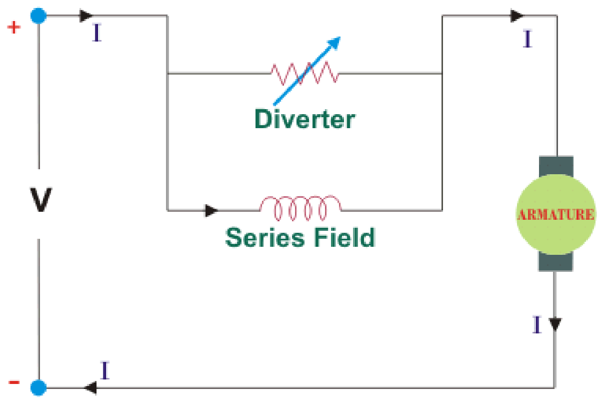


Figure.2.12. Flux control – Field Diverter method for DC Series motor.

2.5.1.2.3. Tapped Field Control Method. This is another method of increasing the speed by reducing the flux and it is done by lowering number of turns of field winding through which current flows. In this method a number of tapping from field winding are brought outside. This method is employed in electric traction.

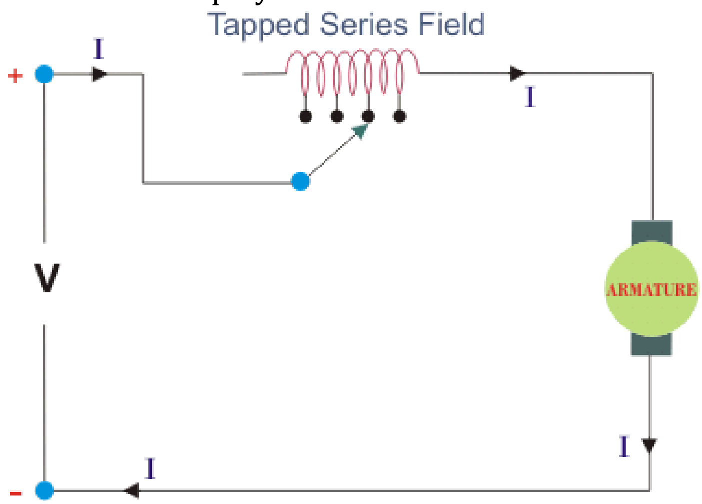


Figure.2.13. Flux control – Tapped field control method for DC Series motor.

2.5.2. Speed Control of DC Shunt Motor. Speed control methods for a DC shunt motor can be classified as

1. Flux control method
2. Armature control method
3. Voltage control methods

2.5.2.1. Flux Control Method. The flux of a DC motor can be changed by changing I_{sh} with the help of a Shunt field rheostat as shown in the figure below. Since I_{sh} is relatively small, shunt field rheostat, R has to carry only a small current, which means I^2R loss is small, so that rheostat is small in size. This method is very efficient.

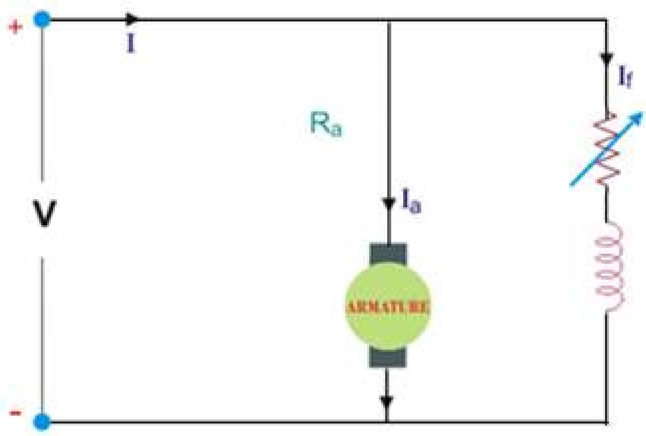


Figure.2.14. Flux control method for DC Shunt motor.

2.5.2.2. Armature Control Method. As the supply voltage is normally constant, the voltage across the armature is varied by inserting a variable rheostat or controller resistance in series with the armature circuit as shown in the figure below. As the controller resistance is increased, potential difference across the armature is decreased, thereby decreasing the armature speed. This method is used when speeds below the no-load speeds are required.

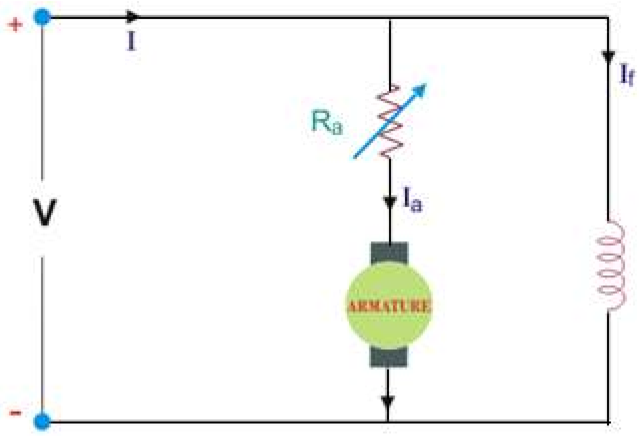


Figure.2.15. Armature control method for DC Shunt motor.

2.5.2.3. Voltage Control Methods. Speed adjustment of a DC shunt motor by voltage control may be done by:
1. Multiple voltage method
2. Ward-Leonard Method

2.5.2.3.1. Multiple Voltage Method. As the shunt field of the motor is connected permanently to a fixed exciting voltage, but the armature is supplied by different voltages by connecting it across suitable switchgear. The armature speed will be approximately proportional to these different voltages. The intermediate speeds can be obtained by adjusting the adjusting the shunt field regulator. This method is rarely used.

2.5.2.3.1. Ward-Leonard Method. This method is used where an unusually wide and very sensitive speed control is required as for elevators, excavators, colliery winders and main drives in steel mills, paper mills etc. The main disadvantage of this system is its low overall efficiency especially at low loads.

2.6. STARTERS OF DC MOTORS.

2.6.1. Necessity of a starter. While starting a DC motor huge amount of current can be driven to the windings due to the absence of the back emf. The current may rise about 4 to 6 times higher than the rated load current of the winding wire. So, it can damage the winding of motor at the time of starting itself. To prevent such high current rush in armature, starters are used in DC motors.

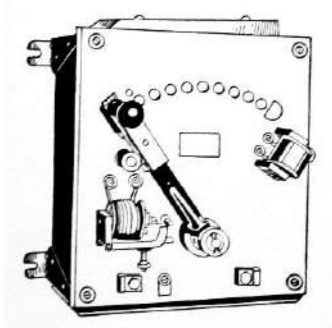


Figure.2.16. Construction of DC motor starter.

Actually, a starter consists of a variable series resistance which is added to the armature of the motor. It is used in order to reduce the starting voltage across the winding. When the motor speeds up the starter resistance decrease gradually and it will disconnect completely when the armature attains enough speed to generate the back emf. At full speed, the starter has no effect on the armature circuit of the motor. Then the contacts of the motor terminals will be directly connected. The various types of starters used for DC motors are three point starter, four point starter and drum controller starter.

2.6.2. Three Point Starter. The 3 point starter is a device whose main function is to start and maintain the speed of the DC shunt motor. It connects the resistance in series with the circuit which reduces the high starting current and hence protects the machine from damage.

Construction of three point starter. It consists of a variable resistance having a number of contact points Off, 1, 2, 3, 4, 5....Run and is called studs. There are three main points or terminals in 3 point starter of DC motor. They are '**L**' Line terminal (Connected to positive supply), '**A**' Armature terminal (Connected to armature winding) and '**F**' Field terminal (Connected to field winding). Point L is further connected to electromagnet called OLR (overload release).

The second point of OLR is connected to the starter handle. The handle is free to move on other side towards RUN against the force of spring. A soft iron piece is attached to handle. A parallel path is derived from stud 1 to No Volt coil (NVC) and other end of NVC is connected to 'F' terminal as shown in the figure 2.13. The Overload release (OLR) and No volt coil (NVC) are two protective devices**.**

Working of three point starter. Initially the handle is in OFF position. When the power is switched on for motor, the handle is slowly moved to stud '1' against the spring force, then the field winding gets supply via parallel path provided through stud 1 and NVC. Now the entire starting resistance is in series with the armature and limits the starting current. As the handle moves further to stud 2,3,4,5 and finally RUN position. It bypasses the starting resistance and the motor rotates at normal speed. NVC coil holds the starter in RUN position so it is also called as Hold on the coil.

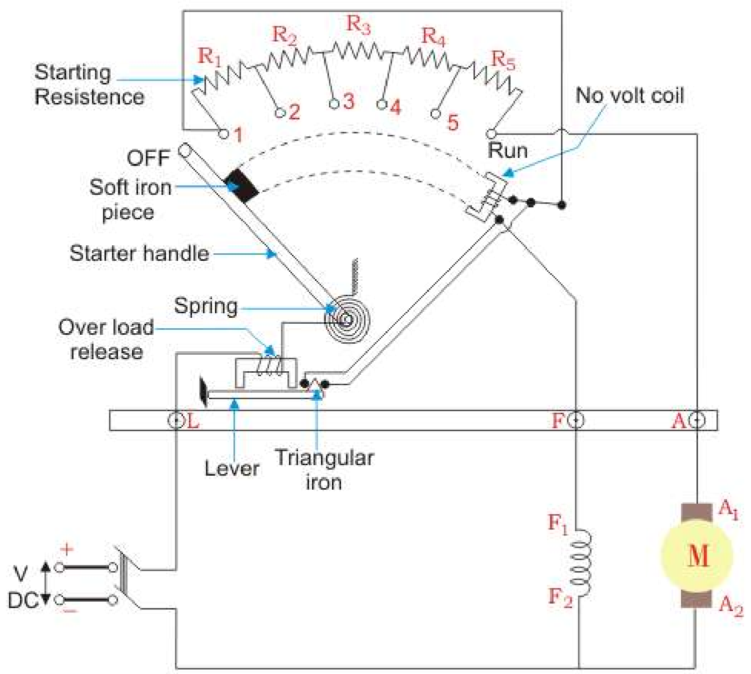


Figure.2.17. Connection diagram of a Three (3) Point starter.

Functions of No Volt Coil (NVC). The field winding is supplied through NVC and field current makes it an electromagnet. The soft iron piece on handle gets attracted by the magnetic force produced by NVC when the handle is at the RUN position. Whenever the field supply is broken then NVC loses its magnetism and leaves the handle. The spring action brings back the handle to OFF position. NVC perform the similar action during low voltage condition and save the device.

Functions of Overload release (OLR). The motor current is supplied through OLR coil, which makes it an electromagnet. Below the OLR coil, there is an arm which is fixed at its fulcrum or lying horizontally. At the end of the arm, a small triangular iron piece is fitted which is in the proximity of two ends of the shorting cable of NVC.

It is so designed that, till the full load current, OLR coil magnetism and gravitational force are balanced and OLR is unable to lift the lever. Whenever motor draws high current the magnetism of the OLR coil pulls the arm and triangular piece of the arm shorts both points of NVC coil. NVC coil loses its magnetism and leaves the handle. The handle then retracts back to OFF position because of spring action. The motor will stop.

Drawbacks of three point Starter. It experiences a huge difference of speed with a modification of the field rheostat. To amplify the motor speed, the field resistance must be amplified. So the flow of current throughout the shunt field is decreased. When NVC is associated in series by shunt field, then minute current will decrease the strength of the electromagnet. This holding magnet may release the arm of the handle during normal operation of the motor and disconnect it from the supply. This can be overcome by **Four-Point Starter,** where NVC is connected in the parallel field.

2.6.3. Four Point Starter. The 4 point starter is similar to a 3 Point Starter. The four point starter acts as a current limiting device while starting the DC motor in the absence of back EMF. The basic difference is that the Hold ON coil (No Volt Coil) removed from the shunt field circuit is connected across the line in series with a current limiting resistance R.

Construction of four point starter. It consists of a variable resistance having a number of contact points Off, 1, 2, 3, 4, 5....Run and is called studs. There are four main points or terminals in 4 point starter of DC motor. They are '**L**' Line terminal (Connected to positive supply), '**A**' Armature terminal (Connected to armature winding) and '**F**' Field terminal (Connected to field winding) and terminal **'N'** connected to the Hold ON coil. L is further connected to electromagnet called OLR (overload release). The second point of OLR is connected to the starter handle. The handle is free to move on other side towards RUN against the force of spring. A soft iron piece is attached to handle.

Working of four point starter. The circuit diagram of a four-point starter is shown in the figure 2.14, and its arrangement can form three parallel circuits. (i) Armature, shunt field winding and starting resistance. (ii) The shunt field winding & a variable resistance coil. (iii) The current limiting resistance and holding coil

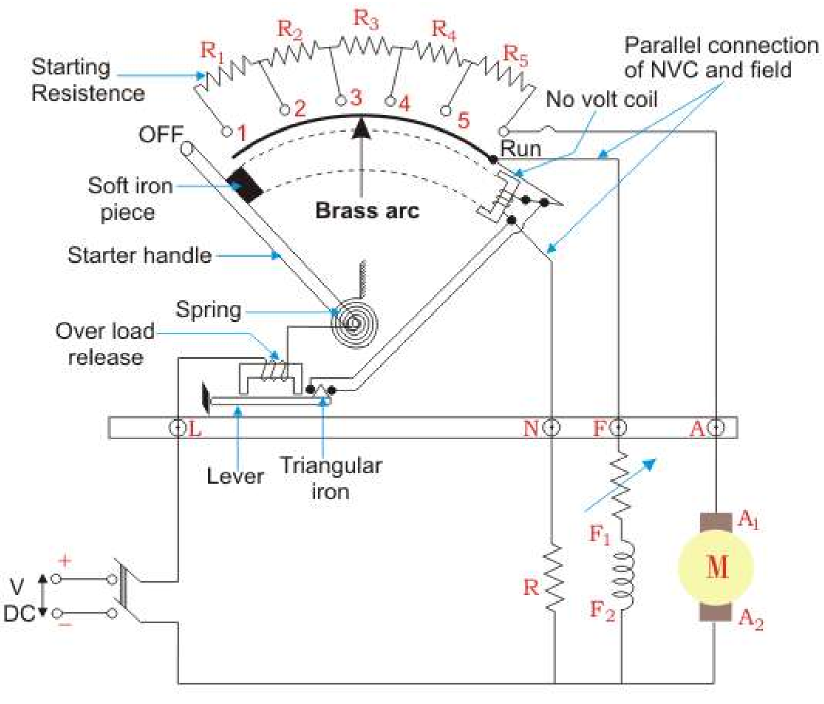


Figure.2.18. Connection diagram of a Four (4) Point starter.

From the above three circuit arrangements, the current passing through the electromagnet (Hold ON coil) is completely unaffected by any change of current in the shunt field circuit. This happens due to the independency of both the circuits from each other. This means that the functioning of electromagnet will not be affected by the regulator (or field rheostat) adjustments. In any case, the Hold ON coil will be able to exert sufficient electromagnetic pull to the starting handle and hence the starting handle will always remain in ON position except when the circuit gets open.

Drawbacks of four point Starter. The four point starter has one major drawback i.e. it does not offer high speed protection to the motor. If the field opens while the motor is in running, the field current will decrease to zero. It should be noted that there is always a little amount of residual flux available in the field winding. The speed of the motor is directly proportional to flux available. Hence, the motor will attempt to run with extremely high speed.

2.7. APPLICATIONS OF DC MOTORS.

The applications of various types of DC motors are as follows.

2.7.1. Series Motors. The series DC motors are used where high starting torque is required, and variations in speed are possible. For example – the series motors are used in Traction system, Cranes, air compressors, Vacuum Cleaner, Sewing machine, etc.

2.7.2. Shunt Motors. The shunt motors are used where constant speed is required and starting conditions are not severe. The various applications of DC shunt motor are in Lathe Machines, Centrifugal Pumps, Fans, Blowers, Conveyors, Lifts, Weaving Machine, Spinning machines, etc.

2.7.3. Compound Motors. The compound motors are used where higher starting torque and fairly constant speed is required. The examples of usage of compound motors are in Presses, Shears, Conveyors, Elevators, Rolling Mills, Heavy Planners, etc.

The small DC machines whose ratings are in fractional kilowatt are mainly used as control device such in Techno generators for speed sensing and in Servo motors for positioning and tracking.

UNIT – 3

AC FUNDAMENTALS

OBJECTIVE

- To learn about various waveforms of voltage and current.
- To learn the definitions related to sinusoidal wave.
- To learn about the calculation of impedance, power and PF.
- To learn about voltage and current relations in star and delta circuits.

8.0. INTRODUCTION

An alternating current or voltage is the one which changes periodically both in magnitude and direction. Such change in magnitude and direction is measured in terms of cycles. Each cycle of AC consists of two half cycles, namely positive and negative cycle. AC can be generated at high voltages and can be stepped up (11 KV to 400 KV). The high voltage reduces transmission losses.

3.1. VOLTAGE AND CURRENT WAVEFORMS

Waveforms are basically a visual representation of the variation of a voltage or current plotted to a base of time. The most common periodic signal waveforms that are used in electrical and electronic circuits are the Sinusoidal waveforms.

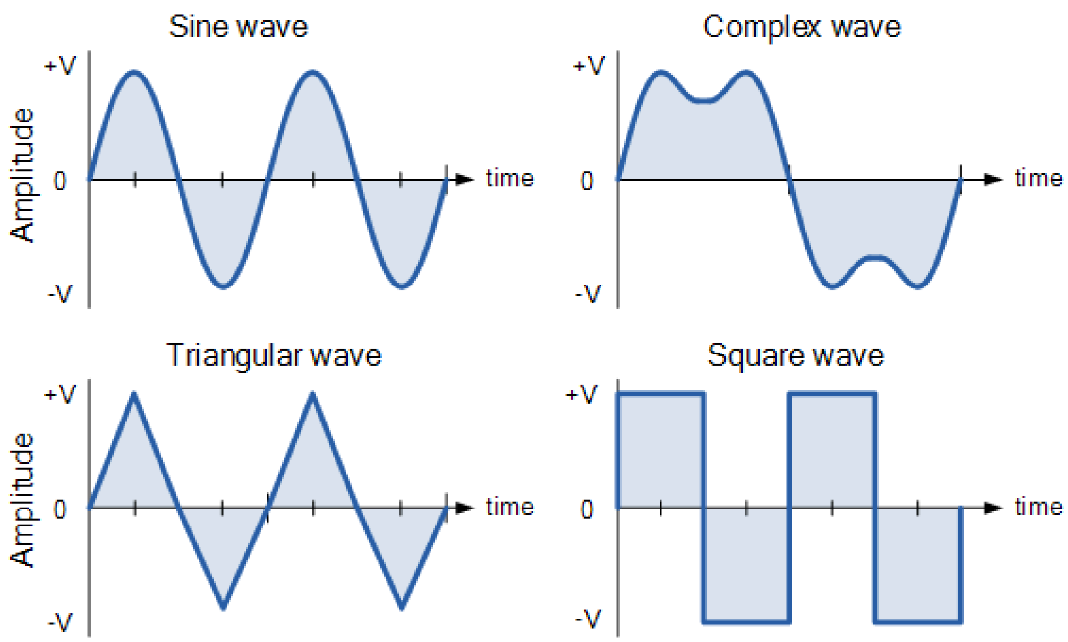


Figure.3.1. Types of AC wave forms.

However, an alternating AC waveform may not always take the shape of a smooth shape. AC waveforms can also take the shape of Complex Waves, Square Waves *or* Triangular Waves as shown in the figure 3.1. Generally, for AC waveforms this horizontal base line represents a zero condition of either voltage or current. Any part of an AC type waveform which lies above the horizontal zero axis represents a voltage or current flowing in one direction and any part of the waveform which lies below the horizontal zero axis represents a voltage or current flowing in the opposite direction.

3.2. SINUSOIDAL WAVE

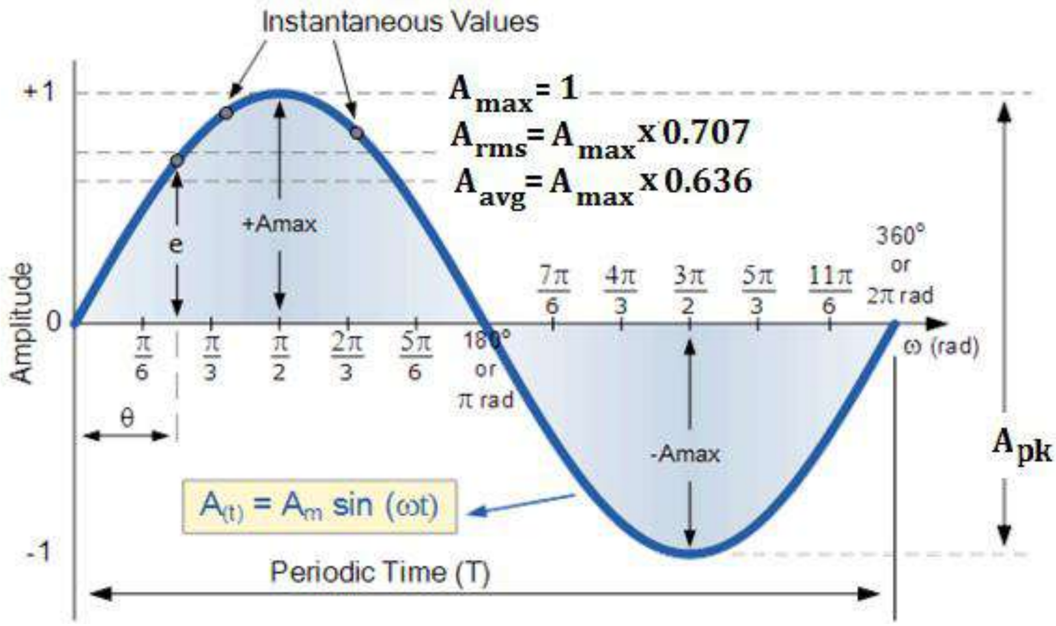


Figure.3.2. Sinusoidal AC wave form.

3.2.1. Cycle. A complete set of all positive half and negative half values of an alternating quantity (voltage or current). Each cycle consists of a positive half cycle and negative half cycle.

3.2.2. Time period. The time taken by the waveform to complete one full cycle and is denoted by T.

$$\text{Time period, } T = [1 / f] \text{ Seconds}$$

3.2.3. Frequency. The number of complete cycles completed within one second and is denoted by f.

$$\text{Frequency, } f = [1 / T] \quad \text{Hertz}$$

3.2.4. Amplitude. The maximum value of an alternating quantity (voltage or current).

3.2.5. Peak value. The highest value to which an alternating quantity (voltage or current) rises in a cycle.

3.2.6. Instantaneous value. The magnitude of an alternating quantity (voltage or current) at a particular instant.

$$I = I_{max} \text{ Sin } \Phi$$
$$V = V_{max} \text{ Sin } \Phi$$

3.2.7. RMS value. The effective value of a sine wave produces the same I^2*R heating effect in a load fed by a constant DC supply. It is known as the Root Mean Squared value.

$$I_{rms} = I_{max} / \sqrt{2}$$
$$V_{rms} = V_{max} / \sqrt{2}$$

3.2.8. Average value. The average value will be the addition of all the instantaneous values added together and then divided by the total number.

$$I_{ave} = 2\ I_{max} / \pi = 0636\ I_{max}$$
$$V_{ave} = 2\ V_{max} / \pi = 0636\ V_{max}$$

3.2.9. Form Factor. It is the ratio between Average value and RMS value. For a pure sinusoidal waveform the form factor will always be equal to 1.11.

$$\text{Form Factor} = \frac{\text{Average Value}}{\text{RMS Value}} = 1.11$$

3.2.10. Peak Factor. It is the ratio between Peak value and RMS value. For a pure sinusoidal waveform the form factor will always be equal to 1.414.

$$\text{Peak Factor} = \frac{\text{Peak Value}}{\text{RMS Value}} = 1.414$$

3.3. PHASE AND PHASE DIFFERENCE

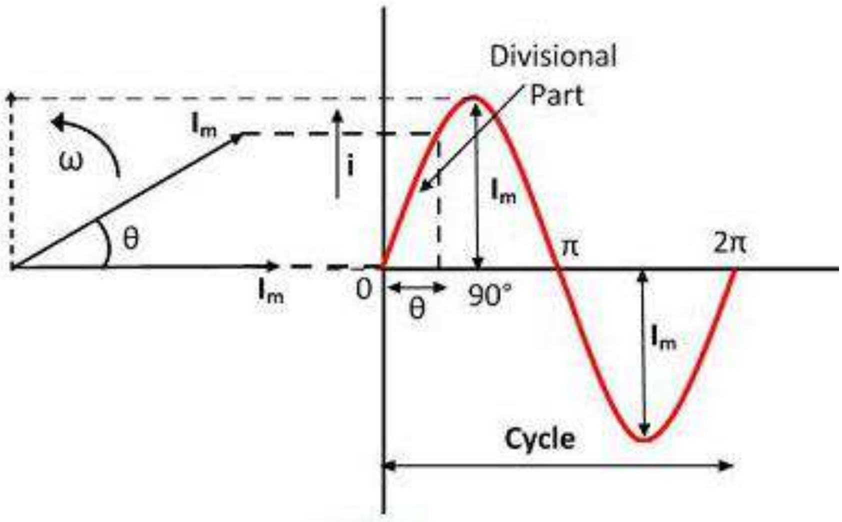


Figure.3.3. Phase in a sinusoidal waveform.

Phase. The phase of an alternating quantity is defined as the divisional part of a cycle through which the quantity moves forward from a selected origin. When the two quantities have the same frequency, their maximum and minimum point achieve at the same point, then the quantities are said to have the same phase as shown in the figure 3.2. The Phase difference equation is represented by

$$A_t = A_{max} \times \text{Sin}(\omega t \pm \Phi)$$

Where,

A_{max} = Amplitude of the waveform.

ωt = Angular frequency of the waveform in radian/sec

Φ = Phase angle in degrees or radians

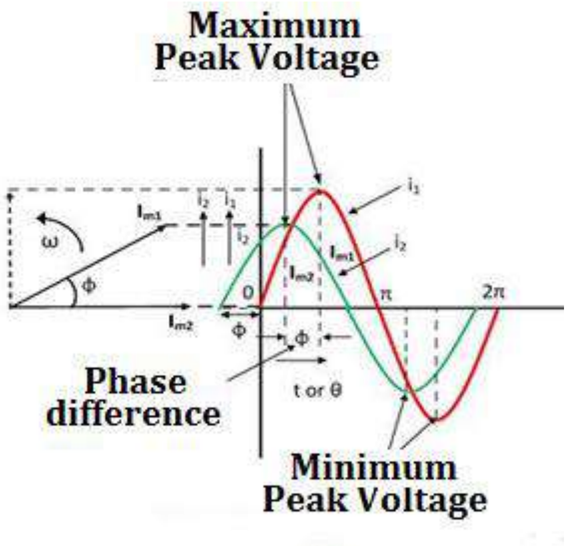


Figure.3.4. Phase difference in a sinusoidal waveform .

Phase difference. The phase difference between the two electrical quantities is defined as the angular phase difference between the maximum possible values of the two alternating quantities having the same frequency. When the two alternating quantities have phase difference when they have the same frequency, but they attain their zero value at the different instant. The angle between zero points of two alternating quantities is called angle of phase difference as shown in the figure 3.4.

3.4. SINGLE PHASE AC CIRCUITS

AC through Pure Resistive circuit. When the switch is closed, an AC voltage, V will be applied to resistor, R. This voltage will cause a current to flow which in turn will rise and fall as the applied voltage rises and falls sinusoidally. As the load is a resistance, the current and voltage will both reach their maximum or peak values and fall through zero at exactly the same time as shown in the figure 3.5.

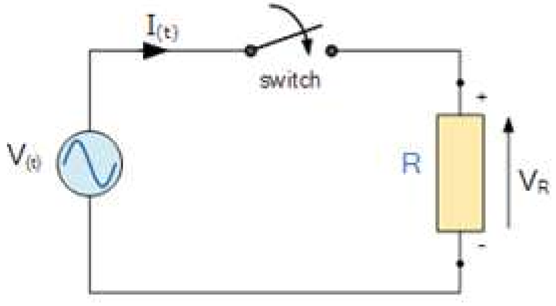


Figure.3.5. AC through pure resistive circuit.

In a pure resistive circuit the voltage and current is in phase and there is no phase difference between the current and voltage as shown in the phasor diagram in the figure 3.6.

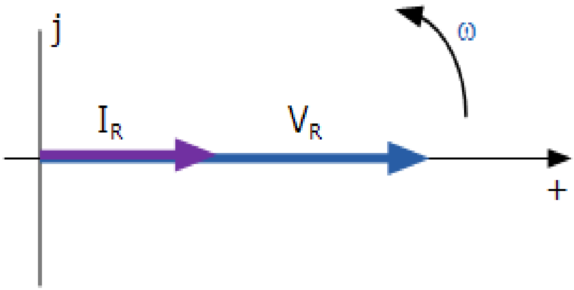


Figure.3.6. Vector diagram of Voltage and current in a pure resistive circuit.

AC through Pure Inductive circuit. When the switch is closed the sinusoidal voltage will cause the current to rise from zero to its maximum value. This rise or change in the current will induce a magnetic field within the coil which in turn will oppose or restrict this change in the current. But before the current had time to reach its maximum value the voltage changes polarity causing the current to change direction. This change in the other direction once again being delayed by the self-induced back emf in the coil, and in a circuit containing a pure inductance only, the current is delayed by 90^o.

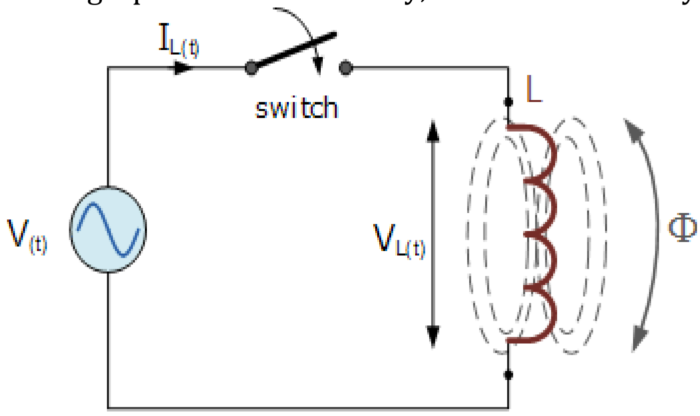


Figure.3.7. AC through pure inductive circuit.

In a purely inductive circuit the voltage leads the current by 90^o. This effect can also be represented by a phasor diagram. But by using the voltage as our reference, we can also say that the current lags the voltage by one quarter of a cycle or 90^o as shown in the vector diagram in the figure 3.8. So for a pure loss less inductor, V_L leads I_L by 90^o or I_L lags V_L by 90^o.

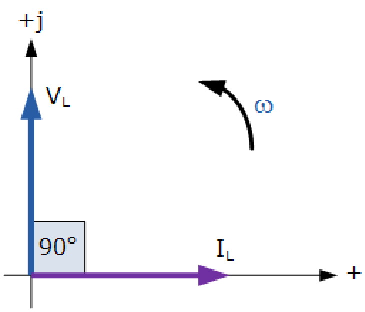


Figure.3.8. Vector diagram of Voltage and current in a pure inductive circuit.

AC through Pure Capacitive circuit. When the switch is closed in the circuit above, a high current will start to flow into the capacitor as there is no charge on the plates at *t = 0*. The sinusoidal supply voltage, V is increasing in a positive direction at its maximum rate as it crosses the zero reference axis at an instant in time given as 0^o. Since the rate of change of the potential difference across the plates is now at its maximum value, the flow of current into the capacitor will also be at its maximum rate. As the sinusoidal supply voltage reaches its 90^o point on the waveform it begins to slow down and for a very brief instant in time the potential difference across the plates is neither increasing nor decreasing therefore the current decreases to zero as there is no rate of voltage change. At this 90^o point the potential difference across the capacitor is at its maximum (V_{max}), no current flows into the capacitor as the capacitor is now fully charged.

At the end of this instant in time the supply voltage begins to decrease in a negative direction down towards the zero reference line at 180^o. Although the supply voltage is still positive in nature the capacitor starts to discharge some of its excess electrons on its plates in an effort to maintain a constant voltage. This results in the capacitor current flowing in the opposite or negative direction. When the supply voltage waveform crosses the zero reference axis point at instant $180^o$the rate of change or slope of the sinusoidal supply voltage is at its maximum but in a negative direction, consequently the current flowing into the capacitor is also at its maximum rate at that instant. Also at this 180^o point the potential difference across the plates is zero as the amount of charge is equally distributed between the two plates.

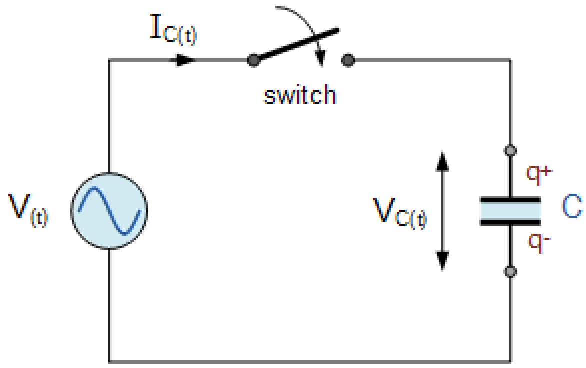


Figure.3.9. AC through pure Capacitive circuit.

In a purely capacitive circuit the voltage lags the current by 90^o. But by using the voltage as our reference, we can also say that the current leads the voltage by one quarter of a cycle or 90^o as shown in the vector diagram in the figure 3.10. So for a pure capacitor, V_C lags I_C by 90^o, or we can say that I_C leads V_C by 90^o.

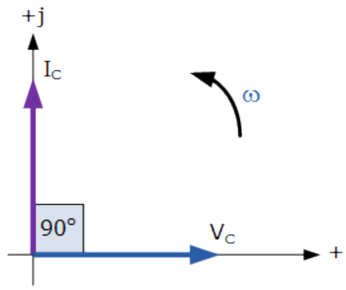


Figure.3.10. Vector diagram of Voltage and Current in a pure capacitive circuit.

3.5. IMPEDANCE AND POWER FACTOR

Impedance. AC circuits contain both resistance and reactance that are combined together to give a total impedance (Z) that limits current flow around the circuit. But an AC circuit's impedance is not equal to the algebraic sum of the resistive and reactive ohmic values as a pure resistance and pure reactance are 90^o out-of-phase with each other. But we can use this 90^o phase difference as the sides of a right angled triangle, called an impedance triangle, with the impedance being the hypotenuse as determined by Pythagoras theorem.

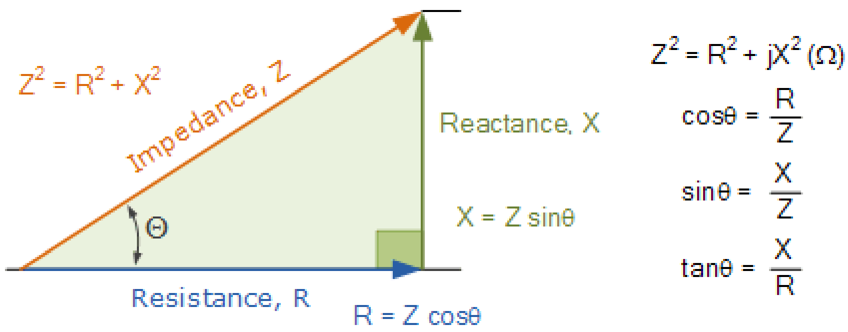


Figure.3.11. Impedance Triangle.

The geometric relationship between resistance, reactance and impedance can be represented visually by the use of an impedance triangle as shown in the figure 3.9. Impedance is the vector sum of the resistance and reactance has not only a magnitude (Z) but it also has a phase angle (θ), which represents the phase difference between the resistance and the reactance. Also note that the triangle will change shape due to variations in reactance, (X) as the frequency changes. But the resistance (R) will always remain constant. The capacitive reactance, inductive reactance and impedance for various circuits are given below.

Capacitive reactance,	$X_C = 1/\ 2\pi\ f\ C$	
Inductive reactance,	$X_L = 2\pi\ f\ L$	
Impedance,	$Z = R$	(pure resistive circuit)
Impedance	$Z = j\ X_C = 1/\ 2\pi\ f\ C$	(pure capacitive circuit)
Impedance	$Z = j\ X_L = 2\pi\ f\ L$	(pure inductive circuit)
Impedance,	$Z = \sqrt{(R^2 + X_C^2)}$	(For R-C series circuit)
Impedance,	$Z = \sqrt{(R^2 + X_L^2)}$	(For R-L series circuit)
Impedance,	$Z = \sqrt{(R^2 + [X_L - X_C]^2)}$	(For R-L-C series circuit)

Power factor. Power factor (Cos θ) is defined as the ratio of real power (P) to apparent power (S) and is generally expressed as either a decimal value. Phase angle is the angle between the current and voltage waveforms, where I and V are the magnitudes of r.m.s value of the current and voltage.

$$\text{Power factor} = \frac{\text{Real Power in Watts}}{\text{Apparent Power in Volt−Amperes}}$$

3.6. COMPARISON BETWEEN SINGLE AND THREE PHASE SYSTEMS

Table.3.1. Comparison between Single Phase and Three Phase system

SINGLE PHASE SYSTEM	THREE PHASE SYSTEM
The Power is supplied through a single conductor	The Power is supplied through three conductors
The capacity of power transfer is minimum	The capacity of power transfer is maximum
The voltage of the single phase is 230 V	The voltage of the single phase is 415 V
The connection is simple	The connections are complicated
The efficiency is less	The efficiency is high
This system is inexpensive	This system is expensive
Losses are maximum	Losses are minimum
The insulation required is less	The insulation required is more.
Maintenance is easy	Maintenance is difficult

3.7. STAR AND DELTA CONNECTIONS

The general methods of inter connections in a poly phase system are Star or Wye (Y) connection and Mesh or Delta (Δ) connection. The total power on a balanced load is same in star and delta connection.

Star Connection. In this method of inter connection, the similar ends (starting or finishing end) of the three coils are joined together at point N. The point N is known as the star point or neutral point. The three conductors meeting at point N are replaced by a single conductor known as neutral conductor as shown in the figure 3.10. This system is known as a four wire, three phase system. The Current and Voltage relations in a star connection are as follows.

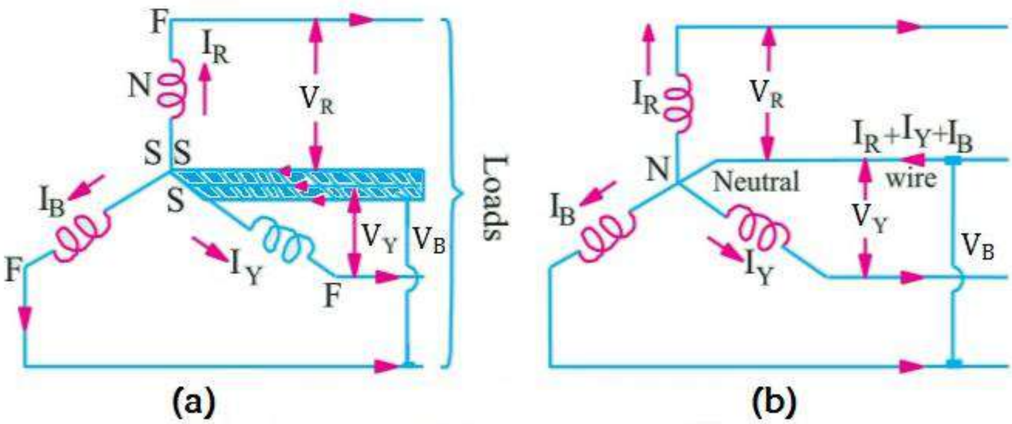


Figure.3.12. Star connected system.

(i) Line Voltage (V_L) = $\sqrt{3}$ x Phase Voltage (V_{Ph})

(ii) Line Current (I_L) = Phase Current (I_{ph})

(iii) Total Power = $\sqrt{3}\ V_L\ I_L \cos \Phi = 3\ V_{Ph}\ I_{Ph} \cos \Phi$, where $\cos \Phi$ is the power factor.

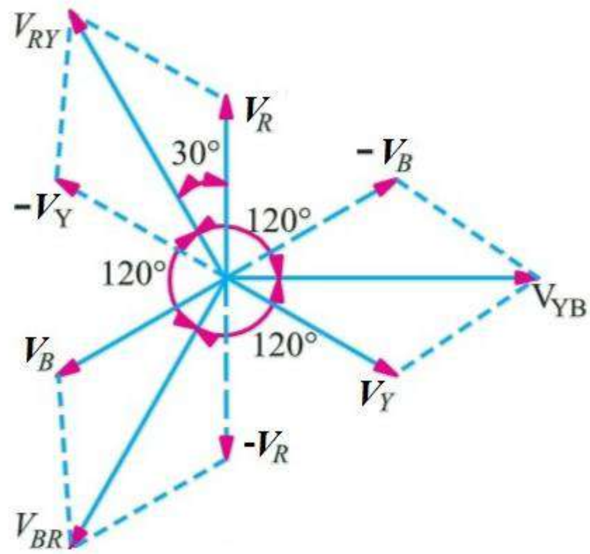


Figure.3.13. Vector diagram of a Star connected system.

From the vector diagram shown in the figure , we conclude that Line voltages are 120° apart from each other, Line voltages are 30° leading from the corresponding phase voltages, The angle between line currents and respective line voltages are (30° + Φ), i.e. each line current is lagging (30° + Φ) from the corresponding line voltage

Delta Connection. In this method of inter connection, the dissimilar ends of the three phase windings are joined together (starting end is joined to finishing end) and so on to form a closed mesh as shown in the figure 3.13. **The voltage between two lines is equal to the phase voltage of the phase winding.** This system is a three wire, three phase system. The Current and Voltage relations in a delta connection are as follows.

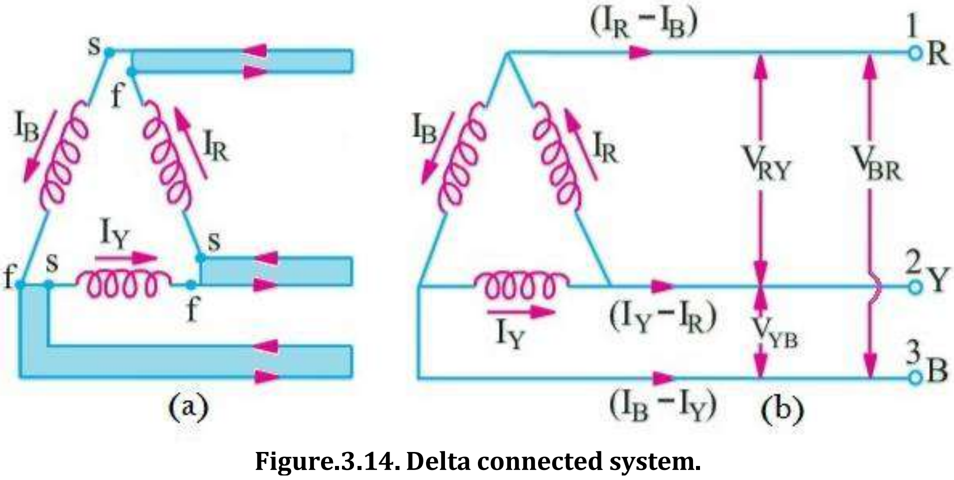


Figure.3.14. Delta connected system.

(i) Line Voltage(V_L) = Phase Voltage (V_{Ph})

(ii) Line Current (I_L) = √3 x Phase Current (I_{ph})

(iii) Total Power = √3 V_{Ph} I_{Ph} Cos Φ = 3 V_L I_L Cos Φ, where Cos Φ is the power factor.

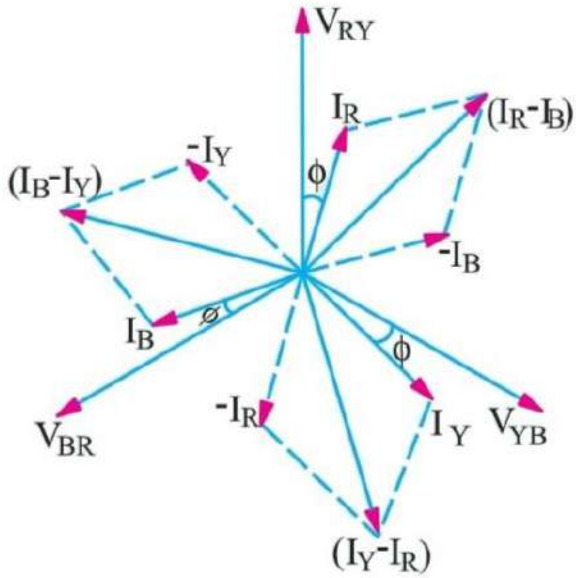


Figure.3.15. Vector diagram of a Delta connected system.

From the vector diagram shown in the figure 3.15., the line currents are 120° apart from each other, line currents are lagging by 30° from their corresponding phase currents. The angle Φ between line currents and respective line voltages is (30° + Φ), i.e. each line current is lagging (30° + Φ) from the corresponding line voltage.

UNIT – 4

TRANSFORMERS

OBJECTIVE

- To learn about the working principle of a Transformer.
- To learn about various types of Transformers.
- To learn about Losses and efficiency of Transformer.
- To learn about various cooling methods of Transformer.

4.0. INTRODUCTION

Transformer is a static piece of apparatus by means of which electric power in one circuit is transformed into electric power of same frequency in another circuit. It can lower or raise the voltage in a circuit but with corresponding increase or decrease in current. Transformers are used in both electrical and electronic circuits.

4.1. CONSTRUCTION OF TRANSFORMER

4.1.1. Working Principle. The Transformer works on the principle of mutual induction between two circuits linked by a common magnetic flux. It consists of two inductive coils which is electrically separated but magnetically linked through a path of low reluctance as shown in the figure 4.1.

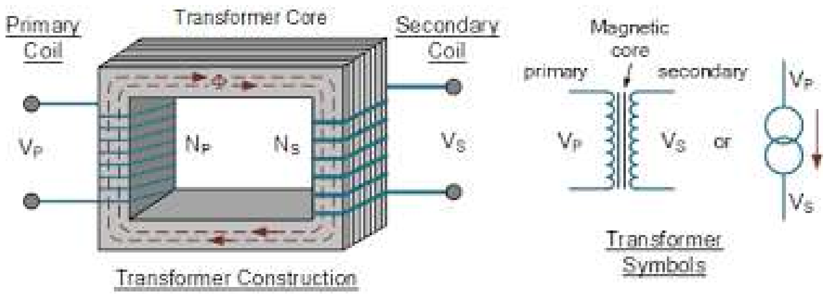


Figure.4.1. Transformer construction.

When an input ac voltage is applied to the primary winding, alternating current starts to flow in the primary winding. As the current flows, a changing magnetic field is set up in the transformer core. As this magnetic field cuts across the secondary winding, alternating voltage is produced in the secondary winding according to faradays laws of electromagnetic induction.

4.1.2. Construction. An elementary transformer consists of a soft iron or silicon steel core and two windings placed on it. The windings are insulated from both the core and each other. The core is built up of thin soft iron or silicon steel laminations to provide a path of low reluctance to the magnetic flux. The winding connected to the supply main is called the primary and the winding connected to the load circuit is called the secondary. Although in the actual construction the two windings are usually wound one over the other.

4.1.3. EMF Equation. EMF equation gives the r.m.s value of the induced emf in the primary and secondary winding in a Transformer.
Let,
N_1 = No. of turns in primary winding
N_2 = No. of turns in secondary winding.
Φ_m= maximum flux in the core in Weber = B_m A
f = frequency of AC input in Hertz

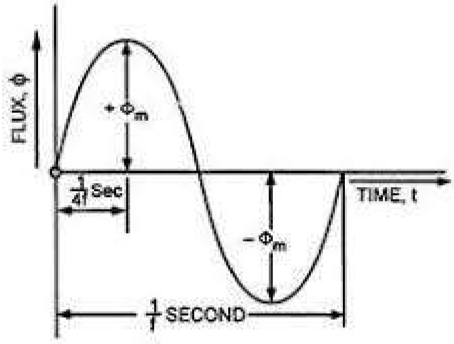


Figure.4.2. Sinusoidal variation of flux with time.

Form factor = (r.m.s value/average value) = 1.11 for sinusoidal AC input.
The r.m.s value of emf/turn = 1.11 x 4 f Φ_m volts
Induced emf in primary winding, $E_1 = 4.44 f N_1 \Phi_m = 4.44 f N_1 B_m A$ ....(1)
Induced emf in secondary winding, $E_2 = 4.44 f N_2 \Phi_m = 4.44 f N_2 B_m A$ ....(2)

From (1) and (2), It is seen that $E_1/N_1 = E_2/N_2 = 4.44 f \Phi_m$. It means that emf/turn is same in both primary and secondary windings. In an ideal transformer on No-Load, $V_1 = E_1$ and $E_2 = V_2$ where V_1 is the input voltage and V_2 is the terminal voltage.

4.1.4. Transformation Ratio. The voltage transformation ratio is derived from equations (1) and (2),
we get, $E_2/E_1 = N_2/N_1 = K$ which is a constant. This constant K is the voltage transformation ratio. If K > 1, then transformer is a step-up transformer and If K < 1, then transformer is a step-down transformer.
For an ideal transformer, input VA = output VA, i.e. $V_1 I_1 = V_2 I_2$ or $V_1/V_2 = I_2/I_1 = 1/K$.

4.1.5. Classification of Transformers. Transformers are classified as given below.
1. Based on the construction - Core type, shell type and berry type
2. Based on the phase - Single phase, three phase
3. Based on the voltage – Step-up transformer, step-down transformer
4. Based on the purpose – Power transformer, distribution transformer, welding - transformer, instrument transformers.

4.2. SPECIAL PURPOSE TRANSFORMERS

4.2.1. Auto transformer. **An autotransformer** has only one single winding which is common to both sides. This single winding is tapped at various points along its length to provide a percentage of the primary voltage supply across its secondary load. The autotransformer has usual magnetic core but has one winding only, which is common to both the primary and secondary circuits.

Therefore in an autotransformer the primary and secondary windings are linked together both electrically and magnetically as shown in the figure 4.3. The voltage at the secondary terminals can be obtained from zero to maximum value of the primary side voltage by slowly moving the sliding brush arrangement over the winding. Auto Transformer works as a voltage regulator.

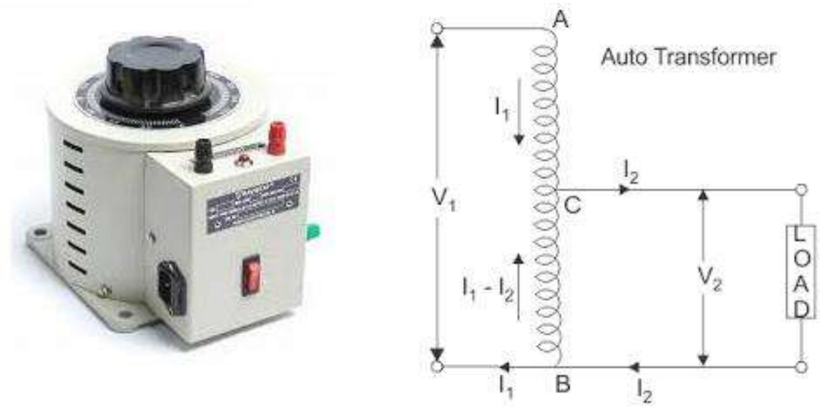


Figure.4.3. Autotransformer.

The main advantage of this type of transformer design is that it can be made a lot cheaper for the same VA rating, but the biggest disadvantage of an autotransformer is that it does not have the primary/secondary winding isolation of a conventional double wound transformer.

4.2.2. Instrument transformer. **Instrument transformers** are used in AC system for measurement of electrical quantities i.e. voltage, current, power, energy, power factor, frequency. They are also used with protective relays for protection of power system. They transform high currents and voltages to standardized low and easily measurable values that are isolated from the high voltage. When used for metering purposes, they provide voltage or current signals with accurate representation of the transmission line values in both magnitude and phase. There are two types of instrument transformers namely potential transformer (PT) and current transformer (CT).

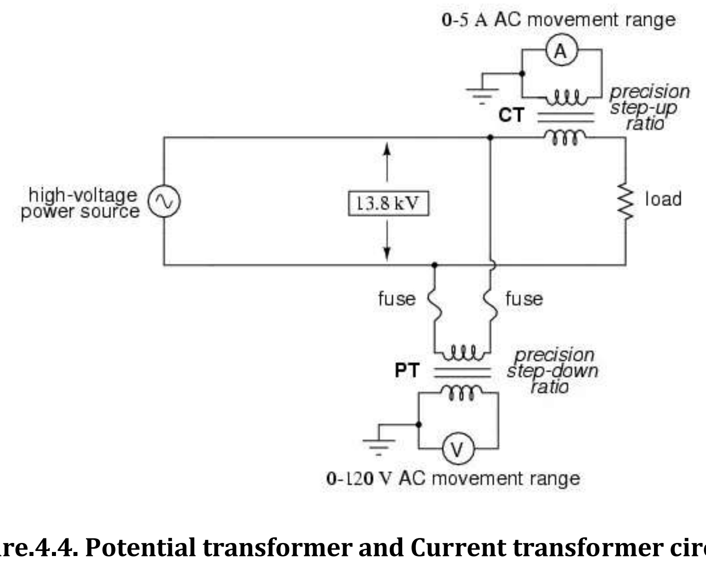


Figure.4.4. Potential transformer and Current transformer circuit.

4.2.2.1. Potential transformer. These transformers are extremely accurate ratio step-down transformers and are used in conjunction with standard low-range voltmeters (usually 0-120V) whose deflection when divided by voltage transformation ratio, gives the true voltage on the high voltage side. A typical potential transformer is as shown in the figure 4.4. They are used for measuring high alternating voltages.

4.2.2.2. Current transformer. These transformers are used with low-range ammeters. They step down the current in a known ratio. The current transformer has a primary coil of one or more turns of thick wire connected in series with the line whose current is to be measured. The secondary consists of a large number of turns of fine wire and is connected across the ammeter terminals (usually 0-5A). A typical current transformer is as shown in the figure 4.4. They are used for measuring high alternating currents.

4.2.3. Welding transformer. A welding transformer is a step down transformer that has thin primary winding with more number of turns and a thick secondary winding with less number of turns. This transformer reduces the source voltage to a very low voltage suitable for welding. The secondary has several taps for adjusting the voltage to control the welding current. When high current flows, heat produced melts the tip of the electrode and fills the gap between the two pieces due to the contact resistance between the electrode and the pieces to be welded.

Single phase transformer are light in weight and generally rated for 200 A welding current. There are few tapping in secondary winding for different current like 100, 125, 150 etc. These transformers work at 230 volt single phase supply. For heavy duty transformers, the input supply voltage is three phase 400 volt. Output current rating is 300 to 600 A. There are three points on output side Common, Low and High. Common is connected to ground and welding lead is connected to low for up to 300 A and high for 300 to 600 A. The open circuit output voltage of welding transformer is nearly 90 volt while during welding it reduces to 50-60 volts. The primary and secondary winding uses strip conductor for winding. Primary winding have tapping for connection to 380 volt or 415 volt by jumper strip setting.

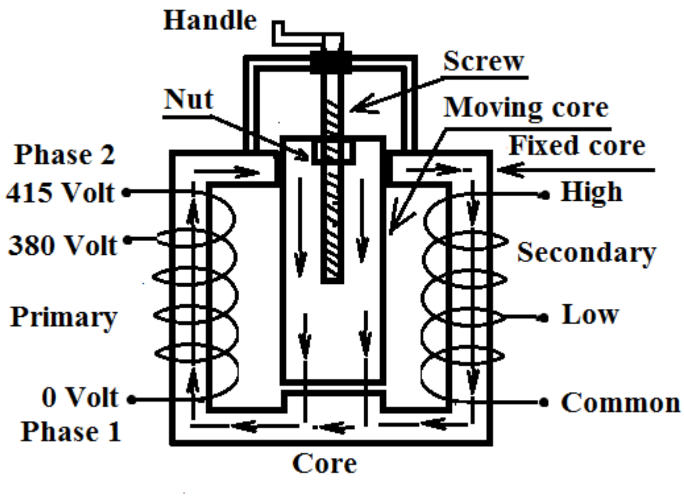


Figure.4.5. A typical Welding Transformer.

When supply is given to primary winding it produces an alternating flux in the core. The secondary winding which is also wound on the same core cuts the flux produced by primary winding. Hence we obtain the welding current as voltage is induced in secondary winding. So to control the current we have to control the flux linkage of the secondary winding. A bypass magnetic path is provided for flux with the help of adjustable magnetic core as shown in the figure 4.5. This adjustable magnetic core slides up and down in between the main core with the help of a current controlling handle. The impedance of welding transformer is higher than that the impedance of a general purpose transformer which helps in the process of establishing an arc and controlling the current.

4.3. COMPARISON BETWEEN CORE AND SHELL TYPE TRANSFORMERS

Table.4.1. Comparison between Core type and Shell type transformers

CORE TYPE TRANSFORMER	SHELL TYPE TRANSFORMER
The winding surrounds the core	The core surrounds the winding
The primary and secondary windings are placed on the side limbs	The primary and secondary windings are placed on the central limb
Concentric or cylindrical winding is used	Sandwich or disc winding is used
The flux is equally distributed on the side limbs of the core	The central limb carry the whole flux and side limbs carry half of the flux
The lamination is cut in the form of L strips	The lamination are cut in the form of the long strips of E and L
The no. of magnetic circuit is 2	The no. of magnetic circuit is 1
The copper required is more	The copper required is less
The insulation required is more	The insulation required is less.
The losses are more	The losses are less
The output is less	The output is high
Maintenance is easy	Maintenance is difficult
This is used for Low voltage and High current rating machines	This is used for High voltage and Low current rating machines

4.4. LOSSES – EFICIENCY – REGULATION OF TRANSFORMER

4.4.1. Losses in a Transformer An electrical transformer is a static device, hence a transformer only consists of electrical losses (iron losses and copper losses) and mechanical losses (windage or friction losses) are absent in it. The various losses in a transformer are

4.4.1.1. Core Losses or Iron Losses. Iron losses are caused by the alternating flux in the core of the transformer as this loss occurs in the core it is also known as Core loss. Iron loss is further divided into hysteresis and eddy current loss.

Hysteresis Loss. The core of the transformer is subjected to an alternating magnetising force, and for each cycle of emf, a hysteresis loop is traced out. Power is dissipated in the form of heat known as hysteresis loss and given by the equation shown below

$$P_h = K\eta B_{max}^{1.6} f\, V \quad \text{watts}$$

Where **f** is the supply frequency, $\mathbf{B_{max}}$ is the maximum or peak value of the flux density and **Kη** is proportionality constant which depends upon the volume and quality of the material of the core used in the transformer. The iron or core losses can be minimised by using silicon steel material for the construction of the transformer core.

Eddy current Loss. When the flux links in a closed circuit, an emf is induced in it and current flows, this value of current depends upon the amount of emf around the circuit and the resistance of the circuit. Since the core is made of conducting material, this emf circulates currents within the body of the material. These circulating currents are called Eddy currents. They will occur when the conductor experiences a changing magnetic field and these currents are not responsible for doing any useful work, and it produces a loss (I^2R loss) in the magnetic material. The eddy current loss is minimised by making the core with thin laminations. The equation of the eddy current loss is given as

$$P_e = K_e B_m^2 t^2 f^2\, V \quad \text{watts}$$

Where, $\mathbf{K_e}$ is co-efficient of eddy current. Its value depends upon the nature of magnetic material like volume and resistivity of core material, thickness of laminations, $\mathbf{B_m}$ is maximum value of flux density in wb/m^2, **T** – thickness of lamination in meters, **F** is frequency of reversal of magnetic field in Hz, **V** is volume of magnetic material in m^3.

4.4.1.2. Copper Loss or Ohmic Loss. These losses occur due to ohmic resistance of the transformer windings. If I_1 and I_2 are the primary and secondary currents, R_1 and R_2 are the resistance of primary and secondary windings, then the copper losses occurring in the primary and secondary winding will be $I_1^2R_1$ and $I_2^2R_2$ respectively. Therefore, the total copper losses will be

$$P_c = I_1^2R_1 + I_2^2R_2$$

These losses vary according to the load as the square of the load current and hence also known as variable losses.

4.4.1.4. Stray Loss. The occurrence of these stray losses is due to the presence of leakage field. The percentage of these losses is very small as compared to the iron and copper losses so they can be neglected.

4.4.1.5. Dielectric Loss. Dielectric loss occurs in the insulating material of the transformer that is when the oil gets deteriorated or the solid insulation gets damaged, or its quality decreases. The efficiency of transformer is affected by these losses.

4.4.2. Efficiency.
The efficiency of a transformer at a particular load and power factor is defined as the output divided by the input.

Efficiency = output/input
= {output/ (output + losses)}
= {output/ (output + cu loss + iron loss)}

i.e. Commercial Efficiency, η = (input – losses)/input = 1 – (losses/input)

Condition for maximum efficiency, Cu loss = Iron Loss, i.e. $\mathbf{W_i = I_1^2 R_{01}}$ or $\mathbf{I_2^2 R_{02}}$

Output current corresponding to maximum efficiency is $\mathbf{I_2 = \sqrt{(W_i / R_{02})}}$

The maximum efficiency at Full Load is given by

$$\eta_{max} = \text{Full load KVA X} \sqrt{\frac{\text{iron losses}}{\text{copper losses at full load}}}$$

The efficiency at any Load is given by

$$\eta = \frac{\mathcal{X} \times \text{Full Load KVA} \times \text{PF}}{(\mathcal{X} \times \text{Full Load KVA} \times \text{PF}) + \text{Wcu} + \text{Wi}} \times 100$$

All day efficiency. The ratio of output in KWh to input KWh for one day is given by,

$\eta_{\text{all-day}}$ = (Output in KWh/input in KWh) [for 24 Hours]

4.4.3. Voltage regulation. The voltage regulation is defined as the change in secondary terminal voltage from no-load to full load and is expressed as a percentage of the secondary no-load terminal voltage.

$$\%\text{ voltage regulation} = \frac{I_2R_2 \cos\emptyset \pm I_2X_2 \sin\emptyset}{E_2} \text{ x } 100$$

Note: + sign is for inductive load and – sign for capacitive load.

4.4. COOLING SYSTEMS OF TRANSFORMERS

A large amount of heat is developed in the transformer winding due to the presence of copper and iron losses in a transformer. Therefore, in order to remove the excess heat to protect the damage of windings and core various types of cooling systems employed in a transformer. They are oil-filled self-cooled, oil-filled water-cooled and air-blast type.

The oil-filled self-cooled system is used in small and distribution transformers. The assembled windings and cores of such transformers are mounted in a welded, oil-tight steel tank provided with steel cover. After putting the core in its place, the tank is filled with purified, high quality insulating oil. The oil serves to convey the heat from the core and windings to the case from where it is dissipated to its surroundings.

The oil-filled water-cooled system is used in high voltage transmission lines. The assembled windings and cores are immersed in oil, but they are mounted near the surface of the oil, a cooling coil through which cold water is kept circulating. The heat is carried away by this water. These transformers require only periodic inspection.

The air-blast type system is used for voltages below 25 KV. This transformer is not immersed in oil, but is housed in a thin sheet-metal box open at both ends through which air is blown from the bottom to the top by means of air-blast fans or blowers.

4.5. PROTECTION OF TRANSFORMERS

The choice of protective gear for a transformer depends upon several factors such as (1) type – distribution transformer or power transformer (2) size of the transformer (3) type of cooling (4) physical location of it in an electrical network.

For protection of transformers against external faults within the shortest possible time, relay systems and fuses are most suitable. For protection of transformers against internal faults such as (i) earth fault (ii) short-circuit fault between phases and (iii) turn to turn fault on the same phase, differential protection (merz-price system of protection) is widely used. The other protection systems against internal faults are Buchholz protection, core-balance leakage protection and combined leakage and overload protection.

Figure.4.6. Buchholz relay.

Buchholz Relay. Buchholz relay is a gas actuated relay installed between the transformer and conservator tank and is used to give warning in case of less severe internal faults in oil immersed transformer and to disconnect it from supply mains in case of severe internal faults which protects the transformer from severe damage. Buchholz Relay is as shown in the figure 4.6.

4.6. APPLICATIONS OF TRANSFORMER

The transformer is used to isolate two electric circuits electrically, increasing or decreasing the alternating voltages in electrical applications and in impedance matching. The transformer is used in rectifiers, voltage regulators, voltage stabilizers, power supplies, voltmeters, ammeters and protective relays etc. Transformers are used to distribute power at high voltages and provide electrostatic shielding for transient noise protection.

UNIT – 5

ALTERNATORS

OBJECTIVE

- To learn the working principle of an alternator.
- To learn the various types of alternator.
- To learn the applications of a different types of alternators.

5.0. INTRODUCTION

An alternator is an electrical machine which converts mechanical energy into alternating electric energy. They are also known as synchronous generators. Alternators in power stations driven by steam turbines are called turbo-alternators. Large 50Hz or 60 Hz three-phase alternators in power plants generate most of the world's electric power, which is distributed by electric power grids.

5.1. PRINCIPLE AND OPERATION

An alternator operates on the same fundamental principles of Electromagnetic induction as DC generators. They consist of an armature winding and a magnetic field. The armature winding is mounted on the stationery element called stator and field windings on a rotating element called rotor, where as in DC generators, the armature rotates and the field system is stationery. The stator consists of a cast-iron frame, which supports the armature core, having slots on its inner periphery for housing the armature conductors. The rotor is like a fly wheel having alternate N and S poles fixed to its outer rim.

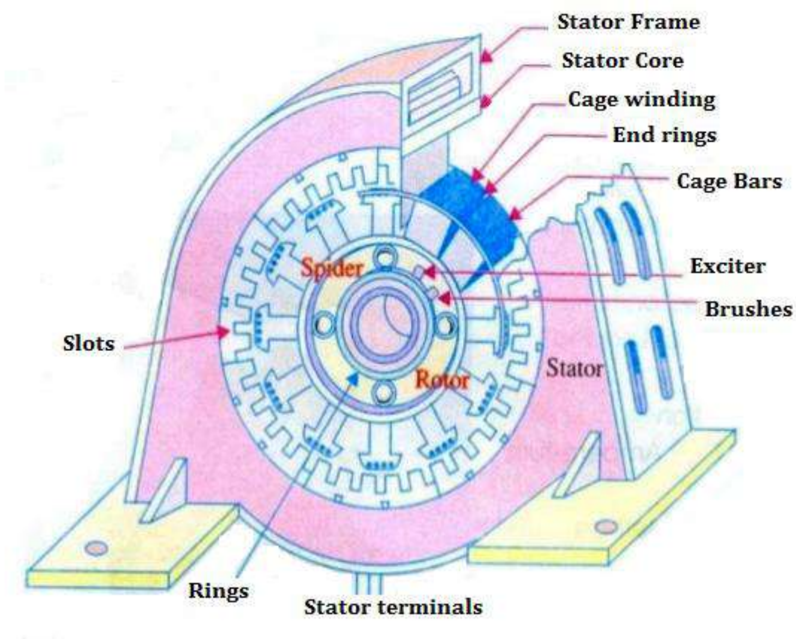


Figure.5.1. Construction of an Alternator.

The magnetic poles are excited (or magnetised) from a DC source of 125 to 600 volts. Because the field magnets are rotating, this current is supplied through two slip-rings. As the exciting voltage is relatively small, the slip-rings and brush gear are of light construction. Recently, brush less excitation systems has been developed in which an AC exciter and a group of rectifiers supply DC to the alternator. Hence, brush, slip-rings and commutator are eliminated. The construction detail of an alternator is as shown in the figure 5.1.

When the rotor rotates, the stator conductors are cut by the magnetic flux, Hence induced emf is produced in them. Because the magnetic poles are alternately N and S, they induce an emf and hence current in armature conductors, first flows in one direction and then in the other. Hence an alternating emf is produced in the stator conductors (1) whose frequency depends on the number of N and S poles moving past a conductor in one second and (2) whose direction is given by Fleming's right-hand rule.

5.2. SPEED AND FREQUENCY

In an alternator, there exists a definite relationship between the rotational speed (N) of the rotor, the frequency (f) of the generated emf and the number of poles (P).

Let,
P = total number of magnetic poles
N = speed of the rotor in rpm
f = frequency of generated emf in Hertz

Since one cycle of emf is produced when a pair of poles passes past a conductor, the number of cycles of emf produced in one revolution of the rotor is equal to the number of pair of poles.

∴ Number of cycles/revolution = P/2 and Number of revolutions/Second = N/60

$$\therefore \quad \text{Frequency} = (P/2) \times (N/60)$$
$$\text{or} \quad f = (P \times N)/120 \text{ Hertz}$$
$$\text{or} \quad N_S = 120 \times f / P$$

N_S is known as the synchronous speed, because it is the speed at which an alternator must run, in order to generate an emf of the required frequency.

5.3. DETAILS OF CONSTRUCTION

5.3.1. Stator Frame. The frame is used to house armature stampings and windings in position. Low speed large diameter alternators have frames which are cast in sections. Ventilation is maintained with the help of holes cast in the frame itself. Instead of castings, frames fabricated with mild-steel plates are welded together these days. The construction detail of an alternator stator frame is as shown in the figure 5.2.

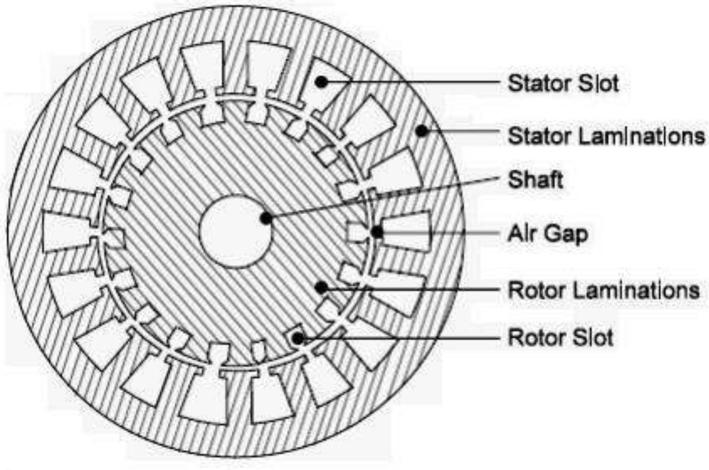


Figure.5.2. Construction of Alternator stator and rotor frame.

5.3.2. Stator core. The armature core is supported by stator frame and is built of laminations of special magnetic iron or steel alloy. The core is laminated to minimise loss due to eddy currents. The laminations are stamped out in complete rings for smaller machines and in segments for large machines. The laminations are insulated from each other and have spaces between them for allowing the cool air to pass through. The slots for housing the armature conductors lie along the inner periphery of the core and are stamped out at the same time when laminations are formed. The various shapes of armature slots are wide-open, semi-closed and closed type.

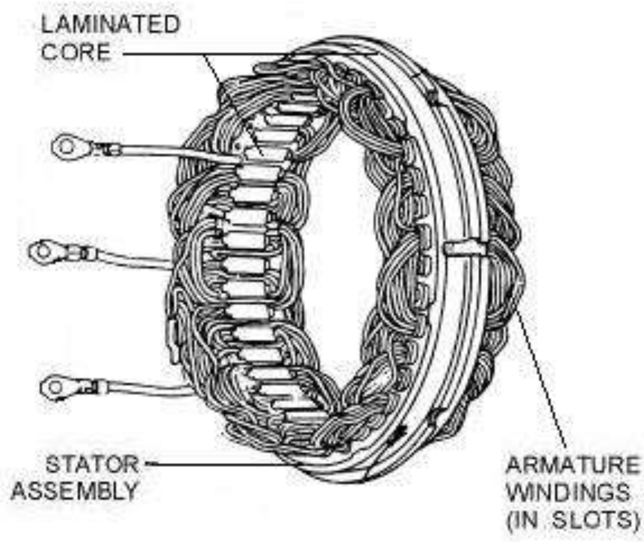


Figure.5.3. Construction of stator core and armature windings.

5.3.3. Armature windings. The alternator armature windings are open. There is no closed path for the armature currents in the winding itself. One end of the winding is joined to neutral point and the other is brought out for a star connected armature. The armature windings used for three phase alternators are single-layer and double-layer winding. The construction detail of armature windings is as shown in the figure 5.3.

5.3.3. Rotor. Rotors used in alternators are salient-pole and smooth-cylindrical type. The construction detail of an alternator stator frame is as shown in the figure 5.4.

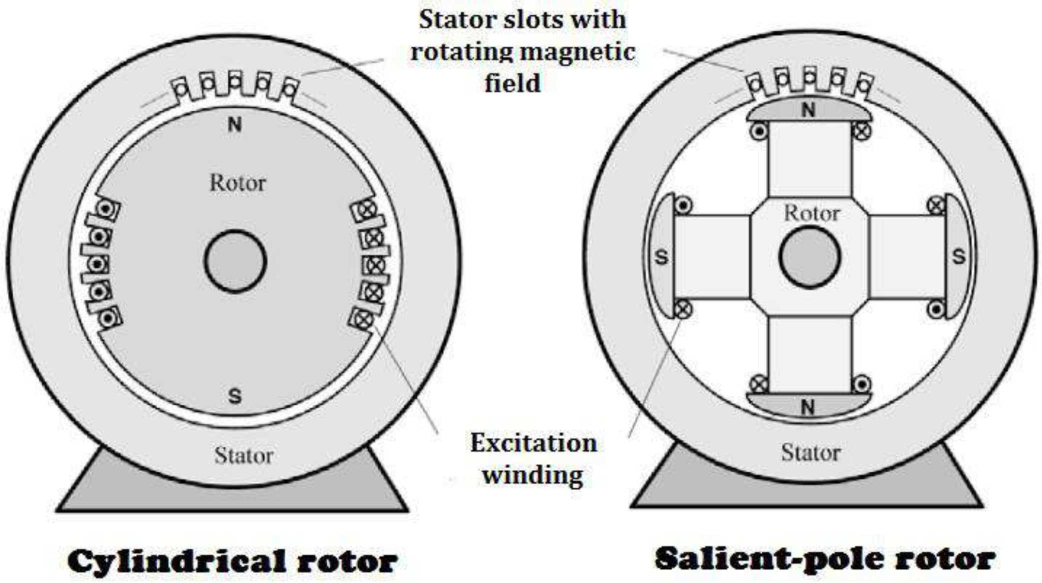


Figure.5.4. Construction of rotors of an alternator.

5.3.3.1. Salient or Projecting pole type. The rotor has a large number of projecting poles, having their cores bolted or dovetailed onto a heavy magnetic wheel of cast iron or steel. These alternators have large diameters and short axial lengths. The poles and pole shoes are laminated to minimise heating due to eddy currents. In large machines, field windings consist of rectangular copper strip wound on edge. It is used in low and medium speed (engine driven) alternators.

5.3.3.2. Non-salient or Smooth cylindrical type. The rotor consists of a smooth solid forged steel cylinder, having a number of slots milled out at intervals along the outer periphery for accommodating field coils. In this type, poles do not project out from the surface of the rotor. To avoid excessive peripheral velocity, such rotors have very small diameters and long axial lengths. It is used for steam turbine driven alternators called turbo alternators. The cylindrical construction of the rotor gives better balance and quieter operation and also less windage losses.

5.4. EMF EQUATION

Let,
Z = No. of conductors or coil sides in series/phase = 2T
T = No. of coils or turns per phase
P = No. of Poles
f = frequency of induced emf in Hertz
Φ = flux pole in webers
k_d = distribution factor = (sin m β/2) / (m sinβ/2)
k_c or k_p = pitch or coil span factor = cos α/2
k_f = form factor = 1.11
N = rotor speed in rpm

RMS value of emf/phase = $1.11 \times 4 f \Phi T = 4.44 f \Phi T$ volt.
The above equation is exactly same as the emf equation of a transformer

Actual available voltage/phase = $4.44\, k_f\, k_c\, k_d\, f\, \Phi\, T$ volts.
If the alternator is star connected, the line voltage is $\sqrt{3}$ times the phase voltage.

5.5. APPLICATIONS OF ALTERNATORS

Three phase 50Hz or 60Hz alternators are used for generation of power in power plants and are connected to electrical power grids for distribution. Automotive alternators are used in automobiles to charge the battery and to power the electrical system when its engine is running. High frequency alternators of variable reluctance type were applied commercially to radio transmission in the low-frequency radio bands. Marine alternators are used in yachts with appropriate adaptation to salt water environment. Diesel electro locomotive alternators are used in traction.

UNIT – 6

THREE PHASE INDUCTION MOTORS

OBJECTIVE

- To learn the working principle of a three phase induction motor.
- To learn the various types of three phase induction motor.
- To learn the various types of starters used for three phase induction motor.
- To learn the applications of a different types of three phase induction motor.

6.0. INTRODUCTION

A Three phase induction motor is a machine which converts electrical energy into mechanical energy. An induction motor is also called asynchronous motor as it runs at a speed other than synchronous speed. These motors are used widely in industrial applications as they are self starting.

6.1. CLASSIFICATION OF AC MOTORS

The different methods of classifying AC motors are given below.

(a) On the basis of principle of their operation
  (i) Synchronous motors
    (1) Plain
    (2) Super

  (ii) Asynchronous
    (1) Induction motors
      1) Squirrel cage motors (single/double)
      2) Slip-ring motors (external resistance)

    (2) Commutator motors
      1) Series (single phase/universal)
      2) Compensated (conductively/inductively)
      3) Shunt (simple/compensated)
      4) Repulsion (straight/compensated)
      5) Repulsion-start induction
      6) Repulsion induction

(b) On the basis of phase
  (i) Single phase
  (ii) Three phase

(c) On the basis of speed
  (i) Constant speed motor
  (ii) Variable speed motor
  (iii) Adjustable speed motor

(d) On the basis of construction
- (i) Enclosed type
- (ii) Semi-enclosed type
- (iii) Open type
- (iv) Ventilated type
- (v) Pipe-ventilated type
- (vi) Reverted frame eye type

6.2. WORKING PRINCIPLE

6.2.1. Production of a rotating magnetic field. The stator of an induction motor consists of a number of overlapping windings offset by an electrical angle of 120^o. When the primary winding or stator is connected to a three phase alternating current supply, it establishes a rotating magnetic field which rotates at synchronous speed. The direction of rotation of a motor depends on the phase sequence of supply lines, and the order in which these lines are connected to the stator. Thus interchanging the connection of any two primary terminals to the supply will reverse the direction of rotation. The number of poles and the frequency of the applied voltage determine the synchronous speed of rotation in the motor's stator. Motors are commonly configured to have 2, 4, 6 or 8 poles.

6.2.2. Production of a magnetic flux. To produce torque and thus rotate, the rotors must be carrying some current. In induction motors, this current comes from the rotor conductors. The revolving magnetic field produced in the stator cuts across the conductive bars of the rotor and induces an emf according to faraday's laws of electromagnetic induction. The rotor windings in an induction motor are either closed through an external resistance or directly shorted.

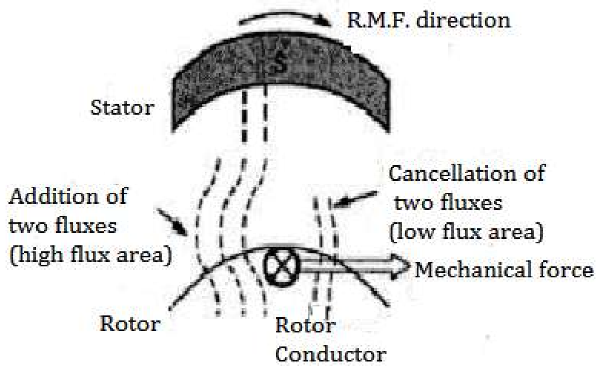


Figure.8.1. Working principle.

Therefore, the emf induced in the rotor causes current to flow in a direction opposite to that of the revolving magnetic field in the stator according to Lenz's law, and leads to a twisting motion or torque in the rotor. This result the rotor starts rotating in the same direction of the stator rotating magnetic field. If the rotor speed is more than stator speed, then no current will induce in the rotor because the reason for rotor rotation is the relative speed of the rotor and stator magnetic fields. The rotation of the magnetic field in an induction motor has the advantage that no electrical connection is to be made to the rotor.

6.3. SLIP

In an induction motor, the rotor never succeeds in catching up with the stator field. The rotor always runs at a speed which is always less than the speed of the stator field. The difference in speeds depends upon the load of the nature.

The difference between the synchronous speed Ns and the actual speed N of the rotor is known as Slip. It is usually expressed as a percentage of the synchronous speed as shown below.

$$\% \text{ Slip, } S = \frac{(Ns - N)}{Ns} \times 100$$

Where,

N_s = Synchronous speed in rpm

N = Rotor speed in rpm

$(N_s - N)$ = Slip speed. Obviously, rotor (or motor) speed, $N = Ns\,(1 - S)$

6.4. FREQUECNY OF ROTOR CURRENT

When the rotor is stationary; the frequency of rotor current is same as the supply frequency. But when the rotor starts revolving, then the frequency depends upon the relative speed or on slip speed.

For any slip speed, the frequency of the rotor current be f'.

Then, $Ns - N = (120 \times f')/P$ Also, $Ns = \frac{120\,f}{P}$

Dividing one by the other, we get, $\frac{f'}{f} = \frac{(Ns - N)}{Ns} = S$

6.5. CONSTRUCTION DETAILS

An induction motor consists of two parts (a) a stator and (b) a rotor.

6.5.1. STATOR. The stator of an induction motor is similar to that of a synchronous generator. It is made up of number of stamping, which are slotted to receive the winding. The stator carries a three phase winding and is fed from a three phase supply . It is wound for a definite number of poles, the exact number of poles determined by the requirements of speed. The construction of stator is a shown in the figure 8.2.

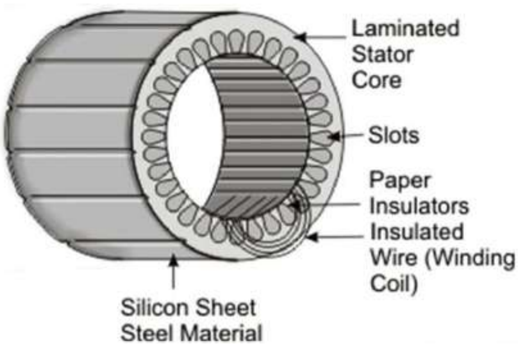


Figure.8.2. Stator construction.

The stator windings, when supplied with three phase currents, produce a magnetic flux of constant magnitude but which revolves at synchronous speed. This revolving magnetic flux induces an emf in the rotor by mutual induction.

6.5.2. ROTOR. The two types of rotors generally used in three phase induction motors are (a) squirrel cage rotor and (b) phase wound or slip-ring motors.

SQUIRREL CAGE ROTOR. This type of rotor has the simplest and most rugged construction. The rotor consists of a cylindrical laminated core with parallel slots for carrying rotor conductors (i.e. heavy bars of copper or aluminium or alloys not wires). One bar is placed in each slot, rather the bars are inserted from one end when semi enclosed slots are used. The rotor bars are brazed or electrically welded or bolted to two heavy short circuited end rings, thus giving us a squirrel cage construction as shown in the figure 8.2.

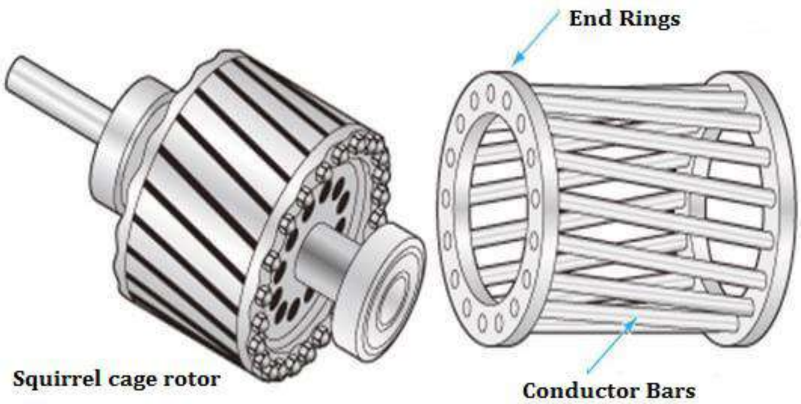


Figure.8.2. Squirrel cage rotor construction.

They do not have the possibility to add any external resistance in series with the rotor circuit for starting purposes. The rotor slots are usually not quite parallel to the shaft but are purposely given a light skew to make the motor run quietly by reducing the magnetic hum and also the locking tendency of rotor. Almost 90% of the induction motors are squirrel cage type.

PHASE WOUND ROTOR. This type of rotor is provided with three phase, double layer, distributed winding consisting of coils as used in alternators. The rotor is wound for as many poles as the number of stator poles and is always wound three phase even when the stator is wound two phase. The three phases are starred internally. The other three winding terminals are brought out and connected to three insulated slip rings mounted on the shaft with brushes resting on them. These three brushes are further externally connected to a three phase star connected rheostat as shown in the figure 8.3.

This helps in increasing the starting torque during starting period and for changing its speed torque characteristics by introducing additional resistance in the rotor circuit. When running under normal conditions, the slip rings are automatically short circuited by means of a metal collar, which is pushed along the shaft and connected all the rings together. Next the brushes are automatically lifted from the slip-rings to reduce the frictional losses and the wear and tear. Hence it is observed that under normal conditions, the wound rotor is short circuited on itself just like a squirrel cage rotor.

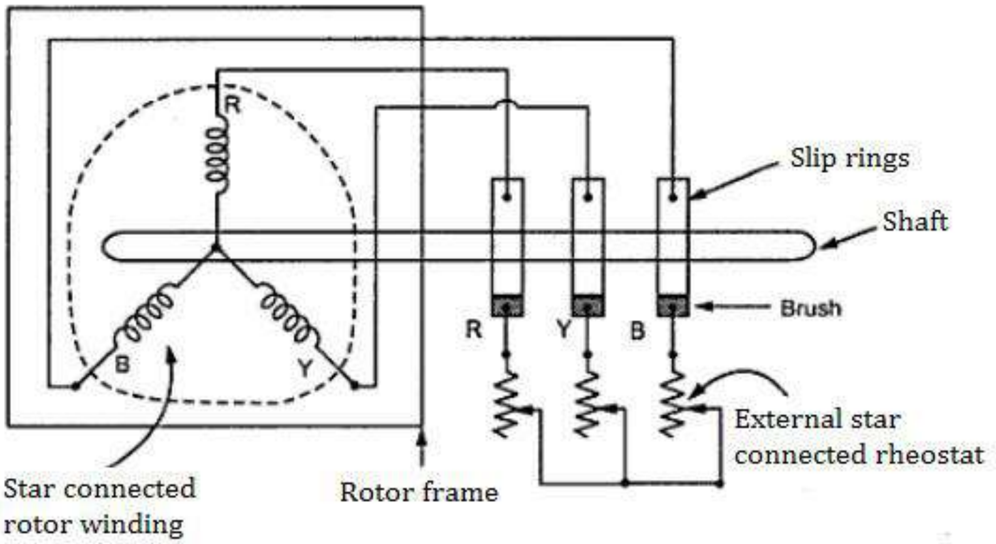


Figure.8.3. Phase wound rotor circuit.

6.6. STARTERS OF 3 – PHASE INDUCTION MOTORS.

6.6.1. Necessity of a starter. If an induction motor is directly switched on from the supply, it takes 5 to 7 times its full load current and develops a torque which is only 1.5 to 2.5 times the full load torque. This large starting current produces a large voltage drop in the line, which may affect the operation of other devices connected to the same line. Hence, it is not advisable to start induction motors of higher ratings (generally above 25kW) directly from the mains supply. To prevent such high current rush in armature, starters are used in Induction motors.

Normally with motors beyond 5 HP, starters are provided. For reduction in the starting current, a lower voltage is applied to the stator, especially for the squirrel cage induction motors. Full voltage is only applied when the motor picks up speed. The various types of starters used for induction motors are DOL starter, Star-Delta starter, Auto transformer starter and Rotor resistance starter.

6.6.2. DOL Starter. Small three phase induction motors can be started direct-on-line, which means that the rated supply is directly applied to the motor. Induction motors can be started directly on-line using a DOL starter which generally consists of a contactor and motor protection equipment such as a circuit breaker.

A DOL starter consists of a coil operated contactor which can be controlled by start and stop push buttons. When the start push button is pressed, the contactor gets energized and it closes all the three phases of the motor to the supply phases at a time. The stop push button de-energizes the contactor and disconnects all the three phases to stop the motor. In order to avoid excessive voltage drop in the supply line due to large starting current, a DOL starter is generally used for motors that are rated below 5HP.

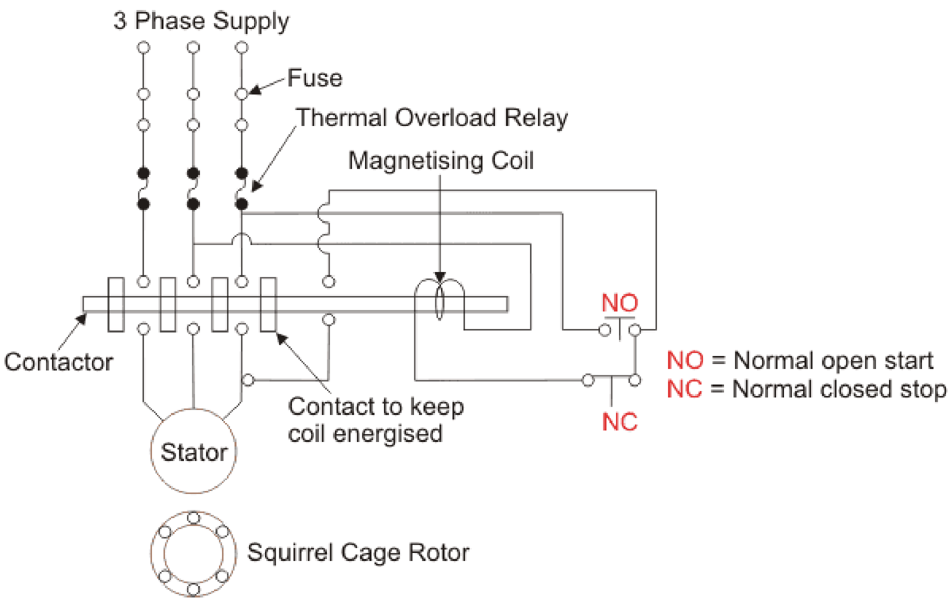


Figure.8.4. Connection diagram of a DOL starter.

6.6.3. Star-Delta Starter. Star Delta Starter, which is sometimes called as Y – Δ or Wye – Δ Starter, is a common type of reduced voltage starter. It can reduce the starting current without the need of any external devices. In this Starter, the initial connection of the stator windings is in the form of 'Star' in START position. When the rotor gains speed about 80% of its rated speed, the starter is quickly changed to RUN position then the connection of stator windings changes to 'Delta' and the motor runs normally.

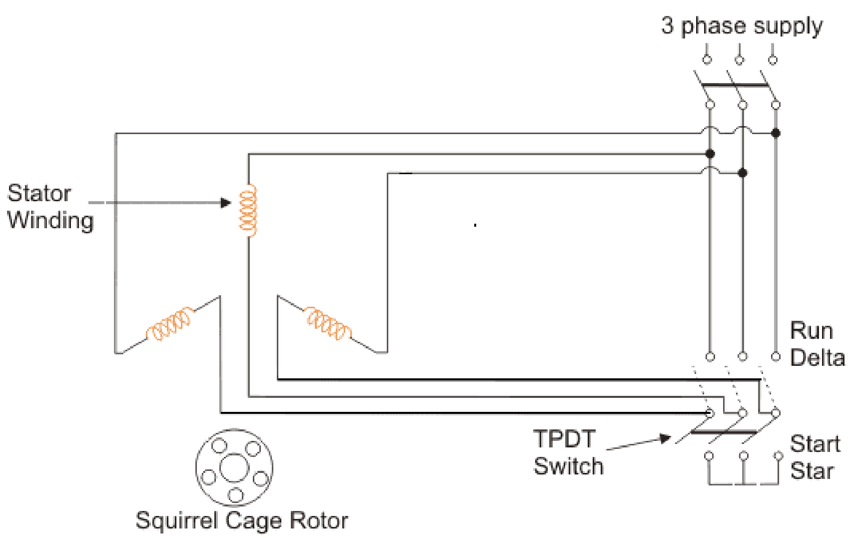


Figure.8.5. Connection diagram of a Star-Delta starter.

A Y–Δ Starter reduces the starting current by connecting the motor winding in Star at the time of starting. This reduces the voltage across the winding. The voltage across the winding will be 1/√3 times of Line voltage. The current flowing in each winding is also reduced by the same amount. Hence, the phase current or the current through winding becomes $I_P = I/\sqrt{3}$. Since the Line current and phase current in star connection are equal, the Line current $I_L = I/\sqrt{3}$. As the motor accelerates and gains speed, the stator windings are disconnected from the Star configuration and connected in the form of Delta. We know that the Line voltage and Phase voltage are equal in Delta connection and let the voltage across the stator windings be V. If I is the Phase Current through the stator winding in Delta connection, then line current is $I_L = \sqrt{3} \times I$. We can conclude that the starting current is approximately reduced to 58% of its rated current.

6.6.4. Auto transformer Starter. An Auto transformer Starter is suitable for both star and delta connected motors. In this method, the starting current is limited by using a three-phase auto transformer to reduce the initial stator applied voltage. The figure below shows the motor with the Auto transformer starter. It is provided with a number of tappings. The starter is connected to one particular tapping to obtain the most suitable starting voltage. A double throw switch S is used to connect the auto transformer in the circuit for starting.

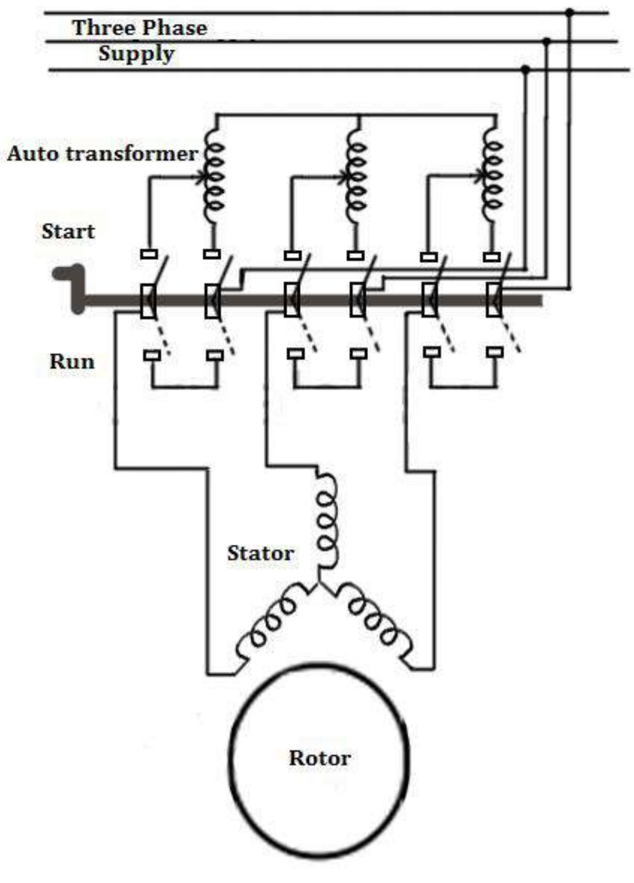


Figure.8.6. Connection diagram of an Auto transformer starter.

When the handle H of the switch S in the START position. The primary of the auto transformer is connected to the supply line, and the motor is connected to the secondary of the auto transformer. When the motor picks up the speed of about 80 percent of its rated value, the handle H is quickly moved to the RUN position. Thus, the auto transformer is disconnected from the circuit, and the motor is directly connected to the line and achieve its full rated voltage. The handle is held in the RUN position by the under voltage relay. If the supply voltage fails or falls below a certain value, the handle is released and returns to the OFF position. Thermal overload relays provide the overload protection.

6.6.5. Rotor resistance Starter. To limit the rotor current which consequently reduces the current drawn by the motor from the supply, the resistance can be inserted in the rotor circuit at the time of starting. This addition of the resistance in rotor is in the form of 3 phase star connected rheostat which is normally wire-wound. They are tapped with points brought out to fixed contactors. The arrangement is shown in the figure 8.7.

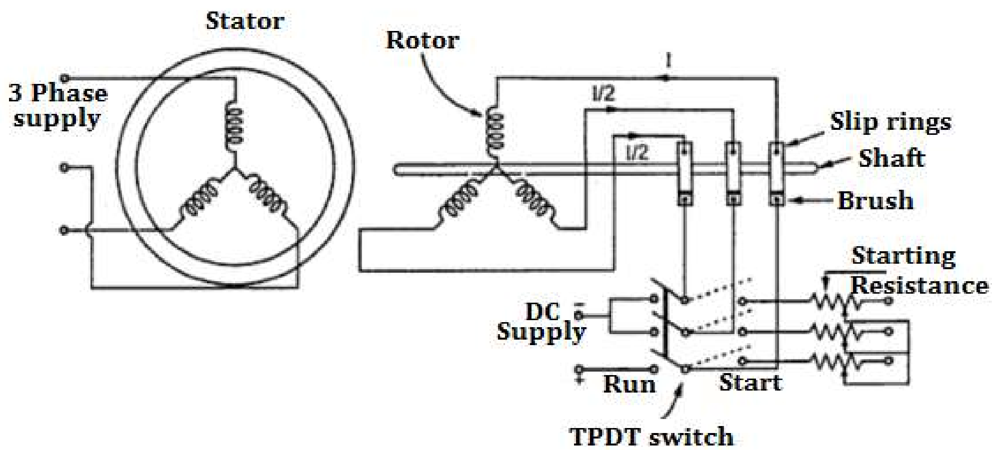


Figure.8.7. Connection diagram of a Rotor resistance starter.

The external resistance is inserted in each phase of the rotor winding through slip ring and brush assembly. Initially maximum resistance is in the circuit. As motor gather speed, the resistance is gradually cut-off. The operation may be manual or automatic. We have seen that the starting torque is proportional to the rotor resistance. Hence important advantage of this method is not only the starting current is limited but starting torque of the motor also gets improved. The only limitation of the starter that it can be used only for slip ring induction motors as for squirrel cage motor the rotor is permanently short circuited.

6.7. COMPARISON SQUIRREL CAGE AND SLIP RING INDUCTION MOTOR

Table.6.1. Comparison between Squirrel cage type and Slip ring type induction motor

SQUIRREL CAGE IM	SLIP RING IM
The rotor is similar to that of a cage.	The rotor is similar to that of a DC machine
It does not have slip rings on the rotor	It has slip rings on the rotor
Starting current is high	Starting current can be reduced
Speed of the motor is constant	Speed of the motor is variable
It can be started by DOL, Star-Delta and Auto transformer starters	It can be started by Rotor resistance starter
Power factor is low	Power factor is high
Maintenance is low	Maintenance is low Maintenance is high
Used in lathe machines, drill machines and blowers	Used in Lifts, Cranes and Hoists

6.8. APPLICATIONS OF 3-PHASE INDUCTION MOTORS.

The applications of various types of poly phase induction motors are as follows.

6.8.1. Slip ring motors. Slip ring motors are suitable for loads requiring high starting torque and where a lower starting current is required. The wound rotor induction motors are used in conveyors, cranes, pumps, elevators and compressors.

6.8.2. Squirrel cage motors. Squirrel cage motors are classified according to class.

Class A motor. These motors have normal starting torque, high starting current and low operating slip. This design has low resistance single cage. The efficiency of the motor is high at full load. Applications of Class A are fans, blowers, centrifugal pumps, etc.

Class B motor. These motor have normal starting torque, low starting current and low operating slip. This design withstands the high leakage reactance as a result, the starting current is reduced. The starting torque is maintained by use of a double cage or deep bar rotor. These motors are commonly used for full voltage starting. Applications of Class B are fans, blowers, centrifugal pumps, etc.
Class C motor. They have high starting torque and low starting current. Such motors are of the double cage and deep bar and has higher rotor resistance. Applications of Class C are compressors, conveyors, reciprocating pumps, crushers, etc.

Class D motor. They have the highest starting torque as compared to all the other class of motors. The bars of the rotor cage are made up of brass. These types of motors have low starting current and high operating slip. The value of full load operating slip varies between 8 to 15%. Thus, the efficiency of the motor is low. These motors are suitable for driving intermittent loads which require frequent acceleration and high loads such as punch presses, bulldozers and die stamping machines etc.

Class E motor. They have a low lip at rated load. For motors above 5 KW rating, the starting current may be sufficiently high as to require a compensator or resistance starter.

Class F motor. They have low starting torque and low starting current and may be started on full voltage. Such motors are of the double cage and deep bar and has higher rotor resistance. Applications of Class C are compressors, conveyors, reciprocating pumps, crushers, fans, blowers, centrifugal pumps, etc.

UNIT – 7

SINGLE PHASE INDUCTION MOTORS

OBJECTIVE

- To learn the working principle of a single phase induction motor.
- To learn the various types of single phase induction motor.
- To learn the applications of various types of single phase induction motor.

7.0. INTRODUCTION

We use the single-phase power system more widely than three phase system for domestic purposes, commercial purposes and some extent in industrial uses. Because, the single-phase system is more economical than a three-phase system and the power requirement in most of the houses, shops, offices are small, which can be easily met by a single phase system. The single phase motors are simple in construction, cheap in cost, reliable and easy to repair and maintain.

7.1. SINGLE PHASE MOTORS

7.1.1. Classification of Single Phase motors. The single phase AC motors may be classified as below.

(1)Single Phase Induction motors

- (a)Split-phase motors
  - (i) Resistance start motor
  - (ii) Capacitor start motor
  - (iii) Permanent (single value) capacitor motor
  - (iv) Two value capacitor motor
- (b) Shaded pole motor
- (c) Reluctance start motor
- (d) Repulsion start motor

(2) Single Phase Commutator motors

- (a)Repulsion motor
- (b)Repulsion induction motor
- (c) AC series motors
- (d) Universal motor

(4) Single Phase Synchronous motors

- (a) Reluctance motor
- (b) Hysteresis motor
- (c) Sub-synchronous motor

7.1.2. Working Principle. The construction of a single phase induction motor is similar to that of a three phase induction motor having squirrel cage rotor, except that the stator is wound for single phase supply. Stator is also provided with a 'starting winding' which is used only for starting purpose. When the stator of a single phase motor is fed with single phase supply, it produces alternating flux in the stator winding.

The alternating current flowing through stator winding causes induced current in the rotor bars (of the squirrel cage rotor) according to Faraday's law of electromagnetic induction. This induced current in the rotor will also produce alternating flux. Even after both alternating fluxes are set up, the motor fails to start. However, if the rotor is given an initial start by external force in either direction, then motor accelerates to its final speed and keeps running with its rated speed. This behaviour of a single phase motor can be explained by double-field revolving theory.

The double-field revolving theory states that, any alternating quantity (i.e. alternating flux) can be resolved into two components having magnitude half of the maximum magnitude of the alternating quantity, and both these components rotating in opposite direction. Each of the two component fluxes, while revolving round the stator, cuts the rotor, induces an emf and this produces its own torque. This two torques (forward torque and backward torque) are oppositely directed and are numerically equal and produces no resultant torque. That is why a single phase induction motor is not self starting. The torque speed characteristics curve is as shown in the figure 7.1.

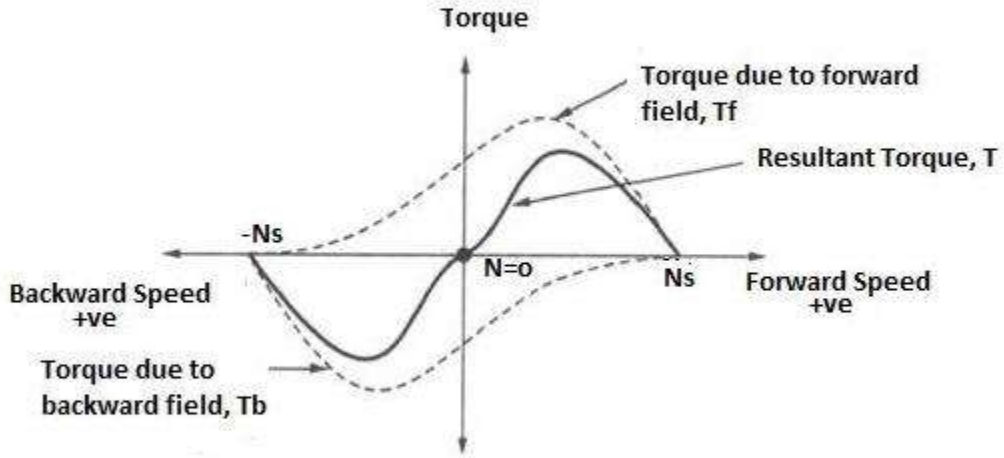


Figure.7.1. Torque speed characteristics.

To make it self-starting, it can be temporarily converted into a two-phase motor while starting. This can be achieved by introducing an additional 'starting winding' also called as auxiliary winding. Hence, stator of a single phase motor has two windings: (i) Main winding and (ii) Starting winding (auxiliary winding). These two windings are connected in parallel across a single phase supply and are spaced 90 electrical degrees apart. Phase difference of 90 degree can be achieved by connecting a capacitor in series with the starting winding.

Hence the motor behaves like a two-phase motor and the stator produces revolving magnetic field which causes rotor to run. Once motor gathers speed, say up to 80 or 90% of its normal speed, the starting winding gets disconnected from the circuit by means of a centrifugal switch, and the motor runs only on main winding.

7.2. SINGLE PHASE INDUCTION MOTORS

7.2.1. Resistance start Split-phase motor. Resistance start split phase induction motor is a single phase induction motor which has two windings called the run winding and a start winding and are connected in parallel. At 75% full speed the centrifugal switch opens, disconnecting the start winding. The centrifugal switch is a normal closed control device that is wired into the start winding.

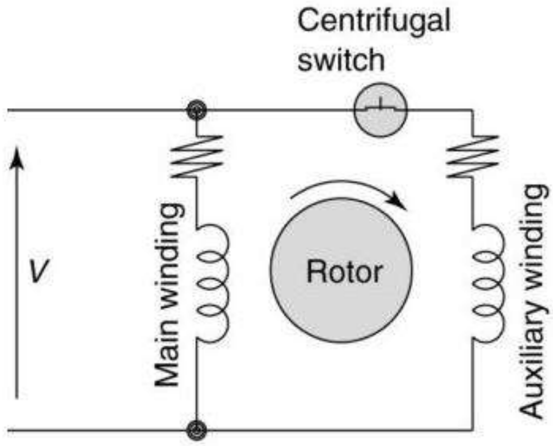


Figure.7.2. Resistance start split phase induction motor.

The purpose of this configuration is that the motor start winding would be taken out the circuit once motor reaches 75 to 80% of its rated speed. Even though it is considered to be a reliable motor this centrifugal switch is a moving part that sometimes fails to reengage when the motor stops spinning. This type of motors is generally found in ceiling fans, washing machines tubs, blower motors for oil furnaces, and small pumps etc.

7.2.2. Capacitor Start Split-phase motor. Capacitor start split phase induction run motor is a single phase induction motor with the capacitor connected in series with the start winding and the centrifugal switch of the motor. This configuration gives the motor past starting power but the application does not require a lot of power doing the runtime.

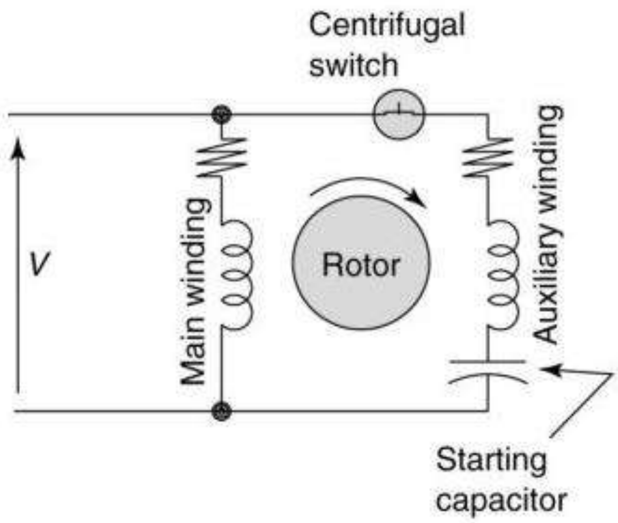


Figure.7.3. Capacitor start split phase induction motor.

The purpose of this configuration is that the motor start winding and the capacitor would be taken out the circuit once motor reaches 75 to 80% of its rated speed. The capacitor of these motors are sometimes built onto the motor or located remotely away from the motor primarily making it easier to replace. This type of motors is generally found in AC units, large blower motors, and condenser fans.

7.2.3. Permanent Capacitor motor. Permanent capacitor motor is a single phase induction motor run with the exception of the start winding and run winding stay in the circuit at all times. The start winding is permanently connected to the capacitor in series. It uses a lower rated capacitor because the capacitor is in the circuit at full load speed at all times for higher running torque.

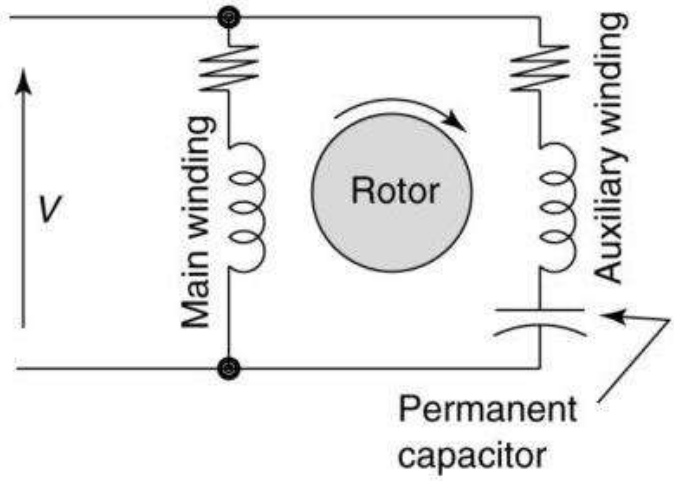


Figure.7.4. Permanent Capacitor split phase induction motor.

This type of motor requires low starting torque but needs to keep a constant torque while running. This type of motor can sometimes be found in the air-conditioning compressor.

7.2.4. Capacitor Start and Run motor. Capacitor start and run motor is a single phase induction motor is a single phase induction motor has two windings called the run winding and a start winding and is connected in parallel. It consists of two capacitors of different rating. One capacitor of higher value is connected in series with the start winding and the other capacitor of lesser value is connected in series with the run winding.

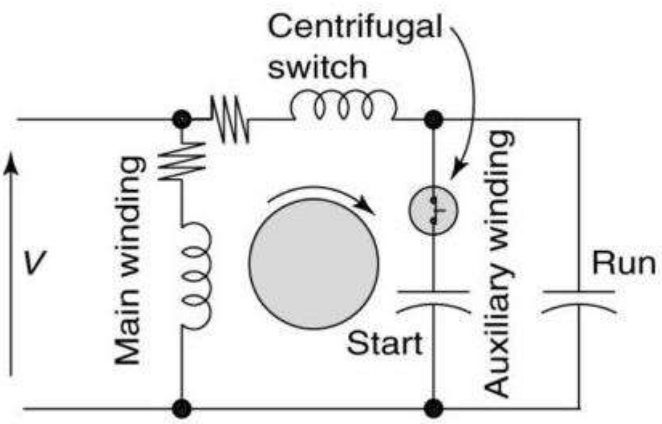


Figure.7.5. Capacitor start and run split phase induction motor.

Capacitor start and run motor has high starting torque and high running torque because of more capacitance in the circuit. This type of motor is generally found in the air-conditioning compressor, large blower motors etc.

7.2.4. Shade pole motor. The shaded pole induction motor is simply a self-starting single-phase induction motor. The shaded pole motor may have two or four poles. The poles of the motor are laminated. The stator of the shaded pole motor has a salient pole. Each pole of the motor is excited by its exciting coil. The slot is constructed at some distance apart from the edge of the poles. The short-circuited copper coil is placed in this slot. The part which is covered with the copper ring is called the shaded part and which are not covered by the rings is called unshaded part.

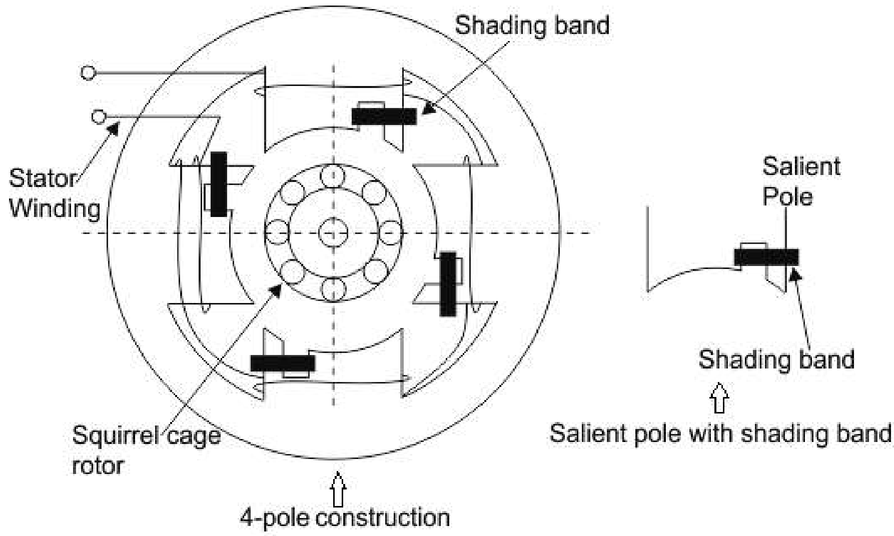
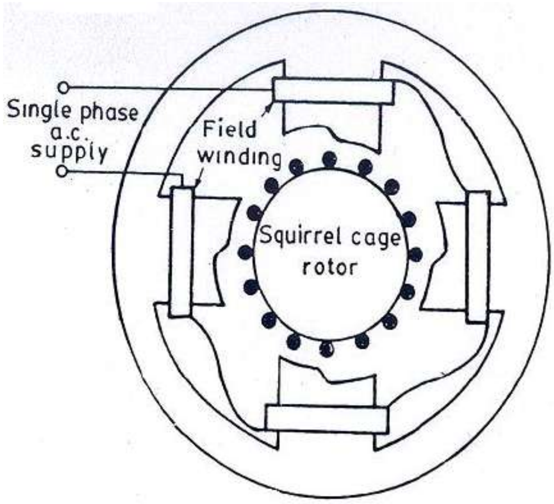


Figure.7.6. Shaded Pole motor.

The copper rings shade the loops. The loops are known as the shading coil. The shading coil acts as a secondary winding of the motor. The shaded pole motor uses the squirrel cage rotor. The bars of the rotor are skewed at an angle of 60º. The skew can be done for obtaining the better starting torque. The shaded pole motor rotates only in one particular direction, and the reverse movement of the motor is not possible. The direction of rotation is from the unshaded side to the shaded ring. This type of motor is generally found in small fans, electric wall clocks, hair driers, ventilators, toys etc.

7.2.4. Reluctance start motor. Reluctance-start induction motor characteristics are similar to that of shaded pole motor. In this motor the magnetic field shifts across the pole, but the effect is obtained by the non-uniform air gap of salient poles. Where there is a greater air gap, the flux in that portion is more nearly in phase with the current. There is a greater lag between flux and current where there is a lower reluctance or where the air gap is smaller. Since both fluxes are produced by the same current, the flux across the larger air gap leads the flux across the smaller one. The two fluxes are obviously displaced in time, and so the magnetic field shifts across the poles from larger air gap to the shorter gap. Thus the direction of rotation is firmly fixed by the construction, and the motor cannot be reversed at all. This motor is an induction motor and should not be confused with reluctance motor which is actually a non-excited synchronous motor.



For most small power applications, the shaded-pole motor is preferred, and the reluctance-start motor has limited use, usually where starting torque requirements are low.

7.2.5. Repulsion start motor. Repulsion start induction run motors starts as a repulsion motor, but normally runs as an induction motor, with constant speed characteristics. It consists of a stator winding, one rotor which is similar to the wire wound DC armature, a commutator and a centrifugal mechanism which short circuits the commutator bars all the way round when the motor has reached nearly 75% of full speed. Then it runs as an induction motor, with a short circuited squirrel cage rotor. Hence brushes do not carry current and are lifted from the commutator to avoid wear and tear. These motor are used where starting period is of comparatively long duration, because of high inertia loads. This type of motor is generally found in machine tools, compressors, pumps, commercial refrigerators, floor polishing and grinding devices etc.

7.3. COMPARISON STARTING WINDING AND RUNNING WINDING

Table.7.1. Comparison between starting winding and running winding

STARTING WINDING	RUNNING WINDING
This winding makes the motor self starting	This winding makes the motor run
It does not have slip rings on the rotor	It has slip rings on the rotor
Starting winding is disconnected when the motor reaches 70 % of its rated speed	Running winding is permanently connected in the motor circuit
Speed of the motor is constant	Speed of the motor is variable
It can be started by DOL, Star-Delta and Auto transformer starters	It can be started by Rotor resistance starter
Power factor is low	Power factor is high
Maintenance is low	Maintenance is low Maintenance is high
Used in lathe machines, drill machines and blowers	Used in Lifts, Cranes and Hoists

UNIT – 8

POWER SYSTEMS

OBJECTIVE

- To learn about various sources of electrical energy.
- To learn about the generation of power from various sources.
- To learn about transmission and distribution systems.
- To learn about the accessories used in substations.

8.0. INTRODUCTION

Electrical energy is generated by conversion of energy available in different forms from different natural sources such as kinetic energy of blowing winds, pressure head of water, chemical energy of fuels and nuclear energy of radio-active substances into electrical energy. For conversion of mechanical energy into electrical energy, electrical machines (generators or alternators) driven by prime-movers (petrol engines, diesel engines, steam turbines, gas turbines or hydraulic turbines) are employed.

The electrical machines employed for generating DC is called generators and those for generating AC is called alternators. The alternate method of generating electrical energy without the use of prime-mover consists of magneto-hydro dynamics, thermionic and thermo-electric generation. The main sources of energy are the sun, wind, terrestrial heat, ocean tides and waves, water, fuels and radio-active substances.

8.1. SOURCES OF ELECTRICAL ENERGY

8.1.1. Conventional Sources. These conventional sources are also known as non-renewable sources of energy. These natural energy resources are present in a limited quantity and are being used for a long time. Once they are depleted, they cannot be generated at the speed which can sustain its consumption rate. The examples include Thermal energy, Hydro electric energy, Nuclear energy, Oil and natural gas.

8.1.2. Non-Conventional Sources. These non-conventional sources are also known as renewable sources of energy. These energy sources are continuously replenished by natural processes. These cannot be exhausted easily, can be generated constantly so can be used again and again. The examples include solar energy, bio energy, tidal energy, geothermal energy and wind energy.

8.2. CONVENTIONAL SOURCES OF ENERGY

8.2.1. Hydro Power station. Power is generated from the generator coupled with the turbine – the turbine being rotated by water energy. The following factors should be considered while selecting the site of a hydro power station. They are (1) Quantity of water available (2)Storage of water (3) head of water (4) distance of power station site from load centres (5) Accessibility of the site.

The different methods of classifying Hydro-electric plants are given below.

(a) Quantity of water available
- (i) Run-off river plants without pondage
- (ii) Run-off river plants with pondage
- (iii) Reservoir plants

(b) Available head
- (i) Low head plants
- (ii) Medium head plants
- (iii) High head plants

(c) Nature of load.
- (i) Base-load plants
- (ii) Peak-load plants
- (iii) Pumped-storage plants for peak-load

A hydro-electric power plants consists of a reservoir for storage of water, a diversion dam, an intake structure for controlling and regulating the flow of water, a conduit system to carry the water from the intake to the water wheel, the turbines coupled with generators, the draft tube for conveying water from water wheel to the tail race, the tail race and a power house i.e. the building consists of turbines, alternators and other miscellaneous items etc. The size, location and type of each of these essential elements depend upon the topography and geological conditions and the amount of water to be used.

A typical layout of a hydroelectric power plant and its basic components are as shown in the figure 8.1.

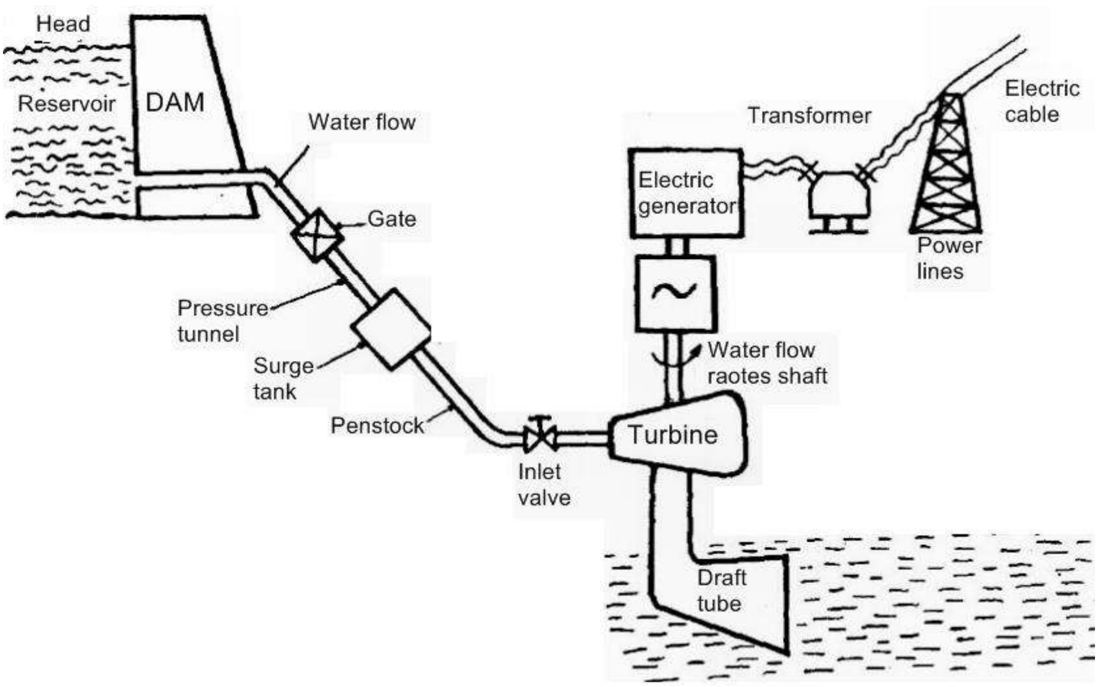


Figure.8.1. Layout of a Hydro power plant.

Dam and Reservoir. The dam is constructed on a large river in hilly areas to ensure sufficient water storage at height. The dam forms a large reservoir behind it. The height of water level called as water head in the reservoir determines how much of potential energy is stored in it.

Control gate. Water from the reservoir is allowed to flow through the penstock to the turbine. The amount of water which is to be released in the penstock can be controlled by a control gate. When the control gate is fully opened, maximum amount of water is released through the penstock.

Penstock. A penstock is a huge steel pipe which carries water from the reservoir to the turbine. Potential energy of the water is converted into kinetic energy as it flows down through the penstock due to gravity.

Water turbine. Water from the penstock is taken into the water turbine. The turbine is mechanically coupled to an electric generator. Kinetic energy of the water drives the turbine and consequently the generator gets driven. There are two main types of water turbine (i) Impulse turbine and (ii) Reaction turbine. Impulse turbines are used for large heads and reaction turbines are used for low and medium heads.

Generator. A generator is mounted in the power house and it is mechanically coupled to the turbine shaft. When the turbine blades are rotated, it drives the generator and electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

Surge tank. These are usually provided in high or medium head power plants when considerably long penstock is required. A Surge tank is a small reservoir or tank which is open at the top. It is fitted between the reservoir and the power house. The water level in the surge tank rises or falls to reduce the pressure swings in the penstock.

When there is sudden reduction in load on the turbine, the governor closes the gates of the turbine to reduce the water flow. This causes pressure to increase abnormally in the penstock. This is prevented by using a surge tank, in which the water level rises to reduce the pressure and also it provides excess water needed when the gates are suddenly opened to meet the increased load demand.

8.2.2. Thermal Power station. A Steam power plant basically operates on the Rankin cycle. Coal is burnt in a boiler, which converts water into steam. The steam is expanded in a turbine, which produces mechanical power driving the alternator coupled to the turbine. The steam after expansion in prime mover (turbine) is usually condensed in a condenser to be fed into the boiler again. The factors to be considered for site selection of steam power plants are nearness to load centre, supply of water, availability of coal, availability of land at a reasonable price, transportation facilities, availability of labour and distance from populated area.

The working of a modern coal-fired steam power plant can be divided into four main circuits namely, (1) Fuel and Ash circuit (2) Air and Fuel gas circuit (3) Feed water and steam circuit and (4) Cooling water circuit.

A typical layout of a Thermal power plant and its basic components are as shown in the figure 8.2.

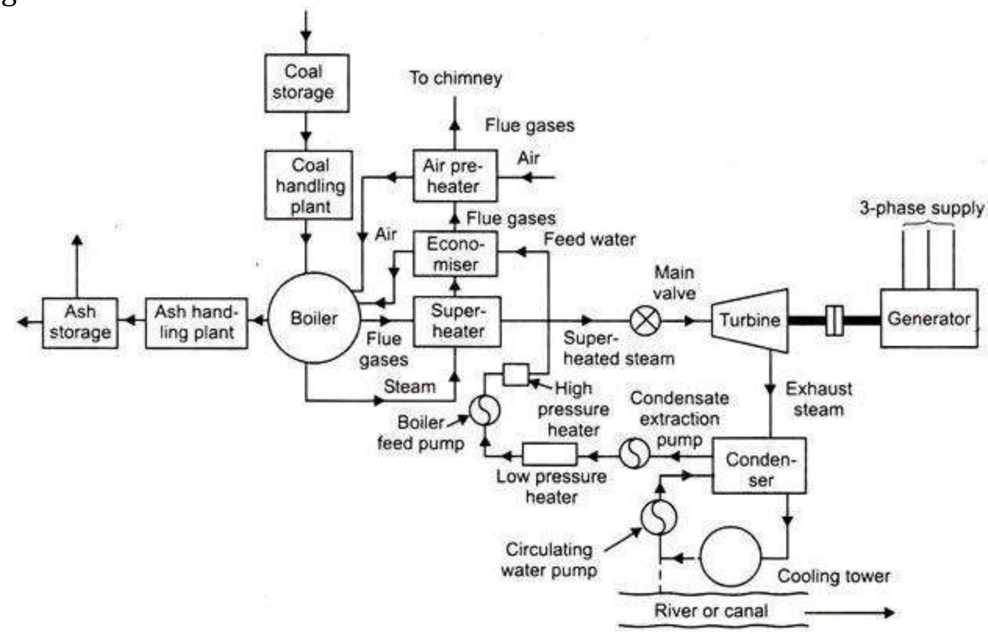


Figure.8.1. Layout of Thermal power plant.

Coal. Coal is transported from coal mines to the generating station. In general bituminous coal or brown coal is used as fuel. The coal is stored in either 'dead storage' or in 'live storage'. Dead storage is generally 40 days backup coal storage which is used when coal supply is unavailable. Live storage is a raw coal bunker in boiler house. The coal is cleaned in a magnetic cleaner to filter out if any iron particles are present which may cause wear and tear in the equipment.

The coal from live storage is first crushed in small particles and then taken into pulveriser to make it in powdered form. Fine powdered coal undergoes complete combustion, and thus pulverized coal improves efficiency of the boiler. The ash produced after the combustion of coal is taken out of the boiler furnace and then properly disposed. Periodic removal of ash from the boiler furnace is necessary for the proper combustion.

Boiler. The mixture of pulverized coal and air (usually preheated air) is taken into boiler and then burnt in the combustion zone. On ignition of fuel a large fireball is formed at the centre of the boiler and large amount of heat energy is radiated from it. The heat energy is utilized to convert the water into steam at high temperature and pressure. Steel tubes run along the boiler walls in which water is converted in steam. The flue gases from the boiler make their way through super-heater, economizer, air preheater and finally get exhausted to the atmosphere from the chimney.

Super-heater. The super-heater tubes are hanged at the hottest part of the boiler. The saturated steam produced in the boiler tubes is superheated to about 540 °C in the super-heater. The superheated high pressure steam is then fed to the steam turbine.

Economizer. An economizer is essentially a feed water heater which heats the water before supplying to the boiler.

Air pre-heater. The primary air fan takes air from the atmosphere and it is then warmed in the air pre-heater. Pre-heated air is injected with coal in the boiler. The advantage of pre-heating the air is that it improves the coal combustion.

Steam turbine. High pressure super heated steam is fed to the steam turbine which causes turbine blades to rotate. Energy in the steam is converted into mechanical energy in the steam turbine which acts as the prime mover. The pressure and temperature of the steam falls to a lower value and it expands in volume as it passes through the turbine. The expanded low pressure steam is exhausted in the condenser.

Condenser. The exhausted steam is condensed in the condenser by means of cold water circulation. Here, the steam loses its pressure as well as temperature and it is converted back into water. Condensing is essential because, compressing a fluid which is in gaseous state requires a huge amount of energy with respect to the energy required in compressing liquid. Thus, condensing increases efficiency of the cycle.

Alternator. The steam turbine is coupled to an alternator. When the turbine rotates the alternator, electrical energy is generated. This generated electrical voltage is then stepped up with the help of a transformer and then transmitted where it is to be utilized.

Feed water pump. The condensed water is again fed to the boiler by a feed water pump. Some water may be lost during the cycle, which is suitably supplied from an external water source.

8.2.3. Nuclear Power station. The concepts of nuclear power generation are much similar to that of conventional steam power generation. The difference lies only in the steam generation part i.e. coal or oil burning furnace and the boiler are replaced by nuclear reactor and heat exchanger. Thus a nuclear power plant consists of a nuclear reactor (for heat generation) , heat exchanger(for converting water into steam by using the heat generated in nuclear reactor), steam turbine, alternator, condenser etc. The reactor and the cooling system have to be heavily shielded to eliminate radiation hazards.

The different methods of classifying Nuclear reactors are given below.

(a) On the basis of Neutron energy
- (i) Thermal reactors
- (ii) Fast reactors

(b) On the basis of fuel used
- (i) Natural uranium
- (ii) Enriched uranium

(c) On the basis of Moderator used
- (i) Graphite reactors
- (ii) Beryllium reactors
- (iii) Water (ordinary or heavy water) reactors

(d) On the basis of coolant used
- (i) Water (ordinary or heavy) cooled reactors
- (ii) Gas cooled reactors
- (iii) Liquid metal cooled reactors
- (iv) Organic liquid cooled reactors

(e) On the basis of type of core used
- (i) Homogeneous reactors
- (ii) Heterogeneous reactors

A typical layout of a Nuclear power plant and its basic components are as shown in the figure 8.3.

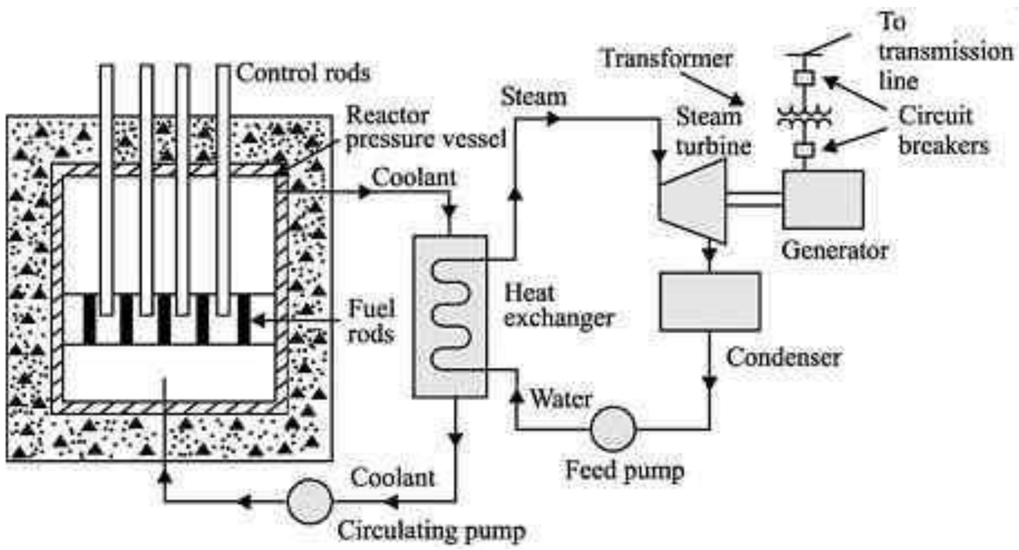


Figure.8.3. Layout of Nuclear power plant.

A Nuclear reactor consists of reactor core, moderator, reflector, thermal shielding, control rods, reactor vessel and coolant. Reactor core contains a number of fuel rods made of fissile material. The moderator material in the reactor core is provided to moderate, or reduce the neutron speeds to a value that increases the possibility of fission occurring. Reflector completely surrounds the reactor core within the thermal shielding arrangement and bounces back most of the neutrons that escape from the fuel core. This conserves the nuclear fuel, as the low speed neutrons thus returned are useful in continuing the chain reactor.

Thermal shielding is provided to prevent the reactor wall from getting heated. Coolant flows over the shielding to take away the heat. Control rods are meant for regulating the fission in the reactor by absorbing the excess neutrons and usually made of boron and are inserted into the reactor core from the top of the reactor vessel. Reactor vessel encloses the reactor core, reflector and the thermal shielding and provides the entrance and exit for the coolant and also the passage for its flow through and around the reactor core. Coolant is a medium through which heat generated in the reactor is transferred to the heat exchanger for further utilisation in power generation.

8.3. NON-CONVENTIONAL SOURCES OF ENERGY

8.3.1. Solar Power generation. Solar energy is harnessed by converting solar energy directly into electrical energy in solar plants. Photovoltaic technology converts sunlight directly into electricity. Photovoltaic cells often electrically connected and encapsulated as a module. When a group of modules are oriented in one plane is referred as a solar panel. Solar cells are usually connected in series in modules, creating for additional voltages and connected in parallel to yield higher currents. It gives non-polluting environment-friendly output and is available abundantly. The largest solar plant of India is located at Madhapur, near Bhuj, where solar energy is used to sterilise milk cans.

8.3.2. Biomass Power generation. Biomass is the organic matter that originates from plants, animals, wood, and sewage. Decomposition of organic matter yields gas, which has higher thermal efficiency in comparison to kerosene, dung cake and charcoal. Biogas plants are set up at municipal, cooperative and individual levels. The plants using cattle dung are known as 'Gobar gas plants' in rural India. The residue left after the removal of biogas is a good source of manure. Biomass energy is also applicable for cooking, lighting, and generation of electricity.

8.3.3. Wind Power generation. Wind energy describes the process by which wind is used to generate electricity. As the wind increases, power output increases up to the maximum output of the particular turbine. Wind farms prefer areas, where winds are stronger and constant. These are generally located at high altitudes. Wind turbines use wind to make electricity. There is no pollution because no fossil fuels are burnt to generate electricity. One of India's largest windmill farms is in Kanyakumari which generates 380mW of electricity.

8.4. SINGLE LINE DIAGRAM OF A POWER SYSTEM

An electric power system or electric grid is known as a large network of power generating plants which are connected to the consumer loads**.** The main components in a Power system are as shown in the figure 8.4.

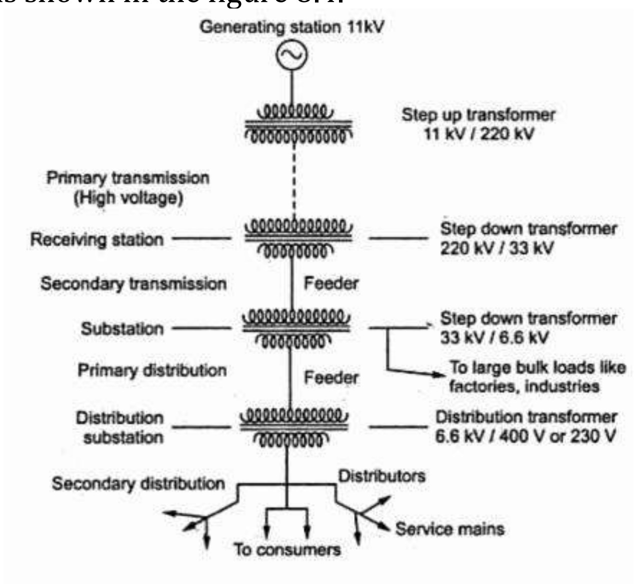


Figure.8.4. Single line diagram of Electrical power system.

Generating station. The place where electric power is produced by the parallel connected three phase alternators/generators is called a Generating Station. The generation voltage is usually 11kV and 33 KV.

Primary transmission. High voltages of the order of 66 kV 132 kV 220 kV and 400 kV are used for transmitting power by 3 phase 3 wire overhead system. This is supplied to substations usually at the out skirts of major distribution centre or city.

Secondary transmission. The primary voltage is reduced to low values of the order of 3.3 kV, 11 kV or 33 kV for secondary transmission.

Primary distribution. The transmission lines or inner connectors terminate at large main substations from which the power is distributed to small secondary substations scattered throughout the load area. The voltage may range from 11 kV to 132 kV.

Primary distribution. The transmission lines or inner connectors terminate at large main substations from which the power is distributed to small secondary substations scattered throughout the load area. The voltage may range from 11 kV to 132 kV.

Secondary distribution. This consists of the low-voltage network laid along the streets, localities and over the rural areas. From these sources connections to individual customers are provided. The circuit used for this is 3 phase 4 wire, 440 V/220 V from which either 3 – Φ, 440 V or 1 – Φ, 220 V supply to the consumers may be provided.

8.5. CLASSIFICATION OF SUBSTATIONS

The different methods of classifying Sub stations are given below.

(a) On the basis of design
- (i) Indoor type
- (ii) Outdoor type
- (iii) Pole mounted type
- (iv) Plinth mounted type

(b) On the basis of service rendered
- (i) Transformer substation
- (ii) Switching substation
- (iii) Converting substation
- (iv) Frequency changer substation
- (v) Power factor correction substation

(c) On the basis of application
- (i) Step-up or Primary substation
- (ii) Primary grid substation
- (iii) Secondary substation
- (iv) Step down or Distribution substation
- (v) Bulk supply and Industrial substation
- (vi) Mining substation
- (vii) Mobile substation

(d) On the basis of operating voltage
- (i) High voltage substations
- (ii) Extra high voltage substations
- (iii) Ultra high voltage substations
- (iv) HVDC substations

(e) On the basis insulation type
- (i) Natural Air
- (ii) SF6 Gas

8.6. TRANSFORMER SUB STATIONS

A Substation is a power transformer with termination equipment for cable and overhead lines. The Distribution Transformer may be mounted on a single pole, H pole structure or on a plinth depending upon site requirements, size and weight of the transformer. The decision for installation of a Pole mounted or Plinth mounted distribution transformer substation is based on the capacity and availability of space. Distribution transformers above 500 KVA have necessarily to be mounted on a plinth and of capacity less than 500 KVA may be mounted on single pole, double pole, 4 pole or on a plinth based on the size of distribution transformer, space available.

8.6.1. Pole mounted substation.

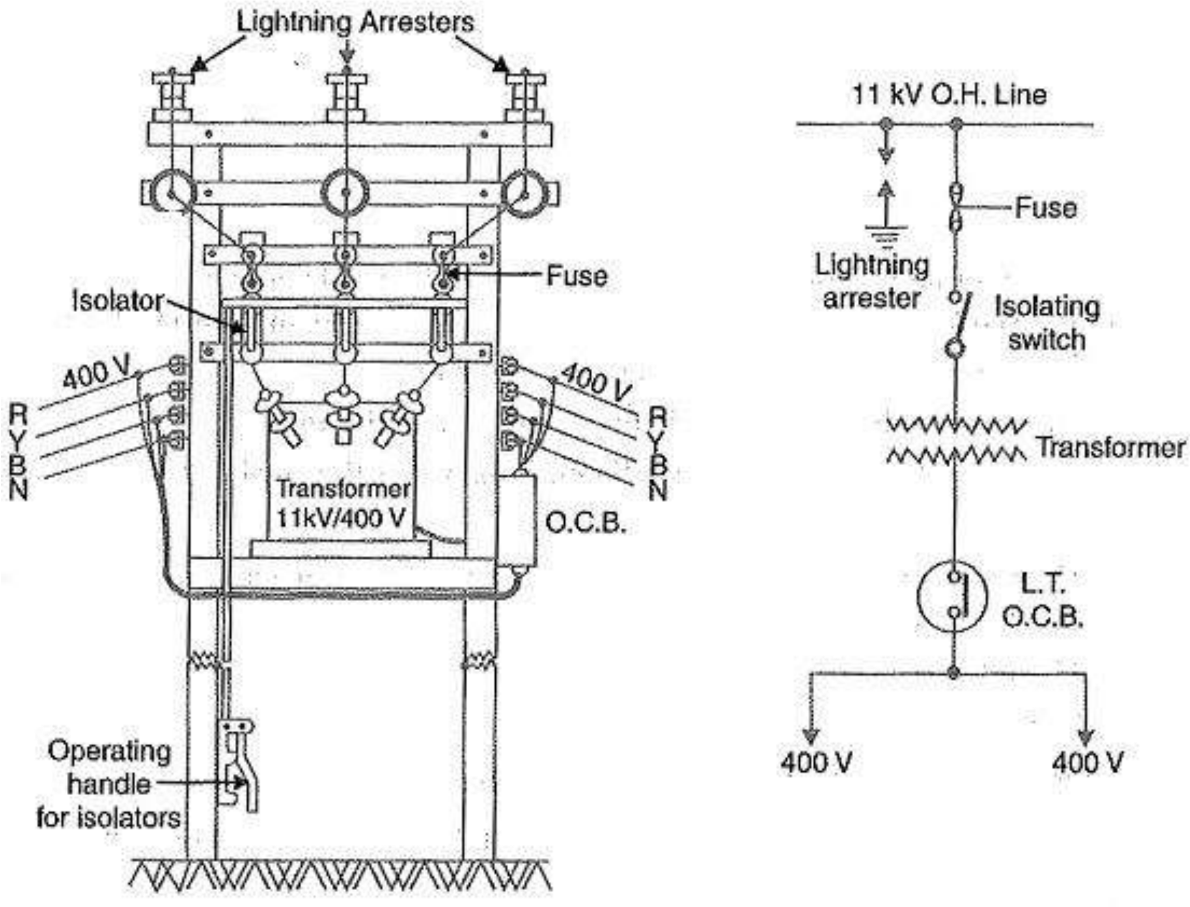


Figure.8.5. Layout and schematic connections of Pole mounted substation.

A single phase distribution transformer up to 25 KVA are installed on single pole/2 pole structure and 3 Phase distribution transformer up to 500 KVA are mounted on 2 pole or 4 pole structure or on plinth. The two poles structure is made of poles with channels and associated accessories creating an H type pole configuration to locate the distribution transformer at certain minimum height from the ground level to meet the ground clearance. The layout of Pole mounted substation and its basic components are as shown in the figure 8.5.

This arrangement of pole type substation needs about 3 meters by 2 meters space (on ground) around the H Pole structure to locate Distribution box and other accessibility. This area is to be provided with suitable fencing and lockable doors to prevent unauthorized access to Distribution box. The structures should also be provided with anti-climbing devices and danger board.

8.6.2. Plinth mounted substation. The distribution transformer above 500 KVA have necessarily to be mounted on a plinth which is a low height platform normally made of concrete structure. It can also be prefabricated by fibre blocks on which the transformers can be mounted. The Plinth should be capable to carry the weight of the distribution transformer and should also have the facility for cable entry and exit at two sides as per the terminals available at the transformer

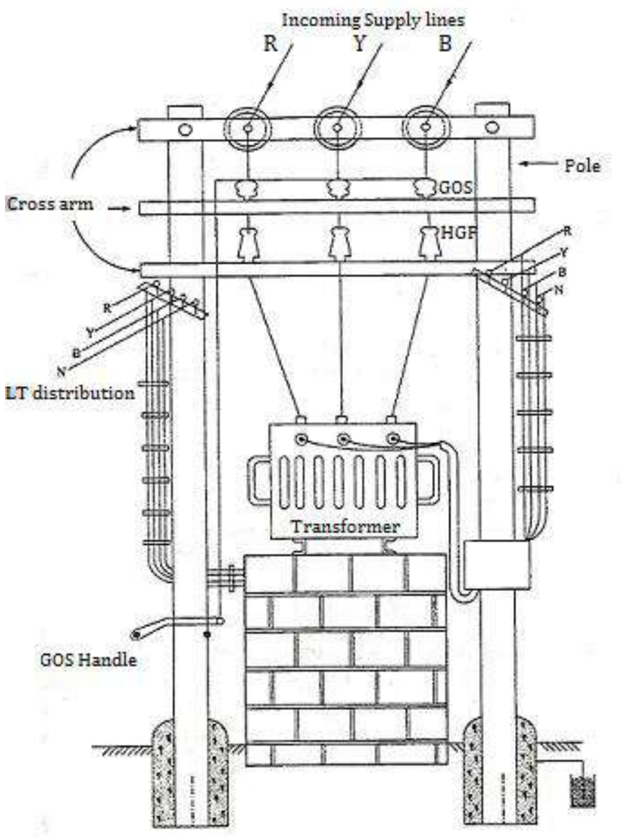


Figure.8.6. Layout and schematic connections of Pole mounted substation.

The layout of Pole mounted substation and its basic components are as shown in the figure 8.6. The plinth shall be higher than the surroundings. Plinth mounted distribution sub-stations should be adequately protected by fencing so as to prevent access to the equipment by unauthorized persons, animals and should be provided with standard danger boards. The enclosure should also permit free circulation of air on all sides. This substation can be indoor type or outdoor type and the rating of transformer may normally be more than 250KVA to 1000KVA depending on load requirement in the localities and also for economic reasons as this needs control gears/ switchgears and proper enclosed wall boundary.

8.7. EQUIPMENT IN OVER HEAD LINES

The main components of an overhead line are the supports (poles or tower), cross arms and clamps, insulators, conductors, Guys and stays, lightening arresters, fuses and isolating switches, phase plates, continuous earth wire, vee guards, guard wires, bird guards, barbed wire, danger plates, beads for jumpers, vibration dampers.

8.7.1. Line Supports. The supports used for transmission and distribution of electrical power must have the characteristics like – high mechanical strength, light in weight, low initial as well as maintenance cost, longer life, good looking and easily accessible for painting and erection of line conductors. Wood, steel, reinforced concrete poles and lattice steel towers are generally used for this purpose.

8.7.2. Conductor materials. The conductor materials used for transmission and distribution of electrical power should have the characteristics like – high conductivity, high tensile strength in order to withstand mechanical stresses, low specific gravity (low weight per unit volume), low cost and no brittleness. Copper, aluminium, steel, ACSR and galvanised steel conductors are generally used for this purpose.

Span – The distance between two successive poles.
Sag – The difference in level between the points of supports and the lowest point. Sag of a conductor suspended between two equal level supports is given by expression,

$$S = (wL^2/8T)$$

8.7.3. Over head insulators. The conductors of an over head transmission (or distribution) lines are secured to the supporting structures by means of insulating fixtures in order that there is no current leakage to the earth through the supports. They should have the characteristics like – high mechanical strength, high relative permittivity, high dielectric strength, high insulation resistance and high ratio of rupture strength to the flash over voltage. Pin type insulators, Suspension type insulators, Strain insulators, Shackle insulators and Egg or Stay insulators are generally used for various voltage levels.

8.7.4. Lightening Arresters. A surge diverter/Lightening arrester is connected between the line and earth to divert the high voltage wave to earth. The choice of lightening arresters depends upon – voltage of the line, frequency of lightning, cost, weather conditions and reliability. Rood gap Arresters, Horn gap Arresters, Electrolyte Arresters, Oxide film arresters, Thyrite arresters, Expulsion type arresters, Valve type arresters are generally used to protect the power system.

8.8. EQUIPMENT IN SUB STATION

The main equipments required for substations and switchgear installations are main bus-bars, insulators, isolators, circuit breakers, load interrupter switches, fuses, power transformers, instrument transformers (CTs and PTs), indicating and metering instruments, protective relays, control cables and carrier-current equipment.

8.8.1. Bus-bar arrangement. The aim of bus-bar arrangements is to achieve adequate operating flexibility, sufficient reliability and minimum cost. Single bus-bar arrangement, Single bus-bar system with sectionalisation, Duplicate bus-bar system, Double main and transfer bus-bar arrangement are various bus-bar arrangements used.

8.8.2. Fuse. Fuse is essentially a short piece of metal (or a fusible material) inserted in a circuit which melts when a predetermined value of current flows through it and thus breaks the circuit. The suitable material for the fuse element must have a low melting point material such as tin, lead or zinc. Fuses may be low voltage type or high voltage type. Low voltage fuses can be further sub-divided into two classes namely the semi-enclosed rewireable fuses and HRC cartridge type fuses. High voltage fuses can be further sub-divided into two classes namely the cartridge type and Liquid type fuses.

8.8.3. Circuit Breakers. Circuit Breakers are mechanical devices designed to close or open contact members, thus closing or opening an electric circuit under normal or abnormal conditions. They carry the full load current continuously without overheating, open and close the circuit on no load, makes and breaks the normal operating current and also makes and breaks the short circuit currents of designed magnitude. Oil circuit breakers, low voltage air circuit breakers, air blast circuit breakers, vacuum circuit breakers and SF_6 circuit breakers are generally used to protect the power system.

8.8.4. Switches. A switch is a device for making or breaking the electric circuit. Switches are classified into Air switches and Oil switches. Air switches are further classified into Air-break switches and isolators.

8.8.5. Bushings. Bushes are necessary to take out live conductor through earthed tanks or metallic parts. The bushings are necessary for transformers, reactors, bulk oil circuit breakers, metal clad switch gear, generators etc. The central conductor is in the form of a copper rod or stranded conductor, passing through brass tube or aluminium tube supporting the bushing core. The bushing assembly is held in position by lock nuts. The bushings are filled with electric insulating oil. The bushings are designed for vertical upright mounting or horizontal mounting.

8.8.6. Instrument transformer. Instrument transformers are used in AC system for measurement of electrical quantities i.e. voltage, current, power, energy, power factor, frequency. They are also used with protective relays for protection of power system. They transform high currents and voltages to standardized low and easily measurable values that are isolated from the high voltage. When used for metering purposes, they provide voltage or current signals with accurate representation of the transmission line values in both magnitude and phase. There are two types of instrument transformers namely potential transformer (PT) and current transformer (CT).

ELECTRICAL TECHNICIAN

Intermediate 2nd Year

ELECTRICAL MACHINES & POWER SYSTEMS

Questionnaire (Chapter-wise)

Chapter – 1

Short Answer Questions

1. Write the emf equation of a DC Generator.
2. Write the Faradays laws of Electromagnetic induction.
3. What is a commutator?
4. Write the various types of losses in DC Generators.
5. List the applications of various DC Generators.

Long Answer Questions

1. Compare Lap winding with wave winding in any six aspects.
2. List various reasons for failure to build up voltage in a self excited generator.

Chapter – 2

Short Answer Questions

1. Define Fleming's left hand rule.
2. Write the emf equation of a DC Motor.
3. What is the necessity of a starter in DC motor?
4. Write the various types of starters used in DC motor.
5. Write the equation for % speed regulation in DC motor.
6. List the applications of various DC Motors.

Long Answer Questions

1. Explain the three point starter with a neat sketch.
2. Explain the four point starter with a neat sketch.

Chapter – 3

Short Answer Questions

1. Draw the different waveforms in AC circuits.
2. Define Form factor of an alternating quantity
3. Define Peak factor of an alternating quantity
4. Define RMS vale of an alternating quantity
5. Define Average value of an alternating quantity

Long Answer Questions

1. Compare Single phase system with three phase system in any six aspects.
2. Write the voltage and current relations in star and delta connection.
3. Calculate the current, Power factor and Power in the following RLC series circuit with R = 6 ohms, X_C = 4 ohms and X_L = 12 ohms.

Chapter – 4

Short Answer Questions

1. Write the emf equation of a transformer.
2. What is transformation ratio?
3. List the various types of special transformers.
4. What are the losses in a Transformer?
5. Name the types of cooling systems in a Transformer.

Long Answer Questions

1. Compare Core type with Shell type transformer in any six aspects.
2. Write a short note on instrument transformers with a neat sketch.
3. Explain the welding transformer with a neat sketch.
4. Write a short note on auto transformer with a neat sketch.

Chapter – 5

Short Answer Questions

1. Write the relation between speed and frequency in an alternator.
2. Write the emf equation of an alternator.
3. List the application of alternators.

Long Answer Questions

1. (a) Write a short note on rotor construction of an alternator with a neat sketch.
   (b) Calculate the Speed and Phase voltage of a 4-pole, 3-phase, 50 Hz, star connected alternator. Take form factor, $k_f = 1.11$, coil span factor, $k_c = 1$, distribution factor, $k_d = 0.96$, turns/phase = 180 and flux per pole, $\Phi = 0.05$ Wb.

Chapter – 6

Short Answer Questions

1. Define Slip.
2. Write the types of AC motors on the basis of construction.
3. List the types of AC motors on the basis of speed.
4. Write the applications of Slip ring motors?
5. Name the various types of starters used in three phase induction motors.

Long Answer Questions

1. Explain the DOL starter with a neat sketch.
2. Explain the Star-Delta starter with a neat sketch.
3. Explain the Auto transformer with a neat sketch.
4. Explain the Rotor-resistance starter with a neat sketch.

Chapter – 7

Short Answer Questions

1. List the types of single phase induction motors.
2. List the types of single phase commutator motors
3. Write the various configurations of Transistor.

Long Answer Questions

1. Write a short note on resistance start split phase motor with a neat sketch.
2. Write a short note on capacitor start split phase motor with a neat sketch.
3. Write a short note on permanent capacitor motor with a neat sketch.
4. Write a short note on capacitor start and run motor with a neat sketch.
5. Write a short note on shaded pole motor with a neat sketch.
6. Write a short note on reluctance start motor with a neat sketch.

Chapter – 8

Short Answer Questions

1. Give the classification of Hydro electric power plants.
2. Write the different circuits in a thermal plant.
3. Give the types of Nuclear reactors on the basis of coolant.
4. Draw the single line diagram of an Electric power system.
5. Name the types of Sub Stations on the basis of services rendered.
6. Define Span and Sag.
7. Write the types of Lightning arresters.
8. List the types of Over head insulators.
9. Write the types of line supports used in transmission and distribution.
10. Write the properties of conductor materials used in a power system.

Long Answer Questions

1. Write a short note on Plinth mounted transformer with a neat sketch.
2. Write a short note on Pole mounted transformer with a neat sketch.
3. Write a short note on Hydro power plant with a neat sketch.
4. Write a short note on Thermal power plant with a neat sketch.
5. Write a short note on Nuclear power plant with a neat sketch.
6. (a) Explain about solar power generation in brief.
   (b) Explain about wind power generation in brief.

Solved Problems (Chapter-wise)

Chapter – 1 :: DC Generators

1. An eight-pole DC generator has 500 armature conductors, and a useful flux of 0.05 Wb per pole. What will be the emf generated if it is a lap-connected and runs at 1200 rpm.

Sol. With lap-winding, P = A = 8
Here, $\Phi = 0.05$, Z = 500, N = 1200, P = 8, A = 8
$E = (\Phi\ Z\ N/60) \times (P/A) = (0.05 \times 500 \times 1200/60) \times (8/8) = 500$ Volts.

2. An four-pole DC generator has 51 slots each slot containing 20 conductors, and a useful flux of 7 mWb per pole. What will be the emf generated if it is a wave-connected and runs at 1500 rpm.

Sol. With wave-winding, A = 2
Here, $\Phi = 7 \times 10^{-3}$, Z = 51x20 = 1020, N = 1500, P = 4, A = 2
$E = (\Phi\ Z\ N/60) \times (P/A) = (7 \times 10^{-3} \times 1020 \times 1500/60) \times (4/2) = 357$ Volts.

3. The armature of a four pole DC shunt generator is lap-wound and generates 216 Volts when running at 600 rpm. Armature has 144 slots, with 6 conductors per slot. If the armature is rewound, wave connected, find the emf generated with the same flux per pole but running at 500 rpm.

Sol. Total number of armature conductors, Z = 144 x 6 = 864
For a Lap winding, the number of parallel paths in armature, A = number of poles, P
$E = (\Phi\ Z\ N/60) \times (P/A) \Leftrightarrow 216 = (\Phi \times 864 \times 600/60) \Leftrightarrow \Phi = 25$ mWb.
Hence if the armature is rewound with wave connection, number of parallel paths = 2
Therefore, at 500 rpm, with 25 mWb as the flux per pole
Armature emf = $(25 \times 10^{-3} \times 864 \times 500/60) \times (4/2) = 360$ Volts.

Chapter – 2 :: DC Motors

1. A DC motor connected to a 460 Volts supply takes an armature current of 120 Amps on full load. If the armature circuit has a resistance of 0.25 Ohms, Calculate the value of back emf at this load.

Sol. Here I_a = 120 Amps, V = 460 Volts, R_a = 0.25 Ohms
Therefore, Back emf, $E_b = V - I_a R_a = 460 - (120 \times 0.25) = 430$ Volts.

2. A DC motor connected to a 460 Volts supply has an armature resistance of 0.15 Ohms. Calculate (a) back emf when the armature current is 120 Amps. (b) Armature current when the back emf is 447.4 Volts.

Sol. (a) Here I_a = 120 Amps, V = 460 Volts, R_a = 0.15 Ohms
Therefore, Back emf, $E_b = V - I_a R_a = 460 - (120 \times 0.15) = 442$ Volts.

(b) Here Eb = 447.4 Volts, V = 460 Volts, R_a = 0.15 Ohms
Since, $E_b = V - I_a R_a \Leftrightarrow Ia = (V - E_b)/R_a = (460-447.4)/0.15 = 84$ Amps
Therefore, Armature current, I_a = 84 Amps.

3. A 4-pole, 240 V, wave connected shunt motor gives 11190 W when running at 1000 rpm and drawing armature and field currents of 50 A and 1.0 A respectively. Assuming drop of 1 volt/brush. Its resistance is 0.1Ohms. It has 540 conductors. Find (a) total torque (b) useful torque (c) useful flux/pole (d) rotational losses (e) efficiency.

Sol. Here, $V = 240$ Volts, $I_a = 50$ Amps, $I_f = 1$ Amp, $R_a = 0.1$ Ohms,
Then, $E_b = V - I_a R_a$ – Brush drop = 240 – (50 x 0.1) – 2 = 233 Volts.
(a) Armature Torque, $T_a = 9.55 \times (E_b I_a / N) = 9.55 \times (233 \times 50/1000) = 111.3$ N-m

(b) Shaft Torque, Tsh = 9.55 x (Output/N) = 9.55 x (11190/1000) = 106.9 N-m

(c) Back emf, $E_b = (\Phi Z N/60) \times (P/A) \Leftrightarrow 233 = (\Phi \times 540 \times 1000/60) \times (4/2)$
$\Leftrightarrow$ Useful flux/Pole, $\Phi = 25$ mWb.

(d) Armature input = $V I_a$ = 240x50 = 12,000 Watts.
Armature Copper loss = $I_a^2 R_a = 50^2 \times 0.1 = 250$ Watts
Brush Contact Loss = 50x2 = 100 Watts
Therefore, power developed = 12000 – 350 = 11,650 Watts
Rotational Losses = Power developed – Output = 11650 – 11190 = 460 Watts
Therefore, Rotational Losses = 460 Watts

(e) Total motor input = VI = 240x51 = 12,340 Watts
Motor output = 11,190 Watts
Efficiency, $\eta = (11190/12340) \times 100 = 91.4$ %.

Chapter – 3 :: AC Fundamentals

1. A RLC series circuit has following components, R = 50 Ohms, L = 0.15 Henry, C = 25 μF Ohms, Voltage = 230 Volts, Frequency, f = 50 Hertz. Find (a) Impedance (b) the Current (c) Power factor (d) Power in the circuit.

Sol. We know that Current, I = V/Z, Power factor, $\cos\theta = R/Z$, Power, $P = VI\cos\theta$ and $Z = \sqrt{[R^2 + (X_L - X_C)^2]}$

(a) $X_L = 2\pi fL = 2 \times 3.142 \times 50 \times 0.15 = 47.12$ Ohms
$X_C = 1/2\pi fC = 1/(2 \times 3.1412 \times 50 \times 25 \times 10^{-6}) = 127.34$ Ohms

(b)Impedance, $Z = \sqrt{[50^2 + (47.12 - 127.34)^2]} = \sqrt{[2500 + 6435.24]} = \sqrt{8935.24} = 94.53$
Impedance, Z = 94.53 Ohms

(c)Current, I = V/Z = 230/94.53 = 2.43 Amps

(d) Power factor, $\cos\theta = R/Z = 50/94.53 = 0.53$

(e) Power, $P = VI\cos\theta = 230 \times 2.43 \times 0.53 = 296.22$ Watts.

2. A RLC series circuit has the following components, R = 6 Ohms, $X_L = 12$ Ohms, $X_C = 4$ Ohms, Voltage = 200 Volts, Frequency, f = 50 Hertz. Find (a) the Current (b) Power factor (c) Power in the circuit.

Sol. We know that Impedance, $Z = \sqrt{[R^2 + (X_L - X_C)^2]}$

(a) Impedance, $Z = \sqrt{[6^2 + (12 - 4)^2]} = \sqrt{[36 + (64)]} = \sqrt{100} = 10$ Ohms
Current, I = V/Z = 200/10 = 20 Amps
(b) Power factor, $\cos\theta = R/Z = 6/10 = 0.6$

(c) Power, $P = VI\cos\theta = 200 \times 20 \times 0.6 = 2400$ Watts.

Chapter – 5 :: Alternators

1. Calculate the speed and phase voltage of three phase, 4-pole, 50 Hz, star connected alternator. Take form factor as1.11, coil span factor as 1, distribution factor as0.96, turns per phase as 180, useful flux per pole as 0.05 Wb.

Sol. Here,
Kf = 1.11, kc = 1, kd = 0.96, f = 50 Hz, Poles, P = 4
Total conductors, Z = 2T = 2x180 = 360
Synchronous Speed, Ns = 120xf/P = 120x50/4 = 1500 rpm
Voltage, Eph = 2 kf kc kd Φ f Z = 2x1.11x1.0.96x0.05x50x360 = 1918 Volts.

2. A three phase, 16 pole alternator has a star connected winding with 144 slots and 10 conductors/slot. The flux/pole is 0.03 Wb, sinusoidally distributed and the speed is 375 rpm. Find the frequency rpm and the phase and line emf. Assume full-pitched coil.

Sol. Frequency, f = PN/120 = 16x375/120 = 50 Hertz.
Since, k_c is not given, it is assumed as unity.
n = 144/16 = 9
β = 180°/9 = 20°
m = 1414/16 = 3
k_d = (Sin m β/2)/(m Sin β/2) = [sin 3x(20°/2)] / [3 Sin (20°/2)] = 0.96
Z = 144x10/3 = 480 and T = 480/2 = 240
Phase voltage, E_{Ph} = 4.44x1x0.96x50x0.03x240 = 1534.5 Volts
Line voltage, $E_L = \sqrt{3}\, E_{Ph}$ = x1534.5 = 2658 Volts

Chapter – 6 :: Three Phase induction motors

1. A 4 Pole three phase induction motor operates from a supply whose frequency is 50 Hertz. Calculate (a) the speed at which the magnetic field of the stator is rotating (b) the speed of the rotor when the slip is 0.04. (c) the frequency of the rotor currents when the slip is 0.03. (d) the frequency of the rotor current at stand still.

Sol. (a) Stator speed revolves at Synchronous speed, Ns = 120xf/P = 120x50/4 = 1500 rpm
(b) Rotor or motor speed, N = Ns(1 – S) = 1500 (1 – 0.04) = 1440 rpm.
(c) Frequency or rotor current, $\frac{f'}{f} = \frac{(Ns - N)}{Ns} = S \Leftrightarrow f' = S\, f$ = 0.03x50 = 1.5 rps = 90 rpm
(d) Since at stand still, S =1 and f' = S f = 1x50 = 50 Hertz.

2. The stator of a three phase induction motor has 3 slots/pole/phase. If supply frequency is 50 Hz, Calculate (a) number of stator poles produced and total number of slots on the stator. (b) speed of the rotating stator flux.

Sol. (a) Here, P =2xn = 2x3 = 6 Poles.
Total no of slots = 3 slots/pole/phasex6 polesx3 phases = 54
(b) Ns = 120xf/P = 120x50/6 = 1000 rpm.

3. A Slip ring induction motor runs at 290 rpm at full load, when connected to 50 Hertz supply. Determine the number of Poles and Slip.

Sol. Assuming Ns to be nearer and greater to the rotor speed, as N = 290 rpm
Let Ns = 300 rpm, Since Ns = (120xf)/ P ⇔ 300 = (120x50)/P ⇔ P = 20
% Slip, $S = \frac{(Ns - N)}{Ns} \times 100 = \frac{(300 - 290)}{300} \times 100 = 3.33\ \%$.

ELECTRICAL TECHNICIAN

PAPER II

DOMESTIC APPLIANCES AND REWINDING

INDEX

Introduction to Domestic Appliances

1.1 Classification of Electrical Domestic Appliances

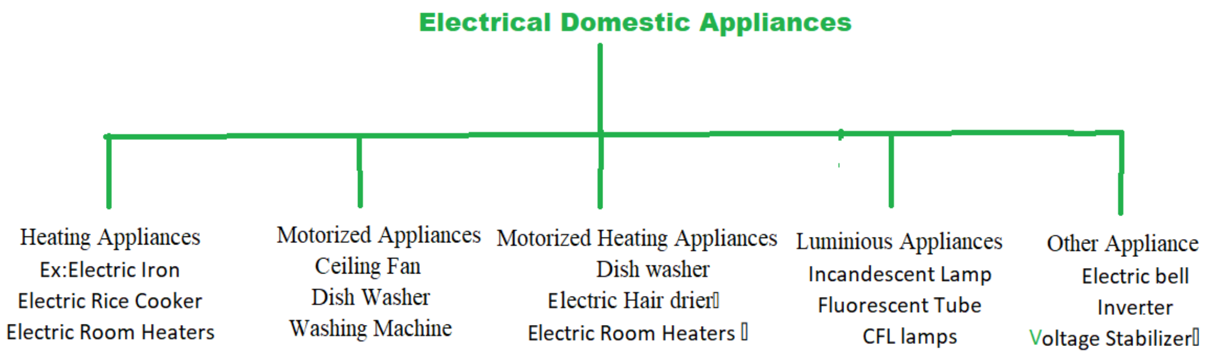
Electricity is one of the most important blessings that science has given to mankind. It has also become a part of modern life and one cannot think of a world without it. Electricity has many uses in our day to day life. It is used for lighting rooms, working fans and domestic appliances like using electric stoves, A/C and more. All these provide comfort to people. In factories, large machines are worked with the help of electricity. Essential items like food, cloth, paper and many other things are the product of electricity. These Appliances are named as **Electrical Domestic Appliances**

The significant role played by a number of electrical appliances in our daily lives is quite undeniable. Man is undoubtedly dependent on different types of home and kitchen appliances likefans, Coolers, air conditioners,CFL lamps, LED lights LCD TVs, heaters, vacuum cleaners, coolers mixer grinder, juicers, toasters, bun warmers, electric hot plate and so forth.

Electrical Domestic Appliances

Domestic Appliances can be classified on the working principle

1. Heating Appliances
2. Motorized Appliances
3. Motorized Heating Appliances
4. Luminous Appliances
5. Other Appliance



Heating Appliances

Electric heating is a process in which electrical energy is converted to heat energy. Common applications include space heating, cooking, water heating and industrial processes. An **electric heater** is an electrical device that converts an electric current into heat. The heating element inside every electric heater is an electrical resistor, and works on the principle of Joule heating: an electric current passing through a resistor will convert that electrical energy into heat energy. Most modern electric heating devices use nichrome wire as the active element; the heating element, depicted on the right, uses nichrome wire supported by ceramic insulators. A warning that these can go to very high temperatures and create excruciating burns

Alternatively, a heat pump uses an electric motor to drive a refrigeration cycle, that draws heat energy from a source such as the ground or outside air and directs that heat into the space to be warmed. Some systems can be reversed so that the interior space is cooled and the warm air is discharged outside or into the ground.

Motorized Appliances

All MOTOR-DRIVEN Appliances are named as **Motorized Appliances.** Motor is very important part ofMotorized Appliances.Motor appliances convert electrical energy into movement.This power cuts and blends foods, opens cans, grinds waste, picks up dirt, and moves air. A motor converts electrical energy into mechanical energy that rotates a shaft. The end of this shaft may have a blade or other attachment that does the actual work. Electric motors have found large use also in the household appliance industry, both for essential functions, as it happens in the washing machine case, where the electric motor is the core of the household appliance, and to carry out auxiliary functions, as in the case of fanned electric ovens. The same happens in refrigerators, in freezers and in the products for the environment conditioning, where the electric motor controls the operation of the compressor, which is the element on which depend all the performances of these household appliances, as it happens in kitchen suction hoods.

Same importance, finally, is hold by electric motors in a broad number of small household appliances, both for their use in kitchen, like food processors, mixers and juicers and in cleaning products, vacuum cleaners, electric brooms and steam appliances, as well as small appliances for shaving, epilation, massage and, more in general, the body care. In all these products, often the electric motor does not represent the most expensive component but it often constitutes their most critical element

Motorized Heating Appliances [Combination Appliances]

Some Heating Appliances includes motors for various purposes. Such appliances are called as Motorized Heating Appliances. These combination appliances have both heat and move. The most popular is the Vacuum Cleaners, Hair Driers, Dish Washers, Room Heaters stirring popcorn poppers, electric bread maker. It mixes dough, then bakes it into bread.

Luminous Appliances

The Appliances which produce illumination by using Electrical Energy are termed as **Electrical Luminous Appliances.**Without light during the night, you won’t be able to see. When you can’t see, you can’t work, you can’t continue on with most of your chores. That would be more than 4 hours lost every day.

An electric light is a device that produces visible light from electric current. It is the most common form of artificial lighting and is essential to modern society, providing interior lighting for buildings and exterior light for evening and night-time activities.

Luminaire or Luminaries provide support and electrical connection to Lamp or Lamps within it. They control, distribute and direct the Light on to the object. They ensure that lamps are operated in a way such that operating temperature is kept within prescribed limits. They should be easy to install and maintain, aesthetically pleasant and economically viable.

Other Appliance

Many more Appliances which are not included in the above category like Electric bell and Emergency Light/Rechargeable Torch, Voltage Stabilizer, UPS and Inverter etc. They work under different principles. Such appliances are categorised as Other Appliances

1.2.1General procedure for servicing

Appliances are an important part of any household. However, these appliances account for about one-fifth of your household's energy consumption. Among all the household electrical appliances, refrigerators, clothes washers, and dryers use the most energy. Different household appliances use different amounts of energy depending upon their efficiency.There are several factors that affect the energy consumption of different appliances. For example, a water heater having improper insulation is less efficient and will use more energy than one with proper insulation. In the same way, a clothes washer in an open location is likely to use more electricity than one located inside the home.

The age of the appliance is an important factor that affects the amount of energy consumption. If you are using a 12-year-old refrigerator, chances are that you are paying more for electricity consumption. If you have purchased a refrigerator within last five years, it is likely to be more energy efficient as most of the newer appliances are becoming more energy efficient in general. In addition, the model and brand of the appliance also decides the energy usage.

When looking to answer this question, keep in mind that every appliance that is plugged in consumes energy. Several appliances consume energy even if they are not "turned on." For example, TVs, computers, VCRs, and other electronic devices use energy when they are in standby mode, albeit a lower amount. Even your mobile charger for your phone or iPod consumes about 4 watts of electricity per hour.

Electrical Power is measured in kilowatts. One kilowatt means 1000 watts, and one thousand watt-hours mean one kilowatt-hour (1kwh) or one kilowatt used over one hour. Your utility bills show kilowatt-hour usage. Let us see how much electricity a typical appliance uses (in watts per hour):

- Electric clothes dryer: 6000 watts
- Cloth washer: 425 Watts
- Refrigerator: 188 watts
- Dishwasher: 200 watts
- Central AC: 6000 watts
- Window AC: 1300 watts
- Flat screen TV: 150 watts
- LCD TV: 213 watts
- Vacuum: 1100 watts
- Humidifier: 90 watts
- Freezer: 273 Watts
- Water heater: 473 Watts
- Toaster oven: 1200 watts
- Heat pump: 5000 watts
- Ceiling fan: 60 watts
- Coffeemaker: 1200 watts
- Blender: 300 watts
- Mixer: 200 watts
- Iron: 1000 watts
- Toaster: 1000 watts
- Computer:95 watts
- DVD player: 25 watts
- VCR: 11 Watts
- Electric blanket: 250 watts

- Cable Box: 20 watts
- Laptop: 50 watts
- PC monitor: 150 watts

Servicing and Maintenance of Home Appliances

Refrigerators and washing machines are an essential part of our daily routine. People find much comfort in washing their clothes at home than giving them away at the laundry houses where clothes are often not dealt with reasonable care. These have become an essential and an important aspect of modern living. It is nearly impossible to find a home which does not use a washing machine or a refrigerator. Even small apartments have these appliances for carrying out their routine activities. Finding a home without refrigerators is nearly impossible. Likewise, heat systems and heat pumps become an essential part of the house during the winter season. In winter, people prevent themselves from the cold and low temperatures by enjoying the heat of these systems. These systems are specially installed in houses to provide a central heating.

Common Problems:

Sometimes most of the households experience some interruptions and malfunctions of service at some point in their lifespan. These appliances face many challenges such as much leakage, electric disorders, burned out switches, dusty and molded ducts, etc. Refrigerators mostly run out of certain oils and lubricants. Their condenser coils get dirty and molded. Likewise, in washers, the faults in timers is the most common problem faced. Much wear and tear take their tolls on the agitator, motor, and timers of these machines. Heat systems face same problems as much of the air conditioning, and air duct systems face.

Assistance and Services:

Many of the daily used appliances encounter a lot of repair and maintenance problems. These may arise due to various reasons which are responsible for decreasing the overall efficiency and lifespan of our appliances. Appliances including heat pumps, heating systems, refrigerators, and washers need a proper repair and maintenance at regular intervals so that your systems keep on running efficiently. Some of the methods include:

* Checking loose fittings
* Checking internal parts for any damages
* Examining external parts and outer coverings for cracks and damages
* Lubricating parts where necessary
* Adjusting and fitting thermostats for heating systems
* Cleaning the condenser coils for refrigerators
* Replacing waterproof switches and wires for washers

Benefits of Servicing:

Repairing the appliances is far better than replacing and using new systems. Improving and maintaining your appliances at regular intervals can speed up the performance, lifespan, and activity of your households. These little steps can go a long way in saving our money. Periodic maintenance would help you lowering your monthly bills, provide comfort and much reliability of your households. Such repairing can prevent many costly breakdowns, makes your home more efficient, extend life of appliances, save energy and improve the overall efficiency of your home appliances

Energy conservation while using kitchen appliances

- Dry grinding of food in mixers and grinders takes longer time than liquid grinding.
- Microwaves ovens consume 50 % less energy than conventional electric / gas stoves.
- Electric stoves can be turned off several minutes before the specified cooking time.
- Flat-bottomed pans that make full contact with the cooking coil reduce loss of heat.
- Pressure cookers should be used as much as possible
- Refrigerated items like vegetables, milk, meat etc. should be brought to room temperature before heating / cooking.
- Solar Water Heaters can be used to replace electric water heaters / fuel based heating systems.

Tips to conserve energy during use of household electronic devices

- When devices like TV, Computers and Audio Systems are not in use, the power should be switched off.
- If computers have to be left on, the monitor should be turned off.
- Screen savers on computer screens are not energy efficient. Shutting computers down when not using them reduces system wear and saves energy.
- Regularly defrosting manual-defrost refrigerators and freezers makes them more energy efficient.
- There should be enough space left between a refrigerator and the walls so that air can easily circulate between them.
- Refrigerator door seals should be airtight.
- A strange but true fact is that a full freezer uses less energy than an empty one. It is because, in an empty freezer, the cold air escapes and the warm air takes its place every time we open the door. The fridge has to work almost double the time to cool it again. Hence, its suggested that zip lock bags filled with water can be placed in the freezer. The stocked up ice will not allow the cool air to escape – so the fridge doesn’t have to work extra time and energy is saved. Moreover, the ice filled bags will keep the fridge cool during power cuts
- Avoid putting hot or warm food straight into the refrigerator.
- Washing machines should be used only with full loads.
- Air conditioners having automatic temperature cut off should be preferred.
- The ceiling fan should be operated in conjunction with the air conditioner to spread the cooled air more effectively throughout the room. The air conditioner can then be operated at a higher temperature.

- Doors and windows should be sealed properly.
- Planting trees or shrubs to shade air-conditioning units makes them use less electricity than the same one operating in the sun.

Do you waste more electricity by turning lights on and off?

While turning off lights saves energy generally, the answer about whether you waste more electricity by turning lights on and off is that it depends. Sometimes it can actually be cheaper to leave a light on rather than turn it off. It all depends, on the light bulb. Incandescent lights — assuming you still have any of these — are the easiest. If you're not using them, turn them off. They're the least efficient light and 90% of the energy they use is heat. Turning them off will also help cool a room in summer, which could potentially affect other energy costs as well, such as air conditioning.

Halogen lights should also be turned off when not in use. They use the same technology as incandescent lighting and are less efficient than CFL or LED bulbs.

Lighting savings get a little trickier with CFL or LED lights. weoffer this general rule of thumb for deciding if turning off CFL lights saves energy: Leave them on if you will return to a room within 15 minutes; if you're going to be gone for more than 15 minutes, turn them off. This strategy can also help extend the life of a CFL bulb because its operating life is more affected by the number of times it's switched on and off.

LED, or light emitting diode, bulbs are not affected at all by being turned on and off. This characteristic makes LED bulbs a top energy savings lighting choice. They're a great option, when used with sensors that rely on on-off operation. They also turn on at full brightness almost instantly.

Disassemble of Major Appliances

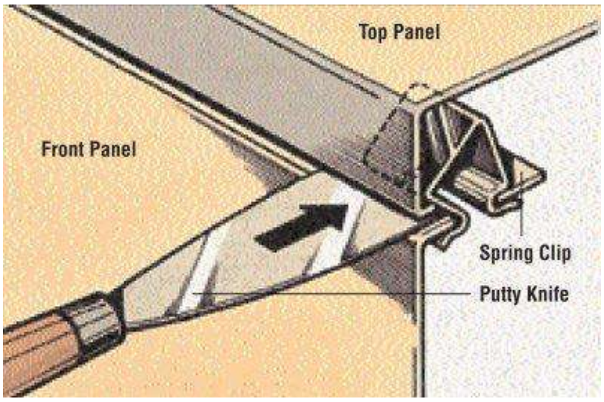


Fig 1.1Releasing the Spring clip

Before you can repair a major appliance, you'll have to disassemble all or part of it. All major appliances are different, but the disassembly procedure is about the same: Remove the parts in reverse of the way the manufacturer put them together. Check your owner's manual for assembly diagrams and instructions. Remember that you'll have to put the appliance back together again, so lay the parts out in the order in which you remove them, with fasteners in hand. If you aren't sure you'll be able to put the appliance back together, take notes and make drawings as you work. Label all terminals and wires if you must disconnect more than one wire at a time.

To disassemble a major appliance, start with the obvious knobs and fasteners. Many knobs and dials are push-fit. Simply pull them off their control shafts. Knobs may also be held in place by setscrews, springs or spring clips, or pins; or they may be screwed on. All of these types of fasteners are easy to release. Housing panels are usually held by screws or bolts. They may also be held in place by tabs. Sometimes, parts are force-fitted and may be hard to remove. Never force parts apart; look for hidden fasteners. For instance, there may be no obvious fasteners holding the top of a washer in place. However, you can locate the clips that hold the top of the washer down by sticking the blade of a putty knife into the seam where the top panel meets the side panel. Run the knife along the seam until you hit an obstruction; this is a spring clip. To release the clip, push the blade of the knife directly into the clip, at a right angle to the seam, while pushing up on the top panel. Repeat this procedure to locate and remove any other spring clips holding the top panel in place. Then lift the panel off.

Fasteners may also be hidden under a nameplate or company logo, behind a scarcely visible plastic plug, under a cork pad on the bottom of the appliance, or under an attachment plate. Carefully pry up the part that is hiding the fastener. When you reassemble the appliance, snap the concealing part back over the fastener, or, if necessary, glue it into place. If you can't find hidden fasteners on force-fitted parts, warm the parts gently with a heating pad; the heat may make disassembly easier. Inside the appliance, watch for clips holding parts to the housing panel.

Before reassembling a major appliance, carefully vacuum inside the appliance to remove all dust and lint. Check for other problems and make any necessary repairs or adjustments. If the appliance has a motor, lubricate the motor. Check carbon brushes in universal motors for wear and replace them if necessary. Lubricate moving parts sparingly and make sure electrical contacts are clean.

Reassemble the appliance in reverse of the way you took it apart. Never force parts together or overtighten fasteners. Make sure moving parts, such as armatures or gears, don't bind. After reassembly, connect the power and turn it on. If it makes noise, smells, or overheats, turn it off and disconnect the power. Then go back over your repair.

Grounding Systems

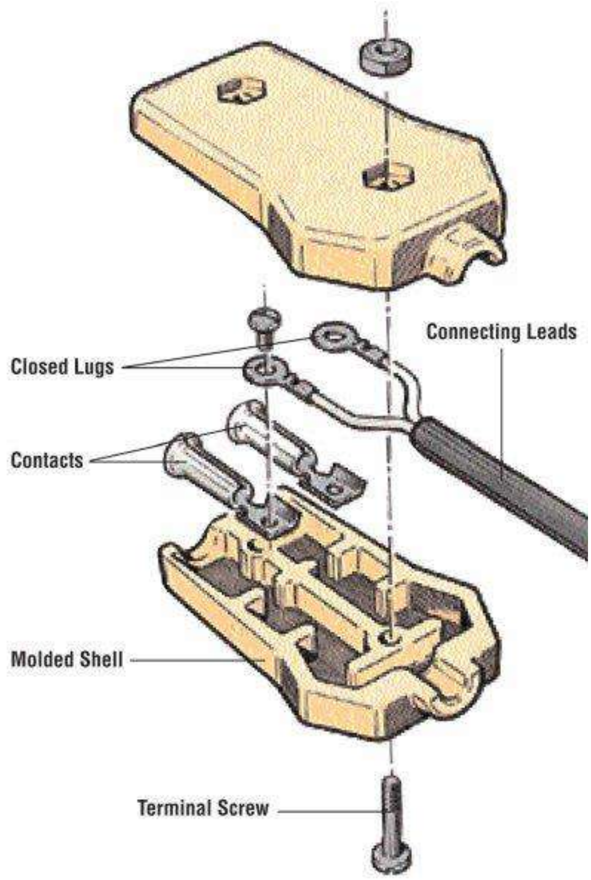
Many homes today are equipped with electrical outlets that have a three-wire system. The third wire is a grounding device and operates the same way as the grounding wire on stationary appliances. Large appliances, whose plugs have two blades and a prong, should be plugged into a grounded outlet or grounded with a special adapter plug. Caution: Never remove the prong from a three-wire plug to make it fit an ungrounded outlet; always use an adapter plug.

Proper grounding is vital for metal-framed appliances. If the insulation on the power cord of a metal-framed appliance (such as a washer or dryer) is broken or worn away at the point where the cord enters the frame, contact between the current conductor and the metal frame could charge the whole appliance with electricity. When this happens, dampness can cause a shock hazard even if the appliance is properly grounded. If you accidently touch a charged metal frame in a damp location or while touching a water faucet or radiator, the current would surge through you and could kill you.

There are three things you can do to eliminate this hazard. First, make sure your major appliances are properly grounded. Second, make sure that all appliance cords are in good repair, and that they are not chafing against burrs or rough spots where they enter the appliance frame. Third, add a ground-fault circuit interrupter (GFI or GFCI) to the circuit. GFIs are monitoring devices that instantly shut off a circuit when a current leak occurs. They are required by the National Electrical Code on all new 15-amp and 20-amp outdoor outlets and for wiring in bathrooms, where dampness is a common problem. GFIs are available to plug into existing outlets as adapters, to replace outlets, and to replace circuit breakers in the electrical entrance panel. A professional electrician should install the circuit-breaker type; you can install the other types yourself. Ground-fault circuit interrupters are available at electrical supply and home center stores.

Double-Insulated Appliances

In double-insulated appliances and power tools, the electrical components are isolated from any parts of the appliance that could carry electrical current. However, these appliances are not completely shock-safe. You should use caution with any electrical device. For example, never operate an electric drill while standing on a wet surface--and never drill into a wall where power lines may be present. Double-insulated appliances and tools should almost always be repaired by a professional, because the double insulation depends on a plastic housing and a plastic buffer between parts that carry electricity. If these plastic parts are not properly positioned, the appliance or tool could produce a harmful electrical shock. Appliances and tools that are double insulated are usually labelled as such.



Repairing Power Cords and Plugs

Major appliances have many components in common, making repairs easier. For example, once you've learned to repair a power cord on a refrigerator, you can apply the same skills to repairing a washing machine's power cord.

The following sections explain common devices that are used on major appliances and offers tips on how to repair them.

Power Cords and Plugs

Many appliance "breakdowns" are really due to worn, frayed power cords or plugs that no longer make proper electrical contact. To ensure safe operation, you should check all appliance cords for problems periodically and replace frayed or broken cords immediately. When you suspect a cord is faulty, remove it from the appliance and test it with a continuity tester. Clip the tester to one blade of the plug and touch the probe to one of the two wires -- or, if it's a plug-in cord, insert the probe into one of the two holes -- at the appliance end of the cord. If the tester lights or buzzes, move it to the other wire or hole and test again. Repeat this procedure to test the other blade of the plug. If the tester lights or buzzes at every test point, the cord is not faulty; if it fails to light or buzz at any point, the cord or the plug is faulty. You can pinpoint the defect by cutting ***Fig 1.2When a female plug malfunctions, open it and check the conductor wires. If the wires are loose, tighten the terminal screws. For other problems, replace the plug.***

off the plug and testing the cut end of the cord; if the tester lights or buzzes at all test points now, the plug is the defective part. The damaged component -- cord, plug, or both -- should be replaced.

Often, the hardest part of replacing an appliance cord is determining how the appliance comes apart so that you can remove the old cord and attach a new one. Sometimes all you have to do is remove the cover from a connection box. In other cases, as with a small hair dryer, the unit itself must be partially disassembled before you can reach the terminals. In nearly all cases, the cord is held in place by a clamp or by a fitted strain-relief device. To remove the cord, unscrew the terminal screws or pull the pressure connectors apart, loosen the clamp or remove the strain-relief device, and pull the cord out. Installation of the new cord is simply a reverse procedure. Be sure to save the strain-relief device and replace it on the new cord. If you damage the strain-relief device when you remove it, replace it with a new one of the same type.

In some equipment, the conductor ends are looped around terminal screws, making new connections easy. Carefully strip off the outer insulation (not the insulation on the inner wires) for about 2 inches at the end of the cord. Then, using a wire stripper, remove about 1/2 inch of insulation from the end of each conductor wire. Twist the exposed filaments of each wire clockwise into a solid prong. Loosen the terminal screws and loop each bare wire end clockwise around a screw. Tighten the screws firmly. Connect the wires at the appliance end of the new cord the same way the old wires were connected.

If only the plug on a major appliance is faulty, you can attach a new plug to the old cord. Male plugs, with two blades or with two blades and a grounding prong, plug into an outlet. Female plugs, often used at the appliance end of the cord, have terminal holes instead of blades. Male plugs can usually be taken apart so you can access the terminal screws. Female plugs may be held together by rivets or by screws. Screw-held plugs can be taken apart, but rivet-held plugs cannot be repaired.

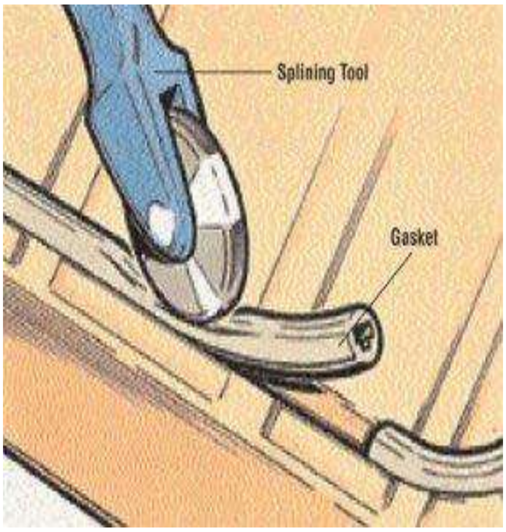
When a plug malfunctions, open the plug, if possible, and check to make sure the conductor wires are properly attached to the plug's screw terminals. If the wires are loose, tighten the terminal screw. This may solve the problem; otherwise, the plug should be replaced. To attach a new male plug:

Step 1: Insert the cord end through the plug opening and pull it through for about five or six inches.

Step 2: Carefully strip off the outer insulation for about 2 inches. Then, using a wire stripper, remove about 1/2 inch of insulation from the end of each conductor wire.

Step 3: Twist the exposed filaments of each wire clockwise into a solid prong. After twisting the conductor ends, tie a tight knot with the inner wires of the cord. Then pull the plug down over the knot, leaving the exposed ends of the conductor wires sticking out. Loosen the terminal screws in the plug.

Step 4: On a two-wire plug, loop each wire around one prong and toward a screw terminal. Loop the bare wire end clockwise around the screw terminal and tighten the screw. If the

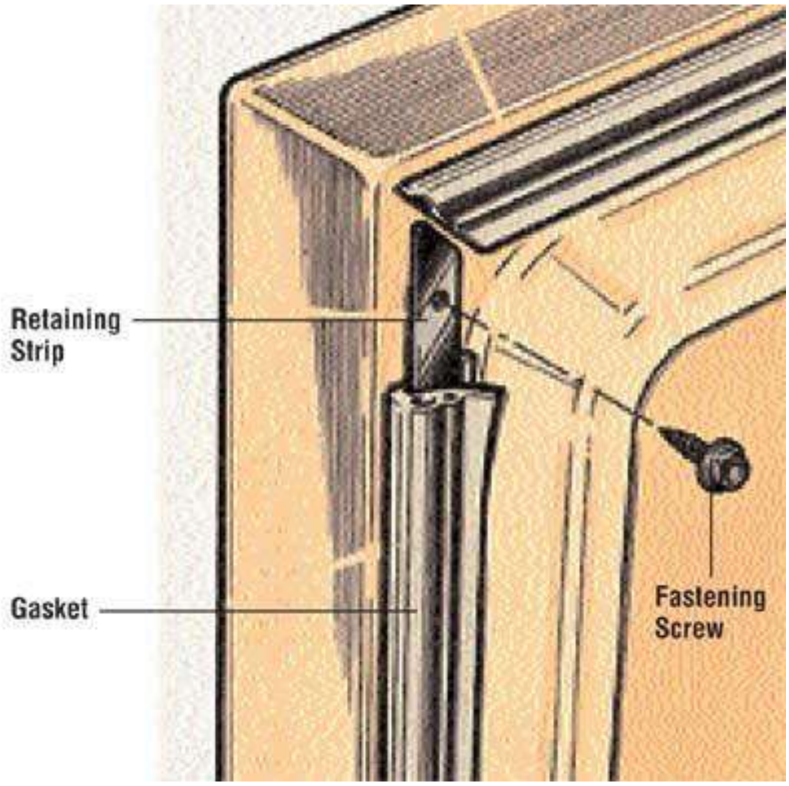


screws are different colours, connect the white wire to the white screw and the black wire to the yellow screw. On a three-wire plug, use the same technique to connect each of the three wires to a terminal screw. Connect the green grounding wire to the green screw terminal.

Step 5: When the conductor wires are firmly secured to the terminal screws, slide the cardboard insulator over the blades of the plug. If the plug has a clamp-type sleeve, clamp it firmly around the cord.

Repairing Gaskets, Wiring, Switches, and Thermostats

We will continue our tour through the inner-workings of your major appliances with an examination of three of the most common components. Let's get started with an item you'll find in most machines that use water -- gaskets.



Gaskets

Gaskets do two things: They prevent leaks of water and air, and they increase the efficiency of the appliance. When a gasket fails, it should be replaced as soon as possible. To determine whether a gasket is faulty, inspect it for cracks and tears. It should feel spongy.

Fig 1.3 A flush-mounted gasket is held in place by a retaining strip, fastened by screws or clips.

If the gasket has hardened, it should be replaced. Be sure to replace a faulty gasket with a new one made specifically for the appliance. Do not use a universal, fit-all gasket.

There are two common types of gaskets -- flush-mounted and channel-mounted. A flush-mounted gasket is secured to the door by a series of screws or clips, or held in place by a retaining strip or a panel. A channel-mounted gasket is held in a retaining groove. A splining or gasket tool makes installation easier. Use gasket cement to install either type of gasket if specified by the manufacturer. To replace a gasket:

Fig 1.4 A channel-mounted gasket is held in a retaining groove.

Step 1: Remove the old gasket. If it's channel-mounted, pull it carefully out of the channel. If it's flush-mounted, remove the fasteners, retaining strip, or panel to release the gasket.

Step 2: Clean the gasket area thoroughly with warm water and liquid detergent, or with mineral spirits, if necessary. Dry the door.

Step 3: Install the new gasket, smoothing it evenly into place and easing it around corners. Use gasket cement if specified by the manufacturer. If you're installing a channel-mounted gasket, press it into place with a splining tool. Make sure the gasket is properly and smoothly positioned, with no part sticking up or curled under.

Step 4: Replace the fasteners or the retaining strip or the panel and its fasteners. Remove any excess gasket cement with mineral spirits, but be very careful not to damage the appliance's finish.

Wiring

Many appliance repair tasks involve wiring or connecting wires to install a new electrical component. The electrical wires in appliances may be connected in one of several ways, including the basic screw-terminal connection, the push-in terminal, and sometimes the sleeve-type lug terminal. Wires may also be joined with the solderless connectors called wirenuts. Components that have many wires -- washer timers, for instance, which control several operating cycles -- are often connected in a wiring harness: a group of wires enclosed in a plastic sleeve. Each type of wire connection, for each individual wire and each wire of a harness, must be properly made when you install a new component. Before you disconnect any wiring in an appliance, make sure you know how it's attached. When you install the new component, attach its wires the same way.

Switches

Switches operate by making contact with the conductor of an electrical circuit. When an appliance is plugged in, it's connected to a circuit in your home. Power runs through the wires of the circuit to the appliance. When the appliance's on/off switch is turned on, the conductors of the appliance cord are moved into contact with the circuit conductors, and electricity flows through the switch to operate the appliance. The current flows in a loop through the appliance, making a complete circuit back through the switch to the line wires. Other basic appliance components are variations of switches. Rheostats, thermostats, solenoids, and timers, for example, are all switches or secondary switches. These components operate inside appliances to turn on motors, open and close valves, control heating elements, and turn on different parts of the appliance during different cycles, such as the rinse and spin cycles of a washer. There are several common types of switches -- push buttons, toggles, rockers, slides, throw switches, and so on.

All switches consist of electrical contacts in a mechanical housing. Switch failure can be caused by problems with either the contacts or the housing. When a switch malfunctions, turn it to the ON position and watch to see if the contacts are moved into position so that they touch. If the contacts are not operating properly, the switch housing is faulty, and the switch should be replaced. If the switch's mechanical operation is all right, its contacts may be dirty or misaligned. If the switch has terminal screws, they may be loose. If the contacts are dirty or corroded, rub them gently with a fine emery board and then with a soft cloth. If they're misaligned, bend them gently back into place. Tighten any loose terminal screws. If the contacts or screws are badly corroded, the switch should be replaced. To determine whether a switch is working properly:

Step 1: Disassemble the appliance to test the switch with a continuity tester or a VOM set to the RX1 scale.

Step 2: With the appliance unplugged, hook the clip of the continuity tester to one lead of the switch and touch the probe to the other; or touch one probe of the VOM to each terminal.

Step 3: Turn on the switch. If the switch is functioning, the continuity tester will light or buzz, and it will stop glowing or buzzing when the switch is turned off; or the VOM will read zero. If the tester doesn't light or buzz, or the VOM reads higher than zero, the switch is faulty and should be replaced. (Note that some switches should have a higher reading than zero, as detailed for each appliance.)

Step 4: Replace a defective switch with a new one of the same type, and connect it in exactly the same way the old switch was connected.

Thermostats

A thermostat is a switch that controls temperature in a heating element or a cooling device. Thermostats used in appliances may use a bimetal strip, bimetal thermodiscs, or a gas-filled bellows chamber to control the electrical contact. Faulty bimetal-strip and thermodisc thermostats should be replaced. Gas-filled thermostats can sometimes be professionally repaired. If repair is possible, it is much less expensive than replacement. To determine whether a thermostat is functioning:

Step 1: Disassemble the appliance to access the thermostat, and test it with a continuity tester or a VOM set to the RX1 scale.

Step 2: With the appliance unplugged, hook the clip of the continuity tester to one lead of the thermostat and touch the probe to the other; or touch one probe of the VOM to each terminal. The continuity tester should light or buzz; or the VOM should read zero.

Step 3: Turn down the temperature control dial; you'll see the contact points open at the thermostat. The tester should stop glowing or buzzing when the contacts open.

Step 4: If the thermostat is faulty, replace it with a new one. Follow the manufacturer's instructions.

As we mentioned in the introduction, most major appliances have two types of parts -- mechanical and control. Up to now we have covered only mechanical parts. In the next section, we will start to learn how to repair control devices.

Repairing Heating Elements and Timers

Many appliances perform several functions -- for example, the various cycles of a washer or dishwasher. These appliances operate automatically; once the on/off switch is turned on, switch components inside the appliance take over to control heat, water or fuel flow, motor speed, and other variables. The most important of these devices -- used to operate switches, levers, and valves automatically -- are solenoids (a current-carrying coil), relays, and sensor/responder pairs.

Heating Elements

Heating elements work very simply. Unlike conductors, they are made of metal with high electrical resistance. When current flows through the element, this high resistance prevents it from flowing easily. Current must work to get through the element, and this work is converted into heat. When the current is turned off, the element cools. There are three types of heating elements: wire, ribbon, and rigid. To determine whether a heating element is functioning:

Step 1: Disassemble the appliance to access the element and test it with a continuity tester or a VOM set to the RX1 scale.

Step 2: With the appliance unplugged, hook the clip of the continuity tester to one terminal of the heating element and touch the probe to the other terminal; or touch one probe of the VOM to each terminal. If the element is functioning, the tester will light or buzz; or the VOM will read from 15 to 30 ohms. If the tester doesn't light or buzz, or the VOM reads higher than 30 ohms, the element is faulty. Replace it.

Note: If you use a continuity tester, look closely at the tester, especially if it is the light-up type. Some heating elements have an extremely high resistance factor, and the light may produce only a dim glow or a faint buzz. This reaction does not mean that the element is faulty, but rather that it converts current to heat efficiently.

Mechanical Timers

The operation of a major appliance that has several cycles (for example, a washer, dishwasher, dryer, frost-free refrigerator, or range) is controlled by a timer -- a complex rotary switch powered by a small synchronous motor. The timer consists of a shaft, gears, and a series of notched cams, one for each circuit or cycle. The timer itself is powered by the timer motor; the appliance is powered by the much larger appliance motor. When the switch is turned on, electrical contact is made with the timer motor, and a spring on a trip arm is coiled. The arm trips when the spring is tight, releasing the spring and moving the cam of the switch to the next circuit. At the last cycle, contact with the motor is broken, and the timer turns the appliance off.

When a timer malfunctions, it should usually be replaced. Professional rebuilding is sometimes possible, but this is likely to be more expensive than replacement. Many timers are sealed units. Some timers have an adjustment shaft, which can be turned with a screwdriver blade. To determine whether a timer is functioning:

Step 1: Test the timer with a continuity tester or a VOM set to the RX1 scale. Make a sketch of the timer wires and then, with the appliance unplugged, disconnect all timer wires from their terminals. Make sure you'll be able to reconnect the wires exactly the same way.

Step 2: Touch or clip one probe of the tester or the VOM to the common terminal. Touch the other probe to each cycle terminal in turn. Rotate the timer control knob as you work. The continuity tester should light or buzz at each circuit; the VOM should read zero.

Step 3: If one or more circuits do not give these results, the timer is faulty and should be replaced. To replace a timer, disconnect its wires one at a time, connecting the corresponding wires of the new timer as you progress in order to avoid the chance of a misconnection.

Digital timers typically cannot be repaired and must be replaced.

Repairing a heating element didn't seem that dangerous, right? Well, heating elements lack a key ingredient that makes the repairs in our next section so dangerous -- combustible gas. Move on to the next to learn how to repair a pilot light or thermocouple.

1.2.7 Repairing Motors

Major appliance motors are usually dependable and long-wearing. You can prolong their life and increase their efficiency by keeping them clean and well lubricated. Use motor-driven appliances sensibly. Don't overload them, don't abuse them, and don't ignore problems until they become serious.

There are several basic rules for operating motor-driven appliances:

- Always connect an appliance to an adequate power source; a 220-240-volt appliance must be connected to a 220-240-volt outlet. If the outlet for a major appliance is not grounded, use a grounded adapter plug to ground the appliance.
- Never use a small appliance that's wet, and never operate any appliance while your hands are wet. If a large appliance, such as a washer or dryer, gets wet, do not operate it or try to unplug it. Have the motor examined by a professional before you use the appliance again.
- Never overload an appliance. Overloading causes inefficient operation and motor overheating, and can cause excessive wear. If a motor turns off because it's overloaded, reduce the load before restarting the appliance.

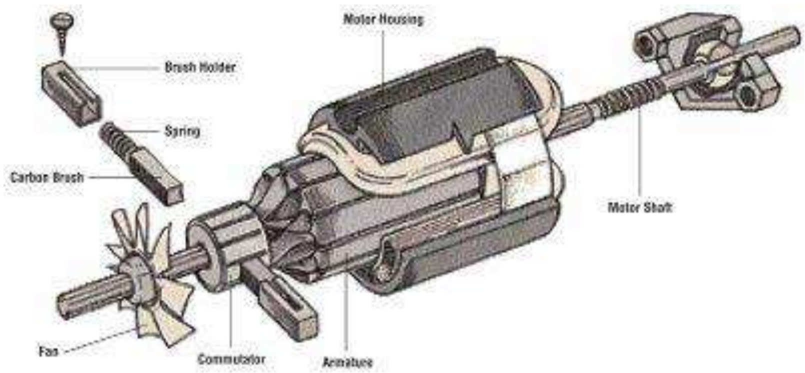


Fig 1.5 A universal motor has an armature and a rotating commutator, mounted on a motor shaft. Carbon brushes make the electrical contact; worn brushes are the most common problem.

Universal Motors: Universal motors consist of a rotor called an armature, with coils of wire wound around it, and a rotating cylinder called a commutator, with alternating strips of conducting and non-conducting material. The armature and the commutator are both mounted on the motor shaft. On each side of the commutator, a carbon brush carries current from the circuit. When the carbon brushes press against the commutator, the armature is magnetized and rotates. Most universal motors also have a cooling fan at the end of the shaft. Universal motors are used in many small and medium-size appliances. They provide strong power at both low and high speeds. Universal motors can operate on either AC or DC current. Their speed is controlled by a rheostat, a tapped-field control, a rectifier, or a governor, or by physical movement of the carbon brushes away from the armature.

Most universal motors are permanently lubricated and sealed by the manufacturer and require no further attention. Some universal motors, however, have covered lubrication ports, usually marked "oil," at the ends of the motor shaft. This type of motor should be oiled every six months, or according to the manufacturer's instructions. Lift each port's lid and apply a drop or two of No. 30 nondetergent motor oil (not all-purpose oil). Do not over-lubricate.

Many universal motor malfunctions are caused by wearing down of the carbon brushes, the soft blocks of carbon that complete the electrical contact to the motor's commutator. When these brushes become worn, the motor will spark, and electrical contact may be incomplete. You can solve both problems by replacing the brushes.

Brushes can be checked visually or tested with a continuity tester. Here's how:

Step 1: To sight-check the carbon brushes, remove the screws that hold the brushes and brush springs into the brush holders at the sides of the commutator. The screws will pop out of the screw holes; turn the motor over to tap out the brushes. The ends of the brushes should be curved to fit the commutator; if they're worn down, new brushes are needed.

Step 2: To check carbon brushes with a continuity tester, remove the motor lead wires from the circuit. Tag the wires as you disconnect them so that you'll be able to reconnect them properly. Hook the tester clip to one motor lead and touch the probe to the other lead; the tester should light or buzz. Slowly rotate the motor shaft, keeping the tester in position. If the tester doesn't light or buzz, or if it flickers or stutters when you turn the motor shaft, the brushes should be replaced. If the springs behind the brushes are damaged, they should be replaced as well.

Step 3: Replace worn carbon brushes and damaged springs with new ones made specifically for the motor. The model information (number and make) is stamped on a metal plate fastened to the motor, or embossed on the metal housing of the motor. If you can't find the model information, take the worn brushes and springs with you to an appliance-parts store to make sure you get the right kind. Insert the new springs and brushes in the brush holders, replace the brush assemblies, and secure the new brushes with the mounting screws that held the old brushes.

Don't attempt other repairs to a universal motor. If a serious malfunction occurs, buy a new motor or take the faulty motor to a professional for repairs. Most large universal motors are fastened to plate-type mountings. To remove the motor, disconnect the wires and remove the holding bolts and any belts that are present. If the faulty motor is in a small appliance, take the entire appliance to the repair shop. It may sometimes be less expensive to buy a new appliance than to have the old one repaired.

Split-Phase Motors

Split-phase motors consist of a rotor turning inside a stator (the non-moving portion of a motor) that has two wire coils: a starting winding and a running winding. Current flows through both windings when the motor is starting up, but when the rotor has reached about 75 to 80 percent of its top speed, the starting winding is turned off and only the running winding receives current. Split-phase motors operate on AC current. They are fairly powerful, and are used in appliances such as washing machines, dryers, and dishwashers.

These motors require no maintenance except cleaning and lubrication. Split-phase motors have a special auxiliary winding -- the starting winding. Don't try to make any repairs yourself. When a motor malfunctions, buy a new motor or take the faulty motor to a professional service person, whichever is less expensive. You can save the expense of a service call by removing the old motor from its mounting and installing the repaired or new motor yourself.

Capacitor-Start Motors

A capacitor-start motor is a shaded-pole motor with a capacitor (an energy-storing device) wired into the starting winding. The capacitor stores current and releases it in bursts to provide extra starting power. When the motor reaches about 75 percent of its top speed, the starting winding is turned off. Capacitor-start motors operate on AC current. They are very powerful and are used in appliances that require a high starting torque or turning power, such as air conditioners and furnaces.

Capacitor-start motors require regular cleaning to keep them free of lint and oil. Ventilation to the motor must be adequate. If the motor has oil ports, lift each port's lid and apply a drop or two of No. 30 nondetergent motor oil (not all-purpose oil). Do not over-lubricate.

Capacitor-start motors are usually hard to get at and have a capacitor and special auxiliary windings. Don't try to make any repairs yourself. When a motor malfunctions, call a professional service person.

Caution: Capacitors store electricity, even after the power to the appliance is turned off. When working with a capacitor-start motor, you must discharge the capacitor with a 20,000-ohm, 2-watt wire-wound resistor, as detailed for each appliance.

As with most do-it-yourself projects, repairing your own household appliances can save you both time and money. If you can remember to take it slow and label your steps, you can disassemble and reassemble most of the simple machinery in your home.

1.2.2 Tools used for repairing domestic appliances

So you want to start doing home maintenance to save money or you're fed up taking time off from work and waiting for tradesmen who don't turn up on time? Anyone can do basic DIY and whether you want to progress to more advanced DIY projects depends on how brave you are, your level of patience and if you are willing to learn by trial and error with a couple of disasters on the way! This guide outlines the most common tools required for basic home maintenance. Of course you don't have to buy them all at once! A toolkit is put together over a lifetime and tools can be bought as the need arises.

1. Hammers
2. Philips and flat screwdrivers
3. Pliers
4. Snips
5. Saws
6. Locking pliers
7. Measuring tapes
8. Wrenches (Spanners)
9. Socket set
10. Pipe wrench and water pump pliers
11. Ladders
12. Voltage testers
13. Torches
14. Paint brushes
15. Drill bits
16. Metal detector and live wire detector
17. Cordless drill
18. SDS drill
19. Knife with disposable blades
20. Tippex marker

Choosing Tools

These tools are sufficient for doing basic maintenance jobs around the home like tightening screws on cupboard doors, hanging pictures, tightening loose nuts, wiring mains plugs, tightening power sockets, cutting and fixing sections of timber and basic plumbing.

It's also a good idea to stock up on essential materials and fixings such as nails, screws, assorted nuts and machine screws, insulating tape, super-glue, epoxy resin and cable ties etc.

1. Hammers

- A **claw hammer** is used for hammering nails, pulling them out and general bashing of stuff. A standard hammer head weighs 1 lb, however you can buy lighter hammers for use with smaller gage nails
- A **lump hammer** or builder's hammer has a heavy head, useful for breaking bricks or blocks, driving large nails, using with a cold chisel for chopping concrete and any other application that requires brute force

Fig 1.6 Various Hammers

Fig 1.7 *Phillips screws*

2. Philips and Flat Screwdrivers

Various sizes of Phillips and flat head screwdrivers, large and small. There are two options:

- ➢ Buy screwdrivers individually or as set
- ➢ Buy a screwdriver handle with a tip that takes various sizes of screwdriver bits

Sets of screwdrivers sometimes include an awl for making holes prior to driving screws or drilling. This looks like a screwdriver but has a pointed tip which is pushed into wood or plastic and turned to make a hole.

3. Pliers

Standard pliers for holding, pulling, bending, twisting etc. They can also be used to undo small nuts.A long (snipe) nose pliers is better for reaching into places that a standard jaw pliers can't access. It's also used for bending ends of wires, holding parts and is a standard tool for electrical/electronic work.

Fig:1.8 Different pliers

4. Snips

A wire snips is useful for cutting and stripping the insulation from wire when wiring plugs, socket outlets, lighting outlets, cutting plant ties when gardening or cable ties.

Fig:1.9 Different Snips

5. Saws

- A standard carpenter's **hand saw** for cutting wood (lumber). You can use it for crosscutting lengths of timber or for cutting through sheets of plywood or MDF
- A **tenon saw** is smaller with finer teeth and better suited for neater cutting of e.g. architrave
- A **junior hacksaw** *12A junior hacksaw can be used for cutting copper and plastic tubing, bolts and other light metal parts* metal, bolts, threaded bar, PEX and copper pipe

Fig 1.10 A hand Saw Fig 1.11 A Tenon saw Fig 1.12A junior hacksaw

6. Locking-Pliers

A locking pliers (also known by the brand name "Vice Grip" or "Mole wrench") can be used for holding nuts, bolts, bars or anything to prevent it turning. It can also be used as a general purpose clamp for holding two parts together.

Fig 1.13Using a locking pliers to hold the body of an outside tap while undoing the top

7. Measuring Tapes

- A 6 m (20 foot) measuring tape is perfect for general purpose use
- A smaller 3 m tape is small and compact and you can slip it into your pocket for measuring stuff while you go shopping for furniture or building materials

Fig 1.14 Measuring Tape

8. Wrenches (Spanners)

Wrenches, known as spanners in the UK, are used for tightening nuts, bolts, taps, plumbing fittings, wall fixings and anything else that requires a nut to be tightened.

You can buy either **open ended wrenches** or **combination wrenches**. The latter are open at one end and ring at the other end. The ring part makes for quicker tightening of nuts without having to take the wrench off the nut or bolt head and put it back on again. Ring or combination spanners can also be used for situations when a nut needs to be undone but the threaded section of the bolt extends too far beyond the nut to fit into a socket.

For domestic work, sockets or wrenches don't need to be greater than 3/4 inch AF (across the flats) or about 22 mm in size.

1.15 Combination spanners (wrenches) 1.16Combination spanners

9. Socket Set

A socket wrench and socket does the same job as a wrench but the ratchet action makes things quicker and easier because you can just pump the handle to tighten or release a nut or bolt. With a wrench you have to continually remove and replace the jaws of the wrench onto a nut/bolt head. A socket wrench is often used in conjunction with a standard wrench, the wrench for holding a nut and the socket wrench for releasing/tightening the bolt (or vice versa). The disadvantage of a socket wrench is that you can't Fig 1.17*Socket wrench set* use it to tighten nuts on long bolts or threaded bar because a socket mightn't be deep enough. You can always use a ring spanner in this scenario or a **through socket** and wrench.

10. Pipe Wrench ("Stilson") and Water Pump Pliers

Fig 1.18(a)Pipe wrenches or "Stilsons"Fig 1.18(b) Tightening a nut on a compression fitting with water pump pliers and vice grips (locking pliers).

If you're going to do any home plumbing, these are useful tools to have for dismantling taps, radiator valves, unscrewing and tightening pipes and plumbing fittings and large nuts (which would normally require a very large wrench). The jaws and handles of a water pump pliers aren't in line, so it's easier to access and turn nuts on e.g. a radiator valve without the handles being obstructed by the wall.

11. Voltage Testers

- A digital multimeter (DMM) can be used to measure voltage, current, test continuity of fuses and wires and check batteries
- A neon phase tester can be used for detecting whether a cable or other electrical parts are "live". The neon bulb in the tester glows when mains voltage is detected. It's essential to use one of these to double check power is definitely off after switching the power off using the MCB at the electrical panel

Fig1.19 Digital multimeter *Fig1.20 Phase tester*

A Fluke non-contact detector "VoltStick" is a standard tool in any electrician’s tool kit, but useful for homeowners also. I use one of these for identifying which conductor is live whenever I'm doing any home maintenance. Unlike a neon screwdriver (phase tester), you can use one of these in situations when live parts/wires are shrouded or covered with insulation and you can't make contact with wires. It also comes in useful for checking whether there's a break in a power flex and where the break occurs.

Note: It's always a good idea to use a neon tester to double check that power is definitely off when doing any electrical maintenance.

12. Ladders

- A **step ladder** is virtually essential for interior and exterior maintenance. You'll inevitably need to clean windows, cut hedges, water hanging baskets, paint, clean cobwebs or clean low-level gutters. A step ladder is safer than standing on a chair or stool because you have a top bar to hold onto to prevent losing your balance
- An **extension ladder** allows you to access top gutters, paint your house, clean the outside of windows, cut limbs from trees etc.

13. Torches

- High powered LED torches are now available that produce a lot lighter than traditional types that used an incandescent bulb. LEDs also last practically forever and don't break if you drop the torch.
- A head torch is extremely useful, one for all sorts of maintenance around the house when we need two hands free

Fig1.22 A head torch keeps your hands free so you can use your tools more effectively in badly lit locations

14. Paint Brushes

At some stage you might decide to try your skills at painting. The 4 most useful sizes are 1/2 inch, 1 inch, 1 1/2 inch and 2 inch. For painting walls, a larger brush about 5 to 6 inches wide is needed.

You can also use a roller for painting internal walls and external flat render.

15. Drill bits

You're going to need these for making holes

- HSS bits for drilling metal or plastic
- Wood bits for timber. There are several choices: Flat bits, lip and spur bits, auger bits and hole saws for large holes
- Masonry bits for drilling concrete, breeze blocks, bricks and stone

Fig 1.23 Drill bits - From left to right masonry bit, lip and spur bit and HSS bit

16. Metal Detector and Live Wire Detector

This tool is for finding metal in walls and live wires before drilling

17. Cordless Drill

A cordless drill is an essential power tool if you need to drive a lot of screws. A combi drill is used for drilling and driving screws. Most 18 volt drills can be used for drilling holes in concrete if you need to insert wall plugs for fixing stuff to walls, but an inexpensive corded SDS drill is faster and more powerful for drilling large holes.

Fig 1.24Cordless drill / screwdriver

18. SDS Drill

You can buy a corded or cordless version. A corded version is a lot cheaper, but obviously has the inconvenience of a trailing power cord.

SDS drills have pneumatic percussion action so they can rapidly drill holes in masonry for wall plugs if you need to fix cupboards to walls. You can also easily drill larger holes in concrete when running plumbing tubing or cables.

Fig 1.25 SDS drill

19. Utility Knife with Disposable Blades - (Stanley Knife)

These are sometimes referred to generically as "Stanley knives" from the name of the manufacturer. Disposable blades are now a standard size for all manufacturers knifes and readily available from discount stores. The most common type has a retractable blade, but folding versions are also available that stowaway the blade safely into a hollow slot in the handle.

Fig 1.26 Carpet knife or "Stanley" knife

20. Tippex Marker

Yes, I know they're used as correction pens, but a Tippex marker is great for marking dark surfaces. If you use a pencil or felt tip marker, it can be difficult to see the mark, but a Tippex marker produces a white line that's really prominent.

1.2.3Electrical Drive

Definition: The system which is used for controlling the motion of an electrical machine, such type of system is called an electrical drive. In other words, the drive which uses the electric motor is called electrical drive. The electrical drive uses any of the prime movers like diesel or a petrol engine, gas or steam turbines, steam engines, hydraulic motors and electrical motors as a primary source of energy. This prime mover supplies the mechanical energy to the drive for motion control.

The block diagram of the electrical drive is shown in the figure below. The electrical load like fans, pumps, trains, etc., consists the electrical motor. The requirement of an electrical load is determined regarding speed and torque. The motor which suited the capabilities of the load is chosen for the load drive.

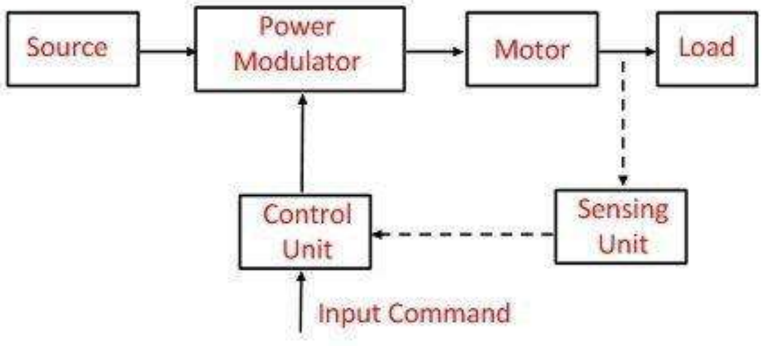


Fig 1.27 Parts of Electrical Drive

The main parts of the electrical drives are power modulator, motor, controlling unit and sensing units. Their parts are explained below in details.

Power Modulator – The power modulator regulates the output power of the source. It controls the power from the source to the motor in such a manner that motor transmits the speed-torque characteristic required by the load. During the transient operations like starting, braking and speed reversing the excessive current drawn from the source. This excessive current drawn from the source may overload it or may cause a voltage drop. Hence the power modulator restricts the source and motor current.

The power modulator converts the energy according to the requirement of the motor e.g. if the source is DC and an induction motor is used then power modulator convert DC into AC. It also selects the mode of operation of the motor, i.e., motoring or braking.

Control Unit – The control unit controls the power modulator which operates at small voltage and power levels. The control unit also operates the power modulator as desired. It also generates the commands for the protection of power modulator and motor. An input command signal which adjusts the operating point of the drive, from an input to the control unit.

Sensing Unit – It senses the certain drive parameter like motor current and speed. It mainly required either for protection or for closed loop operation.

Advantages of Electrical Drive

The following are the advantages of electrical drive.

- The electric drive has very large range of torque, speed and power.
- Their working is independent of the environmental condition.
- The electric drives are free from pollution.
- The electric drives operate on all the quadrants of speed torque plane.
- The drive can easily be started and it does not require any refuelling.
- The efficiency of the drives is high because fewer losses occur on it.

The electric drives have many advantages shown above. The only disadvantage of the drive is that sometimes the mechanical energy produced by the prime mover is first converted into electrical energy and then into a mechanical work by the help of the motor. This can be done by the help of the electrical link which is associated with the prime mover and the load.

Because of the following advantages, the mechanical energy already available from a non-electrical prime mover is sometimes first converted into electrical energy by a generator and back to a mechanical energy of an electrical motor. Electrical link thus provides between the non-electrical prime mover and the load impact to the drive flexible control characteristic.

For example – The diesel locomotive produces the diesel energy by the help of the diesel engine. The mechanical energy is converted into an electrical energy by the help of the generator. This electrical energy is used for driving the other locomotive.

Disadvantages of Electrical Drive

The power failure completely disabled the whole of the system.

1. The application of the drive is limited because it cannot use in a place where the power supply is not available.
2. It can cause noise pollution.
3. The initial cost of the system is high.
4. It has a poor dynamic response.
5. The output power obtained from the drive is low.
6. During the breakdown of conductors or short circuit, the system may get damaged due to which several problems occur.

Application of Electric Drive

It is used in a large number of industrial and domestic applications like transportation systems, rolling mills, paper machines, textile mills, machine tools, fans, pumps, robots and washing, etc.

Different types of motors and their use

When purchasing a motor, it's often asked which technology is better, AC or DC, but the fact is that it is application and cost dependent.

AC Motors

AC motors are highly flexible in many features including speed control (VSD - Variable Speed Drives) and have a much larger installed base compared to DC motors, some of the key advantages are:

- Low power demand on start
- Controlled acceleration
- Adjustable operational speed
- Controlled starting current
- Adjustable torque limit
- Reduced power line disturbances

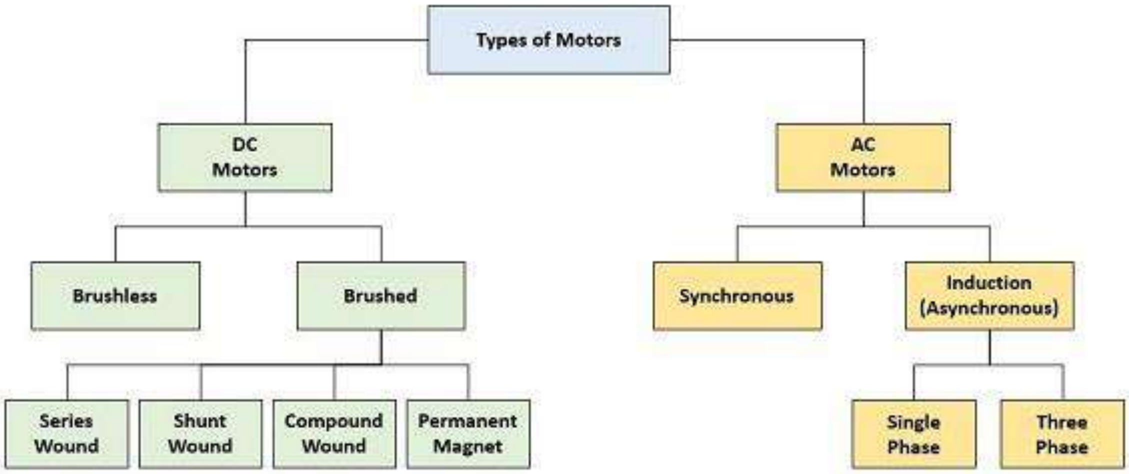


Chart 1.1

The current trend for VSD is to add more features and programmable logic control (PLC) functionality, which are advantages for the experienced used, but require greater technical expertise during maintenance

Types of AC motor include:

Synchronous
In this type of motor, the rotation of the rotor is synchronized with the frequency of the supply current and the speed remains constant under varying loads, so is ideal for driving equipment at a constant speed and are used in high precision positioning devices like robots, instrumentation, machines and process control

Induction (Asynchronous)
This type of motor uses electromagnetic induction from the magnetic field of the stator winding to produce an electric current in the rotor and hence Torque. These are the most common type of AC motor and important in industry due to their load capacity with Single-Phase induction motors being used mainly for smaller loads, like used in house hold appliances whereas Three-Phase induction motors are used more in industrial applications including like compressors, pumps, conveyor systems and lifting gear.

DC Motors
DC motors were the first type of motor widely used and the systems (motors and drive) initial costs tend to be typically less than AC systems for low power units, but with higher power the overall maintenance costs increase and would need to be taken into consideration. The DC Motors speed can be controlled by varying the supply voltage and are available in a wide range of voltages, however the most popular types are 12 & 24V, with some of the advantages being:

- Easy installation
- Speed control over a wide range
- Quick Starting, Stopping, Reversing and Acceleration
- High Starting Torque
- Linear speed-torque curve

DC motors are widely used and can be used from small tools and appliances, through to electric vehicles, lifts & hoists

The two common types are:

Brushed
These are the more traditional type of motor and are typically used in cost-sensitive applications, where the control system is relatively simple, such as in consumer applications and more basic industrial equipment, these type of motors can be broken down as:

- **Series Wound** – This is where the field winding is connected in series with rotor winding and speed control is by varying the supply voltage, however this type offers poor speed control and as the torque to the motor increase, then the speed falls. Applications include automotive, hoists, lifts and cranes as it has a high starting torque.
- **Shunt Wound** – This type has one voltage supply and the field winding is connected in parallel with the rotor winding and can deliver increased torque, without a reduction in speed by increasing the motor current. It has medium level of starting torque with constant speed, so suitable for applications include lathes, vacuum cleaners, conveyors & grinders.
- **Compound Wound** – This is a cumulative of Series and Shunt, where the polarity of the shunt winding is such that it adds to the series fields. This type has a high starting torque and run smoothly if the load varies slightly and is used for driving compressors, variable-head centrifugal pumps, rotary presses, circular saws, shearing machines, elevators and continuous conveyors
- **Permanent Magnet** – As the name suggests rather than electromagnet a permanent magnet is used and are used in applications where precise control and low torque, such as in robotics, servo systems.

Brushless
Brushless motors alleviate some of the issues associated with the more common brushed motors (short life span for high use applications) and are mechanically much simpler in design (not having brushes). The motor controller uses Hall Effect sensors to detect the rotors position and using this the controller can accurately control the motor via current in the rotor coils) to regulate the speed. The advantages of this technology is the long life, little maintenance and high efficiency (85-90%), whereas the disadvantages are higher initial costs and more complicated controllers. These types of motors are generally used in speed and positional control with applications such as fans, pumps and compressors, where reliability and ruggedness are required.

An example of brushless design are in Stepper Motors, which are primarily used in open-loop position control, with uses from printers through to industrial applications such as high speed pick and place equipment.

Brushless motors are also available with a feedback device which allows the control of the Speed, Torque and Position of the motor and the intelligent electronics control all three so if more torque is required to accelerate quicker to a certain speed then more current is delivered, these are knownas Brushless Servo Motors

Fig 1.28Example of a DC Brushed and Brushless Motors

Motors Everywhere

Look around your house and you will find that it is filled with electric motors. Here's an interesting experiment for you to try: Walk through your house and count all the motors you find. Starting in the kitchen, there are motors in:

- The fan over the stove and in the microwave oven
- The dispose-all under the sink
- The blender
- The can opener
- The refrigerator - Two or three in fact: one for the compressor, one for the fan inside the refrigerator, as well as one in the icemaker
- The mixer
- The tape player in the answering machine
- Probably even the clock on the oven

In the utility room, there is an electric motor in:

- The washer
- The dryer
- The electric screwdriver
- The vacuum cleaner and the Dustbuster mini-vac
- The electric saw
- The electric drill
- The furnace blower

Even in the bathroom, there's a motor in:

- The fan
- The electric toothbrush
- The hair dryer
- The electric razor

Your car is loaded with electric motors:

- Power windows (a motor in each window)
- Power seats (up to seven motors per seat)
- Fans for the heater and the radiator
- Windshield wipers
- The starter motor
- Electric radio antennas

Plus, there are motors in all sorts of other places:

- Several in the VCR
- Several in a CD player or tape deck
- Many in a computer (each disk drive has two or three, plus there's a fan or two)
- Most toys that move have at least one motor (including Tickle-me-Elmo for its vibrations)
- Electric clocks
- The garage door opener
- Aquarium pumps

In walking around my house, I counted over 50 electric motors hidden in all sorts of devices. Everything that moves uses an electric motor to accomplish its movement.

Short Answer Questions

1. Classify the Domestic Appliances
2. List any 4Tools used for repairing domestic appliances
3. Write the uses of Water **Pump Pliers and Locking-Pliers**
4. Write the uses of **SDS Drill and lump hammer**
5. **What are the types in Ladders?**
6. **Name the parts of** electrical drives
7. Write the advantages of electrical drives
8. Write Disadvantages of Electrical Drive
9. Name any 4 Drives used in Domestic Appliances.

Essay Questions

1. Write the General Procedure for Servicing of domestic appliances
2. How to maintain domestic appliances
3. Write the Tips to conserve energy during use of household electronic devices
4. Write the advantages and Disadvantages of electrical drives

2.Non-motorised Heating Appliances

2.1.1 HeatingEffectofElectricCurrent

Whiledealingwithelectricityaveryimportantphenomenonisheatingeffectofelectriccurrent. When everthereiscurrentflowthereismotionofelectrons.Duringtheirjourneyelectronscollidewithotherel ectrons,atomsorionspresentintheconductor.Ateachcollision,apartofthekinetic energy.i.e.energyofamovingelectrongetsconvertedtoheat.Heatgeneratedbysinglecollisionishard todetectbuttherearenfinitenumberofcollisionsintheconductor.Theheatgeneratedbyallthesecollis ionsissufficienttoraisethetemperatureofconductor.

'The phenomenaofproductionofheatenergyintheconductorduetocurrent flowingthroughitiscalledHeatingEffectofElectricCurrent."

The heating effect of an electric current depends on three factors:

- The resistance, R of the conductor. A higher resistance produces more heat.
- The time, t for which current flows. The longer the time the larger the amount of heat produced
- The amount of current, I. the higher the current the larger the amount of heat generated.

Hence the heating effect produced by an electric current, I through a conductor of resistance, R for a time, t is given by $H = I^2Rt$. This equation is called the Joule's equation of electrical heating.

Electrical energy and power

The work done in pushing a charge round an electrical circuit is given by w.d = VIt

So that power, P = w.d /t = VI

The electrical power consumed by an electrical appliance is given by $P = VI = I^2R = V^2/R$

Example

1. An electrical bulb is labelled 100W, 240V. Calculate:

a)The current through the filament when the bulb works normally
b)The resistance of the filament used in the bulb.

Solution

1. I = P/V = 100/240 = 0.4167A
2. $R = P/I^2 = 100/0.4167^2 = 576.04\Omega$ or $R = V^2/P = 240^2/100 = 576\Omega$

1. Find the energy dissipated in 5 minutes by an electric bulb with a filament of resistance of 500Ω connected to a 240V supply. {ans. **34,560J**}

Solution

E = Pt = V2/R *t = $(240^2 *5*60)/500$ = 34,560J

1. A 2.5 kW immersion heater is used to heat water. Calculate:

1. The operating voltage of the heater if its resistance is 24Ω
2. The electrical energy converted to heat energy in 2 hours.

{ans. 244.9488V, 1.8*10^{7}J}

Solution

1. $P=VI=I^2R$

$I = (2500/24)^{1/2} = 10.2062A$

$V=IR= 10.2062 * 24 = 244.9488V$

1. $E = VIt = Pt = 2500*2*60*60 = 1.8 * 10^7 J$

OR $E= VIt = 244.9488 * 10.2062 * 2 * 60 * 60 = 1.8 * 10^7 J$

An electric bulb is labelled 100W, 240V. Calculate:
The current through the filament
The resistance of the filament used in the bulb.

Solution

P = VI I = P/V = 100/240 =0.4167A
From Ohm's law, V =IR R=V/I =240/0.4167 = 575.95Ω

2.1.2 Applications of heating effect of electric current

Most household electrical appliances convert electrical energy into heat by this means. These include filament lamps, electric heater, electric iron, electric kettle, etc.

In lighting appliances

1. Filament lamps- it is made of a tungsten wire enclosed in a glass bulb from which air has been removed. This is because air would oxidize the filament. The filament is heated up to a high temperature and becomes white hot. Tungsten is used due its high melting point; 3400^0 The bulb is filled with an inactive gas e.g. argon or nitrogen at low pressure which reduces evaporation of the tungsten wire. However, one disadvantage of the inert gas is that it causes convection currents which cool the filament. This problem is minimized by coiling the wire so that it occupies a smaller area which reduces heat loss through convection.
2. Fluorescent lamps- these lamps are more efficient compared to filament lamps and last much longer. They have mercury vapour in the glass tube which emits ultraviolet radiation when switched on. This radiation causes the powder in the tube to glow (fluoresce) i.e. emits visible light. Different powders produce different colours. Note that fluorescent lamps are expensive to install but their running cost is much less.

In electrical heating

1. Electric cookers- electric cookers turn red hot and the heat energy produced is absorbed by the cooking pot through conduction.

2. Electric heaters- radiant heaters turn red at about 900^{0}C and the radiation emitted is directed into the room by polished reflectors.
3. Electric kettles- the heating element is placed at the bottom of the kettle so that the liquid being heated covers it. The heat is then absorbed by water and distributed throughout the whole liquid by convection.
4. Electric irons- when current flows through the heating element, the heat energy developed is conducted to the heavy metal base raising its temperature. This energy is then used to press clothes. The temperature of the electric iron can be controlled using a thermostat (a bimetallic strip).

To heat and cool your house efficiently, it is important to know how heat transfers to and from objects.

Understanding how heat is transferred from the outdoors into your home and from your home to your body is important for understanding the challenge of keeping your house cool. Understanding the processes that help keep your body cool is important in understanding cooling strategies for your home.

Principles of Heat Transfer

Heat is transferred to and from objects -- such as you and your home -- via three processes: conduction, radiation, and convection.

Conduction is heat traveling through a solid material. On hot days, heat is conducted into your home through the roof, walls, and windows. Heat-reflecting roofs, insulation, and energy efficient windows will help to reduce that heat conduction.

Radiation is heat traveling in the form of visible and non-visible light. Sunlight is an obvious source of heat for homes. In addition, low-wavelength, non-visible infrared radiation can carry heat directly from warm objects to cooler objects. Infrared radiation is why you can feel the heat of a hot burner element on a stovetop, even from across the room. Older windows will allow infrared radiation coming from warm objects outside to radiate into your home; shades can help to block this radiation. Newer windows have low-e coatings that block infrared radiation. Infrared radiation will also carry the heat of your walls and ceiling directly to your body.

Convection is another means for the heat from your walls and ceiling to reach you. Hot air naturally rises, carrying heat away from your walls and causing it to circulate throughout your home. As the hot air circulates past your skin (and you breathe it in), it warms you.

Cooling Your Body

Your body can cool down through three processes: convection, radiation, and perspiration. Ventilation enhances all these processes. You can also cool your body via conduction -- some car seats now feature cooling elements, for instance -- but this is not generally practical for use in your home.

Convection occurs when heat is carried away from your body via moving air. If the surrounding air is cooler than your skin, the air will absorb your heat and rise. As the warmed air rises around you, cooler air moves in to take its place and absorb more of your warmth. The faster this convecting air moves, the cooler you feel.

Radiation occurs when heat radiates across the space between you and the objects in your home. If objects are warmer than you are, heat will travel toward you. Removing heat through ventilation reduces the temperature of the ceiling, walls, and furnishings. The cooler your surroundings, the more you will radiate heat to the objects, rather than the other way around.

Perspiration can be uncomfortable, and many people would prefer to stay cool without it. However, during hot weather and physical exercise, perspiration is the body's powerful cooling mechanism. As moisture leaves your skin pores, it carries a lot of heat with it, cooling your body. If a breeze (ventilation) passes over your skin, that moisture will evaporate more quickly, and you'll be even cooler.

Heating elements

A heating element converts electrical energy into heat through the process of Joule heating. Electric current passing through the element encounters resistance, resulting in heating of the element.

A typical heating element is usually a coil, ribbon (straight or corrugated), or strip of wire that gives off heat much like a lamp filament. When an electric current flows through it, it glows red hot and converts the electrical energy passing through it into heat, which it radiates out in all directions.

Heating elements are typically either nickel-based or iron-based. The nickel-based ones are usually **nichrome**, an alloy (a mixture of metals and sometimes other chemical elements) that consists of about 80 percent nickel and 20 percent chromium (other compositions of nichrome are available, but the 80–20 mix is the most common). There are various good reasons why nichrome is the most popular material for heating elements: it has a high melting point (about 1400°C or 2550°F), doesn't oxidize (even at high temperatures), doesn't expand too much when it heats up, and has a reasonable (not too low, not too high, and reasonably constant) resistance (it increases only by about 10 percent between room temperature and its maximum operating temperature).

Does a heating element need a high or a low resistance?

You might think a heating element would need to have a *really high* resistance—after all, it's the resistance that allows the material to generate heat. But that's not actually the case. What generates heat is the *current* flowing through the element, not the amount of resistance it feels. Getting the maximum current flowing through a heating element is much more important than forcing that current through a large resistance. This might seem confusing and counter-intuitive, but it's quite easy to see why it is (and must be) true, both intuitively and mathematically.

Intuitively...

Suppose you made the resistance of your heating element as big as you possibly could—infinitely big, in fact. Then **Ohm's law** (voltage = current × resistance or V = IR) tells us the current flowing through your element would have to be infinitely small (if I = V/R, I approaches zero as R approaches infinity). You'd have a whopping great resistance, no current, and therefore no heat produced. Right, so what if we went to the opposite extreme and made the resistance infinitely tiny. Then we'd have a different problem. Although the current I might be huge, R would be virtually zero, so the current would zip through the element like an express train without even stopping, producing no heat at all.

What we need in a heating element is therefore a *balance* between the two extremes: enough resistance to produce heat, but not so it reduces the current too much. Nichrome is a great choice. The resistance of a nichrome wire is (roughly) 100 times higher than that of a wire the same size made from copper (an excellent conductor), but only a quarter as much as a similar-sized graphite rod (a fairly good conductor) and maybe only a million trillionth that of a really good insulator such as glass. The numbers speak for themselves: nichrome is an average conductor with only moderate resistance, and not remotely an insulator!

Materials Used for Heating Elements

Many heating equipment's or appliances such as electric furnace, electric oven, electric heaters etc. utilizes the electrical energy to produce the heat. In these equipment's or appliance heating element is used to convert the electrical energy in the form of heat. The **working of heating elements** is based on heating effect of **electric current**. When a current is passed through **a resistance**, it produces the heat.

To produce the heat, the electric energy consumed by resistance is given by,

$$E = I^2 Rt \ Joules$$

Where,

'I' is the current through the resistance (in A)

'R' is resistance of element (in Ω)

't' is the time (in seconds)

The performance and life of heating element depend on properties of the material used for heating element. The required properties in material used for heating elements-

1. High melting point.
2. Free from oxidation in open atmosphere.
3. High tensile strength.
4. Sufficient ductility to draw the metal or alloy in the form of wire.
5. High resistivity.
6. Low temperature coefficient of resistance.

Following material are used for manufacturing heating element

1. Nichrome
2. Kanthal
3. Cupronickel
4. Platinum

Nichrome

Composition of Nichrome

$$Ni = 80\% \ + Cr = 20\%$$

Properties of Nichrome

1. Resistivity: 40 μΩ -cm
2. Temperature coefficient of resistance: 0.0004 /^{o}C
3. Melting point: 1400^{o}C
4. Specific gravity: 8.4gm /cm^3
5. High resistance to oxidation

Use of Nichrome

Used in making heating elements for electric heaters and furnaces.

Note
Nichrome is best suitable and ideal material for making heating element. It is having comparatively high resistance. When the heating element is heated first time, chromium of alloy reacts with oxygen of atmosphere and form a layer of chromium oxide on outer surface of heating element. This layer of chromium oxide works as a protective layer for element and protect the material beneath this layers against oxidation, preventing the element wire from breaking and burning out. Heating elements made of Nichrome can be used for continuous operation at a temperature up to 1200^{o}C.

Kanthal
"Kantahl" is trademark name for alloys made by composing Iron-Chromium-Aluminum (Fe-Cr-Al). These alloys are used in wide range resistance and heating applications. Composition of Kanthal

$$Fe = (62.5 - 76)\% + Cr = (20 - 30)\% + Al = (4 - 7.5)\%$$

Properties of Kanthal
1. Resistivity at 20^{o}C: 145 μΩ -cm
2. Temperature coefficient of resistance at 20^{o}C: 0.000001/^{o}C
3. Melting point: 1500^{o}C
4. Specific gravity: 7.10 gm /cm^{3}
5. High resistance to oxidation

Use of Kanthal
Used in making heating elements for electric heaters and furnaces.
Note

When the element made of "Kanthal" is heated first time, the aluminium of alloy react with oxygen of atmosphere and form a layer of aluminium oxides over heating element. This layer of aluminium oxides, is an electrical insulator but have good thermal conductivity. This electrical insulating layer of aluminium make the heating element shock proof. Heating elements made of Kanthal can be used for continuous operation at a temperature up to 1400^{o}C. Therefore, it is very much suitable for making heating elements for Electric Furnaces used for heat treatment in ceramics, steels, glass and electronic industries.

Cupronickel
Cupronickel is also called as copper-nickel. It an alloy made by composing copper, nickel and strengthening elements such as iron and manganese.
Composition of Cupronickel

$$Cu = 66\% + Ni = 30\% + Fe = 2\% + Mn = 2\%$$

Properties of Cupronickel
1. Resistivity at 20^{o}C: 50 μΩ -cm
2. Temperature coefficient of resistance at 20-500^{o}C : 0.00006 /^{o}C
3. Melting point: 1280^{o}C
4. Specific gravity: 8.86gm /cm^{3}
5. High resistance to oxidation

Use of Cupronickel

Used in making heating elements for electric heaters and furnaces, for making coins.
Note
Cupronickel is having high **electrical resistance**, high ductility and good corrosion resistance. Heating elements made of "Cupronickel" can be used for continuous operation at a temperature up to 600^oC.

Platinum
Platinum is a chemical element. It is having the chemical symbol Pt and atomic no. 78. Platinum is least reactive metal. It has remarkable resistance to corrosion, even at high temperature. Therefore, it is considered as noble metal.
Properties of Platinum

1. Resistivity at 20^oC: 10.50 μΩ -cm
2. Temperature coefficient of resistance at 20^oC: 0.00393 /^oC
3. Melting point: 1768.30^oC
4. Specific gravity: 21.45gm/cm^3
5. High resistance to oxidation
6. High ductility
7. Highly malleable
8. Good mechanical strength
9. Good stability with temperature and mechanical stress

Use of Platinum

1. Platinum is an incredible material with high resistivity and melting point. It is very much suitable for **electrical heating elements**, **rheostats.** But due to very high cost, its use in electrical engineering is limited to laboratory furnaces with a working temperature of 1300^oC, rheostats, and resistance thermometers.
2. Platinum is a precious metal; it is very popular for making jewellery.
3. In medical platinum is used in chemotherapy for treatment of certain types of cancers.

The major types of heating elements

- Electrical heating elements that have nichrome used bare
- Electrical heating elements that use nichrome surrounded by ceramic materials that help it become durable and robust.

Electric heaters

Electric heater can be categorized into various types. The different types of electric heaters are–
1. Electric stove
2. Hot plate
3. Room heater (rod type, bowl type)
4. Immersion heater (U type, coil type), water heater

2.1.3 Electric Room Heaters

Room heaters are great, inexpensive ways of heating various rooms within your home, on your RV or even taking on an ice fishing or camping trip. They also make ideal heaters for college dorms and basements. But like all heating appliances, they are not without safety hazards. They present a potential fire risk; sadly, people are hurt or tragically killed in house fires caused by the incorrect use of space heaters every year. But, if used sensibly, they can be an inexpensive, quick and easy solution to heating various spaces around your home.

As with all appliances, it is important to carefully read the manufacturers guidance and adhere to any safety advice given. And ensure you keep the leaflet for future reference. In this article we're going to look at some of the safety issues these heaters present along with the features to look out for to ensure you and your loved ones are warm and safe.

TYPES OF SPACE HEATERS

Space heaters are simply small, portable heaters which can be used to heat rooms in your home, the garage, basement, shed etc. Or they can be taken on vacation in your RV or trailer or if you're going ice fishing or camping – they'll be a space heater for that too. Fuel types used are primarily:

• Electric,
• Kerosene,
• Propane.

Having a small space heater available could ensure you have heat in an emergency where there is a power outage or issues with your natural gas supply for example. So, it's well worth considering purchasing one, or several units, to keep on hand should you ever need them. They're compact, easy to store and highly portable providing a blast of heat when you might need it most.
Within the fuel sources there are different ways in which the heaters work including:

• Ceramic,
• Oil-filled radiant,
• Infrared,
• Fan heaters.

Electric heaters have been around for decades as a source of heat in homes to provide warmth to us. One of the reason for their popularity is because of lower cost to purchase and easy maintenance compared to other sources of heat. They are usually powered by electricity though a small percentage are still using propane or kerosene as fuel.

They work by converting electricity into heat using metals as heating elements. The metals have high resistance that permit a certain amount of current to flow through them to provide the required heat. Electrical energy is changed into heat energy and the the relationship between the wattage and Btu/hr is:

1 Watt = 3.415 Btu/hr.

There are three types of electric resistance heating wires that are in used today:

- **Open Wire** consists of nickel chromium resistance wire which is mounted on ceramic or mica insulation. For safety reason, they must be protected and should not be contacted by users or metal objects. This protection is vital to prevent the danger of electric shock.

- **Open Ribbon** is similar in material to the open wire type but has more surface area that are exposed for air contact. It too must be protected to prevent the danger of electric shock to the users.

- **Tubular cased wire** uses nickel chromium resistance wire that is surrounded by a magnesium oxide powder which are then enclosed in a heat resistance steel tube. This tube protects the users from the danger of electric shock.

One of the commonly used natural convection heating equipment is known as **Baseboard Heating Unit**. This unit has electrical resistance mounted in a casing which is designed to move air over the elements naturally. They are usually mounted under the window on the wall.

Basically room heaters are of two types :

1. Rod type room heater
2. Bowl type room heater.

Rod type room heater is again of two types :

(a) Single rod room heater
(b) Two rod room heater.

2.2.2 Rod Type Room Heater

Fig 2.1 Rod Type Room Heater

Essential parts of a basic rod type of room heater are–

1. Stand	2. Reflector
3. End connectors	4. Rod
5. Heating element	6. Connecting lead
7. Power cord	8. Plug and Switch

The stand is made of sheet of mild steel or cast iron. The room heater rests on the stands. The function of the reflector is to reflect more heat. It is a concave shaped rectangular chrome plated sheet. The end connectors hold the rod and are made of copper or brass thin sheets. Heating element is wound over the rod. The rod is made of insulating material like china clay and has grooves for placing the heating element. The rod is placed between the two end connectors. The heating element is nichrome wire and is wound on the rod. The connecting leads are three core PVC flexible cable of appropriate rating to which a three pin plug is fitted.

In two rod room heater, there are two rods and two heating elements, one in each rod. In some models a rotary switch having four positions is provided for off position, low, medium and high heat positions. For low heat, the two heating elements are connected in series, for medium heat only one heating element is connected and for high heat both the heating elements are connected in parallel.

2.2.3 BOWL TYPE OF ROOM HEATER

Fig 2.2 Bowl type of room heater

The parts of a bowl type of room heater are

1. Stand	2. Reflector
3. Bowl	4. Heating element
5. Guard	6. Power cord and plug

The stand and the body are made of mild steel sheet. The bowl is made of china clay and is fitted in the body. The bowl may be screw type or pin type and has slots. The reflector is a polished metal body behind the bowl. The heating element is made of coiled nichrome wire wound on the bowl. The guard is a net in front of the bowl. The two end terminals of the heating elements are taken out. A three core PVC power cord with three pin plug is used to give input power. The body of the heater is earthed. Break in heating element and sparking at the point of terminal joints are common problem. A broken heating element should be replaced.

Room heaters should be placed directly on the floor and should be in clear sight. A room heater should be plugged directly into the power outlet and extension cord should never be used. It must not be placed on enclosed areas and combustible materials should be sufficiently away from it.

Electric room Heater Working

Electric baseboard and wall heaters are room air-heating units. A baseboard heater has one or more horizontal heating elements and is controlled by a thermostat. Baseboard heaters are mounted at the base of a room wall. Air is drawn in through the bottom and heated by the electric elements. The warm air then rises into the room. The electric elements are often shaped like metal fins, and some are filled with fluid to maximize their heat retention. Often several units are installed around the perimeter of a room.

An electric wall heater is a forced-air heating device. The wall heater fits into the wall and uses a fan to circulate air that has been warmed by an electric heating element. The fan and row of heating elements inside the unit are controlled by a thermostat. Wall heaters are often installed in bathrooms, laundry rooms, and other areas to provide supplemental or occasional heat.

A portable electric or “space” heater is designed to warm a small area. There are two types. In convective heaters, air heated by one or more heating elements is blown into the room by a fan. In radiant heaters, the elements heat a liquid that radiates heat into the room rather than blowing it in.

A ceramic heater, a type of convective heater, uses a larger ceramic element that allows the heater to be run at lower temperatures, making it somewhat safer than other convective heaters that rely on conventional elements.
Additional components in a typical electric heater include control switches, elements, and a motorized fan. Heaters also typically have a thermostat. For safety, portable heaters usually include a tip-over switch, which shuts off the heater if it’s knocked over, and a thermal cut-off, which shuts off an overheating unit. Some cut-offs reset after the heater has cooled down, but others must be replaced if they trip.

Trouble shooting guide of Electric Room Heaters

Electric heaters are relatively simple in operation and simple to troubleshoot and repair. This topic tells how an electric heater works, what often goes wrong, how to identify the electric heater problem, and what parts and tools you will need to fix it. It then gives simple step-by-step instructions for how to disassemble radiant and convective heaters and how to service a ceramic heating element.
Most replacement parts for electric heaters need to come from the manufacturer or an aftermarket supplier. Because there are so many brands and models, hardware and electrical stores don’t carry very many. However, you can disassemble the heater, remove the problem component, and take it to a knowledgeable clerk for assistance in replacing it. Here are the tools you’ll need:

- Screwdrivers
- Adjustable pliers
- Long-nose pliers
- Multimeter

Steps to Repair Electric Heater

Disassemble a radiant electric heater:

1. Unplug the heater and let it cool completely before disassembling it.
2. To access wiring, remove the screws holding the control housing in place at the edges and lift it away.
3. To remove the thermostat, pull off the knob and remove the electrical leads, marking their location with tape. You may need to remove the retaining nut to free the thermostat.
4. To remove the power switch, label and disconnect the leads. Some switches are secured by clips on the top and the bottom; others are fastened by screws.

Disassemble a convective electric heater:

1. Unplug the heater and let it cool completely before disassembling it.
2. Remove the rear grille and the control knobs. Remove the front grille by unscrewing the fasteners on the back of the housing.
3. Remove the front grille by lifting the control housing and pulling the front grille toward you. The motor, fan, and heating element are now accessible for testing and repair.
4. Remove the thermostat from the control housing and disconnect the wires. Remove the heat control's mounting screws and clips to access and disconnect wires.

Service a ceramic electric heater element:

1. Inspect the unit for screws and hidden fasteners, removing them as needed.
2. Remove clips, fasteners, and other components to reveal the heating element.
3. Test each element using a multimeter set on the RX1 (resistance times 1) scale. The reading should be approximately 10 ohms.
4. To replace a faulty ceramic heating element, disconnect the terminal lead on each side and lift the element out of its housing. Be sure to note the element's position, so it or a replacement can be reinstalled with the least effort.

Electric heater not working: causes and solutions

An electric heater is a very useful appliance in the winter months or colder countries. Not only does it heat a room but also provide with comfort and cosiness. These heaters are of many types such as wall mounted, portable and others. No matter what the type, the appliance may stop working for a number of reasons. If this happens, then it is important to first understand the cause and then find a suitable solution. Moreover, there are certain problems with electric heaters that you can resolve on your others whereas others may need professional approach. The following are the causes and solutions for electric heater not working:

1. Check the power

CAUSE: The first and most common cause for electric heater not working or turning on is problem with the power supply.

SOLUTION: You need to make sure that power is available from the main supply. If yes, then check whether the power switch is working properly or not. This can be done by connecting another power device to the switch and checking whether it is working or not. If not, then there is an issue with the power switch and it needs to be repaired.

2. Blown fuses

CAUSE: The most common cause for electric heater not working is*blown fuses.*

SOLUTION:

- To check this, first unplug the device and check the fuse box of the house for blown fuses as well as tripped circuit breakers.
- If it is fuses or tripped, then what you can do is that you can replace the fuse or reset the circuit breakers if required.

- Now plug the appliance back in and switch it on.
- See if the problem has been resolved. If not, the following given points might prove useful.

3. Auto safety shut off

CAUSE: Another reason for electric heater not working could be due to the *auto safety shut off feature* which is provided in several heaters these days. When heaters get too hot, then this feature shuts off the device for safety purposes. May be because of this feature your heater may not be working.

SOLUTION: So what you can do is that you can reset the feature by moving the power switch to the off position if the device does not turn back on. Unplug the device and let it cool down for 10-15 minutes. Plug it back again and turn the switch on.

4. Check the thermostat

CAUSE: In most cases of electric heater not working, the problem comes out to be with the thermostat. It could either be stuck, gone loose or may have become faulty.

SOLUTION:

- Check the thermostat and see which level it is set at. If it is at an off position or a low temperature, then try turning it on a higher level. See if it starts working now.
- However, keep an eye on it to check that it doesn't stop working due to auto safety shut off feature.
- Also in some cases, the thermostat dial tends to get stuck or become faulty. Because of this reason too the electric heater may not work or not provide enough heat.
- Check the thermostat and if need be, get it replaced by contacting a professional.

5. Problem with the electric cord

CAUSE: Another cause of electric heater not working could be an issue with the electric cord. An electric cord can go faulty and may stop working which in turn effects the working of the heater.

SOLUTION: So make sure you check the cord for any breaks. It must not be torn or broken from anywhere in between.

6. Problem with the heating element

CAUSE: Another possible cause for electric heater not working is heating element gone bad

SOLUTION: To check this issue, you will need to test the continuity of the heating element. This can be done by following the given steps:

- Unplug and turn off the heater from the main supply and power switch.
- Disassemble the electric heater to access the heating element and set the multimeter to RX1 or resistance times 1.
- Now touch the probes of the multimeter to each end of the heating element of the heater.

- If the meter shows high resistance, then this means that the heating element is fine and if the reading is infinity then this means that there is a problem with the element and it is broken.
- In case it is faulty, you need to replace it but make sure you get the same size, make, shape, power rating and resistance.

Now that you know the main reasons for electric heater not working as well as the various solutions for all the common issues, you can repair your heater on your own.

Room heater not blowing hot air: causes and solutions
Room heaters prove to be extremely useful devices during the winter months as they keep us warm and cosy. These appliances usually work smoothly throughout the cold season and may not show any problems if kept well maintained. However, every once in a while you may notice some or the other problem cropping up and one of them is heater not blowing hot air. Well there could be many reasons for the same and some of them have been given as follows along with the appropriate solutions:

1. Blown circuit or resistor
CAUSE: The most common cause of heater not blowing hot air could be a blown circuit or resistor.

SOLUTION: For this you may have to open the case and start testing the circuit by making use of a voltage regulator. See if there are any breaks in the electrical path. You must be aware of the fact that the voltages will change between the circuits which are divided by resistors. If the circuit is broken, you can either replace it yourself or have a professional do the job for you.

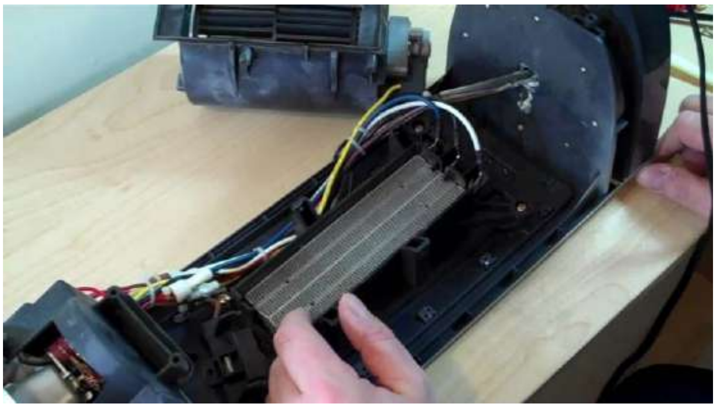


Fig 2.3Blown resistor

2. Broken heater coil
CAUSE: Another common reason for room heater not blowing hot air is broken heater coil.

SOLUTION: Check if there are any breaks in the line after opening up the case. The wires together work as a complete circuit and in case any of them snaps from the constant heating and then cooling then the circuit may get broken and may stop giving off heat. If the heater coil is in factbroken, then in that case you can take a soldering gun to heat up the contacts and remove it. You can then replace them with suitable parts which must meet voltage standards.

Fig 2.4**Broken heater coil**

3. Check the thermostat

CAUSE: Another cause for room heater not blowing hot air could be an issue with the thermostat. It may either not be set up at the right temperature or could be faulty.

SOLUTION: So check the setting at which the thermostat is fixed. If it is at a colder setting, then make sure you turn it and set it correctly. However also check whether it is moving properly because in some cases it becomes free and thus faulty. Replace it in case it is not working properly.

4. Dirty air filter

CAUSE: Sometimes due to constant usage, the air filters of centralised room heaters become dirty and this may lead to the heater not blowing hot air.

SOLUTION: If this is the case then you will need to clean the filters so that the heating can be proper again. For this, first clean the surface of the heater and remove loose dust with a microfiber cloth. Make sure the heater is turned off at this point. After that unscrew the heater's cover spray the interior compartment with an air duster. Use a damp sponge for further cleaning. If the need be, replace the filters and check if the heating has become better.

Key Safety Tips For All Types Of Heaters

These basic safety tips are relevant no matter which type of heater you own:

• Never place anything on top of or covering a heater, especially wet or damp clothes,
• Never plug a heater into an extension cord, or strip, this may cause overheating and is a potential fire hazard,
• Never place a heater on to an uneven or unsafe surface, ensure it's on a flat, heat safe surface,
• Never place a heater where it might touch clothes, curtains, fabrics, towels etc.
• Never leave your space heater unattended.
• Switch off your heater when leaving the room,
• Keep heaters at least 3 feet away from any flammable furniture, cushions, curtains etc.
• Keep heaters away from young children and babies,

Room Heater side effects

Room heaters are great to save yourself from the harsh winters. But at the con side there are few issues to consider related to safety and health.

Room Heater disadvantages -1: Fire accidents

- Room heaters can cause potential fire accidents. Many accidents are reported due to room heaters. Never leave them unattended.
- Do not cover the room heater outlet. It will catch instant fire if you do so. Do not put any polyester clothes near to room heater.
- Avoid any inflammables near to room heaters.
- Be aware, do not allow children to touch the room heaters. Especially the halogen room heaters surface gets very hot and can be very dangerous to children.
- Choose room heater with thermostat so that you can stop the heater when it reaches some degree of temperature. Otherwise at least consider timer based room heaters so that they get switch off after some duration.

Room Heater disadvantages -2: Health issues

Room heaters burn oxygen and reduce the humidity in the air. This is the case with fan based convection room heaters and halogen room heaters.

- Burning of oxygen leads to potential oxygen levels drop and leads to suffocation. You need to open the door little for this.

- Apart from that these heaters reduce the humidity leading to dry eyes, nasal blockage. Try to use humidifier in the room or at least place bowl of water in the corner of room
- By using the oil based filter you can save yourself from low oxygen levels and reduced humidity as oil room heaters do not modify these levels.
- Room Heater makes unwanted noise,It is quite annoying to bare it all night leading to disturbed sleep.

Suggestion

- If possible, drink so many fluids to save yourself from dehydration
- Wear good wool clothes so that you can reduce the dependency on the room heater.

It is evident from the above explanation that Oil filled room heater reduce significant fire accidents and protect from oxygen burning and low humidity levels. Indeed, oil based filters come with advanced features like thermostat and timer. Oil filled room heater are child safe but still user monitoring is essential for perfect safety while it operates.

2.2.4Electric iron

Introduction

There are various electrical inventions used for domestic purposes such as the electric fire, electric iron, and electric water heater that all depend on one common principle; when a current is passed through a piece of wire, the wire heats up and emits heat radiation. This heat is distributed and used for various purposes. Learn more about how this works with information on the electric iron invention. In this article, we will discuss about the various types, parts, and theory of operation.

The Electric Iron

An electric Iron is a general household appliance used to press the wrinkles out of the clothes. This works on the basis that the combination of heat and pressure removes wrinkles. The principle of the electric iron is that when current is passed through a coil, the coil gets red hot and transfers the heat to the base plate of the electric iron through conduction.

Ironing of different types of fabrics like nylon, rayon, silk, wool, cotton, linen etc require different temperatures. Electric irons operate with 220-volt AC and are available with usual power rating between 450 watts and 2.0 kilowatt. The common working temperature is around 100^{o}C and safety devices are provided in some models to prevent temperature rise beyond 200oC or 250oC. Small irons of power rating as low as 300 watts are also available. Now a day’s numerous models from various manufacturers are available. Modern electric irons have attractive features like beautiful look, light weight; multiple adjustable temperature levels to suit different fabrics, non-stick coated sole plate, thermal fuse for safety etc.

In the earlier day’s steam irons were used, but now the electric iron is preferred over the steam ones. Steam irons have some maintenance issues due to clogging. Steam irons usually have vents through which the water passes. As the steam iron gets used, slowly the minerals from the water accumulate at the vents and blocks the water from passing through. Thus the efficiency of the steam iron is compromised. So the steam iron has to be cleaned and maintained regularly to ensure its proper working. If you live in an area where hard water is used, then clogging is a major problem.

This drawback is eliminated in electric iron as it uses a heating element and there are no vents in it. There is considerably less maintenance in an electric iron when compared to a steam iron.

The working of an electric iron is very simple – it takes current from the mains and heats up a coil inside it. This heat is then transferred to the base plate which is pressed against clothes to remove creases.

There are basically two types of electric irons:

- Automatic
- Non-Automatic

There is not much difference between the two types. The former has one regulator to control the temperature of the element and in-turn the temperature of the iron.

Now you may ask, why do we need to control the temperature of the iron?

The answer is simple. Now-a-days we use various types of fabrics such as cotton, silk, linen, etc. So to suit the temperature required for different kinds of fabrics, we use the temperature control.

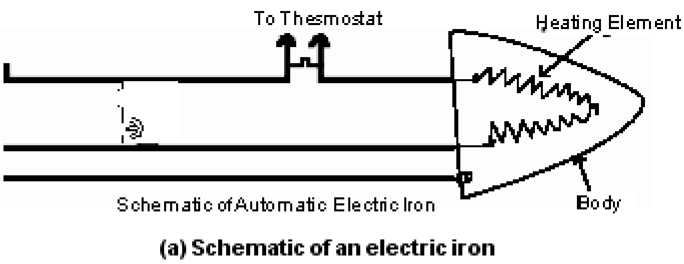


Fig2.5 Wire Diagram

2.3.2 Essential parts of a basic electric iron

1. Sole plate 2. Heating element
3. Pressure plate 4. Cover plate and handle
5. Power cord and plug
Additional parts in automatic irons
1. Indicator Lamp 2. Thermostat
Additional parts in steam iron
1. Steam chamber 2. Water reservoir

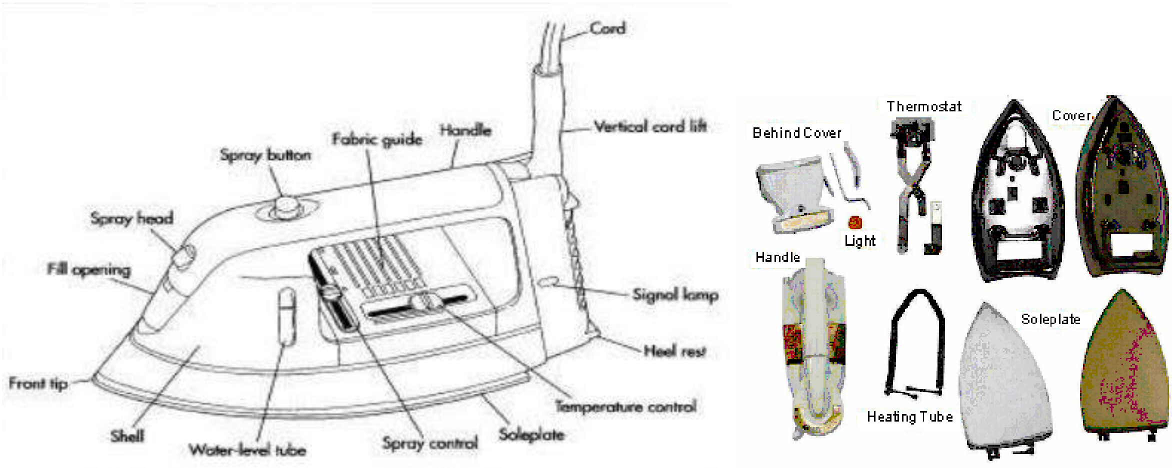
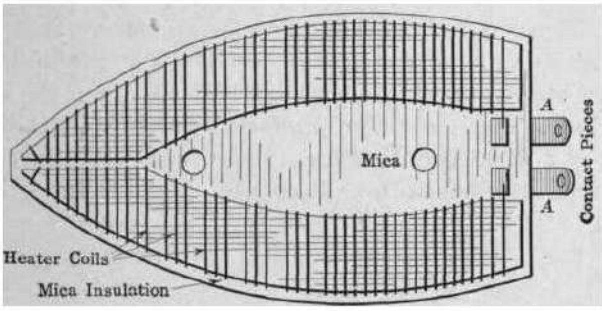


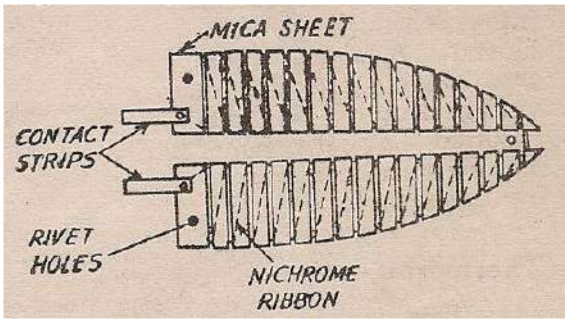
Fig 2.6 Schematic Diagram of Electric iron

Sole plate

The sole plate is the thick, triangular-shaped slab of iron that forms the base over which the electric iron is built up. The bottom surface and edges are heavily chromium plated, to prevent it from rusting. The base plate should hold the iron pressure plate and cover plate in position. For this purpose we can see two or sometimes three studs in the base plate. These studs aid in holding the position of cover plate and pressure plate.

- Aluminium soleplate: This soleplate surface conducts heat well, but may be hard to clean and can scratch easily. It may become sticky after many uses, causing wrinkles instead of gliding smoothly over fabric.
- Ceramic soleplate: This soleplate surface offers a high-quality ironing experience. Ceramic soleplates feature a durable, non-stick surface while distributing steam and heat evenly. These soleplates glide over fabric smoothly.





- Non-stick soleplate: A soleplate surface that prevents starch residue from building up, making the iron easier to clean. It allows the iron to move smoothly on fabric for top speed and performance.
- Stainless steel soleplate: This durable soleplate surface is corrosion, rust and scratch resistant. Highly-polished stainless steel makes ironing even more effortless.
- Steam: This feature distinguishes an iron from the basic iron. Steam is key to removing tough wrinkles from clothes, which can save you time and frustration.
- Vertical steam: Vertical steam irons offer the benefits of a standard steam iron, but also offer a quick and convenient solution to smoothing hanging clothes and drapes, and reducing musty odours.
- Wattage: Higher iron wattage reduces heat-up time and may increase performance.

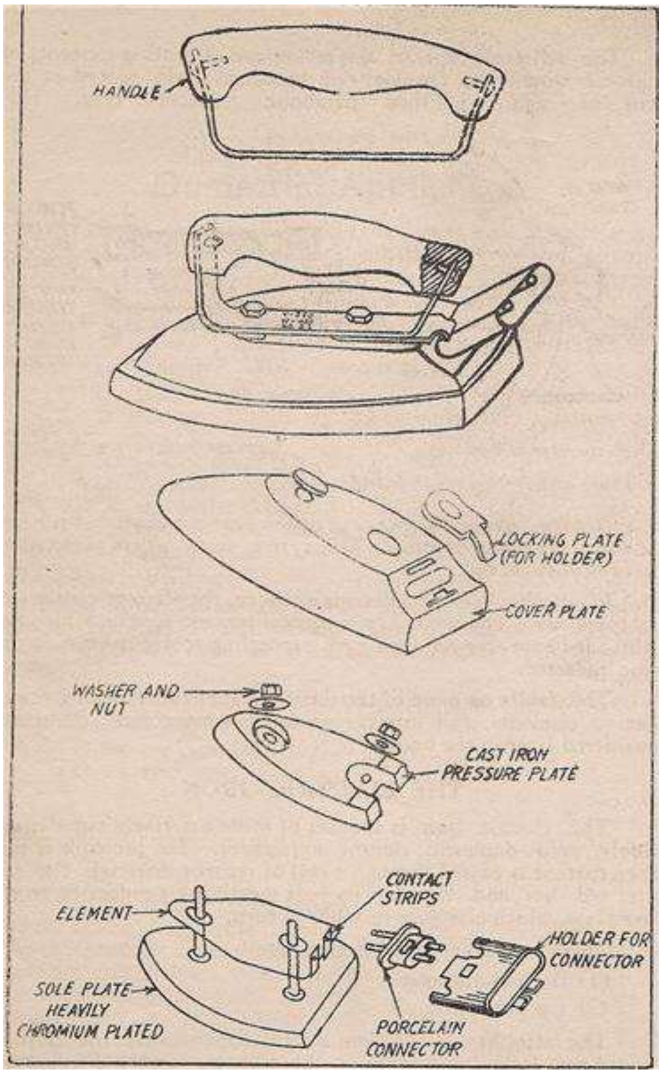
The pressure plate is made of cast iron or steel sheet and in some older models the pressure plate is comparatively heavy. The shape of the pressure plate is similar to that of sole plate.

Heating Element

Fig 2.7 **Heating Element** Fig 2.8

The heating element is a nichrome wire or ribbon wound over a sheet of mica and this sheet is insulated by placing between other two mica sheets. In recent models the heating element is encapsulated in a metal tube. The heating element is properly insulated and remains tightly pressed between sole plate and the pressure plate. The construction of heating element of non automatic and automatic irons is different. In case of automatic iron, there is provision for placing the thermostat assembly for temperature regulation. The two ends of the nichrome wire are connected to the contact strips. The contact strips are connected to the terminals of the iron. There are two reasons for which mica is chosen in the heating material. Mica is a very good insulating material. Besides that mica can also withstand very high temperatures. The entire assembly of mica sheet, nichrome wire and contact strips are riveted together resulting in a mechanically sound and robust construction. There is an asbestos sheet, which separates and thermally insulates the top plate from the heating element.

When current flows through the heating element, heat is produced. This heat gets transferred to the sole plate by convection.



The two end terminals of the heating elements are taken out by means of insulated lead to the power socket on the top plate. In recent models, the input power cord is directly connected to the heating element leads and the power cord is not detachable. A three core power cord is used and the metallic portions of the body of the iron always remain connected to the earthing point. In some models a small capacitor is connected across the two contact points to save the possible damage of the contact points because of frequent on and off of power supply. In non automatic iron there is no provision for controlling or regulating temperature. When the iron is too hot, it is to be manually switched off and when the temperature is less than required, it is to be switched on manually.

Pressure plate
This plate is generally called the top plate as it follows the shape of sole plate. The pressure plate has some holes through which the studs form the base plate passes through. We should tighten the nuts on the studs in such a way that the pressure plate and sole plate are pressed tight against each other. In some iron the pressure plate is heavy and made of cast iron while in some other cases, it is a thin sheet of steel, about ¼ cm thick.

In automatic type of electric iron, the pressure plate has a rectangular or circular hole for locating the thermostat.

Cover Plate
The cover plate is made of thin sheet of iron. It is placed on top of the base plate and it covers all the internal parts of the iron. The handle and connector are only attached to the cover plate. The cover plate is usually made of nickel plated iron sheet and it covers the parts of the iron.

Handle
The handle is made of plastic material and is attached to the cover plate. In some earlier models there were handles made of wood also.

Thermostat
When it comes to an automatic electric iron, the thermostat is the most important item. It uses a bimetallic strip to operate the switch which is connected in series with the resistance (or) heating element.

The bimetallic strip is a simple element which converts a temperature change into mechanical displacement. A bimetallic strip consists of two different metals bonded together. The two metals should have a Fig 2.9 Alignment Diagram

different coefficient of expansion. If such a strip is heated, it starts to curve towards the metal having the lower co-efficient of expansion. On cooling, it straightens and comes back to the normal position.

Now we might wonder why such an element is used in iron. What is the purpose of this element in an electric iron?

The bimetallic strip is attached to a contact spring through small pins. The contact point between the strip and contact points remains closed. When the temperature rises significantly, the unusual expansion causes the strip to curve and the contact between strip and contact spring opens. Thus the supply to heating element is temporarily stopped (until the temperature goes down to normal). A special device called the cam is placed is placed near the contact spring, with which we specify the amount of curving of bimetallic strip required to separate the contact.

Thus using bimetallic strip the temperature is kept constant within certain limits.In the automatic iron thermostat is widely used to regulate temperature and there is an indicator lamp. The indicator lamp is on the top cover and glows when the heating is going on.

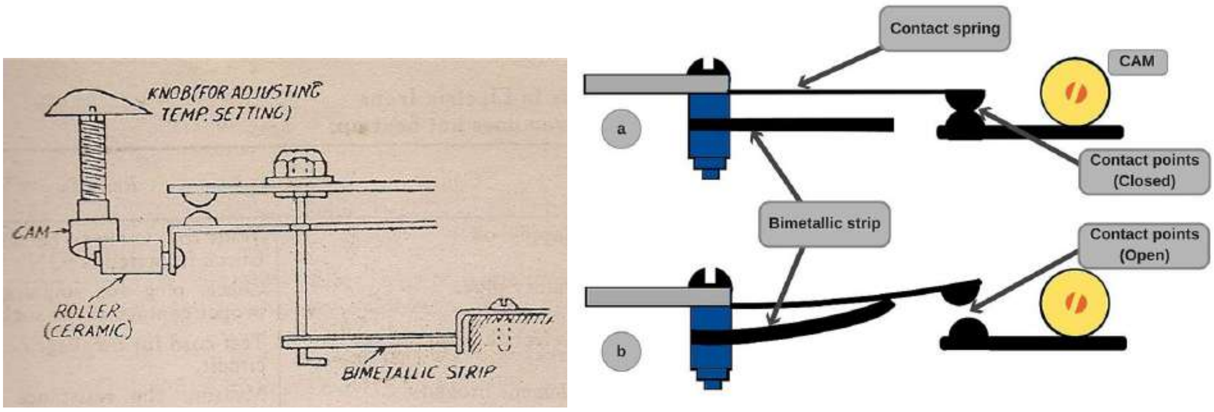


Fig2.10 (a) Under normal temperature, (b) When the iron becomes too hot

The thermostat is a device which makes and breaks the connection between two points depending on temperature. It is like an automatic on off switch. The transition between on and off depends on temperature which can be chosen or set. There is a dial knob by rotating which temperature can be set as per requirement of the type of fabric. If the set temperature is say 150oC, then when the iron is switched on, the thermostat will act as on switch and will allow current flow through the heating element. As current flows through the heating element, temperature rises. Once temperature rises above 150oC the thermostat acts as a off switch and cuts off current flow through the heating element. Then the temperature gradually decreases. Once the temperature is below 150oC the thermostat acts as on switch and allow current flow through the heating element. These on and off conditions continue and the temperature of the iron remains constant at approximately 150oC.

Pilot Lamp

Pilot Lamp located on the cover plate of the iron. One side of the lamp is attached with supply and another side is related to the heating element. There is a shunt resistance across the pilot lamp that provides a voltage drop of 2-5 volts.

Capacitor

A capacitor with specific range also connected across the two contact points. Often making and breaking of circuit damage the contact points. It can lead to interference with radio reception. This is why capacitor is an important part of an electric iron. A capacitor prevents those issues. In steam iron there is a water reservoir on the cover plate and a steam chamber above the sole plate and the sole plate has slots. As the iron is switched on heat produced by the heating element boils the water and steam is produced. The steam gets emitted from the slots of the sole plate ensuring better quality ironing.

The common problems are break in heating element, defect in power cord or thermostat loose connection and improper earthing. A broken element has to be replaced. Defects in power cord and thermostat sometimes can be rectified by adjustment. Loose connection and improper earthing has to be rectified.

2.3.3Working of electric iron

The electric iron that we use to press the creases out of our garments also contains a thermostat, which makes sure that the iron doesn't get too hot if it's kept switched on or left unattended for an extended period of time. Let's take a look at exactly how the mechanism works.

An electric iron relies on a basic combination of heat and pressure to remove creases from clothes. When an electric current is passed through a coil (or any other heating element present in the iron), it gets very hot. This heat is then transferred to the base plate (the smooth, flat surface that you place against clothes while ironing) through conduction, which elegantly and precisely irons your clothes.

However, if the iron is continuously drawing electricity from the power supply, the heating element continues getting hotter. This causes a lot of energy wastage (as an iron consumes a lot of electricity even in a few minutes), ruins your clothes, and in the worst cases, causes nasty (and potentially dangerous!) accidents.

Therefore, it's essential that the iron doesn't heat up to hazardous temperatures. This is where the thermostat enters the picture.

2.2.5 Steam Iron

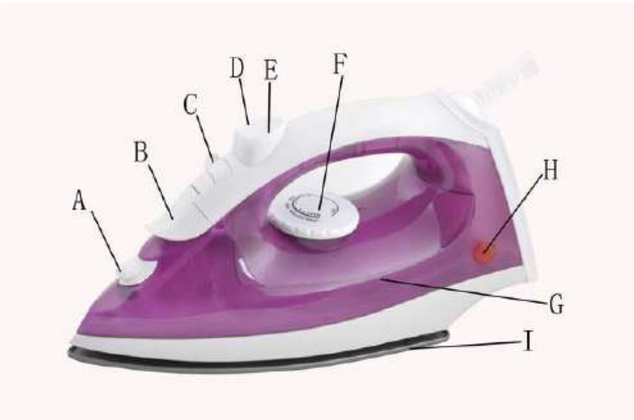


Fig 2.11 Steam Iron

A---Spray Nozzle B---Water Filling Hole C---Steam Regulator D---Burst Steam Button E---Spray Button F---Thermostat Dial G---Water Reservoir H---Power Indicator Light I---Soleplate

Filling with Water:

1. Set the steam regulator to 0(=no steam) (only for steam iron).
2. Hold the iron by hand and slant the iron with 45°down.
3. Fill the water in the box through the Water-Filling Hole, if the water is too hard, it is advisable to use distilled water, do not put the chemically water in the water reservoir.
4. Wipe off the water over the box; pour out the remaining water after use.

Dry Ironing:

1. Before running the iron, please classify the clothes as per its washing label, as it will be quicker for the iron to heat up that to cool, the clothes (such as synthetic fabric, silk etc) with lower ironing temperature shall be ironed firstly, and then iron the clothes(such as wool, cotton and linen etc.)with higher temperature.
2. Stand the iron on its end, and turn the thermostat dial to the MIN position.
3. Plug in the iron and select the temperature by turning the thermostat dial. If there is water in the reservoir, turn the steam regulator to OFF position. Wait until the indicator light goes off showing that the required temperature has been reached.

Steam Ironing:

1. Fill water in the iron as per the water-filling methods.
2. Plug the appliance in the socket.
3. If only set thermostat dial to MAX position as per the temperature indicator, steam iron will be available, otherwise water may leak from the soleplate.
4. It indicates that the temperature has been ready until the indicator light goes off.
5. Set the steam regulator correctly, increase the steam output by rotating the steam regulator anticlockwise. otherwise decrease.

Caution: Synthetic Fabric, Nylon, Synthetic Silk and Silk cannot use the steam iron.

otherwise it will damage the finish of surface.

Burst of Steam:

This function will be able to provide more steam to remove stubborn creases.

1. Set the thermostat dial button to MAX until the indicator light goes off.
2. Release the steam by pressing the steam button.
3. Wait for several minutes and let the steam penetrate through the fabric, and then release more steam through pressing this buttons again.

Note:

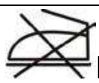
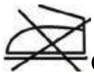
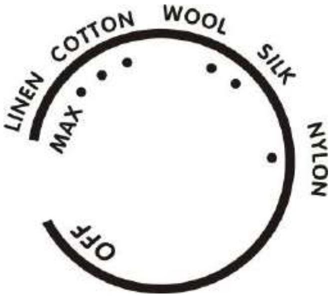
1. There should be 3-5 seconds rest between two times of pressing Steam Button in order to obtain the best steaming result.
2. Fill the water to the MAX position before using this function.

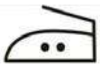
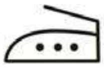
3. In order to prevent the water leaking from soleplate, please do not press the steam button continuously with more than 5 seconds.

Spraying Methods:

1. Fill the water in the iron as per water-filling methods.
2. Press water spray button.
3. Note: No matter what steam ironing of dry ironing is, spray will always be available in any case.

Table 2.1 Type of Fabric and Thermostat Dial Form:

<table>
<tr><td colspan="4">Caution:  Please note that  on the label means that this article may not ironed.</td></tr>
<tr><td>Instructions on Label</td><td>Type of Fabric</td><td>Thermostat dial</td><td rowspan="5"></td></tr>
<tr><td></td><td>Nylon Silk</td><td rowspan="4">MIN
▲

MAX</td></tr>
<tr><td></td><td>Wool</td></tr>
<tr><td rowspan="2"></td><td>Cotton</td></tr>
<tr><td>Linen</td></tr>
</table>

Caution: If the fabric consists of various kinds of fibers, always select the lowest ironing temperature of the composition of those fibers.

After Ironing:

To extend the working life of the iron, whenever you finish ironing, you are recommended to empty the reservoir as follows:

Unplug from the mains socket. Empty the iron. Shake it lightly above a sink. To dry the remaining moisture, turn the iron on again with the thermostat dial in the MAX position with steam regulator in MAX position until Power Indicator Light goes off. Unplug from the mains socket and allow to cool. Clean the plate with a dry cloth as traces of moisture could mark it.

Cleaning and Maintenance:

Before cleaning, remove the plug from the socket and allow the iron to cool down sufficiently.

1. Wipe off the soleplate with a damp cloth and a non-abrasive(liquid)cleaner.
2. If the fiber is adhered to the soleplate, use a damp cloth with vinegar to wipe off the soleplate.
3. Never use strong acid or alkali in order to avoid damaging the soleplate.
4. If the scale blocks the steam hole, please remove the scale with toothpick; do not damage the surface of soleplate.
5. Stand the iron on the end and let it cool down sufficiently, and meantime pour any remaining water out of the box, set the steam regulator to positon"0".

Simple Repair Methods:

Table 2.2

Failure	Possible reasons	Measurement
Not enough heat or too heat	Rotate thermostat dial button improperly	Correct thermostat dial button in position
No steam produces	Check if the thermostat dial has been set towards the steam range	Adjust the regulator towards the steam range
	Check if the steam regulator has been set towards the steam position	Set steam regulator towards the steam range
	No or too little water in box	Fill water into the box
Leaking water from soleplate	Set the thermostat dial out of steam range	Set the thermostat dial as per steam range
	The heat is still not enough	Open steam button only after the indicator light goes off
	The water is over than max position	Pour out the remaining water
Little steam	Check if the steam regulator is in proper location	Set the steam regulator to the proper location
	Steam hole or box is blocked	Clean hole with distilled water
	Too little water in the box	Fill water into the box
No spraying	No enough pressure or air inside	Press the spray nozzle by hand, and push the spray button several times continuously
	No or little water in the box	Fill water into the box

2.3.4 Trouble shooting guide of Electric Irons

Steam Iron Disassembly

Note: Screws inside the steaming Iron may be rusted, therefore it will be difficult/impossible to unscrew them.

Step 1 Steam Iron Disassembly

Fig 2.12

- Start your disassembly on a clean desk, make sure you have trays to store screws and other components, to prevent losing them

Step 2

Fig 2.13

- ***Image 1:*** *Remove the plastic cover to expose the screw*
- ***Image 2****: Unscrew the screw with your screwdriver*
- ***Image 3****: Detach the top of the handle with your hand.*
- *The handle can't be fully detached at this point , because the plug cable goes trough the handle in the back*

Step 3

Fig 2.14

- *Take the top part of the handle, which you removed from the iron in the step before.*
- ***Image 1&2:*** *remove the two large buttons from the handle by pushing them down if they didn't fall out already*
- *Rotate the handle so you see the inner side of the part*
- ***Image 3****: Remove the small sliding button by pushing one of the legs outwards. The sliding button pops from the handle.*

Step 4

- *To replace the rubber component in the front of the appliance, remove it with your hand and replace it with a new one.*
- *This component needs to be replaced if the rubber is dameged, this rubber prevents water leaking into parts of the appliance it is not supposed to be.*

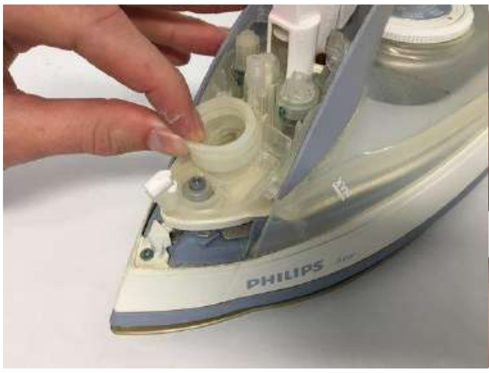


Fig 2.15 Fig 2.16 [Step5]

Step 5

- *To replace the lamp on top of the handle of the steaming iron, detatch te wires carefully from the plastic components*

Step 6

Fig 2.17

- *Follow the instructions at this step if you experience trouble with the top sliding button of the appliance*
- ***Image 1:*** *Remove the screws which connect the white plastic part to the main part of the appliance. (these are the screws on the left and right of the white plastic part, closest to it)*
- ***Image 2:*** *Use your hand to lift the white plastic part, which covers the component you will remove in image 3*
- ***Image 3:*** *Use your hand to lift the part to remove it from the steaming iron. If a spring or another component is broken, replace it and put the part back at its place.*
- *After replacing one of the components put the part back with the tallest pin facing the front of the iron!! See image 3*

Step 7

- *This step removes the remaining part of the handle to gain access to the bottom part of the steaming iron*

- ***Image 1***: *Remove both screws at the front top of the product*
- ***Image 2***: *Remove the screw at the top back of the steaming iron. This screw is located near the power wire*
- ***Image 3:*** *Remove the remaining part of the handle with your hand*

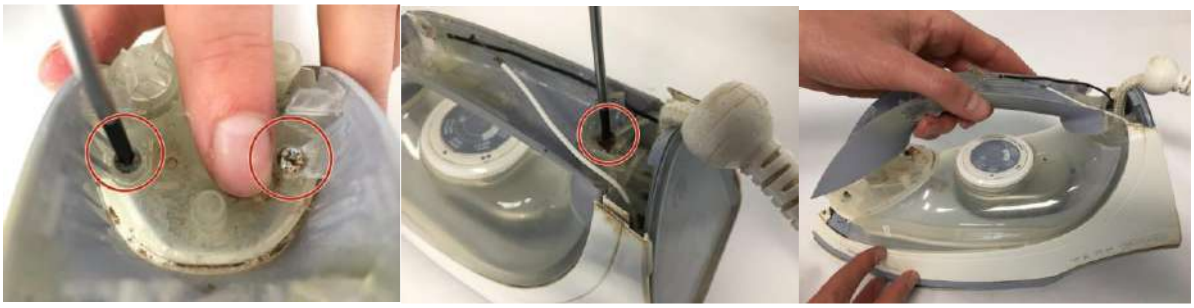


Fig 2.18

Step 8

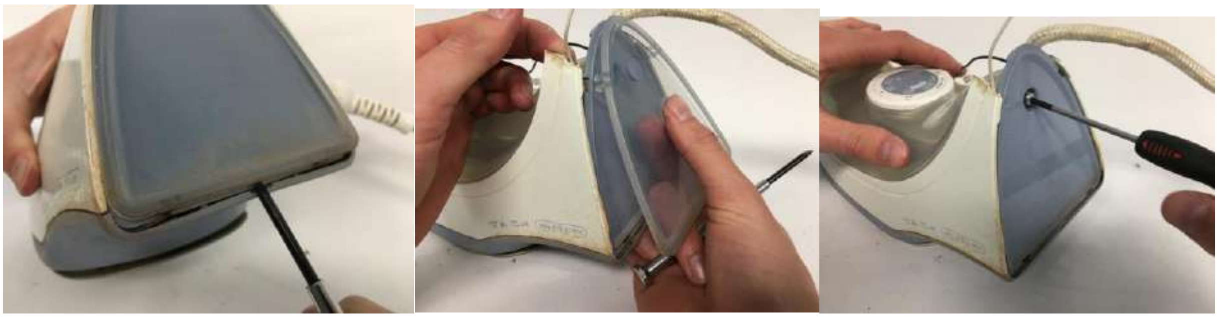


Fig 2.19

- *By following step 8 and 9 you will detach the back surface of the steaming iron and expose the electrical wires. These steps also need to be completed to remove the water tank*
- *The plastic covering plate is connected by snap fits to the product. A hinch is placed between both. apply some pressure with a lever (we used a flathead screwdriver) and pull the part back with your hand to remove the transparent plastic part*
- *Image 3: Unscrew the exposed screw to remove the blue plastic part*
- *Be careful with the snap joints !! You don't want to break them*

Step 9

Fig 2.20

- ***Image 1**: Remove the 'back' of the steam iron with your hand*
- *Image 2 & 3: Unscrew the 2 screws next to the electrical wire. This step is needed if you want to replace the power cord*

Step 10

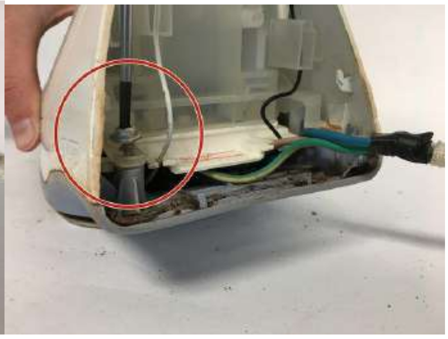



Fig 2.21

- *Step 10,11 &12 will help you remove the water tank*
- *Remove the 2 screws at the back of the screwdriver as shown in the images*

Step 11

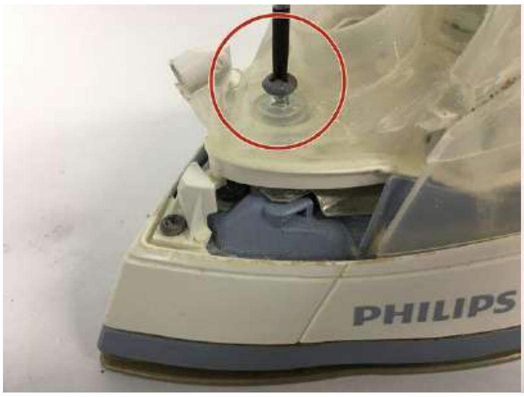


Fig 2.22

- *Remove the 2 screws in front of the steaming iron as shown in the pictures. After removing these pictures, the water tank can be removed, which is described in the next step*

Step 12

- ***Image 1:** Use your screwdriver to 'unclick' the snap joint at the front to detach the water tank from the bottom of the product, as shown in the image.*
- *Make sure you don't apply too much force to the snap joint! You don''t want to break it*

Fig 2.23

- ***Image 2****: Detach the water tank bylifting it up with your hands.*
- *Make sure you don't pull any of the cables in the back while lifting the water tank*

Step 13 ***Fig 2.24***

Fig 2.24

This step shows how to remove the metal plate

- ***Image 1:*** *Remove the screw at the front of the steaming iron*
- ***Image 2:*** *Lift the plate with your hand to remove it*

Step 14

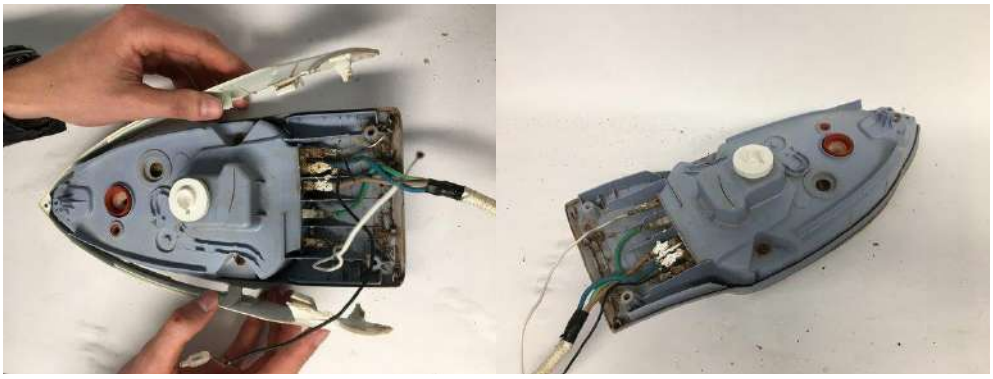


Fig 2.25

- **Image 1**: Detach the white sides of the steam iron by pulling them away from the assembly.

CONCLUSION

To reassemble your device, follow the following instructions in reverse order.

Tools for Electric Iron Repair/Service

Larger hardware stores may have replacement parts for popular brand electric irons. Also, you can get them from the manufacturer or an aftermarket supplier. Maintenance and repair tools you'll need to fix an electric iron include these:

- Screwdrivers
- Toothpicks or pipe cleaners
- Sewing needle
- Commercial electric iron cleaning solution or vinegar and water
- Commercial soleplate cleaner or baking soda and water
- Steel wool
- Emery cloth
- Metal cooking pot

2.3.1Electric Stove

An electric stove is a common domestic appliance used for cooking. It works with 220-volt AC supply and different models are available with power rating usually from 750 to 1500 watts.

Electric stoves are the main alternative to conventional gas stoves. They offer a means of cooking using electricity to produce heat. Electric ranges and ovens are available separately or in a combined package for versatility and space-savings in the kitchen. Electric stoves use several parts to provide clean, consistent cooking heat.

Electric stoves avoid the need for a gas line in the kitchen.

Construction and Working

Fig 2.26 ***Electric Stove***

Parts of an Electric Stove

- Heating element.
- Insulator base with grooves.
- Metal frame

- Thermostat
- Fuses
- Racks
- Control Knobs
- Timer
- Power cord

Heating Elements

Some of the most important parts of an electric stove are the heating elements, which convert electrical energy into heat for cooking. An electric range may use one of a number of different heating element styles, including traditional coil elements, metal disks, hidden radiant heating elements below the range surface or magnetic induction elements.

Electric ovens generally feature two heating elements. One is located near the top of the oven for broiling or heating food from above. The other is located near the base of the oven and supplies heat for baking. Cooks can activate one or both heating elements, depending on cooking needs.

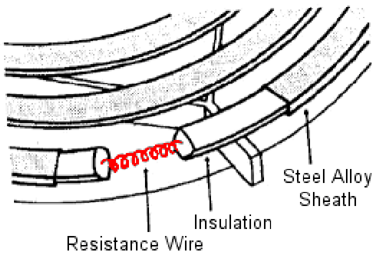
A heating element generally consist of 3 parts:

Fig 2.27

1. A resistance wire that conducts electricity and heat
2. An insulating layer that conducts heat but **not** electricity
3. An outer layer that conducts heat whose main purpose is to hold the inside elements together

The outermost layer is pretty boring. It's usually made of 304 stainless steel. The resistance wire on the inner-most layer is commonly made of Nichrome, a nickel-chromium alloy. It is usually 80% nickel with 20% chromium but that composition can vary. Nichrome is relatively inexpensive and works great as a heating coil for low-temperature (relatively speaking, as it can handle up to 1040 °C) applications like a home stove. For higher temperatures, Molybdenum or Platinum based materials are used.

The mid-layer -- the insulation that the question asks about -- is usually ceramic (ceramic powder, to be exact). The ceramic powder is tightly packed into the tube so that it completely separates the resistance wire from the steel outer shell. Ceramic is a great conductor of heat, but is an insulator to electricity, making it a perfect material for this application.



Cross-Section of a Conventional Coil Element

Insulator base with grooves

The insulator base is made of porcelain and the heating element is placed in the grooves of the base. The base is fitted to the metal frame.

Metal frame

The metal frame acts as a stand for the whole electric stove. The two ends of the heating element are taken to the power supply connector terminals by means of flexible leads. These flexible leads are insulated by covering them with beads of insulating material like porcelain

Thermostat

An electric stove's thermostat is a simple device that monitors the temperature inside the oven and disengages or engages the heating elements as necessary. The thermostat is connected to *the control knobs and may also supply a digital read-out of the desired temperature or activate a light when the oven is heated to the desired level.*

Fuses

Electric stoves use a series of fuses to protect the heating elements. These fuses will blow if too much electricity flows through them, preventing the surge from reaching the heating elements. Electric stove fuses are generally located in a closed fuse box near the base of the oven or behind the stove assembly.

Racks

Electric stoves use conventional oven racks as the cooking surface within the oven. Instead of a separate compartment for broiling, as some gas ovens have, electric stoves require the cook to raise one of the oven racks to a higher position to place the food directly below the upper heating element.

Control Knobs

An electric stove's control knobs give the user a way of setting the temperature of the oven and activating each of the burners on the range individually. The knobs also control the oven's self-cleaning feature and set the timer.

Timer

Electric stoves usually include a digital or mechanical timer for ensuring that food stays in the oven for the proper amount of time. The timer may be linked to a clock or separate from it. Some electric stoves also include a self-timer for setting the oven to turn on or off at a specified time. Other timers simply buzz or beep when they reach the desired time, alerting the user that it's time to check the food or add ingredients.

The heating element is exposed. If water or any other item like tea, milk, curries etc falls on the heating element when it is red hot, the oxidation of the heating element becomes rapid and it may get broken soon. When the heater is ON, anyone getting contact with the exposed heating element through any conducting item (say utensil or spoon) will get electric shock. Earthing should be proper and the metal frame should be properly earthed. Because of alternate expansion and contraction due to alternate heating and cooling loose connection and hence sparking at the power supply terminals is a common problem. The end terminal connection should be tightened properly. When the heating element is broken there is a common tendency to join the broken parts. This should be avoided and the whole heating element should be replaced. The connecting power cord should be of suitable capacity capable of carrying the current safely. The power cord should not become warm or hot when the stove is ON. It should not be operated when the supply voltage is considerably less or more than 220 volts. A modern electric stove may contain controls for variable heat.

2.3.2 Hot plate

Construction and Working

A hot plate is a heating appliance similar to an electric stove. It is basically an electrically heated plate on which flat bottomed containers

Fig 2.28 ***Hot plate***

with items to be heated are placed. It requires 220-volt AC input for operation and are usually available in power rating of 1kW and 2kW. It is used for cooking and for heating liquids in laboratory. A hot plate may be a single unit type or double unit type. Different models are available. A modern hot plate may contain feature such as temperature control.

A basic hot plate consists of
1. Base 2. Plate 3. Heater plate
4. Heating element 5. Switch

The base is made of cast iron or mild steel and may be circular or rectangular in shape. The plate is a thick circular plate made of sheet of cast iron or iron alloy and is on the top of the heater plate. Heater plate is made electrically insulating but thermally conducting material like china clay or fire clay, cement or plaster of Paris. The heating element is a nichrome wire or ribbon. The heating element is embedded in the heater plate and the heater plate is attached to the metal plate. The metal plate along with the heater plate and heating element embedded into it appears as single sealed unit fitted in the base. The end terminals of the heating elements are brought out to the power socket fitted in the base. In case of a single unit type hot plate having one heating element two end terminals come out. In case of twin unit type hot plate having two heating elements, three terminals come out, one terminal being common to both the heating elements.

In twin unit type hot plates, a rotary selector switch connects the heating elements in different positions.

There may be four positions of the rotary switch: (1) Low heat (2) Medium heat (3) High heat and (4) Off position. In low heat position the two heating elements get connected in series. In medium heat position only one heating element gets connected. In high heat position the two heating elements get connected in parallel. In off position no heating element gets connected.

When the hot plate is switched on, current flows through the heating element, and heat is generated. The plate becomes gradually hot. Items to be heated or cooked are taken on flat bottomed containers like sauce pan and are placed on the plate. After it is switched off, the plate gradually cools down and remains warm for some time.

The heating element is not exposed. Common problems are (1) burning out of supply lead elements and (2) break in the element. Supply lead contacts should be cleaned and tightened properly. In case of break in the heating element, it is to be replaced

Electric Stove/Hot Plate Repair

Hot plates are still handy for heating up a pot or skillet of food when a stove isn't handy or necessary. This Guide on hot plate repair tells how a hot plate works, what often goes wrong, how to identify a hot plate problem, and what parts and tools you will need to fix it. It then gives simple step-by-step instructions for how to disassemble and test a hot plate. This article also refers to electrical cord repair and heating element repair for further information.

How Does a Hot Plate Work?

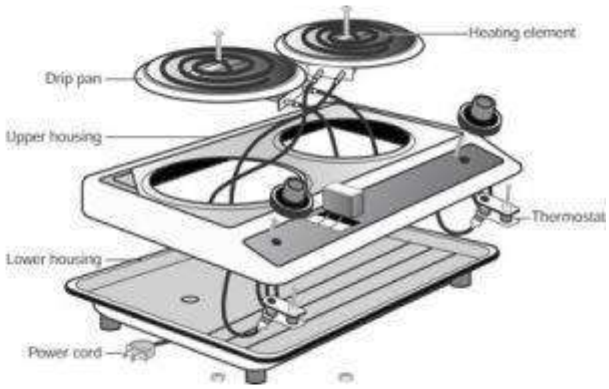


Fig 2.29 Hot Plate Alignment

A hot plate is simply an electric heating element with temperature controls.

A hot plate is a small electric appliance for cooking in a small space. The main parts of a hot plate are the heating element(s) and one or more devices to regulate the heat. Some hot plates have a calibrated thermostat while others simply have an on-off switch.

What Can Go Wrong with a Hot Plate?

A burned-out heating element is one of the most common problems with hot plates. The electrical cord or the thermostat may be faulty. Internal wiring can be damaged. Contacts may have become fused.

Tip

If the cord is detachable, always plug one end firmly into the hot plate before plugging the other end into the wall outlet.

Identify the Hot Plate Problem?

- *If the hot plate doesn't heat, make sure power is on at the outlet and test the electrical cord. You may need to examine internal wiring for damage or wear and replace any wiring or connections that look burned or otherwise faulty. Test the thermostat and the thermal fuse (if the appliance has one) and replace as necessary. Test the heating element and replace it if it is faulty.*
- *If the hot plate is not level or tips when used, check for damaged feet and repair or replace as needed. If the unit includes a levelling leg, adjust it with a screwdriver.*
- *If the hot plate doesn't shut off or heats whenever it's plugged in, inspect the thermostat contacts and repair or replace the thermostat.*

Tip

Food spills can dramatically reduce the life of your hot plate. Keep the burners and plugs clean.

Tools required for Hot Plate Repair

Replacement cords can be found at many larger hardware stores. If you need to buy a replacement part, check with the manufacturer or an aftermarket appliance supply source. The tools you'll need to disassemble and test a hot plate include these:

- *Screwdrivers*
- *Wrenches*
- *Multimeter*

Steps to Repair Hot Plate

Disassemble and test a hot plate:

1. *Unplug the hot plate from the electrical receptacle.*
2. *Find the screws or bolts holding the hot plate together and carefully remove them, noting where they should be reinstalled.*
3. *Remove the housing to access the burner(s), internal wiring, and other components.*
4. *Use a multimeter to test each electrical component; replace as needed.*

Caution!

Don't plug a hot plate into an extension cord; plug it directly into the electrical receptacle to reduce the chance of fire.

2.3.3Rice Cooker

Who said cooking rice is easy? If you are someone using a traditional method of cooking rice in a vessel, you know, you need to stand around in the kitchen to keep an eye until it gets ready. Even if you are using a pressure cooker, you need to add sufficient water in it to get perfect fluffy steamed rice. What if we told you there is a product that is more convenient than pressure cookers? They are electric rice cookers. Electric rice cookers are in demand, since they make the rice cooking an easy task. Electric rice cookers are packed with a bunch of features and they are very effective. They're exactly as essential as washing machines, refrigerator and the lot. However, there are things you should take note of while buying an electric rice cooker.

Size and capacity

Rice cookers come in different sizes and capacities. Unlike most kitchen appliances, these cookers don't take more space than a large vessel. The capacity of a rice cooker is measured by a total number of rice cups it can cook. Electric rice cookers are available with capacities ranging from 1 to 6 litres, and some even more. While buying an electric cooker, the first thing to consider is the size of your family. If you are a small family of 5 to 6 people, consider buying a cooker of 3 to 5 liters of capacity. Also, consider how many cups of rice you typically need.

Construction and Working

Working of Rice Cooker

Rice needs two things to evolve from a hard, little grain to big, fluffy morsels -- lots of water and lots of heat. For this reason, cooking rice happens in four phases:

1. Sitting in water
2. Boiling
3. Absorbing water (steaming)
4. Resting

Fig 2.30 **The inner workings of a typical rice cooker**

How a Rice Cooker Cooks?

After rice and water are measured into the basin, the basin is placed into the container. The container is closed, and the heating element is turned on by flipping a switch. The heating device inside the container begins to heat up the water in the pot to its boiling point. The boiling water is absorbed by the rice, while the cover or lid keeps steam from escaping.

Quick Science Lesson: Water and the Boiling Point

Under normal heating conditions, water cannot heat past its boiling point, which is 212 degrees Fahrenheit (100 degrees Celsius). Any hotter than that, and the water converts to steam. Thus, as long as liquid water remains in the pot, the water will absorb the heat from the heating mechanism, not the rice. Because the water cannot get any hotter than 212 degrees, the pot cannot get hotter than 212 degrees. The thermal sensor monitors this.

How Rice Cookers Prevent Burning and Overcooking

Once it has absorbed all of the water, the rice itself can be heated past 212 degrees F, leading to overdone or burnt rice. Once the rice cooker's thermal sensor detects the pot going above 212 degrees, it means the water has all been absorbed. At that point, the rice is done. To prevent the rice from cooking any further, the sensor automatically trips the shut-off switch for the heating mechanism. This immediately stops the cooking process.

Keeping Rice Warm After Cooking

Many rice cookers come equipped with a warming setting. With this, as soon as the thermal sensors detect the pot going over 212 degrees F, rather than shutting the rice cooker off, it turns the heating to a much lower setting. This is temperature is not hot enough to cook the rice further, but warm enough to prevent any bacteria from growing in the rice. This setting usually keeps rice warm for hours after it finishes cooking. Without a warming setting, rice should not remain in a rice cooker for more than a half hour.

Rice Cooker Circuit/Wire Diagram

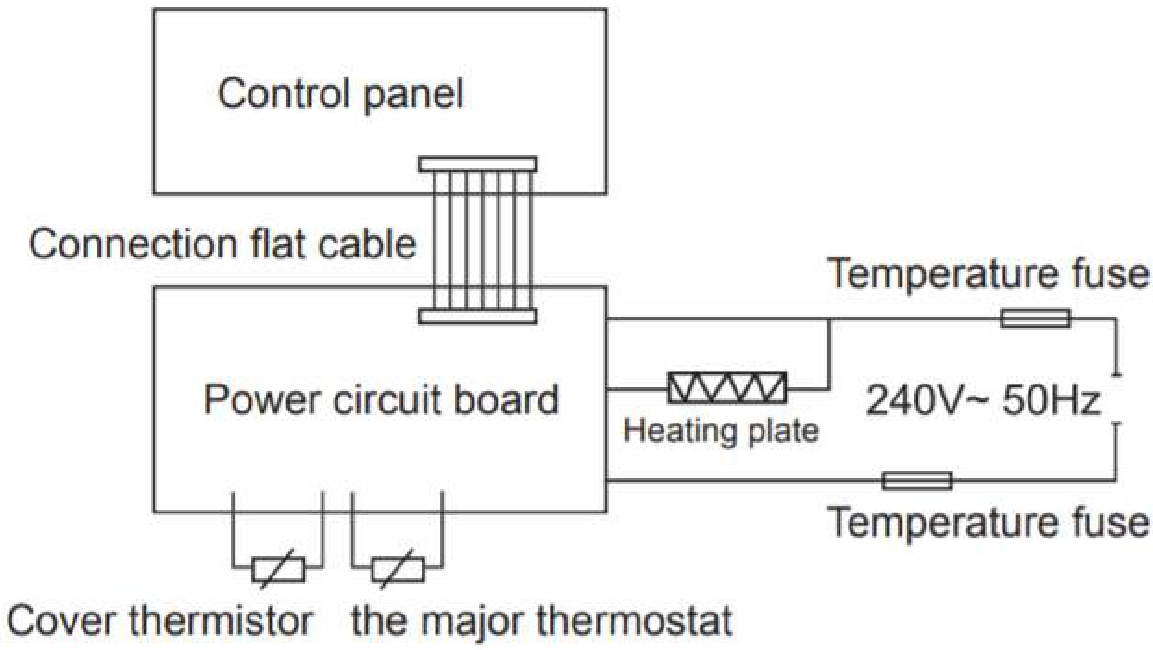


Fig 2.31Rice Cooker Circuit/Wire Diagram

Cleaning of a Rice Cooker

A rice cooker is a piece of electrically powered kitchen equipment that makes it quick and easy to cook rice to exactly the specifications you want. As with any piece of electrical equipment, it should be cleaned and maintained with care. When it is time to clean and care for your rice cooker, the first thing you should do is make sure it is unplugged. The following tips will give you everything you need to know about how to clean a rice cooker.

1. Before Cleaning Your Rice Cooker

These safety precautions will ensure that you avoid any hazards of improper rice cooker maintenance.

- The number one rule with any electrical appliance is not to expose any of the electrical parts to water. The base of your rice cooker that plugs into the wall should be kept dry at all times. This includes the hot plate inside the rice cooker that provides the heat when you turn it on.
- Remove the lid and pot and you will see the hot plate inside the cooker. Cleaning should only be conducted when this plate is completely cool.
- If you have recently used your rice cooker, give the plate at least 30 minutes to cool. The time it takes to cool will depend on which brand and model of rice cooker you have. It is a good idea to read the safety instructions that come with the cooker if you are not sure how long to wait.

2. General Advice

Before reading the rest of these tips on how to clean a rice cooker, you should review and keep in mind these general advice tips.

- The way to maintain a rice cooker and keep it working as long as possible is to clean after each use. Make sure you give the hot plate ample time to cool down if you are cleaning it right after using.

- See the above tip if you're uncertain as to how long you should wait for the cooker to cool down. You can also check with the manual that came with your rice cooker.
- If any food particles such as bits of rice are left on the hot plate when you use it again, they will become even further baked on, making cleaning more difficult and possibly compromising the effectiveness of the cooker.
- If you are using a cleaning solution, do not allow any excess chemical to get inside the rice cooker or around the hot plate. It's better to avoid using any cleaner on the cooker itself. Use a moist rag to absorb any cleaner that accidentally drips down into the cooker.
- Mop up excess moisture that gets inside the cooker and make sure everything is totally dry before you plug it back in and use it again.
- Avoid using abrasive sponges or a scouring cleaner. A smooth cooker functions best.

3. Cleaning the Individual Rice Cooker Parts

To get the most thorough clean for your rice cooker, it is best to wash each part individually. This will help your unit look and preform at its best.

- The inner pot can be removed and left to soak. Use soap and hot water. If there is a thick layer of rice stuck to the inside of the pot, remove it with a plastic spoon or spatula before soaking for optimal results.
- Wash the utensils of the rice cooker while the pot is soaking.
- If there are still some hard bits of rice stuck to the inside of the pot, you can take a spoon and carefully scrape them off. Be gentle with this process as you do not want to scratch the surface of the pot. After removing food remnants, give the pot another quick scrub with a sponge or brush, followed by another rinse.
- The lid may detach. If this is the case, you can wash and clean it just like the other detachable parts.
- If the lid does not detach, use a sponge soaked in hot soapy water to remove any residue and stains, and then go back over it with a rinse cloth, being careful not to get the inside of the cooker wet.
- If you have a dishwasher, you can place all the removable parts in with your other dishes for a deeper clean that's less work for you.
- Allow each of the parts to fully dry after you have finished washing them.

4. How to Clean the Inside

Any residue can be gently removed with a moist cloth. Make sure all moisture dries out before putting the clean pot back in.

Consider using sand paper to scrape hard-to-remove residue off of the hot plate. If you use a metal utensil to scrape off the bits of food or rice that get stuck on the plate, you could accidentally scratch it, making the rice cooker more difficult to clean in the future and possibly inhibiting its functionality. Instead, using the rough side of the sandpaper, give the hot plate a complete rub-down, making sure that there is nothing left caked on. Any bits that are left loose after this process can be wiped away with a moist rag.

5. How to Clean the Outside

Sometimes the exterior of the rice cooker can get food residue or stains on it, especially after a messy recipe. A moist rag should do the trick. If a stain is being particularly stubborn, you may want to use cleaning solution.

It is imperative that you not get any cleaner inside the cooker itself. The best way to prevent this from happening is to spray the cleaning solution directly onto the rag and rub the stain until it is totally removed. Then use a damp cloth to remove any residual cleaner left over.

The cord of the rice cooker might get dirty or stained as well, especially if the color is white or grey. You can clean the cord in much the same way, but remember that you will have to be as gentle as possible as a cord is a delicate part of the equipment and can render the rice cooker unusable if you damage it.

As with all the other steps, make sure every part is completely dry before you plug the cooker back in for the next use.

By following these pointers on how to clean a rice cooker, you will find your rice cooker's life to be extended as long as possible. Following the safe and most effective practices is the best way to maintain any piece of kitchen equipment at optimum efficiency.

Rice Cooker Dismantling

1. **Step 1** Rice Cooker Teardown
   - Start with the rice cooker unplugged, on a flat surface.
2. ***Step 2*** *Remove Pot and Lid*

Fig2.32Remove the lit and pot and turn upside down.

3. ***Step 3*** *Remove Bottom Plate*

Fig2.33

- *Use a Phillips #1 screwdriver to remove the two screws.*
- *Remove the bottom plate by lifting one of the rubber feet.*

4. ***Step 4*** *Remove Internal Screws*

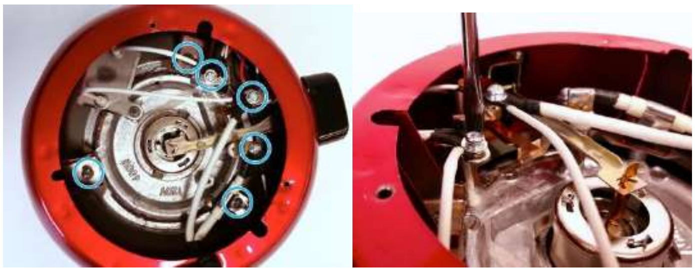


Fig2.34

- *We're inside! Here's our first look at the circuitry. Let's take it apart.*
- *Use a 3/8" or 8 mm flathead screwdriver to remove these six screws.*

5. ***Step 5**_Bend Tab*

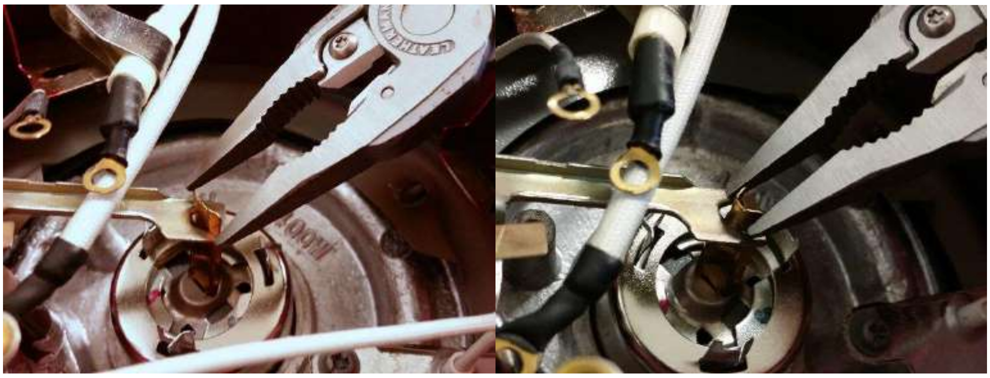


Fig2.35

- *Find the metal tab that connects the center button to the switch lever.*
- *Use pliers to bend the metal tab into a U shape.*
- *Align the tab with the slot so that it falls through.*

6. ***Step 6**_Remove Heating Element*

Fig2.36

- *Turn the rice cooker right-side up.*
- *Grab the center button and pull the heating plate upward. The gray metal ring should come out with it.*

7. ***Step 7**_Remove Temp. Sensor*

- *Use a Phillips #1 screwdriver to remove the screw connecting the temperature sensor to the heating element.*
- *Remove the temperature sensor.Fig2.37*

8. ***Step 8**_Remove Centre Button*

Fig2.38Remove Centre Button

- *Three bent metal tabs connect the center button to the heating element. Use pliers to flatten these three tabs.*
- *Remove the center button from the heating element.*

9. ***Step 9**_Remove Control Panel*

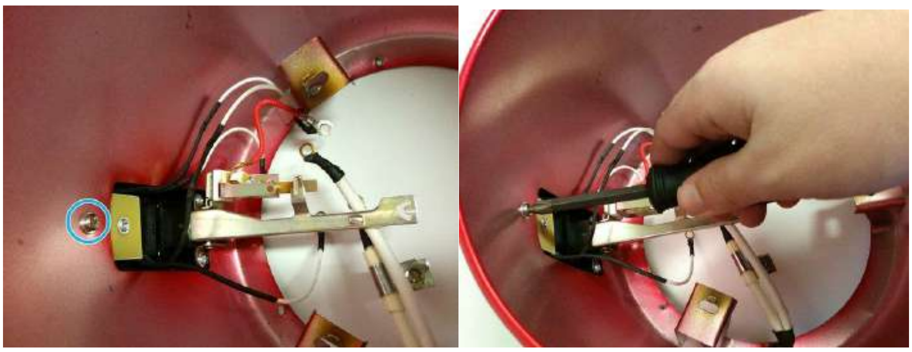


Fig2.39

- *Use a Phillips #1 screwdriver to remove the screw that secures the control panel.*
- *Remove the control panel from the outside of the rice cooker.*

*10. **Step 10** Disassemble Control Panel*

Fig2.40

- *Use a Phillips screwdriver to remove the screw securing the rectangular fiberglass plate. This should free the two light bulbs.*
- *Use a Phillips screwdriver to remove two screws securing the switch lever to the control panel plate. Remove the switch lever.*

*11. **Step 11** Disassemble Switch*

Fig2.41

- *Use pliers or hex wrench to hold the nut while using a Phillips #1 screwdriver to remove the screw holding the switch assembly together.*
- *Pull the switch assembly apart into its parts. Careful not to lose any of these small parts!*

***Step 12** All Done!*

Fig2.42

CONCLUSION

To reassemble your device follow the following instructions in reverse order.

Fuzzy Logic and Rice Cookers

Fuzzy-logic rice cookers have computer chips that direct their ability to make proper adjustments to cooking time and temperature. Unlike basic rice cookers, which complete tasks in a single-minded, mechanical manner.

2.6.5 How to Repair an Electric Rice Cooker

An electric rice cooker is a great appliance that is often used to save a lot of time and effort in preparing fast meals after a long day. By using one, the user can quickly make some rice without worrying of overcooking or burning. As such, many people will choose to make rice in place of pasta or potatoes as a side dish.

Like many electrical appliances, a rice cooker can have some problems as it ages. There are electrical problems that surface as the appliance gets some age on it. Many owners will simply throw it in the trash and buy a new one. However, with the right types of components.

Step 1 - Unplug Power Cord from Wall

Before you start to work on the electric rice cooker, you will want to make sure it is not plugged into any power source.

Step 2 - Remove All Extra Pieces

Take the covering dish out and place it aside. You will also need to remove the burner plate and inner bowl. This will allow you to get to the inner parts of the cooker.

Step 3 - Remove the Base

On the bottom of most electric rice cookers, there are some tabs or screws that hold the base together. Remove the screws or fold back the tabs so that you can remove the base.

Step 4 - Test Heating Element

The cooker's heating element may not be working properly so you'll need to test it first. Disconnect the heating wire from the terminal and test it with a multimeter. Set the meter to read ohms and touch the wire to the terminals. If it reads "0", the wire is fine; otherwise, this part must be replaced.

Step 5 - Test Resistor

If the heating element is fine, then the next space to test is the resistor. Use the multimeter again on the same setting and touch the probes to the resistor. The reading should come out to 20 ohms if the resistor is working properly.

Step 6 - Check and Clean Contacts

Another problem associated with older electric rice cooker appliances is that the switch contacts can become dirty or corroded. When this happens they will not allow a solid current to flow when the switch is pressed to start the cooker.

With the base removed, check the contact areas. Check to see if they are burned, and if so, you will need to replace them. If not, then use some electrical contact cleaner and a clean rag to get them as good as new.

Step 7 - Move Contacts

If you notice that the contacts are not touching when you press the switch, you can fix this by using a small screwdriver to move the contact closer to the switch.

Step 8 - Replace Components

With the inside pieces either replaced or cleaned, you can put the electric rice cooker back together. Make sure that the power cord is not pinched and that all wires are put back into their original position. Then, screw the base back on and replace the bowl and cover. Make a batch of rice afterward to make sure it works correctly.

2.4.1Toaster

A toaster is a domestic appliance used in the kitchen. It is used to toast bread. It operates with 220-volt AC and models are commonly available with power rating from 600 watt to 1.5 kilowatt. Two slice toasters are common in domestic kitchens. An electric toaster usually takes 1 to 3 minute for toasting. There are high capacity toasters to toast more than two slices of bread at a time that are used in restaurants. Modern electric toaster has attractive features like beautiful get up, temperature control, automatic pop up feature etc.

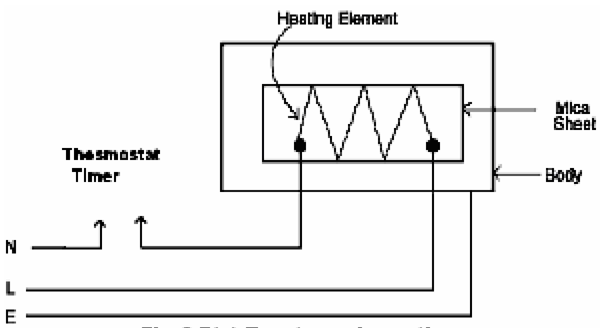


Fig 2.43(a)Wire Diagram

Electric toasters can be classified into three categories
1. Non-automatic 2. Semi-automatic 3. Automatic

Construction and Working

Electric Toaster Parts

The essential parts of an electric toaster are–
1. The body 2. The heating element
3. Controls 4. Power cord

The body is made of stainless steel. In some models the stainless body is housed in plastic case. The heating element is nichrome wire or ribbon and is wound on a mica strip. In some models coiled nichrome wire is used. The end terminals of the heating element are connected to the power cord. There are slots for placing slices of breads. In a two slice toaster there are two slots for inserting one slice of bread in each toaster and the heating element is in between the two slots and usually vertical and parallel to the bread slices.

In the simplest non-automatic toaster slices of breads are placed in the slots and the toaster is switched on. After the breads get toasted on one side, they are reversed. The toaster is switched off when both sides of the breads get toasted and the toasted breads are taken out. No additional controls are there. The quality of toasting depends on the judgment of the toaster.

In semi-automatic toasters there are indicator and temperature control. The indicator is an audio or light signal. When toasting is complete the audio or light signal indicates the completion of toasting. A thermostat or a timer is used to control temperature. The desired temperature of the surface of bread for toasting can be set by means of a knob and dial provided on the body of the toaster. When the toasted bread surface reaches the desired temperature the thermostat or the timer cuts off supply to the heating element.

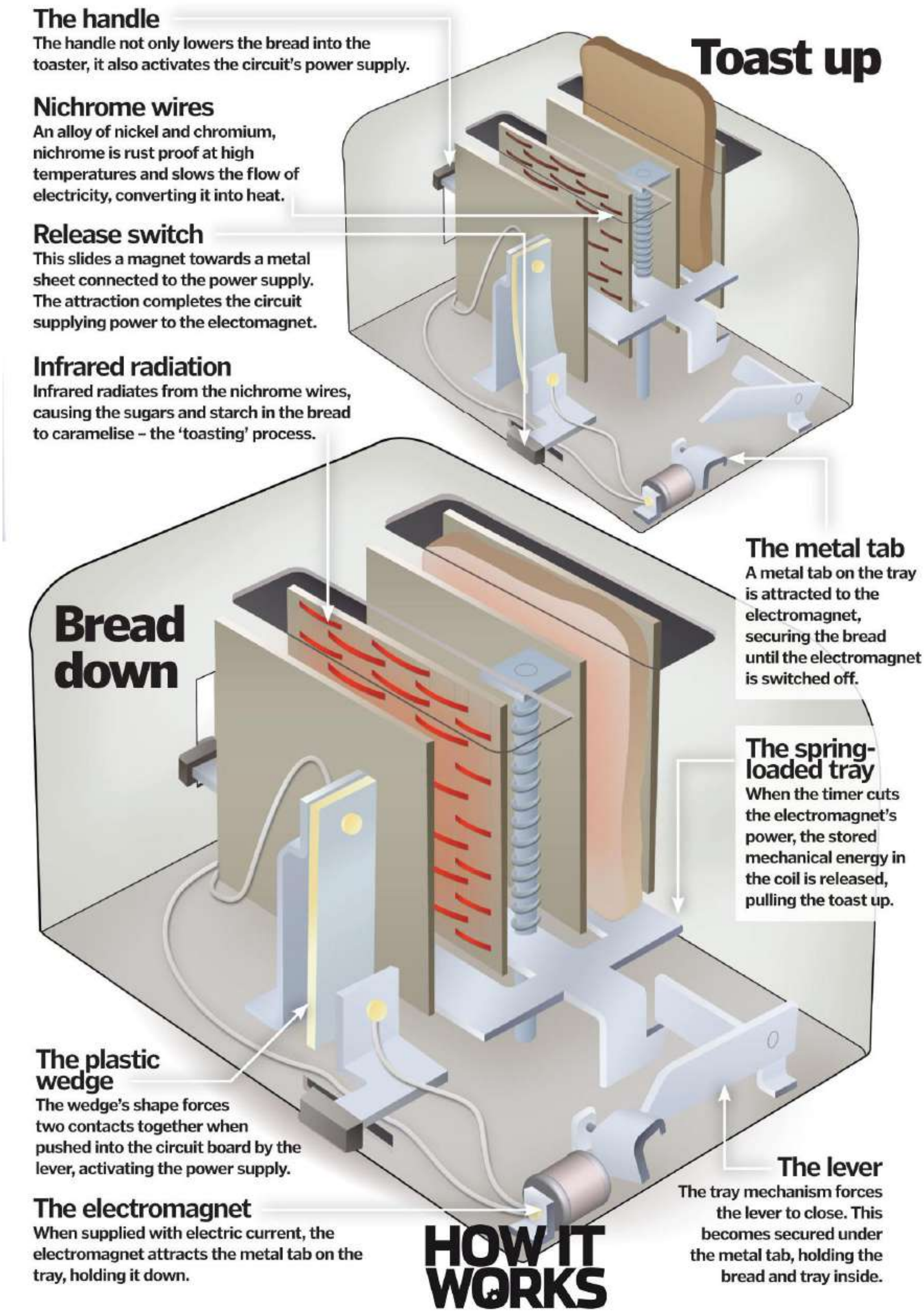


Fig 2.43(b)**Electric Toaster**

In automatic toasters, in addition to the indicator and thermostat as in the semi-automatic toasters, there are some additional facilities. One important facility is automatic popup facility. After placing the breads in the slots, a lever is to be depressed to activate the toaster. When toasting of the breads are complete then the toasted breads are expelled from the slots automatically by the popup mechanism. An automatic toaster does not get switched on if bread is not loaded in its slots. The other features some automatic toasters have are electronic control to select toasting of one slice or one side only, variable browning control of toasted bread, cancel or pop up or extra high lift of the toasted bread etc.

The toaster should be cleaned every time after use. A removable crumb tray is provided in some models. Break in heating element, erratic operation of the timer or the thermostat, misalignment of mechanical movements and loose connection are some of the commonly occurring problems. As there are various models from different manufacturer, it is advisable to thoroughly study a particular model before starting any maintenance activity.

Toasters Working

Most electric pop-up toasters all operate in the same manner. A slice of bread, a frozen waffle, a toaster strudel, or some similar food item is placed through a slot in the top of the toaster and into the carriage. The carriage is lowered into the chassis using the lever at the side of the toaster.

When it reaches the bottom, the carriage latches in position and an internal switch is activated to start the heating process. A thermostat determines how long electric current will be sent from the power cord to the heating elements.

The person who is operating the toaster sets the thermostat using a control knob or lever calibrated between light and dark. When the desired temperature is reached and the heating process is completed, the solenoid turns the current off, then unlocks the latch and allows the carriage to spring up to its original position. At this time, the toasted food is easily reachable and can be removed by the operator of the appliance.

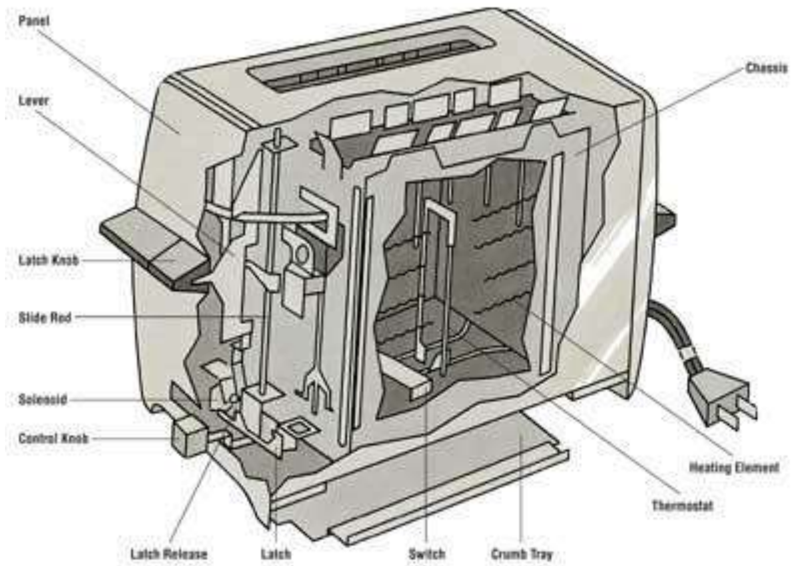


Fig 2.44VARIOUS ELEMENTS

THE VARIOUS ELEMENTS THAT MAKE A TOASTER WORK.

Toasters are categorized as heating appliances. Their function is to develop sufficient heat near a slice of bread to heat and toast it. Breakfast certainly wouldn't be the same without the pop-up toaster.

In many homes, toasters malfunction more than any other small appliance. There are two reasons for this. First, toasters are typically built economically to be a throw-away appliance. Second, malfunctions are frequently not the fault of the toaster itself but of food particles that interfere with its operation. Excess pieces of bread broken off by carriage movement fall into the base of the toaster and accumulate, obstructing carriage movement, shorting out heating elements, plugging the latch release, and interfering with solenoid operation.

That's why most pop-up toasters have a large crumb tray and door at the bottom of the toaster. By sliding or unlatching this crumb door you can release food particles trapped in the bottom of the toaster.

For a toaster that is used daily, this should be done once

a week. Simply unplug the toaster, hold it over a trash

container, and unlatch the door. Once the primary food particles have fallen out, move the toaster around to release other particles that may be trapped at the edges. Periodically clean out the toaster using a can of compressed air, making sure you don't damage sensitive heating elements or switches.

Repairing of a Toaster

Common toaster repairs include servicing the latch assembly, servicing the chassis, recalibrating the thermostat, and servicing the solenoid.

Servicing the Latch Assembly: The carriage and latch are vital components to the operation of pop-up toasters. If they don't work smoothly, bread or other food products cannot be held in position to be heated. To clean and lubricate the latch:

Step 1: To access the latch, remove the end panel by removing levers, knobs, and fasteners. On some models, disassemble the entire case by removing levers, knobs, crumb tray door, and fasteners. Fasteners are usually accessed from the bottom of the toaster, though some models hide them under plates and self-adhesive labels on the side.

Step 2: Once the cover is removed, inspect the latch assembly to determine if there are obvious problems such as a food particle or loose part jamming the assembly. Clean the latch area using a can of compressed air to blow away crumbs.

Step 3: Move the carriage lever up and down to check for smooth operation. If the carriage moves stiffly, carefully lubricate the rod on which the latch lever travels. Use a petroleum lubricant, making sure you don't get any of it on adjacent electrical parts.

Step 4: Check the operation of the latch to ensure that it works smoothly. You may need to carefully bend the latch so it catches properly.

Servicing the Chassis: Most of the mechanism within a toaster is mounted on a frame called the chassis. To repair or replace many internal parts, including the heating elements, you will need to remove the chassis from the toaster shell. Disassemble the toaster by removing levers, knobs, and fasteners, then carefully lift the shell off the chassis.

Some toasters will require that you disconnect the power cord internally before you can fully remove the chassis. Depending on the problem your toaster is having, you may want to replace the entire chassis or just one or two components.

Recalibrating a Thermostat: The thermostat in a pop-up toaster performs a vital function in telling the solenoid how long you want the heating elements to toast the bread. If your toaster seems to ignore your setting, the thermostat may be out of adjustment. To recalibrate the toaster:

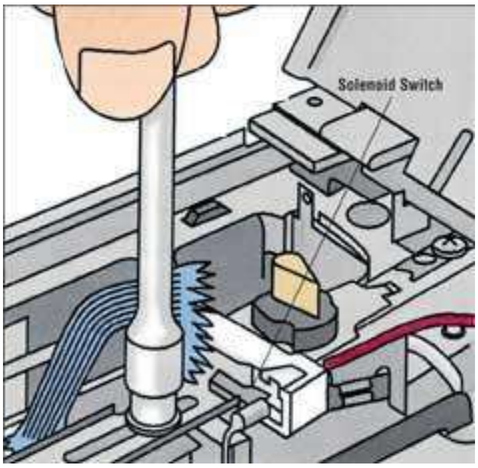


Fig 2.45

A CALIBRATION KNOB, SCREW, OR NUT CAN BE TURNED TO RECALIBRATE THE THERMOSTAT.

Step 1: Clean the toaster to ensure that food particles are not jamming the mechanism or shorting out the electronics.

Step 2: To recalibrate the thermostat, make sure the toaster is cool, turn it over on its top, and open the crumb tray cover.

Step 3: On most units, a bracket from the control

knob will be visible. On this bracket there will be a calibration knob, screw, or nut that can be turned to recalibrate the thermostat. Moving the bracket toward the solenoid switch typically will shorten the toasting cycle, and moving it away from the solenoid switch will lengthen the cycle. You can shorten the cycle if the toast istoo dark or lengthen the cycle if the toast is too light.

Step 4: Close the toaster, plug it in, and toast a piece of bread to determine if the adjustment is correct. If adjusting the thermostat doesn't solve the problem, consider replacing the thermostat or the toaster.

Servicing a Solenoid: The thermostat activates a switch that operates the solenoid. The solenoid releases the latch. So if your toaster burns toast or doesn't want to release the carriage, the solenoid switch or the solenoid itself may be faulty. The solenoid switch is located near the thermostat and can be accessed by opening the crumb tray cover. Test it with a continuity tester. If it is faulty, remove it and replace it with a new switch.

The solenoid is located near the latch at one end of the toaster. To access it, remove the end cover, or the shell. Test the solenoid with a continuity tester and replace if faulty. If either the solenoid or switch is installed with rivets rather than screws, consider replacing the entire chassis or the toaster itself. Riveted parts are difficult to remove and replace without special tools.

How do toasters know when to switch themselves off?

The first electric toasters didn't switch themselves off: they were completely manual. You put a slice of bread in a pivoting metal toasting rack and closed it up so the rack stood against a bank of heating elements. When you could see or smell that your toast was done, you opened *the rack, lifted the bread out, and put it back in the other way to toast the other side. Automatic toasters were a later development.*

Your toaster most likely uses either a timer or a thermostat to switch itself off when your bread is done, but some sophisticated models use electronic light-detector circuits based on photoelectric cells.

Timers
It's reasonable to assume that most people always use the same kind of bread, sliced in a similar way, so their toast will usually take about the same length of time to cook. A simple clockwork or electronic timing circuit can be used to switch off the heating element after a certain period has elapsed. With this kind of toaster, turning up the control simply extends the cooking time.

Thermostats
A thermostat is a mechanical, electrical, or electronic device that switches an electric circuit on or off to keep something (perhaps the room where you're living or the ice compartment of a refrigerator) at a fairly constant temperature. We can also use it to switch a toaster off when the bread is cooked. Suppose there is a **bimetal-strip thermostat** (two different metals welded together) fitted very close to a toaster's heating element. The thermostat will heat up as the bread cooks and the metals will expand by different amounts, so the thermostat will gradually bend into a curve. When the right temperature is reached, it will bend just enough to snap open and switch off the toaster's heating element. In this kind of toaster, turning up the control adjusts the distance by which the thermostat has to bend before it switches off the heater.

Photoelectric cells

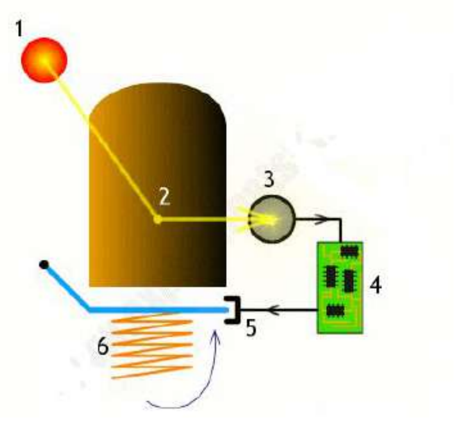


Fig 2.46

Fig2.40: Olving's photoelectric toaster used four modified heating/lighting elements (red circles) to do the cooking. Light reflected from the bread (brown) was collected by a lens (yellow) and bounced down through a prism arrangement (light blue) to a photocell (dark blue) at the bottom, then amplified by some rather ancient electronics (green) to produce an electric current that would flip up the bread once it was done.

A photoelectric cell (or photocell) is an electronic component that generates electricity according to how much light falls on it. Suppose you build your toaster with a miniature flashlight inside it, shining at an angle towards the bread. As toast slowly cooks, the bread effectively turns from white to brown (hopefully not black), so the light reflected off it should slowly decrease in intensity. Place a photocell nearby to measure the reflected light and, in theory, you have an accurate means of figuring out when your toast is cooked that's much more reliable than timers and thermostats.

Pop-up!
When timers and thermostats switch off a toaster, they generally also release a spring that pops up the metal cage holding your toast. It's much easier to get your toast out if it pops up. It's safer too because the inside of the toaster is usually much too hot to be reaching into—and, as we've seen already, you don't want to touch the filaments!

2.5.1Electric Water Heater

Basic Working Principle

If you want to go into the very basic principle, it is simply the conversion of electrical energy into heat through the use of heating element/s to raise the temperature of water to a certain degree.
Obviously this is not much different from a common immersion rod which you can dip into your bucket, plug into the power socket and get going. The only difference is the level of sophistication and slight automation in the geyser.
Of course different heaters of different companies and brands can have slightly different arrangement but the basic concept behind all of them remains the same. You can take a look at the diagram below to understand the construction of a typical heater.

The electric heaters used to heat up water are called electric water heater. It is of three (3) types i.e.

1. Immersion rod water heater,
2. Geyser
   a) Tank-type water heater
   b) Tank-less water heater

Most homes have a tank-type water heater. If you find a large, cylindrical tank standing on end with pipes attached to it, you have a tank-type system. If you don't find a tank, but you have a hot-water heating system that heats your home, it's likely that the hot water reaching your taps is heated by the boiler. In other cases, hot water may be supplied by a stand-alone instantaneous water heater that's mounted near the fixture it serves.

Tank-type or storage tank water heater
As the name suggests tank type geyser or heater has a storage tank to reserve hot water. Tank type geyser maintains the temperature of hot water within the storage tank with the help of an automatic thermal control. The heating element switches on-off periodically to maintain the temperature of water in the storage tank.

Advantages of tank-type water heater

- Tank type water heater has a lower initial purchase price.
- Tank type water heater has low energy requirement

Disadvantages of tank-type water heater

- A tank type water heater is less energy efficient than a tank-less water heater.
- Once all of the available water stored in the tank is used, it takes time to heat more water.
- The freshness and quality of water is sometime compromised. The water you use sits in a tank with corrosion and rust.

- Storage tank of the heater takes up much more floor space.
- The sediment dissolved in water may corrode/damage the inner protection of tank wall and may cause tank leakage problem.

Tank-less water heater

A tank-less water heater does not have a storage tank. It is a like a small rectangular box mounted on the wall, that carries a burner or heating element, thermal control knobs, and internal piping. The water heater only starts when there is a need for hot water. When tap or shower is turned on, water starts flowing through the heater pipes. The heating sensor senses the water flow, which in turn fires the burner or heating element thereby producing hot water for consumption. It is available in electric as well as natural gas models.

Advantages of tank-less water heater

- Tank-less water heater requires less space as there is no storage tank
- It never runs out of hot water.
- Tank-less heater have a longer life compared to tank-type heater
- It uses energy only when it is required.
- It is more energy efficient than tank-type heater.

Disadvantages of tank-less water heater

- Tank-less type water heater are costly.
- It has a large power/gas requirement.

Immersion rod water heater Construction and Working

It is extremely useful, economical way of heating the water. Immersion rod is a device used for the heat the water. To heat the water, immersion rod is installed in utensil or a bucket along with water and plug in the wall socket, that's it. Because of immersion rod simple working principle and economical price, it's quite popular in India. You can buy branded immersion rod in less than Rs. 600 in India. Immersion rod consists a coated metal rod. Electricity passes through the rod as result rod heats up which further heats the water. Only the problem is coating on rod which insulates the electric shock. In the course of duration immersion rod loses it's coating and causes electric shock. Immersion rod needs special care while handling it. It is not child safe.

The electric heater which is immersed in water for heating the water is called Immersion Heater.

In market from 250 watt to 2.0 kilo watt immersion heaters are available. It is used for heating a small amount of water.

Fig 2.47

Its construction is very simple. It consists of two round shaped nickel plates separated by a gap of 2 mm with an insulator.The body is made of metallic substance, and the heating element is made of copper which is installed inside a capillary tube. The tube is found in 'U' or Coil shape. The capillary tube is filled with magnesium oxide which works as insulator. Both the end of the tube is sealed. The supply connection is given through 3 pin socket and plug.

Precautions about Immersion Heater

1. Without immersing the water heater in water, supply cannot be given.
2. One should not touch the immersion rod when supply is ON.
3. Before removing the immersion rod from water it should be disconnect from the plug socket.
4. The water filled bucket should not be touched while the supply is ON.
5. Except water no other liquid substance should be heated by immersion heater.
6. This type of heater is very dangerous. While using this heater one should always keep on watching that it does not come into contact with any metallic substance.
7. Do never try to immerse your finger in the water to check the warmness of the water.

Table2.3Fault and its Causes of Immersion Heater

Fault	Cause
1. The rod of Immersion heater does not get heated.	1. The fuse, element or conductor of the immersion heater is disconnect or dislocated. 2. There may be non supply of A.C. in the socket.
2. The rod of Immersion heater does not get heated but gives shock.	1. Due to leakage in immersion rod. 2. Due to disconnection of natural or earth line.
3. The heating element of the immersion rod gets frequently burn.	1. Excessive flow of current. 2. The wire or mica may be broken and touched with the metallic body.

Electric Geyser Constructionand Working

Geyser or water heater is a commonly used home appliance. It produces hot water that we use for various purposes like bathing, cleaning, washing etc. Water heating is a simple thermodynamic process where a source of energy like electricity, natural gas or solar energy heats the water.Geyser heater is used for large quantity of water. Generally, from 20 ltr to 90 ltr capacity geysers are found in the market.

The basic principle water geyser is not very complex one. It is simple. Here electric heating element is used to heat up the water stored in a storage tank. The only difference from normal immersion type water heater, that it can automatically control the temperature the water by controlling the operating period of the heating elements associated with the geyser which cannot be possible in normal immersion type water heater.

As you can see from the image, there are two pipelines, one for inlet of cold water and the other for outlet of the hot water. The water tank is fitted with heating element/s which is/are controlled by thermostats. The function of the thermostat is to set the temperature to a certain value so that water is not heated above that value.

The tank is normally covered with some insulating material such as glass wool and entire assembly is enclosed inside a metal casing which can be hanged on the wall or wherever required.

The sacrificial anode is used to protect the tank from corrosion by sacrificing itself and helps to prolong the life of the tank.

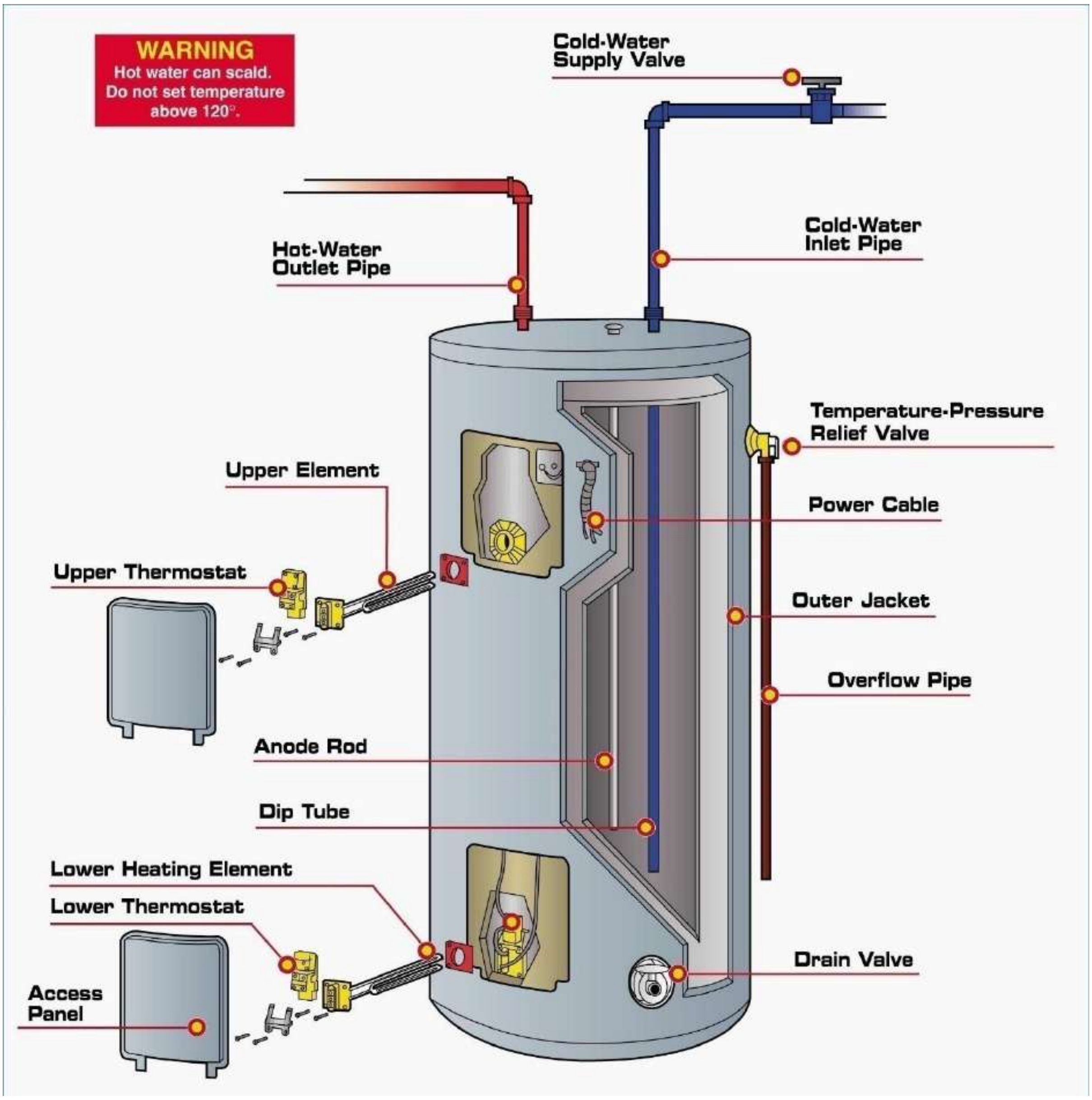


Fig 2.48

In the storage tank, one or two heaters are fixed. For supplying of cold or hot water, specific pipe lines are fitted with the storage tank. That means there are inlet cold water and outlet hot water pipe. To control the flow of water, a valve is installed in the pipeline. To control the heat one thermostat switch is there. The switch gets automatically OFF to avoid misuse of heat. The entire body of the geyser is insulted. When the geyser storage tank is filled up, the water starts flowing through an overflow pipe, and then the inlet valve gets automatically OFF. An anode rod made of aluminium or magnesium is screwed in the storage tank to reduce corrosion of metal body and metal parts of the water storage and supply system. This is because the metal of anode rod is more sensitive to corrosive reactions than the metal of the body structure of the system. Body of the storage tank is generally made of steel. As aluminum or magnesium is corroded faster, it makes the water soften before it can corrode the steel

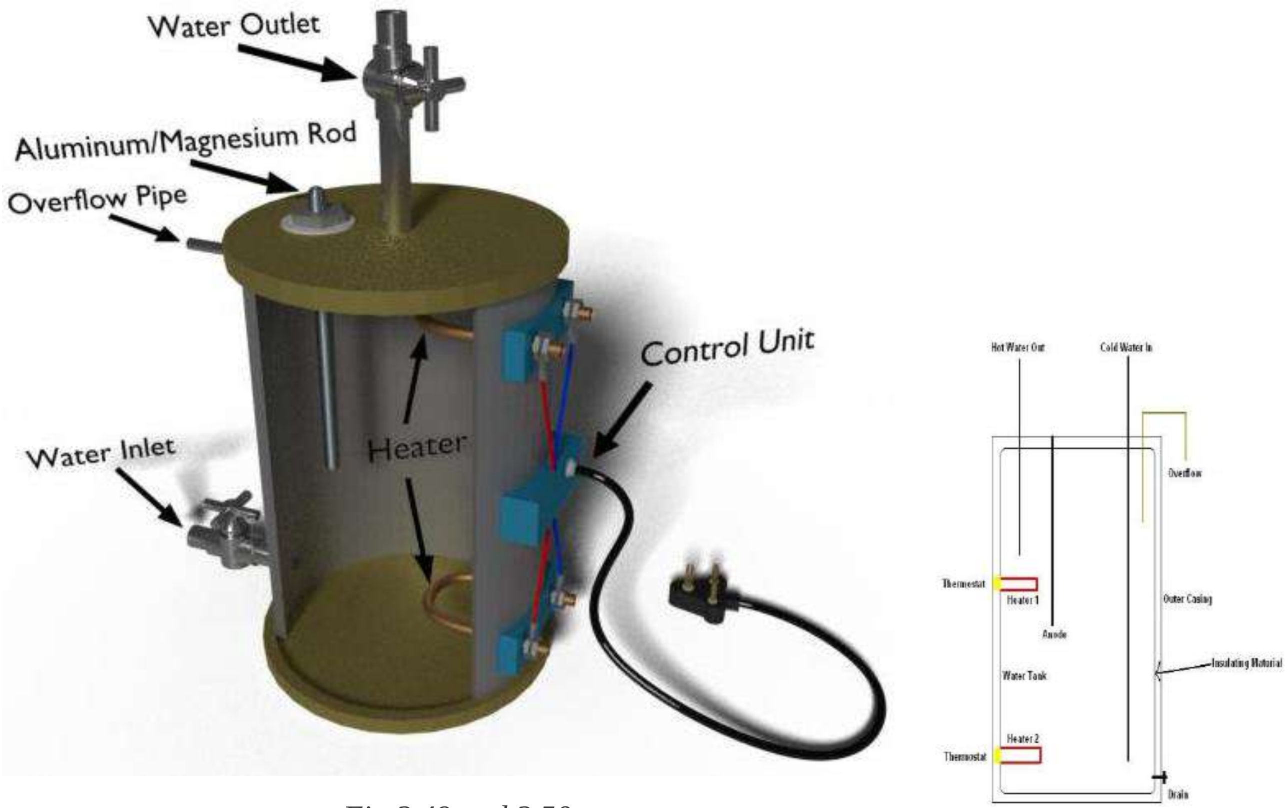


Fig 2.49 and 2.50

Geyser vs Immersion rod Table2.4

Feature	**Immersion rod**	**Geyser**
Price	Economical: Rs. 300 to 600	Little expensive: Rs. 3,000 to 20,000
Portable	Yes, helpful if you are moving houses	No
Water heating time	Takes more time to heat the water	Takes less time to heat the water
Hot water quantity	Very limited	More, depending on model, up to 25 litres
Safety	Not safe, completely not child safe, there is chance of getting electrical shock.	Safe
Convenience	Difficult: Take some time to setup bucket full of water and plug the rod	Easy: Just switch on
Auto off system	Not available	Available
Water heating method	Water is not heated uniformly	Water is heated uniformly

Feature	Immersion rod	Geyser
Well-known brands	Bajaj, Crompton Greaves, Usha, V-Guard, Maharaja	Bajaj, Havells, Racold, V-Guard, AO smith, Kenstar, Crompton

2.9.3 Electric Geyser faults and problems

If your hot water cylinder suddenly stops working (producing hot water) it's a good Idea to go through a checklist of elimination to determine what the fault is before getting any quotes to repair or even replace your Geyser.

Geyser may just need a repair, not a replacement**.**
Does your hot water cylinder suffer from one of the following conditions?

- No Hot Water
- Very Low Temperature
- Knocking (Banging) Noises
- Hot Water Smells
- Low Pressure
- Leaking Hot Water Cylinder
- Damaged Hot Water Cylinder
- Discharge Valves Running Constantly

Hot Water Cylinder Faults and Remedies

NO HOT WATER (Temperature)

Possible Faults: Faulty thermostat, faulty element, blown fuse, power provider ripple control.

WHY HAS THE FUSE BLOWN?

If you have determined that your fuse has blown, there will be a good reason why that has happened in the first place.

This could include the following:

Fig 2.51

- With tear and wear an immersion element will break down over time eventually causing an electrical short due to a broken circuit. This will lead to an RCD tripping (RCD's are not common with hot water cylinder) or fuse blowing. Sometimes a new hot water cylinder element can also be faulty as shown in the image here. Within 2 hours this brand new element failed majorly causing a fuse to blow and leaving the homeowners with no hot water.
- Every hot water cylinder incorporates a thermostat that controls the element. Thermostats are designed to ensure the immersion element switches on when the water temperature is below 60 degrees. Unlike older style thermostats, modern versions cannot be set below 60 degrees. Stipulated by law to prevent the growth of legionnaires bacteria. (for alternative systems to manage legionnaires bacteria please follow our blog for upcoming information) Thermostats may fail, turning off the element permanently. Some models incorporate an integrated trip device which can be reset. Caution is advised though because also in this case, there is a reason why the thermostat has tripped in the first place.

Possible Remedies: Replace thermostat, replace element, replace fuse, unsubscribe, ripple control.

NO HOT WATER (Physically)

Possible Faults: Blocked tempering valve, blocked strainer, incoming water problem, various possible blockages, damaged valve.

CAN MECHANICAL FAULTS RESULT IN "NO HOT WATER"?

Alternative to electrical faults **mechanical faults** may also result in your hot water cylinder not delivering hot water. The reason we say "delivering" is because your cylinder may still be "producing" hot water but delivery prevented by a different component in the system. One of these components is your tempering valve.

Fig 2.52

A tempering valve is installed to protect your household from scolding hot water. Most tempering valves incorporate a non-return valve on the hot, cold or both sides (Tempering valves shall comply with NZS 4617 or AS 1357.2) which prevents the hot water from siphoning back into the cold water line. Additionally, on both the hot and cold sides the tempering valve includes a miniature style strainer which catches any debris before entering the valve. This is designed to protect the valve from damage and prevent maintain clean delivery. Keeping the above in mind two things can happen with this valve that will prevent your hot water cylinder from delivering hot water to your taps.

1. **If your cylinder thermostat recently failed,** then your immersion element would have continued to heat your water to boiling point which can put a lot of strain onto the integral HDPE parts of the tempering valve. Standard tempering valves (not rated for high temperatures such as solar above 99 degrees) incorporate High density Polyethylene parts which are rated to about 99 degrees Celsius. At 99 degrees, depending on age these will start liquefying or breaking down. Once these parts start cooling down again they will fusion preventing further mechanical operation. In this instance we are talking about the non-return valve which will no longer open allowing hot water to travel to its destination.

Fig 2.53

2. The integral miniature style strainers mentioned above have an approximate straining value of 20 microns. If you are getting a new tempering valve installed on an older system you will most likely get some of the existing lime/sludge/debris caught in the strainer which may initially look like the “pressure” has been reduced but will eventually fully clog to point of blockage.

A new installation involves new pipes, new valves and a new hot water cylinder, all of which can contain debris from the installation, transport or product itself. If the system is not flushed properly at time of the installation this will guaranteed lead to valves blocking preventing hot water delivery.

Possible Remedies: Process of elimination, identify fault and repair.

VERY LOW TEMPERATURE (or High/Low Fluctuation)

Possible Faults: if applicable, incorrect controller or thermostat settings, damaged element, damaged or wrongly set tempering valve, damaged diffuser, possible blockages, tapware problem.

Possible Remedies: Change thermostat and/or controller, tempering valve settings. Process of elimination, identify fault and repair.

KNOCKING OR BANGING NOISE (Water Hammer)

Possible Faults: This fault can appear when upgrading from low to mains pressure. Existing pipework not fixed properly, plumbing priority wrong, too much pressure, damaged valves, damaged or unsuitable tapware.

Possible Remedies: Find and fix loose pipework, improve existing priority, install water hammer arrestor. (For more information please view our “what is water hammer” blog.)

HOT WATER SMELLS BAD

Possible Faults: (**External Smell**) Typically an issue that relates to older cylinders or cylinders that have been slowly leaking internally (element thread or minor crack) for longer periods of time. When the insulation between the casing and tank is wet for a long period of time, it will rot and start to smell. (**Internal Smell**) A bad smell coming from the tap when hot water is running may be caused by the following: Bacterial growth due to minimum HWC temperatures not being met, accumulated sludge/rust caused by insufficient protection against electrolysis(?) due to the breakdown of a sacrificial anode. Incoming water affected by filthy water tanks or non-treated roof water. Note that smell is heightened by the higher water temperature.

Possible Remedies: Replace hot water cylinder, process of elimination, identify fault and repair.

LOW PRESSURE

Possible Faults: This fault will depend on whether it's an existing low pressure problem or whether it's a new low pressure problem. (**Existing**) Existing low pressure system and no fault, damaged pressure reducing valve, incoming pressure changes, tapware, related valve issue, excessive sludge/debris blocking outlet. (**New**) *Fig 2.54* Tapware, blockages, valves, incoming pressure.

Possible Remedies: (**Existing**) Replace/repair valves/tapware, remove blockages, insert booster pump, upgrade to mains pressure. (**New**) Replace/repair valves/tapware, remove blockages. Process of elimination, identify fault and repair.

LEAKING HOT WATER CYLINDER

Possible Faults: Split welded seams or welded connections caused by various reasons including thermal expansion and contraction, typically seen with older leaking hot water cylinders, loose fitting, damaged fitting/valve, overheating causing condensation, worn element washer.

Possible Remedies: Repair leak where possible, hot water cylinder replacement.

DISCHARGE VALVES RUNNING CONSTANTLY

Possible Faults: In most cases there is no fault at all. The cold water expansion valve(considered the energy valve) may discharge up to 20L/day in very hot weather and no hot water usage. The idea is to discharge cold water instead of hot water to save on power which is much more expensive than water. Faulty valve, faulty TPR, debris blocking valve spring.

Possible Remedies: Follow manufacturing instructions to manually discharge water from valve to remove debris, regularly maintain valves, repair or replace faulty valves.

WARNING!! When older cylinders are repaired or an element is replaced, they must be drained to enable the process of repair. This draining will cool down the cylinder tank and reduce its pressure. Consequently, higher expansion and contraction will take place when the cylinder is re-pressurised (refilled with water). This process may result in an already poorly welded tank seam cracking which would result in a leak. The danger is that a seam cannot be repaired and a full cylinder replacement would be required, rendering the original repair redundant.

Troubleshooting Table2.5

Symptom	Probable Cause	Corrective Action / Remedy
No hot water	Circuit breaker tripped at source.	Reset circuit breaker.
	On/Off switch in 'OFF' position, if installed.	Turn switch to 'ON' position.
	Circuit breaker at control cabinet tripped, if installed.	Reset circuit breaker.
	Blown fuse in element fuse block, if installed.	Replace fuse.
	Blown fuse in transformer, if installed.	Replace fuse.
	High limit switch tripped.	Reset high limit switch.
	Loose wires.	Tighten wires. Torque screws per torque chart included in Section VI.
	Heating element inoperable.	Check heating element operation by clamping an Amprobe around each wire to the element. The ampere reading should agree with the nameplate 'AMP' figure.
	Low line voltage.	Have source electrical system checked by an electrician.
	Faulty thermostat.	Move thermostat dial through full range. A definite 'click' should be heard. If not, replace thermostat.
	Faulty low water cut-off, if installed.	Check to see if tank is full of water. If not, fill tank. If problem continues and tank is full, check for continuity between the common and normally open contact of the relay board. If continuity is not observed, replace low water cut-off.

	Magnetic contactor does not energize.	Replace complete magnetic contactor. Because of the design of this particular contactor, it is more desirable to replace complete control rather than rebuilding coil, contacts and springs, etc.
Water temperature below settings at all times	Faulty thermostat.	Check thermostat adjustment. Monitor thermostat as described in Section III, Quarterly Inspection. Replace if necessary.
	Blown fuse in element fuse block, if installed.	Replace fuse.
	Heating element not working on all phases	Check to see that heating element is working on all phases, by checking the resistance (ohms) value for each element and comparing with the chart included in Section VI.
	Heater improperly sized	Verify heater is properlysized for the flow rate and temperature rise of your system. See formulas included in Section VI. Replace elements with proper size asnecessary.

Relief valve discharges continuously	Excessive temperature or pressure in tank	Temperature and pressure relief valves are made to operate if the water temperature exceeds 210°F or water pressure exceeds the pressure rating of the safety relief valve. If trouble is excessive temperature, then thermostat is not shutting off at the right setting and thermostat must be replaced.

2.6.1Electric kettles

Kettles are among the simplest of household appliances. Lift the lid and peer inside and you'll see, at the very bottom of the water container, a coil of thick metal called the heating element. When you plug the kettle into an electrical outlet, a large electric current flows into the heating element. The element's resistance (the tendency any material has to stop electricity flowing through it) turns the electrical energy into heat. In other words, the element gets hot. Since it's in direct contact with cold water, the heat passes to the water by conduction and rapidly warms it up too.

Construction and Working

Just like a conventional stove kettle that uses gas or fire to turn cold water into boiling water, the electric kettle uses electricity to warm up the cold water.The Electric Kettle consist of 2 main components one is base and second is kettle jar. Base has a circular shape and with the one up is positive and one is negative. So when this is connected to the power point and we placed the receiver positive and negative ends. It will worm the liquid inside steal body. It’s a decent machine. When your water gets heat it will automatically switch off.

At the bottom of the electric kettle container, there is a heating element, a metal, which is heated by converting electrical energy into heat. The power outlet transfers this energy through the plugged cord to this thick metal heating element, and rapidly warms up the cold water.

Fig 2.55

Electric kettles are very similar to the water heaters and geysers that we use everyday. The hot metal coil is dipped into water, making the cold water hot by transferring that heat.

Benefits of the Electric Kettle

- Electric kettle is a multi-purpose device that can be used for boiling water, making tea, and even for boiling eggs. Such multi-use definitely makes it your daily-use appliance, and easily becoming the must have at home and offices.
- They are faster than conventional stove kettles in most cases, saving your time, by instantly delivering the hot water. The time you were spending in monitoring the stove kettle can be used in other important things you have in your life. No doubt this is one of the major benefit of electric kettles.
- With improving technology, electric kettles are more energy efficient, putting less load to your bill. Although larger models can contribute more to the electric bill since they take more time to heat up the water and consume more electricity.
- Electric kettles are convenient to use, portable enough to travel with, and even cordless modelsare available to make the life easier. There are models available that can run on car charger port as well.
- Electric kettles have sensors that shut them off automatically when desired temperature is reached, enabling you to boil water or make tea without worry.

Disadvantages of Electric Kettles

- While there are many good things about electric kettles, they are comparably expensive than stove kettles. You would not like to spend money on these if you are only boiling water. A metal container could do the better job. Today people in many countries still don’t use electric kettle as their daily-use product.
- Electric kettles are usually made of plastic, and some suggest that it provides less fire safety. Some people do not feel comfortable with plastic and heating.

- The same reason many people avoid microwave ovens. They can be perceived as harmful for health by many. In parts of the world, people still prefer bronze or steel for heating water.
- The plastic may melt or cause the change of taste due to leaching. If the coil has any rust, it can make the change of color and taste apparent.
- Even though they are cheaper, they still use electricity and can increase your electricity bill heavily. Not everyone like to use so much electricity for the reason. If you are connected to a generator or UPS, you might also not be able to run all models due to limited watts available to you.

Standard Kettle Circuit Diagram

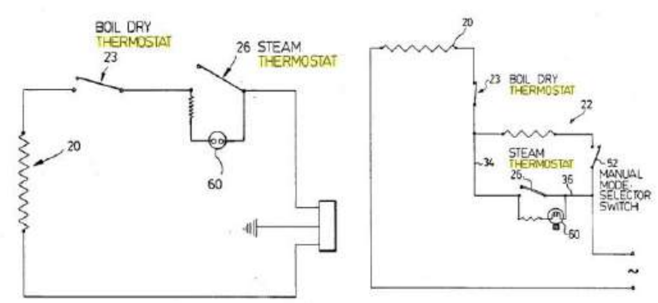


Fig 2.56 ***Circuit Diagram***

Electric Kettle Parts

Fig 2.57

In a domestic kettle the basic electrical components are:

- Switch
- Indicator light
- Heating element
- Thermostat (Steam)
- Thermostat (Boil Dry)

The Heating Element

Electric kettles are powered by a heating element which works in the same way an electric range does. The heating element is a resistor—a material that resists the flow of electricity. When electricity flows into the resistor, it is turned into heat. That heat is what heats up the water inside the kettle.

The Thermostat

The heating element is controlled by the thermostat. The thermostat has a variable resistor inside. The higher you set the temperature, the lower the resistance is. A small current runs through the thermostat, usually controlling an electronic switch called a transistor. The transistor, in turn, controls the heating element. When the resistance goes up in the thermostat, less current flows through, which causes less current to flow through the heating element. This keeps the heating element and the water cooler. When the resistance is reduced, the current through the thermostat increases, which causes the transistor to increase the current through the heating element. This raises the temperature of the water.

Repairing of Electric Kettle

Electrical Kettle is the basic kitchen aid Accessories. Suddenly if the electric kettle is not working then some simple step to repair the electric kettle at home.

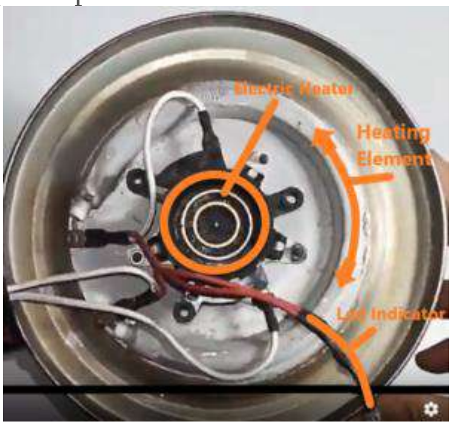


*Fig 2.58*Back Cover

Open the back Cover

So here you have what it contains inside. You can see the heating element, led indicator, which is the actual main component of the electric kettle. Electric heater controls the temperature and once the temperature rises high and heated up fully there is a control to disconnect the power supply and the heating will stop. So there is no damage to the heater. Disconnect the wire and open the thermostat if its not heating the water or not automatically stop after heating.

Replace your Electric Kettle Thermostat with a new one. Because 90 percent problem occurs when your thermostat does not work properly

And 10 percent chance is your heating Element getting wrong. When you go to buy a new thermostat you need to make sure that you are getting the right kind of thermostat. Which can fit into your electric kettle head. Because there are many types of a thermostat in the market some are in round and some are in square shape. You need to make sure that you have got the right one when you are trying to repair or replace your electric kettle.

2.6.2Coffee Percolator

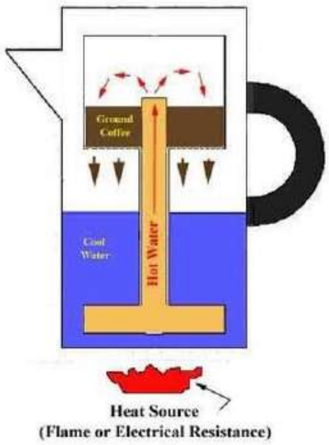
Construction and Working

The word "percolate" is a process where fluid gradually passes through a permeable substance with the inference that a liquid emerges from the union with a different quality than what originally existed before the percolation process.

Coffee Percolator

Coffee can be made in many different ways. There are a number of different kinds of brewing machines and straining mechanisms and methods used when making coffee. However, the most authentic flavours of coffee are derived from the coffee percolation method. A coffee percolator is one method for brewing coffee through the continuous cycle of brewing water. Coffee percolators were the most popular tool for making and enjoying coffee until automatic drip makers came along. The reason why coffee percolators are still around is that they can remove some of the volatile compounds present in the beans. Although there is a slight compromise in flavour, the aroma that the coffee percolator gives is highly aromatic. Despite losses in flavour, percolator enthusiasts maintain that the potential pitfalls of this brewing method can be eliminated by carefully controlling the brewing process.

Brewing Cycle



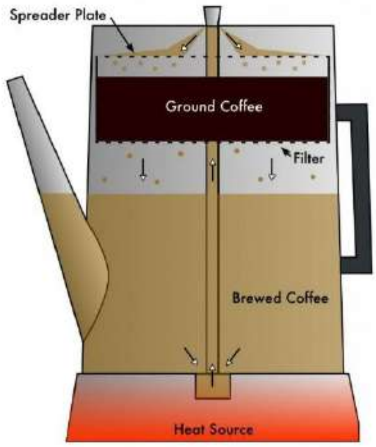


Fig 2.59

As the water boils in larger rolls, it will also splash up through the bottom of the coffee basket affecting the coffee from both sides, as the water will also be flowing down through the coffee and through the bottom of the basket into the rest of the boiling water.

The water will continue to go through this cycle over and over. This makes the coffee stronger and stronger, by infusing the bean oils more and more thoroughly with the water, until the coffee pot is removed from the heat.

In order to be a percolator coffee pot, the pot must have the internal features of an upright pump stem tube and a basket to hold the coffee and for the water to pass through. The tube usually sits upon a stand and the coffee grind basket rests upon the tube. The basket has a perforated spreader cover to put on top of it.

Options

Some form of lid, often made of glass or plastic for viewing the coffee colour and determining readiness, sits atop it all. The pump stem tube goes through the basket and through the spreader cover and holds those pieces secure.

This pot may be made of metal which can be set over a fire to heat, or it may be made of glass and the water may be preheated prior to pouring it into the percolator coffee pot. It also might be made of any number of materials, but be electric so that it heats up simply by plugging the cord into an outlet.

A paper filter is not needed in a percolator coffee pot grind basket. But if all grinds escaping into the pot are to be completely avoided, a customized percolator filter must be used.

The percolator coffee pot functions by utilizing the natural rising action of bubbles created by boiling water at the bottom of a pot.

A hollow pump stem tube ensures a concentration of these bubbles will crowd in together, forcing water in an upward motion through the tube.

This tube then sprays water over the spreader cover, which thoroughly disperses the water over the ground coffee, saturating it. The spreader cover is designed with holes of various sizes to evenly saturate the coffee. The spreader also serves the dual purpose of preventing ground coffee from splashing up into the rest of the pot.

Operation

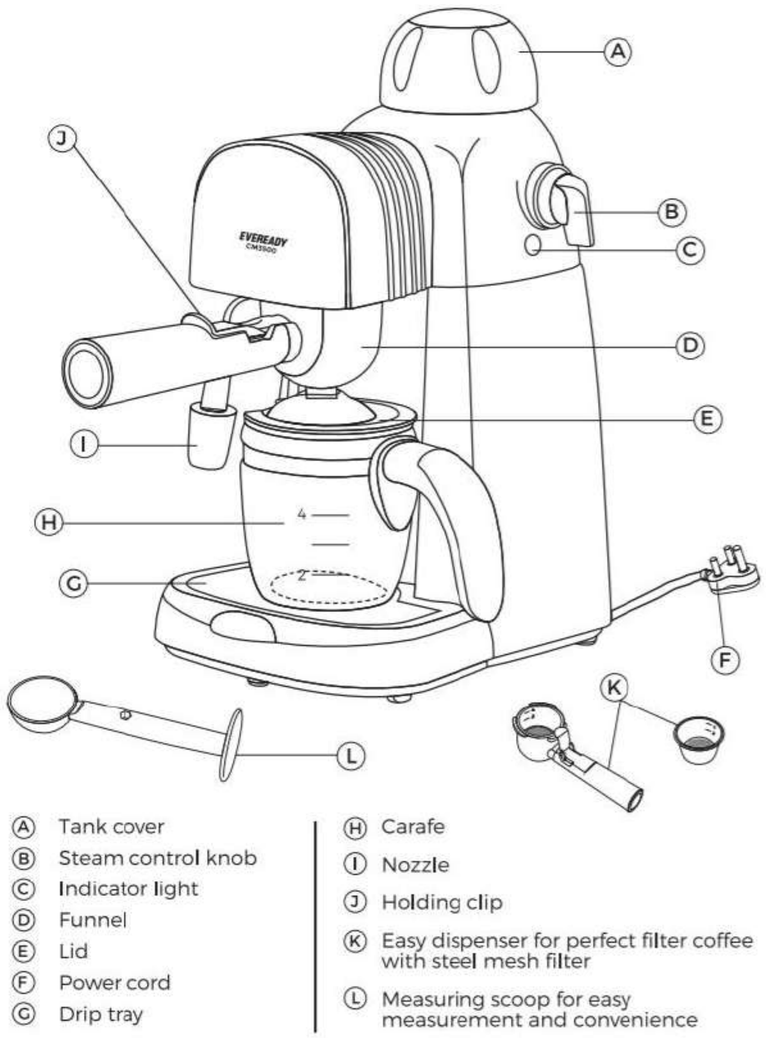


Fig 2.60Coffee Percolator

A coffee percolator consists of a pot with a small chamber at the bottom of the coffee percolator. The chamber is closest to the heat source. There is a vertical tube that leads from this chamber to the top of the coffee percolator. Just below the upper end of the tube is the perforated chamber.

The desired quantity is poured into the chamber of the pot and a certain amount of coarse-ground coffee is placed in the top section of the coffee percolator. The heat source under the percolator heats the water in the bottom chamber. The water at the bottom of the chamber begins boiling, which leads to the formation of the bubbles. These bubbles rise due to similarities in principle with an airlift pump. The principle of the airlift pump involves energy derived solely from compressed air. Since the buoyancy of the air is less than the density of the liquid, the liquid begins rising quickly.

The water eventually begins rising up the vertical tube and out the top of the vertical tube. When the water comes out of the top, the water flows out of the lid of the coffee chamber. The perforations present on top of this lid evenly distribute the water over the finely ground coffee. The water then seeps through the coffee grounds and makes its way to the bottom of the coffee chamber.

A cycle now starts to occur. From the bottom of the coffee chamber, the water drops down to the colder part of the bottom chamber. This forces the water to move up the vertical tube. As the water droplets fall down from a height, it helps to thoroughly mix the fluid in the bottom chamber, while the fluid also keeps ascending the vertical tube. This cycle keeps repeating over and over until a fine brew is formed.

Repairing of a Coffee Maker

Common repairs to coffee makers include servicing the on/off switch, thermostat, heating element, and warming element.

Servicing an On/Off Switch: A coffee maker's switch is a simple device that controls current to the heating unit and pump. Fortunately, this key controller is easy to test and to replace. Here's how:

Step 1: Make sure the coffee maker is unplugged.
Step 2: Remove the base or shell to access the back of the switch.
Step 3: Place test probes across the terminals and activate the switch. The circuit should be closed and show continuity as indicated by the switch positions.
The same test of continuity can be used to test other controllers, such as timers. All operate as switches, conducting electricity in some settings and not in others.

Servicing a Drip Coffee Maker's Thermostat: A thermostat in a drip coffee maker controls electricity to operate the heating element. It can cause problems if it doesn't work correctly. To test the thermostat in a drip coffee maker:

Step 1: Unplug the unit, empty excess water from the reservoir, turn the unit over, and remove the base. (Special head screwdrivers -- available at larger hardware stores -- may be required.)
Step 2: Use a continuity tester or multitester to check the thermostat, placing a probe at each end.

TESTING A DRIP COFFEE MAKER'S THERMOSTAT
Step 3: If defective, remove and replace the thermostat with one of the same rating.
Step 4: Also check the continuity of the fuse and replace it if the circuit is open.
Servicing a Percolator Coffee Maker's Thermostat: The thermostat in a percolator coffee maker serves the same function, but looks different from one in a drip system. To test a percolator coffee maker's thermostat:

Step 1: Unplug the coffee maker, make sure the coffee and filter are removed before turning it over, then remove the base to expose the heating element and thermostat.
Step 2: Test the thermostat's continuity.
Step 3: If the thermostat is an open circuit, replace it. If replacing the thermostat requires unriveting or desoldering it, consider taking it to an appliance-repair shop or replacing the entire coffee maker.
Servicing Heating Elements: A coffee maker's heating element is a critical component. No one wants cold coffee. The heating element in either a drip or percolator coffee maker is accessed through the base of the appliance. To test and replace a heating element:
Step 1: Make sure all liquids and grounds are emptied from the appliance before turning it over to remove the base.
Step 2: Once accessed, the heating element can be tested using a continuity tester or a multitester as you would any conductor. Disconnect the unit from the circuit, then place a probe at each terminal and verify that the element can conduct electricity.

Step 3: If no electricity is being conducted, replace the heating element unit or assembly. With masking tape, mark the location of all wires and components you loosen so you will be able to reconnect them with ease.

Servicing Warming Elements: Once the coffee is brewed, the warming element in the base of the coffee maker keeps it warm. The warming element on some coffee makers remains on all day long, so it may be the first component to fail. In addition, water or brewed coffee may spill and leak into the warming element, shorting it out. Here's how to test and replace a warming element:

Step 1: Remove the coffee maker's base, identify the warming element, and disconnect it from the terminals.

Step 2: Check for continuity using a continuity tester or multi tester.

Step 3: Replace the warming element, if necessary.

Trouble Shooting Table 2.6

Symptom	Cause	Corrections
Carafe leakage or water leaks out from lid of carafe	The carafe is not located properly	Let centreline of the carafe align with leakage opening of the brew basket well.
	The level of water in the tank exceeds the scale of MAX.	The water level in the tank should be within the scale of MIN and MAX.
The metal parts in the tank have rust.	The descaler is not recommended type. It may corrode the metal parts in the tank.	Use the descaler recommended by the manufacturer.
Water leaks from the bottom of Espresso Maker.	There is excess water in the drip tray.	Please clean the drip tray.
	The Espresso maker is malfunctioning.	Please contact authorized service facility for repairing.
Water leaks out of the outer side of filter.	There is some coffee powder on the filter edge.	Clean the edge.
Acid (vinegar) taste exists in Espresso coffee.	Not cleaning correctly after removing mineral deposits.	Clean Espresso Maker as per the content in "Before the first use" for several times.
	The coffee powder is stored in a hot, wet place for a long time. The coffee powder turns bad.	Please use fresh coffee powder, or store unused coffee powder in a cool, dry place. After opening a package of coffee powder, reseal it tightly and store it in a refrigerator to maintain its freshness.
The Espresso maker cannot work any more.	The power socket is not plugged in well.	Plug the power cord into a wall outlet correctly, if the appliance still does not work, please contact authorized service facility for repairing.
The steam cannot froth.	The steam ready indicator is not illuminated.	Only after the steam ready indicator (Green indicator) is illuminated, the steam can be used to froth.
	The container is too big or the shape is not befilling.	Use high and narrow cup.
	You have used skimmed milk	Use whole milk or half-skimmed milk

Short Answer Questions

1. **Write the Applications of Heating Effect**
2. **What are the Materials Used for Heating Elements?**
3. **Write the principle of Heating Appliances**
4. **What are the required properties of a heating element?**
5. **What are the material used for manufacturing heating element?**
6. **List The different types of electric heaters**

7. Classify the room heaters
8. Write the Essential parts of a basic rod type room heater
9. Write the Essential parts of a basic bowl type room heater
10. Write the Safety Tips for using any Types Of Heaters
11. What are the types in Electric Irons?
12. List The Essential parts of a basic electric iron
13. What is Thermostat
14. List The parts of Electric Stove
15. List The parts of Electric cooker
16. Draw the wire diagram of Electric Rice Cooker
17. Draw the wire diagram of Electric Iron
18. What is Fuzzy Logic Rice Cookers
19. Name the parts of a Electric Toaster
20. Name the parts a Water Heater
21. Name the parts Electric Kettle
22. List the parts of Coffee Percolator

Essay Questions

1. Briefly Explain about Rod type room heater
2. Briefly Explain about Bowl type room heater
3. Briefly Explain about the working of room heater
4. With a neat sketch Explain about the Construction of Electric iron
5. With a neat sketch Explain about the Working of Automatic Electric iron
6. Explain about the possible faults and remedies of Electric Iron
7. Explain about the Construction and Working of Electric Rice Cooker
8. Explain about the Repairing of Electric Rice Cooker
9. Explain about the Construction and Working of Electric Toaster
10. Explain about the Repairing of a Toaster
11. Explain about the Construction and Working of Immersion Water Heater
12. Explain about the Repairing of Immersion Water Heater
13. Explain about the Construction and Working of Electric Kettle
14. Explain about the Repairing of Electric Kettle
15. Explain about the Construction and Working of Coffee Percolator
16. Explain about the Repairing of Electric Kettle

3. Motorized Heating Appliances

3.1.1Hair Dryer

A hair dryer, also known as a blow dryer, is an electrical device used to dry and style hair. It uses an electric fan to blow air across a heating coil; as the air passes through the dryer it heats up. When the warm air reaches wet hair it helps evaporate the water. Hair dryers may be used with a variety of brushes and combs to achieve different hair styles.

Design

One of the key factors to consider when designing a portable hairdryer is the amount of heating power it can produce. Since warm air is capable of absorbing more moisture than cold air, the temperature of the airflow is critical. By calculating the specific heat of the air and understanding the maximum temperature that can be used without burning the skin, engineers can calculate the amount of power required for the heating element. This ensures that the device will generate enough heat to dry the hair quickly. However, it is not enough to simply raise the temperature of the hair; the air must also pass rapidly through the hair for efficient moisture removal. Therefore, the efficiency of the fan is also a critical consideration.

Another key design criteria is the safety of the device. First, the hair dryer must not become so hot that it burns the user during operation. The plastic housing must remain at a comfortable temperature and cannot overheat or else it could melt or catch fire. To solve this problem, engineers have developed temperature cut-off switches that prevent the heating coil from getting too hot. This cut off switch also turns off the heating coil if the blower motor on the fan stops functioning. Second, the hair dryer must not cause electric shock. A special shock safeguard,

a Ground Fault Circuit Interrupter (GFCI), is used in modern hair dryers to prevent accidental electrocution.

Other factors to consider include the weight of the unit and a user-friendly design. For the sake of convenience, hair dryers are designed to weigh only about 1 lb (500 grams), and they are made to be easy to handle during operation.

3.1.2 Hairdryer Construction

Hairdryers are assembled from a series of components including the electrical motor, the fan blade, copper wiring, switching mechanisms, and various other electrical components. The plastics used to make the outside shell of the hair dryer must be durable, yet light-weight.

The Manufacturing Process

1. The electric motor and fan blades arrive at the manufacturing plant pre-assembled.
2. Hairdryers produce heat in the same fashion that a toaster does: by passing electric current through a wire. The wire has a high level of electrical resistance that causes it to generate heat as the current passes through it. Hair dryers use a metal heating element that is made of nichrome, an alloy of nickel and chromium. Unlike other electrical wires made of copper, nichrome will not rust at high temperatures. This wire looks like a coiled spring and may be up to 12 in (30 cm) long. It is wrapped around an insulating board so that the entire heating element is only a few inches long.
3. The insulating board is usually made of mica, a mineral that can stand high levels of heat. Two flat pieces of mica several inches long are connected to form what looks like a three-dimensional "x." Notches are cut in the edges of this board such that when the nichrome wire is wrapped around the board it fits snugly into these slots. At the end of the wire there is a connection to the circuit that controls the power supply. Depending on how this circuit is wired, current can be fed to part of, or all of, the heating coil. More heat is produced as current is fed to a greater portion of the wire.

The heating element used in modern hair dryers can produce up to 2000 watts of heat energy.

4. The body of the hairdryer consists of a gun shaped plastic shell. This shell is divided into two sections to allow for easy assembly. The plastic parts are created by injection molding, a process that involves injecting hot, molten plastic (such as polypropylene) into a stainless steel die. After the mold is filled with hot plastic, cold water is circulated around the die to cool the plastic and make it harden. When the die is opened, the plastic parts are removed. One side of the plastic shell has a series of holes molded into it while the matching half has a series of short pins. These help align the two halves during manufacture and keep them firmly attached.

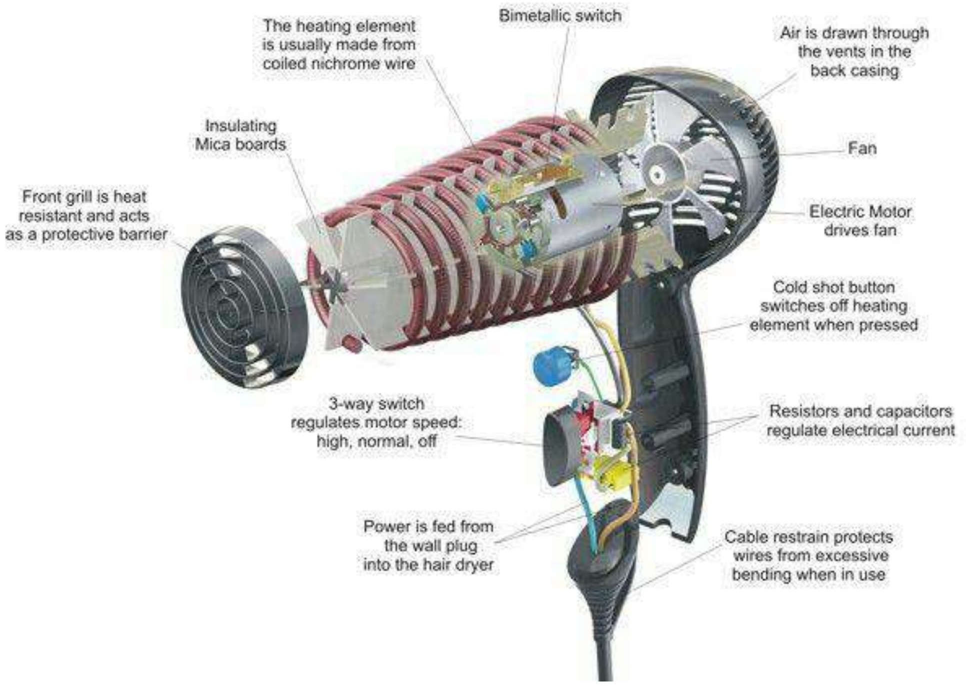


Fig 3.1 A hair dryer and its internal parts.

5. The Shell is moulded with multiple compartments to hold the various electrical components. The handle of the gun contains the switch apparatus and the controls to operate the dryer. The electric motor and fan are found in the central part of the drier located just above the handle. The long barrel of the device contains the heating element. Next to the motor is an air intake air inlet. This inlet is covered with a fine mesh metal screen to prevent objects from accidentally getting caught in the fan blades. Some newer models even had a removable lint screen over the air inlet that can be taken off and easily cleaned. At the end of the barrel is another protective screen that prevents anyone from sticking their fingers or other long objects into the heating element.

6. Other components of the hairdryer are designed to ensure its safe operation. Dryers contain a safety cut off switch that prevents the temperature of the drier from exceeding 140°F (60°C). This switch is a bimetallic strip, which is made from a sheet composed of two metals. These metals expand at different rates when they are heated. As the temperature inside the drier increases, the strip will bend one way or another as the metal strips expand at different rates. When a certain temperature is reached the strip bends to appoint where it trips a safety switch that cuts off the power to the drier.

7. Another Safety device is a thermal fuse built into the electrical circuitry. This fuse has a small metal strip that melts if the temperature of the circuit exceeds a certain amount. This breaks the circuit and instantly cuts power to the drier. Both these safety features are designed to prevent overheating and stop a fire from occurring.

   A third type of safety control is the Ground Fault Circuit Interrupter (GCFI) that is built into dryers to prevent electrocution, The GCFI senses how much current is flowing through the circuit and can shut it off if it detects a leak or a short-circuit.

8. The dryer components can are put in place on an assembly line using a combination of automated equipment and manual labor. First, the electrical components are fitted into the bottom half of the plastic shell. Once this step has been completed, the top half of the shell is locked into place.
9. These pins and holes are lined up when the shell hands are assembled. Screws and other fasteners are used to anchor the plastic parts together and hold them in place. Early hair dryers used dozens of screws to lock the shell hands to place. Because of more efficient designs, modern models only require a few key screw components. This helps control cost and reduce assembly time.
10. After assembly warning labels showing that the hair dryer should be kept away from water must be attached. These labels are attached to the cord as required by the Consumer Products Safety Commission guidelines. Once the dryers have been fully assembled they are boxed along with an instruction booklet and additional safety warning materials and are packaged for shipping.

Quality Control

All electrical appliances may be dangerous if misused. Hair dryers are particularly dangerous because they may accidentally dropped into a sink or bathtub full of water. Therefore, special quality control precautions must be taken to reduce the chance of electrocution. Beginning in 1980, manufacturers were required to include a warning picture on hair dryers to show they should not be used near water. This warning label must be permanently attached to the drier cord. In 1985, manufactures began adding a polarized electrical plug that would help ground the appliance and prevent accidental shock. In 1991, products were required to have design feature that prevents the possibility of a short-circuit whether or not the device is turned on.
Modern hair dryers use GFCI to prevent any power flowing into the device when a short-circuit is detected. By the year 2000, recorded deaths due to electrocution by hairdryer had already dropped to less than four a year, and it is anticipated that this additional safety feature will completely prevent accidental electrocutions once all the older hair dryer models have disappeared from the market.

Principle

Normally, evaporation is controlled by relative humidity — the ratio of the amount of water the air holds to the amount it could hold. For example, if the relative humidity is 90%, that means that the air is holding 90% of its maximum volume of water. When air is heated, its relative humidity decreases. It still has the same amount of water, but it can hold more. The lower the relative humidity, the more easily water evaporates. Therefore, hot air will dry your hair faster, since the water in your hair will evaporate more quickly.

Hair Dryer Working

Basic models have two **switches**, one to turn them **on and off** and one to control the **rate of airflow**. Some models have an extra switch that also lets you regulate the **temperature** of the dryer

A hair dryer needs only two parts to generate the blast of hot air that dries your hair:

- a simple motor-driven fan
- a heating element

Hair dryers use the motor-driven fan and the heating element to transform electric energy into **convective heat**. The whole mechanism is really simple:

1. When you plug in the hair dryer and turn the switch to "on," current flows through the hair dryer.
2. The circuit first supplies power to the heating element. In most hair dryers, this is a bare, coiled wire, but in models that are more expensive there can be fancier materials in action, like a tourmaline-infused ceramic coating.
3. The current then makes the small electric motor spin, which turns the fan.
4. The airflow generated by the fan is directed down the barrel of the hairdryer, over and through the heating element.
5. As the air flows over and through the heated element, the generated heat warms the air by forced convection.
6. The hot air streams out the end of the barrel.

The heating element in most hair dryers is a bare, coiled **nichrome wire** that's wrapped around insulating mica boards.Nichrome wire is an alloy of two metals, nickel and chromium. This alloy is used in heating elements in a number of household products, from curling irons to toasters. Nichrome wire has two features that make it a good producer of heat:

- It's a poor conductor of electricity compared to something like copper wire. This gives the alloy enough resistance to get hot from all of the current flowing into it.
- It doesn't oxidize when heated. Other metals like iron rust pretty quickly at the temperatures used in toasters and hair dryers.

The airflow generated by the fan is forced through the heating element by the shape of the hair dryer casing. When the air initially enters the barrel, it is much cooler than the nichrome wire, so heat flows from the wire to the air. As the air is pushed along by the fan and convection, it is replaced by cooler air and the cycle is repeated.

How hot the air coming out of the dryer can get depends on:

- The power supplied to the heating element. The higher the wattage, the more heat is generated by the heating element and transferred to the air. Early hair dryers put out only about 100 watts of heat, but nowadays hair dryers can produce up to about 2,000 watts, drying hair considerably faster. Hair dryers that offer high heat and low heat settings vary the power supplied in order to modulate the temperature of the airflow. These models are wired so that you can flip a switch and cut off part of the circuit that feeds the heating element.
- The time the air spends in the barrel of the dryer being heated by the nichrome wire. Most hair dryers limit this to approximately one-half second to prevent the air temperature from getting too high.

Something seen more often these days are hair dryers with a ceramic coating on the heating element. Coming in a variety of different configurations, ceramic-coated heating elements are said to heat more evenly and effectively. It's also popular to infuse the ceramic with materials such as crushed tourmaline, which is said to support the creation of ions and ideal heat flow.

Hair Dryer Safety

The heat shield keeps the barrel of the hair dryer from becoming too hot.

The basic idea behind hair dryers is pretty simple, but producing one for mass consumption requires some hard thinking about **safety features**. Manufacturers have to predict how their hair dryer might be misused. They then try to design a product that will be safe in the widest variety of conditions.

Besides the ground fault circuit interrupters, we learned about on the first page, here are some other safety features hair dryers commonly have:

- **Safety cut-off switch** - Your scalp can be burned by temperatures more than 140 degrees Fahrenheit (approximately 60 degrees Celsius) [source: Hardin]. To ensure that the air coming out of the barrel never nears this temperature, hair dryers have some type of heat sensor that trips the circuit and shuts off the motor when the temperature rises too much. This hair dryer and many others rely on a simple bimetallic strip as a cut-off switch.
- **Bimetallic strip** - Made out of sheets of two metals, both expand when heated but at different rates. When the temperature rises inside the hair dryer, the strip heats up and bends because one metal sheet has grown larger than the other. When it reaches a certain point, it trips a switch that cuts off power to the hair dryer. (For more information on bimetallic strips, see How Thermometers Work).
- **Thermal fuse** - For further protection against overheating and catching fire, there is often a thermal fuse included in the heating element circuit. This fuse will blow and break the circuit if the temperature and current are excessively high.
- **Insulation** - Without proper insulation, the outside of the hair dryer would become extremely hot to the touch. If you grabbed it by the barrel after using it, it might seriously burn your hand. To prevent this, hair dryers have a **heat shield** of insulating material that lines the plastic barrel.
- **Protective screens** - When air is drawn into the hair dryer as the fan blades turn, other things outside the hair dryer are also pulled toward the air intake. This is why you'll find a wire **screen** covering the air holes on either side of the dryer. After you've used a hair dryer for a while, you'll find a large amount of lint building up on the outside of the screen. If this were to build up inside the hair dryer, it would be scorched by the heating element or might even clog the motor itself. Even with this screen in place, you'll need to periodically pick lint off the screen. Too much lint can block the airflow into the dryer, and the hair dryer will overheat with less air carrying away the heat generated by the nichrome coil or other type of heating element. Newer hair dryers have incorporated some technology from the clothes dryer: a **removable lint screen** that's easier to clean.
- **Front grill** - The end of the barrel of a hair dryer is covered by a grill made out of material that can withstand the heat coming from the dryer. This screen makes it difficult for small children (or other especially inquisitive people) to stick their fingers or other objects down the barrel of the dryer, where they could be burned by contact with the heating element.

For more information on other household appliances showing their warm, fuzzy side -- whether by drying your clothes, toasting your bread or starting your car -- get your motor going below with a bunch of interesting links.

Hair Dryer Repair

What Can Go Wrong with a Hair Dryer?

Because hair dryers are simple small appliances, few things can go wrong. The electric cord may be faulty, the appliance may not heat, and the fan may not operate. That's about it.

Solution:
Hair dryers will overheat and the thermostat will turn it off if the vent becomes clogged with hair or dust. Periodically brush or vacuum the grille and filter screen. Also tighten screws occasionally so hair and moisture don't enter the housing.

How to Identify a Hair Dryer Problem?


Fig 3.2

Remove the fasteners holding the housing halves together. Pull the halves apart carefully because some switches will fall out.

Here's where to start looking if your hair dryer fails:

- If the appliance doesn't work at all, make sure the power is on at the outlet and check the electrical cord.
- If it still doesn't run, disassemble it to check the thermal cut-out and service if necessary. Also test the motor, switches, and heating element with a multimeter.
- If the fan doesn't work on every setting, check the fan switch and service if faulty.
- If the dryer doesn't heat on every setting, check the heat switch and service if necessary.
- If the fan works but the heat doesn't, check the heat switch and the heating element and service if needed.
- If the heat works but the fan doesn't, check the fan-speed switch and the fan motor and service if faulty.

Solution:
The heating elements inside a hair dryer (and toasters, as well) are very fine wires. Treat them with special care to ensure that they aren't damaged as you are repairing other components. Also, inspect them for breaks and repair or replace any that look worn or broken.

What Do I Need for Hair Dryer Repair?

You can buy some replacement parts for hair dryers at small appliance parts stores and larger hardware stores. Or you can contact the manufacturer or online aftermarket parts dealers for replacement parts. The tools you may need to work on a hair dryer include these:

- Screwdrivers
- Wrenches
- Multimeter

What Are the Steps to Hair Dryer Repair?

Disassemble a typical hair dryer:

Make sure you lay out the components so they are easier to reassemble once you've fixed the hair dryer.

1. Unplug the dryer.
2. Remove the hair dryer nozzle and filter. On some models, they are held on by tension while on others by a small screw where the nozzle or filter meets the main body.
3. If the unit has an intake filter screen, remove and clean it.
4. Remove screws that hold the housing together and remove the housing.
5. Locate any switches, the fan, and the motor, then test them. In some cases, you can see obvious damage or problems that can be repaired quickly. Or you may need to find and install replacement parts.

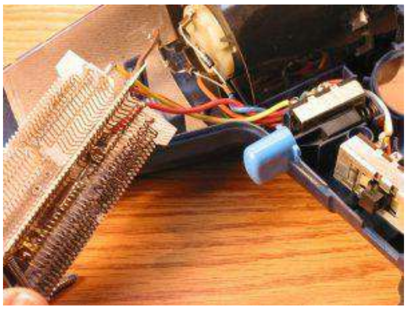


Fig 3.3 Remove and clean the hair dryer filter screen.

Service a hair dryer thermal cutout:

1. Open the housing as above to open the heating element assembly.
2. Inspect the thermal cut-out for damage or discoloration. The thermal cut-out will be connected to one of the two wires leading from the electrical cord and inside the housing.
3. Carefully use canned air to clean internal components of dust, hair, and other debris. Be careful not to damage the sensitive element wires in the heating unit.

Caution!

For safety, remember to let a hair dryer cool down before storing it.

3.1.2MICROWAVE OVEN

A microwave oven is used to cook (or heat) food with the help of microwaves produced by magnetron – the device producing microwaves in the oven. Microwave ovens are so quick and efficient because they channel heat energy directly to the molecules (tiny particles) inside food.

Microwave oven Working

Radiation

Heat between a source and a recipient can be transferred in three ways: conduction, when the two are in direct contact, like when you touch a hot cup; convection, when the heat is transferred by a medium, usually fluid, like when hot air contacts colder air; and finally, radiation, when the heat is transferred by the means of an electromagnetic wave, which requires no medium to propagate, such as the warmth imparted by the sun's light that travelled millions of miles through empty space. Microwaves are electromagnetic waves, radiation is how the heat in a microwave oven is transferred.

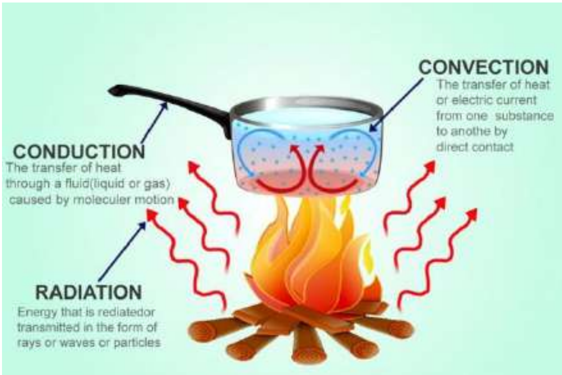


Fig 3.4(a) The three types of heat transfer.

However, it is still unclear how the heat is distributed throughout the food being subjected to the waves. Microwaves are extremely adept at exciting and vibrating water molecules, and since food is mostly water, the vigorous motion of the molecules creates intermolecular friction, which generates the heat to cook the food item. Remember that microwave ovens are constructed in a way that allows no waves to escape them, so the reflected energy bounces off the walls and is re-reflected by the metal bowl.

How does a microwave turn electricity into heat?

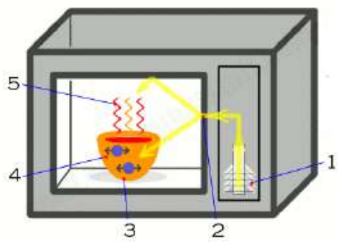


Fig 3.4(b)

1. Inside the strong metal box, there is a microwave generator called a magnetron. When you start cooking, the magnetron takes electricity from the power outlet and converts it into high-powered, 12cm (4.7 inch) radio waves.
2. The magnetron blasts these waves into the food compartment through a channel called a wave guide.

3. The food sits on a turntable, spinning slowly round so the microwaves cook it evenly.

4. The microwaves bounce back and forth off the reflective metal walls of the food compartment, just like light bounces off a mirror. When the microwaves reach the food itself, they don't simply bounce off. Just as radio waves can pass straight through the walls of your house, so microwaves penetrate inside the food. As they travel through it, they make the molecules inside it vibrate more quickly.

5. Vibrating molecules have heat so, the faster the molecules vibrate, the hotter the food becomes. Thus the microwaves pass their energy onto the molecules in the food, rapidly heating it up.

Why Microwaves?

The energy of an electromagnetic wave increases with an increase in its frequency, so why don't we use infrared or ultraviolet rays to cook food more quickly and efficiently? Infrared or ultraviolet rays aren't used because they are absorbed by the food item's surface before they reach the water beneath. Microwaves, however, can penetrate to greater depths, where the water lies. Heating the meat with infrared or ultraviolet might make it 'look' hot, but the flesh beneath will remain uncooked. That being said, prolonged infrared heating will eventually heat the meat as well, something that is evident in regular heating, when one cooks on a stove. In fact, many ovens are infrared-based.

Lastly, while microwave heating is the quickest and most efficient way to cook food, not every food can be heated with equal ease. Obviously, food items suffused with moisture are the easiest to heat. Food items containing sugar or fat, however, require greater effort. This is because the dipole movement of their molecules is much less than the dipole movement of water molecules.

Also, one must avoid microwaving any food item in a metal container. The fact that metals reflect electromagnetic waves is the working principle of radar. If you feed an oven a metal bowl, most of the microwave energy, as though a metallic ship, will be reflected by it.

Microwave oven Construction

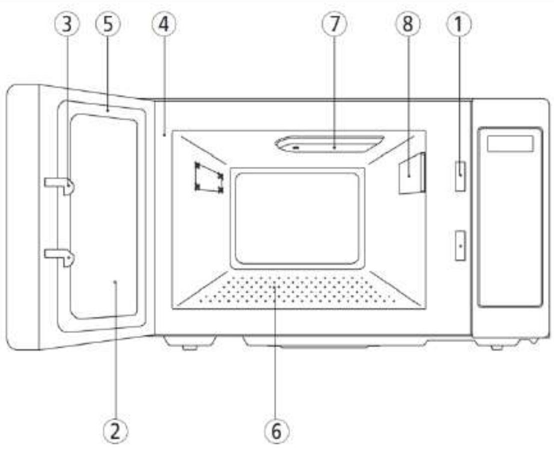


Fig 3.5 ***Microwave oven***

1 **Safety Interlock System.**

2 **Door Viewing Screen -** Allows viewing of food. The screen is designed so that light can pass through, but not the microwave.

3 **Door Hook -** When door is closed, it will automatically shut off. If the door is opened while the oven is operating, magnetron will immediately stop operating.

4 **Oven Cavity.**

5 **Door Seal -** Door seal maintains the microwave energy within the oven cavity and prevents microwave leakage.

6 **Plate Tray -** Made of special heat resistant GLASS. Food in a proper receptacle is placed on this plate for cooking.

7 **Stirrer Cover -** This is located on the ceiling with the stirrer fan.

8 **Inlet cover -** Protect the air hole from splashes of cooking foods.

Operation procedure
This section includes useful information about oven operation.

1. Plug power supply cord into a standard 3- pronged 230 AC 50Hz power outlet.
2. After placing the food in a suitable container, open the oven door and put it on the plate tray.
The glass tray must always be in place during cooking.
3. Shut the door. Make sure that it is firmly closed.
The oven light is on when the microwave oven is operating or the door is opened.
The oven door can be opened at any time during operation by opening the door. The oven will automatically shut off.
Each time a pad is touched, a BEEP will sound to acknowledge the touch.
The oven automatically cooks on full power unless set to a lower power level.
The display will show ":0" when the oven is plugged in.
When the STOP/CLEAR pad is touched during the oven operation, the oven stops cooking and all information retained.
To erase all information, touch the STOP/CLEAR pad once more. If the oven door is opened during the oven operation, all information is retained.
If the START pad is touched and the oven does not operate, check the area between the door and door seal for obstructions and make sure the door is closed securely.

The oven will not start cooking until the door is completely closed or the program has been reset.

COOKING INSTRUCTIONS
Only use utensils that are suitable for use in microwave ovens.

UTENSILS TEST
Place the utensil in question next to a glass measure filled with water, in the microwave oven. Microwave at high power for 1-2 minutes. If the water heats up, but the utensil remains cool, the utensil is microwave-safe. However, if the utensil becomes warm, microwaves are being absorbed by the utensil and it should not be in the microwave oven. You probably have many items on hand in your kitchen right now that can be used as cooking equipment in your microwave oven. Read through the following checklist.

COOKING UTENSILS
Recommended Use

- **Glass and glass-ceramic bowls and Dishes -** Use for heating or cooking.

- **Microwave browning dish** - Use to brown the exterior of small items such as steaks, chops, or pancakes. Follow the directions provided with you browning dish.
- **Microwaveable plastic wrap** - Use to retain steam. Leave a small opening for some steam to escape and avoid placing it directly on the food.
- **Wax paper** - Use as a cover to prevent spattering.
- **Paper towels, and napkins** - Use for short term heating and covering; they absorb excess moisture and prevent spattering. Do not use recycled paper towels, which may contain metal and can catch fire.
- **Thermometers** - Use only those labelled "Microwave Safe" and follow all directions. Check the food in several places. Conventional thermometers may be used once the food has been removed from the oven.
- **Microwave cling film, microwave roasting bags** - Microwave cling film and bags must be vented for steam to escape, pierce in 4~5 places. Do not use plastic or metal ties as they may melt or catch fire due to electrical arcing.

Limited Use

- **Aluminium foil** - Use narrow strips of foil to prevent overcooking of exposed areas. Using too much foil can damage your oven, so be careful.
- **Ceramic, porcelain, and stoneware** - Use these if they are labeled "Microwave Safe." If they are not labelled, test them to make sure they can be used safely. Never use dishes with metallic trim.
- **Plastic** - Use only if labelled "Microwave Safe." Other plastics can melt.
- **Thin plastic, paper, straw and wooden containers** - Always attend the oven closely. Look at the oven from time to time when cooking or reheating food in disposable containers of plastic, paper or other combustible material. Only use for warming food. Pay special attention as over-heating may cause a fire in your oven.

Not Recommended

- **Glass jars and bottles** - Regular glass is too thin to be used in a microwave, and can shatter.
- **Paper bags** - These are a fire hazard, except for popcorn bags that are designed for microwave use.
- **Styrofoam plates and cups** - These can melt and leave an unhealthy residue on food.
- **Plastic storage and food containers** - Containers such as margarine tubs can melt in the microwave.
- **Metal utensils** - These can damage your oven. Remove all metal before cooking.

Microwave OvenInstallation

1 Steady, flat location

This oven should be set on a steady, flat surface. This oven is designed for counter top use only.

2 Leave space behind and side

All air vents should be kept a clearance. If all vents are covered during operation, the oven may overheat and, eventually, oven failure.

3 Away from radio and TV sets

Poor television reception and radio interference may result if the oven is located close to a TV, Radio antenna, feeder and so on. Position the oven as far from them as possible.

4 Away from heating appliance and water taps

Keep the oven away from hot air, steam or splash when choosing a place to position it, or the insulation might be adversely affected and breakdowns occur.

5 Power supply

• Check your local power source. This oven requires a current of approximately 14 amperes, 120V 60Hz.

• Power supply cord is about 1.0 meters long.

• The voltage used must be the same as specified on this oven. Using a higher voltage may result in a fire or other accident causing oven damage. Using low voltage will cause slow cooking. We are not responsible for damage resulting from use of this oven with a voltage of ampere fuse other than those specified.

• If the supply cord is damaged, it must be replaced by the manufacturer or its service agent or a similarly qualified person in order to avoid a hazard.

6 Examine the oven after unpacking for any damage such as:

A misaligned door, Broken door, A dent in cavity. If any of the above are visible, DO NOT INSTALL, and notify dealer immediately.

7 Do not operate the oven if it is colder than room temperature.

(This may occur during delivery in cold weather.) Allow the oven to become room temperature before operating.

8 The minimum height of free space necessary above the top surface of the oven is 150mm.

SPECIFICATIONS

Table 3.1

POWER SUPPLY		230V AC 50Hz SINGLE PHASE WITH EARTHING
MICROWAVE	POWER CONSUMPTION	1500W
	OUTPUT POWER	1000W
	FREQUENCY	2450 MHZ
OUTSIDE DIMENSIONS (W x H x D)		542 x 329 x 452(21.34 x 12.95 x 17.78 in.)
CAVITY DIMENSIONS (W x H x D)		350 x 230 x 357(12.78 x 9.06 x 14.06 in.)
NET WEIGHT		APPROX. 18Kg(39.68 lbs.)
TIMER		60 min.
POWER SELECTIONS		5 LEVE

IMPORTANT

The wires in this mains lead fitted to this appliance are coloured in accordance with the following code.

Green-and-yellow: Earth

Blue: Neutral

Brown: Live

As the colours of the wires in the mains lead of this appliance may not correspond with the coloured markings identifying the terminals in your plug, proceed as follows: the wire which is coloured green-and-yellow must be connected to the terminal in the plug which is marked with the letter 'E', the earth symbol or coloured green-and-yellow. The wire which is coloured blue must be connected to the terminal which is marked with the letter ‘N’ or coloured black.

The wire which is coloured brown must be connected to the terminal which is marked with the letter 'L' or coloured red.

Important Safety Instructions

Warning: To prevent fire, burns, electric shock and other warnings:

Listed below are, as with all appliances, certain rules to follow and safeguards to assure high performance from this oven:

a. Do not use the oven for any reason other than food preparation, such as for drying clothes, paper, or any other nonfood items or for sterilizing purposes.
b. Do not use the oven when empty, this could damage the oven.
c. Do not use the oven cavity for any type of storage, such as papers, cookbook, cookware, etc.

2. Make sure you remove caps or lids prior to cooking when you cook food sealed in bottles.
3. Do not put foreign material between the oven surface and door. It could result in excessive leakage of microwave energy.
4. Do not use recycled paper products for cooking. They may contain impurities which could cause sparks and/or fires when used during cooking.
5. Do not pop popcorn unless popped in a microwave approved popcorn popper or unless it's commercially packaged and recommended especially for microwave ovens. Microwave popped corn produces a lower yield than conventional popping; there will be a number of unpopped kernels. Do not use oil unless specified by the manufacturer.
6. Do not cook any food surrounded by a membrane, such as egg yolks, potatoes, chicken livers, etc., without first piercing them several times with a fork.
7. Do not pop popcorn longer than the manufacturer's directions. (popping time is generally below 3 minutes). Longer cooking does not yield more popped corn, it can cause scorching and fire. Also, the cooking tray can become too hot to handle or may break.
8. If smoke is observed, switch off or unplug the appliance and keep the door closed in order to stifle any flames.
9. When heating food in plastic or paper containers, keep an eye on the oven due to the possibility of ignition.
10. The contents of feeding bottles and baby food jars shall be stirred or shaken and the temperature checked before consumption, in order to avoid burns.
11. Always test the temperature of food or drink which has been heated in a microwave oven before you give it to somebody, especially to children or elderly people. This is important because things which have been heated in a microwave oven carry on getting hotter even though the microwave oven cooking has stopped.
12. Eggs in their shell and whole hard-boiled eggs should not be heated in microwave ovens since they may explode, even after microwave heating has ended;
13. Keep the waveguide cover clean at all times. Wipe the oven interior with a soft damp cloth after each use. If you leave grease or fat anywhere in the cavity it may overheat, smoke or even catch fire when next using the oven.
14. Never heat oil or fat for deep frying as you cannot control the temperature and doing so may lead to overheating and fire.
15. Liquids, such as water, coffee, or tea are able to be overheated beyond the boiling point without appearing to be boiling due to surface tension of the liquid. Visible bubbling or boiling when the container is removed from the microwave oven is not always present. THIS COULD RESULT IN VERY HOT LIQUIDS SUDDENLY BOILING OVER WHEN A SPOON OR OTHER UTENSIL IS INSERTED INTO THE LIQUID.
16. **To reduce the risk of injury to persons:**
    a. Do not overheat the liquid.
    b. Stir the liquid both before and halfway through heating it
    c. Do not use straight-sided containers with narrow necks.

   d. After heating, allow the container to stand in the microwave oven for a short time before removing the container.
   e. Use extreme care when inserting a spoon or other utensil into the container.

17. Oven should be cleaned regularly and any food deposits removed.
18. Failure to maintain the oven in a clean condition could lead to deterioration of the surface that could adversely affect the life of the appliance and possibly result in a hazardous situation.
19. This appliance is not intended for use by persons(including children) with reduced physical, sensory or mental capabilities, or lack of experience and knowledge, unless they have been given supervision or instruction concerning use of the appliance by a person responsible for their safety.
20. Children should be supervised to ensure that they do not play with the appliance.

Repairing of a Microwave Oven

Warning: 1) Read and Follow the warning label on the microwave oven. 2) Never open back cover on power plug in. 3) Capacitor must be discharged before beginning any repair

Step 1: Unplug Power and Remove Moving Parts

Fig 3.6

Be sure the power cord is unplugged and then remove the moving parts from microwave oven.

Step 2: Open the Back Cover

Fig 3.7

There are 2 screws on right side and 1 screw on left side. They can be easily remove with normal screwdriver. But there are 4 screws on the back are little special, a star screwdriver is needed.

Step 3: Check the Fuse First

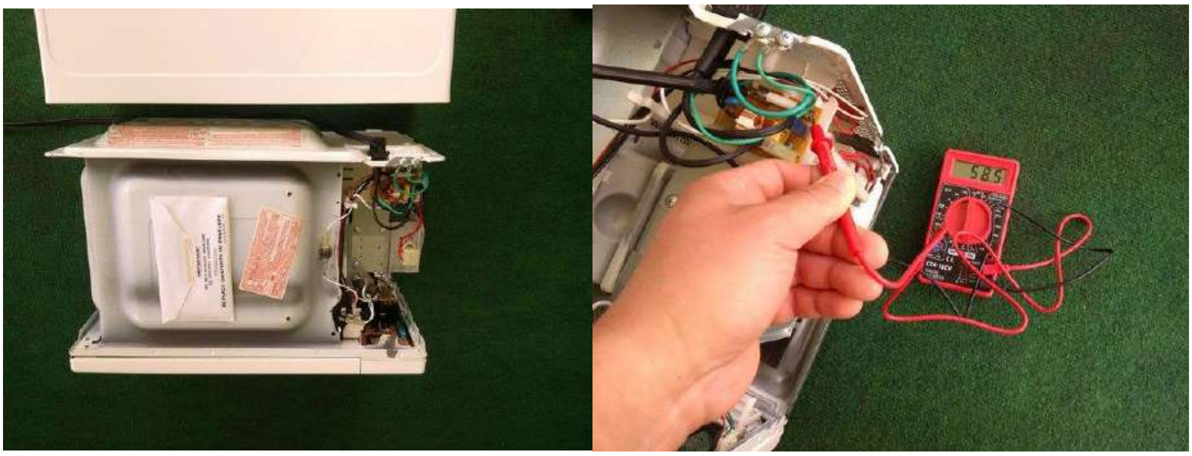


Fig 3.8

After open the back cover, check the fuse first. I checked it with a resistor tester, if it shows the fuse resistance value is infinity. That means the fuse is broken. Only need to change a fuse for the microwave oven. But it showed a resistance value on the meter, this means the fuse is not broken. I have to go to find problem in some other places.

Step 4: Inspect Door Switches

The next step is to inspect door switches. There are 3 switches in the microwave oven. See their location in the pictures. Press down the pin beside the switch and rotate the switch a little to take it out. Inspect one by one, I found one switch is little different with others, the first is press the button there is no contacts click voice, the second, found there is something burned on the plastic by visual inspection.

Fig 3.9(a)

Step 5: See Inside of the Switch

Fig 3.9(b) Switch Inside

Open this switch to verify. In the picture, press the button down, the contacts cannot be connected. Yes, this one is broken. Since some plastic is burned, this switch has to be changed.

Step 6: Buy a Replacement Part
Found the spec and model on the back of the switch, I bought a similar switch online - the grey one on the picture, to replace the broken switch.

Step 7: Install the New Switch

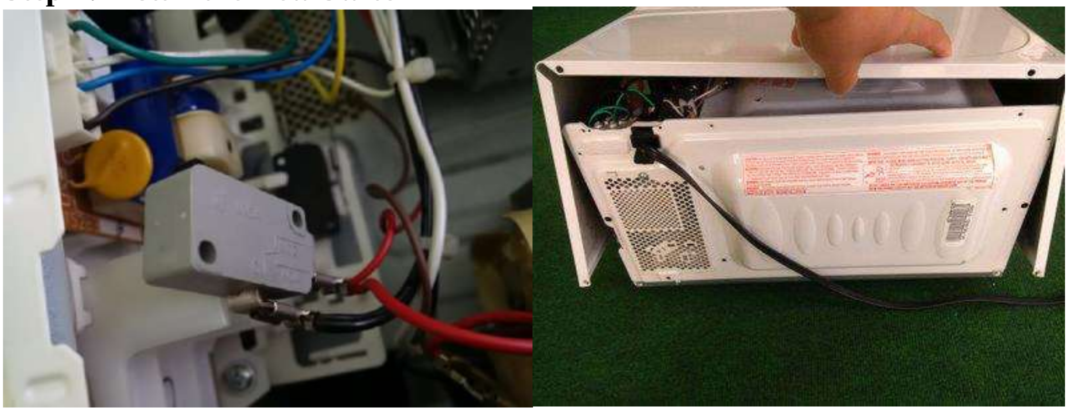


Fig 3.10

The following things are connecting wires to the new switch and install it properly. Just reverse the operation what I did. Close the back cover, drive in all screws and put the moving parts back.

Plug in power to test, the microwave oven works very well.

Step 8: About Discharge Capacitor
In my case, since the microwave oven has stopped working and unplugged power for a long time and there is one discharge resistor in the circuit. The capacitor must be discharged before beginning any repair.

The capacitor is in the back side lower corner. In my oven, it is covered by a plastic sheet. Please check it online how to discharge a capacitor.

Maintenance/Troubleshooting Table 3.2

Trouble	Possible Cause	Possible Remedy
Oven will not start	a. Electrical cord for oven is not pluggedin. b. Door isopen. c. Wrong operation isset.	a. Plug into theoutlet. b. Close the door and tryagain. c. Checkinstructions.
Arcing or sparking	a. Materials to be avoided in microwave oven wereused. b. The oven is operated whenempty. c. Spilled food remains in thecavity.	a. Use microwave-safe cookwareonly. b. Do not operate with ovenempty. c. Clean cavity with wettowel.

Unevenly cooked foods	a. Materials to be avoided in microwave oven wereused. b. Food is not defrostedcompletely. c. Cooking time, power level is notsuitable. d. Food is not turned orstirred.	a. Use microwave-safe cookwareonly. b. Completely defrostfood. c. Use correct cooking time, powerlevel. d. Turn or stirfood.
Overcooked foods	Cooking time, power level is not suitable.	Use correct cooking time, power level.
Undercooked foods	a. Materials to be avoided in microwave oven wereused. b. Food is not defrostedcompletely. c. Oven ventilation ports arerestricted. d. Cooking time, power level is not suitable.	a. Use microwave-safe cookwareonly. b. Completely defrostfood. c. Check to see that oven ventilation ports are notrestricted. d. Use correct cooking time, powerlevel.
Improper defrosting	a. Materials to be avoided in microwave oven wereused. b. Cooking time, power level is notsuitable. c. Food is not turned orstirred.	a. Use microwave-safe cookware only. b. Use correct cooking time, power level. c. Turn or stirfood.

3.3.1 DISHWASHERS

A **dishwasher** is a machine for cleaning dishware and cutlery automatically. Unlike manual dishwashing, which relies largely on physical scrubbing to remove soiling, the mechanical dishwasher cleans by spraying hot water, typically between 45 and 75 °C (110 and 170 °F), at the dishes, with lower temperatures used for delicate items.

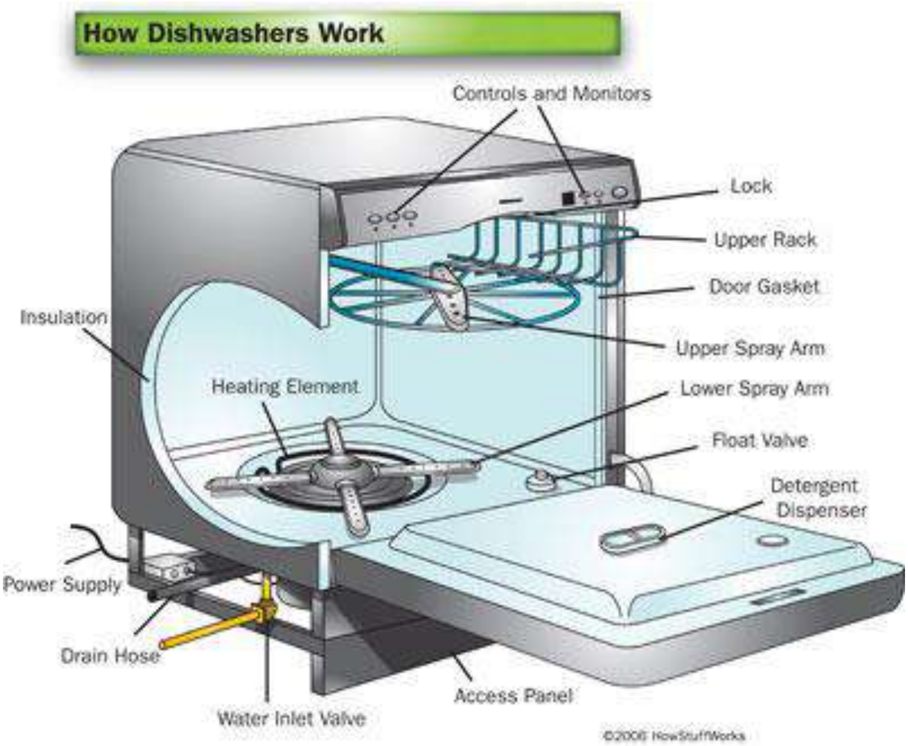


Fig 3.11

Dishwashers have become a staple in just about every kitchen.

Basically, a dishwasher is a robot that cleans and rinses dirty dishes. Humans have to load the dishes, add detergent, set the proper washing cycles and turn it on, but the dishwasher accomplishes a whole series of functions by itself. A dishwasher:

- Adds water
- Heats the water to the appropriate temperature
- Automatically opens the detergent dispenser at the right time
- Shoots the water through jets to get the dishes clean
- Drains the dirty water
- Sprays more water on the dishes to rinse them
- Drains itself again
- Heats the air to dry the dishes off, if the user has selected that setting

In addition, dishwashers monitor themselves to make sure everything is running properly. A timer (or a small computer) regulates the length of each cycle. A sensor detects the water and air temperature to prevent the dishwasher from overheating or damaging your dishes. Another sensor can tell if the water level gets too high and activates the draining function to keep the dishwasher from overflowing. Some dishwashers even have sensors that can detect the dirtiness of the water coming off the dishes. When the water is clear enough, the dishwasher knows the dishes are clean.

Inside a Dishwasher

Although dishwashers are watertight, they don't actually fill with water. Just a small basin at the bottom fills up. There, heating elements heat the water to 130 to 140 degrees Fahrenheit. Then a pump propels the water up to the water jets, where it is forced out and sprayed against the dirty dishes. Think about a garden hose with no nozzle - if you put your thumb over the end of the hose, decreasing the space for the water to come out, it sprays out more forcefully. The dishwasher's jets work on the same principle. The force of the water also makes the arms that hold the spray jets rotate, just like a lawn sprinkler.

When the washing and rinsing is finished, the water drains down to the basin again, where the pump propels the water out of the dishwasher. Depending on the type of dishwasher, the drain water might go right into the pipes under your sink, or travel up a hose into your sink itself.

The final step in a wash cycle is optional - the dry cycle. The heating element at the bottom of the dishwasher heats the air inside to help the dishes dry. Some people just let them dry without heat to save energy.

Main parts of a dishwasher

Control mechanism

The control mechanism is located inside the door behind the control panel. Many units use a simple electro-mechanical system: a timer determines how long each part of the cycle lasts and activates the proper function at the proper time (such as the detergent dispenser, wash spray and draining functions). Units that are more expensive might have a computerized control system. Modern units also have a door latch that must be closed for the unit to run. Some also have child safety locks.

Intake valve
This is where water from the home's water supply enters the dishwasher. The unit's pump doesn't pump the water into the basin – when the intake valve opens, water pressure drives the water into the unit.

Pump
An electric motor powers the pump. During the pump cycle, the pump forces water up into the spray arms. During the drain cycle, the pump directs the water into the drain hose. The motor-pump assembly is mounted beneath the basin, in the center of the dishwasher. There are two main types of pump:

- **Reversible** These pumps switch between pumping water to the spray arms and pumping water to the drain by reversing the direction of the motor. Reversible pumps are usually vertically mounted. **Reversible pump**
- **Direct-drive** The motor runs in one direction, so the direction of flow is switched from spray arms to drain by a **solenoid** that opens and closes the appropriate valves or switches one hose connection to another. Non-reversible pumps are usually horizontally mounted. **Direct-drive pump**

Dishwashers can be installed in either a portable or a permanent configuration. Portable units have finished sides and top that can be used as a countertop. When not in use, the machine sits in place next to the wall. When it's time to run a cycle, the unit can be rolled on casters over to the sink, where it connects to the faucet and plugs into a nearby outlet. In a permanent installation, the dishwasher goes underneath the existing countertop and bolts into place. Hoses underneath the kitchen sink connect directly to the hot water line and the drain line, and the unit usually plugs in under the sink as well. Both types of installation require a 230-volt grounded line.

Dishwasher Working

The main function of a dishwasher is to cut grease and sterilize the dishes by spraying hot soapy water at them. This is accomplished using an electric motor and pump mounted at the bottom of a water reservoir, or tub.

The pump takes suction from the tub and forces water up through spray arms, which spray the dishes. The water then simply drops back into the tub for recirculation.

Of course, hot water must get into the tub in the first place. An electric (solenoid) valve provides for this function. The hot water comes straight from your house's water heater, on regular house pressure.

At the end of the cycle, the water must be evacuated from the tub. The drive motor drives a pump to accomplish this function.

Even under the best of circumstances, dishwashers tend to be a little shorter-lived than other major appliances. Why? Well, to answer that question, let's all be little deviants for a moment, and design ourselves a torture chamber—for an electric motor.

What is absolutely the worst enemy of electricity in a machine? Water, right? Well, then, let's use the motor to pump water, and let's *mount* the motor right underneath the water seal. That way if the seal leaks at all, lots of hot, steamy water will run right down on top of the motor and rust it up and short it out. While we're at it, let's run some bits of broken glass and big chunks of food and nutshells and seeds through the pump, so we can chew up the seals and the impeller and also to introduce some nice, sudden deceleration shocks to the motor and pump. And of course, for maximum heat build-up, let's mount the whole motor and pump package in a tiny, cramped, steamy, dusty, poorly ventilated space, right beneath a tub full of hot steamy water.

CYCLES

Starting drain cycle
Cold water can kill your wash quality. So before letting any hot water into the tub, we must make sure the tub has no cold water left in it from the last wash. Therefore, in most designs, a new wash cycle starts with the pump operating for a minute or so in the "drain" mode.

Fill cycle
An electric solenoid fill valve then opens to let hot water into the tub. The timer controls how long the solenoid valve stays open, which controls the water level. A flow-control washer built into the valve compensates for variations in the water supply pressure.

Most designs use an anti-flood float switch to prevent accidental overflow during the fill cycle.

Wash cycle
The pump then starts in the "wash" mode. Water is channelled to the spray arms which spray the hot water at the dishes. In some models, detergent is dispensed during the wash cycle. The timer controls when this occurs. In most designs, the dispenser is opened either by a solenoid or by a bi-metallic trigger. GE uses a cam on the timer to trip open the dispenser.

Water heating
Most designs also have a water heater in the tub to maintain proper water temperature during the wash cycle. In some designs, the heater also dries the dishes at the end of the wash.

Rinse cycle
Note that the dishwasher also operates in the "wash" mode during the "rinse" cycle. The only substantial difference is that no detergent is being released during the "rinse" cycle.

2nd or 3rd Drain cycle
At the end of the "wash" and "rinse" cycles, the pump enters the "drain" mode. The pump drains water from the tub in one of two ways. In some "direct-reversing" designs, the motor reverses direction and a separate impeller pumps the water out. (Figure 3.12)

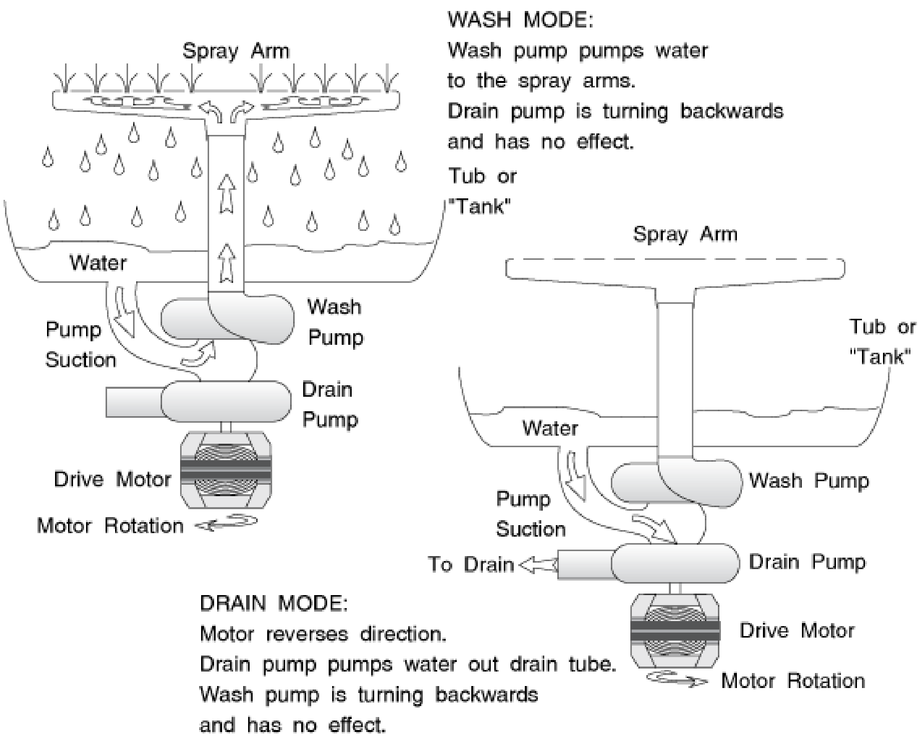


Fig 3.12

Typical Direct-Reversing Design

In other designs, a solenoid-controlled valve opens to allow the pump to discharge to the drain line. (Figure 3.13) The timer controls the direction of the motor or the opening of the drain valve.

Dry cycle

Most models also have a "dry" cycle. In some machines, the heater does this. In others, a blower fan circulates air inside the cabinet to evacuate steam and dry the dishes somewhat.

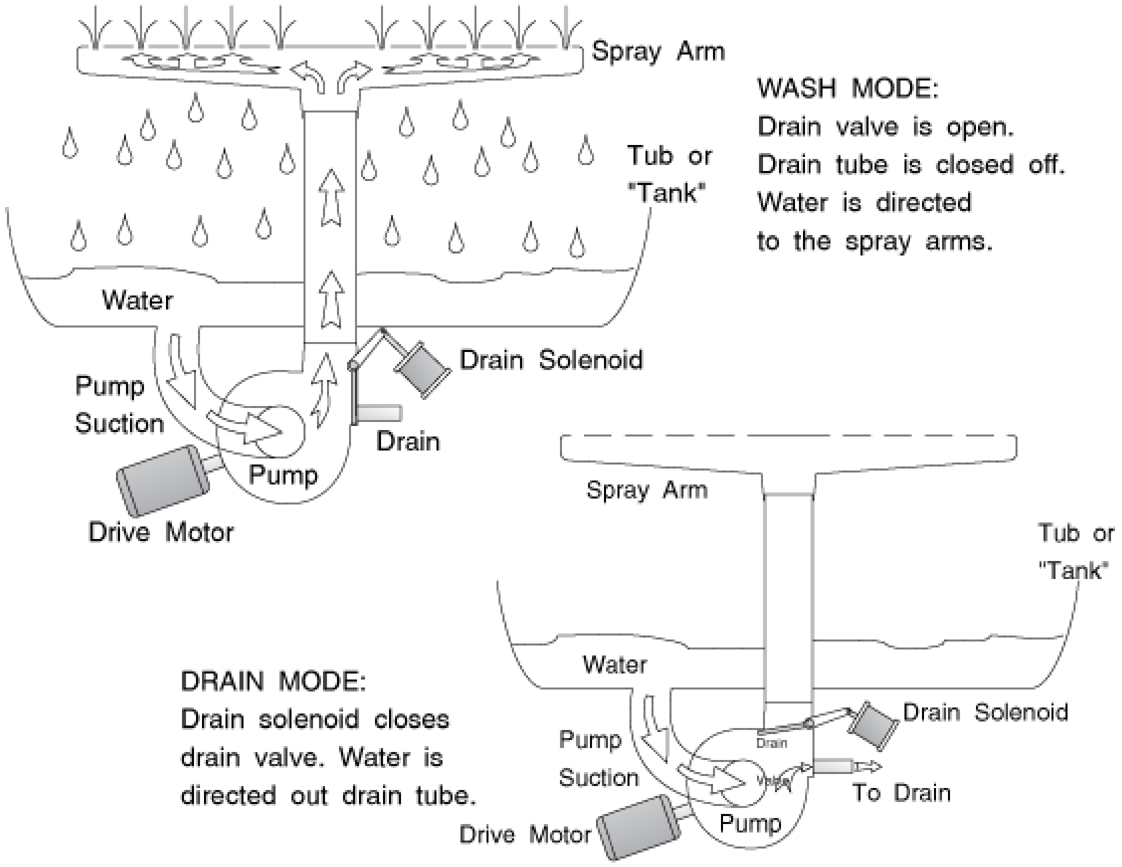


Fig 3.13**Typical Single-Direction Machine**

Dishwasher Maintenance

If your dishwasher isn't getting your dishes clean, you may not be loading it properly.

Even though the dishwasher does most of the work, humans play a part too. Here are some guidelines that can help your dishwasher operate safely, effectively and efficiently.

- Don't use regular dish soap. The suds will overflow the dishwasher.

- Don't overload the dishwasher. You need to leave room for the water jets to spray onto the dishes.
- Face the dirtiest part of the dishes toward the spray jets, which usually come from the centre.

Fig 3.14

- Don't mix steel and silver items. Putting two different types of metal in contact in a humid environment is a perfect recipe for corrosion.
- Try to keep bowls, spoons and other dishes with identical shapes separated. Otherwise, they will tend to nest together, and the water cannot reach every part of the dish.
- Don't put wood, cast iron, fine china, crystal or hand-painted dishes into the dishwasher. Wash these items by hand.

- Use the dishwasher at a time of day when water pressure is high, such as late at night. The dishwasher will clean better if you're not using a lot of water for something else, like washing clothes.
- If your home has hard water, use slightly more detergent.
- Use a rinse aid to avoid spots and help your dishes dry more quickly.
- Don't put plastics on the bottom rack, especially if you use the hot drying cycle. The heating element could melt some plastics.
- Don't pre-clean dishes. Dishwashers actually depend on the bits of food that cling to dirty dishes to maintain an appropriate ph level inside the dishwasher. Large pieces should be scraped into the garbage, though.

Detergent

Detergent is an important consideration when running a dishwasher. Detergents counteract mineral deposits, or **hardness**, in the water. They contain solvents that help dissolve food, have abrasives that scour away stuck-on gunk and help food slide off dishes more easily. You can't use just any detergent in a dishwasher; only detergents specially formulated for dishwashing machines will work. Other detergents could damage dishes or generate so many suds that the dishwasher would overflow. Which detergent to choose – tablet, powder, or gel – is really based on personal preference. One type hasn't been shown to clean better than another type.

The problem most people encounter with dishwashers is a simple inability to get the dishes clean. There might be stuck-on food or residue from the detergent. A water pressure problem may be the culprit. You may need to replace the water intake valve. Another common problem is mineral build-up. If your house has hard water, the mineral build-up can clog the water jets. Clear each jet with a wire or pin, and run an empty load with some vinegar in the detergent dispenser about once a month.

Sometimes, the dishwasher has problems draining properly. There could be a clog in the drain hose, or a problem with the pump. It's also possible that the dishwater is getting too sudsy, and sensors in the washer aren't detecting the soap foam as water. This causes it to shut down the drain cycle too early. Just use less detergent.

Modern dishwashers all function in the same basic way. Even cheaper models do a good job of cleaning dishes. That makes buying one a matter of finding features you'll use and avoiding ones you don't need. Durability, size and convenience are the primary factors that set one model apart from another.

3.3.5 Dishwasher Size

Dishwashers come in a wide variety of sizes. The smallest are in-sink dishwashers. These units fit into one-half of a double kitchen sink, use less water, and can wash a complete load in about 20 minutes. When not in use, a cover on the unit lets it serve as a countertop.

The standard size for a dishwasher is 24 inches wide. However, 18-inch units are available, sometimes known as "apartment-sized" dishwashers. Obviously, the wider the dishwasher, the more dishes it can hold. If you have a large family, a 30-inch model might be the right size. Any larger than that, and you're probably looking at a commercial dishwasher.

The Dish Drawer is a small dishwasher the size of a large kitchen drawer. It also uses less water and energy than a full-size dishwasher uses, and is suited for small kitchens that don't have enough room for a full-size unit. They also come in double drawer models that function independently.

Basins and Racks
Lower-end models have plastic basins, while some mid- and all high-priced units have stainless steel basins. In cheaper models, bits of food settle into a filter that must be manually cleaned on a regular basis. Models that are more expensive have self-cleaning filters, and some include small grinders that grind up large chunks so they drain with the dirty water. Dish racks come in many configurations. The more you pay for the dishwasher, the more flexibility and adjustability you'll get, with collapsible racks, folding tines, extra shelves, and removable racks for loading outside the machine. If you have large or oddly shaped dishes that you'll be washing regularly, bring them along to the appliance store to make sure they'll fit the racks.

Extra Features
Controls and cycle types are among the extra features that can drive up the cost of a dishwasher. Cheaper units have mechanical controls, using a dial and a timer to regulate the different cycles. Push-button controls with digital readouts and computerized timers are more expensive, but they don't clean dishes any better. Some dishwashers offer a cornucopia of cycle options, including high pressure super heavy-duty, crystal/china and sanitizing modes. However, three basic cycles will cover most of your dishwashing needs: Light, Normal and Pots & Pans. A Rinse and Hold cycle lets you clear extra food off dishes that will be sitting in the washer for a few days before they are cleaned. Hot Dry cycles dry dishes more quickly, but use extra energy.

Dishwasher Troubleshooting

Nameplate information
The metal nameplate is usually found inside the door. It may also be fastened to the top edge of the door itself. If you cannot find the nameplate, check the original papers that came with your dishwasher when it was new. They should contain the model number somewhere.

In any case, and especially if you have absolutely NO information about your dishwasher anywhere, make sure you bring your old part to the parts store with you. Sometimes they can match it up by looks or by part number.

Preventive maintenance
It's important to know that washing dishes in a dishwasher is not just a matter of blowing hot water at them. It is not just simply a mechanical or hydraulic process. It is also a *chemical* process. The chemicals you use, from detergent to rinse agent, are extremely critical. I recommend you use the following stuff regularly:

1) Use dry (powder) Cascade"™. The real stuff. Do not use liquid detergent. And especially do not use regular liquid dish soap.
2) Use "Jet-Dry"™ and check it regularly. "Jet-Dry"™ causes water to sheet and run off the dishes, instead of beading up and spotting them. Also use a product called "Glass Magic"™ to assist in preventing filming of the glass surfaces or calcium build up.
3) If you live in an area with hard water, be on the lookout for any white film build up you may get in the tub. It may be most
obvious on any black plastic parts inside. This is primarily calcium. It can make plastic parts brittle and cause abrasion in moving parts, as well as spotting or filming on the dishes themselves.
In extreme cases of hard-water build-up, run 1/2 cup of white vinegar through a single rinse-and-drain cycle, without any dishes in the machine.
Every few months, do a thorough cleaning. Pay special attention to any build-up of detergent around door seals, especially along the bottom edge of the door. Also be on the lookout for cloudy film or calcium build up.

Every six months or so, open the kick plate and check for leaks. Also exercise the hot water shutoff valve under the sink, to make sure it will close when you need it to.

Every few months, open, check and if necessary, clean out the air gap. Be sure you load the dishwasher properly. Cups, glasses, bowls, etc. should be upside-down so they don't hold water. Large items must be loaded so they do not block the waterjets from the spray arms, or block the spray arms themselves as they rotate. Silverware should be secure.

Re-coat or replace any rusty dishracks. You can purchase a paint-on dishwasher rack coating from your appliance parts dealer or local hardware store. Replacing rusty dishracks costs a bit, but a pump leak caused by rusty grit getting into the pump seals can cost you more.

TROUBLESHOOTING

Understanding how your dishwasher works will help you repair the machine smoothly and safely. Your dishwasher heats water as high as 140 F in its lower basin (the area below the bottom rack) with a metal heating element. Spray arms pump that water over the dishes while dispensing detergent. After a second rinsing spray, the heating element kicks in again to dry the dishes. High temperature and water pressure mean that the door and other potential escape points must remain perfectly sealed.

Most dishwasher issues centre around basic, core functions such as those that require only simple tools and basic skills.

What typically goes wrong with most dishwashers

Dishwasher Is Overflowing

Located in the dishwasher basin, the float assembly is a saucer-shaped device that rises as water rises in the basin. When water reaches a certain height, the attached overfill float switch signals the dishwasher to cut off the water. If the float is not moving or switch not working, the water will keep rising until it overflows.

Fixing the Float

Often, fixing a stuck float is a simple matter of raising and lowering it by hand a few times to unstick it. The float needs to move freely in order to activate the switch. If this is not happening or if the float is visibly damaged, replace the entire float assembly.

Fixing the Overfill Float Switch

The float switch is a relay switch smaller than a cigarette lighter which allows or cuts off a low-voltage electrical current. Lift the float and listen carefully. If you hear a hard metallic click, there is a good chance that the switch itself is working correctly. If not, replace this inexpensive part.

Access points to the float switch vary between models, so you will need to consult your owner's manual to find the location. Depending on your model, it may be located behind the machine or in front, under the toe kick.

After performing shut-down procedures, locate the relay switch. Replacement is simple. The current switch will unsnap, with the new switch snapping in.

Dishwasher Door Is Leaking

If water is dripping from the bottom or sides of your dishwasher door, most likely your door seal is no longer functioning properly and needs to be replaced. Your door may leak even though the machine is working well or it may be leaking in conjunction with overflow problems.

Check Door Obstructions

If the door is leaking at random times, it may be because you have loaded the machine improperly. Large items placed on the lower rack towards the sides may be imperceptibly preventing the door from firmly closing. Water may leak out as a result. Load large items far back, clear of the door.

Replace Door Seal

The door seal, also called a tub gasket, degrades over time. Located on the machine (not the door), this seal is inexpensive and easy to replace.

1. Pull the seal out by hand. Clean the channel with a mild mixture of dish soap and warm water, as debris will prevent the seal from adhering. Let the channel dry.
2. Use a hair dryer on low heat to straighten out the seal as it will be creased and folded from being in the package.
3. Press the seal into the channel, starting at the top and working down to the left and right sides.

Dishwasher Is Not Draining

When the dishwasher does not drain or drains slowly, your machine probably has a blockage that you can clear. Follow these steps in order:

1. Look at the kitchen sink first. Your sink and dishwasher share a common drainage system. If the dishwasher drain is clogged, the sink might be, too.
2. While under the sink, verify that the dishwasher's drain tube (a corrugated plastic tube) is not kinked. It should run in a smooth curve from the dishwasher to the drain.
3. Check out your dishwasher drain filter at the bottom of the machine, in the basin. Some food particles pass through the filter. But the filter is designed to block larger particles. Clear by pulling the particles out (do not force them into the filter).
4. If there are no visible particles, remove the filter cage by removing two screws from the top of the cage. After removing the cage, clear blockages.
5. Shut down and remove the machine. Locate the plastic drain tube attached to the back of the machine. Detach it and blow into the tube. If air does not flow freely, the tube is blocked. Clear by forcefully running water into it in a sink. If the block is difficult to clear or the tube appears damaged, purchase a new one.

Dishwasher Is Not Cleaning Well Enough

It can be frustrating to run your dishwasher on a full cycle, only to discover caked-on food. Is your machine on the way out? Maybe not. For machines that aren't cleaning dishes well, try these things:

Clean the Spray Arms

Water leads to mineral build up. Remove all spray arms and soak in vinegar to remove mineral deposits.

Replace the Water Inlet Valve

With many models, you can leave the machine in place (but you still need to perform shut-down procedures for safety).

1. Remove the toe kick access panel. Remove the water line that attaches to the inlet valve.

2. With Channel lock pliers, remove the brass fitting, then with a hex-nut driver, remove the valve bracket from the machine.
3. Remove the attached electrical harness. Attach the new inlet valve fitting, taking care to first wind Teflon tape on the threads.
4. Reattach the assembly and the toe kick.

Dishwasher Is Not Drying the Dishes

- Dishes not dry after a full cycle? That metal horseshoe-shaped heating element at the bottom of the machine, in the basin, is in charge of drying operations. It is relatively inexpensive and is simple to replace.

How to Replace the Heating Element?

1. Shut down the machine safely and remove it.
2. On the back of the machine, locate the two wires that attach to the heating element terminals. With a flat head screwdriver, gently pry the wires loose.
3. Set the wires on the floor, taking note of their positions (left or right).
4. With a wrench, unscrew the two plastic retainer nuts. Sizes may vary, but typically you will use a 3/4-inch wrench.
5. Go to the front of the machine and push it halfway back into its bay.
6. Open the door and remove the lower rack.
7. Remove the heating element. Since you have already loosened it from the back, it is only a matter of lifting it out.
8. Replacement works in reverse, carefully tightening the retainer nuts to avoid cracking them.

Safe Shut-Down and Removal Procedures for Your Dishwasher

For all repairs that involve removing the machine from its location, follow these procedures:

1. Turn off the circuit breaker at the service panel.
2. Under the kitchen sink, shut off the water supply line. Disconnect the dishwasher drain and supply lines. Disconnect the power cord.
3. Open the door. Unscrew the machine where it is attached to its metal frame.
4. Open the door slightly to gain a hand-hold on the machine. Hold both sides of the door. Gently wiggle the machine side to side while pulling towards you.
5. Do not open the door with the machine out of its bay as it can tip forward and injure you. Push halfway into the bay to prevent the machine from tipping.

CLOGGING OF THE DISHWASHER WATER SYSTEM

The pump suction screen or spray arms can become clogged by hard water lime or by bits of food or glass from broken dishes.

To diagnose, remove the spray arm assembly as shown in Chapter 3 and shake it. Any bits of glass or other debris will make a noisy clatter. Try to remove them. It can be difficult; it's a lot like trying to fish coins out of a piggy bank. Try putting tape over the holes in the spray arm, then partially fill it with water, then shake the water out...most of the broken bits of debris should come out with the water. If it's too hard, just replace the spray arm.

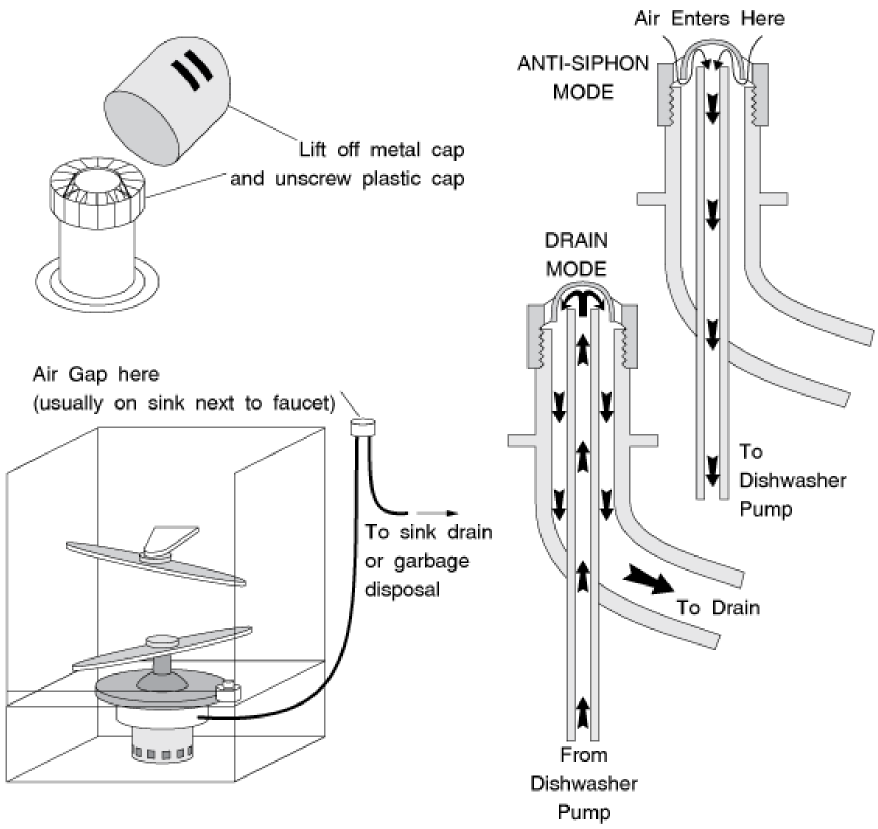


Fig 3.15

If you have a lime or hard water build up clogging any water holes, run some Lime-Away through your machine as described in preventive maintenance.

WATER VALVE

Remove the kick plate and look at the water inlet solenoid valve.
On occasion, the guts of the water valve may rot out.
This usually shows up as a very slow drip coming from the top of the water valve solenoid. If the leak has been going on for a while, there may also be traces of rust or mineral deposits on top of the solenoid. The solution is to shut off the water supply and replace the valve.

On rare occasions, the diaphragm within a water valve has been known to rupture. When this occurs, water will start filling the tub and will not stop. The anti-flood float switch will not close the valve. All it does is shut off the valve electrically, and this is not an electrical problem. The water will continue flowing no matter how much runs out onto the kitchen floor.

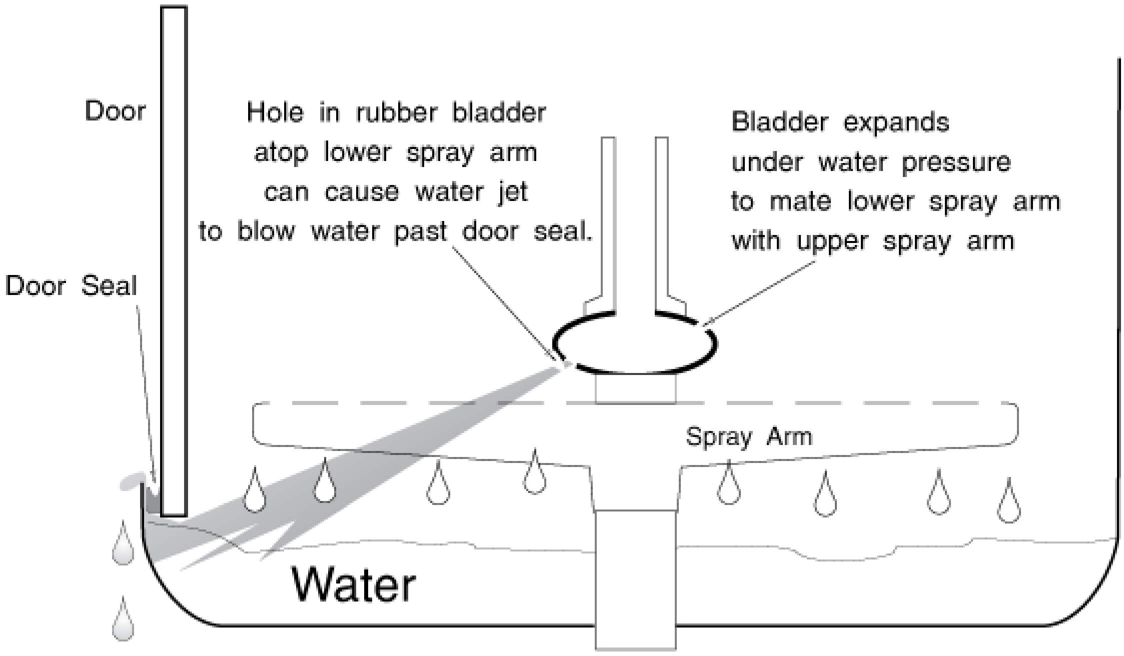


Fig 3.16 **Figure Dishwasher Bladder-Top Leaks**

The solution is to shut off the water supply and replace the valve.

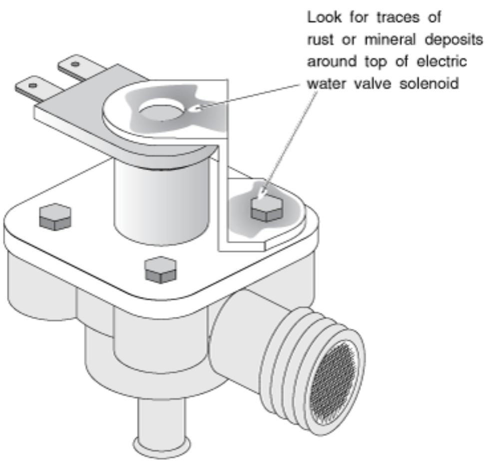
THERMOSTATS

A thermostat is just a switch that opens and closes according to temperature changes that it senses. They can be difficult to test. However, most are usually inexpensive. So if you think you have a bad one, just replace it.

TIMERS

The timer is the brain of the dishwasher. It controls everything in the cycle. In addition to telling the motor when to run, it may also activate the heating circuit or heating control circuits, fill valve, detergent dispensers, motor direction or drain valve solenoid, etc.

Most timers are nothing more than a motor that drives a set of cams which open and close switches. Yet it is one of the most expensive parts in your dishwasher, so don't be too quick to diagnose it as the problem.



Usually the FIRST thing a layman looks at is the timer; it should be the LAST. And don't forget that timers are electrical parts, which are usually non-returnable. If you buy one, and it turns out not to be the problem, you've just wasted the money.

Solid state timers are difficult and expensive to diagnose. If you suspect a timer problem in a solid-state system, you can try replacing it, but remember that it's expensive and usually non-returnable (being an electrical part.) If you have one of these units that's defective, you can check into the cost of replacing it.

Figure 3.17: Solenoid Valve Leaks

3.3.7 Dishwashers Need Cleaning Too!

The very name "dishwasher" implies that the appliance is self-cleaning, which it is for the most part. Every now and then, however, the trusty and beloved kitchen accessory needs a hand in order to keep functioning in peak condition. This is especially because the warm, moist environment and alkaline pH values inherent in the machines make them prime breeding grounds for some pretty nasty fungi and bacteria. In fact, a small study published in the journal Fungal Biology found that 62 percent of dishwashers tested contained fungi that can be problematic for humans. Yet another paper, published in the journal Applied and Environmental Microbiology, found significant bacteria and fungi present in dishwashers, which they describe as "diverse habitats for microorganisms to adapt and flourish." Fortunately, it really isn't difficult or time-consuming to keep your dishwasher humming along cleanly, provided you follow a few steps:

1. Wipe It Down from Time to Time
Most dishes go in dripping at least some sauce or other food-related liquid. Although it's not necessary to totally pre-rinse dishes before loading them, the foodstuffs on dishes can build up over time and leave residue in the dishwasher. To fix, simply use a damp cloth with a very small amount of liquid dish detergent to wipe down the rubber seals and the door interior. This will keep grime and other nastiness from building up to epic levels.

Also, every dishwasher comes equipped with a dishwasher spray arm, which should be removed and wiped down with a damp towel about every six months or so. The owner's manual contains easy instructions on specific steps, but a common recommendation is to dislodge any potentially problematic blockages in the spray holes of the spray arm using a simple toothpick.

2. Clean the Filter
Don't feel bad if you didn't know that your dishwasher has a filter – most people don't. Typically located at the bottom centre of the dishwasher, the two-part device serves a couple of purposes. The upper filter is designed to keep chunks of food and other foreign particles from invading the ever-important pump, while the lower filter prevents food bits from going back out onto the clean dishes.

Indications that the filters need cleaning include any obvious grossness on the upper filter, or dishes that keep coming out soiled or "gritty" despite running through a full cycle. As a general rule of thumb, the more you use your dishwasher and the less you rinse/scrape food, the more you need to clean out the filter. If you rinse and scrape your dishes before putting them in the dishwasher, you only need to clean the filter once or twice a year. If you don't, more like once per month.

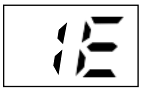
To remove the filter, check your dishwasher's manual for easy steps. Then once it's out, just hold it under running water until all or most of the offending soils are washed off. Reinstall according to manufacturer directions. It's a lot easier than it sounds, we promise.

3. Run a Cleaning Rinse
If your local water is hard, mineral deposits can build up over time, so many manufacturers recommend running a dishwasher-specific cleaning solution about every month or so (a bunch of products are commercially available but 2 cups of white vinegar can work as well). This can also tackle soap scum. Be sure to follow the directions on the bottle and run it in an empty machine, typically on highest heat and the heaviest setting available.

TROUBLE SHOOTINGMETHODS TABLE

A. Troubleshootingaccordingtodisplayederrormessage

Table 3.3

ERROR MESSAGE	**POSSIBLE CAUSE FOR ERROR OCCURRENCE**	**REMEDY**
INLET ERROR  displayed **Condition** Notreachedtothenor-malwaterlevelinspite of10min.watersupply	• The Water Tap is not opened. • The Inlet Hose is kinked. • The Filter of inlet valve clogged by impure water. The Inlet Water Valve is normal ? The water pressure is very low. • (below0.5kgf/ cm^2) • Inlet valve is blocked by safety device • for leakage sensing.(In case of Inlet Valve)	Open the Water Tap. Repair the Inlet Hose. a) Close the WaterTap. b) UnscrewtheInletHose(InletValveside) c) Clean the Filter of Inlet Valve. Replace or repair the Inlet Valve. • Checkthewaterremainonthebase. 1) Checkthepointofdamagesand repairorreplacetherelatedparts. 2) Disconnect the inlet hose to dishwashertounlockthesafetyvalve.
DRAIN ERROR  displayed **Condition** Notfullydrainedoutin spite of 5 min. drain operation	The Filter clogged. TheDrainHosekinkedorblocked. • TheDrainPump/Motororcircuitis • troubled.	Clean the Filter. Removethecauseofkinkorblock. • ReplacetheDrainPump/Motoror • repair theCircuit.

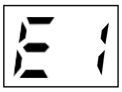
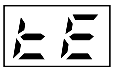
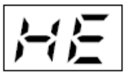
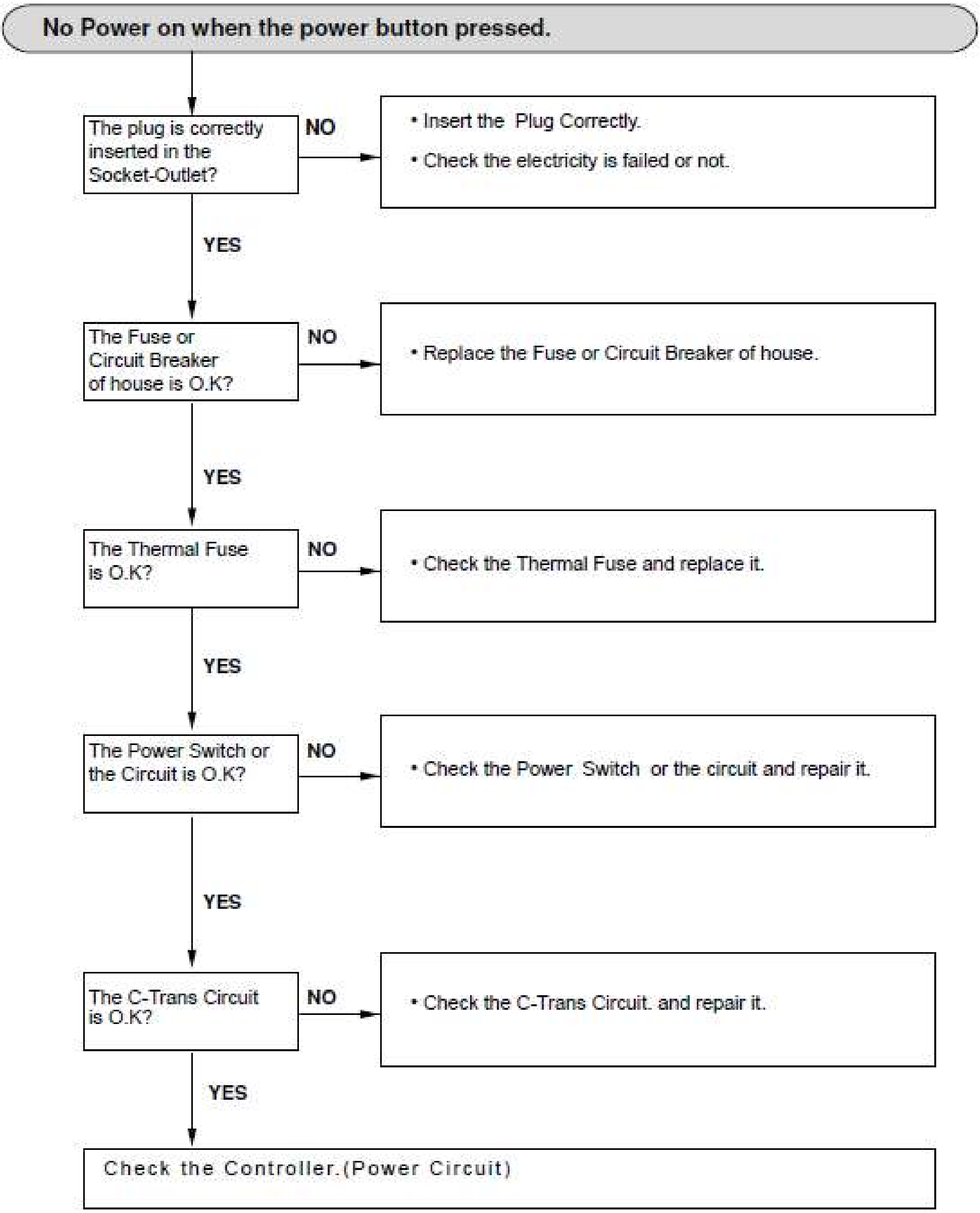
LEAKAGE ERROR  displayed **Condition** ThewaterlevelinTub goes down during operation	WaterleakageinHoseconnections. Waterisleakedbydamages.	ReplacetheconnectionsofHose . Checkthepointofdamagesand repairorreplacetherelatedparts.
EXCESS ERROR  displayed **Condition** Excessive water is sup-plied than normal water level.(Automatically drain Pump operated.)	The Inlet Valve is troubled. The Air Break is troubled. The Sensor Assembly is troubled. The Controller is troubled.	Replace the Inlet Valve. Replace the air breaker. Replace the sensor assembly. Repair or replace the Controller.
THERMAL ERROR  displayed **Condition** Theresistanceofther-mistornotnormallyout put.	TheCircuitofthermistoristroubled. Thermistor istroubled. The Controller is troubled.	RepairtheCircuitofthermist or. Replace theThermistor. Repair or replace the Controller.
HEATER ERROR  displayed **Condition** Thewaterisnotheated or the temperature in the Tub is overheated to over95¡C	TheCircuitofHeateristroubled. The Thermistor istroubled. The Heater is shorted. The Relay Circuit is troubled.	RepairtheCircuitofHeat er. Replace theThermistor. Replace the Heater. RepairtheRelayCircu it..

Table 3.4

B. TROUBLE DIAGNOSES AND REPAIR BY SYMPTOM



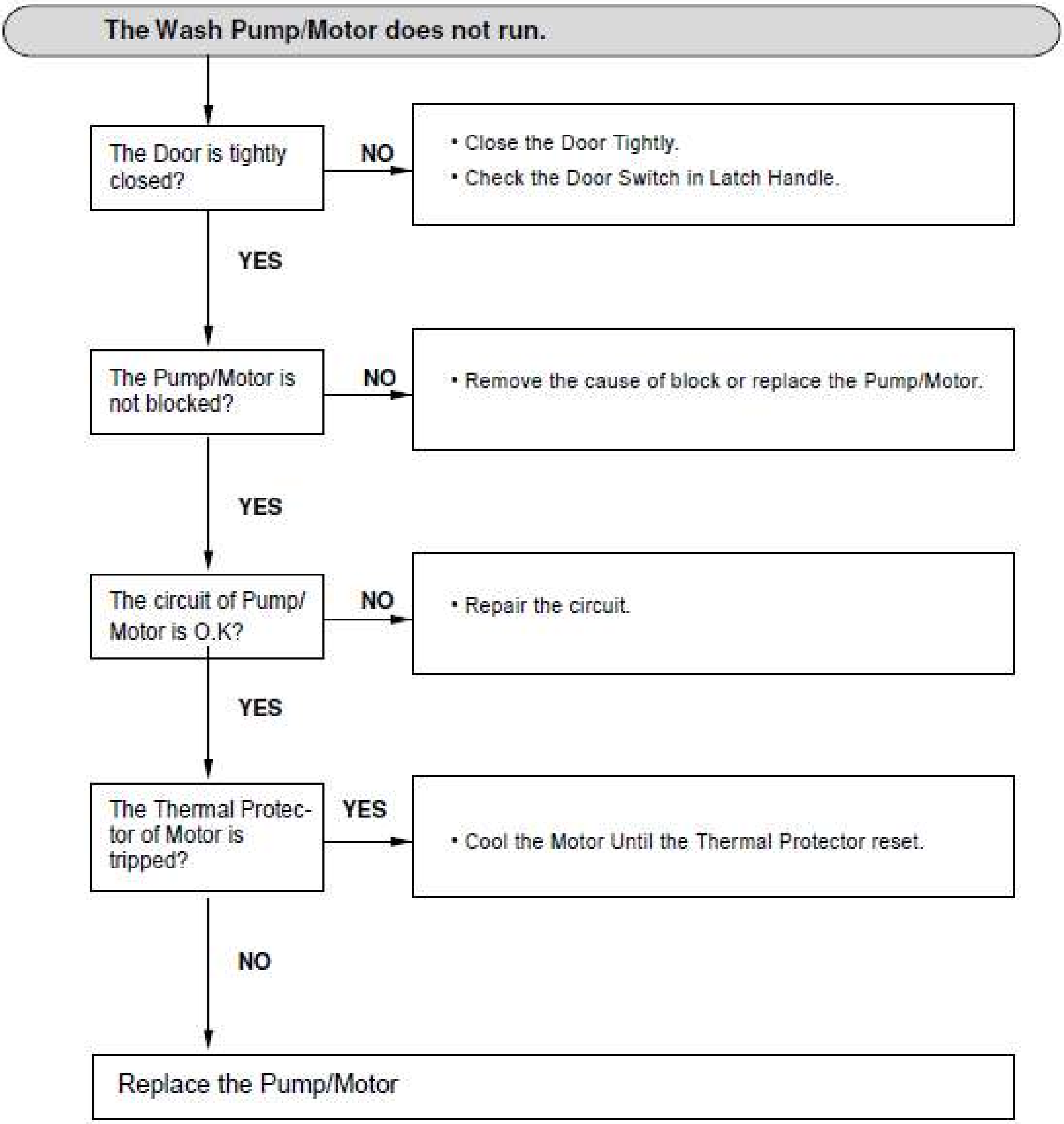

The Wash Pump/Motor does not run.
The Door is tightly closed?
NO
• Close the Door Tightly.
• Check the Door Switch in Latch Handle.
YES
The Pump/Motor is not blocked?
NO
• Remove the cause of block or replace the Pump/Motor.
YES
The circuit of Pump/ Motor is O.K?
NO
• Repair the circuit.
YES
The Thermal Protec- tor of Motor is tripped?
YES
• Cool the Motor Until the Thermal Protector reset.
NO
Replace the Pump/Motor

Table 3.5

Washing Results are not Satisfactory

After washing, are there still White deposits or streaks on the dishes?

YES

- Reduce the amount of Rinse-Aid (for Streak)
- Does salt refill lamp blink? (Refill salt)

NO

After washing, are there still food soils on the dishes?

YES

Check that : - the amount of detergent Correctly used or not
- Filters clogged or not.
- the holes of spray arms blocked or not.
- Utensils are correctly arranged or not.
- Utensils are overloaded or not.
- the spray arm rotating is obstructed or not.
- the program is correctly selected or not.

Dry Results are not satisfactory

Increase the amount of Rinse-Aid.(Set the number higher)

Select the Program that the Rinse temperature is higher.

Table 3.6

Power Button not automatically off after operation.

Check the button is blocked by foreign materials.

Check the Power Switch.(Replace it, if necessary.)

Check the Controller.(Replace it, if necessary.)

Short Answer Questions

1. List the parts of Hair Drier
2. List the parts of **Microwave oven**
3. Write the **Important Safety Instructions** of **Microwave oven**
4. List the parts of **Dish Washer**
5. Write the uses of **Dish Washer**

Essay Questions

1. With a neat sketch Explain about the Construction and working of Hair Drier
2. Explain about the possible faults and remedies of Hair Drier
3. With a neat sketch Explain about the Construction and working **Microwave oven**
4. Explain about the Trouble Shooting of **Microwave oven**
5. With a neat sketch Explain about the Construction and working **Dish Washer**
6. Explain about the Repairing of **Dish Washer**

4.Motorized Appliances

4.1 Classification of Motors used in Domestic Appliances

Look around your house and you will find that it is filled with electric motors. Here's an interesting experiment for you to try: Walk through your house and count all the motors you find. Starting in the kitchen, there are motors in:

- The fan over the stove and in the microwave oven
- The dispose-all under the sink
- The blender
- The can opener
- The refrigerator - Two or three in fact: one for the compressor, one for the fan inside the refrigerator, as well as one in the icemaker
- The mixer
- The tape player in the answering machine
- Probably even the clock on the oven

In the utility room, there is an electric motor in:

- The washer
- The dryer
- The electric screwdriver
- The vacuum cleaner and the Dust buster mini-vac
- The electric saw
- The electric drill
- The furnace blower

Even in the bathroom, there's a motor in:

- The fan
- The electric toothbrush
- The hair dryer
- The electric razor

Your car is loaded with electric motors:

- Power windows (a motor in each window)
- Power seats (up to seven motors per seat)
- Fans for the heater and the radiator
- Windshield wipers
- The starter motor
- Electric radio antennas

Plus, there are motors in all sorts of other places:

- Several in the VCR
- Several in a CD player or tape deck
- Many in a computer (each disk drive has two or three, plus there's a fan or two)
- Most toys that move have at least one motor (including Tickle-me-Elmo for its vibrations)
- Electric clocks
- The garage door opener
- Aquarium pumps

When purchasing a motor, it's often asked which technology is better, AC or DC, but the fact is that it is application and cost dependent.

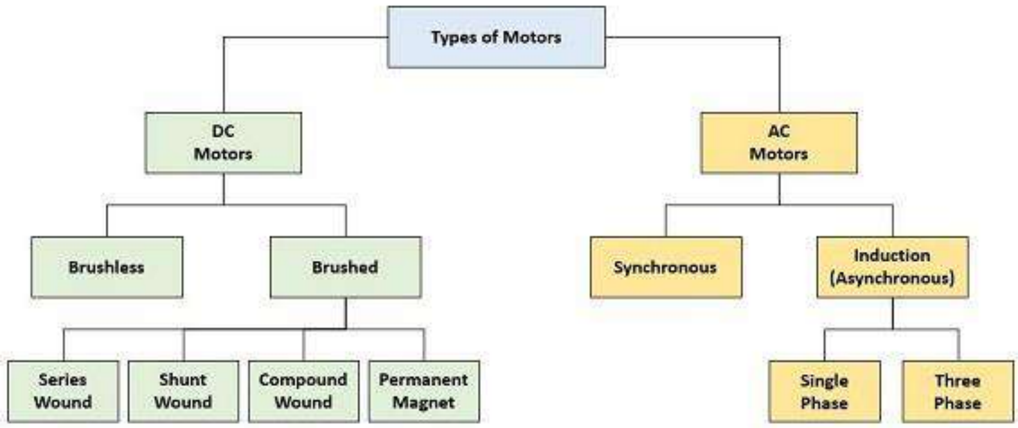


Fig 4.1

4.1.2 Uses of AC Motors

AC (alternating current) motors are low-cost and high-efficiency mechanisms used in large variety of applications. AC motors offer a simple design, consisting of a magnetically driven, copper wounded stator and a rotor mechanism. In AC motors, the input alternating current creates a rotating magnetic field over the stator, which ultimately moves the rotor, which is connected with an output shaft. From heavy industrial to household environments; different types and categories of AC motors have applications wherever electrical appliances are utilized.

Synchronous Motors

In synchronous AC motors, the speed of rotor is proportional to the stator, i.e., they both rotate in a synchronized fashion. These motors are known for their efficiency in maintaining the power of the overall system and can be used as stepper motors in some cases. Synchronous motors find their major applications in areas where accuracy is important, for instance, in clocks, timers, electromechanical robots, metering pumps, speed controllers and other industrial processes. Also, synchronous AC motors are specifically used in high-precision drill machines and similar devices.

Induction Motors

Induction motors are the most common type of AC motors used in daily life processes, and their output rotation speed is proportional to the applied frequency of alternate current. Used in almost every process, induction motors are mainly used in water pumps, kitchen appliances, fans and air conditioners, automobiles and common industrial machinery like boiler pumps and compressors. AC induction motors are efficient and flexible, which allows them to match the load demand for almost any type of electrical application.

Linear Motors

Linear AC motors are quite different in terms of operational and functional characteristics than conventional AC motors. These motors produce a linear power to push or pull an object along their length, in place of creating a torque-based (rotation around stator axis) rotary action. This happens because of their flat and spread-out structure in contrast to other AC motors. Due to these properties, linear AC motors are widely used in ground-based rails, monorails, magnetic levitation lines, roller coasters and similar transportation machinery.

Adjustable Speed Motors

Adjustable speed AC motors provide a special feature in terms of their speed control and management. These motors change their rotor speed among some pre-defined values just by switching the number of poles (pairs of copper wounded permanent magnets) contained within. This specific characteristic gives them applications in marine and land machinery, electrical power plants, cargo pumps and water cooling equipment. In general, adjustable speed AC motors are used in all systems and processes where automatic switching of rotor speed is required.

Universal Motors

Universal Motors are generic AC motors that are operated on both alternate current and direct current sources. The most significant feature of universal AC motors is their constant high rotary speed (often measured in thousands of rounds per minute), which makes them useful in a wide range of applications like railway traction mechanisms, high-power engineering and commercial drill machines, industrial and kitchen blenders, vacuum cleaners, dryers and trimmers.

Due to their poor efficiency and relatively limited life, universal motors are tending to be replaced by newer types when the cost of the necessary electronic control systems drops to sufficiently low levels.

DC Motors

DC motors were the first type of motor widely used and the systems (motors and drive) initial costs tend to be typically less than AC systems for low power units, but with higher power the overall maintenance costs increase and would need to be taken into consideration. The DC Motors speed can be controlled by varying the supply voltage and are available in a wide range of voltages, however the most popular type are 12 & 24V, with some of the advantages being:

- Easy installation
- Speed control over a wide range
- Quick Starting, Stopping, Reversing and Acceleration

- High Starting Torque
- Linear speed-torque curve

DC motors are widely used and can be used from small tools and appliances, through to electric vehicles, lifts & hoists

The two common types are:

Brushed

These are the more traditional type of motor and are typically used in cost-sensitive applications, where the control system is relatively simple, such as in consumer applications and more basic industrial equipment, these type of motors can be broken down as:

- Series Wound – This is where the field winding is connected in series with rotor winding and speed control is by varying the supply voltage, however this type offers poor speed control and as the torque to the motor increase, then the speed falls. Applications include automotive, hoists, lifts and cranes as it has a high starting torque.
- Shunt Wound – This type has one voltage supply and the field winding is connected in parallel with the rotor winding and can deliver increased torque, without a reduction in speed by increasing the motor current. It has medium level of starting torque with constant speed, so suitable for applications include lathes, vacuum cleaners, conveyors & grinders.
- Compound Wound – This is a cumulative of Series and Shunt, where the polarity of the shunt winding is such that it adds to the series fields. This type has a high starting torque and run smoothly if the load varies slightly and is used for driving compressors, variable-head centrifugal pumps, rotary presses, circular saws, shearing machines, elevators and continuous conveyors
- Permanent Magnet – As the name suggests rather than electromagnet a permanent magnet is used and are used in applications where precise control and low torque, such as in robotics, servo systems.

Brushless

Brushless motors alleviate some of the issues associated with the more common brushed motors (short life span for high use applications) and are mechanically much simpler in design (not having brushes). The motor controller uses Hall Effect sensors to detect the rotors position and using this the controller can accurately control the motor via current in the rotor coils) to regulate the speed. The advantages of this technology is the long life, little maintenance and high efficiency (85-90%), whereas the disadvantages are higher initial costs and more complicated controllers. These types of motors are generally used in speed and positional control with applications such as fans, pumps and compressors, where reliability and ruggedness are required.

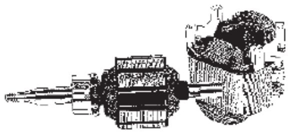
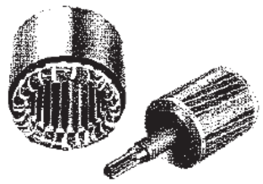
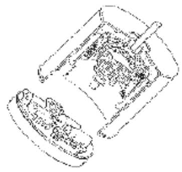
An example of brushless design is in Stepper Motors, which are primarily used in open-loop position control, with uses from printers through to industrial applications such as high speed pick and place equipment.

Brushless motors are also available with a feedback device which allows the control of the Speed, Torque and Position of the motor and the intelligent electronics control all three so if more torque is required to accelerate quicker to a certain speed then more current is delivered, these are known as Brushless Servo Motors.

Application of DC Machines ***Table 4.1***

Application Area	**Sub-Application Area**	**DC Motor Type**
Medical Applications	Sleep Apnea Treatment	BLDC[1]
	Medical Analyzer	BLDC
Automotive	Power Steering	MCBS BLDC[2]
	Engine Cooling Fan	MCBS BLDC
	Fuel/Water Pump	MCBS BLDC
	HVAC Motors	MCBS BLDC
Solar Airplane		BLDC
Spacecraft		ERHA PM BLDC[3]
	Condition Monitoring	
Speed Control		BLDC
Solar Heating System		
Electric Aircraft	EHA, EMA	BLDC
Space Operated Vehicles	AFC, Guided Missiles	
Fuel Pumps		Stepper Motor
Tissue Paper Machine		Brushed/BLDC
Hard Disk Driver		BLDC
Solar Tracking		Brushed/BLDC
UAV	Propulsion System	BLDC
Robotics		Stepper Motor
Textile	Textile Rewinding Machine	Stepper Motor
Electric Vehicles		DC/PM BDLC
Industry		
Cement Plants		
Chopper	DC Chopper Motor Drive	

Table 4.2 Features and typical applications of the three main types of electricappliance motors

WITH BRUSHES	BRUSHLESS	COMMUTATION
		
UNIVERSAL	INDUCTION	AUTOCOMMUTATED Perm. Magnet or Var. Reluctance
	FEATURES	
– AC or DC supplied – High torque at starting	– AC supplied – Robust	– Electronic replaces brushes – High torque at starting
	APPLICATIONS FIELDS	
– Washing machine (EU) – Hand tools	– Washing machine (WW) – Heating-Ventilation-Air conditioning – Immersed pump / Com-pressor / Fan	– Washing machine – H.V.A.C. – Pump / Fan
– Food processor – Vacuum cleaner	– Dish washer / Tumble drier – Freezer / Refrigerator	– Food processor – Vacuum cleaner – Freezer / Refrigerator

CONVENTIONAL ELECTRIC MOTORS

Three main families of electric motors are commonly used in home appliances. Their power can range from 50W to 1.5 kW. The first two families, **Brush Motors** (i.e. Universal Motors) and **Brushless Motors** (i.e. Induction Motors) are the most popular and these cheap and well known motor designs may be connected directly to the AC mains.

Electrical Fans

We all are familiar with electric fans. Fan is a very useful domestic appliance and is indispensable in summer. Fan produces air flow and circulates air. The flow of air gives a comfortable cooling effect in summer. Fans are used for cooling, ventilation, drying etc.

Basically a fan consists of an electric motor and blades attached to the rotor of the motor. The blades are slightly inclined. When the motor rotates, the blade pushes the air and this result in a flow of air stream.

The different types of fans are–

1. Ceiling fan
2. Table fan
3. Pedestal fan
4. Wall fan
5. Exhaust fan
6. Industrial fan
7. Instrument fan

Table fans are portable, can be placed on desktop or on table and are used for personal comfort during summer. Ceiling fans are fixed in ceiling of room. Wall fans are fixed on walls of home.

Pedestal fans are portable high capacity fans and can stand on floor and circulate large volume of air. They are commonly used in big rooms or halls during festivities etc. Exhaust fans are permanently fixed in kitchen, dining hall, bathroom, laboratory etc and they expel smoke, gas, odour etc. Industrial fans are very high capacity fans used for cooling or for blowing hot air required for industrial processes. Instrument fans are low capacity fans used for cooling purposes in an instrument e.g. small fan inside a personal computer. Numerous models of different types are available from various manufacturers. Here we will briefly describe the common types of fans used in homes: ceiling fan, table fan and exhaust fans.

According to use of power supply type of electric fan

According to power supply there may be three main type of fan

1. DC table fan or ceiling fan
2. AC table or ceiling fan
3. AC/DC table or ceiling fan

In case of AC fan mainly two types of single phase motor are used.
1. Shaded core type motor
2. Capacitor run type motor
In case of AC or DC fan the universal motor are used in which the bound armature and field winding are connected in series. the speed of the fan are controlled by regulators. the regulator of resistance steps in series of the supply. the applied voltage to the motor is varied by voltage changing these resistances is steps and the fan work on the speed which be required.

4.2.1Ceiling Fan

The electrically powered ceiling fan was invented in 1882 by Philip Diehl. He had engineered the electric motor used in the first electrically powered Singer sewing machines, and in 1882 he adapted that motor for use in a ceiling-mounted fan.
A ceiling fan is suspended from the ceiling and circulates air in a room. Ceiling fans run on single phase 220-volt AC and power consumption is usually between 60 to 120 watt. The speed of a ceiling fan is commonly between 200 RPM to 400 RPM where RPM stands for revolutions per minute.
Ceiling fan is a Single Phase Induction motor. Generally, we use a capacitor start & run AC Motor for **ceiling Fans**. Ceiling fans work using a single phase induction motor with windings of 18, 20 or 22 poles. The operating speed of the ceiling fan depends on the number of winding poles present in the ceiling fan. Most commonly used winding poles in ceiling fans is 18 poles. For better control of the speed in your ceiling fan, it needs to have higher rotor resistance through the inbuilt stator voltage control operation.

Motor Used in Ceiling Fans:
Most commonly used the motor in ceiling fans are a single phase induction motors. They are very easy to install and control in a ceiling fan due to its simple structure and low cost. It is

very economical to fit in any locations as the current consumption is very low when compared to other household devices.

Working and construction of electric fan

Working Principle of the Ceiling Fan

whenever current carrying conductor is placed in a magnetic field-it experiences force.

Working of a ceiling fan:

The ceiling fan has a motor that converts electrical energy into mechanical energy. First, the capacitor of the ceiling fan torques up the electric motor, thereby causing it to start and run. As the electrical current reaches the motor, it enters coils of wire that are wrapped around a metal base. When this current passes through the wire, it creates a magnetic field which further exerts force in a clockwise motion. In this way, the electric energy is converted into mechanical energy and causes the motor coils to spin. The blades attached to the motor also start gaining motion with the spinning of the coils

How The Ceiling Fan Cools?

The mechanism behind the ceiling fan is quite simple. It is a known fact that air naturally stratifies – the lighter, warm air rises up while the cool air, that is heavy, sinks down. The rotation mechanism of the ceiling fan is built in way so as to attract the warm air upwards. As the hot air rises up, the blades of the fan slice this air and push it down. This being a continuous process causes the air in the room to circulate in the entire room. Thus, a ceiling fan only moves the air around. Contrary to the common belief, fans do not exactly cool. Rather they speed up the process of evaporation of sweat on our body, which naturally makes us feel 'cool'.

4.2.3 Main parts of a ceiling fan

The main parts of a ceiling fan are–

1. Electric motor
2. Capacitor
3. Blades
4. Canopy/Switch Cup Speed regulator
5. Ball bearing
6. Suspension rod/Down rod
7. Fly Wheel
8. Speed regulator

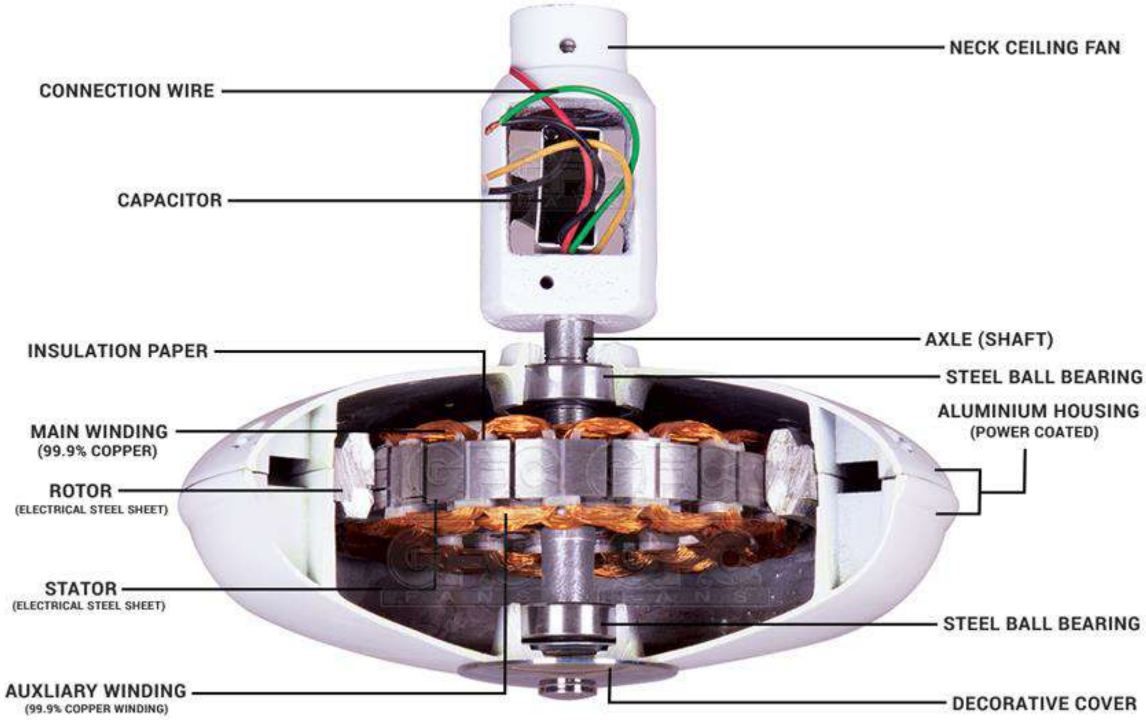


Fig 4.2 Ceiling Fan Motor Internal View

1. Electric motor:

The electric motor in a ceiling fan is generally a single phase AC induction motor. There are several types of single phase AC motors. Spilt phase capacitor type Single phase AC motor is generally used in Ceiling fans. The motor has a rotor and a stator. In case of ceiling fan outer part is the rotor and inner part is the stator. Usually three blades are fitted with the rotor.

The rotor is a closed ring like magnetic core and is made of laminated steel. It has slots. Copper or aluminium bars are placed on the slots and are short circuited on both ends. The rotor is fitted with bearings on both ends. The bearings separate moving parts and stationary parts. There are provisions for attaching blades to the rotor.

The stator consists of a hollow shaft to which is attached a core of laminated steel. The core has slots for placing winding. There are two windings in a ceiling fan located 90 degree electrical apart. The windings are distributed windings and are placed in the slots of the core attached to the hollow shaft. One winding is called starting winding and the other winding is called running winding. Three leads come out of the stator winding. One lead is common to both starting winding and running winding. The resistance of the running winding is generally less than that of the starting winding. Running winding and the series connection of the capacitor and starting winding are connected in parallel with the 220-volt AC supply.

2.Capacitor:

There are two windings in a ceiling fan located 90 degrees electrical apart. The starting torque relies on sine of angle among starting winding and running winding current. Thus Capacitor is used generate needed phase shift among these current and therefore to generate high starting torque and will be connected in series with starting winding. The value of the capacitor is between 2 to 5 microfarad.

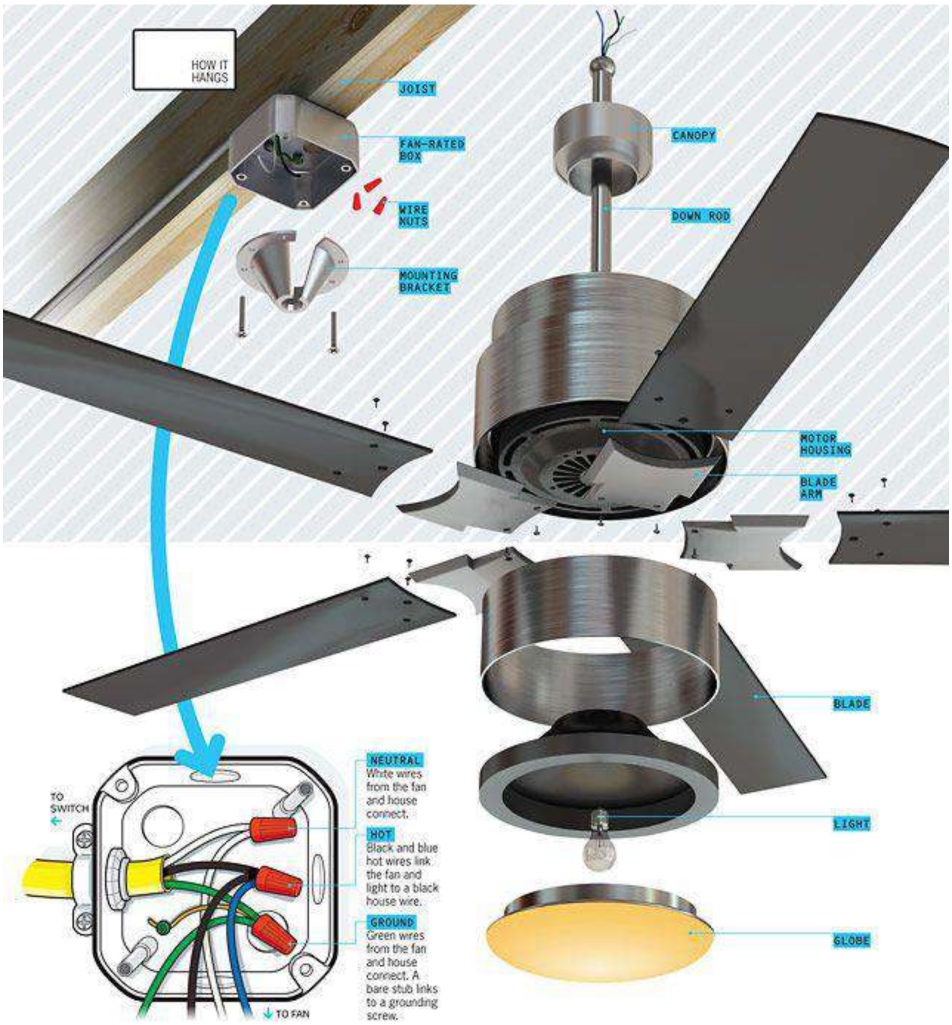


Fig 4.3 Ceiling Fan Allignment

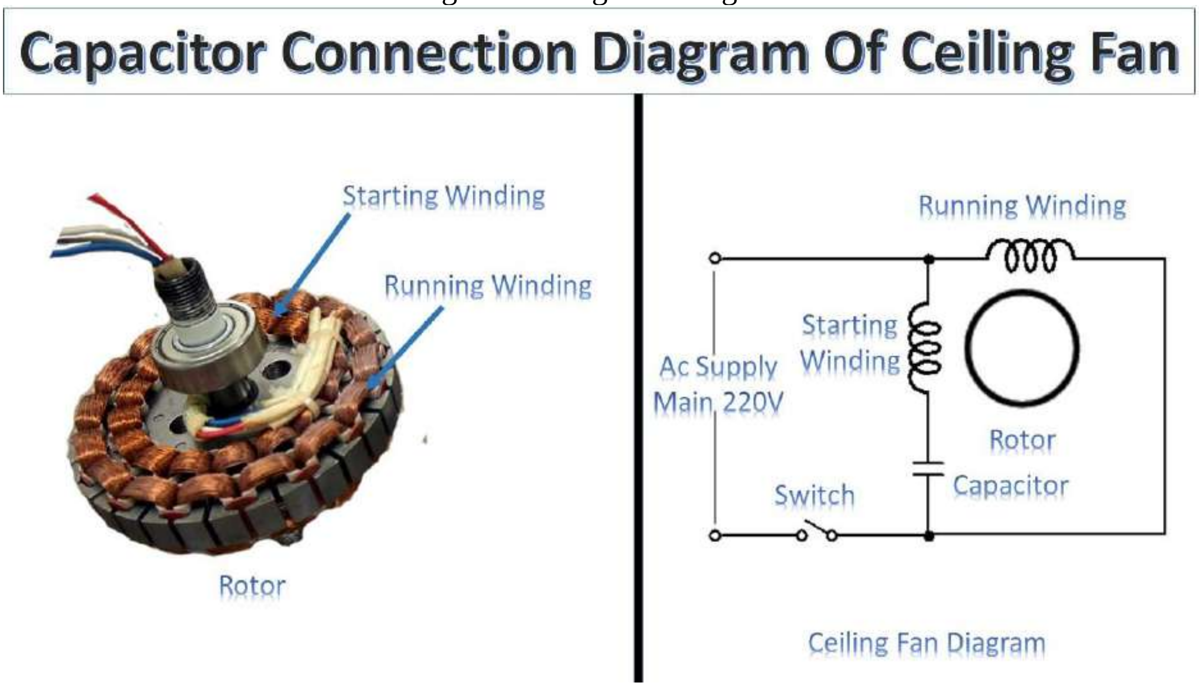


Fig 4.4

3. Blades:

The blades are built up of sheet steel or aluminium sheets. Aluminium blades are much lighter than steel sheet plates and also enhance the efficiency of the fan. The ceiling fans generally comprise 3 or 4 angular blades. The four blade fan provides more air circulation compared to three blade fans. The blades are 120^{o} mechanically apart and might be curved at an angle of 10^{o}.

Blade flanges:

Blade flanges alternatively termed as blade irons, blade arms or blade holders. These are metal arms that connect the blades to the motor.

4. Canopy/Switch Cup:

There are two canopies top and bottom, built up of metal cylinder, located along suspension rod. Top canopy is mounted like that it covers the hook, nut, and bolt. Bottom canopy is mounted under and in the centre of the motor of the fan. This is employed to conceal and protect several components that can involve wires, capacitors and switches. On fans which need oiling, the bottom canopy frequently conceals the oil reservoir that lubricates the bearings.

5. Ball bearing:

Friction free and noise free movements of rotating parts are make sure through providing ball bearing among the rotating and stationary parts. The ceiling fan might comprise single or double ball bearings. The bearings made up of high quality steel are frequently greased with superior quality for the long life and noise free operation of it.

6. Suspension rod/Down rod:

Suspension rod is made up of rigid galvanized steel pipe of suitable length and diameter. This metal pipe is employed to defer the fan from the ceiling. One end of the pipe is bolted or screwed at the position particularly made on the motor body to receive the suspension rod. Another end of the suspension rod is attached to 2 plates, to from a "U" shaped joint, along with the help of a nut and bolt (with extra lock nut).
The "V" shaped end of the rod is additional attached with the ceiling hook along with the help of bolt and nut with extra lock nut and split pin to eliminate chances of disconnection at some stage.

7.Flywheel:

A flywheel is a rubber disc or plastic or elastic extremity that attaches the ceiling fan motor's shaft to the blades. The rubber helps minimize vibration in the blades, but over time the material can crack and break.

8. Speed regulator:

Speed regulator is employed to control the speed of the fan. The speed of the fan can be changed by altering the applied voltage. The most general technique to change the applied voltage is
i) By tapped field resistors and
ii) By tapped series inductors.
These days thyristor based electronic type regulators mainly employed compared to above mentioned electric types.

Fig 4.5

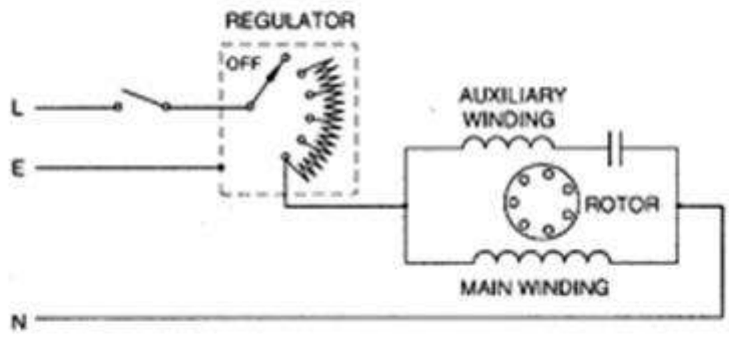


Fig 4.6Diagram - Resistance type Fan regulator

The regulator of electronic fan is fault-free, have a long life and more efficient as compared to electrical fan regulators. The schematic diagram of a fan with resistance type regulator is displayed in the above diagram.

Trouble shooting guide of Ceiling fan

Ceiling Fan Doesn't Work at All

Be sure to turn off the fan's circuit breaker before disassembling the fan or its switch!

These are instructions for troubleshooting a fan that is completely dead. In other words, it doesn't hum or try unsuccessfully to spin. You flip the switch, and nothing happens. Zero. Zilch.

COMMON CEILING FAN PROBLEMS

- Ceiling Fan is Not Working
- Ceiling Fan is Wobbling
- Ceiling Fan is Noisy
- Ceiling Fan Speeds are Not Working
- Fan Light Kit is Not Working
- Ceiling Fan is Not Reversing
- Ceiling Fan is Turning On/Off
- Ceiling Fan has Airflow Issues

Ceiling fan is not working

If your ceiling fan will not start, use the following steps to determine cause of the problem:

1. Check the circuit breaker to confirm the power is on. If the circuit breaker tripped, reset the breaker. If there are any blown fuses, replace the damaged fuses.
2. Turn the power off the circuit breaker. Loosen the canopy, check all the wire connections are correctly assembled and secured with wire nuts.
3. Make sure the fan blades spin freely. Pull the pull chain to make sure it is on.
4. Confirm the reverse switch is not in a neutral position. Flip the switch several times to lock into position.
5. Verify the plug connection in switch housing is securely fastened and all color-coded cables are aligned.

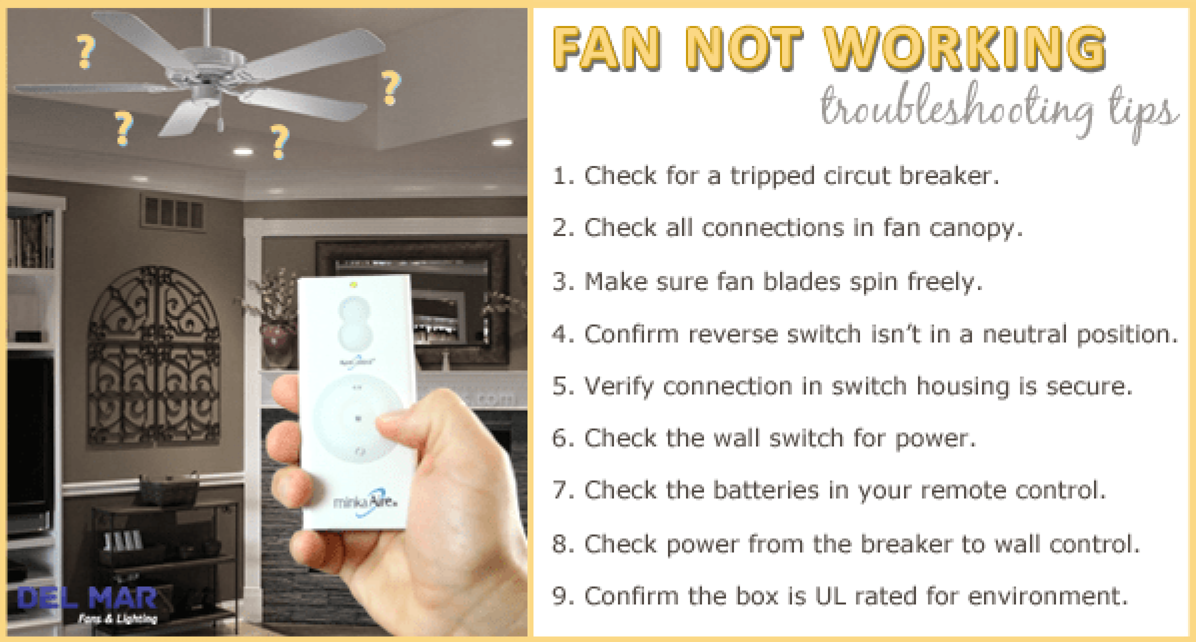


Fig 4.7

6. If you have the electrical know-how, check the wall switch for power. If you are inexperienced in this area, call an electrician to check the wire connections. An electrician can diagnose the issue at a reasonable cost.
7. If you are using a remote control, check that the batteries are installed properly and are not dead. Check that the dip switches on the remote and receiver are set to the same frequency.
8. If you're using a wall control, check the power to the breaker from your control and try working your ceiling fan manually.
9. If your ceiling fan is located in a damp or wet environment, confirm the fan and outlet box is UL rated for that environment. While damp-rated and wet-rated ceiling fans can be installed indoors, dry-rated fans should not be installed outdoors as these fans are not equipped to withstand moisture or direct contact with water.

If your ceiling fan is new, go through each of the steps listed above. If the issue is not resolved, contact your ceiling fan manufacturer and explain the problem as this is most likely an issue with the specific model. Many manufacturers offer a limited or lifetime warranty on the ceiling fan.

If your ceiling fan is found to only be rated for indoor use, you will need to purchase an outdoor ceiling fan for the damp or wet rated areas around your home.

Ceiling fan is wobbling

If your ceiling fan wobbles or shakes, it may be due to several factors such as bent blade brackets, loose screws, or dusty or warped fan blades. Use the steps below to determine the cause of the problem:

1. Remove any dirt or debris from all fan blades.
2. Tighten any loose screws on the light kit, fan blades, motor coupling, down rod, and mounting hardware.
3. Confirm the hanger ball is firmly seated in the mounting bracket.
4. Confirm the outlet box is ceiling fan-rated and designed to support the ceiling fan's weight.

5. Confirm the outlet box is securely attached to a beam or a support brace. If the outlet box is installed directly to the ceiling, this could cause wobbling and eventually damage the ceiling.

Fig 4.8

Ceiling fan is noisy

Many people find the gentle whooshing of a ceiling fan soothing; however, anything louder can be a sign of a serious problem. To determine the cause of your noisy fan, use the steps below:

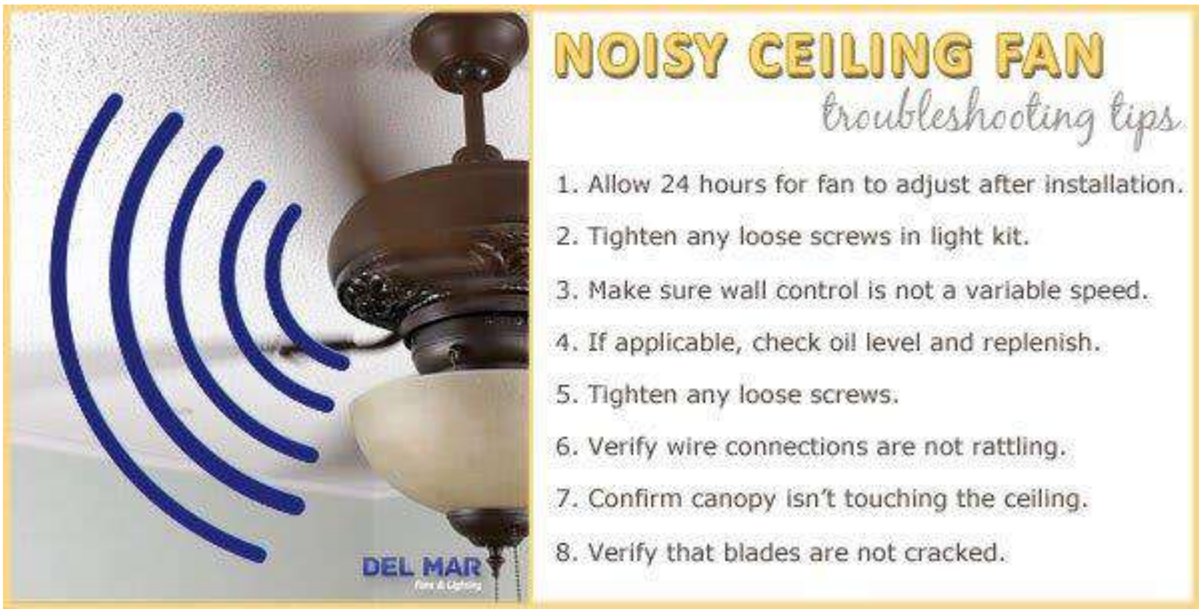


Fig 4.9

1. If you've recently installed the fan, allow 24 hours for the ceiling fan to adjust.
2. If your ceiling fan has a light kit, tighten any loose screws securing the glassware. Confirm the light bulbs are firmly threaded into the socket.
3. If you're using a wall control, make sure the control is not an infinitely variable speed type. A stepped speed control should be used instead.
4. If your ceiling fan has an oil bath, check the oil level and replenish oil as needed.
5. Locate and tighten any loose screws on lower switch housing, blade holders, motor coupling, and down rod. Confirm all pins are firmly in place.
6. Verify the wire connections are not rattling against each other or the interior wall of the switch housing. Verify wire nuts have not fallen off.

7. Confirm the canopy is not touching the ceiling while the fan is in operation.
8. Verify the fan blades are not cracked. If the fan blades are cracked, replace the damaged blades with a new blade set from the same brand as your ceiling fan to ensure compatibility.

Ceiling fan speeds are not working

If your ceiling fan won't turn on or your speed settings are not working properly, you may notice a sharp change in the airflow. To determine the cause of the fan speed malfunction, follow the steps below:

Fig 4.10

1. Clean and lubricate the ball bearings.
2. Replace the ceiling fan capacitor.

3. Feel motor for heat.

3. - Run the ceiling fan for a few minutes.
4. - Turn off the ceiling fan and allow the blades to come to a full stop.
5. - Feel the motor housing to determine if it's hot (be careful not to burn yourself). If the motor housing is hot, the bearings are shot and the motor needs to be replaced. To replace the motor, contact the ceiling fan manufacturer directly. Many ceiling fan manufacturers offer a limited or lifetime warranty on the motor.

Fan light kit not working

If your ceiling fan is operating correctly, but the light kit fails, use the steps below to determine the cause:

1. Check that the light bulb is securely fastened into the socket. Confirm the bulb has not burned out. If so, turn the power off and replace the light bulb. Restore power and resume normal use.
2. Be careful not to over tighten the light bulb into the socket. This can cause the light bulb to flatten a small tab in the light sockets interior, causing the socket to fail and preventing ceiling fan from powering the light. Turn off the power and use a small knife or screwdriver to pull the tab up.
3. Inspect the light bulb sockets for charred or burn marks. If so, you may have a short in the wiring and you will need to fix or replace the wiring.
4. Verify the light bulb's wattage does not exceed the light kit's wattage limit. Some ceiling fans are equipped with a wattage limiting device, which disables the fan's light

kit. If so, turn the power off and replace the light bulb, keeping the wattage under the recommended watts. Restore the power and resume normal operation.

5. Verify the wires in canopy and switch housing are wired properly and secured with wire nuts. Generally, the blue wire controls the light kit.
6. If you are using a remote or wall control to operate the light kit, confirm the dip switches on the receiver and control are set to the same frequency.

Fig 4.11

Ceiling fan is not reversing

If you've attempted to reverse your ceiling fan for the winter, but noticed no change in the direction of the fan blades, there could be several causes. Turn off the ceiling fan and allow the blades to come to a full stop before flipping the switch. Follow the steps below to determine the cause:

Fig 4.12

1. Confirm the reverse switch is not in a neutral position. Flip the switch several times to make sure it is the right place.
2. If you have an older ceiling fan, the switch may be worn out. In this case, replace the reverse switch.
3. If you are using a remote or wall control to reverse the ceiling fan, confirm the dip switches on the control and receiver are set to the same frequency.

4. If your ceiling fan is brand new, contact the manufacturer for a replacement fan.

Ceiling fan/light turning on and off

If your ceiling fan and light kit turn on and off by themselves, don't be alarmed as this is more common than you may think. Use the following tips to identify the cause:

Fig 4.13

1. Confirm the circuit breaker is not malfunctioning.
2. Verify the wire connections are not frayed and are securely connected with wire nuts.
3. Remote and wall controls often come with default factory settings. So if your neighbours recently purchased a new fan, they could very well be controlling yours. When installing a new ceiling fan, create a unique frequency.

Ceiling fan has airflow issues

Fig 4.14

If your ceiling fan is not moving air, use the steps below to determine the cause:

1. Confirm the ceiling fan is spinning in the right direction.
2. Verify the ceiling fan is suspended to hang between 7-8 feet from the floor so the air is reaching the ground. Also, a fan that is too close to the ceiling or wall will provide poor airflow.
3. Consider using a longer down rod that allows the ceiling fan to hang at least eight - nine feet from the floor.

4. If you have an older ceiling fan, turn it off for a few minutes and then carefully touch the base to see if it's hot. If so, you may need a new fan motor or bearings.

How to Replace a Fan's Flywheel?

A flywheel is a rubber disc that attaches the ceiling fan motor's shaft to the blades. The rubber helps minimize vibration in the blades, but over time the material can crack and break.

Ceiling Height	**Drop Rod**

If the fan stops turning but the motor continues to hum, you probably have a damaged or broken flywheel.Cut power to the motor immediately to avoid further damage, and inspect:

- If the blades appear to have dropped, either to rest on top of the switch housing, onto the the light kit, or all the way to the floor below
- If the blades are drooping significantly on one side
- If you pick up one blade and all other blades move along with it.

In short, if the motor spins independently of the blades but all of the blades remain attached to each other, you probably have a broken flywheel.

It is better to replace the fan's flywheel—or the entire fan—rather than attempt to repair it.

Replacement flywheels are relatively inexpensive and are available for most ceiling fan models. Determine which make and model ceiling fan you have. If this is not immediately apparent, remove the broken flywheel and measure it carefully. Make sure to note the inside and outside diameter and locations and spacing between bracket and screw holes.

Then find a replacement through a licensed retailer or appliance parts house—or search the part online.

To remove the broken flywheel, you must disassemble the fan assembly.

It's helpful to take pictures of the fan as you disassemble it to make reassembly easier.

Before working on the fan, be sure to turn the power off at the circuit breaker.

Ceiling Fan disassembling

1. Remove the fan's blades and open the fan switch housing.
2. Detach any switches and controls, noting how and where these were connected.
3. Disconnect any wires attached to the motor, making sure you know where to re-connect them once the new flywheel is in place. Then remove the entire switch housing with a screwdriver, wrench or pliers, depending on the model.
4. Remove the broken flywheel, making note of its exact placement on the shaft. It may be a good idea to mark the location with a permanent marker once the flywheel is removed.
5. Slide the new flywheel into place and make sure any wires are fed through the correct holes as they were with the previous assembly. Tighten any screws and replace any other parts that may have been removed in the process.
6. Re-connect any switches or controls and replace the housing. Re-attach the blades to the fan and test it.

(feet)	Length (inches)
9	12
10	18
11	24
12	36
13	48

4.2.6 Sizing & Locating a Fan

A rule of thumb is to use a 52-inch fan for up to a 400-square-foot room, a 44-inch fan for up to 225 square

feet, and a 42-inch fan for up to 144 square feet. For rooms more than 18 feet long, consider using two medium-sized fans.

WHERE TO HANG A CEILING FAN?

Table:4.3

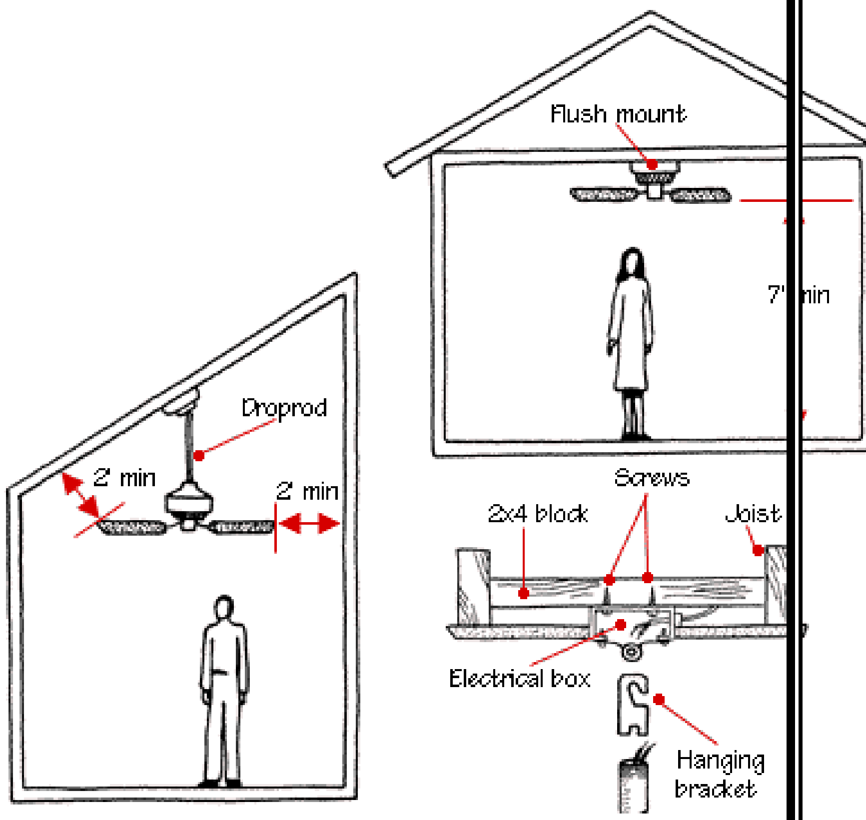


Fig 4.15

Choosing an installation site is as important as selecting the ceiling fan itself. The right location ensures your safety as well as the fan's performance and efficiency. When selecting an installation site, consider the following details:

If possible, put the fan in the middle of the room, close to where people gather. Be sure the blade tips are at least 24 inches from walls or sloping ceilings. Fans mounted close to a ceiling may produce a “cavitation effect,” which means they move less air. Some surface-mounted, low-profile fansare designed to circulate more air than standard models.

Here are the suggested lengths of drop rod for ceilings ranging from 9 to 13 feet or more:

For ceilings taller than 8 feet, hang the fan from a drop rod so that it’s down where it can be more effective. The distance the fan should hang from the ceiling will depend on the ceiling’s height. A fan should never hang lower than 7 feet from the floor.

Strong support is required for all ceiling fans. Their heavy weight and centrifugal motion strains hangers. Because of this, they must be mounted to conventional ceiling light fixture boxes that are securely fixed to framing members or they must attach to hooks, metal crossbars, or special hangers meant for fans.

Judging Ceiling Fan Quality

Although fans are rated by the amount of air they move, measured in cubic feet per minute (CFM), these ratings are not terribly relevant because they are not based on universally accepted standards and because a fan is rarely used at full speed.

Movement of air is a factor of the pitch, length, and number of blades; their distance from the ceiling; and their revolutions per minute (rpms). A weak motor can spin short blades quickly if the blades are at a minimum pitch of about 10 degrees, though this type of fan is likely to be noisier than a fan that swirls longer blades at a 14-degree pitch more slowly.

Some inexpensive fans sold through mass merchandisers have motors made in China. These have proven to be unreliable, as evidenced by high return rates. Low-end fans lack quality in construction and design— they're likely to wobble and hum even at low speeds.

A motor should have sealed bearings that require no lubrication (these should run quietly for up to 12 years). The best measure of motor quality is a company's reputation and warranty. Also be sure it is listed by Underwriters Laboratories or an equivalent testing agency.

Installation of a Ceiling Fan

How to install a ceiling fan, explained in easy-to-follow step-by-step instructions that show you how, including information on installing a hanger bar for the necessary support.

Installing a ceiling fan is a good project for the do-it-yourself, as you can simply replace a traditional lighting fixture with a fan or fan-and-light kit. You can wire the fan's light to be controlled by the light switch on the wall and allow the fan to be turned on manually by pulling a cord, install a second switch to control the fan, or purchase a unit operated by remote control.

You'll need to ensure that the junction box to which you will connect your fan can support its weight (it should say "suitable for fan support"), that you have enough clearance between the fan blades and the ground (at least 7 feet), and that your fan is the appropriate size for your room.

InstallationSteps:

Ceiling fan installation is not much difficult, but based on the type of the fan it may take long hours.

Tools required: ladder, pliers. Wire strippers and screwdriver

1) Mounting bracket installation

- The outlet box is ready to mount bracket with washers and nuts.
- Through the opening on the bracket, provide the electrical wires, shipping blocks from the motor must also be removed, but save screws for blade iron installation.

2) Motor housing assembling

- The fan wires must be trimmed with 6 inches long and strip ½ inch of insulation at the wire end.
- Motor coupling set screw must be removed carefully
- Down rod must be tightened using thread wires for 4-5 full turns through down rod that was assembled previously.
- Tight the screw with pliers.
- Take the canopy and pull the wires and down rod.

- If it is correctly done, canopy will be placed loosely on top of motor housing.

How to wire a ceiling fan?

- Into the slot in the ceiling bracket, place the down rod ball of assembled motor.
- It must be ensured that the fan gets locked, so rotate when you are sure about the lock.
- Mounting bracket must be placed with the control receiver
- Take a bare metal leads and pace a plastic wire connector to connect the wires and twist clockwise to ensure secured connection.
- Push the whole connection to outlet box.
- Grounded and ungrounded wires must be separated on both sides.

Connect fan wiring and receiver wires

- Connect the grounding wires from down rod, ceiling and hanging bracket with a wire nut.
- Connect white wires from fan and receiver marked "To motor" with a wire nut.
- Similarly do the same for black wires and blue wires

Connect wire receiver and supply line

- Connect black wires from ceiling and receiver marked "AC In" with a wire nut
- Similarly repeat the same for white wires too.
- Connections must be turned up and push into the outlet box.
- Separate grounded wires and ungrounded ones as did before.

Connect wires to the wall control

- Remove all wires from the switch.
- Black wires in the outlet box must be connected and green wires must be connected to the grounding wires from the wall control.
- Push all wire connections to outlet box and separate grounded and black wires to different sides.
- Insert wall control also to outlet box and screw it up.
- Switch plate cover must be installed with screws then.

Canopy installation

- Canopy holes must be adjusted with screw holes by sliding to mounting bracket.
- Screw the canopy tightly

Attach fan blades

- Check the holes in fan blades and screw it with blade iron securely
- Attach the blades with motor with screws and tighten the screws at last for an additional security

Switch housing

- Housing assembly will have screws and screw two of them into the motor housing.
- Provide the wires to upper switch housing through the hole at the centre.

- Twist clockwise to lock correctly after wrapping keyhole slots around the screws.
- After inserting the third screw, all must be tightened once again.

Sync wall control

- Turn power on at wall switch and circuit breaker. Sync the fan and switch according to the fan model.

4.2.8 Recommended Tools For Installing A Ceiling Fan

You have purchased the perfect ceiling fan – the right size, style, and finish, and are looking forward to basking under the gentle breeze. As you prepare to install the new ceiling fan, here are 10 basic tools to keep handy in your toolbox for any application. Having the right set of tools to install a ceiling fan guarantees a safe project and timely finish.

1. Crescent Wrench – Also known as an adjustable wrench, a crescent wrench has a set screw that adjusts the width of the wrench by moving one of the two jaws to the right or left. Use a crescent wrench to tighten a support brace or any bolts.
2. Cordless Drill with Long Bit – Drills holes in various materials. Use a cordless drill to install the junction box or utility box to the ceiling joists.
3. Voltage Tester – Also known as a test light, the tester consists of two leads that detect the presence of electricity in a fixture. Use a voltage tester when wiring a ceiling fan by placing one of the leads on the ground wire and the other lead on the hot wire to ensure there is no electricity running through these wires.
4. Wire Cutters/Strippers – Also known as diagonal pliers, wire cutters as their name implies cut wire by indenting and wedging the wire apart. Wire strippers strip the electrical insulation from the end of electrical wires. Many hand tool manufacturers offer wire cutters and strippers as a combo. Use these tools to install a ceiling fan by cutting and stripping the ceiling fan wires during the down rod assembly.
5. Pliers – Holds an object firmly in place. Use pliers to tighten set screws and lock nuts during the down rod assembly.
6. Screwdrivers – Used to turn or drive screws. The most common screwdriver types are flat-head screwdrivers and Philips screwdrivers. Use a screwdriver to tighten and secure the screws on the motor housing and blades to prevent any wobbling or shaking. Some brands may include a screwdriver in the packaging.
7. Electrician’s Tape – Also known as insulating tape, secure electrical wires and other materials that conduct electricity. Electrical tape is pressure-sensitive and flexible while providing long-lasting insulation. Use electrical tape to insulate all wire connections.
8. Ladder – Use a ladder to reach the mounting bracket and hang the motor assembly as well as wire the ceiling fan. If your ceiling is 9 feet or higher, choose a 5-foot stepladder. If your ceiling is 12 feet or higher, choose an 8-foot stepladder. If your ceiling is 15 feet or higher, choose an 11-foot stepladder.
9. Dusk Mask – Protects you against inhaling dust and other debris while assembling, installing, or cleaning a ceiling fan.
10. Safety Glasses – Shields your eyes from hazardous materials and flying debris during the installation process.

Fig 4.16

Use these tools to install a ceiling fan or to troubleshoot your existing ceiling fan,

4.2.9 Cleaning a Ceiling Fan and Maintenance

The ceiling fan is the most ignored angel of our lives. We always take it for granted. Come inside the room switch it on and just ignore it. Yes, that's what we do with our lovely ever serving ceiling fan. Jokes and philosophy apart, have any of us given a serious thought on how a ceiling fan works so tirelessly and efficiently.

When is the last time you cleaned your ceiling fan? Like any other home appliance, regularly cleaning a ceiling fan is important to ensure optimal performance. Light maintenance such as replacing blades and keeping the ceiling fan from shaking, wobbling, or squeaking is necessary to keep the fan running smoothly. Cleaning fans properly also help with longevity.
When it comes to ceiling fans, one thing that you generally don't want to hear is a grinding noise. Here some tips for Ceiling Fan Maintenance.

Tips for Ceiling Fan Maintenance

- **Clean out the fan**. Cleaning a ceiling fan should be done at least once a year. You, however, need to reach it first by standing on a stool or something elevating. Start by cleaning the blades with a brush and then use a damp cloth that has been dipped in soapy water to remove the remaining sticky stains. Leave the fan to dry on its own before using it again. You can easily find a fan brush from any home equipment store near your house. Also, you can vacuum out the motor as dust can accumulate on it and cause a fan to run slow. A well dusted and clean fan is always going to function efficiently. On the other hand, if you ignore this fact, your fan will soon look very dirty. Nobody likes the site of a dirty and grubby looking device swinging around. The design of the blades is such that the dirt starts accumulating near the edges. As time goes by, the dirt goes towards the centre. The moment the entire blade is covered in dust; it will start spew dust all over the room every time you switch the fan on.
  It is not very difficult to dust the fan. You can easily overcome the height problem by making use of a long brush. You can also use a chair or a ladder to get close to the fan so that you can wipe it clean with your hands. The latter option is preferable because you will have a better view of the blades.

However, this also means that you will need somebody to help you out because it is not a good idea to stand on a tall ladder that reaches close to the ceiling without anybody holding on to it. In any case, you should clear the area surrounding the ladder so that you do not fall on some other object and hurt yourself badly.
If you are planning to go in for a long brush, make sure you go in for two brushes. You can use one to keep the blades in place as you use the other to clean the blades. This is important because the fan can start rotating and this will make it very difficult and dangerous for you to get a good grip.
Furthermore, you may use excessive force and cause the fan to swing and may even cause the blades to twist. All this can be avoided if you hold the fan in place.

- **Tighten all screws**. Ceiling fans are made of different parts that are put together using screws. While the fan is running, it generates small vibrations that loosen some of those screws. You can detect loose screws through a noisy or shaky fan. Simply use a screwdriver to tighten back those screws with a special focus on the fan, ceiling plate, and the light fixture – if available.
- **Lubricate the fan**. Some ceiling fans require periodic lubrication to operate smoothly. Use any light oil (similar to the oil used on a sewing machine), to fill the oil hole that is located on the top side of the motor. Fill this hole till the oil flows over and rinse the excess with a tissue or rag.
- **Check for movement**. It is important to check your ceiling fan for movements or wobbles. The center of the fan should not make any side movement while the fan is in operation. If it does, the fan needs to be balanced. You can use a fan balance kit to do this. Also, it is important to note that a faulty blade may cause a fan to wobble. Check to see if there are parts missing on blades. Lastly, it is important to check if there is any bent or warped blade. You can do this by removing all blades and place each on top of another. The blades should fit perfectly on top of another.

Balancing a Ceiling Fan

Standing in a room where there is a high-speed wobbling fan can cause shivers to run through your body. A ceiling fan that is not properly fixed is a visual distraction on the one hand and an irritation on the other hand. It also causes damage to the bushings and bearing of the motor. This leads to some annoying whines and squeaks originating from your motor. When your fan is not properly balanced, you don't need to rush into buying another one before you try balancing it out.

Basic Steps for Balancing a Ceiling Fan

The blade bracket screws sometimes get loose and this may be the main cause of imbalance in your fan. The other cause may be the accumulation of dust which tends to put extra weight on one blade over the other. If tightening of the screws and wiping off the dust doesn't solve your problem, then you need to proceed with rest of the balancing procedure.
Before you even begin the balancing process, you need to mark your blades so that throughout the balancing act you are able to keep track of them easily. The biggest cause of imbalance in ceiling fans is the build-up of dust. It is quite easy to forget cleaning your fan during the routine cleaning processes. Dust tends to settle on the blades in an uneven manner causing some to become heavier than others.
In the first step of balancing, therefore, you need to banish the dust off the blades. If dust has built over time, the chances are that it is now hardened and may require more than a swipe of a duster to get off. You will need to climb the ladder and carry a damp rag alongside to clean both sides of the blades. Have another fresh rag to assist you to dry the blades after removing the dirt. Try spinning the blades to check whether the problem has been fixed.

If the fan is still not balanced, the next step is to check the base screws. These screws are located between the flywheel and the blades. Try to give a clockwise turn to each screw using the screwdriver just to ensure that they are properly tightened. If you find any loose screw, then you are likely to solve the issue that has been affecting your fan. After you are done with the tightening, spin the fan to check if the problem has been sorted out. If it hasn't been fixed, the next step is to check the blade alignment.

In this step, you will require a ruler or a yardstick to be able to measure precisely. You will need to take three different measurements between the ceiling and the blades at the same point for each of the blades. The ideal measurement locations are the central location of the fan close to the flywheel, the halfway of the blade along its length, and the tip of the blade. In case there is variance among any of the blades, you will have to slightly bend the blade holder in a gentle manner and straighten it back in a bid to solve the misalignment issues. Just be careful so that you don't break either the blades or the holder. If by the end of this step the fan hasn't regained its balance, then you will have to proceed to the next level of balancing. At this level you will require to use a balancing kit.

Additional Steps to Balance a Ceiling Fan

We have already seen the basic steps that you need to take to achieve balance for an indoor ceiling fan unit. In this section, we will share some more steps that will help you address the wobbling issues considering the fact that the basic steps have failed to do so.

The first thing you will need to do is to open the canopy cover by loosening its screws. This cover is usually adjusted together with the ceiling. You then need to open the mounting bracket so as to slide down the cover. Having exposed the mounting bracket, the next step involves tightening its screws. The mounting bracket will enable you to see the outlet box whose screws also needs to be tightened. In this step, therefore, you will tighten the screws on both the mounting bracket and the outlet box. The next step will involve checking the down rod. You will need to confirm that the pins and the down rod screws are securely fasten. Ensure you tighten any loose screws and place the pins firmly on the down rod.

Having fixed the down rod, the next step involves checking the fan blades. Various components need to be fixed as far as the fan blades are concerned. They include the blades, the motor housing, and blade holders. You will start by fixing the blades on to the blade holders. Once they are in place, you will then proceed to the motor casein order to secure these blade holders. The housing comes with a bracket that needs to be adjusted by gently bending it. The blade holders then need to be pressed up and down to achieve the required adjustment.

The next step that comes after securing the blades involves checking the vertical distance. Ensure that each blade has the same distance between the holder and the tip. You will have to measure these distances and correct for any discrepancies by adjusting the holders. Continue doing these corrections until all the blades have the same equal distances on their vertical axis. Having finished these steps, you will then need to switch on the fan and verify if the issue has been solved. If the wobbling hasn't stopped, it is time to get the balancing kit for the blades. In the next section, I will share some tips for using this kit.

TROUBLE-SHOOTING TABLE

Table 4.4

TROUBLE	PROBABLE CAUSES	SUGGESTED REMEDY
1. Fan will not start (**Warning:** THE ceiling must be switched OFF, and the assistance of a licensed electrician maybe required.)	A. Fuse or circuit breaker blown.	Check main and branch circuit fuses or circuit breakers.
	B. Loose power line connections to the fan.	Check line wire connections to fan
	C. Speed controller not in correct position.	Check speed controller's position.
2. Fan Wobbles (Refer to Wobble section of the manual for further information.)	A. Fan blades are not horizontal to ceiling.	Refer to "wobbling fixing" section of manual. - The blade may require adjustment at the blade mounting screws; - The blade is out of shape, thus causing wobbling. New blades set will require to be replaced. Contact your local Beacon Lighting store.
	B. Blade screws are loose.	Make sure all screws are securely fastened.
	C. Blade/s are out of shape	Remove blade and lay on a flat surface to check if blades are out-of-shape. Contact agent or manufacturer for replacement blades.
3. Fan sound noisy	A. Top canopy touching ceiling.	Lower canopy from ceiling to ensure minimum 3 mm clearance.
	B. Loose fan blade screws.	Re-tighten all screws on fan blades but never over-tighten.
	C. Ceiling fan not secured against ceiling.	Re-tighten all screws in the hanging bracket or plate.
	D. Incorrect speed controller.	Change the controller to the one supplied.
	E. Audible buzzing noise. Cause by Ripple Control signals. Please refer to the Ripple Control section of this manual.	Install a Ripple Control filter. (Refer to the Ripple control information in this manual.)
4. Mechanical Noise	A. Allow at least 8 hours settling-in period.	
5. Light will not turn ON (Optional light kit ONLY)	The globe/lamp has failed.	Replace globe/lamp

WARNING: THE CEILING FAN MUST BE SWITCHED OFF, BEFORE TROUBLE SHOOTING IS PERFORMED.

4.2.2 Table Fan

Introduction

Electric Table Fan is a portable fan and one of the common electric appliances used in houses, offices, shops and business establishments to provide air circulation and to cool down temperature. Fan circulates the air, which enhances the evaporation rate of sweat from body, due to which body is cooled. Table Fans are manufactured 200 mm, 300 mm and 400 mm sweep sizes, but the one, which is most commonly used, is of 400 mm sweep size. Modern table fans are light weight, efficient and are available with attractive look. Numerous models of different types are available from various manufacturers. They run on 220-volt AC and have power consumption between 50 to 100 watts and can have speed up to 1400 RPM.

Table Fan Construction

Table fans are basically of two types:
1. Non oscillating table fan
2. Oscillating table fan.

All of the table top fan parts are fairly simple.

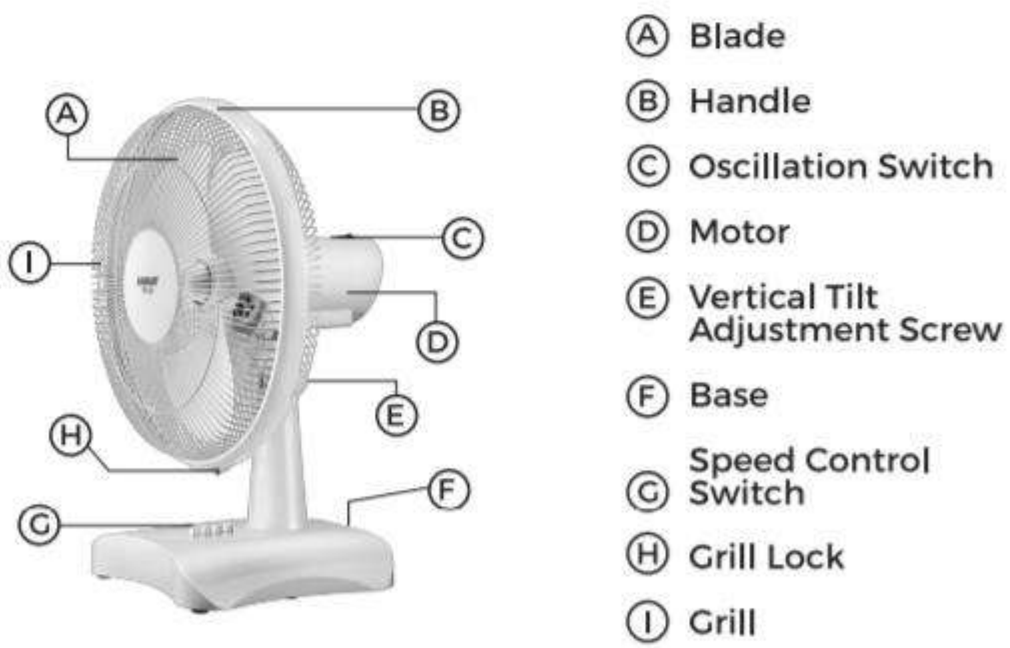


Fig 4.17**Table Fan**

- **Base**. Supports the entire mechanism. Usually where you will find the on-off switch (regulator), which may have 2 or 3 optional speeds - low, medium, and high.
- **Motor Housing**. Contains the electric motor - the rotor to which the blade assembly is attached.
- **Motor**: The electric motor used in a table fan is a Single phase AC motor. Commonly it is a split phase type or permanent capacitor type motor.In some old table fans shaded pole motor or universal motor were also used. It has two parts, Stator and Rotor
- **Stator: The** stator is hollow cylindrical in shape and is made of laminated steel. It has slots for placing stator windings. The stator is fitted inside the outer frame or the body of the motor. Two windings of copper wire are placed in the stator slots. One is called the starting or auxiliary winding and the other is called the running or main winding. In a permanent capacitor motor, a capacitor is connected in series with the starting winding. In split phase motors a capacitor or a resistance is connected in series with the starting winding. The starting or auxiliary winding is connected to the power supply during starting of the motor. There is a centrifugal switch which disconnects the starting winding once the motor attains speed.

- **Rotor:** The rotor is tightly fitted on the shaft and is surrounded by the stator. The rotor is a laminated solid cylindrical core made of steel and has slots. Copper or aluminium bars are inserted in the slot and are shorted at both the ends.
- **Blade/Impeller assembly**. Cuts the air and pushes it forward.
- **Blade guard**. Prevents curious fingers or kitty cats from suffering injury.
- **Speed Regulator:**Every table fan has a regulator to increase or decrease fan speed. These are also known as **resistive regulators**. The box consists a wire wound resistor with different taps which is connected in series with the motor of the fan.
- **Bearings**: The main work of the bearing is to convert rotary (mechanical) motion of shaft (inner end) into stationary or static (outer end) energy of guard. Its inner end is connected with motor shaft and outer end with guard.
- **Gearbox:** Gearbox which controls the oscillation of the Table Fan. The end of the motor rod that enters the gearbox is threaded, which then makes contact with a gear. This gearbox allows the fan to oscillate without using a separate motor, making for an efficient design.

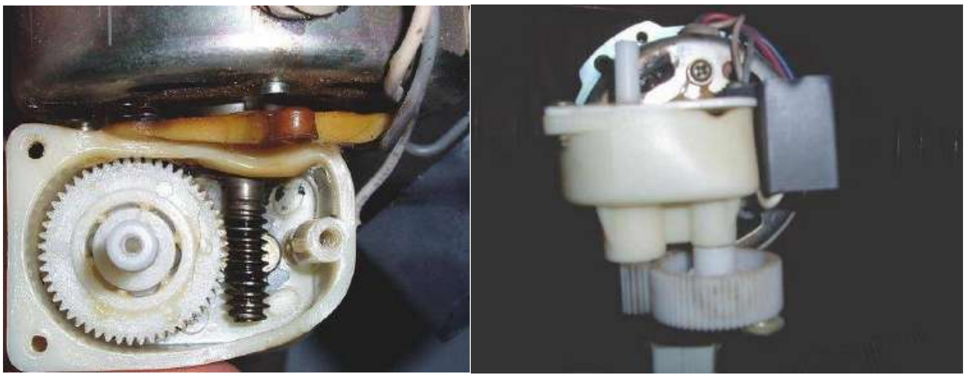


Fig 4.18

- **Lever Gear:**The bottom end of the insert is a gear. This gear is always touching a gear that is located on the underside of the gearbox. This gear has a lever attached to one side of its face. The other end of the lever is attached to the frame. This design changes the rotation motion of the gear into the side-to-side sweeping motion that makes the oscillating fan.
- **Power cord with plug**. Connects to your home's electric service power supply. Some are grounded (3 pins) and/or polarized (one blade wider than the other) some are not.

Commonly a table fan has three or four blades made of metal like aluminium or plastic. There are some models that have five or more blades. Sweep diameter of 200mm, 300mm and 400mm are common.

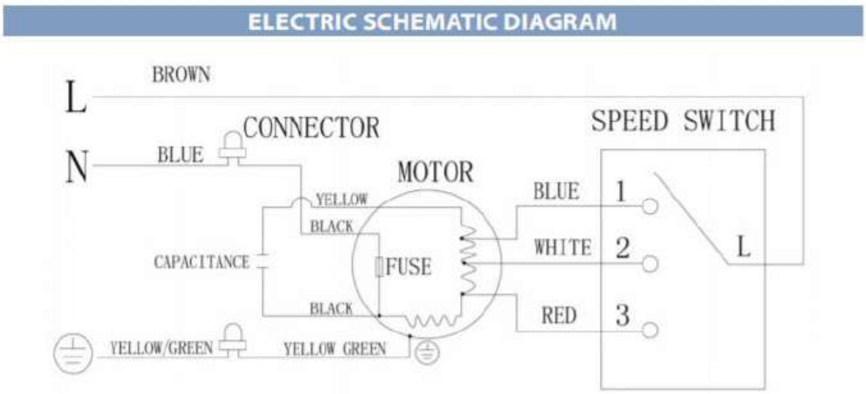


Fig 4.19 Table Fan Connection Diagram

The speed regulator is placed on the base or on the stand. It is either an electronic unit or a variable series resistance. Speed can be changed by rotating the speed regulator knob.
Oscillating table fan oscillate back and forth and thereby provides air circulation in a large volume of space. There is a gear box assembly fitted with the rotating shaft. As the fan rotates, because of the gear box the fan oscillates. Oscillating fan can be used in stationary or oscillating mode. A knob is provided by means of which oscillation mode can be selected.
The body and side covers are generally made of cast iron. There is a wire guard that encloses the fan blades and the rotor shaft. Bearings are tightly fitted with the shaft.

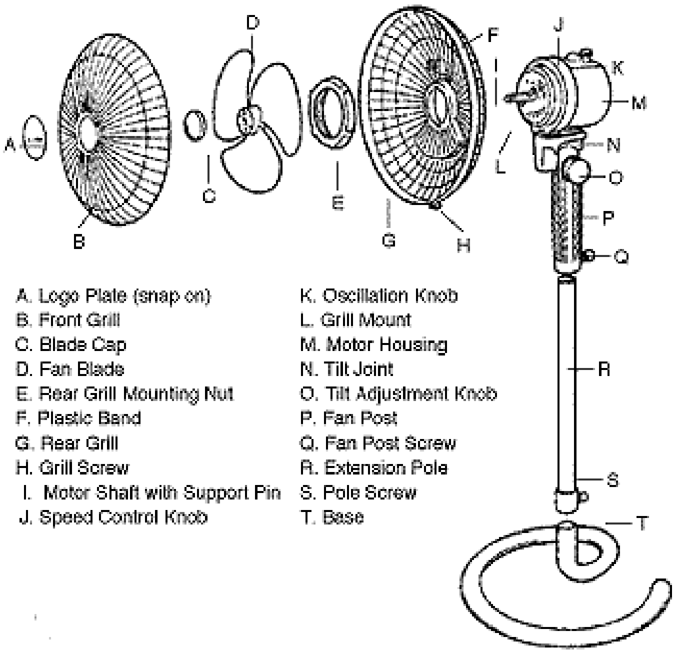


Fig 4.20(a) Pedestal Fan

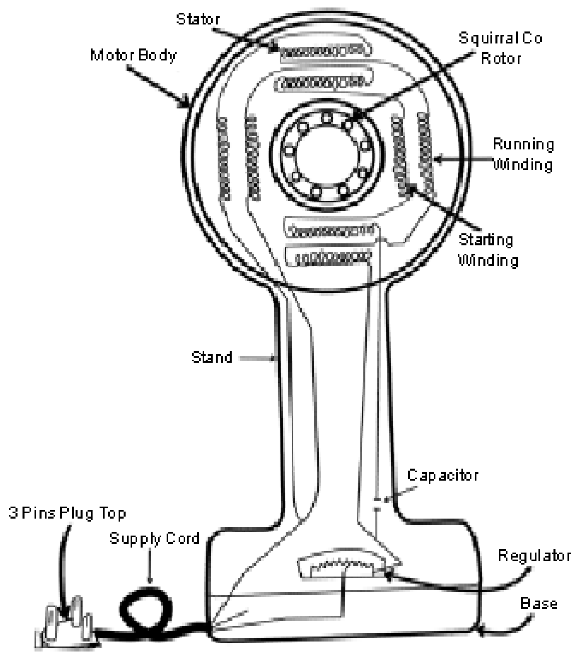


Fig 4.20(b)Wire Diagram of Table Fan

Troubleshoot Table Electric Fans

Electric table fans are simple home appliances that use a motor to drive fan blades for circulating the air. Inside the plastic or metal housing is an electric motor connected to a fan propeller, wiring and a rheostat-type switch for turning the motor on and off, and adjusting the speed.

Step 1
Disconnect the electric fan from the wall outlet.

Step 2
Remove the safety cover from the front of the fan by unscrewing the cover and removing the 4 to 6 Phillips head screws or by pulling open the metal clips that hold the front cover to the back. Metal clips swing upward from the edge of the safety cover.

Step 3
Clean the front and back of the fan blades with paper towels dampened with window or countertop cleaner such as Windex or 409 to restore proper speed to the electric fan. Be sure to

remove dust and dirt from the back of the blades and along the motor shaft, as this accounts for most problems with poor performance, including slow fan blades.

Step 4
Troubleshoot a sluggish driveshaft by applying a few drops of WD-40 lubricant to the shaft and rotating the fan blades by hand.

Step 5
Remove the motor housing from the back of the fan by extracting the screws that hold it in place.

Step 6
Inspect the back of the motor to be sure the two electrical wires are secured firmly to the contacts on the motor.

Step 7
Use a dry paint brush to remove accumulated dust and dirt from the motor, then add additional WD-40 to the drive shaft where it attaches to the front of the motor. The drive shaft should spin freely when turned by your fingers.

Step 8
Check the oscillating pull knob (it makes the fan turn from side to side) on some models to make sure the knob engages and disengages the motor when it is pulled. Adjust the knob if necessary so the hook attaches to a clip on the motor. If the knob is broken, it may be possible to repair it with glue, although your best bet will probably be to live without the oscillating feature or replace the fan.

Step 9
Reattach or tighten broken or loose motor wires by stripping 1/2-inch of insulation from the ends of the wires, then twisting the wire strands and wrapping them to the contacts.

Step 10
Tighten the contact screws with the screwdriver and replace the motor housing.
Step 11
Turn the fan upside down and remove the cover from the bottom of the base by extracting the four screws holding it in place.

Step 12
Check the two wires that should be connected to the bottom of the fan switch and reattach if loose or broken.

Step 13
Clean the metal switch contacts by scraping the surface with the tip of the screwdriver to remove any corrosion and create a better electrical connection.

Step 14
Reassemble the base and attach the screws.

4.3MIXTURE GRINDER

Introduction

A mixer grinder is a very useful domestic appliance of the kitchen and is used to grind fruits, nuts, vegetables etc and to prepare delicious drinks like milk shakes. Dry grinding of spices, cereals, pulses, seeds, dry fruits etc and wet grinding of garlic, ginger, onion, vegetables etc are also done in mixer grinders. There are mixture grinders for mincing meat. Hotels and restaurants use high capacity mixer grinders. Different types of mixer grinders are also known as Food processor, juicer and grinder, food grinder, mixi, liquidizer etc.

Numerous models of different capacities from various manufacturers are available. Now-a-days efficient models with attractive getup and added features are available and they make less noise and vibration compared to older models. Domestic mixer grinders work on 220-volt AC and commonly have power rating between 500 watt to 1.5 kW. Typical values are 500 watts, 750 watts, 1.1 kW etc. Maximum speed of 18000 to 20000 RPM is common.

Mixture Grinder Construction

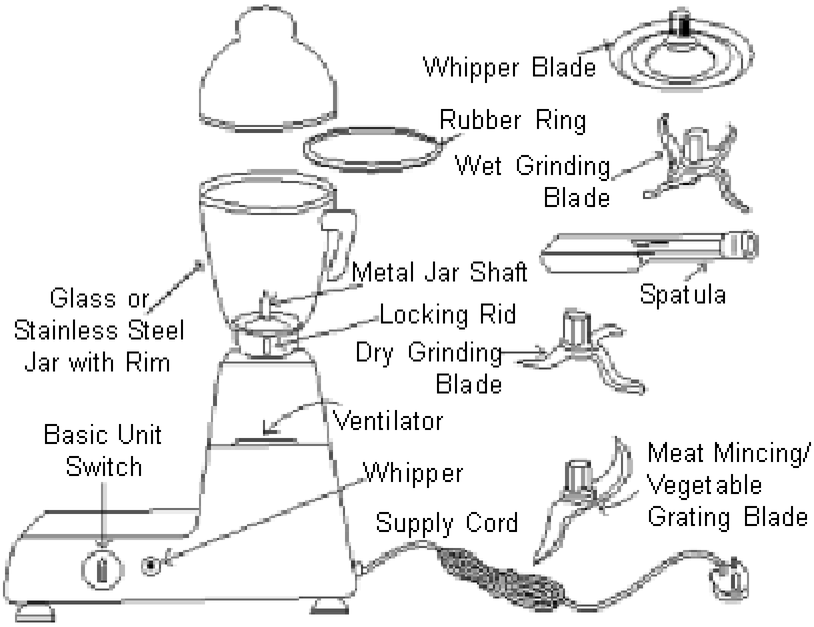


Fig 4.21

The main parts of a basic mixer grinder are–

1. Electric motor
2. Speed control switch
3. overload protection and reset switch
4. Coupling
5. Jars and blades
6. Body
7. Accessories

Electric motor

The motor used in mixer grinder is generally a universal motor. The motor has stator and rotor. The stator is made of laminated steel. There are poles on the stator. Usually two poles are there. Field coils are wound on each pole. The rotor, also called armature is also made of laminated steel, has slots and is tightly fitted with the shaft. Rotor windings are placed on rotor slots. Ends of rotor windings are permanently connected to commutator segments. Commutator segments are around the shaft on one side. There are two brushes that make contact with two commutator segments at a particular instant. As shaft rotates, the commutator segments that come in contact with the brushes also change. Field windings in the stator and rotor windings are connected in series through the rotor commutator. Universal motor can run on both AC and DC. They have high starting torque and speed.

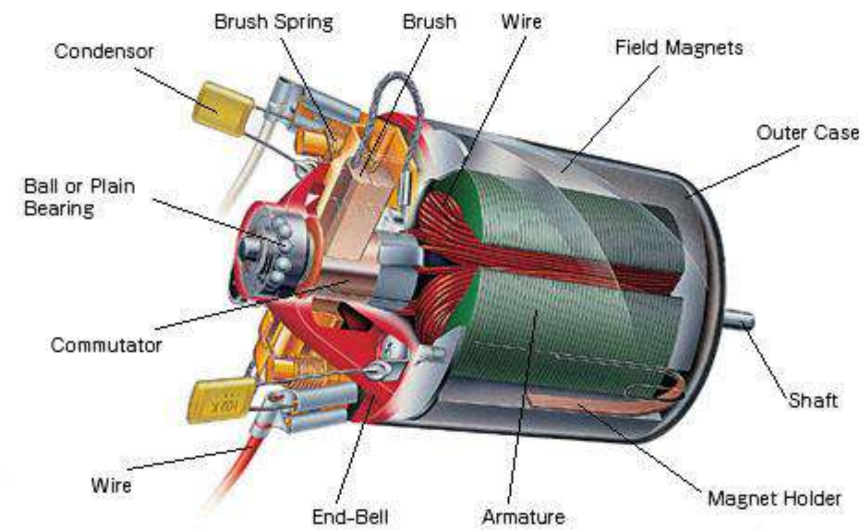


Fig 4.22

The motor is fitted to the base unit with its shaft in vertical position. A top bowl contains the couplings that are tightly fitted on the top of the shaft where jars with blades are placed. The base of top bowl is sealed by rubber gaskets and is made leak proof Couplings are made of high quality food grade plastic or polycarbonate materials.

Speed control switch

The speed control switch is generally a three speed switch. Low, medium or high speed can be selected by rotating the knob of the switch.

overload protection and reset switch

There is overload protection for the motor. If the motor gets overloaded it automatically gets switched off. An overload reset switch is provided. Once the motor gets switched off because of overloading, the motor can again be started after pressing the overload reset switch.

Jars and blades

Jars are made of stainless steel with transparent covers made of polycarbonate material. Coupling is at the bottom and blades are fitted inside. Base is sealed by rubber gaskets in such a way that even a drop of water cannot leak through the base. The body is made of good quality plastic material, is insulated and shock proof. Accessories include jars of different capacity, blades of different types for dry grinding, wet grinding, vegetable mincing etc, rubber ring, spatula, power cord etc.

The jars are filled with food material to maximum two thirds of the jar volume and then placed on the top bowl of the mixer grinder. Proper coupling of the jar is ensured and jar cover is put on the jar. During operation jar should be kept securely held by holding the jar cover.

Jars and intended purpose

Blender Jar

The liquidizing / blending jar performs all types of liquidizing and blending operations such as lassi, milk shakes, purees, juices etc.Use the pulse button for better results. Use the handle of the jar for easier pouring. Do not use this jar for wet grinding - the blades are optimized for blending only. The liquidizing / blending jar performs all types of liquidizing and blending operations such as lassi, milk shakes, purees, juices etc.Use the pulse button for better results. Use the handle of the jar for easier pouring. Do not use this jar for wet grinding - the blades are optimized for blending only.

Fig 4.23

Grinder Jar

The wet / dry grinding jar can be used for grinding items like idli and dosa coconut chutney, groundnut, red chilli, sugar, palak etc.

Chutney Jar

The chutney jar can be used to grind small quantities of jeera, dhania, coconut, green chillies, pepper, garam masala etc. Do not add excess water when using this jar. Do not run the mixer continuously as it tends to reduce the flavour of the ingredients being ground - short spurts are recommended. While dry grinding, friction may heat up the jar. This is not abnormal.

Common mixer grinder problems and their repair

A mixer grinder is one of the most useful kitchen appliances and also one which fulfils several purposes at once. Not only does it helps to grind solids and liquids but proves useful on an everyday basis. Thus when it starts showing certain faults or signs of damages, it can prove to be really limiting for us and hinders our work pace. To solve mixer grinder related problems, you must know which are the most common ones. Common problems are defects in the motor or switch, worn out brushes, broken or loose blades, leak in top bowl or jars etc. The mixer grinder should not be continuously run for long periods. There should be a gap of minimum one minute between two successive switching on. The motor must be off and the shaft must be stationary at the instants of placing or removing the grinder or the jar.

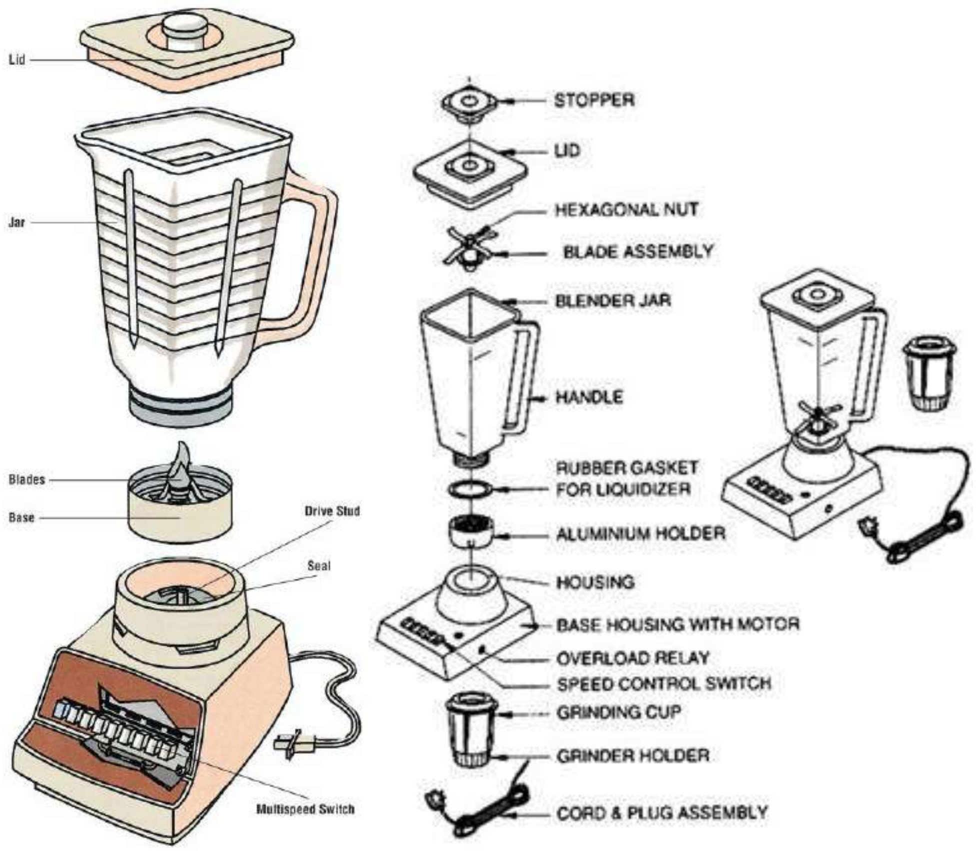


Fig 4.26 Mixer Allignment Diagram

The following are the most common mixer grinder problems and their repair methods.

1. Leaking mixer grinder

Leaking proves to be one of the most common mixer grinder problems. To correct it, you first need to check the blade assembly and ensure that it is tightly screwed onto the jar. Another reason for a leaking mixer could be problem with the rubber gasket. You can replace it easily by purchasing it from a local hardware store. Leaking can also result due to a crack in the jar and in this case you may need to replace the jar altogether.

2. Stuck buttons of the mixer grinder

Another one of the common mixer grinder problems is stuck buttons. This usually happens when foods and liquids spill a little bit and enter the space in between the buttons. To correct this issue, you must unplug the appliance and give it a nice thorough cleaning. Some models have the option of removing the face of the buttons and in this case you can easily clean the button spaces to remove liquids and food particles. Take an old toothbrush for a better cleaning.

3. Slow moving blades

Out of the many common mixer grinder problems, one is slow moving blades. This can prove irritating because in this case the foods and liquids take a long time to get mixed or churned. In most of the cases, this problem is caused due to food particles clogging the blade assembly. There is a very easy solution for this. You just have to disassemble the blade assembly and soak the parts in soapy water which is slightly warmed for another half an hour. Scrub the parts properly and reassemble them all. Try turning on the mixer grinder and press the 'ON' button to see whether the blades turn faster now.

For availing the best use out of a mixer grinder, you must clean it on a regular basis and follow preventive maintenance tips and methods. After all it is one kitchen appliance upon which you are very dependent and if it goes bad, you may have to bear the brunt. Now that you know the common mixer grinder problems and their repair, you can easily mend one at home.

4.Mixer blade not rotating

A mixer grinder or simply a mixer is undoubtedlythe most useful and essential home appliance which you would find in almost all kitchens across the country,and is one which is used almost every day and sometimes even several times a day.It is difficult to imagine cooking without it. Mixer grinders fulfil several purposes such as mixing of foods and liquids properly, grinding solid and liquid items and several others. Whether it is to make particles finer or to prepare dishes, the appliances proves extremely useful. However sometimes it can encounter certain problems which may make it difficult for us to use it and hence limit its use.The appliance may show signs of problems and faults and one of them is mixer blade not rotating. Without this main function of the appliance, it becomes almost redundant. This is why it is important to resolve the problem because There could be several reasons for the blade not rotating and before you go on to solve the issue, you must know the exact reason. The following are some of the causes as well as solutions for mixer blade not rotating:

1. Damaged bearing

CAUSE: The most common cause of mixer blade not rotating is *damaged bearing.* What happens is that water as well as salty liquids tend to leak in through the mechanism of coupling and can thus reach into the bearings of the blades of your mixer. This salty water tends to corrode the metallic bearings and can damage them to a point where the blade is unable to rotate. This practically makes your appliance useless.

SOLUTION:

- In such a case, what you can do is that you can turn the mixer blades in the opposite direction manually a few times.
- If this doesn't help, then drop in a few drops of coconut or mustard oil on the coupling mechanism. Put the jar upside down.
- Now try to rotate the blades manually again and keep the jar aside for about 10 minutes.
- Attach it to the motor unit and give it a test run again.
- If it rotates without any problems or glitches, then the problem has been resolved.
- If not, contact a professional for repair work.

2. Broken motor coupler

CAUSE: Another possible reason for mixer blade not rotating could be *broken motor coupler*. The cause of this could be *overloading, poor quality material of the coupler* and also the *appliance being used for a long period.*

SOLUTION: In this case, the solution is to get the motor coupler replaced. You must call an authorised professional for this job.

3. Damaged electric wire

CAUSE: If any of the wires within the appliance have become damaged, then this too could lead to mixer blade not rotating.

SOLUTION: To solve this problem, it is to inspect the wires and see which one has gone faulty. If you are not sure how to do this, it is better to contact a professional. If the wire is damaged, then you can either get it replaced or in some cases, you may have to replace the mixer altogether.

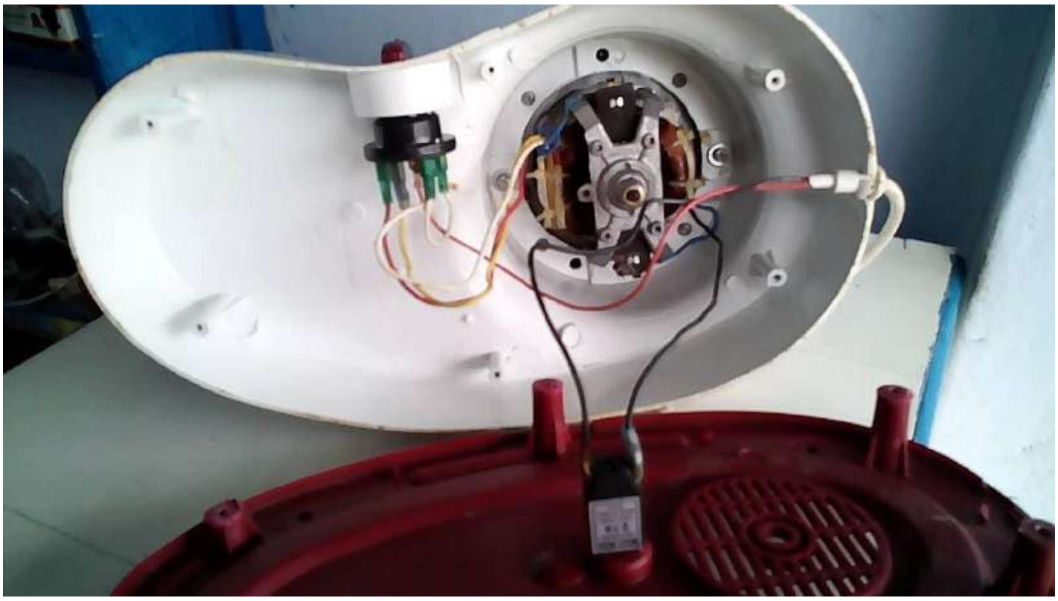


Fig 4.27

Now that you know the main causes of mixer blade not rotating, you can take the repair steps accordingly.

Mixer grinder jar jammed

One of these common problems is the jar of the mixer grinder getting jammed. If you too are facing the issue of mixer grinder jar jammed, then you can resolve the issue using certain tips and tricks. They are given as follows:

1. Use cooking oil to open the jar

In most cases of mixer grinder jar jammed, the seal of the bearing of the blender mixer blades leaks and the salty water from liquids of foods tend to seep into the bearings of the mixer blades, thus making it corroded and hence the jar jammed. In such a situation, it would be impossible to use the appliance. One of the best solutions for this problem is keeping the jar upside down and pouring some cooking oil into the space of the motor coupler. If you are confused about the quantity of oil to be used, then take oil enough to keep its level to below the rubber or the plastic motor coupler. Leave the jar in this position for a few minutes.

After that, twist the plastic or rubber motor coupler using a hand tool such as a plier. The first turns might prove tight but after that it will ease of and become loose. Once the jar blades tend to move freely put it on the motor base and run it empty. Once it starts running, put a little water and turn it on again. Throw the water away.

2. Let air in the mixer grinder escape

Sometimes, the lid of the jar too gets jammed and may prove difficult to open. What happens is that when you close the lid of the jar, the air inside the jar tends to get compressed and when it is in ON position, the air gets further compressed. And if the material inside the jar is evens slightly hot, then the air gets even more compressed, thus leading to jar lid jamming. To avoid such a situation, it is advised that you do not block the small air vent which is provided with each jar lid. Also do not start the appliance immediately after closing the lid, allow a few seconds for the air to pass through the vent.

If you follow these tips and tricks, the mixer grinder jar jammed shall ease up and open up. However, it is best to clean and maintain your mixer grinder on a regular basis to avoid such a problem.

Table4.5

Trouble shooting chart

What's wrong	Possible reasons	What to do
Mixer-grinder does not run	No power supply	Check mains
	Wire cord loose	contact service point
	Faulty switch	contact service point
Mixer grinder motor stops suddenly during usage	Overload due to excess grinding material	Reduce the amount of grinding material and press overload button to reset
Vibration	Uneven platform	Place unit on a flat surface
Mixer-grinder generates abnormal noise	Blade assembly is loose	Tighten dome nut of the blade assembly
	Coupler is loose	Contact service point
Smell emanating from the unit	Motor may be burnt	Contact service point
Jar leaks at base	Sintered bush / spindle worn out	Contact service point
Jar leaks at top	Lid gasket is damaged	Contact service point
	Excess water	Reduce the volume of water

Mixer grinder Maintenance

Mixer grinders or simply mixers are very commonly used kitchen appliances which can be found in almost all households across the world. These appliances help us with several tasks in the kitchen and it is impossible to imagine even a single day without them. To avoid facing any problems which can interrupt the usage, you must maintain and clean the mixers on a regular basis. If you are confused as to how to clean a mixer, then this article will prove to be really useful for you. The following are some of the tips that will help you learn how to clean a mixer grinder:

1. Use lemon peels to clean a mixer

One of the best ways to clean a mixer is to make use of lemon peels. For this, first extract all the juice out of a lemon and then use the peel. Rub the peel on the lid as well as the inner part of the utensil. This will not only help remove the pungent smell but will also help you scrub it to remove small particles. Let the utensil be for 15 minutes and then wash it properly using clean water.

2. Use baking powder

Another great way to clean a mixer is to use baking powder. Take baking powder and some water and make a paste. Now apply this paste on the mixer and leave it there for about 15 minutes. Now wash the container using clean and clear water. This helps to clean it completely and also remove the odour that is left inside.

3. Use vinegar for stains

In order to clean stains that are left on the mixer due to extended usage, you can make use of vinegar. Make a solution using 2 tablespoons of vinegar and some water. Pour this solution into the mixer container and grind for about 2 seconds. Check if all the stains have been removed. If not, then grind again with a little less water in the container.

4. Use liquid detergent solution for cleaning
Take about one or two drops of liquid detergent and drop it in the mixer container with some water. Swirl this solution in the mixer for about 2 seconds and then rinse the container well using clean water. This method too helps to clean a mixer properly and can be done on a regular basis.

5. Use alcohol to clean a mixer
To make your mixer a shiny one and also in order to remove the pungent smell, you can make use of alcohol to clean the mixer. Soak the mixer in a solution made of alcohol and water and let it be there for about 10 minutes. Rinse the container properly using clean water.

4.4Washing Machine

Introduction

A washing machine is a modern domestic appliance and is used to wash clothes. Washing of clothes involves soaking, application of soap, stirring and rinsing. Dirt gets removed from clothes when soap water is forced through pores in the clothes. Once dirt is removed by soap water, the clothes are to be rinsed with water several times. Rinsing removes soap water. Factors that determine quality of washing are water, detergent, heat, time and physical motion. Use of less water increases concentration of detergent. Detergent gets dissolved easily in hot water compared to cold water. Some dirt or stains take time to get dissolved. Application of physical motion like agitation or scrubbing helps dirt removal. In an washing machine washing of clothes is done in two stages: first stage is called wash cycle and second stage is called spin cycle or rinse cycle. In wash cycle clothes soaked in soap water are agitated or rotated in a tub till dirt gets removed from clothes. Soap water containing dirt is then drained out and clothes are rinsed with fresh water by spinning the tub. This is the spin cycle or rinse cycle. There are two types of rinsing: spray rinsing and deep rinsing.

Less amount of water is used during spray rinsing while deep rinsing uses sufficient water. This is repeated till the clothes are free from soap water. With advances in science and technology, numerous models from various manufacturers are available. Latest models have beautiful get up, additional features and complicated mechanisms and control.

Domestic washing machines run on single phase 220-volt AC supply. Low capacity models without heater can have power rating of 300watt, 500 watts etc. High capacity models with heater can have power rating in the range of 2kw to 4 kW. The capacity of washing machine is expressed in kg and it is the weight of clothes that can be put in the machine at a time for washing. Typical values of capacity of available models are 5.5 kg, 6.0 kg, 6.5 kg, 7.0 kg etc.

Types of Washing Machines

Washing machines are classified as
1. Automatic 2. Semi-Automatic.

Depending on how clothes are loaded, they are categorized as
1. Front loading 2. Top loading

In automatic washing machine once the dirty clothes, detergent and water are given as input and necessary instructions are given by means of the control switches, the machine takes control and completes washing. Dirty clothes are to be loaded and washed clothes are to be unloaded and there is no manual work in between. In case of semi-automatic machines, some manual work is involved in between. Loading and unloading of clothes is required before final unloading. Semi-automatic washing machines are generally top loading type. Automatic washing machines can be top loading type or front loading type. Automatic machines have sophisticated control and are costlier compared to semi-automatic machines. In top loading machine the clothes are loaded through a door at the top and the tub is vertical. In front loading machines the clothes are loaded through a door in front of the machine and the tub is horizontal.

1. **Semi-Automatic**

   A semi-automatic washing machine contains two tubs, one for washing and the other for drying. After washing the cloths, if drying is needed, the cloths have to be transferred manually to the drying tub for the drying cycle.

   Advantages:

   - Not necessary to have a continuous water flow. Manually water can be poured to the desired level based on the cloths to be washed.
   - Consumes less water as compared to a fully automatic model
   - Washing cycle requires less time
   - Can be moved easily to any location

   Dis Advantages:

   - Manual intervention is required to transfer the cloths from wash tub to spin tub for drying process
   - You may have to remove the electrical connection while moving clothes from washing to drying, if wiring in the house is not properly earthed
   - Most of the controls are manual
   - Requires more space because the machine may be larger than the fully automatic

2. **Fully Automatic (Top Loading)**

   This is the most common type of washing machine. Clothes are placed into the top of the washing tub, and a lid closed.

   Advantages:
   - Generally cheaper than front loaders
   - Set the required functions and then the machine works automatically and completes the whole cycle from washing to drying. You can select only wash or wash & dry or any other functions as per the model specifics.
   - Usually lighter in weight
   - Wide range of models and feature choices is available

   Dis Advantages:
   - Running flow of water needed for the machine to complete the cycle automatically
   - Consumption of water is high

3. **Fully Automatic (Front Loading)**

   This washing machine will have door at the front for placing clothes inside. It moves clothes around by rotating the drum.

Advantages:

- Comes with a built in heater (model specific)
- Generally, more water efficient
- Wash quality may be better because of a tumble wash
- Generally, has more cycle settings – some washers have a heating element for an extra hot wash

Dis Advantages:

- Higher initial cost
- Slower wash cycle – although some models have a quick setting
- Weight will be higher than top loading machines
- Smaller range and capacities available
- Needs a fixed place. Cannot be moved around

Difference between Semi-Automatic, Fully Automatic Washing Machines

Table4.6

Feature	Semi-Automatic(feet)	Top Loading Agitator(inches)	Top Loading Impeller(feet)	Front Loading(inches)
Capacity	4 Kg to 8 Kg	5.5Kg to 6 Kg	5.5 Kg to 10 Kg	5 Kg to 8 Kg
Wash quality	Ok	Good	Good	Best
Delicate Clothes	Ok	Rougher	Good	Best
Fuzzy logic	No	Yes	Yes	Yes
Wash cycle	Fastest	Fast	Fast	Slow
Hot Wash	No	Few	Few	All
Space Required	More	Less	Less	Less
Easily Moveable	Yes	Yes	Yes	No
Water Connection	Not Required	Required	Required	Required with pressure
Adding of clothes after wash cycle started	Yes	Yes	No, not at all	No, not at all
Human effort	Very high	Very less	Very less	Very less

Washing Machine Construction

Let us see the important parts of the washing machine; this will also help us understand the working of the washing machine. Please refer to the image below.

1) Water inlet control valve: Near the water inlet point of the washing there is water inlet control valve. When you load the clothes in washing machine, this valve gets opened automatically and it closes automatically depending on the total quantity of the water required. The water control valve is actually the solenoid valve.

2) Water pump: The water pump circulates water through the washing machine. It works in two directions, re-circulating the water during wash cycle and draining the water during the spin cycle.

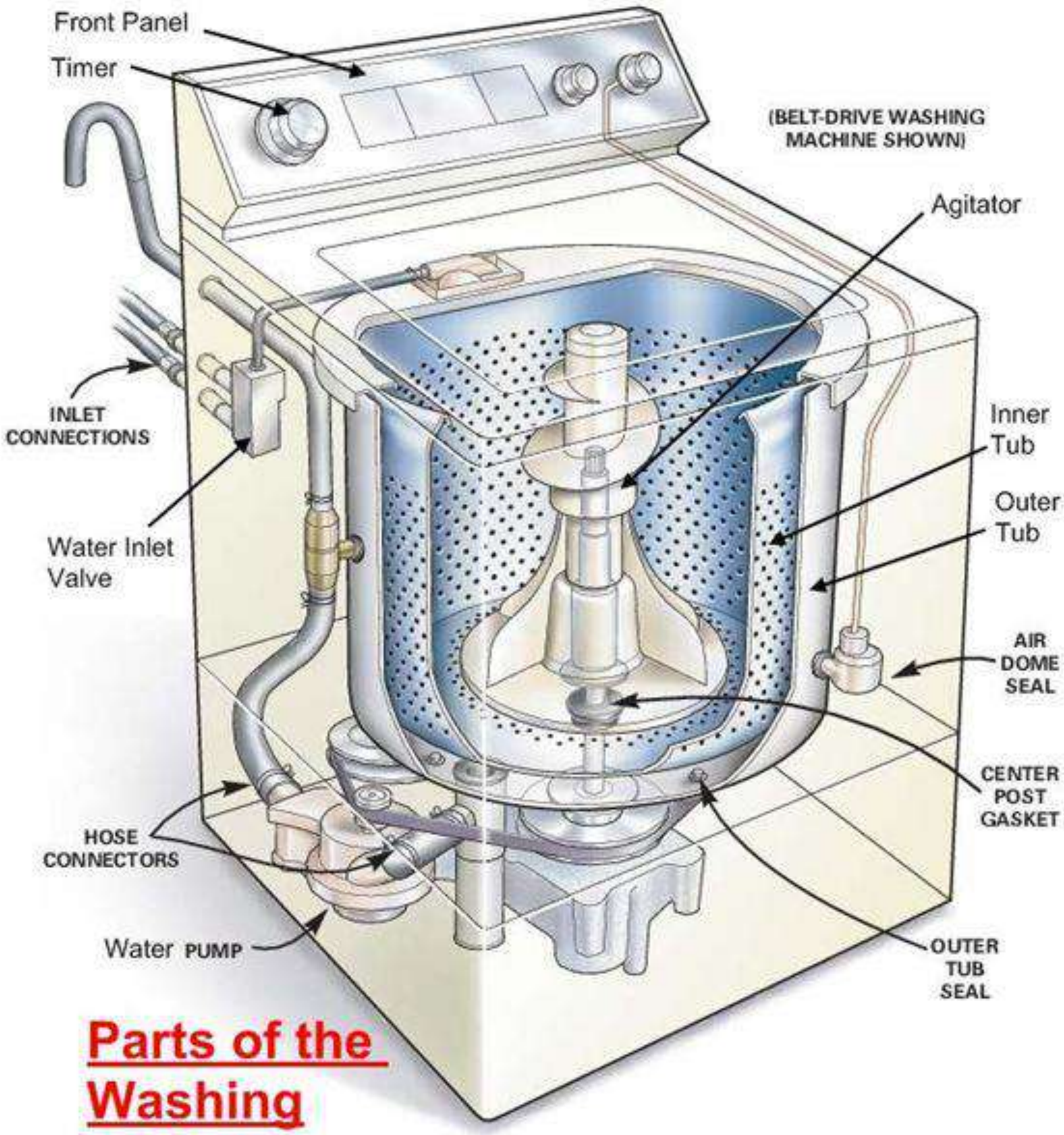


Fig 4.28**Washing Machine**

3) Tub: There are two types of tubs in the washing machine: inner and outer. The clothes are loaded in the inner tub, where the clothes are washed, rinsed and dried. The inner tub has small holes for draining the water. The external tub covers theinner tub and supports it during various cycles of clothes washing.

4) Agitator or rotating disc: The agitator is located inside the tub of the washing machine. It is the important part of the washing machine that actually performs the cleaning operation of the clothes. During the wash cycle the agitator rotates continuously and produces strong rotating currents within the water due to which the clothes also rotate inside the tub. The rotation of the clothes within water containing the detergent enables the removal of the dirt particles from the fabric of the clothes. Thus the agitator produces most important function of rubbing the clothes with each other as well as with water.

In some washing machines, instead of the long agitator, there is a disc that contains blades on its upper side. The rotation of the disc and the blades produce strong currents within the water and the rubbing of clothes that helps in removing the dirt from clothes.

5) Motor of the washing machine: The motor is coupled to the agitator or the disc and produces it rotator motion. These are multispeed motors, whose speed can be changed as per the requirement. In the fully automatic washing machine the speed of the motor i.e. the agitator changes automatically as per the load on the washing machine.

6) Timer: The timer helps setting the wash time for the clothes manually. In the automatic mode the time is set automatically depending upon the number of clothes inside the washing machine.

7) Printed circuit board (PCB): The PCB comprises of the various electronic components and circuits, which are programmed to perform in unique ways depending on the load conditions (the condition and the amount of clothes loaded in the washing machine). They are sort of artificial intelligence devices that sense the various external conditions and take the decisions accordingly. These are also called as fuzzy logic systems. Thus the PCB will calculate the total weight of the clothes, and find out the quantity of water and detergent required, and the total time required for washing the clothes. Then they will decide the time required for washing and rinsing.

8) Drain pipe: The drain pipe enables removing the dirty water from the washing that has been used for the washing purpose.

Washing Machine Working

Dirty clothes are put in a tub. The tub is cylindrical and is made of aluminium or copper or steel or fibre glass. There are small holes on the tub. In top loading machines, the tub is vertical and is fitted inside a solid outer tub. Generally, an agitator is there at the centre of the tub. Agitator is driven by motor and it stirs and agitates soaked clothes. The action of agitator cleans the clothes by flushing out dirt particles from clothes. Soap water is drained out and the clothes are rinsed with water several times till they become free from soap. Water is extracted from the clothes by spinning the tub. The spinning speed is usually between 400 to 1000RPM. When the tub is spinned water from the clothes come out through the holes to the outer tub due to centrifugal force and is drained out. Top loading models without an agitator undergo pulsating oscillation to agitate the soaked clothes.

Troubleshooting Washing Machine

If your appliance is still under guarantee, please carry out a few simple checks as we advise below, and also check your manufacturer's manual (especially if your machine is displaying an error code) before you go to the trouble of calling our Technical Support line.

Machine has stopped, or won't drain

If you can open the door:

Heavy or uneven loads can prevent the machine from creating a balance and so cause it to stop.

- Resolve this by reducing the spin speed for small loads or bulky items like towels.
- If the load is very large, you may need to remove some items and spin them separately.

If you can't open the door:

You'll need to drain the drum manually.

- Turn off the appliance and disconnect it from the mains.
- Lay down some towels and have a mop to hand.
- Slowly loosen the filter, allowing the water to drain.
- The filter is generally located at the bottom right of the appliance, but this can vary (check your manual)

Then in both cases:

- Once the appliance is drained, remove the filter and check the filter and its housing for any signs of obstruction.
- Run the filter under warm water and clean it gently with a soft brush but NO detergent.
- Remove any obstructions from the filter housing and replace the filter, ensuring it's tightened sufficiently.

The wash cycle isn't starting

The most common cause of this is that the child lock has been activated. Find instructions to deactivate in your user manual

Machine isn't cleaning properly

Your clothes need space to move freely within the drum during a cycle:

- If the drum is too full it may affect the efficiency of a cycle or even prevent it from completing.
- Try reducing the load and seeing if this helps.

If this doesn't work, you may need to do a maintenance wash.

- Find instructions on how to do this in your user manual; it will be longest hottest cycle with no detergent added.
- Remove the drawer and clean it and the aperture housing it thoroughly with hot water, but not washing up liquid.

Machine isn't turning on

It may sound obvious, but:

- Check the connections to make sure the machine is plugged into the mains socket and switched on

If it is:

- Can you check the Residual Current Device (RCD) in the consumer unit (known as the fuse box)? Has this tripped? If so, you may need to reset by flicking the switch.
- If you don't feel confident about doing this, or it happens more than once, the please do consult an electrician.

Machine is noisy and unstable

If your washing machine appears noisy or unstable when using it for the first time:

- Please make sure the protective brackets or transit bolts (used for safe transportation) have all been removed before using your washing machine.

- You can keep them in case you need to transport your appliance again in the future
- Full instructions on how to do this are usually on the first few pages of your user manual
- It may also be that the machine or the floor beneath is not level, or that the floor is "bouncy". You may need to add a flat board beneath the machine to stabilise it.

Machine is leaking

Before your washing machine leaves the factory, the manufacturer tests it to ensure that it won't leak from any internal components after you've installed it. Any leaking before or during its first use is most likely due to water still remaining in the machine following testing.

If we've installed the machine for you, please get in touch. If not, you can carry out these further checks:

- First, check the fill hose, drain hose and mains plumbing for leaks.
- Check the fill hose connection to your washing machine and to the mains plumbing (taps) is secure.
- It’s also possible for a leak to appear from your detergent dispenser, which can be caused by excessive water pressure or the washing machine not having been levelled properly during installation.
- You can raise the front of the appliance by adjusting the feet at the front of the machine.
- We would also recommend double checking the water supply hose connections (at both ends) as well as checking the drain hose during the pump out process.

Machine smells

There are a number of reasons that could cause your washing machine to smell:

- Consistently washing at low temperatures is better for saving energy, but means that bacteria and possibly undissolved detergents can build up, causing your machine to smell.
- To resolve this, run your machine empty at 90°C using some biological detergent to help destroy the build-up of bacteria and detergents. It's a good idea to do this monthly.
- If you live in a hard water area, then descale your machine regularly
- You should also check if your washing machine drain hose connects to your under sink plumbing. If so, make sure this is clean and free from any blockages.

Washer won't drain

A washing machine not draining is one of the most common problems we encounter. It can be caused by one of the following:

- The drain hose or pump is clogged with a small item of clothing, residual gunk or other debris.

- The washer is malfunctioning and not engaging the drain/spin cycle properly. It may present with an error code - check with your product manual or give the manufacturer a call to clarify what this refers to.

- The drain pump is broken (the washer will generally make an unpleasant sound and/or start leaking if this is the case).

Solutions

Resetting your washing machine

- First, you should perform a general reset of the machine. Turn the machine off at the PowerPoint, wait for one minute, and then turn it back on.
- If you see no change, you can try a Master Reset. This will reset all of the on-board componentry and is often successfully used by appliance technicians. Open and close the door of the washing machine 6 times within 12 seconds. Then, run the rinse/spin cycle without clothing to see if your problems are resolved. If it drains, problem solved! If not, let’s move onto the unclogging!

Unclogging the drain hose

- Turn the machine off at the PowerPoint. You should always do this before moving the machine or making any adjustments.
- Check that the drain hose is not kinked or bent. This can affect the washer's draining and may be causing the error.
- Now, remove the drain hose from the back of the machine. This is usually attached with a couple of simple screws. You may need a hand to pull the washer from its spot to access the hose entry point.
- Run some water through the hose to force the clog out. An outdoor hose connection works well. You can also use a plumbing snake, stick or long object to push the clog or item out.

If you aren’t able to easily remove the drain hose, run the hottest cycle on your machine without clothing, as this may loosen up the blockage and push it through.

- Once water is steadily running through the washer drain hose, re-attach it to your machine. To ensure your machine drains efficiently, make sure that the end of the hose is not more than 12cm into the drain hole, and that it’s not kinked or bent.

The washer door won’t unlock

This is a problem most commonly found in front loaders, as top loaders don’t need to lock their doors to keep water inside.

Front loaders need to stay tightly sealed during operation. It’s not until the end of the wash cycle that the machine will unlock automatically. However, sometimes a front loader will malfunction and remain locked, trapping clothes and water in the machine.

There are a few possible reasons for this:

- The locking mechanism could have jammed (maybe some clothes have gotten in the way).

- There could be a glitch in the washer’s computer.

- The washing machine may not be draining properly, leaving the washer door locked and the drum filled with water.

Solutions

- **Restart it:** If you think it might be a digital problem, try the old reset trick. Turn the washing machine off at the power point for at least 60 seconds, and then turn it back on. With a little luck, the master reset should restart the wash programs.
- **Run a short cycle:** If you think the problem is your clothes physically jamming the lock, you can set the washer to run another short cycle. This should get the clothes moving and hopefully unjam the lock. Sure, your clothes will get washed twice, but it saves calling out a technician for a simple solution!
- **Check the drainage hose:** If the machine isn't draining, it may be time to inspect the drainage hose for clogs. A kinked drain hose can also affect wash cycles.
- **Contact the manufacturer**: If all else fails, contact the manufacturer – they can provide you with advice, and if your machine is under warranty, arrange for a

Pause Washing Machine Mid-Cycle

If phone is trapped inside the washer / left favourite shirt out of the wash!

It may seem blatantly obvious, but we've all done it – we've all forgotten to clean something important, or left something important (like a mobile phone) in our pocket when doing the laundry.

If you've got a top loader, this is an easy one to solve. Just open the lid and add/remove the item in question. No mess, no fuss.

In a front loader, things get a bit more complicated. Front load washers lock their doors during cycles to prevent water from spilling all over your laundry floor.

Solutions

Unless you've purchased a washing machine in the last couple of years, you won't be able to open your front loader once the wash cycle has started.

Manufacturers now make front-loading models that can be paused before the main wash cycle so that clothes can be added.

Fuzzy logic Washing Machine

Fuzzy logic controls the complete washing process. Depending on the clothes quantity, washing machine's fuzzy logic automatically decides the required amount of water,water temperature,rinse and spine, advice to use required amount of detergentand wash them. As there is no standard for fuzzy logic, different manufacturers, uses different types of sensors or combination of sensors are used to determine best wash conditions by fuzzy logic. These sensors monitor the whole wash process and makes corrections to gives best wash quality. In some more advanced washing machines, weigh the clothes so that you can't have to overload the machine, automatically draw required detergent from the inbuilt detergent tray, some other machines use advanced past experience learning, memorizing programs, adjust the wash cycle in such a way the it minimizes the total running cost.

Fuzzy logic checks the balance of washing load. If sensors detect the imbalance, it makes rebalance and starts the machine, In other case, it slow down the spinning speed. This control washing machine spinning, reduces the spinning noise as well as improved durability of washing machine.

Washing Machine Maintenance

1. Inspect the hoses.

Every month or so, make sure there are no bulges or cracks and the fittings are tight.

2. Don't overload it.

Oversize loads can damage your washer, so break up your laundry into smaller loads.

3. Use the right type of detergent.

Make sure you're using the right kind for your model. Many energy-efficient washers require a low-sudsing detergent.

4. Use the right amount of detergent.

Too much detergent will leave a residue and is hard on your washer. Pods make it easy, but if you're using liquid, measure according to the manufacturer's directions.

5. Clean the interior and dispensers.

Yes, you need to wash the washer. This will help keep it clean and smelling fresh. TIP! Every month or so, run an empty load of hot water with 2 cups of white vinegar. In the middle of the wash cycle, add ½ cup of detergent. Let the full cycle complete.

6. Wipe down the drum, door and gasket.

Doing this once a month will help ensure the washer won't give off odours that can seep into your laundry. TIP! Use equal parts water and vinegar to clean the gasket.

7. Leave the door ajar after a load.

Ever notice a smell when you open your washer to start a load? This can help with that.

8. Transfer clean laundry to the dryer as soon as it's done.

Letting wet clothes languish in the washer can trigger mold and mildew.

Trouble shooting guide of Washing machines

Table 4.7

Problem	LED Alarm	LCD Alarm	Possible Solution
The machine does not turn on or start			• Make sure that the power plug is inserted. • Make sure there is power in the socket. • Make sure that the selector switch, programme selector knob 1, is not in the OFF position.
The machine turns on but does not start and LEDs No. 1 and 2 flash (LED model) or F1 appears on display (LCD model) .	o o ● ●	F1	• Make sure the door is well closed
The machine does not take water and LEDs. 1 and 3 flash (LED model) or F2 appears on display (LCD model) .	o ● o ●	F2	• Make sure there is water supply. • Make sure the water tap is opened. • Make sure the water inlet hose is not squashed. • Make the water electro-valve filter is not clogged
LED number 2 and 3 flash (LED model) or F3 appears on monitor (Display model).	o ● ● o	F3	• Switch off and then switch on the washing machine. In the fault persist contact an authorised service centre.
The machine does not empty, does not spin and LED 1 and 4 flash (LED model) or F4 appears on display (LCD model)	● o o ●	F4	• Make sure the drain pump filter is not clogged. See page 22. • Make sure the rinse hold special function is enabled. • Make sure that the drain hose is not squashed and the internal diameter of the drainage is larger the that of the drain hose.

Problem	LED Alarm	LCD Alarm	Possible Solution
LED number 2 and 4 flash (LED model) or F5 is displayed (Display model).	● o ● o	F5	• Switch off and then switch on the washing machine. If the fault persists contact an authorised service centre.
LED number 1, 2 and 4 flash (LED model) or F6 is displayed (Display model).	● o ● ●	F6	• Switch off and then switch on the washing machine. If the fault persists contact an authorised service centre.
The door does not open			• Make sure the red pilot lamp turns off. • Make the special function SOAK or RINSE HOLD is not activated • Push the door from the door locking side or give a slight tap and at the same time pull it to open.
The is water on the floor			• Make sure both the water inlet hose and drain hose are whole and do not leak. • The washing detergent could not be ideal or could be excessive. • Reduce the detergent quantity.
The washing machine pelting in water even when it is off.			• Reduce the pressure of water supply or the water pressure pumping system (water autoclave). • Tap should be off when washing has done.
The machine vibrates noticeably.			• Ensure that the transportation screws have been removed during installation. • Make sure the drain pump filter is not clean. Ensure that the drain pump is squashed and that the machine drains effectively. • Ensure using the correct detergent for washing machine. • Make sure that the laundry is not amassed or knotted and that the spin speed is adequate for the laundry load. It so recommended that for excessive laundry load and less than half the nominal load capacity set the spin speed to low. • Ensure that the machine is properly levelled on the floor. It is recommended that for any eventual feet imbalance compensation the feet must regulated and lock them in place with the locking knob (see figure 3b on page 10).

4.5.1Vacuum Cleaner

Vacuum Cleaner

Dust in the house contains the bacteria, fungal, allergic particles, mist, and environmental contaminants like perfluorooctanoic acid (PFOA), carbon dioxide, nitrous and sulphur oxides. Environmental contaminant concentration increases drastically in cities and metros due to the automobiles. A vacuum cleaner is one of the solutions to get a clean environment in the house. It helps in reducing the allergic environment in the house. Microfiltration bags used in the modern vacuum cleaner have the ability to capture 99% of the dust particles of size up to 0.3 microns.

Working principle of the vacuum cleaner

When you sip soda through a straw, you are utilizing the simplest of all suction mechanisms. Sucking the soda up causes a pressure drop between the bottom of the straw and the top of the straw. With greater fluid pressure at the bottom than the top, the soda is pushed up to your mouth. This is the same basic mechanism at work in a vacuum cleaner, though the execution is a bit more complicated.

There are many different types of vacuum cleaner, but all of them work on the same principle of creating negative pressure using a fan, trapping the sucked-up dirt, cleaning the exhaust air and then releasing it. The world would be a much dirtier place without them.

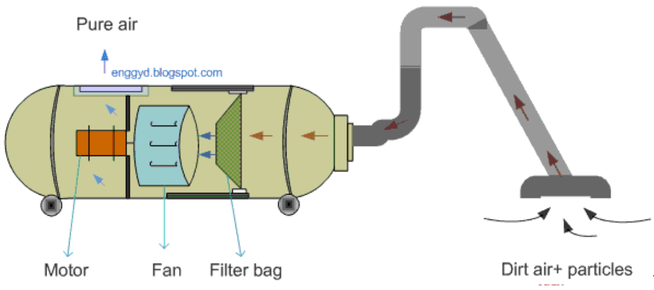


Fig 4.29

Materials flow from one location to another when a pressure difference is created between two locations. This phenomenon is the basic working principle of an ideal vacuum cleaner. When a centrifugal fan rotates it makes the air to flow by adding it external kinetic energy. Air is sucked from behind and pushed forward with pressure and so negative pressure it creates behind the fan. An ideal vacuum cleaner has such centrifugal fan in it connected to a motor. This unit has suction and discharge connections, on the suction side filter bag is fitted before the hose connection. The discharge has another air purifier filter and opened to the atmosphere. When the electric power is given the motor rotates and so the centrifugal fan. Air from the suction side is sucked into the unit, along with the air all air born particles, cat allergen, mist, dirt, and small solid particles are carried to the suction filter. They are trapped in the filter and dirt free air is pushed out from the discharge opening.

Types of vacuum cleaners

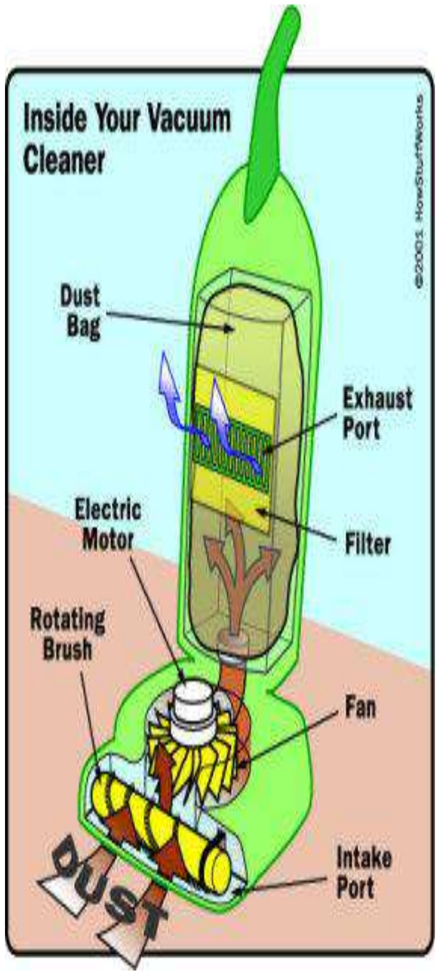
Domestic

- Vertical and horizontal dry and wet cleaners
- Robotic vacuum cleaners:

Construction of the vacuum cleaner

Different Parts of Vacuum Cleaner and Its Function

Vacuum cleaners consist of dozens, sometimes hundreds of parts. While many of these components aren't vital to the mechanical operation of the vacuum cleaner itself (i.e. the wheels), knowing what parts of your vacuum cleaner are crucial to its operation is important to understand what has to be fixed if and when these machines do eventually break down.



Intake Port and Rotating Brush

The intake port and rotating brush work together to draw dust, dirt and other undesirables from the floor into the vacuum cleaner. Like many other parts of the vacuum, these are powered by the internal motor.

Internal Fan

The internal fan, usually located behind the rotating brush in most vacuum cleaners, continues to guide the dirt and dust to the filter and dust bag/bin.

Motor

The motor is the heart of the vacuum cleaner, powering all of the belts and fans that keep the device running properly.A **universal motor** is typically used as suction motor across vacuum cleaners. It is attached to a fan which forces air over the exhausted unit. The suction power and performance all depend on this motor power. High power motor offers more sucking capabilities eventually but you should look other factors a well to determine the best performance of a vacuum cleaner.

Fig 4.30

Filter

The filter in a vacuum cleaner is used to separate the heavy, solid objects from the dust. This is important to the regular function of the vacuum, as it helps prevent large objects from either breaking fan blades or punching holes in the dust bag.

Dust Bag

The dust bag, which is often times not even a bag but a plastic bin, is where the vacuum deposits the trash that was picked off of the floor. Some vacuum models have the dust bag split into two sections -- one for solid items, the other for dust, dirt, paper, etc.

Control Module

The control module or digital display is usually used on a central suction unit of a vacuum cleaner. Some cases many residential vacuum cleaners also got control module. It will show you the current status of bag, filters and other important matters.

Power Head

Powerhead or power nozzle is found at the base of any vacuum cleaners. They offer height adjustment capacity of brush roll for different types of floor. They are suitable using any kind of floors form wooden floors to carpet floors. Many power head includes clog port for easy removal of blockages. That power head is lack of clog ports often damage your unit. So, it’s a better option to have.

Attachments

The power of a vacuum cleaner is determined not just by the power of its motor, but also the size of the intake port, the part that sucks up the dirt. The smaller the size of the intake, the more suction power is generated, as squeezing the same amount of air through a narrower passage means that the air must move faster. This is the reason that vacuum cleaner attachments with narrow, small entry ports seem to have a much higher suction than a larger one.

Cord

Maximum full range vacuum cleaners use power cords to penetrate current to the internal unit. The Cords can come with different length. Its depend on vacuum models though and also type of vacuum cleaners like tile floor or pet hair vacuum or more. Many vacuum cleaner has a useful feature to retract cords. They have an automatic switch to retract power cord inside the cleaner. But for others, you have to wrap them manually.

Power Source

The power source, usually either a battery or a long cord that connects into a power outlet, is used to supply electricity to the unit as a whole.

Filters of the vacuum cleaner

The air, however, does not just pass through and get ejected out the other side. It would be very harmful to people using the vacuum. Why? Well, on top of the dirt and grime that a vacuum picks up, it also collects very fine particles that are almost invisible to the eye. If they are inhaled in large enough quantities, they can cause damage to the lungs. Since not all of these particles are trapped by the bag or canister, the vacuum cleaner passes the air through at least one fine filter and often a HEPA (High Efficiency Particulate Arresting) filter to remove almost all of the dust. Only now is the air safe to be breathed again.

Vacuum cleaner filter types - India

Vacuum cleaner cleans surface by sucking dust, dust particle into it by air pressure and store dust, dirt etc. in dust bag or bin, during this process on top of the dirt and grime that a vacuum picks up, it also collects very fine particles that are almost invisible to the eye. It releases air back in into a home which might be contaminated with allergens. If they are inhaled in large enough quantities, they can cause damage to the lungs. To avoid releasing contaminated air into the home environment, filters are used to purify the air. Contaminated air forced to pass through the filter and filter trap, block the airborne disease causing allergens, bacteria, viruses, dust mites

Cartridge filter

Cartridge filters are made up of foam, synthetic products. It capable to capture minute 3.0 microns dust particles. This disposable filters need to be replaced time to time depending on the usage in order to vacuum cleaner perform well. Usually cartridge filters are in cylindrical shape which are fitted into the cylindrical, airtight space made in vacuum cleaner. Cartridge filter size varies model to model vacuum cleaner, so before buying a new cartridge filter s look for the measurement of old cartridge filters. Here the few featured cartridge filters that are well known by their name are as follows.

- HEPA filter
- ULPA filter

Fig 4.31

HEPA filter

HEPA stands for High Efficiency Particulate Air. Vacuum cleaner which are equipped with HEPA filter exhaust less dust, dirt particles during vacuuming, cleaning. HEPA filters pushes dust, dirt air to passes through it, during this process HEPA blocks, traps pullen, dust particles and at the end it releases purified air back to in your leaving home.

Basically, most of HEPA filters are made up of glass fibres. Many glass fibres are arranged in such a manner that it forms a heavy mesh, mat filterin which air can easily pass through it, but whatever contaminants present in air such as dust, pollen (powdery substance), dust mites, pet dander are trapped, blocked by HEPA filter. True HEPA filter capable to capture 99.9% contaminants of 3.0 microns and larger. Although, HEPA filter do its best part, but still there remains some contaminants which are can easily removed by using some other pre and post filters. Prefilter like cloth filter capture large dust particles therefore helps to increase efficiency and durability of HEPA filter.

However, HEPA filters are inefficient to treat unpleasant smell, bad odour or VOC (Volatile Organic Compounds - such as released from burning fuel like wood, coal, diesel and petrol). Activated Carbon filter is best one to treat bad odour. Activated carbon filter absorbs bad odour and exhaust, releases purified air back to in your room.

HEPA filters are non-washable or non-reusable. You have to replace HEPA filters frequently depending on the usage, frequency of cleaning. If you are asthma or allergies sufferers, HEPA filter is perfect, absolute choice for you. However, HEPA filter work perfectly where it air tight fitted in vacuum cleaner. In case of dire gaps, HEPA it loses its efficiency and releases unpurified air back into your home.

ULPA filter

ULPA stands for Ultra Low Penetration Air. ULPA more related and just like HEPA filter, moreover ULPA filters are more efficient than HEPA filters. It capable to remove 99.999% of contaminants of diameter size 0.1 microns and larger.

Just like HEPA filter, ULPA filter also made up of many randomly arrange glass fibres which together form a thick mesh. Only the difference between ULPA and HEPA is, ULPA capable to capture very minute 0.1 micron and larger particles whereas HEPA captures 0.3 micron and larger particles.

Table4.8

	Made of material	**What it can extract**	**Reusability or washable**
HEPA	Glass fibers	Removes particles of size 0.3 microns in diameter	Most of are non-washable
ULPA	Glass fibers	Removes particles of size 0.12 microns in diameter	Most of are non-washable
Clothe filter	Clothe	Large size particles	Most of are washable
Foam filter	Foam	Small size particles	Most of are washable
Disk filter	Cloth or paper	Small size particles	Most of are non-washable

Cloth Filters Fig 4.32(a)

Cloth filters are used to filter large size dust, dirt particles. Mostly these type of filters are fitted in heavy size vacuum cleaner which are designed to used at industrial sites. Cloth filters are washable and can be reused many times. Here some featured cloth filters are as follows.

Foam filter Fig 4.32(b)

Foam filter are used as secondary filter. Foam filters separate air and dust particles before it exhausts out. Most of the foam filters are washable so that you can reuse many times.

Disk Filters Fig 4.32(c)

As it names, these filters are in shape of disk. These filters are made up of cloth or paper. Most of robotic vacuum cleaner are integrated with this type of filters. Disk filters are capable to handle low to moderate level of dust particles. Disk filters are made to equipped in moderate powered vacuum cleaners.

Here the some of features that might be included in above mention vacuum cleaner filters. These feature are clubbed with cartridge, cloth, foam or disk filters.

Feature: Allergen filters
These are the cloth filters that capable to capture minute particles. However, allergen filters capacity not more than HEPA filters.

Feature: Micro Fresh filters
Micro Fresh is a non-toxic chemical element that prevents the development of airborne disease causing bacteria, viruses and fungus. Micro fresh sterilize, disinfect the exhaust air before it release in outer environment.

Feature: Washable filters
As it names these filters are washable and can be reuse again. Washable filters increase the performance of vacuum cleaner and they reduce the vacuum cleaner running cost. However, all vacuum cleaner's filters are not washable, to know your filters are washable or not check your vacuum cleaner user manual.

Feature: Scented filters
Scented filters adds pleasant smell to filtered air before it releases air back into room. Wherever vacuum cleaner sucks the dust particles, whatever filter might block dust particles but air might be contaminated by bad odour. These scented filters add pleasant smell and maintain aesthetic environment in your home.

There are a lot of vacuum cleaner filter types and each of them comes with its own distinguished features that make it stand out from the crowd. In view of this fact, put into consideration the type of work the filter will do, the environment where it will be used, and the health issues when you want to buy one.

Vacuum cleaner Working

When you plug the vacuum cleaner in and turn it on, this is what happens:

1. The electric current operates the **motor**. The motor is attached to the **fan**, which has angled blades (like an airplane propeller).
2. As the **fan blades** turn, they force air forward, toward the **exhaust port**
3. When air particles are driven forward, the **density** of particles (and therefore the **air pressure**) increases in front of the fan and decreases behind the fan.

This **pressure drop** behind the fan is just like the pressure drop in the straw when you sip from your drink. The pressure level in the area behind the fan drops below the pressure level outside the vacuum cleaner (the **ambient air pressure**). This creates suction, a **partial vacuum**, inside the vacuum cleaner. The ambient air pushes itself into the vacuum cleaner through the intake port because the air pressure inside the vacuum cleaner is lower than the pressure outside.

As long as the fan is running and the passageway through the vacuum cleaner remains open, there is a **constant stream of air** moving through the intake port and out the exhaust port.

The suction created by a vacuum cleaner's rotating fan creates a flowing stream of air moving through the intake port and out the exhaust port. This stream of air acts just like a stream of water. The moving air particles rub against any loose dust or debris as they move, and if the debris is light enough and the suction is strong enough, the **friction** carries the material through the inside of the vacuum cleaner. This is the same principle that causes leaves and other debris to float down a stream. Some vacuum designs also have **rotating brushes** at the intake port, which kick dust and dirt loose from the carpet so it can be picked up by the air stream.

As the dirt-filled air makes its way to the exhaust port, it passes through the **vacuum-cleaner bag**. These bags are made of porous woven material (typically cloth or paper), which acts as an **air filter**. The tiny holes in the bag are large enough to let air particles pass by, but too small for most dirt particles to fit through. Thus, when the air current streams into the bag, all the air moves on through the material, but the dirt and debris collect in the bag.

You can put the vacuum-cleaner bag anywhere along the path between the intake tube and the exhaust port, as long as the air current flows through it. In upright vacuum cleaners, the bag is typically the last stop on the path: Immediately after it is filtered, the air flows back to the outside. In **canister vacuums**, the bag may be positioned before the fan, so the air is filtered as soon as it enters the vacuum.

In the last section, we saw that vacuum cleaners pick up dirt by driving a stream of air through an air filter (the bag). The power of the vacuum cleaners suction depends on a number of factors. Suction will be stronger or weaker depending on:

- The **power of the fan**: To generate strong suction, the motor has to turn at a good speed.
- The **blockage of the air passageway**: When a great deal of debris builds up in the vacuum bag, the air faces greater resistance on its way out. Each particle of air moves more slowly because of the increased drag. This is why a vacuum cleaner works better when you've just replaced the bag than when you've been vacuuming for a while.
- The **size of the opening at the end of the intake port**: Since the speed of the vacuum fan is constant, the amount of air passing through the vacuum cleaner per unit of time is also constant. No matter what size you make the intake port, the same number of air particles will have to pass into the vacuum cleaner every second. If you make the port smaller, the individual air particles will have to move much more quickly in order for them all to get through in that amount of time. At the point where the air speed increases, pressure decreases, because of Bernoulli's principle (see How Airplanes Work to learn about this physical principle). The drop in pressure translates to a greater suction force at the intake port. Because they create a stronger suction force, narrower vacuum attachments can pick up heavier dirt particles than wider attachments.

Wet/Dry Vacuums

For heavy-duty cleaning jobs, a lot of people use **wet/dry vacuum cleaners**, models that can pick up liquids as well as solids. Liquid material would soak paper or cloth filters, so these cleaners need a different sort of collection system.

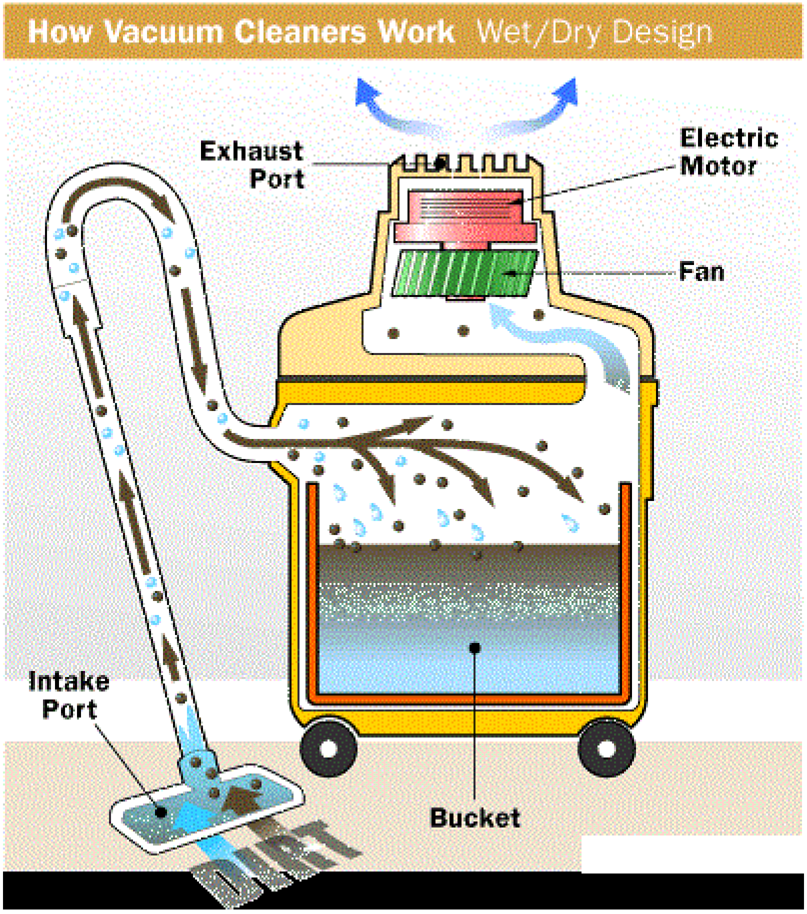


Fig 4.33

The basic design is simple: On its way through the cleaner, the air stream passes through a **wider area**, which is positioned over a **bucket**. When it reaches this larger area, the air stream **slows down**, for the same reason that the air speeds up when flowing through a narrow attachment. This drop in speed effectively loosens the air's grip, so the liquid droplets and heavier dirt particles can fall out of the air stream and into the bucket. After you're done vacuuming, you simply dump out whatever has collected in this bucket.

One type of wet-dry vacuum is the steam cleaner. These vacuums dispense cleaning fluid onto the carpet, massage it in, and then suck up the fluid along with any dirt.

Next, we'll look at two more innovations in vacuuming: the cyclone vacuum and the robotic vacuum.

One recent vacuum-cleaner variation is the so-called "cyclone vacuum." This machine, developed in the 1980s by James Dyson, doesn't have a traditional bag or filter system. Instead, it sends the air stream through one or more **cylinders**, along a **high-speed spiral path**. This motion works something like a clothes dryer, a roller coaster or a merry-go-round. As the air stream shoots around in a spiral, all of the dirt particles experience a powerful **centrifugal force**: They are whipped outward, away from the air stream. In this way, the dirt is extracted from the air without using any sort of filter. It simply collects at the bottom of the cylinder.

The cyclone system is a marked improvement on traditional vacuum cleaners -- there are no bags to replace and the suction doesn't decrease as you suck up more dirt.

Upright Vacuum Cleaners Working
An upright vacuum cleaner uses a motor and fan to pull dirt from a surface and deposit it in a bag. Dirt is loosened and swept into the vacuum with a rotating brush called the beater bar. The upright vacuum cleaner is guided by the operator using the handle on which the bag and controls are mounted. Operation is simple. Maintenance and repairs are easy to perform.

How Canister Vacuum Cleaners Work
A canister vacuum cleaner places the majority of its weight (vacuum motor, filters, bag, and cord winder) in a separate unit to make the power head lighter.

With a long hose, the canister can be placed in the middle of the room and the power head moved more easily. This design allows larger and more powerful motors to be used.

As with the upright, the canister vacuum cleaner loosens dirt with the beater bar, located in the power head and driven by a smaller motor. Dirt is pulled through the hose by the main motor in the canister. Wheels on the canister make it easily portable. Because the fan in a canister vacuum is more isolated than the fan in an upright vacuum, it is generally less susceptible to damage.

Robotic Vacuums
These are the best human caretakers and help in maintaining the room clean. Due to their fuzzy navigation system, they automatically identify and remove the dirt and dust on the floor. Motion sensors provide the robotic vacuum cleaner with the ability to pass between the objects in-house without any obstruction.

Selection of vacuum cleaners

Specifications to be known before buying a vacuum cleaner:

- Collection Bag pore size in micron
- Outlet filter life and pore size in micron
- Motor capacity
- The weight of the equipment
- Movability and easy handling facility
- Self-cleaning feature
- Accessories like painter tool, adsorbent, cord spring
- Less noise generation during cleaning

Maintenance of vacuum cleaner
Like all machinery, vacuum cleaners work best when well maintained. It is also helpful to use them properly. Here are some tips that will give your vacuum maximum performance and longevity. Periodic cleaning of the filter bag maintains the cleaning performance for longer time and power consumption can be maintained consistently.

1. Always Read the Owner's Manual
Whenever you have a new machine you should always read the owner's manual carefully. There will be many hints and tips for getting the best use and longest effective life from your machine.

2. Don't Use Vacuums to Clean up Everything

It is a bad habit to use a vacuum cleaner as the only tool in the house to pick up rubbish. Before using the vacuum use a broom and dustpan to remove the most obvious dirt and debris. Unless you have a wet/dry canister cleaner you should never pick up damp or wet items, and never water or juices that have been spilled.

3. Use the Right Settings

Most vacuum cleaners have height settings for different surfaces. Having a vacuum set too low when in use on a carpet can lead to extra pressure on the motor and brush roller. You should also make use of the correct accessories for special circumstances. For example, don't use the carpet cleaning head for a wooden floor.

4. Regularly Check for Built-Up Dirt

Some parts of a vacuum cleaner accumulate dirt. Areas around the brush roller can get caked with dirt which should be cleaned off regularly. The brush roller should be cleaned frequently. It is particularly important to remove any fibres that have been wound around the roller bearings.

5. Check the Filters

Some filters in vacuum cleaners can be cleaned but others need to be replaced. When a filter is no longer doing the job it should be replaced. Always replace filters with the correct size and avoid cheap copies.

6. Empty Canisters Frequently

It is best if you empty your canister or vacuum cleaner bag after each use. This will ensure you have the maximum power available and avoid the risk that you will leave the bag so long that it will cause the motor to overheat.

7. Replace Bags Frequently

If you use paper bags that can be emptied remember that they do not last forever and you should replace them while they still feel sound. It is too late if they are feeling soft and more flexible, by this stage they are letting larger pieces of grit through.

8. Check the Vacuum Tube

Each time you use the vacuum tube inspect it carefully for damage. It is much more effective to reinforce an area around a small worn area than it is to repair a split in the tube. Also check the tube for any blockages or large items that have not been sucked all the way through it. Do not use the vacuum tube to tow the machine from point to point.

9. Inspect the Power Line

The power cable to vacuum cleaners is subject to all sorts of abuse. Make sure that there is no damage to the outside insulation. Never use the cable at the maximum extension because you could damage the plug or the socket in the wall. Do not pull on the cord from across the room to unplug it and never use a vacuum with a frayed plug or cord.

Common vacuum cleaner problems

Before commencing vacuum repair, find a suitable place in your home to do the work. Expect there to be some dirt created during the repair work and so you should dress accordingly! If you are doing the work inside your house, then take care to protect your flooring and furnishings with a sheet or tarp to capture any dirt. We would also recommend wearing a dust mask, which is essential if you suffer from allergies.

Upright Vacuum Cleaner Repairing

The following tips offer easy instructions for servicing an upright vacuum cleaners on/off switch, beater bar, drive belt, dirt fan, and motor. You'll also learn how to repair an on/off switch, a power-head wire connection, a beater bar, a motor, and a cord reel for a canister vacuum.

Servicing an On/Off Switch: Because of its repeated use, a vacuum cleaner's on/off switch can malfunction. Fortunately, on most models the switch is easy to access and test. Some are fastened in place with rivets, but most use screws. To test and replace the switch:
Step 1: Make sure the vacuum is unplugged, then remove the cover plate to expose the back side of the switch. The switch may be on the handle or on the housing.
Step 2: Check the wires to make sure they are completely attached to the switch.
Step 3: Use a continuity tester or multitester to make sure that there is an open circuit when the switch is off and a closed circuit when it is on.
Step 4: If there is a problem with the circuit, or if the switch doesn't test correctly, remove and replace the switch with one designed to be a replacement.

Servicing a Beater Bar: The beater bar in an upright vacuum cleaner is the first contact your upright vacuum has with dirt. It's also one of the first components to need servicing.
The beater bar is a round roller with an offset row of brush fibres. The brushes can wear down, the roller can be damaged, the end cap can come off and be lost, or the drive belt can come loose. To remove and replace the beater bar:
Step 1: To inspect the beater bar, turn the vacuum upside down. The beater bar will be at the front edge of the housing.
Step 2: Remove the clips at each end, remove the drive belt, and lift the beater bar from the housing.
Step 3: To disassemble the beater bar, remove the end cap and flange; pull the brush from the casing.
Step 4: If worn, replace the brush. If broken, replace the cap, flange, or case. If necessary, replace the entire beater bar.

Servicing a Drive Belt: The drive belt in an upright vacuum cleaner passes power from the motor to the beater bar. The drive belt should be checked once a month to ensure that it is in good condition. Some beater bars have an adjustment that allows the drive belt to be tightened or loosened. To replace the drive belt:
Step 1: Remove one end of the beater bar (see "Servicing a Beater Bar") from the vacuum housing.
Step 2: Loosen the drive belt from the motor pulley and remove it from around the beater bar.
Step 3: Slip the replacement drive belt over the beater bar and around the motor pulley.
Step 4: Reinstall the beater bar and adjust the drive belt as necessary.

Servicing a Dirt Fan: The dirt fan in an upright vacuum cleaner is located underneath the motor. It pulls dirt swept back by the beater bar up into the vacuum bag. In most cases, the dirt fan doesn't need replacement, only periodic maintenance. Here's what you need to do:
Step 1: Remove the motor cover and dismount the motor from the vacuum frame. The fan will be on the underside of the motor.
Step 2: Clean the fan's blades and base with a moist cloth. Inspect the blades for damage caused by vacuuming solid objects.
Step 3: Unscrew or unbolt the dirt fan from the motor shaft to inspect and clean the back side.
Step 4: Check whether the motor shaft needs lubrication.
Step 5: If the dirt fan needs replacement, make sure the new part is an identical replacement. Take the old unit to an appliance-parts store to verify the replacement.

Servicing a Motor: Most upright vacuum cleaners are designed for reasonably long life. However, some will last longer than others. Much depends on the quality of the motor. If a

vacuum's motor stops working unexpectedly, check the power cord, the fan (for jams), and the on/off switch. It's also possible that you have a defective motor. Here's how to find out:
Step 1: If you suspect that the motor is defective, first test the motor's brushes with a continuity tester or multitester.
Step 2: Turn the motor shaft or beater bar by hand. The motor should maintain continuity.
Step 3: If not, replace the brushes or take the vacuum to an appliance-repair shop to have it done. If the motor is unrepairable, consider replacing the entire upright vacuum, as the cost of a new motor is a major investment.

TROUBLE SHOOTING TABLE 4.9

Problem	Possible cause	Solution
The electric motor does not work	• Check if the power plug is plugged well to the socket. • Check if there is power in the socket. • Check if the switch of the appliance is turned on.	• Re-plug the plug to the socket. • Make sure there is power in the socket. • Press the On/Off switch to turn on the appliance.
The suction power is weak	• Check if the floor brush or the hose is clogged. • Check if the dust bag is full of dust. • Check if the front cover is closed. • Check if the filter is clogged. • Check if the extendible metal tube is connected with the floor brush right.	• Remove the clogging timely. • Clean or replace the dust bag. • Close the front cover. • Clean the filter. • Connect the extendible metal tube and floor brush right.
The power line cannot wind up completely	• Check if the power line is twisted.	• Pull out the power line for 2-3m, and then re-winding.
The power line cannot be pulled out smoothly	• Check if the power line is twisted.	• Press the cord rewinding button, wind-up and pull-out the power line repeatedly.
The speed cannot be regulated	• The speed control knob does not work, or the speed regulation engine falls off.	• Turn on and turn off the machine for several times, and if it still does not work, send to the maintenance department for repair.
The power line winds up automatically	• The winder winds up the power line automatically.	• Pull out and wind up the power line for 4-5 times, and if it is still out of order, send to the maintenance department for repair.

Canister Vacuum Cleaner Repairing

A canister vacuum cleaner has its own set of repair procedures. Here they are:
Servicing an On/Off Switch: Like the switches on smallest appliances, the on/off switch on a canister vacuum cleaner gets a lot of use. Considering the ease of repair and its low replacement cost, this switch is one of the first components to check if a vacuum doesn't turn on or off correctly. To test and replace the switch:
Step 1: Open or remove the canister housing to access the back side of the switch.
Step 2: Use a continuity tester or multitester to ensure that there is an open circuit when the switch is in the OFF position and a closed circuit when the switch is in the ON position.
Step 3: Also check the wiring and terminals to ensure that they are connected properly.

Step 4: If the switch doesn't test correctly, remove it and replace it. Some switches are fastened to the housing with screws, others with clips or friction snaps. A few are riveted in place.

Servicing a Power-Head Wire Connection: An advantage of the canister vacuum is that the part that is pushed and pulled across the floor is lighter than with a single-unit upright vacuum. A disadvantage is that power must be delivered first to the canister, then to the separate power head.

The wire connection between the two units is often a source of problems, even in better-quality canister vacuum cleaners. The reason is that there are four sections to the connecting wire: from canister to hose, from one end of the hose to the other, from one end of the power-head tube to the other, and within the power head itself. The end of each section of wire has a connector. If the connection is not made sufficiently, the power head doesn't operate or operates intermittently.

In most cases, servicing the power-head wire connection simply requires that each connector be checked and tightened as needed. If a specific connector frequently makes a poor connection, you can clean the male and female connections with a small piece of emery paper and a can of compressed air.

Broken wires or worn insulators can sometimes be reconnected and wrapped with electrical tape. However, the wire may be located inside the hose, requiring that the hose be replaced as well.

Servicing a Beater Bar: The beater bar on a canister vacuum cleaner is serviced in almost the same manner as one on an upright unit. Here's how:

Step 1: Remove the clips at each end of the beater bar, and pull it and the drive belt from the power-head case. In many cases, all you have to do is clean the brush and the two ends. Remove any excess pet hair or carpet fibers that get wound into them.

Step 2: If needed, remove the beater bar end cap and flange to remove the brush from the shaft and clean or replace it.

Step 3: Also check the drive belt and replace it if it is worn or damaged.

Step 4: When reinstalling the beater bar, make sure there is sufficient tension on the drive belt to rotate the bar by pulling on the belt. If the belt is loose, adjust it following the instructions in the owner's manual.

Servicing a Motor: The motor for a canister vacuum cleaner is easy to access on most models. To test and replace the motor's brushes:

Step 1: Open the canister's top cover and remove the motor cover to expose the motor itself.

Step 2: Place the probes of a continuity tester or multitester on the two wires that lead to the motor from the on/off switch.

Step 3: Rotate the motor shaft a few revolutions by hand. The motor should test as a closed circuit with some resistance. If an ohmmeter indicates no resistance or infinite resistance, the motor is probably damaged.

Step 4: Check the motor's brushes in the same manner, if they are accessible. Replace the brushes if needed.

For other motor repairs, take the appliance to an appliance-repair service or motor-repair shop. If the motor needs replacing, evaluate the overall condition of the vacuum and consider replacing the entire appliance.

Servicing a Cord Reel: The cord reel on a canister vacuum cleaner is a gadget that simply makes storage of the cord easier. It doesn't clean anything. The cord reel unit is usually located at the rear of the canister.

An internal spring offers sufficient tension to retract the cord onto the reel. The cord reel winds the cord in a circle, so the internal end of the cord must also move in a circle. At the same time, it must be electrically connected to the motor.
To make this work, the cord is attached to a rotating contact called a commutator block. It is a circular conductor of electricity that passes current from the internal end of the cord to a stationary block. If the blocks become dirty or corroded, they will not pass current to the motor.
To remove and clean or replace the cord reel:
Step 1: Open the top cover of the canister. Another sealing cover will protect the cord reel -- and probably the motor as well -- from the vacuum chamber.
Step 2: Depending on whether you're cleaning or replacing the cord reel, you may need to remove it from the housing. To do so, find the clips or fasteners holding it into place and undo them. If necessary, cut the two wires leading from the cord reel to the motor. In some cases, you may be able to make adjustments and repairs without cutting the motor wires.
Step 3: Clean the cord reel of dirt, then clean the commutator and stationary block with some isopropyl alcohol on a soft rag. If pitted, the blocks should be lightly sanded and wiped clean.
Step 4: Adjust the spring as needed and reinstall the unit in reverse order, replacing any cut wires.

TOOLS YOU MAY REQUIRE FOR VACUUM REPAIR:

- flat-head and phillips screwdrivers
- pliers
- scissors
- cleaning cloth
- duct tape
- mutlimeter

Ensure that your vacuum cleaner is unplugged from the electrical outlet before undertaking any vacuum repairs!

4.7.9 Advantages and Disadvantages of Vacuum Cleaner

There are many advantages and disadvantages of vacuum cleaner, as it has now become a valuable tool for cleaning dirt and dust in every home. As a matter of fact, they are one of the handiest domestic tools ever made. They purify air quality, offer an effective way for cleaning the floor and reduce the risk of allergy break out. To make vacuum cleaners more functional and efficient, manufacturing companies are coming up with shinning body, latest design and other amazing features. Try our Vacuum cleaner to choose right washing machine by answering simple questions without reading any buying guide.

Advantages of Vacuum Cleaner

- **Vacuum Cleaner Saves Time and Energy**
  Cleaning with vacuum cleaner is not only hygiene but also it more secure than cleaning manually using broom. Vacuum cleaners capable to clean within tens of minutes whereas manually cleaning takes approximately hours. With vacuum cleaner, you can achieve the purpose of thorough cleaning within the shortest time possible. They are fast and easy to use. Additionally, you only need less effort and energy to handle vacuum cleaner.
- **Easy to use**
  Installing, usage of vacuum cleaner is quite easy. Just plug into electricity socket and let move on the floor, anywhere you want to clean.
- **Removes allergen from breathing air**
  Vacuum cleaner are equipped with HEPA or other type of filters which blocks, removes air borne disease causing germs, bacteria and viruses present in your home.
- **Removes pet hair**

Vacuum cleaners are expert in removing pet hair which are stuck in piles of carpet. Due to high suction power vacuum cleaner removes pet hair as well as bad odors from carpet.

- **Vacuum cleaner comes with advanced features**
  Vacuum cleaners of nowadays have series of sophisticated features that you cannot even envisage. When you have vacuum cleaner with sophisticated features, cleaning

Upright vacuum cleaner	
Advantages	**Disadvantages**
○ Large capacity compared to other model vacuum cleaners. ○ Capable to clean a large cleaning area, moreover expert in clean floor with lot of floor traffic. ○ Vacuum cleaner floor head can capable to catch pet hair which stuck in carpet piles.	○ Upright vacuum cleaners heavy, bulky machine. It hard moves machine in corner to clean ○ Incapable to clean stair. ○ It's bend break job to move upright vacuum cleaner to up and down stairs if you are living multi floor home. ○ Very new in India, even it's tricky to get spare parts. vacuum bags in India.

will be easy for you. Furthermore, with vacuum cleaners with advanced features, you will always get the benefit of having automatic surface revealing sensor to ascertain and work
effectively.

Table 4.10

- **Vacuum cleaner is a low cost tool**
  Due to the fact that vacuum cleaner is a low cost tool; you will always get advancement towards any term. Therefore, you can always obtain the advantage of saving time and energy by spending less. The average cost of vacuum cleaner varies depending on the size and the type you want for your cleaning. You can get good vacuum cleaner in range rupees 5,000 to 10,000 rupees in India. Eureka Forbes, Euro Clean, Karcher, Black and Decker and Bissell are trending, well known vacuum cleaner manufactures in India.
- **Discern the quantity of dirt and set settings**
  You will get the benefit of setting up the available alternatives robotically, if you buy the robotic vacuum cleaner. In addition, the vacuum cleaner will become aware of the amount of dirt and work accordingly. As a result, you are not expected to operate the machine physically in order to do the cleaning of your home for you.
- **Clean your home even when you are away**
  The robotic vacuum cleaners will clean your home, even when you are not at home. Thanks to their advanced features that can make them work robotically.

Advantages and disadvantages of upright vacuum cleaners
Disadvantages of Vacuum Cleaner

- **Heavy to lift**

Vacuum cleaners are bulky, cumbersome machine that often hard to move around the home. Moreover, in case of upright vacuum cleaner it almost impossible to move up and down stairs. Vacuum cleaner was manufactured in a fairly large size, although not

Canister vacuum cleaner	
Advantages	**Disadvantages**
Flexible to move around the whole home. Easy to carry up stairs, moreover efficient to clean stairs too. Flexible to clean tricky places like underneath furniture, bed. Work perfectly on sofa set, sofa uphoisoriesw, arm chairs. Can be used to clean the car. Canister vacuum cleaner can be consider as all in one purpose vacuum cleaner.	Canister vacuum cleaners not well perform on carpet.

- heavy. Moving and storing of this device will require a big place.
- **Running electricity bill**
  Depending on the vacuum cleaner model uses hundreds to thousands watts of electricity. Absolutely, if you are using vacuum cleaner, your electricity bill starts running.
- **No Reusable dustbin bags**
  You have to buy reusable dustbin bags when you want to clean your home or other places because some vacuum cleaners don't offer them.

Advantages and disadvantages of canister vacuum cleanerTable 4.11

Applications of different vacuum cleaners Table 4.12

Vacuum cleaner type	Cleaning places
Canister vacuum cleaner	Everything: floor, carpet, stairs, furniture (like sofa), car interiors
Upright vacuum cleaner	Only floor, carpet with the best cleaning
Stick vacuum cleaner	Only floor, carpet, stairs with moderate cleaning
Handheld vacuum cleaner	Only furniture (sofa, curtains, cupboards) and car interiors
Robotic vacuum cleaner	Only floor, carpet with the Robot help

Bag or bag less vacuum cleaners

Depending on the where and how collected dirt stored in vacuum cleaner are divided into two categories.

- Bagged vacuum cleaners
- Bag less vacuum cleaners

Bagged vacuum cleaner

Bagged vacuum cleaners are equipped with a dust bag in its body, in which collected dust, dirt stored in that. When dust bag is full, it can either empty the bag or replace the bag depending on the vacuum cleaner bag type (reusable bag or disposable bag).

Vacuum cleaner bag types

Depending on the reusability vacuum cleaner bags are divided into two categories.

- Reusable bags
- Disposable bags

Reusable bags can be emptied on full and reuse again. Most of reusable bags are washable, so that you can wash the bag when it’s required to avoid dust, dirt clogging. Multiple times reusability makes flexibility to avoid purchasing bags again and again. Although, reusable bags are also limited reusability, depending usage have to replace bag once in a year.

Fig 4.34

Disposable bags are use and throw one, can be used only once. Once the bag is full of dust, dirt you have to replace the bag. It gives you freedom from exposing to dust, it will great feature if you are asthma, allergic patient. Whereas cons side disposable bags make additional overhead. Each time you have to spend hundreds of rupees for a new bag.

Whatever, reusable or disposable bagged vacuum cleaner you are going to choose, make sure that new, spare bags are available in the market, online market or not. Moreover, look for new, spare bags price, they are in your budget or not. It recommended that don’t go for the vacuum cleaner whose cost is low, whereas spare bag cost is high.

Advantages of bagged vacuum cleaners

- In case of disposable bags, just pull off old bag and throw into the dustbin and fit new bag. That’s it, no worrying about exposing to dust.
- The bagged vacuum cleaner provides better filtration. When pressured air passes through the bag it works as a filter along with HEPA filter it provides best cleaning functionality.

Disadvantages of bagged vacuum cleaners

- In case of reusable bags, while emptying dust, dirt flew everywhere, whereas disposable bags this one is not the case.
- For disposable bags you have to continuously spend money on that. The worst thing is, it's very hard to find new bags in small Indian vacuum cleaner market.
- Vacuum cleaner loses its suction power as it gets full.

Bag less vacuum cleaner

Bag less vacuum cleaner contains plastic container (mostly transparent container), the collected dust stored in that. On full of containers, unmount it and dump the dirt into into dustbin.

Generally, bag less vacuum cleaners are two types, one is Filtered and another is Cyclonic bag less vacuum cleaners. In filtered vacuum cleaner, dust particles are trapped, block by filter (HEPA or similar type filter) and fresh, filter air push back into the home. Whereas, Cyclonic vacuum cleaners use cyclonic action to separate dirt and dust particles from air and fresh air push back into the home. However, cyclonic vacuum cleaners are currently not available in India.

Advantages of bag less vacuum cleaners

- Don't have to buy vacuum cleaner bags every day
- As vacuum cleaner dust bin gets full does not lose its suction power
- With use of a bag less vacuum cleaner, you can easily see dust particles collecting in the bin and makes when to empty the bin and you can easily recognize if vacuum cleaner sucks any valuable thing like gold rings, coins etc.

Fig 4.35

Disadvantages of bag less vacuum cleaners

- However,bag less vacuum cleaners save money by avoiding buying bags, but most of the bag less vacuum cleaner equipped with cheap non washable filters and bag less vacuum cleaner makes more pressure to pass air through the filter which makes dust, dirt clogging into the filter. They have to replace once in a year and cost approximately 2,000 rupees. If you are really worried about the maintenance cost, look for the bag less washable filters.
- While emptied the vacuum cleaner bin dust flew everywhere. If you have bad asthma and allergies bag less vacuum cleaner not for you, simply go for the bagged vacuum cleaner with disposable bags feature.

Quick vacuum cleaner bag less vs bagged comparison Table4.

Bagless Vacuum Cleaners	**Bagged Vacuum Cleaners**
You can empty and reuse bins countless times	You have to buy new bags regularly

Bagless Vacuum Cleaners	**Bagged Vacuum Cleaners**
Exposed to dirt while emptying the bin	You are not exposed to dirt
	Best for asthma and allergy patients
Costly *price range: 6,000 - 14,000*	Economical *price range: 3,000 - 6,000*

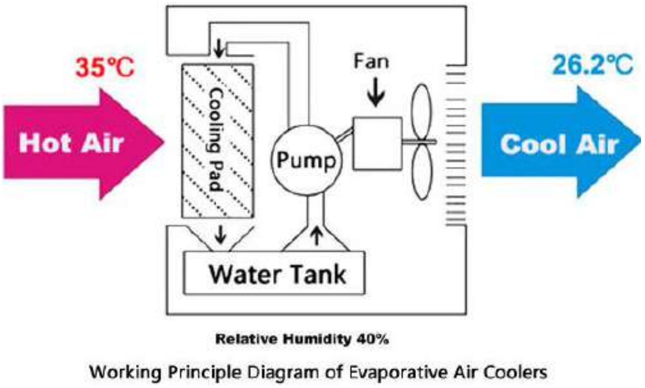
Table 4.13 and 4.14

Robotic vacuum cleaner Advantage	**Robotic vacuum cleaner Disadvantage**
Robotic vacuum cleaners cleans without human Interference.	Robotic vacuum cleaners cannot clean stairs.
You can clean your home when you are away from home.	Expensive compared to other models like canisters, upright, handheld.
Perform best on hard floors.	Perform average on soft floors and carpets.
Can clean underneath of furniture.	Can easily struck up in the clutter of wires and threads if any.
Robotic vacuum cleaners save time.	Long-time of cleaning as it is automated.
Require only weekly maintenances.	Too expensive in India. It costs approximately 20,000 rupees to 50,000 rupees.
	Moderate cleaning quality compared to it's counterpart canister, upright vacuum cleaner.
	You could not use robotic vacuum cleaner to vacuum sofa, bed or curtains.
	Robotic vacuum cleaners have short battery life.

4.5.2Air Coolers

4.8.1 Air Coolers Working

Air coolers, otherwise known as evaporative or swamp coolers, use the evaporation of water to cool an environment. When the air blows past water, some particles on the surface of the water are carried away. Those particles take some heat with them, cooling the air. That is how sweating works: The water particles on the surface of the skin carry off heat with them as they evaporate, cooling the skin. As a bonus, these air coolers use 75 percent less energy than central air conditioners, the Department of Energy reports.



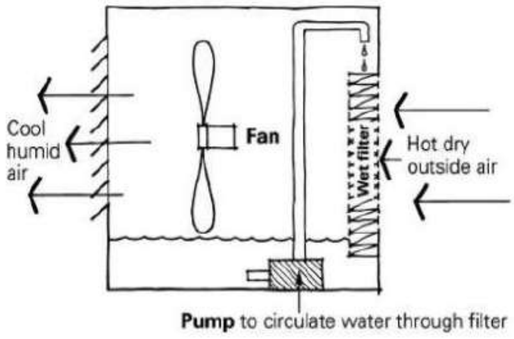


Fig 4.36 and 4.37

Air coolers works by converting the warm air in the environment into cool air by way of water. A fan blows the warm air over water saturated pad that cools the air and adds a bit of moisture before blowing it out into the air of your environment.

The warm air is converted to a cool, moist air. This process is natural and does not use harmful chemical coolants as portable air conditioners do. This unit reduces the heat that comes into the room.

Newer models come with new technologies that combine the benefits of an air cooler and air conditioner all in one portable unit. Many models come with more than one speed. Some models come with a shut off timer that can be set to your preferences. They even come with remote control option to turn your cooler on from across the room.

Levels of Effectiveness

Traditional air conditioners work well in nearly any weather conditions, but evaporative cooling is more suited to some conditions than others. The air can hold only a certain amount of moisture, based largely on temperature. If it reaches that level, water starts to condense out of the air as fast as it evaporates into it, effectively preventing evaporative cooling. The relative humidity is a measure of the proportion of the maximum humidity the air can contain. For example, if the relative humidity is at 20 percent, the air contains 20 percent of its maximum humidity. On hot, dry days, the air can hold a lot more humidity than it contains, and evaporative cooling can decrease the temperature by as much as 30 degrees Fahrenheit. As it gets muggier, however, evaporative cooling becomes less effective. This cooling method works best in hot dry climates and worst in hot, humid climates.

Construction

Evaporative coolers have different designs. In some, a fine mist is sprayed into the air and then propelled out with a fan. The water in this mist consists of fine droplets, causing the mist it to evaporate quickly, absorbing heat from the air. In other systems, air is actually blown past or through some material covered with water. It can be blown through a fine mesh, for example, or past wet pads. The evaporation cools the wet material, which in turn cools the air.

Parts of an Air Cooler

1) On-site Water

Air coolers must have water on site as the coolant for the air cooler. Homeowners might not always have access to on-site water, forcing them to bring water to the site through pipes or other means, which can become expensive in some areas.

2) Fan and vents

A fan is needed to direct the cool air towards the room. These fans continuously flow cool air in the rooms.

The vent on the air cooler has a fan that blows the cooled air into the home. In many cases, when the home has mild weather, the homeowner can set the air cooler to vent-only, which turns the air cooler into simply a fan that directs air to the occupants, cooling them. The vent option does not waste as much energy and does not need a source of water to function.

3) Water source

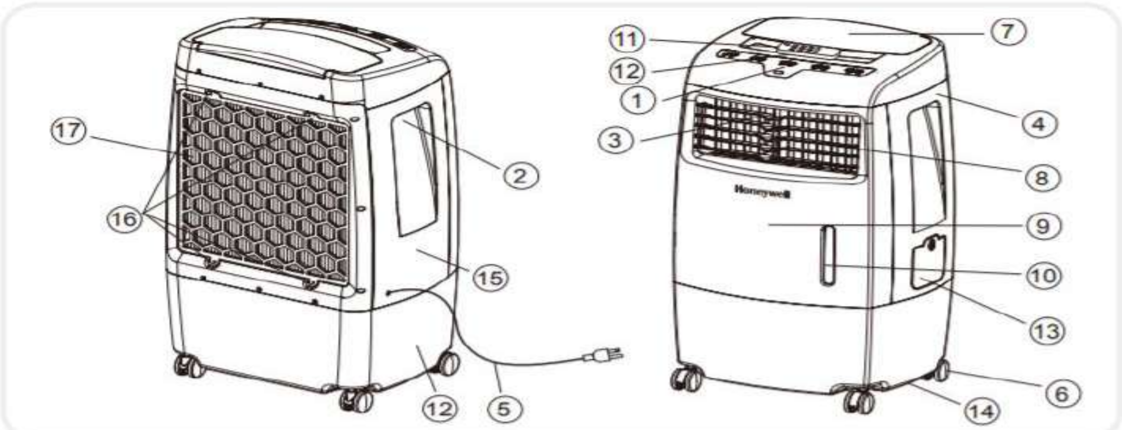
Evaporative cooler uses water so it is necessary to fill the cooler with water so that the cooling can take place.

4) Cooler Pads

Air coolers have pads that absorb water and allow as much air as possible to flow through them. These pads serve as the main medium for cooling the air and thus cooling the home. These pads are made out of pliable aspen wood fibre or special cellulose papers. Synthetic versions of the natural pads last longer but do not hold as much water as the natural versions. They must resist mildew and foul smells since water serves as an ideal breeding ground for mold.

5) Distributor

Water distribution features take water from the on-site source and continually run the water over the pads so that they can remain saturated; otherwise, the water will evaporate too soon. Pumps and motors power the flow of water into the water distribution channels. The pumps must shut off automatically when they do not have enough water to power the pump, or the pumps will overheat and sustain damage. The motors are either axial or centrifugal. Some of these motors need yearly lubrication while other motors have sealed bearings that eliminate the need for yearly maintenance. Homeowners who want quiet air coolers will need belt drive motors though direct drive motors have more efficiency and do not break down as often.



1 Control Panel
2 Side Handle
3 Horizontal Louvers (Manual Adjustment)
4 Left Side Panel
5 Power Cord & Plug
6 Casters
7 Ice Compartment Lid
8 Vertical Louvers (Automatic Movement with SWING)
9 Front Panel
10 Water Level Indicator
11 Remote Control
12 Water Tank
13 Water Fill Door
14 Drain Plug
15 Right Side Panel
16 Rear Grill Removal Screws
17 Carbon Filter & Honeycomb cooling media

Fig 4.38

Installation and Maintenance

These units are easy to install. The job can easily be done by any adult. There is no hose to connect or compressor to deal with as portable air conditioners have. Because the air cooler works to convert warm air to cool, all they need is to be positioned by a window. Open the window an inch or more, according to the directions that come with your unit. Do not worry about letting warm air in, it is needed for the unit to then cool that air and cool your room.

Simply plug the unit in to a regular electric outlet. Pour water into the tank. Point the front of the air cooler to where you want the cool air directed. Then turn it on and enjoy the fresh cool air. Keep water in the cooler tank this will keep the pads wet and the cooler operating sufficiently.

Maintenance can be done by the owner without expensive professional fees attached. Most coolers come with an instruction manual that will walk the owner through any problems and tell you how to fix them yourself. Make sure to follow all instructions on maintenance for your unit. A well-maintained unit will run at peak performance and will cool the air efficiently throughout each day.

These units are easy to install. The job can easily be done by any adult. There is no hose to connect or compressor to deal with as portable air conditioners have. Because the air cooler works to convert warm air to cool, all they need is to be positioned by a window. Open the window an inch or more, according to the directions that come with your unit. Do not worry about letting warm air in, it is needed for the unit to then cool that air and cool your room.

Simply plug the unit in to a regular electric outlet. Pour water into the tank. Point the front of the air cooler to where you want the cool air directed. Then turn it on and enjoy the fresh cool air. Keep water in the cooler tank this will keep the pads wet and the cooler operating sufficiently.

Maintenance can be done by the owner without expensive professional fees attached. Most coolers come with an instruction manual that will walk the owner through any problems and tell you how to fix them yourself. Make sure to follow all instructions on maintenance for your unit. A well-maintained unit will run at peak performance and will cool the air efficiently throughout each day.

HEALTH

Portable air coolers help our health through their natural cooling. It is only water and air, nothing else. They help to cut down on allergies as the air is always fresh and never stale or stuffy. These units are highly recommended for areas of high heat and low humidity, a portable air cooler can offer that small bit of moisture needed in the air to make your breathing space easier and more comfortable.

They are beneficial for everyone in these environments whether you already run an air conditioner or a main air cooling unit in your home. The portable versions are wonderful additions and can be run anywhere to offer the moisture needed in dry stuffy air.

For homes with air conditioners, the portable air cooler can offer just enough moisture to keep health hazards associated with dry air (such as nose bleeds, and sinus infections) to a minimum.

Air coolers come with a way to sanitize the water to kill bacteria, some units will do this automatically to ensure you get the cleanest air possible; a more sanitized air than air conditioners or fans can offer.

Air coolers are the perfect addition for any home. They are healthy. practical and convenient and they work to meet the owners needs and desires. There is nothing better to keep the air cool where you need it most.

TROUBLESHOOTING GUIDE Table 4.15

PROBLEM	POSSIBLE CAUSE	SOLUTION
No discharge of air	Cord is not plugged in.	Make sure power cord is plugged in and the supply switch is on.
	Power is not on.	Turn the unit ON by pressing button on the control panel.
Not Cooling / Unit is making noise	Pump is not turned ON.	On Control Panel, turn COOL FUNCTION to "ON".
	Low or no water in tank, when COOL is selected.	Refill water tank.
	Damaged Pump or Calcium deposits on blower.	Contact service center.
Odors	When the Cooler is new.	When the unit is used for the first time, the Honeycomb Cooling Media will have an odor, which will dissipate within a few hours of initial use.
	If the Cooler has been used.	There may be an algae issue. Replace the Honeycomb Cooling Media.
The unit does not respond to remote control	Remote control batteries.	Check batteries. Replace if needed. Try to operate using the control panel.
	Damaged PCB.	Try with remote control. If the unit responds, PCB board fasteners may be loose. Contact service center.
		If neither remote control nor control panel works, PCB board may be damaged. Contact service center.

Short Answer Questions

1. Classify the Motors
2. List the two motors with domestic applications
3. List the different types of Fans
4. List the main parts of a ceiling fan
5. List the main parts of a Table Fan
6. List the main parts of Electric mixer
7. List the common Mixer Problems
8. Draw the wire diagram Ceiling Fan
9. Draw the Table Fan Connection Diagram
10. What are the types in Washing Machines?
11. What are Types of vacuum cleaners
12. What are Types in the filters of vacuum cleaners
13. What are the advantages of HEPA filter and ULPA filter?
14. What is the Wet Vacuum Cleaner?
15. Write the Washing Machine Maintenance
16. Fully Automatic Washing Machines
17. Write the Working principle of vacuum cleaner
18. What is Robotic Vacuum cleaner
19. List the main parts Air cooler

Essay Questions

1. With a neat sketch Explain about the Construction and working of Ceiling Fan
2. Explain about the possible faults and remedies of Ceiling Fan
3. Explain How to Install a Ceiling Fan
4. With a neat sketch Explain about the Construction and working Table Fan
5. Explain about the Trouble Shooting of Table Fan
6. With a neat sketch Explain about the Construction and working Washing Machines
7. Explain about the Trouble Shooting of Washing Machines
8. Write the Difference between Semi-Automatic, Fully Automatic Washing Machines
9. With a neat sketch Explain about the Construction and working vacuum cleaner
10. Explain about the Trouble Shooting of vacuum cleaner
11. Explain about the Maintenance of vacuum cleaner
12. With a neat sketch Explain about the Construction and working Table Fan
13. Explain about the Trouble Shooting of Table Fan
14. Explain about the Construction and working Air cooler
15. Explain about the Trouble Shooting of Air cooler

5Other Appliances

The Nature of Light

Light Sources: There are several light sources to consider when lighting your home. They each have different characteristics, advantages and disadvantages. The technical term for a removable light source is a ‘lamp’, though in practice ‘light bulb’ is used for light sources which have the shape of a conventional bulb. Main sources of light

1. Natural light

2. Artificial light

As technology has progressed, artificial light sources have become cleaner, easier to control, cheaper and more efficient. The naked flame, candles, gas and pressure mantle lights have been replaced by electric lighting. While the the earlier types of lighting still have some applications, the focus here is on the main practical light sources for the home.

Natural light Daylight – Light from the Sun

Light from the sun is created by nuclear fusion. It is perceived as extremely bright light – direct sunshine – or diffused through clouds. At sunrise and sunset when the sunlight has further to travel through the earth’s atmosphere, the light has a warmer colour temperature because the blue light is scattered by atmosphere.

Light from the sun is free, consumes no natural resources, has a colour temperature ‘in tune’ with the human activity cycle, and has excellent colour render. The intensity of sunlight can be controlled by blinds or curtains and there is some scope for transporting sunlight using light tubes or sun pipes. But it is, of course, impossible to control the rotation of the earth or the weather, both of which affect the brightness and availability of sunlight.

Significantly increasing the amount of sunlight in a room or space is likely to require structural work – adding or enlarging windows. Without building work, sunlight can be maximised by limiting obstructions and shadows and using pale surface finishes. There are certain circumstances – notably watching television – where the intensity of sunlight will need to be effectively limited.

Artificial Light:

Filament lights:

It normally considered that Thomas Edison was the inventor of the incandescent lamp, but actual history was not like that. There were numbers of scientists who worked and designed prototype for the incandescent lamp before Edison did. One of them was British physicist Joseph Wilson Swan. From the record, it is found that he got the first patent for the incandescent lamp. Later Edison and Swan merged to produce incandescent lamps in commercial scale.

5.1.1Construction of Incandescent Lamp

The filament is attached across two lead wires. One lead wire is connected to the foot contact and other is terminated on the metallic base of the bulb. Both of the lead wires pass through glass support mounted at the lower middle of the bulb. Two support wires also attached to glass support, are used to support filament at its middle portion. The foot contact is isolated from metallic base by insulation materials. The entire system is encapsulated by a coloured or phosphate coated or transparent glass bulb. The glass bulb may be filled with insert gases or it is kept vacuum depending upon rating of the incandescent lamp.

The filament of incandescent lamps is air-tightly evacuated with a glass bulb of suitable shape and size. This glass bulb is used to isolate the filament from surrounding air to prevent oxidation of filament and to minimize convention current surround the filament hence to keep the temperature of the filament high. The glass bulb is either kept vacuum or filled with inert gases like argon with a small percentage of nitrogen at low pressure. Inert gases are used to minimize the evaporation of filament during service of the lamps. But due to convection flow of inert gas inside the bulb, there will be greater chances of losing the heat of filament during operation. Again vacuum is a great insulation of heat, but it accelerates the evaporation of filament during operation. In the case of gas-filled incandescent lamps, 85% of argon mixed with 15% of nitrogen is used. Occasionally krypton can be used to reduce filament evaporation because the molecular weight of krypton gas is quite higher. But it costs greater. At about 80% of atmospheric pressure, the gasses are filled into the bulb. Gas is filled in the bulb with the rating more than 40 W. But for less than 40 W bulb; there is no gas used.

The various parts of an incandescent lamp are shown below.

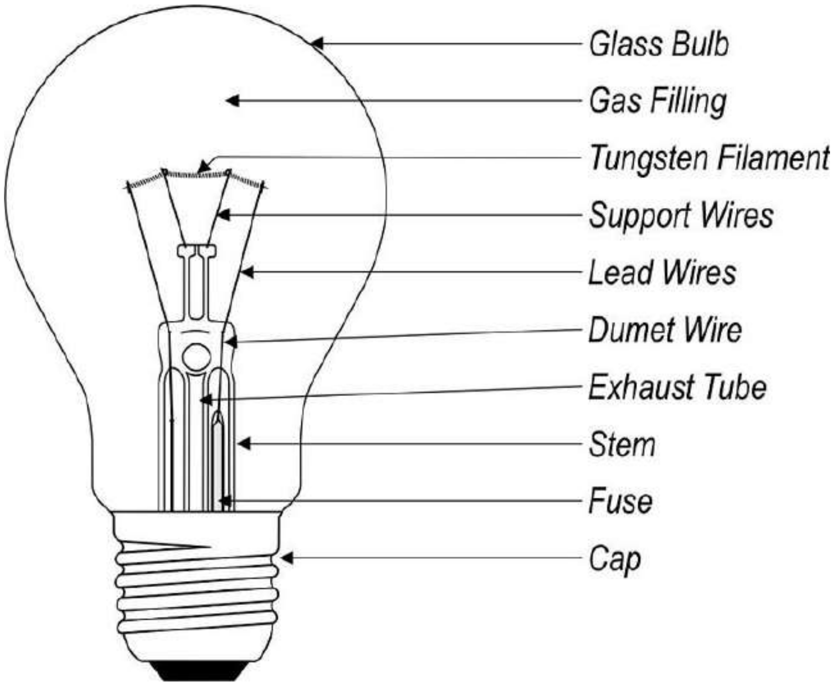


Fig 5.1 Filament of Incandescent Lamp

Life Span of Incandescent Lamps

Whatever may be the technology of manufacturing, each type of incandescent lamps has some approximate life span. This is because of filament evaporation phenomenon which can be minimized but cannot be avoided completely. Due to filament evaporation, the glass bulb becomes darken over a period. Due to filament evaporation the filament becomes thinner which makes the filament less luminous efficient and at last, the filament is broken. As the filament lamps are directly connected to the power supply line, the voltage fluctuations in the line affect the performance of the bulb. It is found that luminous efficacy of an incandescent lamp is directly proportional to the square of supply voltage but at the same time, the life span of the lamp is inversely proportional to 13th to 14th power of supply voltage. Main advantages of incandescent lamps are that these are cheap enough and very suitable for lighting at small areas. But these lamps are not energy efficient and about 90% of input electrical energy is lost as heat.

Availability of the Incandescent Bulbs in the Market

There are various attractive shapes and sizes of the bulbs available in the market. PS30 lamps have a pear shape, T12 bulb is tubular with diameter 1.5 inch, R40 bulb is with reflector bulb envelope with a diameter of 5 inches. Based on availability of wattage the bulbs are common in the market with 25, 40, 60, 75, 100, 150 and 200 W etc. We can follow the table below to get important data about the incandescent lamp.

Incandescent light bulb Advantages and Disadvantages

If you're considering using incandescent bulbs, here are some Advantages and Disadvantages to consider.

Incandescent light bulb Advantages

- **Quality of light**
  These bulbs are as close to the gold standard (the sun) as you can get.

- **Affordability**
  Looking to stay under your monthly light bulb budget? Pop a few incandescent bulbs in your sockets and let someone else take care of the utility bills.

- **Aesthetics**
  Even the lighting industry itself can't deny that the aesthetics of a Incandescent light bulb are hard to beat. Heck, LED manufacturers have spent years just trying to figure out how to make an LED bulb that resembles a classic incandescent.

- **Dimmability**
  Incandescent are also the gold standard for dimmability. They don't flicker or emit worse light when paired with a dimmer switch, like some products using other lighting technologies. The LED industry is working overtime just to make something that can dim like an incandescent.

Incandescent light bulb cons

- **Short life**
  If your lighting maintenance bill is out the roof, incandescent bulbs aren't going to help. You'll be replacing them every 3-5 months, assuming 8-10 hours of burn time a day.

- **Energy consumption**
  As I said earlier, 90 percent of the energy used to make incandescent light is actually converted to heat. And if you aren't wanting your light sockets to double as space heaters, you're going to have to crank up your AC bill to compensate for the collective heat emitted from your incandescent light bulbs.
- **Option limitations**
  Compared to LEDs, incandescent bulbs are very limited in their colour temperatures, lumen output, directionality, and other specifications that help to customize lighting today.

5.1.2 Fluorescent Tubes or Compact Fluorescent Light Bulbs

Fluorescent Tube Light Working

A fluorescent lamp or a fluorescent tube is a low pressure mercury-vapour gas-discharge lamp that uses fluorescence to produce visible light. An electric current in the gas excites mercury vapour which produces short-wave ultraviolet light that then causes a phosphor coating on the inside of the bulb to glow. A fluorescent lamp converts electrical energy into useful light much more efficiently than incandescent lamps.

The luminous efficacy of a fluorescent light bulb can exceed 100 lumens per watt, several times the efficacy of an incandescent bulb with comparable light output.

Here we discuss the internal elements in a fluorescent tube light.

- A fluorescent lamp basically consists of a long glass gas discharge tube. Its inner surface is coated with phosphorous and is filled with an inert gas, generally argon, with a trace of mercury.
- The tube is then finally sealed at low pressure with two filament electrodes each at its both ends.
- These electrode filaments are used to preheat the tube and initiate a rapid conduction of electrons between the two end electrodes. The process initially requires a relatively high amount of power.
- The energy also converts some of the mercury from a liquid to a gas. Electrons then collide with the gaseous mercury atoms, increasing the amount of energy. As electrons return to their original energy level, they begin to release light. However, the light they emit is ultraviolet, and not visible to the naked eye, so another step needs to take place before we can see the light.

This is why the tube was coated with phosphorous. Phosphors will give off light when exposed to light. When exposed to the ultraviolet light, the particles emit a white light which we can see. Once the conduction of electrons between the electrodes is complete, no more heating of the filaments is required and whole system works at a much lower current.

How to Wire Fluorescent Lights

Here is one example of a tube light fixture consisting of a large heavy square "choke" or "ballast" and a small cylindrical "starter." Let's try to understand how the whole system works. Please refer to the circuit diagram on the right as you read the following points:

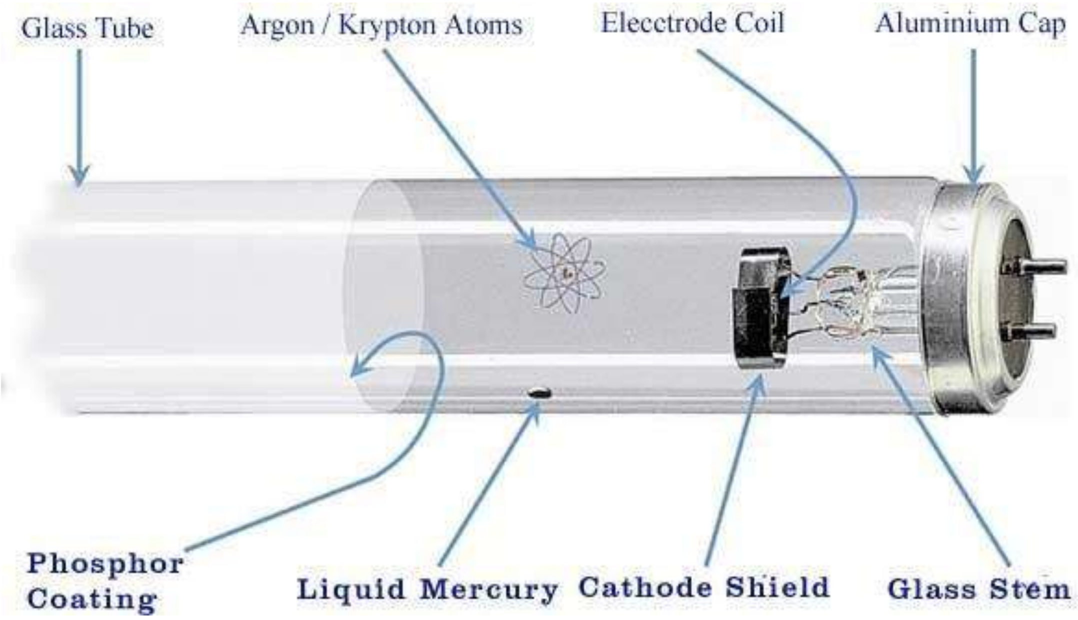


Fig 5.2**Fluorescent Tube Light**

- The choke is in fact a large inductor. It consists of a long copper winding over iron laminations.
- An inductor by nature always has a tendency to throw back the stored current in it, every time the power through it is switched OFF. This principle of the choke is exploited in lighting a fluorescent tube light.
- When an AC voltage is applied to a tube light fixture, the voltage passes through the choke, the starter, and the filaments of the tube.
- The filaments light up and instantly warm up the tube. The starter is made up of a discharge bulb with two electrodes next to it. When electricity passes through it an electrical arc is created between the two electrodes. This creates light, however the heat from the bulb causes one of the electrodes (a bimetallic strip) to bend, making contact with the other electrode. This stops the charged particles from creating the electrical arc that created light. However, now that the heat from the light is gone, the bimetallic strip cools and bends away from the electrode, opening the circuit again.
- At this point, the ballast or choke "kick's back" it's stored current, which again passes through the filaments and ignites the tube light once again.
- If the tube does not sufficiently charge up, subsequent kicks are delivered by the choke due to rapid switching of the starter, so that finally the tube strikes.
- After this the choke only acts like a low impedance current limiter to the tube as long as the light is kept illuminated.

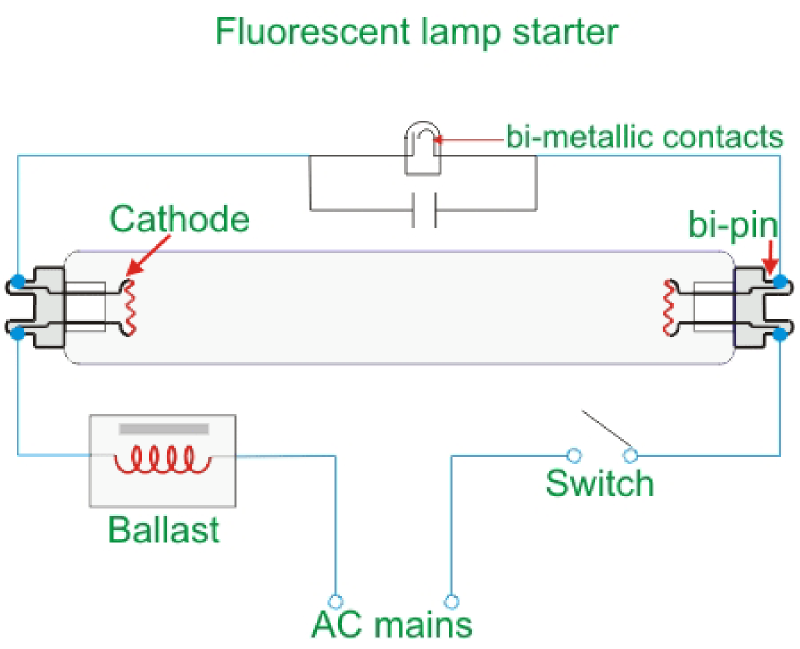


Fig 5.3 Tube Light Circuit

A common problem associated with these types of fixtures is humming or buzzing. The reason for this lies in the loosely fitted choke on to the fixture which vibrates in accordance with the 50 or 60 hertz frequency of our AC mains and creates a humming sort of noise. Tightening the choke's screws may instantly eliminate the problem.

The working principle of today's modern electronic ballasts is to avoid the use of starters for the preheating purpose. They are also very light in weight. These inhibit the initial flickering of the tube light as normally seen in the ordinary tube fixtures by changing the frequency of the mains power to a much higher 20,000 hertz or more. Moreover, electronic ballasts are very energy efficient.

5.1.3Compact fluorescent light bulbs (or CFLs)

Compact fluorescent light bulbs (or CFLs) use the same technology as fluorescent strip lights but in a form which allows them to be used as direct replacements for incandescent light bulbs – the tube is folded or twisted to fit the dimensions of conventional bulbs. CFLs are widely available with standard screw (E27) or standard bayonet (B22d) caps and the electronic ballast needed to start the lamp is integrated into the base of the bulb. As with incandescent, they emit light evenly around the bulb

While compact fluorescents were heralded as the eco-friendly replacement for filament bulbs, the performance of most CFLs – especially the cheap ones – is hugely disappointing. When compared to incandescent, they are very slow to reach full brightness, have poor colour render (colours look dull or washed out) and dimming performance is mixed. While CFL quality has improved, it is clear that LED technology now offers better performance for practical lighting.

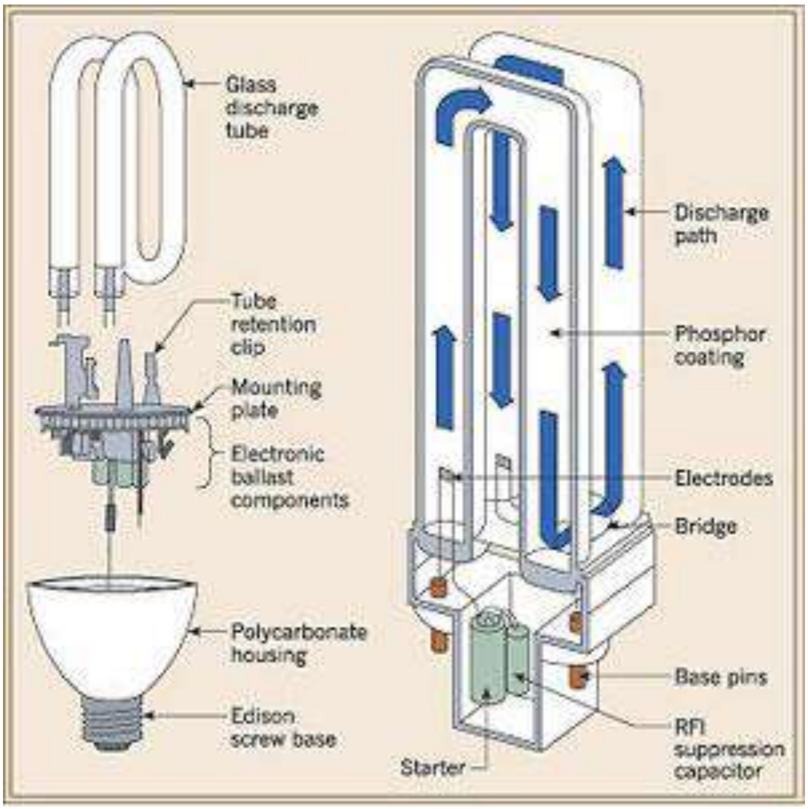


Fig 5.4**Compact fluorescent light bulbs**

Fig 5.5 Three light sources (left to right): incandescent, compact fluorescent and LED

5.2.1 ELECTRIC BELL

Electric bell working

An electric bell contains an electromagnet, consisting of coils of insulated wire wound round iron rods. When an electric current flows through the coils, the rods become magnetic and attract a piece of iron attached to a clapper. The clapper hits the bell and makes it ring.

Process of the working of an electric bell

Now that you have an understanding of the important parts in an electric bell, the step by step process of the working of the electric bell is described below:

- The switch is pressed and current flows through the circuit.
- The electromagnet is powered and generates a magnetic field that attracts the iron strip towards it.
- The striker strikes the gong (bell).
- When the striking arm strikes the gong, the contact is broken and current stops flowing through the circuit.
- This causes the electromagnet to lose its magnetic field.
- The connected spring arm returns the striker to its original rest position.
- The contact is restored and current flows through the circuit (provided the main switch is still pressed).
- The process is repeated from the beginning.

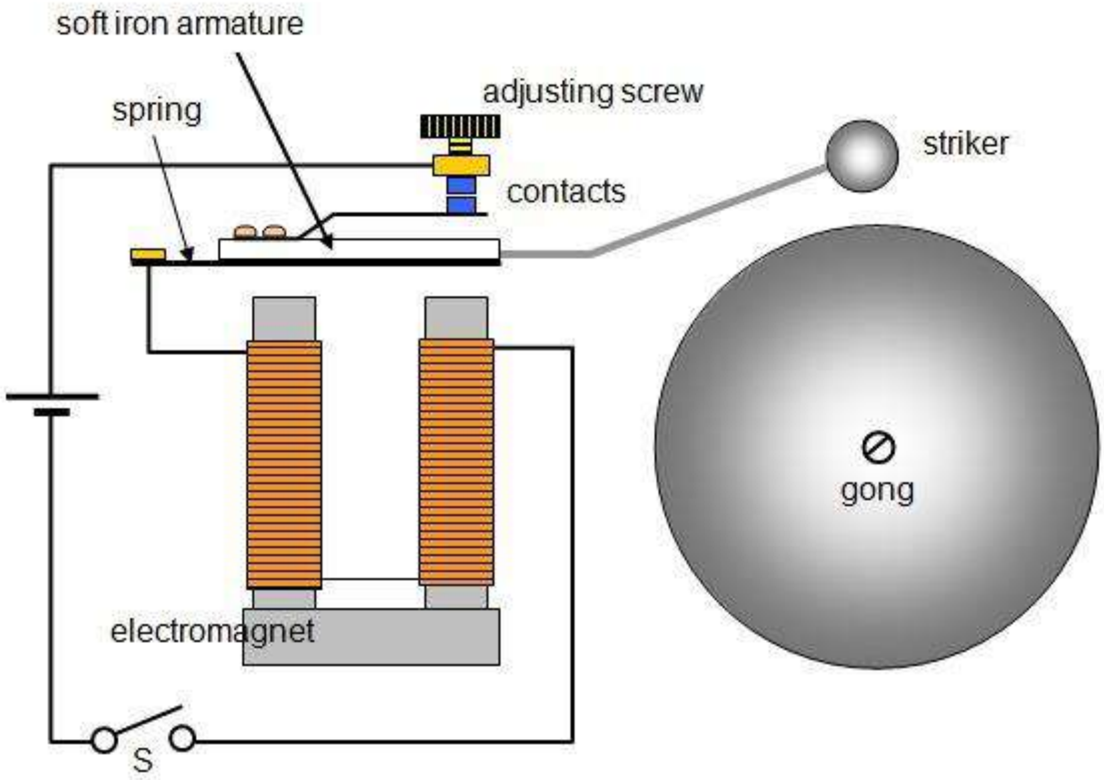


Fig 5.6

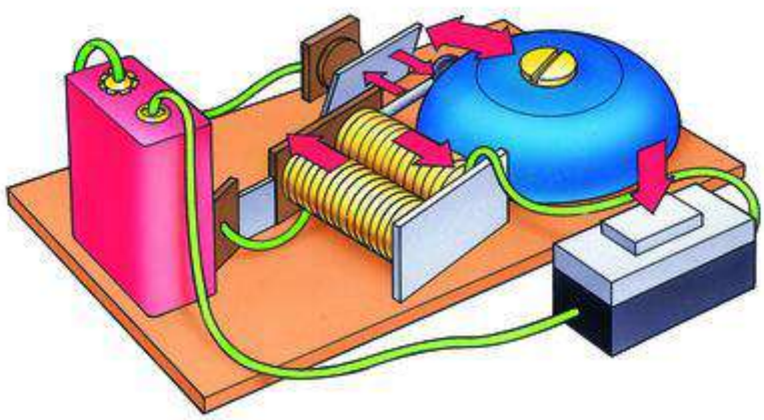


Fig 5.7

5.2.2 Rechargeable Torch Based on White LED

Rechargeable torches don't come without problems. You need to replace the bulbs and charge the batteries frequently. The average incandescent light-emitting diode (LED) based torch, for instance, consumes around 2 watts. Here's a white LED based rechargeable torch that consumes just 300 mW and has 60 per cent longer service life than an average incandescent torch.

LED based rechargeable torch circuit

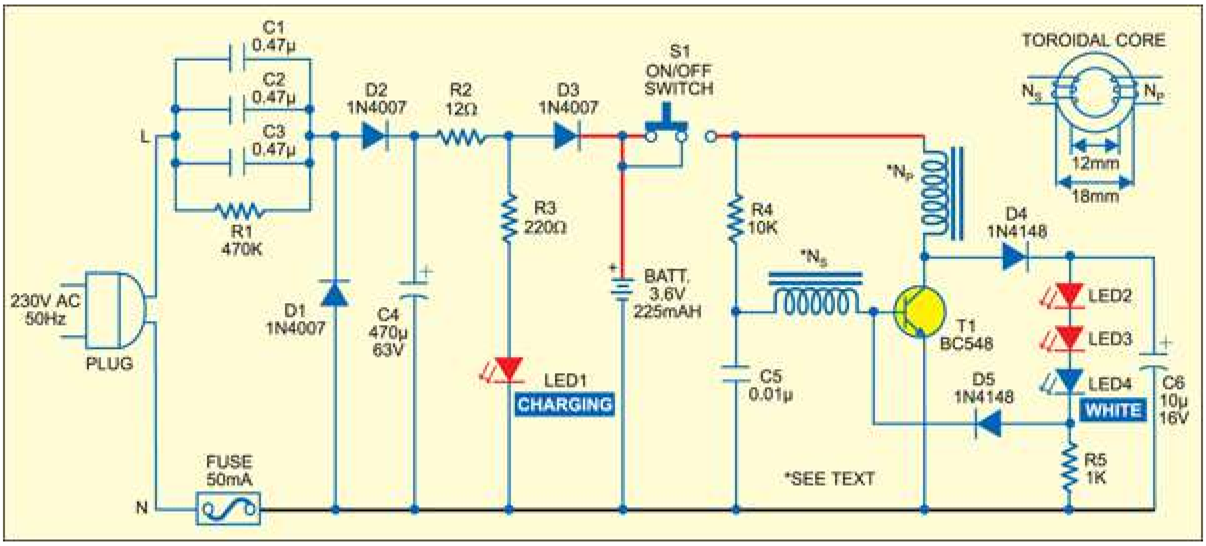


Fig 5.8 Circuit diagram of the LED based rechargeable torch

Fig.5.8 shows the circuit of the rechargeable white LED-based torch. The reactive impedance of capacitors C1 through C3 (rated for 250V AC) limits the current to the charger circuit. The resistor across the capacitors provides a discharge path for the capacitors after the battery is charged. The red LED1 indicates that the circuit is active for charging.
The torch uses three NiMH rechargeable button cells, each of 1.2V, 225 mAH. A normal recharge will take at least 12 hours. Each full recharge will give a continuous operational time of approximately 2.5 hours. Recharge the battery to full capacity immediately after use to ensure its reliability and durability. The charging current is around 25 mA.

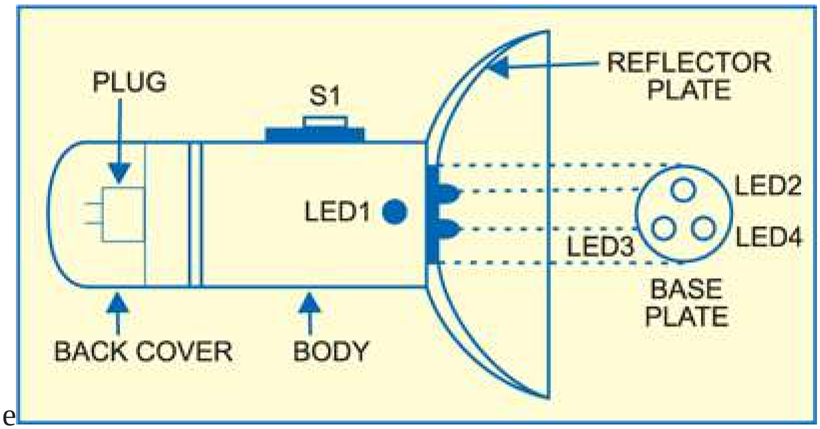
e


Fig.5.9: Suggested enclosure for the torch

A voltage booster circuit is required for powering the white LEDs (LED2 through LED4). An inverter circuit is used to achieve voltage boosting. Winding details of the inverter transformer using an insulated ferrite toroidal core is given in the schematic. The number of 35 SWG wire turns in the primary and secondary coils (NP and NS) are 30 and 3, respectively. If the inverter does not oscillate, swap the polarity of either (but not both) the primary or the secondary winding. A reference voltage from resistor R5 provides a reflected biasing to the transistor, and keeps the output constant and regulated.

5.3.1 Stabilizer

Introduction to Stabilizer:

Voltage fluctuations cause temporary or permanent failure of the load. These voltage fluctuations also reduce the life span of the home appliances due to the unregulated low or higher voltage than the intended voltage required for the load. These voltage fluctuations occur due to sudden load changes or due to faults in the power system. So, it is required to supply stable voltage to the load, considering home appliances' importance and the need for their protection. Voltage stabilizers are used for maintaining a stable voltage supply to the load such that the home appliances can be protected from over and under voltages.

What is Stabilizer?

A Stabilizer is a thing or device used to maintain something or a quantity steady or stable. There are different types of stabilizers based on the quantity they are used for maintaining stability. For example, a stabilizer used for maintaining the voltage quantity stable in a power system is called as voltage stabilizer.

Fig.5.10

Voltage Stabilizer

Voltage stabilizer is designed for maintaining the stable voltage level to provide a constant supply in spite of any fluctuations or changes in supply in order to protect the home appliances. Generally, voltage regulators are used to maintain constant voltage and these voltage regulators which are used to provide constant voltage to the home appliances are called as Voltage Stabilizers.

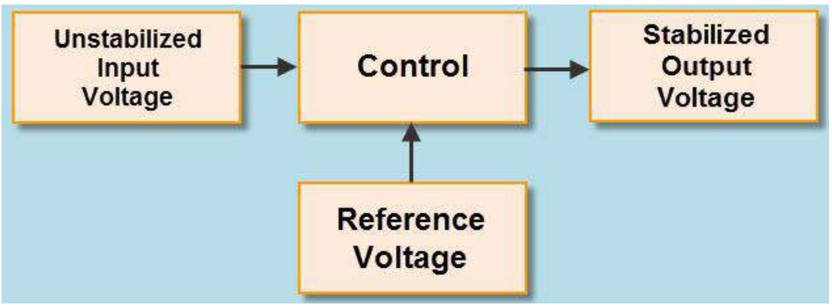


Fig.5.11

There are different types of voltage regulators such as electronic voltage regulators, electromechanical voltage regulators, automatic voltage regulators and active regulators. Similarly, there are different types of voltage stabilizers such as servo voltage stabilizers, automatic voltage stabilizers, AC voltage stabilizers and DC voltage stabilizers.

What is a Voltage Stabilizer?

It is an electrical appliance which is designed to **deliver a constant voltage** to a load at its output terminals regardless of the changes in the input or incoming supply voltage. It protects the equipment or machine against over voltage, under voltage, and other voltage surges.

It is also called as **automatic voltage regulator (AVR)**. Voltage stabilizers are preferred for costly and precious electrical equipment's to protect them from harmful low/high voltage fluctuations. Some of these equipments are air conditioners, offset printing machines, laboratory equipment, industrial machines, and medical apparatus.

Voltage stabilizers regulate the fluctuating input voltage before it could be fed to the load (or equipment which is sensitive to voltage variations). The output voltage from the stabilizer will stay in the range of 220V or 230V in case of single phase supply and 380V or 400V in case of three phasesupply, within given fluctuating range of input voltage. This regulation is carried by buck and boost operations performed by internal circuitry.

The common **types of voltage stabilizers** include manual operated or switchable stabilizers, automatic relay type stabilizers, solid state or static stabilizers, and servo controlled stabilizers. In addition to the stabilizing function, most stabilizers come with additional features such as input/output low voltage cut-off, input/output high voltage cut-off, overload cut-off, output start and stop facility, manual/auto start, voltage cut-off display, zero voltage switching, etc.

Importance of Voltage Stabilizers

Generally, each and every electrical equipment or device is designed for a wide range of input voltage. Depending on the sensitivity, the working range of the equipment's are limited to a specific values, for instance, some equipment can tolerate ± 10 percent of the rated voltage while others ± 5 percent or less.

The voltage fluctuations (rise or dip of the magnitude of rated voltage) are quite common in many areas, especially at terminated lines. The most common reasons for voltage fluctuations are lighting, electrical faults, faulty wiring and periodic turning off the device. These fluctuations create mishap to the electrical equipments or appliances.

Long time over voltage will result

- Permanent damage to the equipment
- Insulation damage to the windings
- Unwanted interruption in the load
- Increased losses in cables and associated equipments
- De-rating life of the appliance

Long time under voltage will result

- Malfunctioning of the equipment
- Longer working periods (as in case of resistive heaters)
- Reduced performance of the equipment
- Drawing large currents which further lead to overheating
- Computational errors
- Reduced speed of motors

So the voltage stability and accuracy decide the correct operation of the equipment. Voltage stabilizers therefore ensure that the voltage fluctuations at the incoming power supply does not affect the load or electrical appliance.

Voltage Stabilizer Working

Basic Principle of voltage stabilizer to Perform Buck and Boost Operations

In a voltage stabilizer, voltage correction from over and under voltage conditions is performed through two essential operations, namely b*oost and buck operations*. These operations can be carried manually by switches or automatically through electronic circuitry. During under voltage condition, boost operation increases the voltage to a rated level while buck operation reduces the voltage level during over voltage condition.

The concept of stabilization involves in adding or subtracting the voltage to and from the mains supply. For performing such task stabilizer uses a transformer which is connected in different configurations with switching relays. Some stabilizers use a transformer with taps on winding to provide different voltage corrections while servo stabilizers use an auto transformer to have wide range of correction.

To understand this concept, let us consider simple step down transformer of 230/12V rating and its connection with these operations are given below.

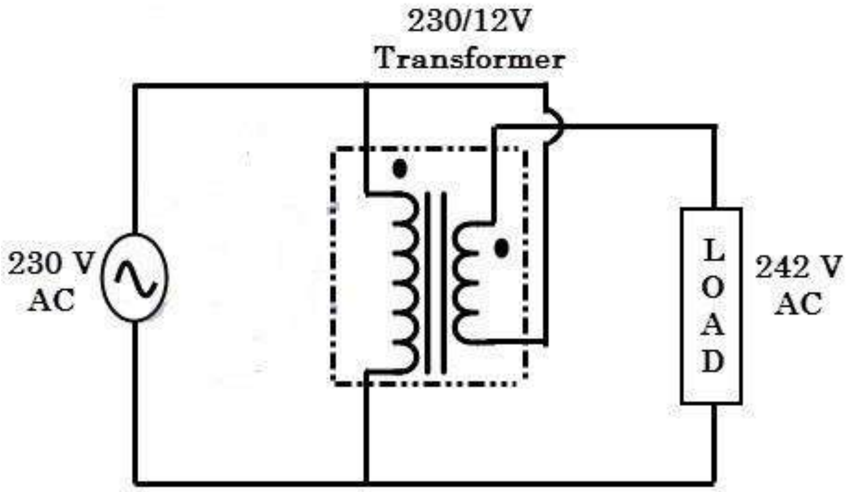


Fig.5.12

The figure above illustrates the boosting configuration in which the polarity of the secondary winding is oriented in such a way that its voltage is directly added to the primary voltage. Therefore, in case of under voltage condition, transformer (whether it can be tap changing or autotransformer) is switched by the relays or solid state switches such that additional volts are appended to the input voltage.

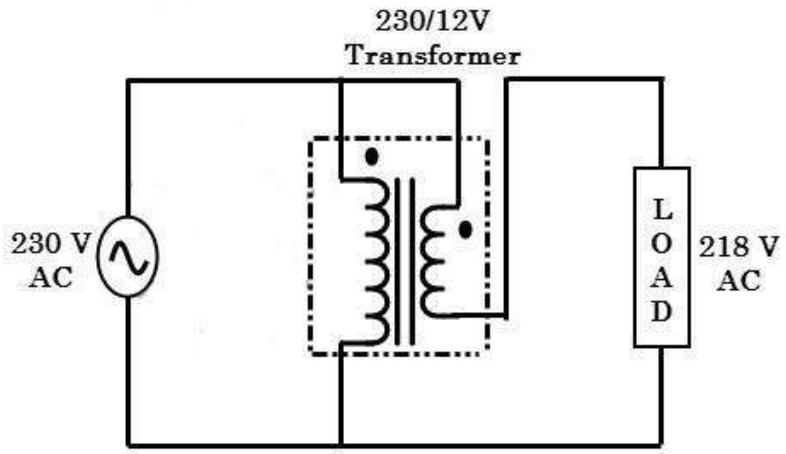


Fig.5.13

In the figure above, transformer is connected in bucking configuration, wherein the polarity of secondary coil is oriented in such a way that its voltage subtracts from the primary voltage. The switching circuit shifts the connection to the load to this configuration during over voltage condition.

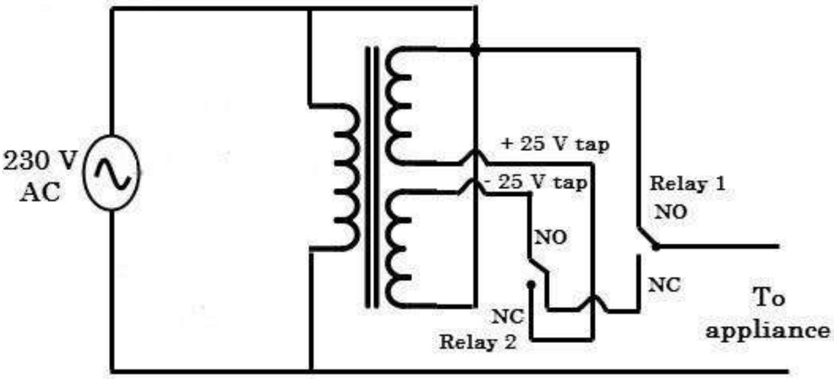


Fig.5.14

The figure above shows two stage voltage stabilizer which uses two relays to provide constant AC supply to the load during overvoltage and under voltage conditions. By switching the relays, buck and boost operations for two specific voltage fluctuations (one is under voltage, for instance, say 195V and another for overvoltage, say 245V) can be performed.

In case of tapping transformer type stabilizers, different taps are switched based on the required amount of boost or buck voltages. But, in case of auto transformer type stabilizers, motors (servo motor) are used along with sliding contact to obtain boost or buck voltages from the auto transformer as it contains only one winding.

How to Choose a Correct Sized Voltage Stabilizer?

It is foremost thing to consider several factors before buying a voltage stabilizer for an appliance. These factors include wattage required by the appliance, level of voltage fluctuations that are experienced in the installing area, type of appliance, type of stabilizer, working range of stabilizer (to which stabilizer going correct voltages), overvoltage/under voltage cut-off, type of control circuit, type of mounting, and other factors. Here we have given basic steps to consider before buying a stabilizer for your application.

- Check the power rating of the apparatus that which you are going to be used with a stabilizer, by observing the nameplate details
- Since the stabilizers are rated in kVA (Same as the case as Transformer rated in kVA instead of kW), it is also possible to calculate the wattage by simply multiplying voltage of the appliance by maximum rated current.
- It is recommended to add a safety margin to stabilizer rating, typically a 20-25 percent. This could be useful for future plans to add more devices to the stabilizer output.
- If the appliance is rated in watts, consider a power factor while calculating kVA rating of stabilizer. On the contrary, if stabilizers are rated in kW instead of kVA, multiply the power factor with voltage and current product.

Example to select proper sized voltage stabilizer for your electrical appliance(s)

Suppose if the appliance (air conditioner or refrigerator) is rated as 1kVA. Therefore, the safe margin of 20 percent is 200 watts. By adding these watts to actual rating we get 1200 VA wattage. So 1.2 kVA or 1200 VA stabilizer is preferable for the appliance. For home needs 200 VA to 10 kVA stabilizers are preferred. And for commercial and industrial applications, single and three phase of large rating stabilizers are used.

5.3.2 Uninterruptible Power Supply

Uninterruptible Power Supply Working

The full form of the UPS is an uninterruptible power source or uninterruptible power supply. It is an electrical device, gives emergency power to various loads when the input power typically fails. A UPS fluctuates from an emergency power system in that it will deliver near-instantaneous safety from i/p power interruptions by providing energy stored in batteries, super capacitors. The run time of battery for most UPS is relatively short but enough to start a standby power source. The main purpose of a UPS is to provide a protection to the equipments like computers, electrical equipment, computer and data centres when there is a power disruption. This device keeps a computer running for a few minutes after a power disruption and protects the data in the computer. In present days, there are various types of UPS systems coming with software component that enables you to automobile backup in case there is no power disruption when you are away from the computer.

Construction of UPS:

Mainly UPS consists of the following elements as shown in block diagram:

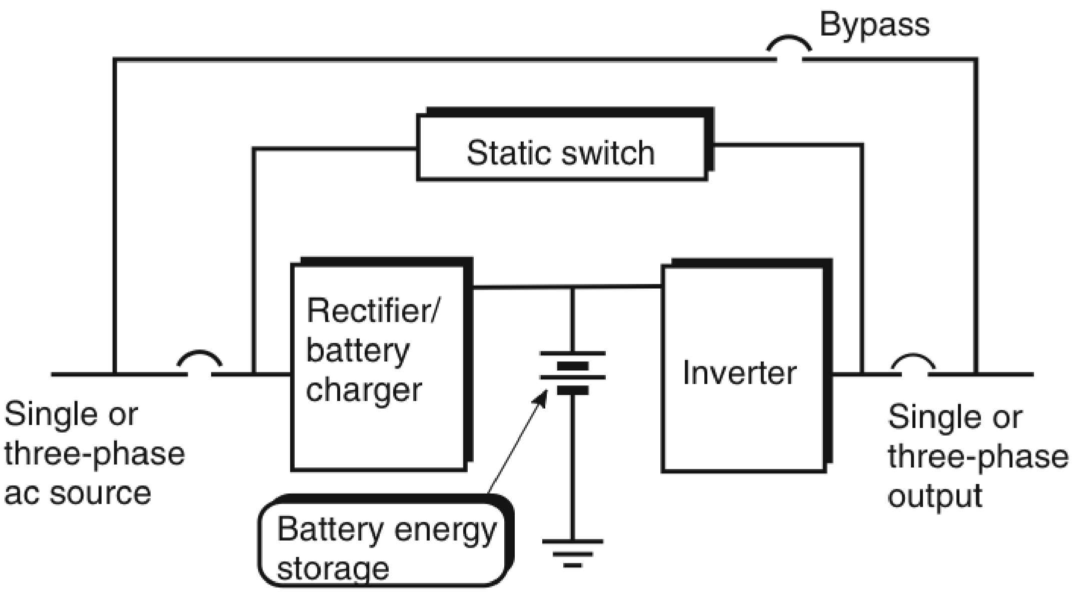


*Fig.5.15*Uninterrupted Power Supply Circuit Diagram

1. Rectifier (Battery Charger)
2. Battery
3. Inverter
4. Static Switch or Contactor

Rectifier: As we all know that the main function of rectifier is to convert alternating input supply to D.C. which will be used to charge the battery and then fed to inverter circuit. Its output may depends upon the load requirement.

Battery: The storage battery is used to store energy for future use in case of main supply failure. This battery may be lead acid or any other type depends on the requirement.

Inverter: It does the invert process of rectifier. It converts the incoming D.C. supply to alternating power supply for the use of load. The output of inverter is sine wave. It converts D.C. to A.C. of constant frequency and amplitude. The output of Inverter may contain harmonics which can be eliminated by using external circuit or special type of inverters.

Static Switch or Transfer Switch: A static switch or transformer switch is required to change over the circuit that is to transfer the source of power. The operation of this time should be very fast. Generally, the switches having switching time within 10 milli seconds are used.

Types of UPS

Electrical power supply intrusions can come in a different forms like surges, voltage dips, voltage spikes and harmonics. These troubles can cause serious damage to electrical gears, mostly during the production stages or critical processing of an action. To decrease the risk of power supply distortion, UPS systems are frequently integrated in electrical networks. Electronic power supply equipment makers can offer consistent, high-quality power flow for various electrical load gear and these devices are generally found in industrial processing applications, medical services, emergency gear, telecommunications, & computerized data systems. A UPS system can be a helpful device for ensuring accurate power supply performance.

Types of UPS

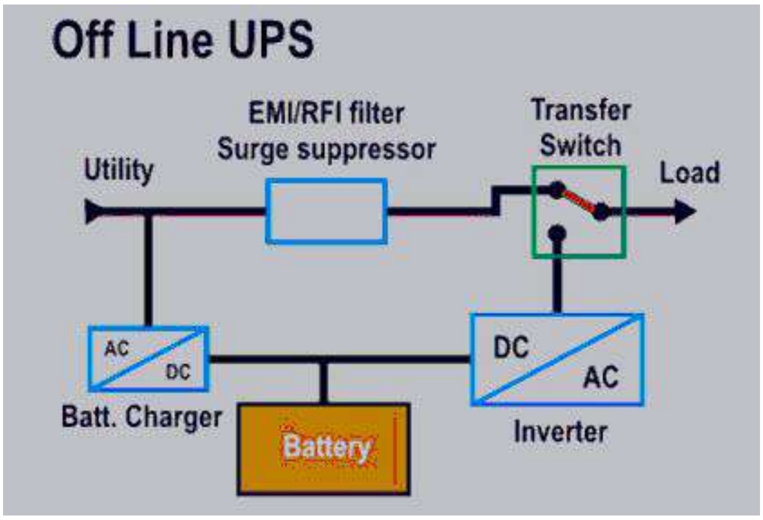
Uninterruptible Power Supply devices are classified into three types such as

- The Standby UPS
- The Line Interactive UPS
- Online UPS

The Standby UPS

The standby Uninterruptible Power Supply is also called as off line UPS, that is generally used for PCs. The block diagram of this UPS is shown below. This UPS includes a battery, an AC or DC & DC or AC inverter, a static switch and a LPF which is used to decrease the switching frequency from the o/p voltage & a surge suppressor.The standby UPS system works with the switch arrangement to select the AC i/p as a primary power source,and interchanging*Fig.5.16*Standby UPS

to the battery & inverter as backup sources in case of primary power gets disrupted. The inverter normally relies on standby, only triggering when the power fails and the transfer switch routinely switches the load to the backup units. This kind of UPS system offers a small size, high degree of efficiency, & pretty low costs, making of this UPS is easy.



The Line Interactive UPS

The block diagram of Line Interactive UPS is shown below; it is the most common UPS used for small business. The designing of line interactive UPS is alike to a standby UPS, in addition the design Line Interactive generally includes an automatic voltage regulator(AVR) or a tap-changing transformer. This enhances the regulation of voltage by regulating transformer taps as the i/p voltage differs. Voltage regulation is a significantfeature when the conditions of a low voltage exist, otherwise the UPS would transfer to battery & then finally down the load. The usage of more common battery can cause early battery failure. The features of this UPS are small size, low cost, high efficiency can make the UPS in the range of 0.5-5kVA power

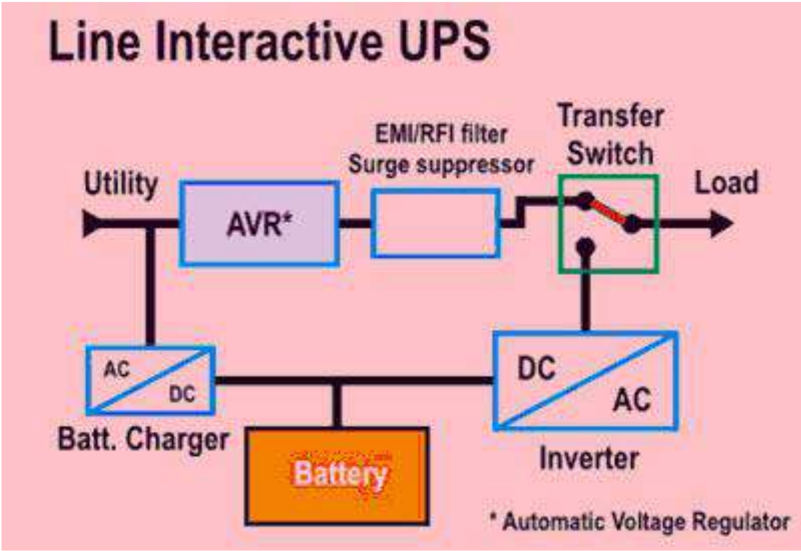


Fig.5.17 Line Interactive UPS

Online UPS

The online UPS is also called as double conversion online uninterruptible power supply. This is the most commonly used UPS and the block diagram of this UPS is shown below. The designing of this UPS is similar to the Standby UPS, excluding that the primary power source is the inverter instead of the AC main. In this UPS design, damage of the i/p AC does not cause triggering of the transfer switch, because the i/p AC is charging the backup battery source which delivers power to the o/p inverter. So, during failure of an i/p AC power, this UPS operation result in no transfer time.

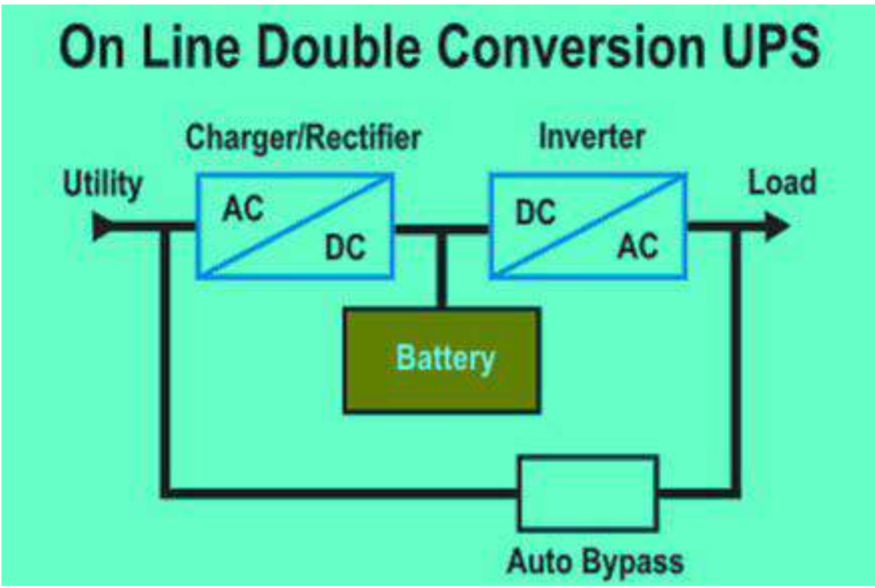


Fig.5.18 Online UPS

In this design, both the inverter and the battery charger change the total load power flow, resulting in reduced efficiency with its associated increased heat generation. This UPS affords nearly perfect electrical o/p performance. But the constant wear on the power components decreases reliability over further designs and the energy spent by the electrical power inefficiency is an important part of the life-cycle cost of the UPS. Also, the i/p power drawn by the large battery charger has been frequently non-linear and can interfere with the building power wiring with standby generators.

This is all about what is UPS (Uninterruptible Power Supply), circuit diagram of UPS with explanation, types of UPS. We hope that you have go a better understanding of the concept of UPS. Furthermore, any queries regarding this topic or electronics projects, please give your feedback by commenting in the comment section below. Here is a question for you, what are the applications of UPS?

Applications of UPS are showing below

- Data Centers.
- Industries.
- Telecommunications.
- Hospitals.
- Banks and insurance.
- Some special projects (events)

Need of UPS:

With the development in Electronics and Computer based devices, the use of sensitive electronics equipment like Personal Computers, Super Computers, Data Processors, Digital Controllers etc. increases. Such devices require interruption free power supply, because these devices have to handle with data in Memories and Processors. As we know these devices are very sensitive to corrupted power supply. For example, If you Turn Off your Personal Computer directly by removing power plug instead of shutting down then you will lose your data and sometimes your computer's operating system may get corrupted. So when dealing with large data in large scale industries it is essential to provide interruption free supply to these devices for the safety of data. To fulfil this need UPS (Uninterrupted Power Supply) is used.

Problems in Main Power Supply:

In the Mains power supply there are many interruptions in different forms. These fluctuations may cause damage to sensitive electronic equipment and data. The best solution for this is the use of UPS. Some corruptions in mains power supply are explained as under:

- **Voltage Fluctuations**: In mains power supply, the voltage generally increases or decreases than rated voltage. For example, in our homes the voltage fluctuates from 210 Volts to 240 volts. We can see these fluctuations by connecting a digital voltmeter to supply. The large change in these fluctuations may cause damage to equipment or corruption of useful information (data).
- **Transient Impulses**: The original sine wave of alternating supply can be disturbed by any reason which will result in instant increase or decrease in amplitude. These disturbances are known as Transient Impulses. The instant increase in amplitude is known as spike and instant decrease in amplitude is known as notch.
- **Voltage Surges**: When we connect a heavy load to power supply, the voltage of whole system may increase or decrease for a small time. These variations are known as Voltage Surges.
- **Noise**: A distortion in alternating sine wave which comes for small duration is known as Noise. The main causes of addition of noise are Radio and TV transmission and poor grounding. Noise may cause damage to data or equipment.
- **Frequency Variation**: The instantaneously change in load may cause the variations in supply's frequency which may cause damage to useful data.

- **Black Outs**: Instant failure in mains power supply due to any reason is known as black outs. In the case of black outs, UPS maintain continuously power to load from batteries. UPS transfers supply very quickly (in micro seconds) so the device and data will safe.
- **Brown Outs**: The planned power cuts imposed due to over loading of power are known as brown outs. The power supply can be maintained from other sources during brown outs.

5.3.3 Inverter

Inverter working principle: An inverter is an electronic device that changes direct current to alternating current. We should remember that inverter never produces any power, the power is provided by the DC source.

In most of the cases, the input DC voltage is usually lower. We can't use lower voltage in the home appliance. This is why we need to use inverter when we use solar power panel.

There are, broadly speaking, two kinds of inverters: modified square wave inverters and sine wave inverters. The modified square wave inverters is actually a square wave where the voltage is periodically 0

During the conversion process, the voltage is increased. In Ohm's law, we know that an increased voltage also leads to a decrease in current. So the overall current is decreased when the DC signal is converted into an AC

Depend on the working principle, there are two types of inverters:

1. Stand-alone inverters
2. Grid tie inverters.

Stand Alone Inverters

It is the basic type of inverters which along with the inversion of DC to AC and also produce increase the amplitude of the voltage hence produce a change in the frequency.

This kind of inverter output usually in sine wave but some cases the output gets distorted due to several reasons and appears in the form of a modified sine wave or a square wave.

Grid Tie Inverters

As the name refers that the output AC power is supplied to a grid-type network. For example, A large-scale supply unit. Then the power is distributed through the unit. For this reason, it has a complex construction and internal circuitry because they have to synchronize with the grid network.

These are the two basic type of inverter. Inverters can be enormous and heavy—particularly on the off chance that they have worked in battery packs so they can work in an independent manner. They additionally produce bunches of warmth, which is the reason they have extensive warmth sinks (metal balances) and regularly cooling fans also.

Here is the inverter working principle. The **inverter** is a kind of oscillator. It can produce a high-power AC output from a DC supply.

Usually, **DC supply** is a 12V battery. The inverter will change it into **AC 220V**, 50Hz to use any appliances.

A battery is the best!

The inverter does make an energy. But the battery is energy or source. The energy out of the battery is always approximately equal to using the energy of load.

For example, the load requires 10W at 220V AC. So, the battery needs to give the power about 10W at 12V. Also, the battery can give the current.

According to Ohm's Law. We can find the current of battery should has, is P/V = I or 10W / 12V = 0.8A.

While **inverter is working**. It will always lose energy inside it. The battery should have the power more than 1A.

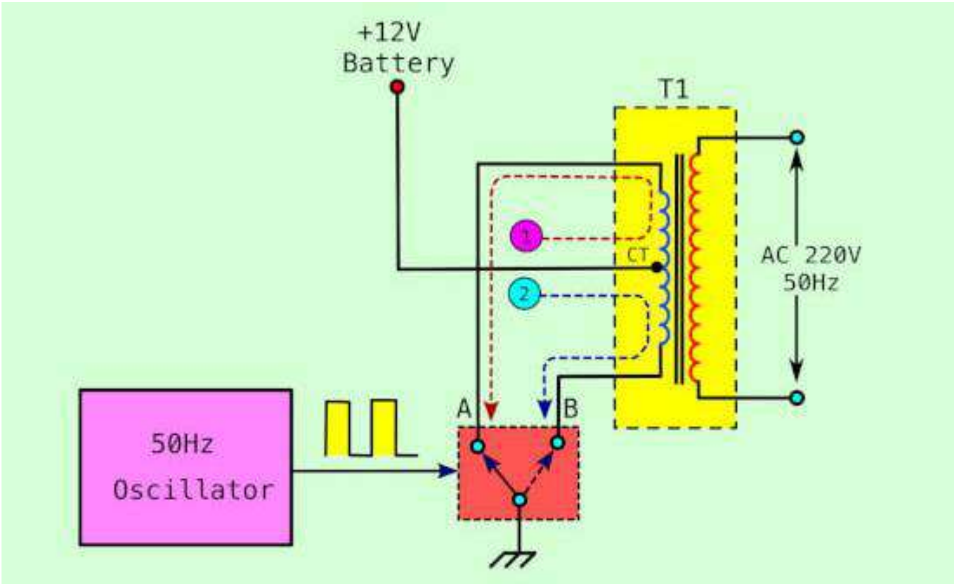


Fig.5.19

The inverter has a simple working principle
Which first important thing is the **transformer**.
The most common type of transformer is the laminated core, 12V-CT-12V.
Normally, the 220V winding is primary. Then, **12V** is secondary, the output is 12V.
But this turns. the 12V winding is input or primary. The output or secondary is 220V winding instead.

inverter circuits with simple principle

We use this principle to make a lot of circuits. For example, .

1. ***555 inverter circuit using MOSFET***
2. ***Inverter circuit, 12V to 220V at 500W***
3. ***100w Inverter circuit 12V to 220V using Transistor***
4. ***Simple inverter circuit using 6 transistors***

Inverter working.

The 12V from the positive terminal of the battery comes to the centre tap(CT) of 12V winding. Now it is the primary coil. The two ends of the coil (A and B point) are connected to the 2 ways switch to the ground. First, if the switch connects to A point. The current number 1 flows from the battery into CT through A contact of the switch to the ground. Second, if you turn the switch from A into B. It causes the current number 1 to stops flowing. Then, the current 2 flows to the ground through CT and contact B of the switch. Third, this 2 ways switch is controlled with the square wave oscillator. which It generates a frequency of approximately 50 Hz.

It causes the switch to selects between A and B point with speed about 50 times per second. Also, the current 1 and 2 flow to the transformer alternately at a rate of 50 times per second.

Now, the current flows into the transformer alternately look like AC voltage.

According to the theory of transformers. The electromagnetic field swells and collapses. And then, a current will be inducted into the secondary, 220V winding.

Which it causes **AC voltage** 220V 50Hz. The voltage is ready to be supplied to the various types of electrical equipment that require AC 220 Volt in operation.

Choosing transformer in inverter

As above in Ohm's Law, the transformer can increase the voltage step-up. But the output current always decreased to lower levels.

If you want to take the inverter to 10W load. The current of transformer should be at least of about 1A.

Short Answer Questions

1. ***List the parts of Incandescent Lamp***
2. ***List the parts of Tube Light***
3. ***List the parts of CFL***
4. ***List the parts of UPS***
5. ***Draw the circuit of Tube Light***
6. ***What is a Stabilizer?***
7. ***What is Uninterruptible Power Supply***
8. ***What are the Types of UPS?***
9. ***Write the Applications of UPS***
10. ***Draw the Block Diagram of Uninterrupted Power Supply***

Essay Questions

1. With a neat sketch Explain about the Construction and working of **Incandescent Lamp**
2. Explain about the Construction and working of Tube Light
3. With a neat sketch Explain about the Construction and working CFL
4. With a neat sketch Explain about the Construction and working OF Electric Bell
5. With a neat sketch Explain about the Construction and working ofEmergency Light
6. With a neat sketch Explain about the Construction and working ofStabilizer
7. With a neat sketch Explain about the Construction and working ofUninterruptible Power Supply

6.1 General procedure for Winding and Rewinding

Electric Motor Rewinding Importance

From small kitchen appliances, like blenders and mixers, to larger household machines, like washers and dryers, electric motors fill your home. Water pumps, generators, and other machines that make life simpler also rely on electric motors, and when they fail, it can be more than a nuisance. Did you know **rewinding an electric motor** can give it new life after it's burned out and even prevent breakdowns? why this step is so important.

There are some risks that come with rewinding an electric motor, so it's best to leave the work to the professionals. During the process, they will remove the motor from its housing so they can access the windings. After carefully counting the number of coils so they can rebuild the motor successfully, they cut and remove them. At this point, they carefully examine the stator to verify it's in good condition and perform any needed repairs.

Fig 6.1

Rewind the motor using the same gauge of magnet wire that was removed. They can even upgrade the quality of the wire for a longer-lasting motor. This part of the process must be done precisely the way it was before. The winding must start at the same place and follow the same pattern. This is done with one continuous wire so it can successfully create the magnetic field needed to get the motor running. When the professional is done winding it, the ends are connected.

Top 3 Signs You Need Motor Rewinding

Motors are ubiquitous in today's world. They're necessary and useful tools throughout many industries, and can even be found in everyday appliances and devices. However, when one stops working or malfunctions, you may not know whether it needs a motor rewinding or complete replacement. properly diagnosing the problem is key to choosing the correct solution.

Identifying the Need of Motor Rewinding

1. Physical Signs

First, examine the motor to get a better understanding of its physical condition. Check for broken parts and signs of corrosion. If the motor has been contaminated, you may see oil, water, grease, or rust. Try to remove the motor from its drive and find out whether it will rotate by hand. If not, there's likely a mechanical issue.

2. Resistance Measurement

Next, measure the motor's the winding resistance, as this will tell you whether there are any shortened coils. Record this reading and compare it to the expected resistance, which can be found in the manual. If your measurement is not consistent with the manufacturer's specifications, then you may need a motor rewinding.Fig 6.2

3. Insulation Resistance

You can also measure the insulation resistance to determine the motor's condition. For most models, the reading should be above 2M ohms. However, if it has fallen below this value, then the insulation has most likely begun to deteriorate or fail. This issue usually occurs due to age, damage, or excessive vibrations.

6.1 Tools and special equipment required for winding /rewinding

1. Air Filter / Lubricator
2. Air Gap Gauge, Armature
3. Air Grinder
4. Armature Air Gap Gauge
5. Armature Wedge Remover
6. Bearing Tool Sets
7. Brushes, Slot Cleaning
8. Bur Kit, Carbide
9. Carbide Bur Kit
10. Chamfering Tools
11. Coil Tamping Pliers
12. Coil Tamping Tools
13. Coil Tampers
14. Commutator Slot Shaver
15. Commutator Slot Shaver
16. E-Z Chamfers
17. Electrician's Knives
18. Enamel remover
19. Files, Slotting
20. Filter / Lubricator, Air
21. Gauge, Air Gap, Armature
22. Grinder, Hand, Air/Electric
23. Hammers and Mallets
24. Dead Blow
25. Needle nose pliers
26. Nylon and Rawhide Faced
27. Hand Grinder, Air/Electric
28. Hand Mica Saw
29. Horn, Winder's
30. Internal Coil Tampers
31. Insulation Trimmers, Hand
32. Knives, Electrician's
33. Knurling Tool
34. Lacing Hook
35. Lamination Tooth Straightener
36. Mallets
37. Mini-Bar Mica Hand Saw
38. Orange Sticks
39. Paper Insulation Trimmers
40. Saw, Mica Hand, Mini-Bar
41. Scraper, Slot, Adjustable
42. Shaver II, Slot, Commutator
43. Shears, Winder's
44. Slot Cleaning Brushes
45. Slot Scraper, Adjustable
46. Slot Shaver, Commutator
47. Slot Shaver II, Commutator
48. Slotting files
49. Stethoscope
50. Sticks, Orange
51. Sand blaster or wire brushes
52. Straightener, Lamination Tooth
53. Strippers, Wire
54. Multi Meter
55. Tampers, Coil
56. Tamping Tools, Coil
57. Tiger torch
58. Trimmer, Insulation, Hand
59. Tooth Straightener, Lamination
60. Wedge Drivers, Armature
61. Wedge Remover, Armature
62. Winder's Horn
63. Winder's Lacing Hook
64. Winder's Shears
65. Wire Skinner and Straightener
66. Wire Strippers:

6.1.3 Rewinding Advantages

Motor Rewinding Can Improve Efficiency

Once an electric motor dies, you have the option to replace or rewind it. Unfortunately, electric motor rewinding has a negative reputation due to flawed techniques of the past. While these processes have been updated, many motor owners are still under the impression that rewinding is not a viable option. The truth is, rewinding your motor is the best and most environmentally friendly choice

Reducing Environmental Strain

There are millions of electric motors in India alone, and many of them will fail as time passes. If every motor owner chose to replace their failed electric motor, the strain on the environment would be significantly higher than if they chose to rewind. Rewinding an electric motor is the greenest option, as all the old engine materials and parts are recycled.

Restoring Efficiency

Organizations that use electric motors every day dread the moment their devices will begin to show signs of failure. Their biggest concern is the increased cost associated with a reduction in efficiency, so they immediately jump to replace instead of considering an eco-friendly alternative. Over time, motor rewinding experts have perfected their techniques and can restore your motor to its optimal level of efficiency.

Perks of Winding Redesign

Increased Efficiency

The most cost-effective way to improve an electric motor's efficiency is by having the professionals redesign its wiring. Tune-ups like these will improve its functionality and permit the motor to use only the amount of energy necessary for powering up your appliances. You'll conserve energy and notice lower utility expenses not long after the completion of electric motor repairs.

Green Solutions

Electric motor repairs, such as winding redesign, are also an eco-friendly solution. Repairs provide you with a great opportunity to create less waste since you won't have to discard your old device for a new one. As a result of winding redesign, your electric motor will be more energy efficient, which reduces carbon emissions and does a tremendous service for the health of the planet.

Avoid Replacement Fees

It's a simple fact that electric motor repairs are much cheaper than the cost of purchasing an all-new device. You will lengthen the life span of your current motor, thereby making the most of your original investment. Winding redesign will provide you with the freedom to spend money on other important aspects of your household or business.

Types of Conducting materials used in armature winding

Basically two types conducting materials used in armature windings

1. Copper
2. Aluminium

Copper Vs. Aluminium Windings in Motors

The great debate of copper vs. aluminium windings in motors is still going on. it remains a topic of discussion today as engineers in a variety of industries question whether the quality and performance of aluminium windings can possibly compare with copper. In the 1960s, aluminium house wiring was the subject of much attention because of the apparent fire hazards it created. It turned out that the cause of these house fires was not the wire itself, but rather connection problems. The junctions would become so hot, the heat would transfer to the wire itself, eventually deteriorating the wire insulation.

Consequently, all forms of aluminium wire received a bad rap. This is unjustified; aluminium can be a perfectly good material for motor windings in many applications. There are, however, two factors to keep in mind.

Conductivity and Connections

First, aluminium's conductivity is lower than copper's. To compensate, aluminium magnet wire must have larger cross-sections than the equivalent copper wire to offer the same conductance.

This means windings wound with aluminium wire will likely have greater volume compared with an equivalent copper wire motor.

The second consideration is properly connecting the ends of the aluminium magnet wire. The reason for this goes back to your high school chemistry course. You may remember that aluminium oxidizes much faster than other metals. In fact, if exposed to air, powdered aluminium will completely oxidize in a few days, forming a fine white powder. But, when exposed to air, fabricated aluminium (sheets, wire, etc.) tends to form a hard, insulating oxide layer that stops the oxidizing process.

Piercing

To make a proper connection that ensures conductivity, the oxide layer of the aluminium magnet wire must be completely pierced in such a way to prevent air from coming in any further contact with the aluminium.

Motor manufacturers have developed high-pressure, piercing crimp connectors to do the job. These improved connection methods have helped make motors with aluminium windings as reliable as motors with copper windings.

It must be pointed out that motor efficiency is much more complicated than the great copper vs. aluminium debate. It is possible to match the power performance of a motor wound with aluminium to a motor wound with copper.

But since aluminium requires more turns and/or a larger diameter wire, this may not always be economically feasible in some applications. In situations where efficiency and volume are not issues (such as where the motor only has to work occasionally or for very short periods of time), aluminium magnet wires make an acceptable motor.

The bottom line is that, in terms of motor quality, reliability, and life span, comparisons are fair as long as you keep efficiency issues apart when looking at aluminium vs. copper.

WINDING WIRE

Introduction

Winding wire is solid wire, which, to allow closer winding when making electromagnetic coils, is insulated only with varnish, rather than the thicker plastic or other insulation commonly used on electrical wire. It is used for the winding of electric motors, transformers, inductors, generators, speaker coils, etc.

A wire is a single, usually cylindrical or rectangular cross-section, length of metal. Wires are used to carry electricity and telecommunications signals. Wire is generally formed by drawing the metal through a hole in a die or draw plate. Standard sizes are determined by various wire gauges. The term wire is also used more loosely to refer to a bundle of such strands, as in 'multistranded wire', which is more correctly termed a wire rope in mechanics, or a cable in electricity. The metals must in the first place be ductile and strong in tension, the quality on which the utility of wire principally depends. The metals suitable for wire, possessing almost equal ductility, are platinum, silver, iron, copper, aluminium and gold; and it is only from these and certain of their alloys with other metals, principally brass and bronze, that wire is prepared. By careful treatment extremely thin wire can be produced. Copper wires could be plated with other metals, such as tin, nickel, and silver to handle different temperatures, provide lubrication, provide easier stripping of rubber from copper. Wire used to carry electricity is made up of materials having very low resistivity such as pure copper or aluminium.

PROPERTIES OF CONDUCTORS

Electrical Properties: 1) The conductivity must be good. 2) Electrical energy dissipated in the form of heat must be low. 3) Resistivity must be low 4) Temperature resistance ratio must be low.

Mechanical Properties: 1) Good Ductility: It is that property of a material which allows it to be drawn into a wire. 2) Solder ability: The joint should have minimum contact resistance.
3) Resistance to corrosion: Should not get rusted when used outdoors. 4) Withstand stress and strain. 5) Easy to fabricate.

Economic Factors: 1) Low cost 2) Easily available 3) Easy to manufacture

Characteristics of a Good Conductor Material: The conductor materials should have low resistivity so that any amount of power can be transmitted without much loss in the conductor.

The Choice of A Conductor Material Depends On The Following Factors:

1) Resistivity of the materials 2) Temperature coefficient of resistance 3) Resistance against corrosion 4) Oxidation characteristics 5) Ease of soldering and welding6) Ductility 7) Mechanical strength 8) Flexibility and abundance 9) Durability and low cost 10) Resistance to chemicals and weather

Comparison of Copper and Aluminium as conductors for Power Transmission Lines:

Table 6.1

Copper	Aluminium

1. Metal is costly 2. 100 per cent conductivity 3. Good resistance to corrosion 4. Heavier as compared to aluminium 5. Good ductility and malleability 6. Excellent soldering and welding capacity 7. Less suited for low temperature 8. Very small cross-section can carry heavy current 9. Because of softness and flexibility, it can easily be twisted repeatedly. 10. The wind pressure and weight of snow is less because of smaller cross-section.	Metal is cheap 75 per cent conductivity Good resistance to corrosion Lighter as compared to copper Good ductility and malleability Poor solderability and weldability Well suited to cold climate Cross-section should be 50 percent more to carry the same current as that of copper. Due to brittleness, cannot be twisted. The wind pressure and weight of snow is more because of higher cross-section.

ENAMELLED WIRE:

Enamelled wire is a wire coated with a very thin insulating layer. The core material ('wire') is copper or aluminium, coated with a thin layer of a polyurethane, polyamide, or polyester resin - called as "enamel".

The thin layer of insulation coated on **Enamelled wire,** prevents the wire surfaces from being in a short circuit when wound into coils. It is used mainly in the construction of motors, electromagnets, transformers and inductors. For ease of manufacturing inductive components like transformers and inductors, most new enamelled wire has enamel that acts as a flux when burnt during soldering. This means that the electrical connections at the ends can be made without stripping off the insulation first. Older enamelled copper wires normally require sandpapering or scraping to remove the insulation before soldering.
Enamelled wires are classified by their diameter (as SWG number) or area (square millimetres), temperature class and insulation class. Enamelled wires are manufactured in both round and rectangular shapes. Rectangular wire is used in larger machine windings to make the most efficient use of available winding space.

Breakdown voltage depends on the thickness of the covering, which can be of 3 types: Grade 1, Grade 2 and Grade 3. Higher grades have thicker insulation and thus higher breakdown voltages. The temperature class indicates the temperature of the wire at which it can have a 20,000hour service life. At lower temperatures the service life of the wire is longer (about a factor 2 for every 10 °C lower temperature). Common temperature classes are 120, 155 and 180 °C.

PROPERTIES OF ENAMELLED WIRES:

Excellent dielectric strength. Very low dissipation factor, remaining reasonably constant at high frequencies or under humid conditions. No mechanical or chemical stripping required. Adequate ventilation required when tinning or soldering. Thermoplastic flow temperature not less than 320ºC, Smooth Glossy surface finish, chemically very stable, resists extraction with R22, methanol trichloroethylene and perchlorethylene. Usable in hermetically sealed coils Excellent stability with a heat shock of not less than 205ºC. Good resistance to abrasion. Good flexibility and adhesion to the conductor Smaller coefficient of friction, Higher mechanical intensity, Excellent heat resistance. Good solder ability.

Limitations: Insulation properties downgraded over 200ºC. Prone to hydrolysis if used in hermetic systems or encapsulations when in the presence of cellulosic materials or moisture. Prolonged contact with aggressive solvents (e.g. keytones, alcohol) may cause enamel softening.

TYPES AND SHAPES OF WINDING WIRES:

The winding wires used in electrical motors are classified as follows. 1) Round wires 2) Rectangular straps 3) Stranded wires

1. **Round Wires:** It has thin and thick conductors and are used in semi-closed slot type motors and mush winding rotors. It is wounded in reels and available in Kilograms.
2. **Rectangular straps:** It is used in open type slot motors. These conductors are available as long straps in meters. They are used in the following places. 1) Low voltage motor windings.2) Used as conductor in high current motor. 3) Series field motor winding coils.
3. **Stranded wires:** Stranded wire is composed of a bundle of small-gauge wires to make a larger conductor. Stranded wire is more flexible than solid wire of the same total cross-sectional area. Stranded wire is used whenever ease of bending or repeated bending are required. Such situations include connections between circuit boards in printed-circuit-board devices, where the rigidity of solid wire would produce too much stress as a result of movement during assembly or servicing; A.C. line cords for appliances; musical instrument cables; computer mouse cables; welding electrode cables; control cables connecting moving machine parts; mining machine cables; trailing machine cables; and numerous others. 1) Cotton covered insulating wire
2) Silk covered insulating wire 3) Paper insulated wire 4) Varnish coated glass paper covered wire 5) Enamel coated round shaped wire.

Note: **Usage of alternate sizes**

1. If rewinding is done, use the existing winding wire gauge number for the new winding. Sometimes if same gauge winding wire is not available then we can use the 2 runs of wire each having half of the area of cross section of the original one.

Table 6.2 A sample of gauge No's and its equivalent are given in the following table.

Standard Gauge Number	**Equivalent Gauge Number and runs**	**Standard Gauge Number**	**Equivalent Gauge Number and runs**
10	Two runs of 13 SWG	19	Two runs of 22 SWG
12	Two runs of 15 SWG	19	Two runs of 25 SWG
14	Two runs of 17 SWG	19	Two runs of 27 SWG
17	Two runs of 20 SWG	19	Two runs of 28 SWG

1. Area of Cross-section of one particular wire gauge number is two times more than that of gauge number, when increased by three. For example, area of cross-section for 17-gauge wire is approximately two times more than that of 20 gauge wires. If 17-gauge wire is not available, then we use two 20 gauge wires.

2. When 20 gauge and 17 gauge wires are used for particular length, then the weight of 17-gauge wire is double as that of the weight of the 20-gauge wire, because weight is directly proportional to the area of cross-section of the wire.
3. Resistance of the winding wire is indirectly proportional to the cross-sectional area of the wire. Therefore, the resistance of 17-gauge wire is half of the resistance value of 20-gauge wire.
4. Resistance of winding is measured in two methods.

   (i) By using multimeter, the resistance of the winding is directly measured in ohms or kilo ohms.
   (ii) 15 to 20% value of the rated voltage is applied by using auto transformer to each phase of three phase winding. Then current in each phase is measured and then the resistance of the winding is calculated.

Insulating Materials

Insulating materials are non-metallic materials that does not allow electric current to pass through it at normal temperatures. There are number of insulating materials used in Electrical apparatus and machinery. They may be organic or inorganic, uniform or heterogeneous in composition, natural or synthetic. there are many properties such as resistivity, breakdown voltage, thermal stability etc. that determine the suitability of a material to be used as insulating material.

Properties of insulating materials

An ideal insulating material must should have the following properties.

1. High dielectric strength at the specified temperature
2. high resistivity
3. low dielectric hysteresis
4. Good thermal conductivity
5. good moisture withstanding capacity
6. it should be chemically inert
7. It should be able to withstand vibration, abrasion and bending

Classification of Insulating materials

Insulating materials can be classified in two way.

1. Based on their material
2. Based on their temperature withstand capacity

Classification based on substances and materials. Table 6.3

State	Materials	Examples
Solid Insulating Materials	Fibrous materials	wood, paper and card board, insulating textiles
	Impregnated fibrous materials	impregnated paper, varnished or impregnated textiles
	Non resinous materials	asphalts and bitumens, waxes
	Ceramics	porcelain, steatite, alumina,

State	Materials	Examples
		titanate, etc.
	Glass	fused quartz or silica glass, Pyrex, fiber glass
	Natural and synthetic rubbers	natural rubber, hard rubber, butyl rubber, neoprene, hypalon, silicon rubber
		Mica and its products; Asbestos and its products
Liquid Insulating Materials	Oils	Refined hydrocarbon minerals oils, Linseed oil, silicon liquids, vegetable oils etc.
	Varnishes	synthetic varnishes and spirit
Gaseous Insulating Materials		Carbon dioxide (CO_2), Dry air, argon, nitrogen, etc.

Temperature withstand capacityTable 6.4

Class of Insulation	Temperature Range	Insulation Materials
Y	90 Deg. C	Cotton, Natural Silk, Cellulose Fibre, Paper and paper products, Pressboards, Vulcanising Fibre etc.
A	105 Deg. C	Impregnated cotton, silk, Paper and paper products, oil enamels, Laminated wood, Wire Enamel based on polyamide resins etc.
E	120 Deg. C	Wire enamels based on Polyvinyl formal, Polyurethene or Epoxy resin, Phenol-formaldehyde mouldings of cotton, paper etc. Cellulose triacetate film etc.
B	130 Deg. C	Glass Fibre, Asbestos, Oil-modified synthetic resin, varnished glass fibre and asbestos, Shellac, asphalt, Bituminous

		compounds, Built up mica, Glass Fibre laminate, Asbestos laminate etc.
F	150 Deg. C	Alkyd, Epoxy, Polyester, Silicon-Alkyd and Silicon phenolic resin impregnated glass fibre cloth, Built-up Mica with Alkyd, Epoxy, Cross Linked Polyester and Polyurethene Resins with Superior Thermal Stability Silicone Alkyd Resins.
H	180 Deg. C	Silicon Varnished impregnated Glass Fibre Cloth, Mica Silicon resin Bonded Built-up mica and combinations of Mica and other class materials with suitable bonding materials.
C	Above 180 Deg. C	Mica, Porcelain, Glass Quartz, Asbestos, Built-up Mica Treated Glass fibre cloth.

Insulating Materials - Forms

Insulating materials are availableindifferentshapesandsizes.Insulatingmaterialsareavailable as Tapes, rolls, sleeves, paper andcloth.

Insulation Tapes and sleeves: Insulation tapes are used cover the windings(coils)ontheoverhangside.Shellacorvarnishareappliedover thiscoveringtopreventitfromabsorbingmoistureandimproveinsulation strength. Tapes are sold as rolls in required lengths. Different types of Insulationtapesavailableare:Cottontape,PVCtape,Silktape,Polyester tape,Asbestostape,GlassFibertape,Empireclothtape,Micatape Insulation sleeves are used to cover the joints made at the coil ends and coil leads. It gives physical protection to joints and also provides insulation. They come in rigid and flexible types. They are available for standard wire sizes.

Insulation paper:A variety of insulating papers are available specifically designed for insulating electrical circuits. In motors it is used to insulate the slots, in between coils. Following are the most often used insulating materials: Leatheriod paper, Press pan paper, Manila or hemp paper, Triflexil paper, Asbestos paper, Micanite paper

Insulation cloth: It is inserted between the coils after they are placed in slots. Sometimes it is also used as slot liner. Empire cloth, Asbestos cloth, Glass cloth, Mica cloth, Micanite-cloth are some of the types.

Insulation Materials:

Leathroid paper: These papers are pressed form of a non-woven fabric of fibers from good and tough wood. It is available from 0.05mm thickness. It is sold as rolls in meters. Generally used for low voltage machines. This A-grade insulating material is mainly used as insulation in electrical appliances, machineries, and power equipments.

NOMEX: NOMEX is widely used in a majority of electrical equipments. It is used in almost every known electrical sheet insulation application. Available in various thicknesses with a density from 0.9 to 1.0, NOMEX is ideal choice to use as slot insulation in hand-wound motors and for covering of coils, and is also used in other applications such as folded or punched parts. It is also widely preferred as sheet insulation in fluid filled transformer applications due to its improved impregnability. Dielectric strength of NOMEX ranges from 24 to 30 kV/mm. This is Insulation class F (155 °C) materials.

The NOMEX sheet can be used with virtually all classes of electrical varnishes and adhesives (polyimides, silicones, epoxies, polyesters, acrylics, phenolics, synthetic rubbers), Resins quickly penetrate and pass through the sheet to form a cohesive bond between motor end turns. Due to its stiff structure it can be quickly and easily inserted between coils. Mechanical toughness of the sheet helps to keep the shape of the insulation intact during motor assembly. NOMEX is able to maintain its insulation properties over a long period even if it is subjected to temperature variations. This assures proper insulation between phases and gives good reliability for the motors. NOMEX sheets can also be used with transformer fluids (mineral and silicone oils and other synthetics) and with lubricating oils and refrigerants used in hermetic systems. Common industrial solvents (alcohols, ketones, acetone, toluene, xylene) have a slight softening and swelling effect on NOMEX paper, similar to that of water. These effects are largely reversible when the solvent is removed. The Limiting Oxygen Index, LOI, (ASTM D-2863) of NOMEX paper at room temperature ranges between 27 and 32% (depending on thickness and density). Materials with LOI above 21% (ambient air) will not support combustion.

Triflexil: Combined flexible insulating material, this is **Insulation class F** (155 °C) material conforms to IEC 626-1. The material consists of two or three layers: Inner layer: Polyester film, Outer layers: Polyester non-woven fabric, esterimide-impregnated. Good adhesion between impregnating or trickle resins. Smooth surface, therefore good machinability, Low moisture absorption, good chemical resistance. Dielectric strength: 7 – 24 kV. Used widely as Slot insulation, slot closure, layer insulation. Triflexil is available in sheets, rolls, strips, and in thicknesses from 0.25 mm.

Film paper: Polyester film is a flexible, strong and durable film with right balance of properties making it suitable for many industrial applications. It is **Insulation class E** (120 °C) material. In motor applications, certain types of polyester film are used for ground insulation as slot liners and wedges, as well as phase insulation. Polyester film is a tough general purpose film which is semi-transparent with thickness ranging from 0.075 mm or above. Generally, it has a tensile strength of an average 210 MPa, highly resistant to moisture and most chemicals. It is able to withstand temperatures ranging from extremes –70°C to150°C. Since it contains no plasticizers, film does not brittle with age under normal conditions. Dielectric Strength is 2,5 to 20 kV/mm. Melinex, Mylar, Teonex are some of the trade names of the films used.

Press Board: It is a mixture of cellulous and old cloth and is manufactured in short lengths. It is also called as Fuller board. It is similar to a press pan paper. It is available from 0.1 to 0.8 mm thickness of wire and 1 to 3 mm thickness of plates. **Insulation class A** (105 °C). Brown colour, non-glazed (mat), glazed (polished) on both sides. Dielectric strength is 11 kV/mm. It is used as slot insulation, Core insulation, Separator, Used under bamboo sticks.

Empire cloth: It is made by using cotton or silk cloth dipped in varnish. It is yellow or black in colour. It cannot withstand high heat, but flexible and can withstand high moisture. It has good mechanical and dielectric strength. Used as cover for armature winding, slot insulation along with leathroid paper, Insulation paper between coils, in between small transformer windings.

Bamboo sticks: During running of motor, the coils may be come out from the slots due to centrifugal force. This is avoided by inserting bamboo sticks at the top side of the slots. The sticks are made to size depending on the slot size. Hard trees are used for making these sticks.

Paper: It is prepared from wood pulp and manila fibres beaten and rolled into sheets. Its dielectric strength is 4 to 10 kV/mm thickness. It is moisture absorbent and so is particularly suitable for impregnation. Electrical properties are quite good. It is rarely used in un impregnated condition but can be used successfully under oil. It catches fire at 1250 C so that the temperature of any paper insulated apparatus is limited to about 1000 C.

Wood: The dielectric constant of wood varies in the range 2.5 to 2.7. Dry resistivity is in the order of 1010 to 1013 cm. It can withstand a voltage gradient of 40 kV/mm in service. These properties vary over a wide range, depending on the type of wood, seasons of cutting, grain direction, and especially the water content. Used for slot wedges, Papers, etc.,

Asbestos board: Its dielectric strength is 3 to 4.5 kV/mm thickness. It is highly moisture absorbent. Its strength increases by impregnation but heat resistance and non-inflammability reduces. It melts at 15000 C. It is neither mechanically strong nor flexible. Purified fibers with clay filler have better electric strength. Asbestos electrical insulating paper is supplied in thickness of 0.2 to 1.0 mm and, depending on its thickness, has a minimum breakdown voltage from 0.9 to 2.4 kV. It is manufactured by using zinc chloride solution with paper plate. It is in grey colour or yellow colour After the coils are inserted in the slots, this is provided on the top of the slot as a protection to coils and also used as insulated between coils. Other types of boards are

1. Hard board 2. Ivory board 3.Hylum sheet

Mica: It is a mineral consisting of silicate of aluminum with silicate of soda potash and magnesia. It occurs in the form of crystals, can easily be split into very thin sheets. It is affected by oils. The resistivity of mica at 250 C ranges from about 1012 to 106 cm. The dielectric strength varies from 40 to 150 kV /mm. It is least affected by heat but dehydrates at high temperatures. It has high dielectric strength and low power loss. It is rigid, tough and strong. Moisture does not have any effect on it. Its electrical properties are deteriorated in the presence of quartz and feldspar. The Mica paper is not sufficiently strong or self-supporting. Hence, it has to be given backing of glass cloth or other binding material such as epoxy resin. Epoxy resin bonded mica paper is extensively used in both low and high voltage machines. For non-epoxy system a varnish impregnation is essential to fill the air pockets and also to act as a barrier against moisture and chemicals present in the atmosphere. The varnish used should have the property of forming an unbroken tight adhesive and reasonably flexible film.

Mica resists to a high degree the attack of gases such as combination products but is attacked by warm hydrochloric acid potassium hydrate, warm alkaline carbonates, and water containing carbon dioxide. Mica is used as insulation separator for commutator segments, washers, gaskets for core end bolts. It also used as composite tapes and sheets.

Micanite: Normally, mica is available in the form of very thin splitting. Hence it is bound to a supporting sheet of electrical grade paper or glass cloth with a suitable binding agent. The resulting mica sheets are known as micanite. Its dielectric strength is 30 kV/mm. It is used as insulating sheets between coils of different phases.

Bakelite: It is a type of phenol formaldehyde. Its dielectric strength is 6 to 15 kV/mm thickness. It is hard thermosetting and dark colored material. Used for making terminal boards, and slot wedges.

Glass: It is a thermoplastic inorganic material comprising complex system of oxides. The volume resistivity at 2000 C is extremely high, Quartz glass is non-hygroscopic, has very high chemical resistance, withstands temperature fluctuations, and has a low co-efficient of linear expansion of 5.5×10^{-7} cm per 0 C. It is not subjected to thermal ageing. Glass has a very high compression strength [6000 to 21000 kg/cm^2] but a low tensile strength [100 to 300 kg/cm2] and is extremely brittle. The dielectric constant varies from 3.8 to16.2. At room temperature it can withstand a voltage gradient of about 8- 20 kV/mm. Toughened glass is used for insulation in EHV lines, of voltages more than 100 kV. Glass fiber tapes, threads and sleeves are indispensable part of a motor insulation.

Cotton or silk: Cotton is hygroscopic (absorbs moisture) and has low di electric strength, so it must be impregnated with varnish or wax after winding. Cotton covered wire is extensively used for winding of small magnet coils, armature windings of small and medium sized machines,chokes and transformer coils etc. Silk is more expensive than cotton but takes up less space and is therefore used for windings in fractional horse power machines.

Silk is less hygroscopic and has a higher dielectric strength than cotton, but like cotton it requires impregnation. The operating temperature of cotton and silk is 1000 C and the material may catch fire above this temperature.

Rubber: Rubber is obtained by vulcanizing raw rubber [natural or synthetic]. Ordinary electrical insulating rubbers, have the following electrical characteristics under normal conditions:

The electric strength of organic rubbers strongly depends on the kind of current involved, the degree of stretch, and the time during which the voltage remains applied. When left upstretched and subjected to a short-time 50 Hz test voltage, rubber will have an electric strength within the following limits, depending on the pure-rubber constant.

For a 20 to 25 % rubber content… 20 to 30 kV/mm

For a 30 to 35 % rubber content… 30 to 45 kV/mm

The di electric strength of rubber is 2 to 2.5 times the electric strength at 50 Hz.

Although rubber is practically water and gas tight its electrical characteristics are affected by moisture, especially for rubbers compounded with considerable quantities of the substances which increases the sensitivity to moisture. Only specially compounded rubbers can maintain their electrical characteristics nearly unchanged when kept continuously in contact with moisture. Normally used as seals, gaskets and washers.

For normal rubbers the maximum operating temperature is usually 550C, for rubbers of great heat resistance it is 650C. For butyl rubbers the working temperature can be as high as 900C. Rubbers possess a limited post resilience and at sufficiently low temperatures become brittle.

Silicon rubbers: They have high electrical insulating properties, heat resistance, frost resistance, moisture resistance, as well as resistance to ozone and light. These rubbers can be produced as adhesive tapes [lined with a layer of vulcanized rubber] suitable for insulating the windings of high-voltage electrical machines. Those tapes also serve to insulate the terminal leads of electrical machines designed for high temperature rise. Silicon rubbers retain their flexibility at temperature as low as -100C. One of their drawbacks is relatively low mechanical strength, another is high cost.

Insulating fabrics: Base materials for insulating fabrics include natural fibers such as cellulose, cotton and silk; synthetic organic fibers of, for example cellulose derivatives, polyamides [nylon], polyethylene tarepathalates; and inorganic fibers, chiefly glass and asbestos. Non-woven synthetic organic fibres are usually bonded into a fabric by use of a bonding resin or by fusion. They find electrical use chiefly as a base for resin-impregnated insulation.Unimpregnated woven fabrics find some limited use in electrical insulation. The electric strength of such fabrics generally does not exceed the breakdown strength of an equivalent air gap and indeed be less. Their chief use, therefore, is to provide mechanical strength, abrasion

PLASTICS: Aplasticinabroadestsenseisdefinedasanynon-metallicmaterialthatcan bemouldedtoshape.Themostcommondefinitionforplasticsisthattheyarenaturalorsynthetic resins,ortheircompoundswhichcanbemoulded,extruded,castorusedasfilmsorcoatings. Mostoftheplasticsareoforganicnaturecomposedofhydrogen,oxygen,carbonandnitrogen. Thesyntheticplasticdevelopmentdatesfrom1909whenDrBakelandannouncedtheproduction ofphenol-formaldehyde.Sincethenseveralnewplasticshavebeendeveloped.

Theplasticspossessinfinitevarietyofproperties.Propertiescommontomostoftheplastics are given below:

1. Lightweight. 2. Lowthermalconductivity 3.Awiderangeofcolours
4. Resistance to deteriorationbymoisture 5. Low electrical

conductivity Plastics, most commonly, areclassifiedas (1). **Thermoplastic** and (2)**Thermosetting**.

Thermoplasticmaterialsarethosewhichsoftenontheapplicationofheat,withorwithout pressure but they require cooling to set them to shape.

Thermosetting materials are those plastics which require heat and pressure to mould them into shape.

Thermoplastic Materials:

Polyethylene or Polythene: Polythenes are obtainable as viscous liquids, gums and tough flexiblesolidssuitableformoulding.Theyhavewaxlikeinappearance,semi-transparent,odourless and one of the lightest plastics. Flexible over a wide temperature range. High resistivity and dielectricstrength.Chemicallyresistant.Donotabsorbmoisture.Dielectriclossesanddielectric constant are low. They are relatively cheaper incost.

Polyvinyl chloride (PVC) : The vinyl chlorides are formed from hydrochloric acid, limestone, andnaturalgasorcoal.Theformsofvinylchloridearealmostunlimited.PVCisusedinelectric and electronic equipment such as circuit boards, cables, electrical boxes, computer housing, insulation and adhesivetapes.

The flexible types are strong, tear resistant and have good ageing properties. The rigid types

Softening temperature	..…….	120^0C
Insulation resistance…	……...	10^{12}-10^{13}

have good dimensional stability and are water resistant. They are resistant to acids and alkalies. It becomes soft beyond 80^0C. It is self-extinguishing when ignited and the source of flame is removed. It offers more resistance to oxygen, ozone and sunlight.

Dielectric strength……. 30kV/mm

Forexample,PVCisdifficulttoigniteandintheabsenceofapowerfulexternalflamewillnotcontinue to burn. This is due to its chlorine compound. This makes it an ideal construction and cable material. The incineration (burning) of PVC causes the release of toxic chemicals like dioxins and other chemicals that are harmful to humans.

Thermosetting Plastics
Aminos

[a] Urea formaldehyde resins: They are derived from the reaction of urea with formal - dehyde or its polymers. These resins cannot offer high resistance to heat.

[b] Melamines: When the resin is used with asbestos or glass fiber as filler material, its heat resistance is in the range of 2000 C. It is highly resistant to chemicals. Possess outstanding electric arc resistance. Excellent resistance to water. Available in full range of transluscent or opaque colours. Boards are made from these material are used as distributor heads, casings for electric devices, terminal boards.

Phenolics [Phenol formaldehyde resin]: They are made by a reaction between phenol and formaldehyde. They are probably the most widely used and cheapest of thermosetting plastics. Strong, rigid and dimensionally stable.

Heat and solvent resistant. Non-conductors of electricity. Used as Electrical appliance handles, TV and Radio cabinets

Why is an insulation paper inserted during motor winding?

The conductor used during wiring is to be insulated from ground and each other as there is potential difference among them. In general, after few turns of winding insulation paper is inserted to avoid **Inter-Turn Breakdown.**

Suppose the winding is of 200V having 1000 turns, this means the difference between 1st turn and last turn will be about ***1kV.*** So only Enamelled insulation will not withstand this voltage.

That's why paper insulation is used in winding.

6.3General procedure for rewinding

Electric motors are relatively simple mechanical devices, but rewinding them isn't—in fact, it's one project that's usually best left to the professionals. Given the sheer number of different motors and winding patterns, the rewinding process can vary greatly. However, it generally involves cutting the original windings out of the motor's stator or armature and replacing them with new coils made from wire of the same basic type and gauge.

Part 1

Disassembling the Motor

1 Wipe off your work surface with a lint-free cloth. Run the cloth lightly over the table, desk, or work bench where you'll be doing your tinkering to remove any standing dust or debris. It should be completely clean before you crack open the motor.

- Working on a dirty surface could introduce dust or debris into the motor housing.
- It's especially important to make sure there are no metal shavings in the area, as you'll be working with magnetic parts that can accidentally attract them in if you're not careful.

Fig 6.3

2.Remove the motor's outer housing. On most types of small motors, this will require you to unfasten four screws from around a small endplate on the top and bottom of the unit. Once they're out of the way, you'll be able to see each of the motor's primary internal components, including the stator, armature, and windings.

- The stator is a fixed steel drum encircling the innards of an electric motor. It's typically magnetized or fitted with coils of magnet wire.
- The armature (also known as the "rotor") is a small bearing-like piece in the center of the motor construction. When it receives the magnetic force of the stator and windings, it spins, powering the motor.
- The windings are long coils of copper wire typically located around the stator. They channel electromagnetic energy into the rotor to cause the motor to turn.

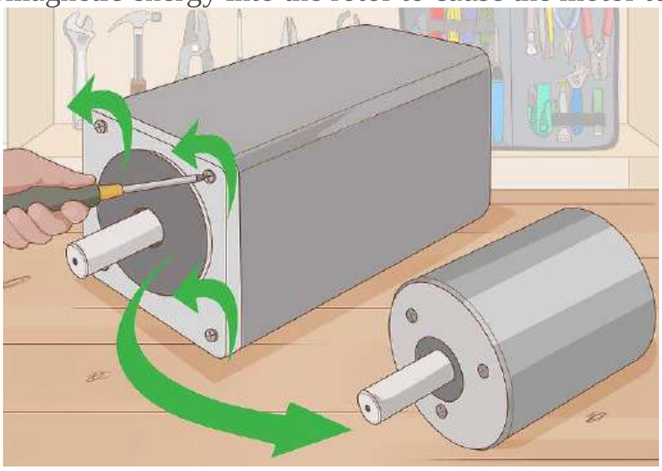


Fig 6.4

3.Take pictures of the motor's current configuration. Snap a few photos of the inside of the motor from different angles and make a note of the way each of the main components looks. Documenting the motor's appearance before you begin making modifications to it can be helpful in case you make a mistake.

- You could even make a video recording of the deconstruction process in order to ensure that you're recreating the original winding pattern and connections precisely.

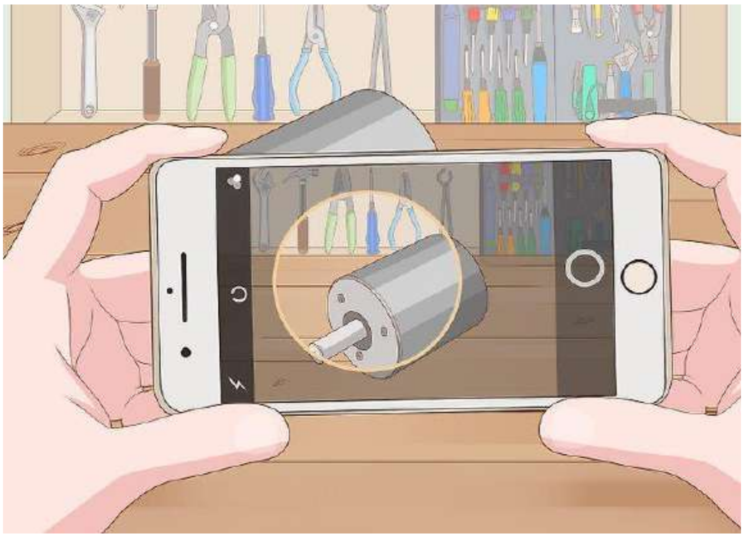


Fig 6.5

4.Force the armature out of the stator by hand. Once you've removed the upper endplate from the motor housing, guide the armature straight out the bottom of the circular stator, along with the attached lower endplate. You'll encounter some resistance from the magnets around the stator, which means you may have to push a little harder than you might expect before it will give way.

- Wear gloves to protect your hands and avoid transferring the oils from your skin to any part of the stator or armature.
- Be careful not to damage the armature or any of the surrounding parts of the motor, especially the conductive copper commutation pads.
- Once you've removed the stator and armature, set the housing aside where it won't accidentally attract stray metal pieces.

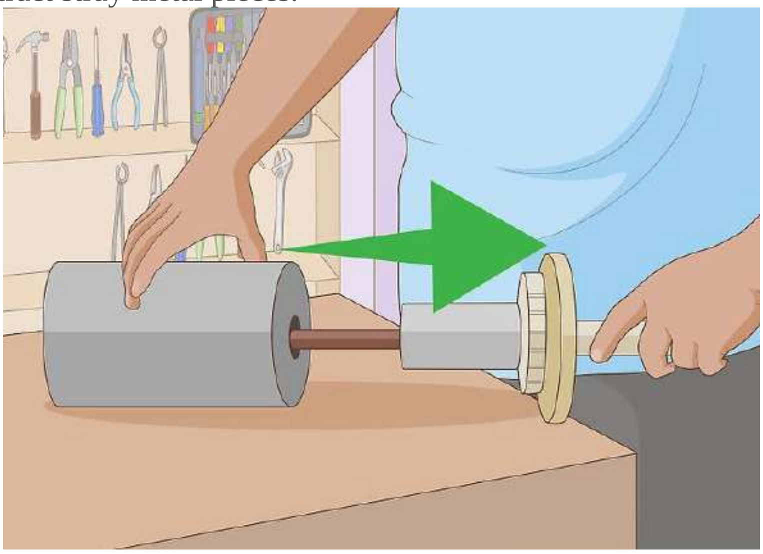


Fig 6.6

Part 2

Removing the Original Windings

1.Use a screwdriver to pry open the tabs on the brush pads. Wedge the tip of a flat-blade screwdriver underneath the thin metal tabs, then pull up gently on the handle to lift them enough to loosen the coiled wire. On some motors, there may be as many as 12-16 tabs in total.

- Try to bend the tabs as little as possible to avoid damaging them. If one of them happens to break off, you may have trouble keeping the replacement windings in place later on.

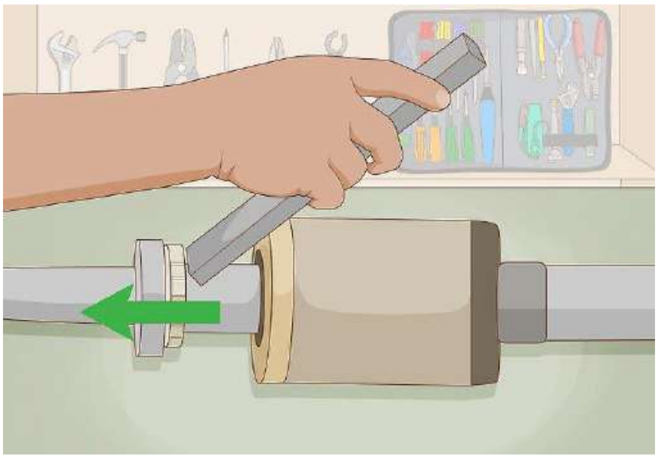


Fig 6.7

2.Cut the old windings free using a pair of wire cutters. Depending on the type of motor you're working on and where the problem lies, the faulty windings may be found on either the stator or the armature. Snip each coil of wire where it connects at the top of the protruding posts.

- Cutting out the spent windings can be painstaking work. It may be necessary to sever one wire at a time to make removing the coils more manageable.
- Be sure to count the number of winds in each coil so that you can rebuild the motor in the exact same configuration.

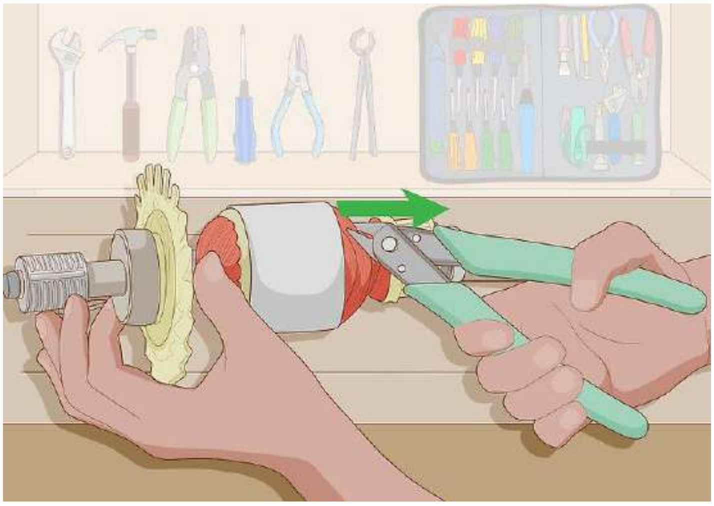


Fig 6.8

3.Pull the cut coils free of the armature or stator by hand. Once you've cut every last connection, the old windings should come out with a couple of tugs. If you're having trouble getting them started, use the tip of your screwdriver or a pair of pliers for extra leverage.

- Before you handle the cut coils, pull on a pair of thick work gloves to safeguard yourself against cuts and scratches.

- If the coils refuse to budge, it's possible that they haven't been severed completely. Look for connections around the posts or bottom of the coil that you might have missed.

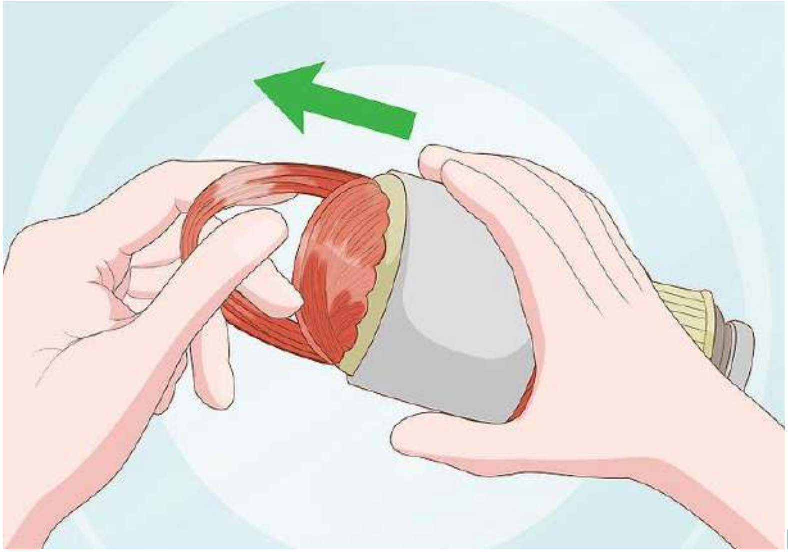


Fig 6.9

4.Replace the insulation paper lining the stator if necessary. First, pull out the old paper out of the slots in the stator using a pair of pliers or tweezers and make sure the empty slots are free of debris. Then, measure the width of the slots and cut a sheet of insulation paper into strips of the same width. Fold the strips gently and slip them into the slots in the stator individually by hand.

- If the insulation paper that's already in place appears to be in good shape (it should be clean and intact), you can simply leave it where it is and begin the rewinding process. If it appears burnt or otherwise damaged, it's a good idea to replace it before proceeding.
- Do not, under any circumstances, attach the new wire directly to the bare steel stator or armature posts. The coils must be insulated at all times.
- You can order electric motor insulation paper online from suppliers that carry electrical materials.

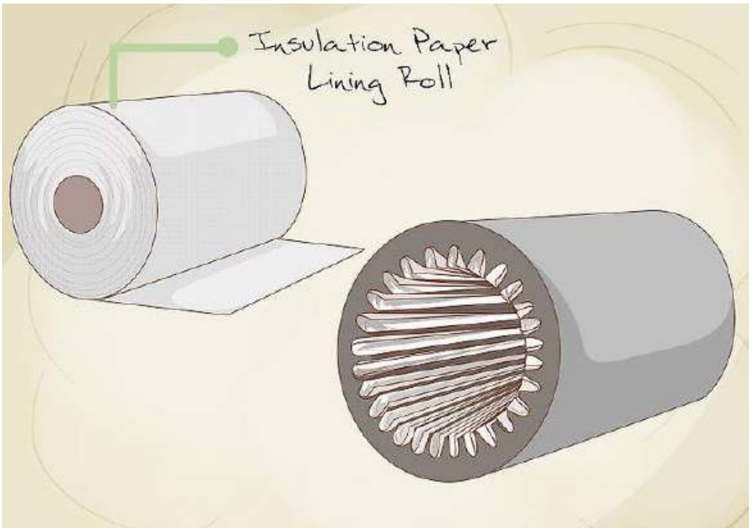


Fig 6.10

Part 3

Installing the New Windings

Fig 6.11

1.Rewind the armature or stator using the same gauge of wire. It's important that the wire in the new coils be the same thickness and have the same number of winds as the original windings. Otherwise, it may be a poor fit or cause conductivity issues.

- Run a search for your engine's voltage online to see what gauge of wire it's commonly fitted with. If you don't see the voltage displayed anywhere, you may have no choice but to eyeball it.
- If you're unable to find magnet wire in the same gauge as the motor's original windings, opt for a size larger rather than smaller. **Thicker wire can slow the motor down slightly, but presents less risk of overheating.**
- Consider using this opportunity to upgrade from outdated enamel-coated wire to a higher quality variety, such as nylon and polyurethane-coated wire.

2.Recreate the original winding pattern for each set of coils. The exact configuration you use will depend on the specific type of motor you're repairing. To ensure optimal performance, take great care to make each coil tight, precise, and compact, without any unnecessary crimping or spacing.

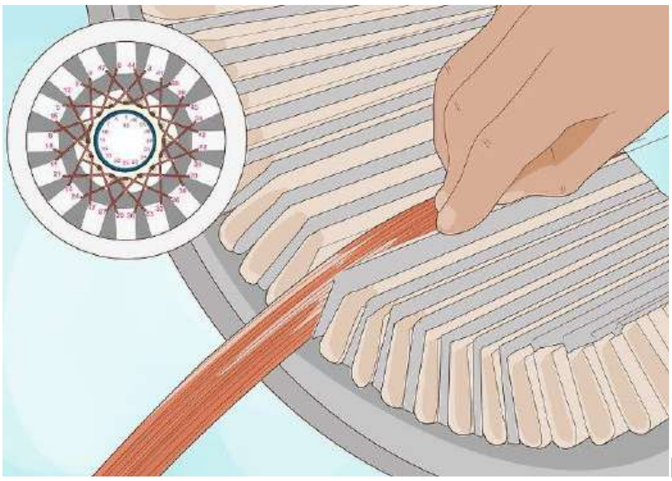


Fig 6.12

- Leave the end of your first winding free and make sure it's long enough to reach one of the metal tabs circling the brush pads.

- Unless you're familiar with the necessary winding pattern, it's recommended that you leave the job to a professional. Your motor may not work correctly if you make a mistake.

3.Secure completed windings using the tabs around the stator. Every time you finish a section, lower the tabs down over the coils. This will help hold them in place while you work and ensure a proper connection once the motor is operational.

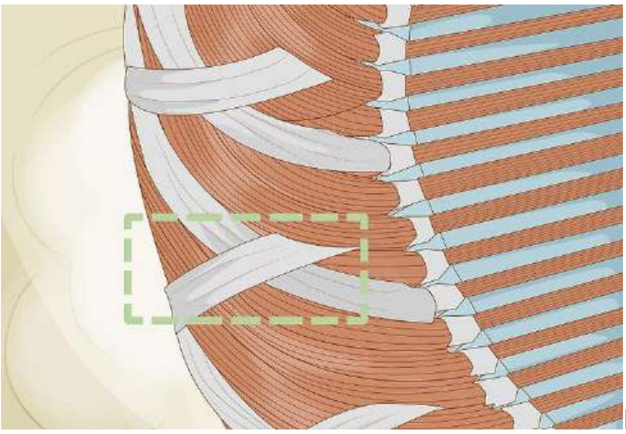


Fig 6.13

- If you wish, you can remove a small amount of insulation paper from the spot where the wire makes contact with the tab using a sharp knife or sandpaper to improve the connection.

4.Connect the loose ends of the first and last windings to the starting tab. Twist the two wires tightly around the edge of the tab. Doing so will complete the circuit, allowing energy to flow from the generator through the windings to the armature.

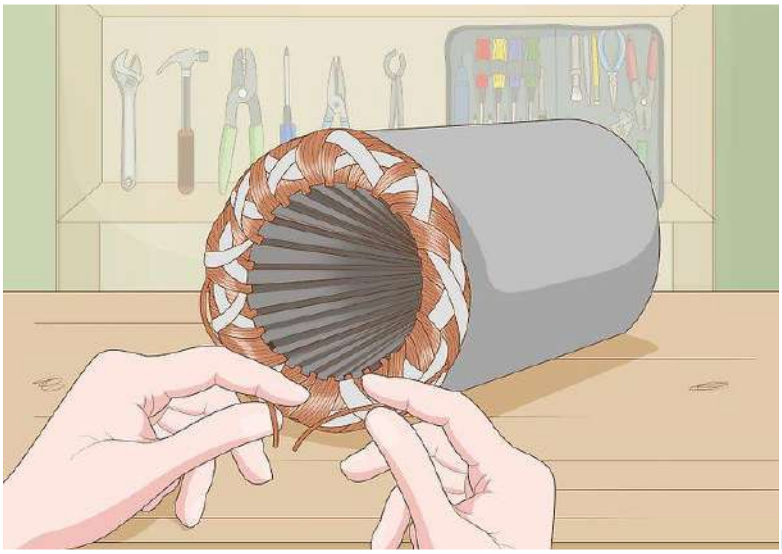


Fig 6.14

- Double-check to make sure that none of the wires connected to the tabs are touching one another.

6. Reassemble the motor. Once you've successfully rewound your motor, reinsert the armature into the stator and fit both pieces back into the motor housing. Replace the end-plates on either side of the unit and tighten the screws until they're secure. If you've done everything properly, your motor should function like new.

- If you don't remember how the motor is supposed to fit together, refer to the photos or videos you took earlier.

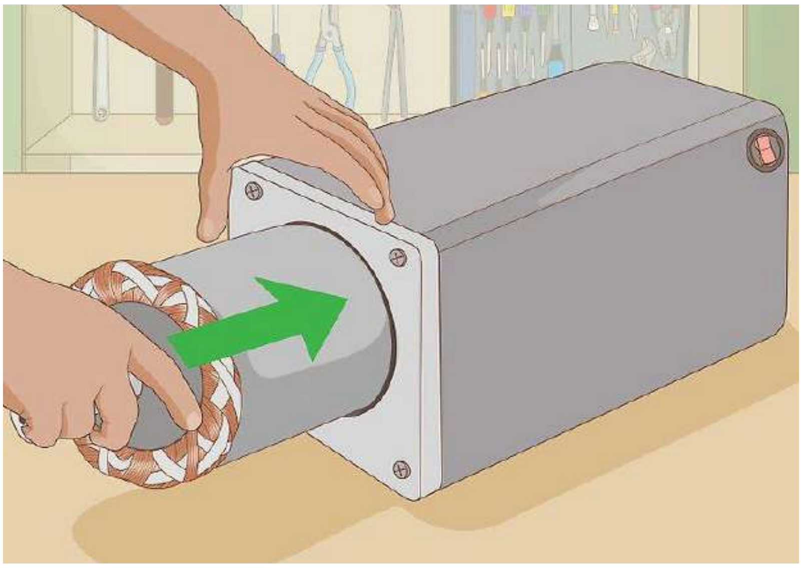


Fig 6.15

7.Test the motor out. Reinstall the motor in the device it came out of and give it a trial run. If it doesn't work, there's a good chance you made a mistake somewhere along the way. At this point, you'll have no choice but to take it in for professional repairs or purchase a new motor.

- Turn the motor off immediately if you see smoke or detect a burning smell. It's possible that the new windings are overheating, or that there's a short somewhere in one of the connections.

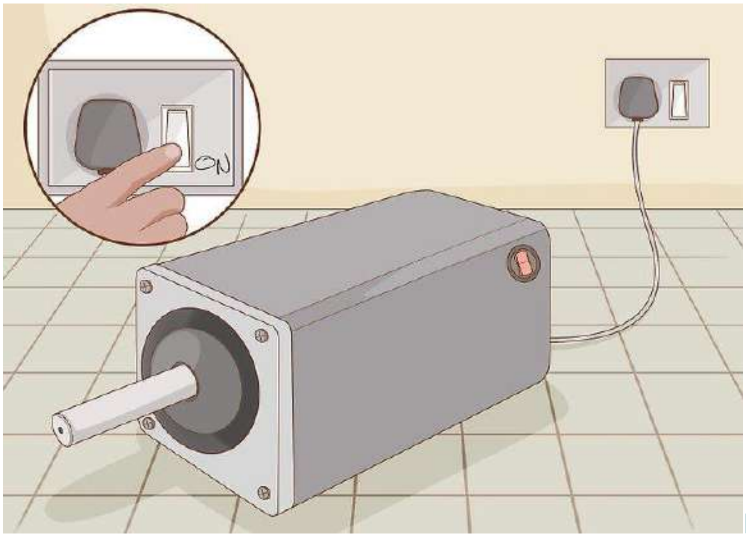


Fig 6.16

Rewinding and disassembling motor is very time consuming work, you will need following tools:

- Basic tools (screwdrivers, hammers, wrenches...)

- Pulleys for bearings

- Chisels, to cut off old winding

- Butane torch (or other heating device)

Special Material:

- Copper wire

- Isolate paper
- Stator lacing thread
- Spray Lubricant (WD-40 or similar)
- Motor lacquer

INSULATING VARNISHES

Varnish coating, also called Secondary Insulation, is an important component of the insulation system of an electrical machine. Varnishes, of different types are used in the insulation system of electrical machines for impregnation and finishing applications. Advantages of these coatings are:

- ❖ Increased mechanical bonding to the winding wires
- ❖ Improved dielectric properties
- ❖ Improved thermal conductivity
- ❖ Protection to the winding against moisture and chemically corrosive environment.

Varnishes are classified based on:

1. Applications of varnish. 2. Type of (varnish) curing method. 3. Based on main raw material used in varnish.

Insulating varnish based on applications:

2. Impregnating varnish 2. Finishing varnishes 3. Core plate varnishes

4. Bonding varnishes 5. Special purpose varnishes

Insulating varnish based on Curing method:

1. Air drying type 2. Oven baking type

Main raw material used: Alkyd Phenolic, Alkyd, Polyurethane, Isophthalic Alkyd, Modified polyester, Epoxyester Melamine, Polyestermide, Epoxy, Phenolic, Phenolic Melamine - based. The above varnishes come in Solvent based and Solvent-less based.

Method of applying varnish:

❖ Applying a coating with a paint brush ❖ Dipping the specimen into varnish

❖ Vacuum pressure method ❖ Conveyorised dip method.

Impregnating varnish: The main function of impregnating varnish is not electrical insulation of current-carrying conductors. but to fill the empty spaces in and around windings and to provide mechanical reinforcement of the loose grouping of conductors, even at high temperatures. The filling of empty spaces not only gives mechanical strength, but also hinders or prevents penetration of unwanted substances from the environment. This gives the component improved resistance to chemical attack, to moisture, thus extending its service life. They are applied by dipping the component in the varnish, or less often by trickling process. These type of varnishes needs to be cured (heated in a oven) at temperatures ranging from 100oc to 160oc for 2 to 12 hours' time.

Finishing (coating) varnish: Finishing varnish is used not to strengthen the windings, but to protect the component from external attack by environment conditions. They are applied purely as a surface coating, and are characterized by outstanding film forming properties. Often applied by paint brush or sprayed, in repair shops after rewinding works. They are mostly air drying type. It takes almost a day to completely cure.

Core plate varnish: This varnish is applied to electrical laminations used in electrical machines. This acts as insulating layer between successive laminations. It is baked at high temperatures, 350^{o}-450^{o}C for about 5 min.

Binder varnish: This type of varnish is used as bonding agent between two insulating materials. Mechanically weak materials when bonded show good rigidity. It is baked at temperatures of about 120^{o}c to 450^{o}c for a duration of 3min. to 60 min, depending on the grade of the varnish.

Properties of Insulating varnish coating after curing: Varnish after application and after undergoing required curing process at appropriate temperature forms into a uniform film on the materials. The elastic varnish film has very good mechanical properties such as hardness, flexibility, penetration, good adhesion and Bonding strength. The cured film is resistant to moisture, dilute acid, alkalis, chemicals like benzene & Toluene, oils and tropical climate from 0ºC to 55ºC. It has good dielectric behavior and dielectric strength.

Applying Varnishes: For treating coils, windings, and insulating parts with insulating varnishes the methods generally used are Vacuum impregnation, Hot dipping. Finishing varnishes are usually applied by brush or spray. Mica sticking varnishes are applied by brush or sometimes by machine[by passing a roller which dips in the varnish]. Synthetic varnishes are frequently used for impregnation by dipping and require baking to develop their properties fully.

TYPES OF INSULATING VARNISHES FOR VARIOUS APPLICATIONS

1. Clear baking varnish… Armatures, field coils and instruments.
2. Black baking varnishes…..…..Armatures, field coils and transformers when higher electric strength and resistance to moisture, acids, and alkalies are wanted. They have less resistance than those of clear.

Baking

The dip-and-bake system is probably one of the most common conventional methods of applying varnish. In this process, the complete stator and coil assembly is submerged in a tank of varnish, either under normal atmosphere or under vacuum or pressure.

Various parts may be either preheated or at ambient temperature depending on the type of varnish being used. The size of the part and configuration of the windings will determine the amount of time it takes for the varnish to fill the voids in the slots and windings. Submerging the part for various time intervals, weighing the part, and electrically testing the part after baking will determine the proper dip time. One disadvantage of dipping parts in varnish is that removal of the varnish in unwanted areas is required after baking, thus adding to the cost of the finished assembly. Conventional dip-and-bake systems using convection heat typically have dip times in the range of 5 to 30 min for larger parts and bake times of 2 to 4 h at 350°F (205°C). Times range from 30 s to 5 min for smaller parts. Parts coated with water-based varnishes will operate at lowertemperatures.

Production lines processing over 200 parts per hour most often can justify and utilize a dip-and-bake system.

Dipping systems primarily use three different processing methods.

1. Indexing rack system. In the first method, a part is set on a rack or lowered by a hoist into the varnish. It is then removed from the varnish, allowed to drain, and set into a chain-type conveyor system. Once the rack is loaded onto the chains, it is conveyed through the oven and allowed to
cure for the recommended time. Transformers are often manufactured by this method.

2. Batch oven system. The second method of curing uses the same dipping system, but the coated rack of parts is placed into a tray oven or batch oven. Midsized stators are often processed by this method. Curing is normally completed all at one level. Stacking the racks with separators is required if multiple levels of parts are to be cured in the oven.

3. Continuous system. In the third method, the part is hung on an overhead conveyor which either is indexed on timed intervals or is continuously moving. The conveyor travels through a preheat zone, goes on through the dip tank into the bake oven, and returns back to the loading/unloading area. Quite often, cooling by forced ambient air or chilled air is incorporated into the system as the final step in the process. Parts are hung on the conveyor either by single wire hooks or on a multipart fixture. Multipart fixtures and drag-through dip systems are very common and can process the highest volume of parts per hour.

Short Answer Questions

1. List the parts of **Tools and special equipment required for Re-winding**
2. What is Enamelled wire
3. Write the Properties of Enamelled wire
4. What are the Types of Conducting materials used in armature winding?
5. Why is an insulation paper inserted during motor winding?
6. List the Insulating Materials using in the Windings

Essay Questions

1. Explain about the General procedure for rewinding
2. Explain about the Varnishing and Baking
3. Classify the Varnish

7 D. C. Machine Winding

Armature Winding

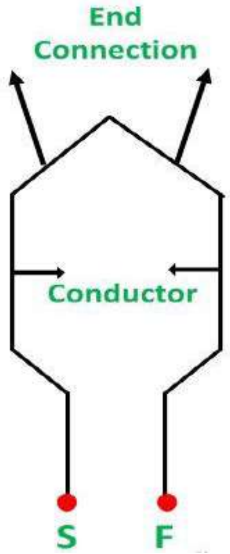
Armature winding is an arrangement of conductors to develop descried emfs by relative motion in a heteropolar magnetic field. In winding, conductor or group of conductors are distributed in different ways in slots all over the periphery of the armature. The conductors may be connected in series and parallel combinations depending upon the current and voltage rating of the machine.

7.1 Fundamental terms used in Armature winding

It is necessary to understand some of the important terms before discussing winding. The most commonly used term in describing a winding are given below.

- **Conductor.**
  Each individual length of wire lying within the magnetic field is called the conductor. It may be made of one or two or more parallel strands. Symbol Z will be used for the total number of conductors in the armature winding.

- **Turn**
  When the two conductors lying in a magnetic field are connected in series, so that emf induced in them help each other or the resultant induced emf becomes double (assuming full pitch coil) of that due to one conductor, it is known as a turn.



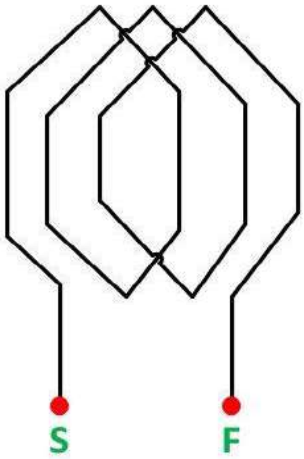


Fig7.1

Fig7.2

- **Coil**
  When one or more turns are connected in series and the two ends of it are connected to adjacent commutator segments (in lap winding) it is termed as a coil. Signal turn and multi-turn coils are shown in Fig. 7.1 and7.2 respectively. Multi-turn coils are used when total number of armature conductors is excessive and it is not feasible to use single turn coils, because it will have required large number of commutator segments and if used it will not give sparkless commutation and it will not be economical due of more copper in end connections. Symbol C will be used for the total number of coils symbol C will winding.

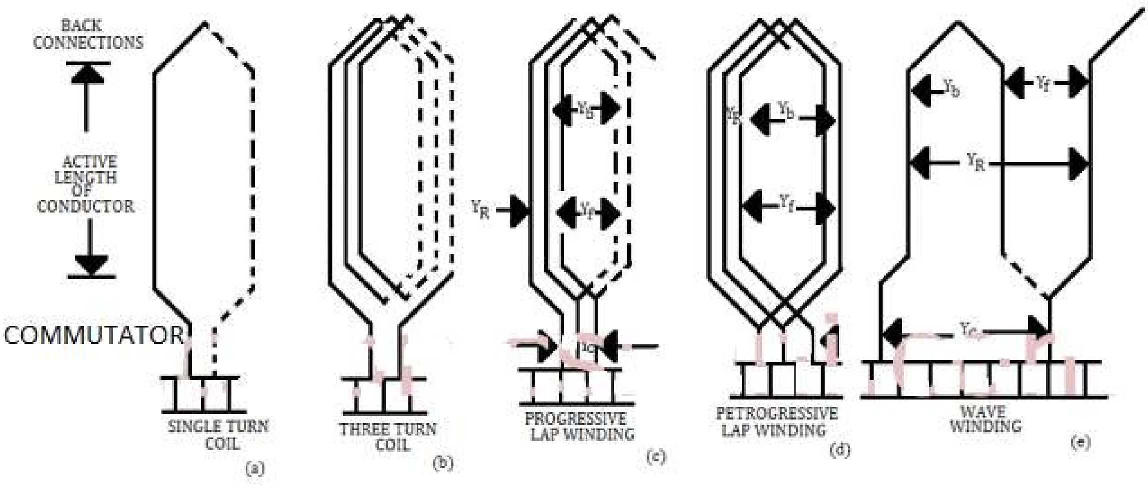


Figure 7.3 Armature Winding

Coil of dc machine is made up of one turn or multi turns of the conductor. If the coil is made up of single turn or a single loop of conductor, it is called single turn coil. If the coil is made up of more than one turn of a conductor, we refer it as a multi-turn coil. A single turn coil will have one conductor per side of the coil whereas, in multi turns coil, there will be multiple conductors per side of the coil. Whatever may be the number of conductors per side of the coil, each coil side is placed inside one armature slot only. That means all conductors of one side of a particular coil must be placed in one single slot only. Similarly, we place all conductors of opposite side of the coil in another single armature slot.

- **Coil side**

Each coil, signal-turn or multi-turn, has two sides called the coil sides, embedded in two different slots nearly a pole pitch apart.

- **Coil Group**
  A coil group may have one or more single coils.
- **Winding**
  Number of coils arranged in coil group is called the winding. The beginning of the turn or coil is identified by the symbol **(S)** meaning **Start**, and the end of the turn or coil is represented by the symbol **(F)**meaning **Finish**.

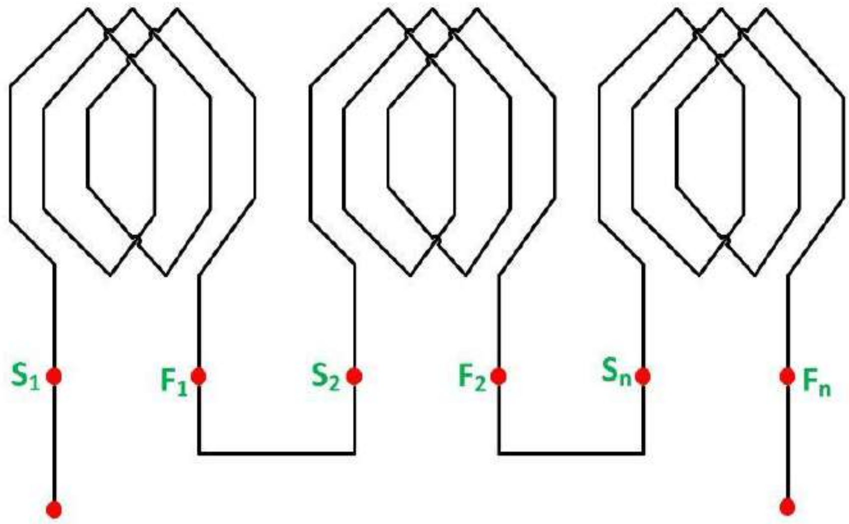


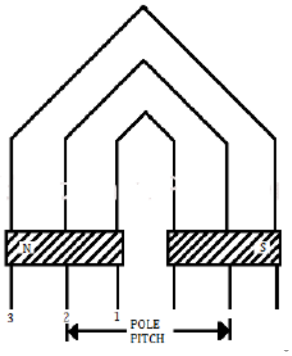
Figure 7.4

- **Inductor**
  One of the wires making up the coil side is called the inductor and a voltage is induced in the inductor.

- **Front End Connected**
  A wire that connects the end of a coil to a commutators segments, is called the front end connector. This wire is located at that part of the coil that is nearest the commutator.

- **Back End Connector**
  A wire that connects an inductor on one side of coil to an inductor on the other side of the coil is called the back end connector. It is on the end opposite to that of commutator.
- **Pole Pitch**
  The **pole pitch** is defined as peripheral distance between centre of two adjacent poles in DC machine. This distance is measured in term of armature slots or armature conductor come between two adjacent pole centres.
  Pole Pitch is naturally equal to the total number of armature slots divided by the number of poles in the machine. If there are 96 slots on the armature periphery and 4 numbers of poles in the machine, the numbers of armature slots come between two adjacent poles centres would be 96/4 = 24. Hence, the **pole pitch** of that DC machine would be 24. As we have seen that, pole pitch is equal to total numbers of armature slots divided by total numbers of poles, we alternatively refer it as **armature slots per pole**.
- **Front Pitch**
  It is defined as the distance in terms of number of armature conductors between the second conductor of one coil and the first conductor of next coil which are connected to the same

commutator segment on the front or commutator end. It is represented by Y_f' as shown in Figs. 1 (c), (d) and (e).



Back Pitch

It is defined as the distance in terms of number of armature conductors between the last and the first conductors of the coil. It is also called the coil span or coil spread. It is denoted by Y_b as illustrated in Figs. 1 (c), (d), and (e).

Resultant Pitch

It is defined as the distance in terms of number of conductors between the start of one coil and start of next coil to which it is connected. It is denoted by Y_R, as illustrated i figs. 1 (c), (d), and (e).

Commutator Pitch

It is defined as the distance measured in terms of commutator segments between the segments to which the two ends of a coil are connected. It is denoted by Y_c as shown in Figs. 1 (c), (d) and (e).

Coil Span or Coil pitch. When the coil span of the winding is equal to pole pitch, the coils are called the full pitched coils. Full pitched coils have the advantage of giving maximum emf induced in the coil. Coils 1, 2 and 3 shown in Fig. 2 are short-pitched, full-pitched and over-pitched coils respectively.

coil span is the distance between two coil sides of a coil, and coil pitch is the centre to centre distance of two adjacent poles which is commonly expressed in electrical degrees or in terms of no of slots on periphery. If the coil span is equal to the pole pitch (ie, when we connect one coil side in the first slot of north pole and the other side in the first slot of the adjacent south pole) the winding is called full pitched coil. If coil span is less than pole pitch the winding is known as short pitched winding. Short pitch is done to reduce harmonics to get more sinusoidal type wave form in the output of the generator.

Figure 7.5: Pole Pitch (short-pitched, full-pitched and over-pitched)

Since coil No. 1 has span less than the pole pitch, during the revolution of armature there will be an instant during which both sides of such coils will be under the influence of one and the same pole so emf induced in these two sides of the coil will be in opposition. Similarly, there will be an instant during which both sides of an over-pitched coil will be under the influence of two similar poles and emf induced in the two sides of such a coil will be in opposition.

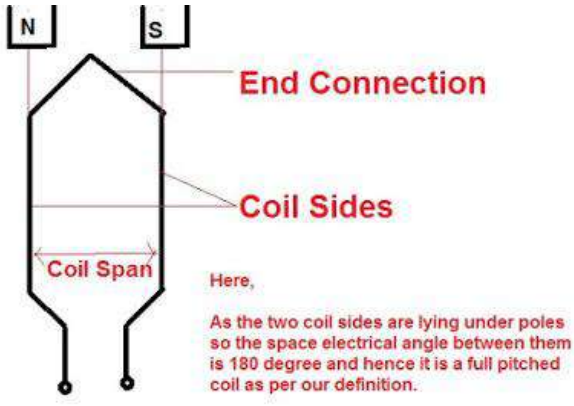
The advantages of fractional pitch winding are that substantial saving is affected in the copper of end connections and commutation is improved, owing to lesser mutual inductance between the coils.

Advantages and Disadvantages of Short-Pitch Winding

For better understanding of advantages and disadvantages of Short-pitched winding, we shall first understand the meaning of short-pitched coil and full-pitched coil. It will take some 10 minutes of your precious time to go through the write-up but it will really help you.

Full Pitch Coil:

A full pitched coil is defined as the coil whose two coil sides are 180 electrical degree apart. As the Pole Pitch, which is defined as the space electrical angle between two consecutive poles is 180 degree, therefore in an alternate manner we can also say that a Full Pitch Coil has its two coil sides one pole pitch apart. This can be seen in the figure below.



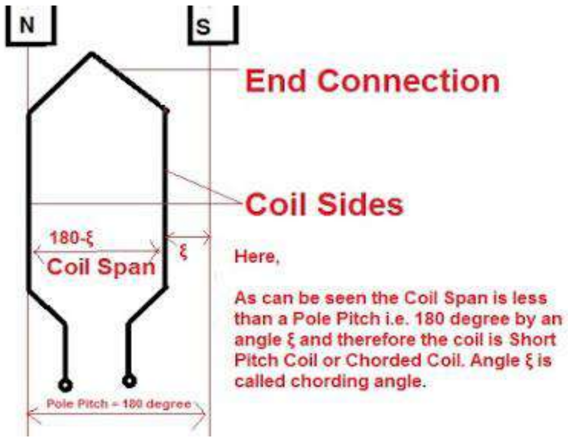


Figure 7.6 **Full Pitch Coil** Figure 7.7 **Short Pitch Coil**

Short Pitch / Chorded Coil:

If it happens that the two coil sides are not lying under the pole, then obviously the space electrical angle between the coil sides will not be 180 degree rather it will be less than 180 degree as shown in figure below.

Thus we can define a Short Pitch Coil as the coil having the coil span (Coil Span is defined as the space angle between the two coil sides of a coil) less than 180 degrees. A short pitched coil is also known as Chorded Coil.

Chording Angle ξ is defined as the angle by which the coil span departs from a pole pitch i.e. 180 degrees.

Thus, Chording Angle $\xi = 180° –$ Coil Span

If Chording Angle ξ is zero, then it is a full pitch coil.

So we are now familiar with the Full Pitched Coil and Short Pitched Coil. ***But is it sufficient to judge the advantage and disadvantage of Short Pitched Coil?***

No, this much information is not enough to have an idea of advantage and disadvantage of short pitch coil. But if we can see the effect of the above two types of winding on Generated EMF then we could have some idea. So we will just see the effect of short pitching on the generated EMF.

The rms value of EMF Generated in a Full Pitched Winding of N turns

$$\mathbf{E = 1.141\ \pi f N Ø}$$

Whereas the rms value of EMF Generated in a Short Pitched Winding of N turns

$$\mathbf{E = 1.141\ \pi f N Ø \cos(\xi/2)}$$

Here the term $\mathbf{\cos(\xi/2)}$ is called Pitch Factor.

$\mathbf{K_p}$**= Pitch Factor =** $\mathbf{\cos(\xi/2)}$

Thus it can be seen that a Short Pitched Coil reduces the output voltage by a factor Kp i.e. $\cos(\xi/2)$. ***Thus is the disadvantage of Short Pitch Coil.***

Advantages of Short Pitch Coil or Chording

- Short Pitching reduces the amount of copper needed for End Connection when compared with Full Pitched Coil as can be observed from the figure above.
- It Reduces the effects of distorting harmonics and thus the waveform of the generated voltage is improved and making it a sine wave.
- They improve the waveform of generated EMF i.e. generated EMF can be made to approximate to a sine wave more easily and the distorting harmonics can be reduced or totally eliminated. Suppose you want to eliminate 3rd harmonic from the Generated EMF. So what we do is that we will select Chording Angle ξ in such a manner that $\text{Cos}(n\xi/2)$ becomes zero i.e. Pitch Factor becomes zero for 3rd harmonics only. **Mind here that Pitch Factor for nth harmonic is Cos(nξ/2).**

Therefore, $\text{Cos}(n\xi/2) = 0$

For eliminating 3rdharmonic from Generated EMF,

$\text{Cos}(3\xi/2) = 0$

$3\xi/2 = \pi/2$

$\xi = \pi/3 = 60°$

- Due to the elimination of high frequency harmonics, eddy current and hysteresis losses are reduced, thereby increasing the efficiency.

Disadvantages of Short Pitch Coil:

The disadvantages of using short-pitch winding is that, the total voltage around the coils is somewhat reduced. In order to compensate for this reduction in Generated EMF, more number of turns and therefore more copper is required.

Mechanical degrees: the degree of physical or mechanical rotation a single conductor in an alternator. Electrical degrees: the degree or the cycle of emf induced in a single conductor in an alternator

Consider a Two pole Alternator, when a conductor rotates in the field, the emf induced in the conductor will be maximum when the conductor is at the center of the pole and the emf induced will be minimum when the conductor is in the middle of the gap between the two poles. so when we consider the graph of the induced emf versus the position or degree of rotation. For one complete rotation of the conductor in the field - One complete cycle of emf is generated in the conductor (Positive half cycle at south pole and negative half cycle at north pole).

The same way when we consider a 4 pole alternator a single conductor when completing one mechanical rotation will cross the four poles there by giving the induced emf graph with two positive half cycles and two negative half cycles which gives us two complete cycles of induced emf.

So for One Mechanical rotation (360 degrees) the induced emf completes two cycles (360 * 2 = 720 degrees in terms of the sine wave)

So the relation between Electrical and Mechanical degrees can be written as

Elect. Degrees = (N0. of Poles / 2) * Mech. Degrees

Coil Span or Coil Pitch

Coil of dc machine is made up of one turn or multi turns of the conductor. If the coil is made up of single turn or a single loop of conductor, it is called single turn coil. If the coil is made up of more than one turn of a conductor, we refer it as a multi-turn coil. A single turn coil will have one conductor per side of the coil whereas, in multi turns coil, there will be multiple conductors per side of the coil. Whatever may be the number of conductors per side of the coil, each coil side is placed inside one armature slot only. That means all conductors of one side of a particular coil must be placed in one single slot only. Similarly, we place all conductors of opposite side of the coil in another single armature slot.

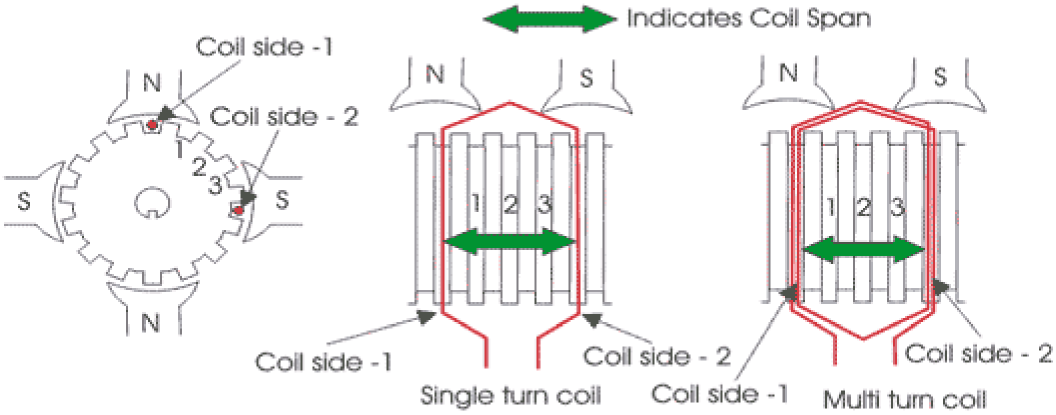


Figure 7.8

Definition of Coil Span

Coil span is defined as the peripheral distance between two sides of a coil, measured in term of the number of armature slots between them. That means, after placing one side of the coil in a particular slot, after how many conjugative slots, the other side of the same coil is placed on the armature. This number is known as coil span.

If the coil span is equal to the pole pitch, then the **armature winding** is said to be full – pitched. In this situation, two opposite sides of the coil lie under two opposite poles. Hence emf induced in one side of the coil will be in 180° phase shift with emf induced in the other side of the coil. Thus, the total terminal voltage of the coil will be nothing but the direct arithmetic sum of these two emfs.

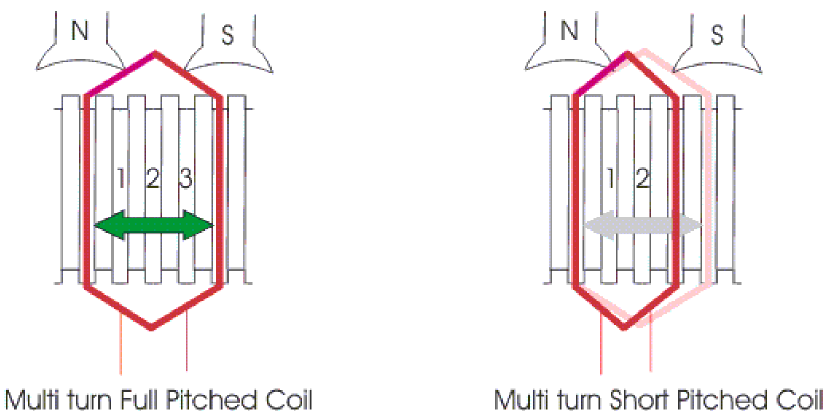


Figure 7.9

If the coil span is less than the pole pitch, then the winding is referred as fractional pitched. In this coil, there will be a phase difference between induced emfs in two sides, less than 180°. Hence resultant terminal voltage of the coil is vector sum of these two emfs and it is less than that of full-pitched coil.
In practice, **coil pitch** (or Span) as low as eight tenth of a Pole Pitch, is employed without much serious reduction in emf. **Fractional pitched windings** are purposely used to effect substantial saving in copper of the end connection and for improving commutation.

Coil Span Factor

The **Coil Span Factor** or **Pitch Factor** K_C is defined as the ratio of the voltage generated in the short pitch coil to the voltage generated in the full pitch coil. The distance between he two sides of a coil is called the **Coil Span** or **Coil Pitch Factor**. It is also known as **Chording Factor**

The angular distance between the central line of one pole to the central line of the next pole is called **Pole Pitch**. A pole pitch is always 180 electrical degrees, regardless of the number of poles on the machine. A coil having a span equal to 180° electrical is called a **full pitch coil** as shown in the figure below.

A Coil having a span less than 180° electrical is called a **short pitch coil** or fractional pitch coil. It is also called a Chorded coil. The short pitch coil factor is shown in the figure below.

A stator winding using fractional pitch coil is called a chorded winding. If the span of the coil is reduced by an angle α electrical degrees, the coil span will be (180 – α) electrical degrees.

In case of a full pitch coil, the distance between the two sides of the coil is exactly equal to the pole pitch of 180° electrical. As a result, the voltage in a full pitch coil is such that the voltage of each side of the coil is in phase.

For full pitch coil, the value of α will be 0°, cos α/2 = 1 and $\mathbf{K_C = 1}$.

For a short pitch coil $\mathbf{K_C < 1}$.

Distribution Factor

The **Distribution Factor** or the **Breadth Factor** is defined as the ratio of the actual voltage obtained to the possible voltage if all the coils of a polar group were concentrated in a single slot. It is denoted by $\mathbf{K_d}$ and is given by the equation shown below.

$$K_d = \frac{\text{Phasor Sum of the coil volatges per phase}}{\text{Arithmetic sum of coil voltages per phase}} \quad \ldots\ldots\ldots.(1)$$

In a concentrated winding, each phase of a coil is concentrated in a single slot. The individual coil voltages induced are in phase with each other. These voltages must be added arithmetically. In order to determine the induced voltage per phase, a given coil voltage is multiplied by the number of series connected coils per phase. In actual practice, in each phase, coils are not concentrated in a single slot. They are distributed in a number of slots in space to form a polar group under each pole.

The voltages induced in coil sides are not in phase, but they differ by an angle β which is known as the angular displacement of the slots. The phasor sum of the individual coil voltages is equal to the total voltage induced in any phase of the coil.

Pitch of Armature Winding

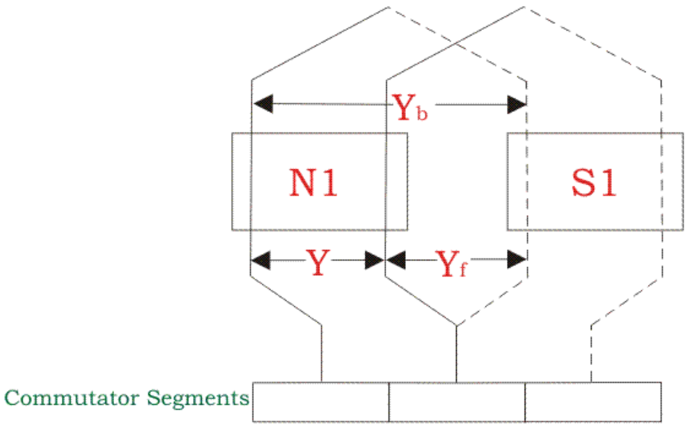


Figure 7.10

Back Pitch (Y_b)

A coil advances on the back of the armature. This advancement is measured in terms of armature conductors and is called **back pitch**. It is equal to the number difference of the conductor connected to a given segment of the commutator.

Front Pitch (Y_f)

The number of armature conductors or elements spanned by a coil on the front is called **front pitch**. Alternatively, we define the front-pitch as the distance between the second conductor of the next coil which connects the front, i.e., commutator end of the armature. In other words, it is the number difference of the conductors connected together at the back end of the armature. We are showing both front and back pitches for a lap, and a wave winding in the figure below.

Resultant Pitch (Y)

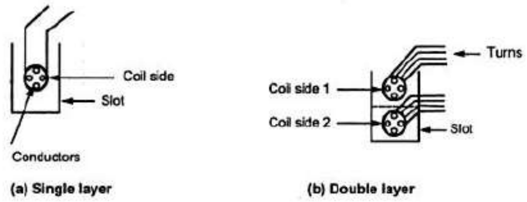
It is the distance between the beginning of one coil and the beginning of the next coil to which it is connected. As a matter of precautions, we should keep in mind that all these pitches, though normally stated concerning armature conductors, are also times of armature slots or commutator bars.

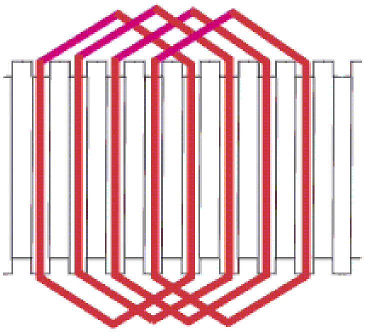
Commutator Pitch

Commutator pitch is defined as the distance between two commutator segments which two ends of same armature coil are connected. We measure commutator pitch in term of commutator bars or segment.

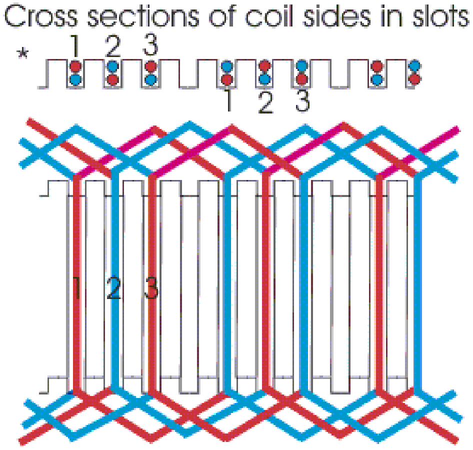
Single Layer Armature Winding

We place armature coil sides in the armature slots differently. In some arrangement, each one side of an armature coil occupies a single slot. In other words, we place one coil side in each armature slot. We refer this arrangement as single layer winding.





Multi turn Single Layer Winding



Multi turn Double Layer Winding

[*In Double layer winding, 1,2,3 are marked to only three coils among many]

Figure 7.11

Two Layer Armature Winding

In other types of armature winding, arrangement two coil sides occupy every armature slot; one occupies upper half, and another one occupies the lower half of the slot. We so place the coils in two layers winding that if one side occupies upper half, then another side occupies the lower half of some other slot at a distance of one coil pitch away.

Winding Factor

The winding factor is the method of improving the rms generated voltage in a three phase AC machines so that the torque and the output voltage does not consist any harmonics which reduces the efficiency of the machine**. Winding Factor** is defined as the product of Distribution factor (K_d) and the coil span factor (K_c).

7.2 Armature Winding

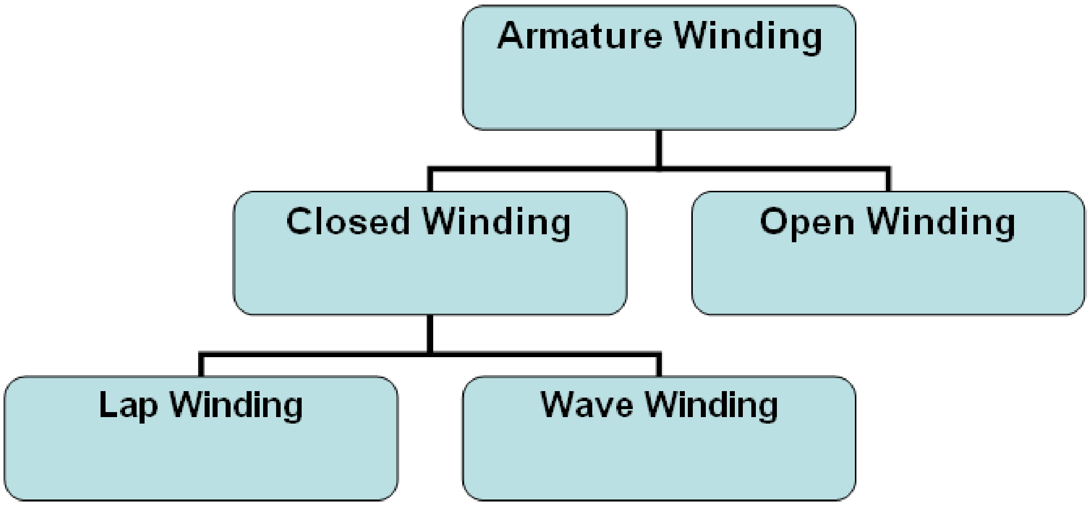
Armature winding in an electrical machine is that winding which carries the load current. In other words, it can also be defined as the winding in which emf is generated due to air gap field flux. It should be noted here that, air gap flux or working flux is produced due to flow of DC current in the field winding.

Generally, armature winding is housed on stator slots and field winding on rotor slots for Synchronous machine. In DC machine, armature winding is placed in rotor slots and field winding on stator slots.

Armature winding is made of copper and consists of large number of insulated coils. These insulated coils may have one or more turns. These coils may either be connected in series and parallel depending upon the type of winding required.

Types of Armature Winding

There are mainly two types of armature winding: Closed Winding and Open Winding



Closed Winding

Closed winding means the winding which is close in itself in the sense that if one starts and traverse the winding then he will return to starting point again. Such type of winding is mainly used for DC machine and AC commutator machine.

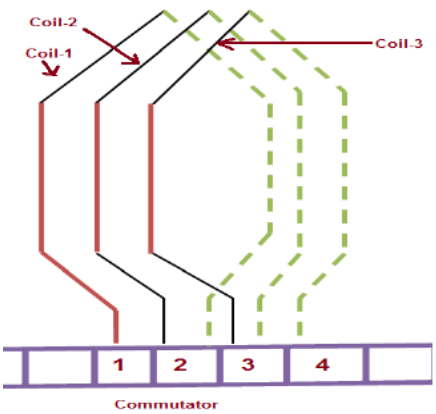
Closed armature winding can further be classified into following types: Lap Winding and Wave Winding

7.2.1 Lap Winding

In lap winding, the consecutive coils overlap each other. The first end of the winding is connected to the one segment of the commutator, and the starting end of the other coil is placed under the same magnet (different pole) and join with the same segment of the commutator. The conductors are connected in such a way that the number of parallel paths equals to the number of poles. Consider the machine has P poles and Z armature conductors, then there will be P parallel paths, and each path will have Z/P conductors in series. The number of brushes is equivalent to the number of parallel paths. The half of the brush is positive, and the remaining is negative.

In lap winding the two coil sides of a particular coil are connected to adjacent commutator segment as shown in figure below.

It can be seen from the above figure that, the coil sides of coil-1 are connected to commutator segment 1 & 2 respectively. Thus the commutator pitch for lap winding is 1. Note that commutator pitch is the distance between the two commutator segments to which the two end of coil is joined.



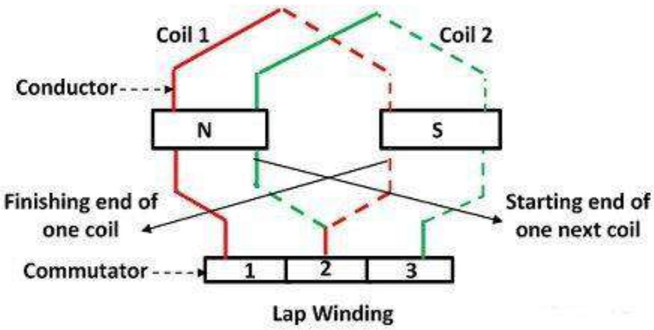


Figure 7.12

There are three different types of Lap Winding:

- **Simplex Lap Winding –** The distance between the segments of commutator to which the coil ends are connected is 1. Thus commutator pitch is unity.
- **Duplex lap Winding –** In duplex lap winding, the commutator pith is 2. This means if one coil end is connected to commutator segment 1 then the other is connected to segment 3.
- **Triplex Lap Winding –** The commutator pitch for triplex winding is 3. This means if one coil end is connected to commutator segment 1 then the other is connected to segment 4.

Simplex Lap Winding
A winding in which the number of parallel path between the brushes is equal to the number of poles is called **simplex lap winding**.

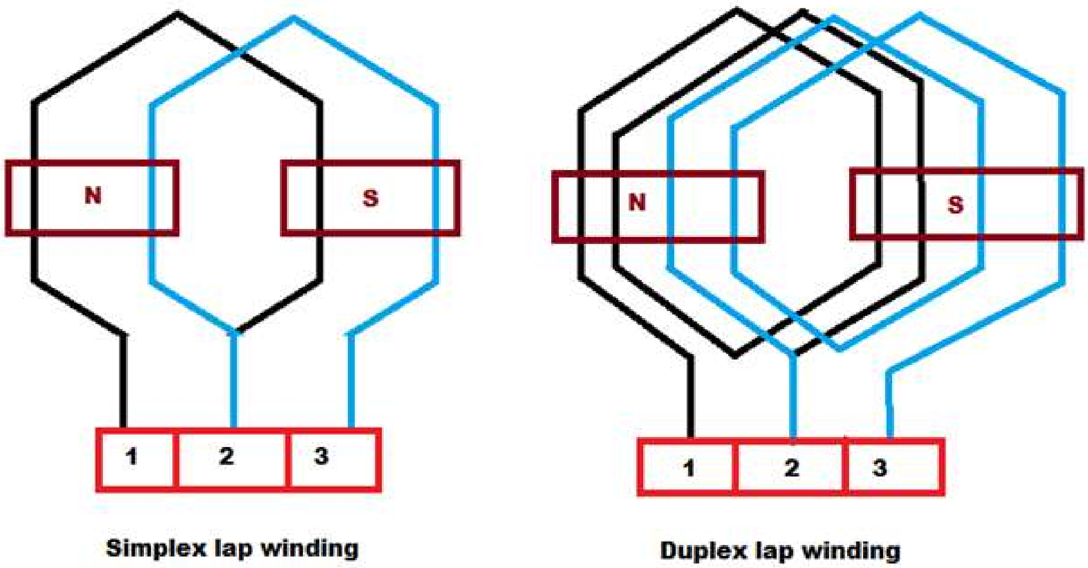


Figure 7.13

Duplex Lap Winding
A winding in which the number of parallel path between the brushes is twice the number of poles is called **duplex lap winding**.

Lap Winding Advantages

1. As there are more parallel paths so this winding is used where there is requirement of large current.
2. These windings are suitable for low voltage and high current applications

Lap Winding Disadvantages

1. As this winding has low emf so no. of conductors required more for generating same emf as in wave winding. This will leads to higher cost
2. This winding utilize lower space on armature so leading to less utilization of space.

Some important points to remember while designing the Lap winding:
If,

Z = the number conductors
P = number of poles
Y_B = Back pitch
Y_F = Front pitch
Y_C = Commutator pitch
Y_A = Average pole pitch
Y_P = Pole pitch
Y_R = Resultant pitch

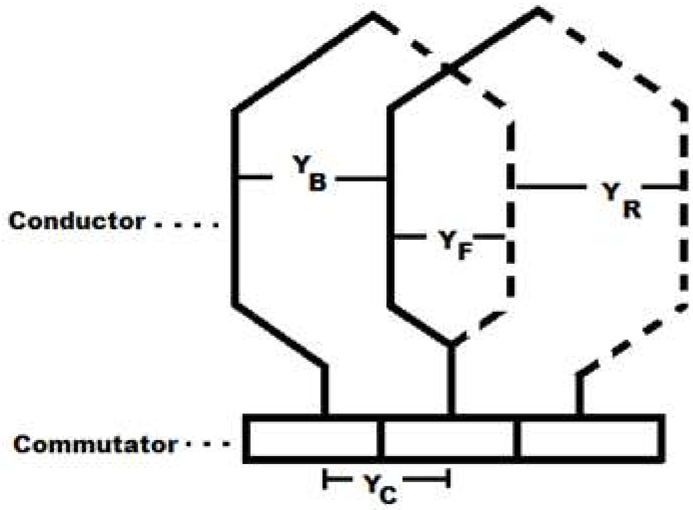


Figure 7.14

Then, the back and front pitches are of opposite sign and they cannot be equal.
$Y_B = Y_F \pm 2m$
m = multiplicity of the winding.
m = 1 for Simplex Lap winding
m = 2 for Duplex Lap winding
When,
$Y_B > Y_F$, it is called progressive winding.
$Y_B < Y_F$, it is called retrogressive winding.
Back pitch and front pitch must be odd.
Resultant pitch (Y_R) = $Y_B - Y_F = 2mY_R$ is even because it is the difference between two odd numbers.

Example: Draw a developed diagram of a simple 2-layer lap-winding for a 4-polegenerator with 8 coils.
Solution: The number of commutator segments = 12Number of conductors or coil sides 8×2 = 16 Pole pitch = 16/4 = 4

For Progressive Lap Winding
Back Pitch (Y_B) = (Z/P) +1
= (16/4) +1 = 5
Front Pitch (Y_F) = (Z/P) -1
= (16/4) -1 = 3

Table 7.1

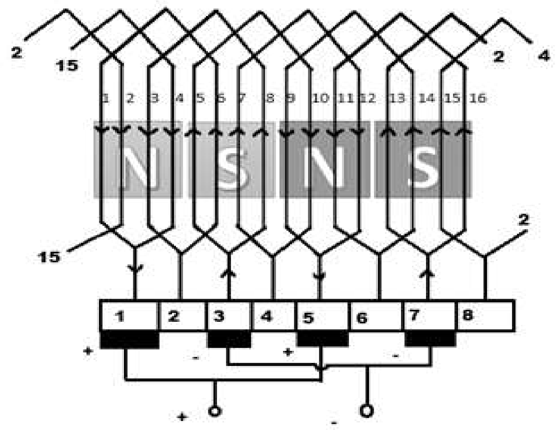
Back connections [$Y_B = 5$]	Front connections[Y_F =3]

1 to (1+Y_B) = (1+5) = 6	6 to (6-Y_F) = (6 – 3) = 3
3 to (3+5) = 8	8 to (8-3) = 5
5 to (5+5) = 10	10 to (10-3) = 7
7 to (7+5) = 12	12 to (12-3) = 9
9 to (9+5) = 14	14 to (14-3) = 11
11 to (11+5) = 16	16 to (16-3) =13
13 to (13+5) = 18 = (18-16) = 2	2 to (18-3) = 15
15 to (15+5) = 20 = (20-16) = 4	4 to (20-3) = 17 = (17-16) = 1

Average pitch $(Y_A) =$

Back pitch $(Y_B \approx$

Commutator pitch (Y_C) = ±m
Number of parallel path in the Lap winding = mP
Let us start from 1st conductor, **Fig:7.15**

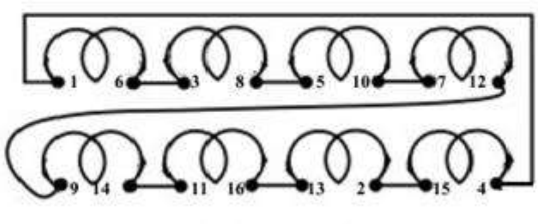


Advantages of Lap Winding

1. This winding is necessarily required for large current application because it has more parallel paths.
2. It is suitable for low voltage and high current generators.

Disadvantages of Lap Winding

1. It gives less emf compared to wave winding. This winding requires more no. of conductors for giving the same emf, it results high winding cost.
2. It has less efficient utilization of space in the armature slots.



Simplified connection

7.2.2 Wave Winding

Wave winding is one type of armature winding. In this winding, we connect the end of one coil to the starting of another coil of the same polarity as that of the first coil. In this type of winding the coil side (A – B) progresses forward around the armature to another coil side and

goes on successively passing through N and S pole till it returns to a conductor (A_1-B_1) lying under the starting pole.
This winding forms a wave with its coil, that's why we call it as **wave winding**. Since we connect the coils in series here, we also call it series winding.
There are three types of Wave Winding:

- Simplex Wave Winding
- Duplex Wave Winding
- Triplex Wave Winding

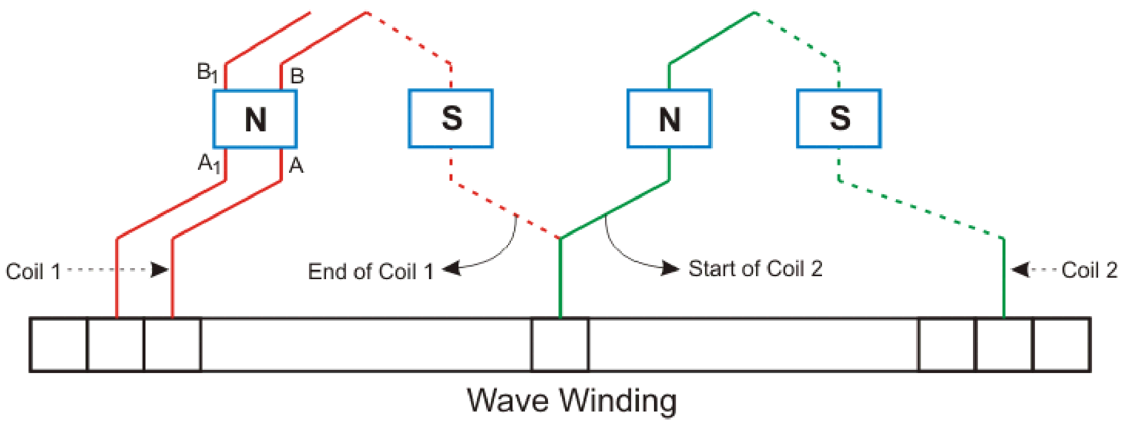


Fig:7.16

Progressive Wave Winding
If after one round of the armature the coil falls in a slot right to its starting slot the winging is called Progressive wave winding.

Retrogressive Wave Winding
If after one round of the armature the coil falls in a slot left to its starting slot the winging is called **Retrogressive wave winding**.

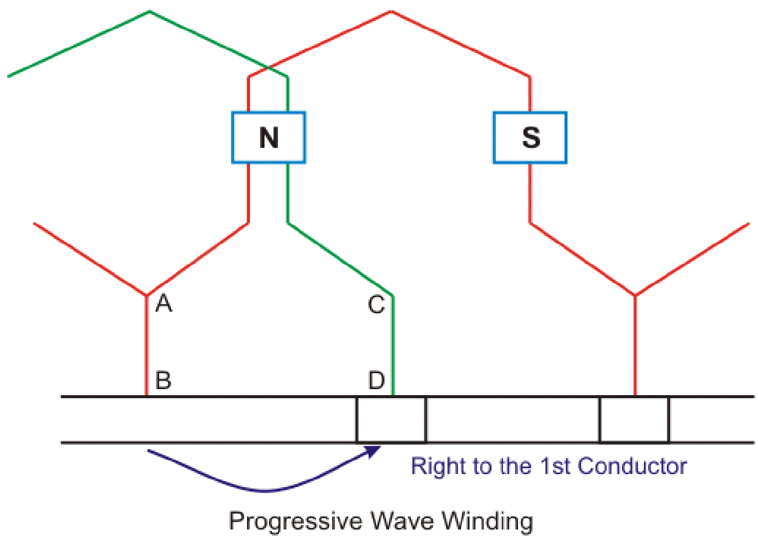


Fig:7.17

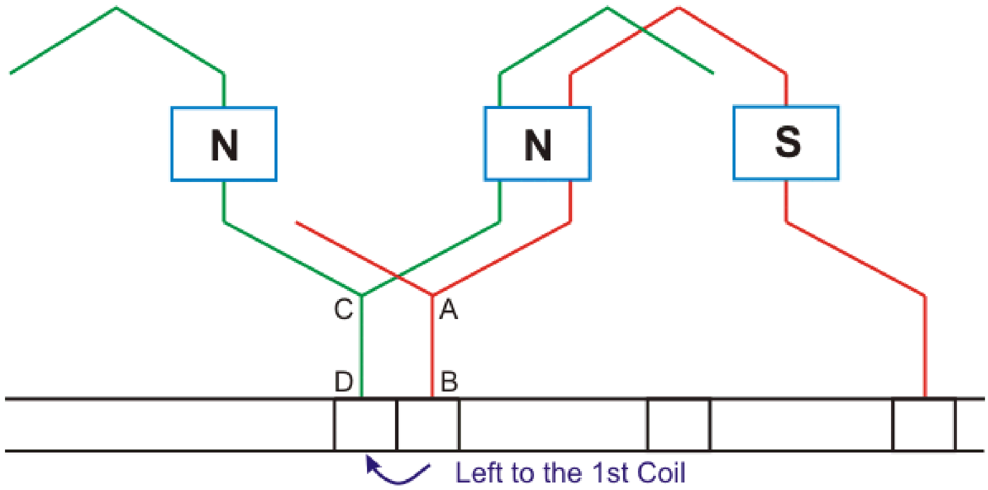


Fig:7.18

Retrogressive wave winding.

Here in the picture above we can see that 2nd conductor CD is in the left of the 1st conductor.

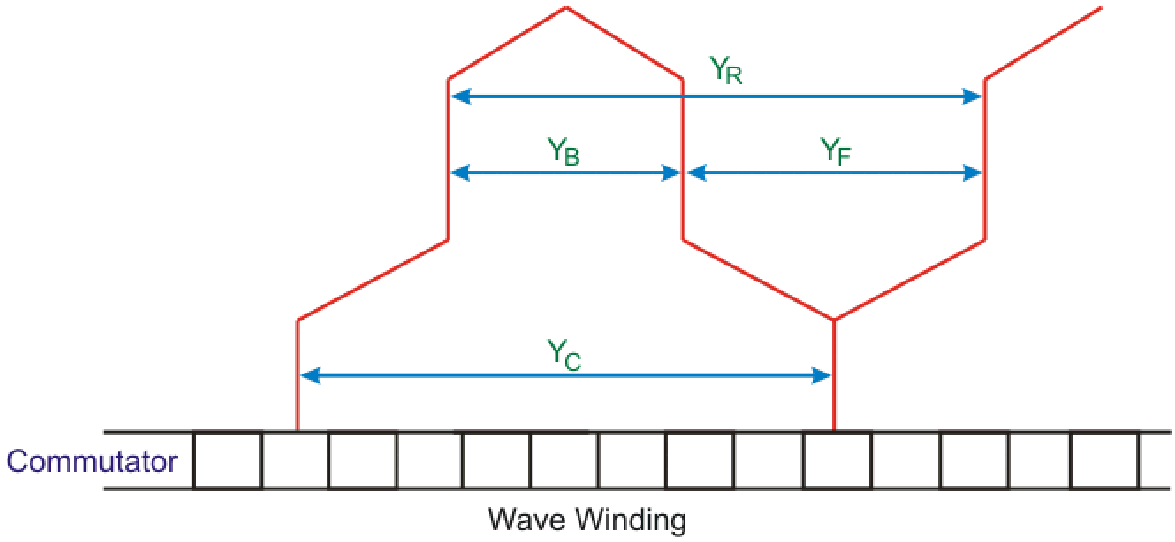


Fig:7.19

Important Points Regarding Wave Winding

(a) In simplex wave winding

1. Back pitch (Y_B) and front pitch (Y_F) are both odd and are of same sign.
2. Back-pitch and front-pitch are nearly equal to the pole pitch and may be equal or differ by ±2. + for progressive winding, – for retrogressive winding.

3. Back and front pitches must be nearly equal to the pole pitch and may be equal or differ by 2 in which case, they will be one more or one than average pitch.

4. Commutator pitch, Y_c = Average pitch, Y_{av}

5. The average pitch, Y_{av} is given by $Y_{av} = \frac{Y_b + Y_f}{2} = \frac{Z \pm 2}{p}$ where Z is the number of conductors or coil sides and P is the number of poles. In order that the

wave winding may close itself, the average pitch Y_{av} must be a whole number and agree to the above formula.

In the above formulae ± 2 has been taken due to the reason that after one round of the armature the winding falls short of two conductors from the starting conductor. If it is not done and the average pitch is taken equal to Z/P then after one round of the armature, the winding will come back to the starting conductor or winding will close itself without including all coil sides.

The + ve sign in the above formulae will give progressive winding and – ve sign a retrogressive winding.

Since average pitch Y_{av} should be a whole number, this winding is not possible with any number of coil sides. For example with 28 conductors in a 4-pole machine, since $Y_{av} = \frac{28 \pm 2}{4} = 7\frac{2}{2}$ or $6\frac{1}{2}$ being fractional number, the wave winding is not possible but for 26 or 30 conductors, this winding can be employed since $Y_{av} = \frac{26 \pm 2}{4} = 7$ or 6 and $Y_{av} = \frac{30 \pm 2}{4} = 8 or 7$.

5. For even number of pairs of poles i.e. for 2, 4, 6, or 8 pair pole machine.

(i) the average pitch, $Y_{av} = \frac{Y_b + Y_f}{2}$ may be odd or even.

(ii) the number of coils must be odd.

(iii) the number of commutator segments mus be odd.

For odd number of pairs of poles such as 3, 5, 7

(i) the number of coils is even or odd.

(ii) the number of commutator segments may be even or odd.

(iii) if the number of coils is even, average pitch must be odd and if the number of coils is odd, average pitch must be even.

(b) In Multiplex Wave Winding

1. The relation between the back pitch and the front pitch for multiplex wave winding is also the same as for the multiplex lap winding, so $Y_b = Y_f \pm 2m$ where m is the multiplicity of the winding; + ve sign indicates progressive winding and – ve sign indicates retrogressive winding.
2. The average pitch for multiplex wave winding is given as $Y_{av} = \frac{Z \pm 2m}{P}$ and it must be an integer.
3. In a duplex winding having an odd number of pairs of poles, whose average pitch is odd, must have an odd number of commutator segments and coils and one whose average pitch is even must have an even number of commutator segments and coils.

If the duplex winding has an even number of pairs of poles, the number of commutator segments and coils must be even irrespective of whether the average pitch is odd or even.If in a duplex winding average pitch Y_{av} is odd, the winding will be singly re-entrant and if even, doubly re-entrant.

$$Resultant\ pitch\ Y_R = Y_B + Y_F$$

$$Commutator\ pitch\ (Y_C) = average\ pitch\ (Y_A)$$

$$Average\ pitch\ Y_A = \frac{Y_B + Y_F}{2} = \frac{Z \pm 2}{P}$$

Here, Z is the no of conductors in the winding. P is the no of poles.

Average pitch (Y_A) must be an integer number, because it may close itself.
We take ± 2 (two) because after one round of the armature the winding falls sort of two conductors.

If we take an average pitch Z/P then after one round the winding will close itself without including all coil sides.

Since average pitch must be an integer, this winding is not possible with any no. of conductors.

Let us take 8 conductors in a 4 pole machine.

$$Then,\ Y_A = \frac{Z \pm 2}{P} = \frac{8 \pm 2}{4} = \frac{10}{4} = 2\frac{1}{2}\ or\ 3\frac{1}{2}$$

Being fractional no the wave winding is no possible but if there was 6 conductors then the winding can be done. Since,

$$Y_A = \frac{Z \pm 2}{P} = \frac{6 \pm 2}{4} = \frac{8}{4} = 2 = an\ integer.$$

For this problem the DUMMY COILS are introduced.

Dummy Coil
The wave winding is possible only with particular number of conductors and slots combinations. It is not always possible to have the standard stampings in the winding shop consist of the number of slots according to the design requirements. In such cases dummy coils are employed. This coils are placed in the slots to give the machine the mechanical balance but they are not electrically connected to the rest of the winding.

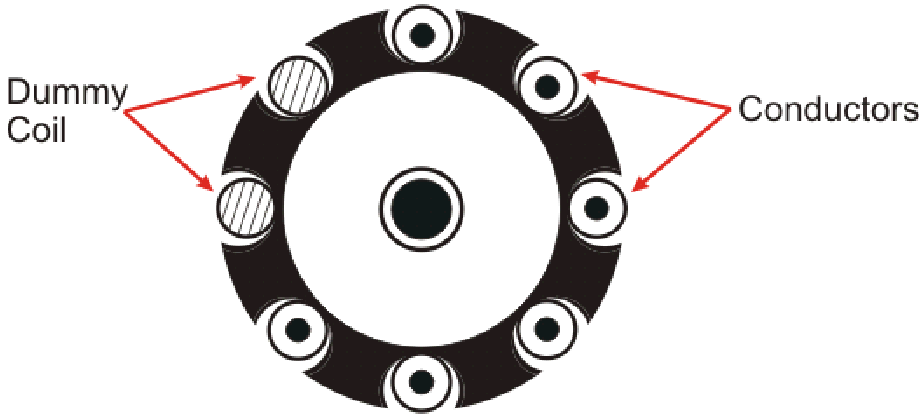


Fig:7.20

In multiplex wave winding:

$$1.\ Y_B = Y_F \pm 2m$$

Where:
- m is the multiplicity of the winding
- m = 1 for simplex winding
- m = 2 for duplex winding

2. *The average pitch for multiplex wave winding is*

$$(Y_A) = \frac{Z \pm 2m}{P}$$

and it must be an integer.

Construction of Wave Winding

Let us develop a simplex and progressive wave winding diagram of a machine having 34 conductor in 17 slots and 4 poles.

Average pitch:

$$Y_A = \frac{Y_B + Y_F}{2} = \frac{Z+2}{P} = \frac{34 + 2}{4} = 9$$

$$Therefore,\ Y_A = Y_B = Y_F = 9$$

Now we have to construct a table 7.2 for the connection diagram:

Back Connections	Front Connections
1 to (1+Y_B) $= (1 + 9) = 10$	10 to (10+Y_F) $= (10 + 9) = 19$
19 to (19+9)=28	28 to (28+9)=37=(37-34)=3
3 to (3+9)=12	12 to (12+9)=21
21 to (21+9))=30	30 to (30+9)=39=(39-34)=5
5 to (5+9)=14	14 to(14+9)=23
23 to (23+9)=32	32 to (32+9)=41=(41-34)=7
7 to (7+9)=16	16 to (16+9)=25
25 to (25+9)=34	34 to (34+9)=43=(43-34)=9
9 to(9+9)=18	18 to (18+9)=27
27 to (27+9)=26=(36-34)=2	2 to (36+9)=45=(45-34)=11
11 to(11+9)=20	20 to (20+9)=29
29 to (29+9)=38=(38-34)=4	4 to (38+9)=47=(47-34)=13
13 to (13+9)=22	22 to (22+9)=31
31 to (31+9)=40=(40-34)=6	6 to (40+9)=49=(49-34)=15
15 to (15+9)=24	24 to(24+9)=33
33 to (33+9)=42=(42-34)=8	8 to (42+9)=51=(51-34)=17
17 to (17+9)=16	26 to (26+9)=35=(35-34)=1

Table 7.2Wave Winding Diagram

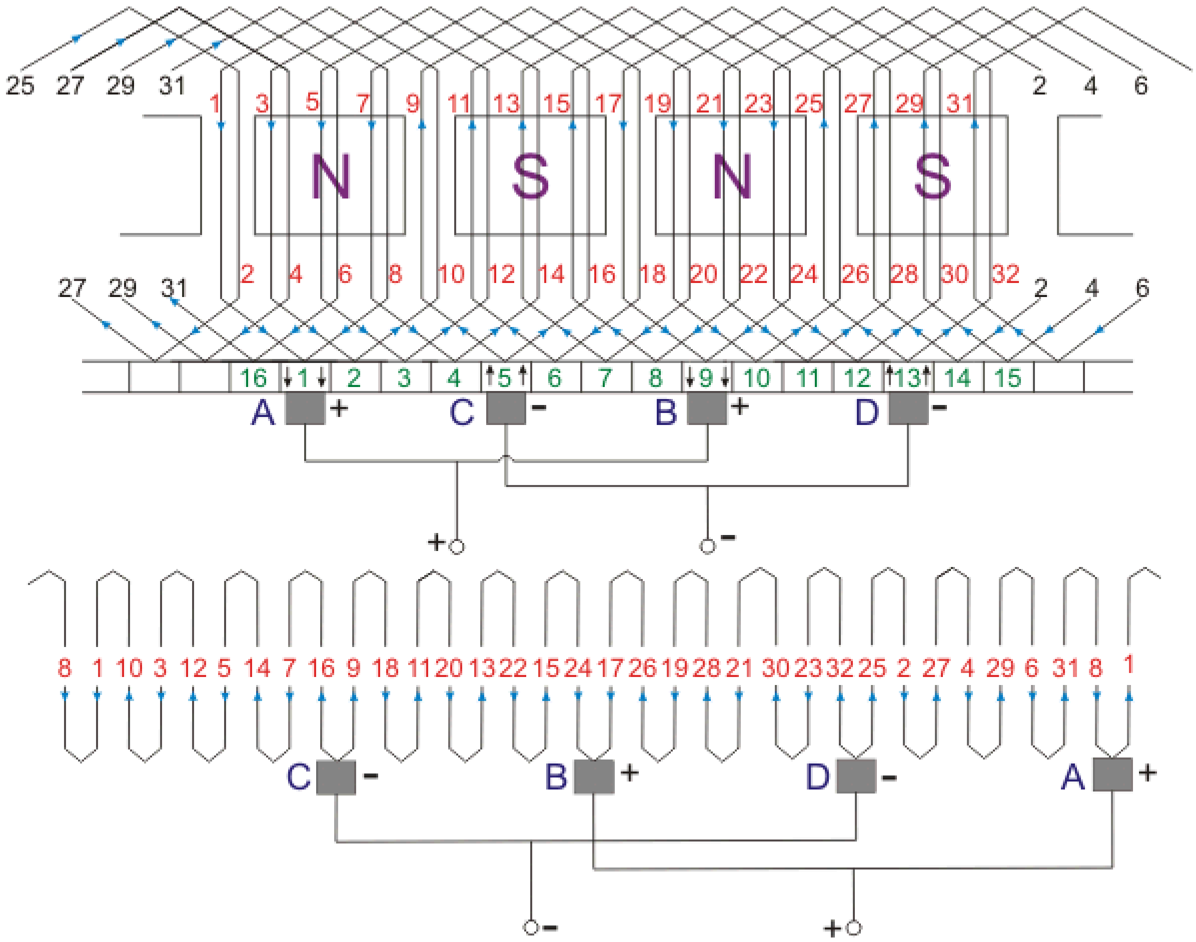


Fig:7.20Wave Winding Development Diagram

Simplex Wave Winding Advantages

1. In this winding, only two brushes are required but more parallel brushes can be added to make it equal to the no. of poles. If one or more brushes set poor contacts with the commutator, satisfactory operation is still possible.
2. This winding gives sparkles commutation. The reason behind that it has two parallel paths irrespective of no of poles of the machine. The conductors in each of the two parallel path distributed around the armature in the entire circumference.
3. No. of conductors in each path = Z/2, Z is the total no. of conductors.
4. Generated emf = average emf induced in each path X Z/2
5. For a given number of poles and armature conductors it gives more emf than that of lap winding. Hence **wave winding** is used in high voltage and low current machines. This winding is suitable for small generators circuit with voltage rating 500-600V.
6. Current flowing through each conductor.
   $$= \frac{current\ per\ path\ (I_a)}{2}$$
   I_a is the armature current. The current per path for this kind of winding must not be exceeded 250A.
7. Resultant emf around the entire circuit is zero.

Simplex Wave Winding Disadvantages

1. **Wave winding** cannot be used in the machines having higher current rating because it has only two parallel paths.

Open Winding

Open winding is one in which the winding terminals are open. Such type of armature winding is used only for AC machine like Induction machine, Synchronous Machine etc. It should be noted here that 3 phase DELTA connected winding in AC machine is a closed circuit, though it can be made open and reconnected in STAR if required. Thus open winding can be open-circuited but closed winding can never be open circuited in any case.

7.3 Difference Between Lap & Wave Winding

The insulator conductor house in an armature slot is known as an armature winding. In armature winding, the conversion of power takes places, i.e., in the case of the generator the mechanical power is converted into an electrical energy and in the case of a motor the electrical energy is converted into mechanical energy.
The armature winding is mainly classified into two types, i.e., the lap winding and the wave winding. One of the major difference between them is that in a lap winding the end of each coil are connected to the adjacent segment whereas in the wave winding the end of armature coil connected to commutator segment at a distance apart.

Content: Lap V/S Wave Winding

- Comparison Chart
- Definition
- Key Differences

Comparison Chart

Basis For Comparison	Lap Winding	Wave Winding

Basis For Comparison	Lap Winding	Wave Winding
Definition	The coil is lap back to the succeeding coil.	The coil of the winding form the wave shape.
Connection	The end of the armature coil is connected to an adjacent segment on the commutators.	The end of the armature coil is connected to commutator segments some distance apart.
Parallel Path	The numbers of parallel path are equal to the total of number poles.	The number of parallel paths is equal to two.
Other Name	Parallel Winding or Mulitiple Winding	Two-circuit or Series Winding.
EMF	Less	More
Number of Brushes	Equal to the number of parallel paths.	Two
Types	Simplex and Duplex lap winding.	Progressive and Retrogressive wave winding
Efficiency	Less	High
Additional Coil	Equalizer Ring	Dummy coil
Winding Cost	High (because more conductor is required)	Low
Uses	In low voltage, high current machines.	In high voltage, low current machines.

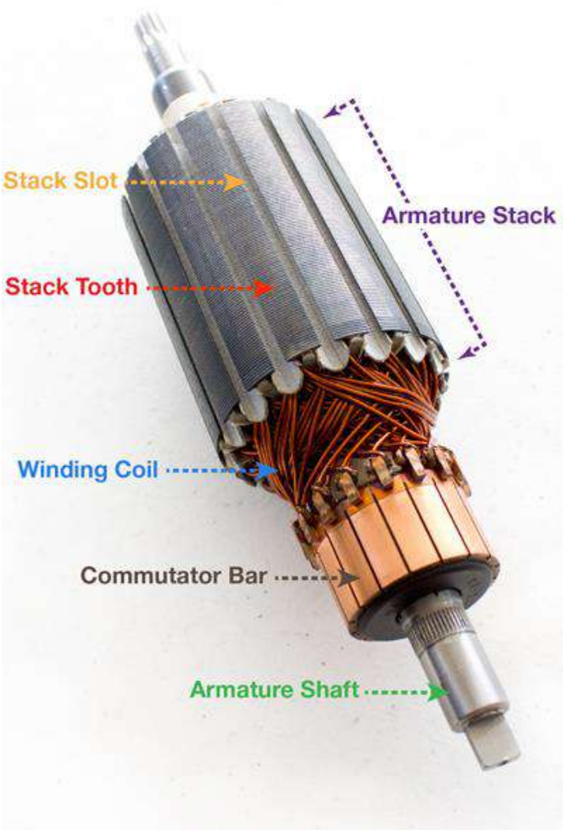
Table 7.3

7.4 Methods to find common faults while testing DC armature

Inspecting a motor armature for damaged windings

If you have access to a volt/ohm meter, there are three quick checks you can do that will tell you if a motor armature is functioning properly. But first we must understand some basics of armature design.

BASIC ARMATURE DESIGN



An armature (Shown in Fig) has a continuous series of windings from each bar on the commutator, which loop around the iron stack teeth and connect to the next bar on the commutator. The winding continues to loop all the way around the armature in the same manner. Loops are either single or parallel conductors (wires), and can circle any number of times around the stack teeth (called turns in a coil). The wire can vary in gauge as is required for the design of the motor. Each wire is insulated with an enamel coating, isolating it from every other wire in the loop, and only terminates at a commutator bar. The turns in every coil wrap around the iron stack to create an electro-magnet. When energized, an electro-magnetic field is generated in the motor armature. This EM field inter-acts with the magnetic fields of the permanent magnets in the motor (in the case of a permanent magnet motor) or with the electro-magnetic field created by the stator (in the case of a universal motor). These magnetic forces work to attract each other, inducing a torque on the armature shaft, causing it to turn.

If a motor is driven too hard for its environment and temperatures are allowed to rise beyond the thermal limits of the insulation, it is possible for the insulation on the wires to break down and short together, or short to the armature stack. If windings are shorted together, the electro-magnetic fields cannot be created for that coil, causing the motor to run erratically or fail all together.

Fig 7.21

ARMATURE TEST 1

To check the condition of the armature windings, the armature will probably have to be removed from the motor. However, if the motor design has external brush holders, you can unscrew the brush caps and remove the brushes. Depending upon brush size, this may allow access to the commutator without removing the armature from the motor.

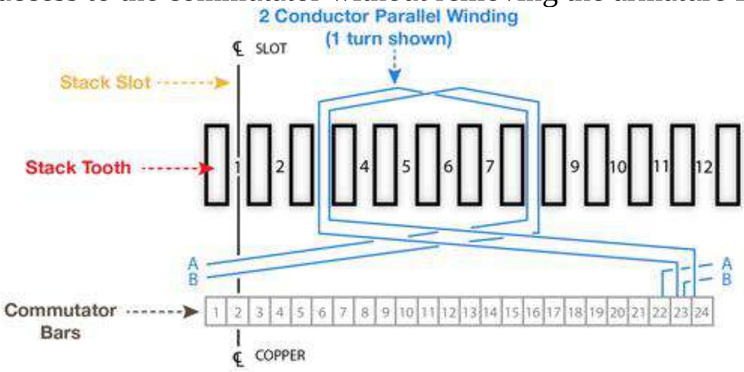
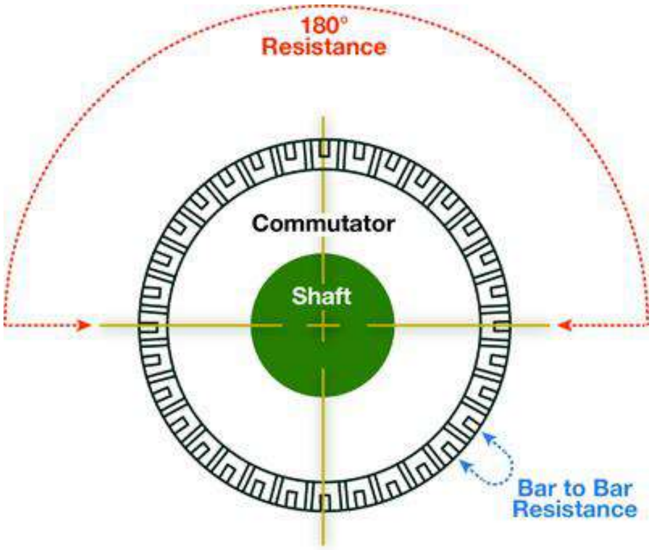


Fig 7.22

The first check to see if your armature windings are shorted is the “180° Resistance” test. A volt/ohm meter can be used to check the resistance of the series windings connected between the two commutator bars of each coil. Set the meter to measure resistance (Ohms) and then measure the resistance from two commutator bars 180° across from each other. Rotate the armature and check the resistance between every pair of bars on the commutator. Figure 3 depicts a 32 bar commutator, so this check must be done between each of the 16 pairs. The resistance you will measure is dependent upon the number of turns in each coil and the gauge of wire used. It is also dependent upon the operating voltage for which the motor is designed. For example, a 90 V dc motor will have smaller conductors and more turns per coil to raise resistance, whereas, a 12 V dc motor will have larger conductors and less turns per coil to lower resistance. Though you probably will not know the armature’s intended resistance value, each measurement should read about the same. If the resistance drastically varies, there could be a problem with the windings. A drop in resistance could indicate a short between wires in the coil. A huge spike in resistance could indicate that a wire is burned through or broken, interrupting the circuit.



ARMATURE TEST 2 Fig 7.23

The second check is the “Bar to Bar Resistance” test (pictured on right). This will check every coil in the motor armature. Again, the specific value is based on the motor design (wires per loop, number of turns per coil, and wire gauge). As with the first test, the important thing to observe is that each measurement should be about the same. (Note: The resistance you will measure in this test will be much less that in the first test, because you will be measuring only one coil. In the first test, the measurement taken is the resistance of all the coils in series between the two bars.) Similar to Test #1, a drop in resistance will indicate a short between wires in that coil, and a spike in resistance could indicate a broken or burned wire in a coil.

ARMATURE TEST #3

The third and final test is to measure the resistance of every commutator bar to the iron armature stack. If the motor armature stack is directly pressed onto the armature shaft, you can use the armature shaft for the measurement. However, in some cases, even the armature shaft is insulated from the armature stack. In that case, you will have to measure from each commutator bar to the iron armature stack directly. In either case, the commutator bars should never have electrical continuity to the armature stack and/or the armature shaft.

If any of these measurements fail, it can be assumed that the armature is damaged.

Common faults on armatures described

Commutators

The most common fault with armatures is *worn commutators*, caused by the friction of carbon brushes against the commutator surface. Over time the insulation between the commutator segments becomes proud as the copper of the commutator surface wears away. This is especially so with older commutators as the insulation that was used to separate the

commutator segments was mica, which is harder than the copper. When the commutator has worn down to this point it will also quickly wear down the brushes.
This fault can usually be repaired without rewinding the armature by turning the commutator brush surface down below the damage and then undercutting the insulation between the commutator segments.

Burnt-out

Another common fault is for the armature to burn out. This can be caused by an number of different problems such as overloading, poor airflow, regulator failure, stalling, insulation breakdown, earthing etc. If the armature has burned out then it will need to be rewound.
Before the invention of resin-covered wire, copper wire was insulated by the method *double-cotton covered*, a thin strand of cotton wrapped around the wire. Overtime the expansion and contraction of the copper wire through constant heating and cooling, combined with centripetal force, can cause the turns within the coils to short-out. The shorted turns get hot as the voltage generated in them has only the resistance of that one turn so the current it draws can be high and that high current generates heat. This heating causes further shorts and more heating until eventually the winding itself burns out.
If too much current is demanded from the dynamo, either through a fault on the voltage regulator, too many high-power light bulbs, a fault on the battery or a low resistance introduced to the system, then the armature can get very hot. As the armature heats up, the internal resistance of the armature goes up causing more power to be dissipated across the armature itself, generating even more heat. This can cause the solder connecting the armature coils to the commutator to melt. As the armature is spinning the solder is thrown from the armature, causing the connections between the armature coils and the commutator to be broken.

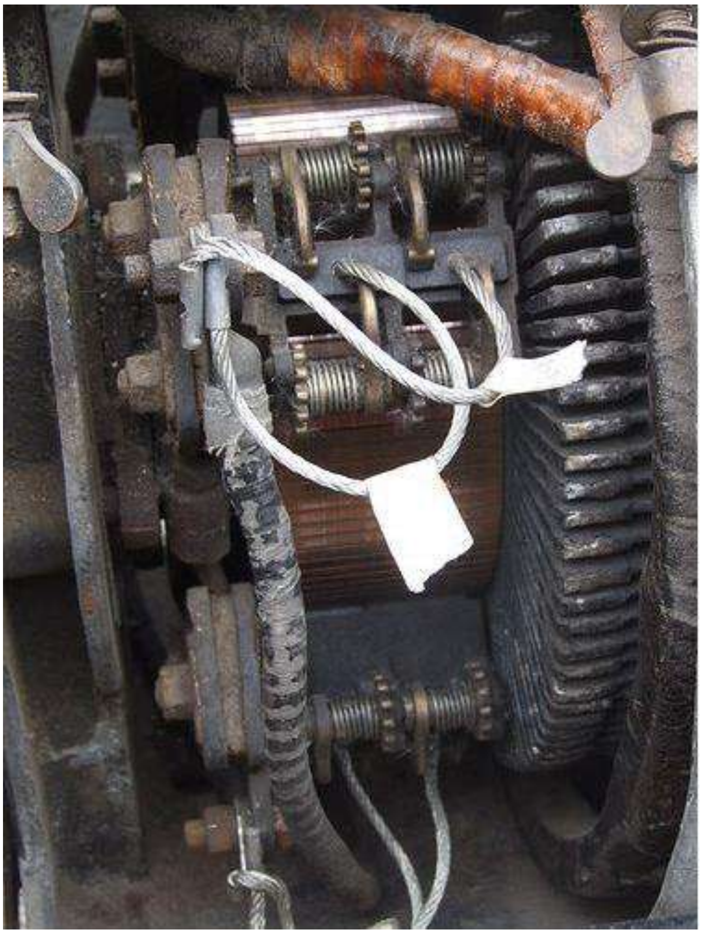
Earthing

Earthing (grounding) is a common fault which occurs when part of the winding becomes connected to the metal core of the armature. The armature windings are insulated from the metal core and the metal core is often connected to the negative side of the battery, through the body of the dynamo (unless it is an insulated return in which the negative side of the dynamo is connected to the battery with a wire). Earthing usually occurs when insulation brakes down, usually through overheating or through fatigue on the edge of a slot through constant heating, cooling and spinning.
common Causes of Electric Motor Failures
There are six main causes of electric motor failures:

1. Over-Current
2. Low Resistance
3. Over heating
4. Dirt
5. Moisture
6. Vibration

These causes are briefly explained below:
1. Over-Current (Electrical Overload): In different operating conditions, electrical devices will sometimes start to draw more current than their overall capacity. This unpredictable event will happen very suddenly and will greatly impact the motor. To avoid an over-current, there are some devices that need to be installed that can prevent it from happening. These devices are usually wired in the circuits and will automatically shut down the extra amount of current flowing in the circuit.

2. Low Resistance: Most motor failures occur due to low insulation resistance. This issue is considered to be the most difficult one to tackle. In the initial stages of motor installation, the insulation resistance is observed to be more than one thousand megaohms. After some time, the insulation performance starts to degrade at an alarming level because the resistance starts to decay gradually. After a lot of research, a solution has been found which can prevent low resistance failures. There are automatic devices that test insulation resistance from time to time and safeguard rotating equipment is installed that prevents such failures. It is important that the insulation performance is monitored at regular intervals.



3. Over Heating Excessive heat in motors can cause a number of performance problems. Overheating causes the motor winding insulation to deteriorate quickly. For every ten centigrade rise in temperature, the insulation life is cut in half. It has been concluded that more than 55% of the insulating failures are caused by overheating.

Overheating occurs due to a number of factors. Every electric motor has a design temperature. If a motor is started off at a bad current value, it starts operating in a much warmer condition than the design temperature. It is very important that the motors should be matched with their ideal current values.

Overheating also occurs when an electric motor is forced to operate in a high temperature environment. This causes the rate at which heat can be conducted to reduce at an alarming rate. The area where electric motors are operating must have a proper cooling system and a ventilation system should **Fig7.24** be there in case the cooling system stops working.

4. Dirt: Dirt is one of the major sources that cause damage to the electric motors. It can damage the motor by blocking the cooling fan which causes its temperature to raise. It can also affect the insulating value of the winding insulation if it settles on the motor windings. Proper steps should be taken to prevent the motors from dirt. Shielding devices are available which are used for this purpose.

5. Moisture: Moisture also affects the performance of electric motors. It greatly contributes in the corrosion of the motor shafts, bearings and rotors. This can lead to an insulation failure also. The motor inventory should be kept dry all the time.

6. Vibration: There are a number of possible causes of vibration, such as misalignment of the motor. Corrosion of parts can also cause the motor to vibrate. The alignment of the motor should be checked to eliminate this issue.

Armature Test by Using Growler

ARMATURE TEST. - There are two practical tests for locating shorts, opens, and grounds in armatures - the growler test and the bar-to-bar test.

To test for short circuits, place the armature on the V-block of the growler and turn on the current. With a thin metal strip (hacksaw blade is good) held over the core, as shown in figure 2-17, rotate the armature slowly through a complete revolution. If a short is present, the steel strip will become magnetized and vibrate. To find out whether the armature coils of the commutator are short-circuited, clean between the commutator segments and repeat the test. Should the thin metal strip still vibrate, the armature is short- circuited internally and must be replaced.

Not all armatures can be tested for short circuits by the method just described. These armatures can be identified by excessive vibration of the saw blade all around the armature during the test. With these armatures, test for short circuits by using the milliampere contacts on an ac millimeter, as shown in figure 2-18. In doing so, keep the armature stationary in the V-block and move the contacts around the commutator until the highest reading is obtained. Then turn the armature to bring each pair of segments under

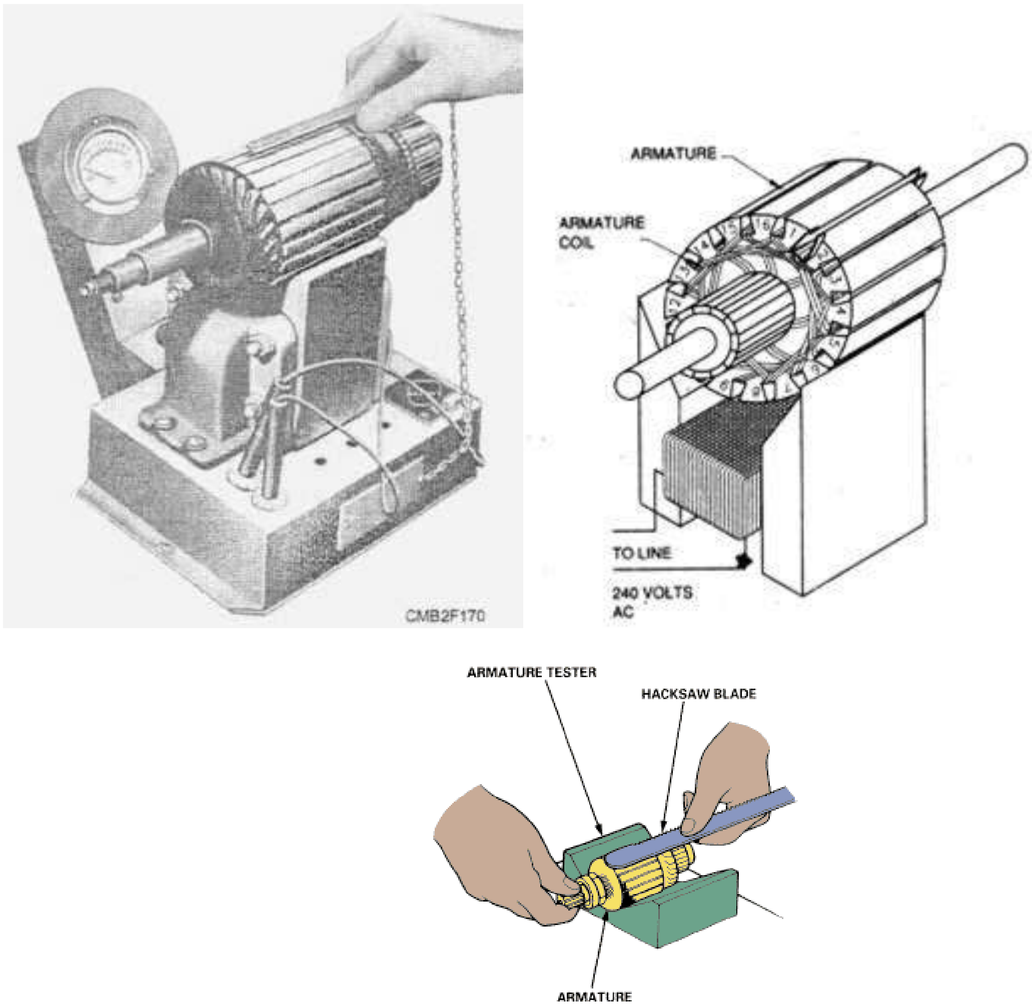


Figure **7.25-** Using an armature growler.

the contacts and read the milliammeter at the same time. The readings should be nearly the same for each pair of adjacent bars. If a coil is short-circuited, the milliammeter reading will drop to almost zero.

Test the armature for grounds by using the test light circuit, which is a part of most modern factory- built growlers (fig. 2-19). Place the armature on the V-block and touch one of the test probes to the armature core iron.

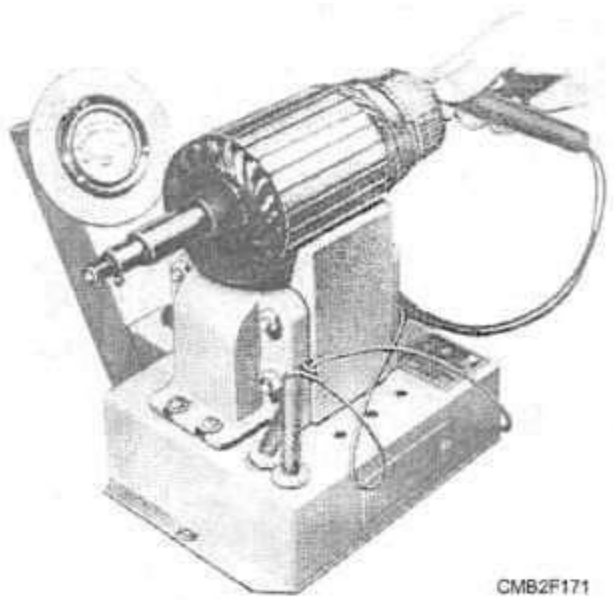


Figure **7.26** Testing an armature for a short circuit with a milliammeter.

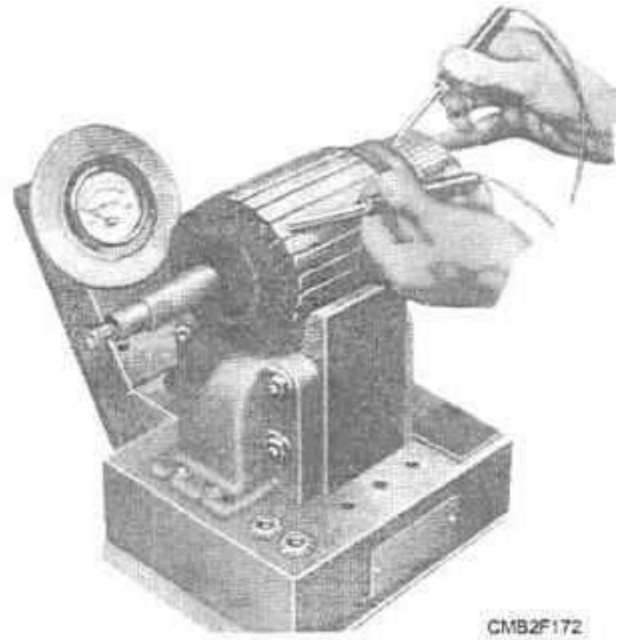


Figure **7.27**Testing an armature for grounds.

armature core iron. Touch the other probe to each commutator segment in turn. If the armature is grounded, the bulb in the base of the growler will light. In contacting armature surfaces with the test probes, do not touch the bearing or the brush surfaces of the commutator. The arc would burn or pit the smooth finish. Replace the armature if it is grounded.

In testing individual armature coils for open circuits, use the test probes, as shown in figure 2-20. Place them on the riser part of adjacent commutator

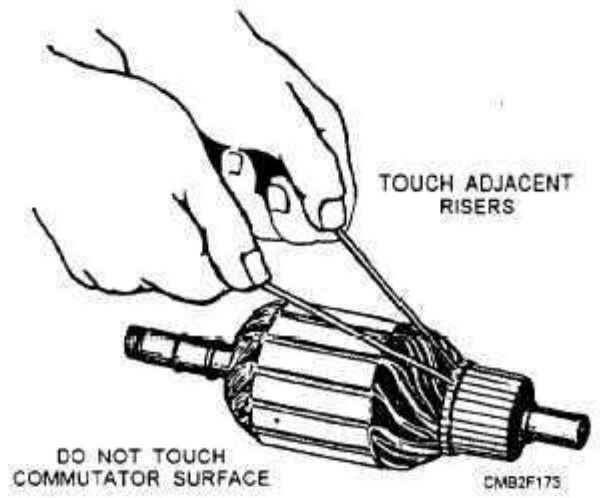


Figure **7.28** Testing an armature for open circuits.

bars, not on the brush surfaces. If the test lamp does not light, there is a break somewhere in the coil. Repeat this test on every pair of adjacent bars. Do this by walking the probes from bar to bar. Should you find an open coil, the fault may be at the commutator connectors where it is possible to make repairs with a little solder. If a coil is open-circuited internally, the armature should be discarded.

Short Answer Questions

1. What is Armature Winding
2. What is a Turn and Coil?
3. What is a Coil Group and Winding?
4. Define Pole Pitch and Coil Pitch
5. Define Front Pitch and Back Pitch
6. What is a Resultant Pitch and Commutator Pitch?
7. What is Full Pitch and Short Pitch Winding
8. Write the Advantages and Disadvantages of Short-Pitch Winding
9. What is single and Multi-Layer Winding
10. What are the Types in Armature Winding?
11. What is Lap Winding?
12. What is Wave Winding?
13. What are the Advantages of Lap Winding?
14. What are the dis advantages of Lap Winding?
15. What is Progressive and Retrogressive Wave Winding?

Essay Questions

1. Write the differences between Lap and Wave Winding
2. Explain about the Methods to find the faults in DC armature
3. Develop simple 2-layer lap-winding for a 4-polegenerator with 8 coils.
4. Develop a simplex and progressive wave winding diagram of a machine having 34 conductor in 17 slots and 4 poles

8. A. C. Machine Winding

Introdcution to Armature Winding

Basically the first question is what is armature winding? Armature winding is an one type of arrangement of conductors to produce emf by relative motion in hetropolar magnetic field.

The armature is provided with slots on its circumference in which the conductors are housed. These conductors are connected by two methods according to our requirement:

1. Connected in series for increasing voltage ratings.
2. connected in parallel for increasing current ratings.

Comparison between closed and open winding Table 8.1

Closed Winding	Open Winding
Closed path around the armature periphery	open at one or more points forming several sections
winding are double layer type	can be single or double layer type
used in D.C. machines	used in A.C. Machine
not flexible design	flexible design

Comparison between open windings and closed windings

In ac machines, the stator has ac armature winding in which the alternating emf is induced. The winding for armature of a dc machines is closed and the closed windings are always double layer type. The armature used for armature of ac machines is open.

open layer can be either single layer or double layer. The stator winding consists of single turn or multi turn coils, arranged in slots and connected properly so as to obtain the required phase grouping. The AC winding must be properly arranged, so that the emf induced in all the phases are of equal magnitude and frequency. The emfs of all the m phases of ac machine must have identical wave-shape and displaced in time phase by (2 * pie/m).

Why it is called open coil winding?

In ac machines the wave shape of the generated emf depends upon the flux distribution in the air-gap of a machine. In ac winding the ends of the first coil and last coil or the beginning of the first coil and the ending coil of the last coil is kept open, so this is know as **open coil winding**.

8.1 Types of AC armature winding

Armature Winding of Alternator
Armature winding in an alternator may be either closed type open type. Closed winding forms star connection in **armature winding of alternator**.
There are some common properties of armature winding.

1. First and most important property of an armature winding is, two sides of any coil should be under two adjacent poles. That means, coil span = pole pitch.

2. The winding can either be single layer or double layer.
3. Winding is so arranged in different armature slots, that it must produce sinusoidal emf.

There are basic two types of AC armature winding:

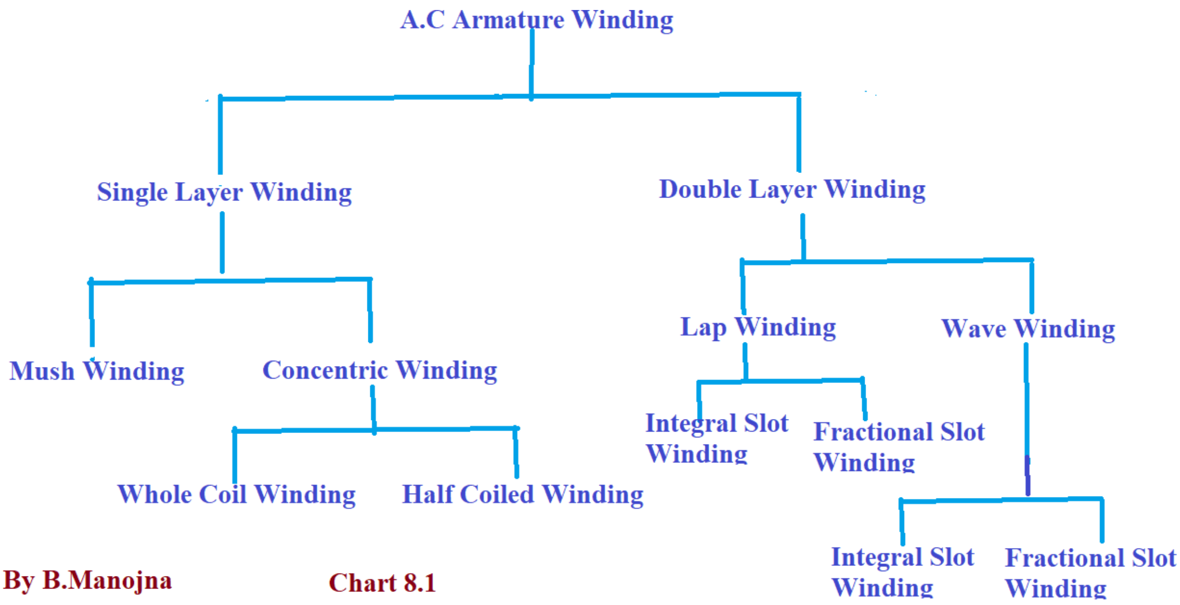


Chart 8.1

Types of Armature Winding of Alternator

There are different **types of armature winding** used in alternator. The windings can be classified as

1. Single phase and poly phase armature winding.
2. Concentrated winding and distributed winding.
3. Half coiled and whole coiled winding.
4. Single layer and double layer winding.
5. Lap, wave and concentric or spiral winding and
6. Full pitched coil winding and fractional pitched coil winding.

In addition to these, **armature winding of alternator** can also integral slot winding and fractional slot winding.

Single Phase Armature Winding

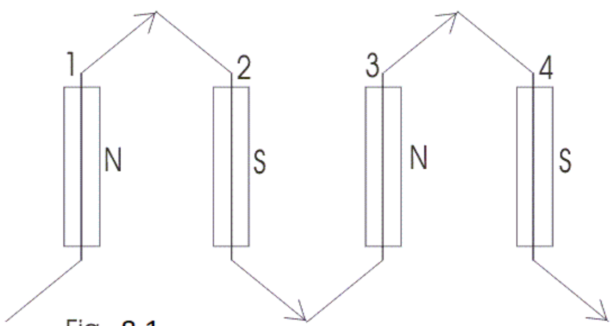


Fig - 8.1

Single phase armature winding can be either concentrated or distributed type.

Concentrated Armature Winding

The concentrated winding is employed where the number of slots on the armature is equal to the number of poles in the machine. This armature winding of alternator gives maximum output voltage but not exactly sinusoidal.

The simplest single-phase winding is shown below in the figure-8.1. Here, number poles = the number of slots = number of coil sides. Here, one coil side is inside one slot under one pole and the other coil side inside other slots under next pole. The emf induced in one coil side gets added to that of adjacent coil side.

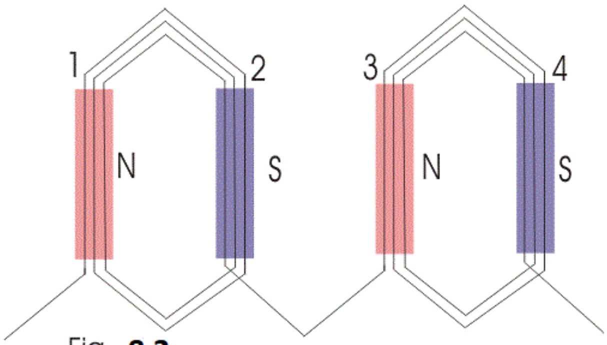


Fig - **8.2**

This arrangement of an armature winding in an alternator is known as skeleton wave winding. As per the fig-8.1, coil side-1 under N-pole is connected to coil side-2 under S-pole at the back and coil side-3 at the front and so on.

The direction of induced emf of coil side-1 is upward and emf induced in coil side-2 is downward. Again as coil side-3 is under N-pole, it will have emf in the upward direction and so on. Hence total emf is the summation of emf of all coil sides. This form of armature winding is quite simple but rarely used as this requires considerable space for end connection of every coil side or conductor. We can overcome this problem, some extent by using multi turns coil. We use the multi-turn half coiled winding to get higher emf. Since the coils cover only one half of the armature periphery thus, we refer this winding as Half coiled or Hemi – tropic winding. Figure 8. 2 shows this. If we distribute the all coils over the whole armature periphery, then the armature winding is referred as whole coiled winding.

Figure 8.3 shows a double layer winding, where we place one side of each coil on the top of armature slot, and another side in the bottom of the slot. (Represented by dotted lines).

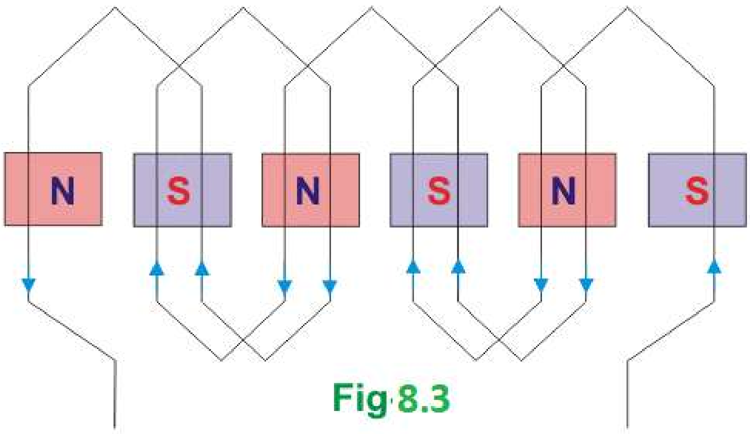


Fig 8.3

Distributed Armature Winding of Alternator

For obtaining smooth sinusoidal emf wave from, conductors are placed is several slots under single pole. This armature winding is known as distributed winding. Although distributed armature winding in alternator reduces emf, still it is very much usable due to following reason.

1. It also reduces harmonic emf and so waveform is improved.
2. It also diminishes armature reaction.
3. Even distribution of conductors, helps for better cooling.
4. The core is fully utilized as the conductors are distributed over the slots on the armature periphery.

Lap Winding of Alternator

Full pitched lap winding of 4 poles, 12 slots, 12 conductors (one conductor per slot) alternator is shown below.

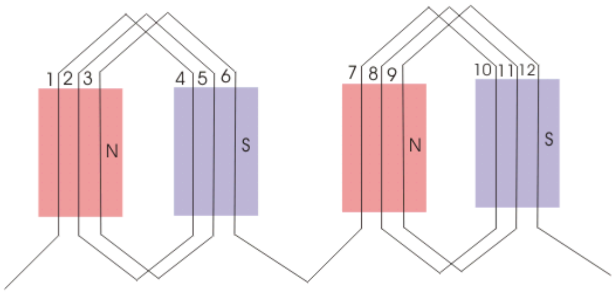


Figure – 8.4

Wave Winding of Alternator

The back pitch of the winding is equal to the number of conductors per pole, i.e., = 3 and the front pitch is equal to back pitch minus one. The winding is completed per pair of the pole and then connected in series as shown in figure – 8.4 Above

Wave winding of the same machine, i.e., four poles, 12 slots, 12 conductors is shown in the figure-e below. Here, back pitch and front pitch both equal to some conductor per pole.

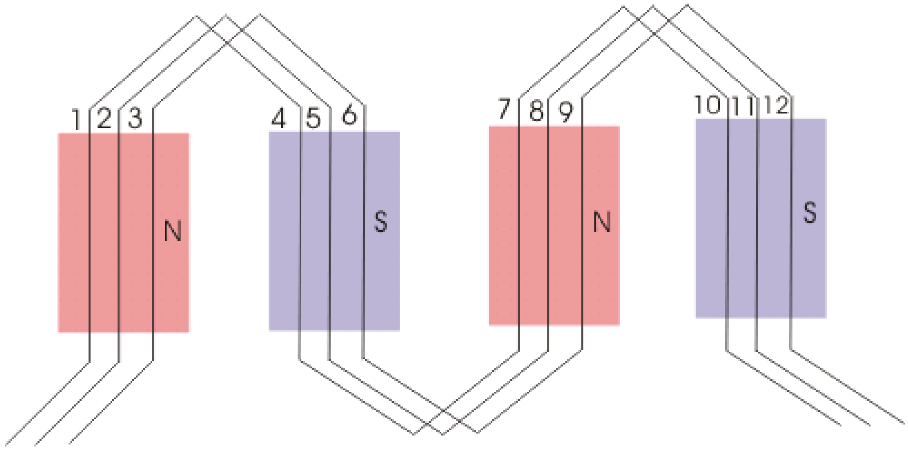


Fig 8.5

Concentric or Spiral Winding

This winding for the same machine, i.e., four poles 12 slots 12 conductors alternator is shown in the figure-f below. In this winding, the coils are of different pitches. The outer coil pitch is 5, the middle coil pitch is 3, and inner coil pitch is one.

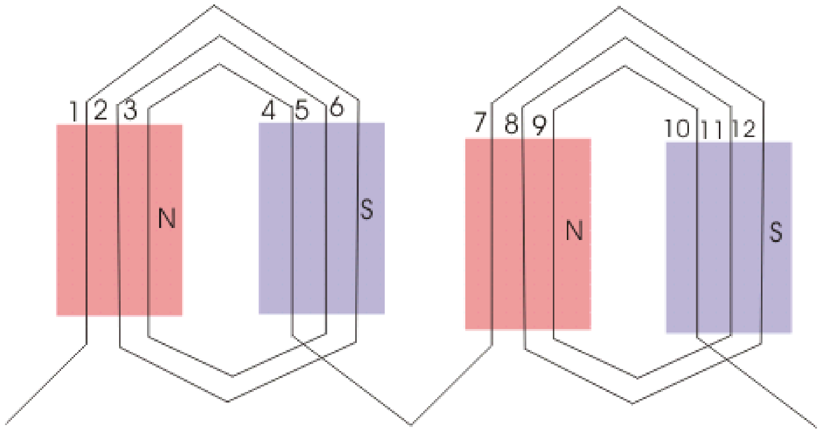


Fig 8.6

Poly Phase Armature Winding of Alternator

Before discussing poly phase **armature winding of alternator**, we should go through some of the related terms for better understanding.

Coil Group

It is product of number of phases and number of poles in a rotating machine. Coil group = number of poles × the number of phases.

Balanced Winding

If under each pole face, there are an equal number of coils of different phases, then the winding is said to be balanced winding. In balanced winding, coil group should be an even number.

Unbalanced Winding

If the number of coils per coil group is not a whole number, the winding is known as unbalanced winding. In such case, each pole face contains unequal of coils of different phase. In two-phase alternator, two single-phase windings are placed on the armature by 90 electrical degrees apart from each other.

In case of three phase alternator, three single-phase windings are placed on the armature, by 60 degrees (electrical) apart from each other.

The figure below represents, a Skelton 2 phase 4 pole winding two slots per pole. The electrical phase difference between adjacent slots = 180/2 = 90 degree electrical).

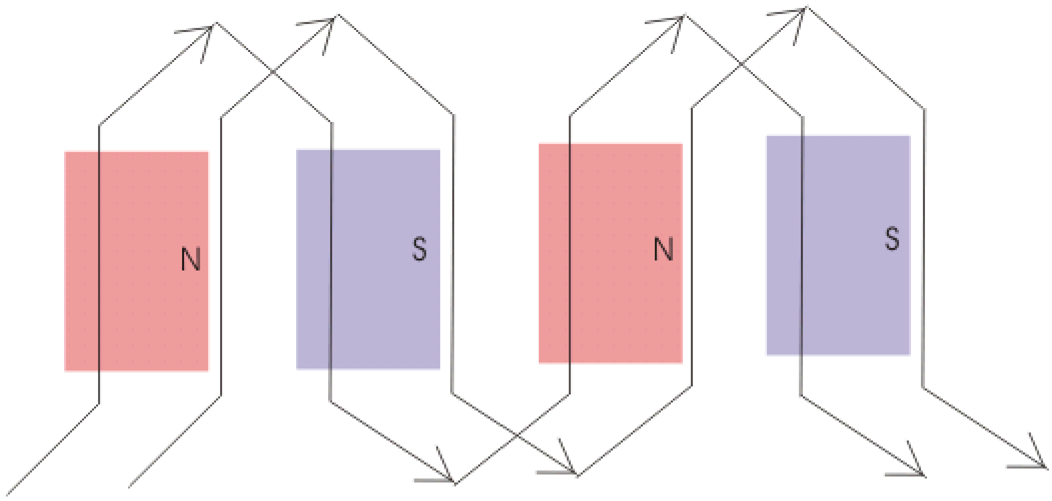


Fig 8.7

Point a and b are starting point of the first and second phase winding of two, phase alternator. a’ and b’ are finishing point of first and second phase wining of the two-phase alternator, respectively. The figure below represents a Skelton 3 phase 4 pole winding, three slots per pole. The electrical phase difference between, adjacent slots is 180/ 3 = 60 degree (electrical) a, b and c are starting point of Red, Yellow, and blue phases and a’, b’, and c’ are the finishing points of same Red, Yellow and Blue phases of the three-phase winding.

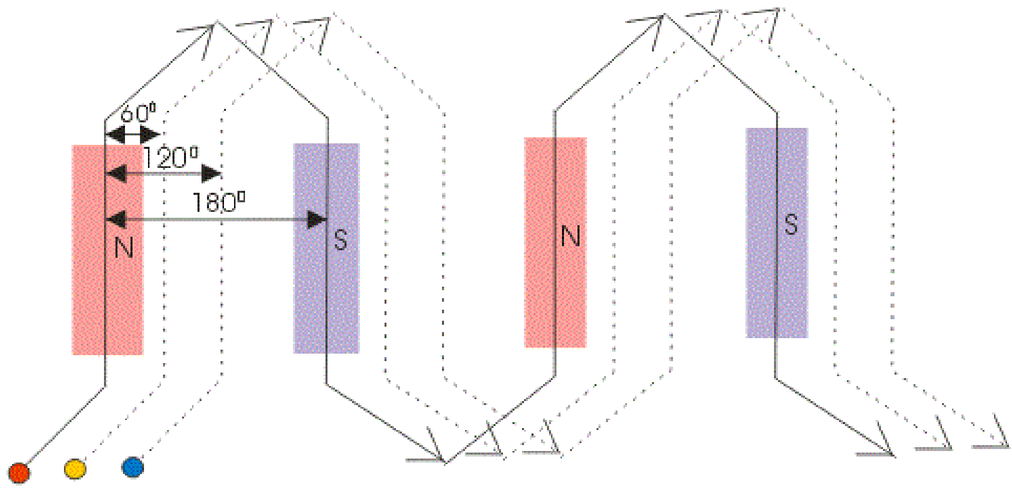


Fig 8.8

Say red phase winding starts at slot no 1 and ends over slot no 10. Then yellow winding or second winding starts at slot no 2 and ends over slot no 11. Third or blue phase winding starts at slot no 3 and ends at slot no 12. The phase difference of induced emfs, in red phase and yellow, yellow phase and blue phase and blue phase and red phase winding respectively by 60 degrees, 60 degree and 240 degrees (electrical respectively). Since in three phase system, the phase difference between red, yellow and blue phase is 120 degree (electrical). This can be achieved by revering yellow phase (second winding) winding as shown in the figure above.
Figure- below represents 4 pole, 24 slot, single layer, full pitched 3 phases distributed winding.

Slots No: 1, 2, 7, 8, 13, 14, 19, and 20 for R phase

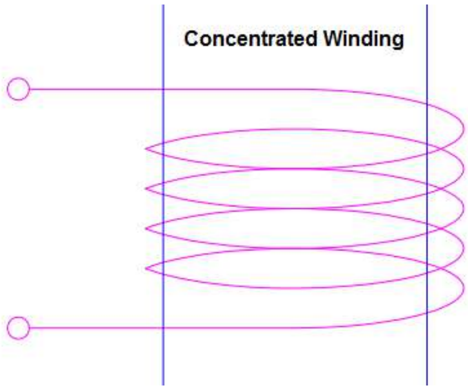
Slots No: 5, 6, 11, 12, 17, 18, 23 and 24 for Y phase 
Slots No: 3, 4, 9, 10, 15, 16, 21 and 22 for B phase

Table 8.2

The figure below shows three phase full pitched double layer lap winding. Each winding is spaced 120 electrical degrees from two adjacent winding. This winding has 12 slots per pole per phase. Since the winding is the full pitched coil, so the pitch of each. The coil is 12 slots. Since one pole presents 180 electrical space degrees, so the slots pitch corresponding to 180/12, i.e., 15° (electrical).

In a fractional pitch winding, we make the coil span less than 180 degrees electrical space degrees. In the figure above a coil instead of having a pitch of 12 slots now has a pitch of 10 slots so that its spread is no longer equal to pole pitch.

There are two types of coil span. The first one is full pitched coil where two sides of the coil are 180 degrees (electrical) apart. In full pitched coil when one side of the coil is under N pole, the other side is in the corresponding position, under S pole. The induced emfs on two opposite side of coil differ by 180 degrees (electrical). Hence the resultant, emf of the coil, is just arithmetic sum of these two emfs.

The second one is the short-pitched coil, where, two opposite side of a coil is not exactly 180 degree (electrical) it is less than that. In this case, the phase difference between emf of two coil side is also less than 180 degree (electrical). Hence, the resultant emf of the coil is not a simple arithmetic sum of two emfs, but it is the vector sum of two emfs. Hence, resultant emf of a short-pitched coil is always less than that of a full pitched coil. But still, we preferably use short pitched coil because short pitched coil reduces or elements harmonics from waveforms.

Integral Slot and Fractional Slot Winding

When the number of slots per pole per phase is an integer, the winding is the integer slot winding but when the number slots per pole per phase is fractional number the winding we refer as fractional slot winding.

Fractional slot winding is practicable only with the double layered winding. It limits the number of parallel circuits available because phase group under several poles must be connected in series before a unit is formed and the widening respects the pattern to give the second unit that can be put in parallel with the first.

Fig 8.9

Difference between Concentrated and Distributed Winding

Concentrated Winding

In concentrated type of winding, all the winding turns are wound together in series to form onemulti-turn coil. Examples of concentrated winding are field winding for salient pole synchronous machine and DC machine. In concentrated winding, all the turns have the same magnetic axis. Primary and secondary winding of a transformer also form concentrated winding. Figure below shows one example of concentrated winding.Since the coils are concentric in this type of winding, there is no concept of pitch factor and distribution factor for such winding. In fact, the value of pitch factor and distribution factor for concentrated winding is unity. Thus the emf induced E by working flux Ø in such type of winding having N series turns is given as below.

$$E = \sqrt{2}\pi f N Ø$$

No rotational torque is produced if both field winding and armature winding are of concentrated type. Example is transformer which does not rotate.

Distributed Winding

In distributed type of winding, all the winding turns are arranged in several full-pitch or fractional pitch coils. These coils are then inserted into slots spread along the air gap periphery. Stator and rotor of Induction Machine, armature winding of synchronous and DC machine are some of the examples where distributed winding is used. Figure below depicts distributed winding.It can be seen from above figures that, the three phase winding are distributed among the 12 slots. The induced emf in any phase is the phasor sum of individual emf induced in coils side located at different slots. For better understanding of how emf is calculated in distributed winding, please read Distribution Factor.

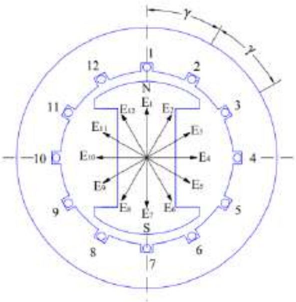


Fig 8.10

Difference between Concentrated and Distributed Winding

The major difference between the concentrated and distributed winding is that, concentric oils are used in concentrated winding whereas coils are spread along the air gap periphery in distributed winding.

Some of the important difference between concentrated and distributed winding are tabulated below.

S. No.	Concentrated Winding	Distributed Winding
1)	The coils of concentrated winding are co-axial. This means, all the winding coils have the same magnetic axis.	The coils of distributed windings are not co-axial. They are rather distributed in various slots along the air-gap periphery.
2)	The emf induced in the such winding is independent of pitch and distribution factor. $E = 1.414\pi f N Ø$	The emf induced in the distributed winding is dependent on the value of pitch factor K_p and distribution factorK_d. $E = 1.414\pi K_p K_d f N Ø$

3)	This type of winding is used in transformer, electromagnets etc.	Distributed winding is used in armature winding of induction machine, synchronous machine, DC machine etc.
4)	For concentrated winding, the number of pole is equal to number of slots.	Number of pole is not equal to number of slots.

Table 8.3

8.2 TROUBLESHOOTING of AC MOTOR

1. MOTOR FAILS TO START UPON INITIAL INSTALLATION

- **Motor is wired incorrectly**
  - Refer to the wiring diagram to verify the motor is wired correctly.
- **Motor damaged and rotor is striking stator**
  - Rotate the motor's shaft and feel for rubbing.
- **Power supply or line trouble**
  - Check the source of power, overload, fuses, controls, etc..

2. MOTOR HAS BEEN RUNNING, THEN FAILS TO START

- **Fuse or circuit breaker is tripped**
  - Replace the fuse or reset the breaker.
- **Stator is shorted or went to ground (Motor will make a humming noise and the circuit breaker or fuse will trip)**
  - Check for leaks through the coils. If leaks are found, the motor must be replaced.
- **Motor overloaded or jammed**
  - Inspect to see that the load is free. Verify the amp draw of motor versus the nameplate rating.
- **Capacitor (on single phase motor) may have failed**
  - First discharge the capacitor. To check the capacitor, set the volt-ohm meter to RX100 scale and touch its probes to the capacitor terminals. If the capacitor is OK, the needle will jump to zero ohms, and drift back to high. Steady zero ohms indicates a short circuit; steady high ohms indicates an open circuit.

3. MOTOR RUNS BUT DIES DOWN

- **Voltage drop**
  - If the voltage is less than 90% of the motor's rating, contact your power company or check to see that another piece of equipment isn't taking power away from the motor.
- **Load increased**
  - Verify that the load has not changed and the equipment has not gotten tighter. If it is a fan application, verify that the air flow hasn't changed.

4. MOTOR TAKES TOO LONG TO ACCELERATE

- **Defective capacitor**
  - Test the capacitor per previous instructions.
- **Bad bearings**

- Noisy or rough feeling bearings should be replaced by the motor supplier.

- **Voltage too low**
  - Make sure the voltage is within 10% of the motor's nameplate rating. If not, contact your power company or check if some other equipment is taking power away from the motor.

5. MOTOR RUNS IN THE WRONG DIRECTION

- **Incorrect wiring**
  - Rewire the motor according to the schematic provided with the motor. Groschopp wiring diagrams can be found within the "Wiring Diagrams" page of our resources section or on individual motor pages.

6. MOTOR OVERLOADED/THERMAL PROTECTOR CONTINUOUSLY DRIPS

- **Load too high**
  - Verify that the load is not jammed. If the motor is a replacement, verify that the rating is the same as old motor. If the previous motor was a special design, a stock motor may not be able to duplicate the performance. Remove the load from the motor and inspect the amp draw of the motor unloaded. It should be less than the full load rating stamped on the nameplate (only true for three phase motors).
- **Ambient temperature too high**
  - Verify that the motor is getting enough air for proper cooling. Most motors are designed to run in an ambient temperature of or less than 40°C. (Note: A properly operating motor may be hot to the touch.)

7. MOTOR OVERHEATING

- **Overload. Compare actual amps (measured) with nameplate rating**
  - Locate and remove the source of excessive friction in the motor or load. Reduce the load or replace the motor with one of greater capacity.
- **Single phasing (three phase only)**
  - Check the current at all phases. It should be approximately the same.
- **Improper ventilation**
  - Check external cooling fan to be sure air is moving properly through the cooling channels. If there is excessive dirt build-up, clean the motor.
- **Unbalanced voltage (three phase only)**
  - Check the voltage at all phases. It should be approximately the same.
- **Rotor rubbing on stator**
  - Tighten the thru bolts.
- **Over voltage or under voltage**
  - Check the input voltage at each phase of the motor to make sure the motor is running at voltage specified on the nameplate.
- **Open stator winding (three phase only)**
  - Check the stator resistance at all three phases for balance.
- **Improper connections**
  - Inspect all the electrical connections for proper termination, clearance, mechanical strength, and electrical continuity. Refer to the motor lead diagram.

8. MOTOR VIBRATES

- **Motor misaligned to load**

  - Realign the load.
- **Load out of balance (direct drive application)**
  - Remove the motor from load and inspect the motor by itself. Verify that the motor shaft is not bent.
- **Defective motor bearings**
  - Test the motor by itself. If the bearings are bad, you will hear noises or feel roughness.
- **Load too light (single phase only)**
  - Some vibration at a light load is standard. Consider switching to a smaller motor for excessive vibration.
- **Defective winding**
  - Test the winding for shorted or open circuits. The amps may also be high. For defective winding, replace the motor.
- **High voltage**
  - Check the power supply to make sure voltage is accurate.

9. BEARINGS FAIL

- **Load to motor may be excessive or unbalanced**
  - Check the motor load and inspect the drive belt tension to ensure it's not too tight. An unbalanced load will also cause the bearings to fail.
- **High ambient temperatures**
  - If the motor is used in an environment with high ambient temperatures, a different type of bearing grease may be required. You may need to consult the factory.
- **High motor temperatures**
  - Check and compare the actual motor loads to the motor's rated load capabilities.

10. CAPACITOR FAIL

- **Ambient temperature too high**
  - Verify that the ambient temperature does not exceed the motor's temperature rating (found on the nameplate)
- **Possible power surge to the motor (caused by a lightning strike or other high transient voltage)**
  - If this is a common problem, install a surge protector.

8.2 Testing and Troubleshooting of A. C. Windings

Rewinding is very long process. It took about two days to rewind it, replace all old parts and reassemble it. Howto disassemble electric motor, remove bearings, make winding diagram, rewind motor, chose right capacitor and reassemble it with new bearings.

Step 1: How to identify the Single Phase Motor?

Single phase motor usually has two coils, main with bigger resistance (generating a pulsating magnetic field) and auxiliary with smaller resistance (gives motor a direction of rotation). There must be a capacitor on the motor. Its value is different for different electric engines (for smaller electric engines around 20 microF). 2 capacitors can be on motor, "run" capacitor (always connected, lower value capacitor) and "Start" capacitor (connected with centrifugal switch, higher value capacitor)

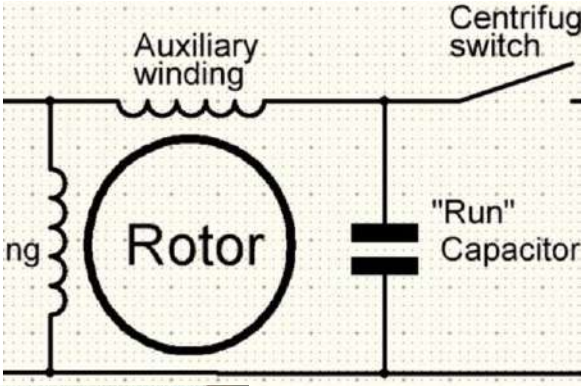


Fig 8.11 Fig 8.12

Picture 8.11: Scheme of single phase electric motor
Picture 8.12: Wires from stator (there should be 4 wires from stator)

Step 2: Tools

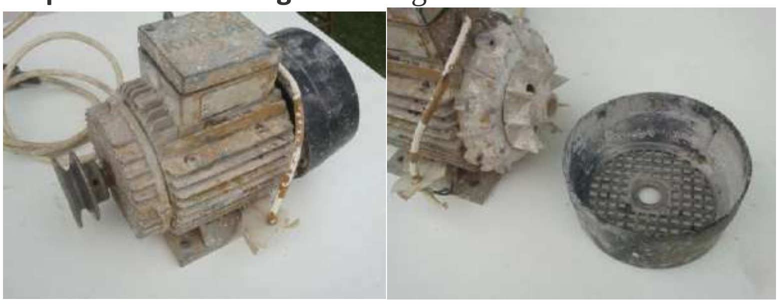
Rewinding and disassembling motor is very time consuming work, if you don´t have professional equipment. You will need following tools:

- Basic tools (screwdrivers, hammers, wrenches...)
- Pulleys for bearings
- Chisels, to cut off old winding
- Butane torch (or other heating device)

Special Material:

- Copper wire
- Isolate paper
- Stator lacing thread
- Spray Lubricant (WD-40 or similar)
- Motor lacquer

Step 3: Disassembling Motor Fig 8.13



Take few pictures of motor, and Remove the fan protective cover. Usually the cover is not screwed with screws on housing but it's just plugged on housing.
Put all removed parts of motor in one box so you don't lose them.

Step 4: Disassembling Motor Fig 8.14

Gently heat up motor fan and remove it. Be careful you don't break it; it should go very smooth. You can help yourself detaching it with two big screwdrivers.
After detaching motor fan remove clamp from axis.

Step 5: Disassembling Motor Fig 8.15 and 8.16

Mark the position of individual covers, on the side of covers (usually we put numbers 1, 2, 3 on side of covers, so we will know to assemble it).
Unscrew the screws securing the cover (picture 8.15). Remove the cover of motor and put it in the box with other parts.

Step 6: Disassembling Motor Fig 8.17 and 8.18

Observe the motor winding if burned out (black colour and smell of burned lacquer).
Observe the Bearings. If brokenit creates loud sound when you spin it

Step 7: Disassembling Motor Fig 8.19 and 8.20 and 8.21 and 8.22


Unscrew the screws securing the front cover (as you have done 2 steps before). Gently remove the front cover with rotor out of main housing and put it in the box with other parts.

Step 8: Disassembling Motor Fig 8.23 and 8.24 and 8.25



Unscrew the screws securing the top cover. Remove the top cover and sealing and put it in the box with other parts.
Take few pictures of electrical installation and remove all the wires and electrical clips. Remove capacitor, if you have one on motor

Step 9: Take Motors Name Plate Data

Try to write down all information from inscription board. It is located on motors housing. There are some useful information on it (voltage, current, number of turns per minute, capacitor...).
Fig 8.26

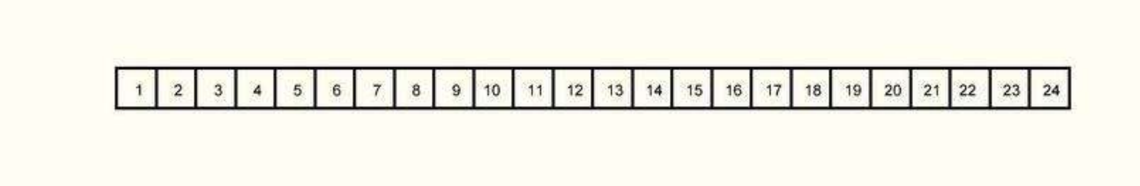
Step 10: Winding Diagram

In next steps we are going to make winding diagram.Winding diagram is diagram which helps you rewind motor. It show how stator coils are connected with each other.

Step 11: Winding Diagram Fig 8.27 and 8.28

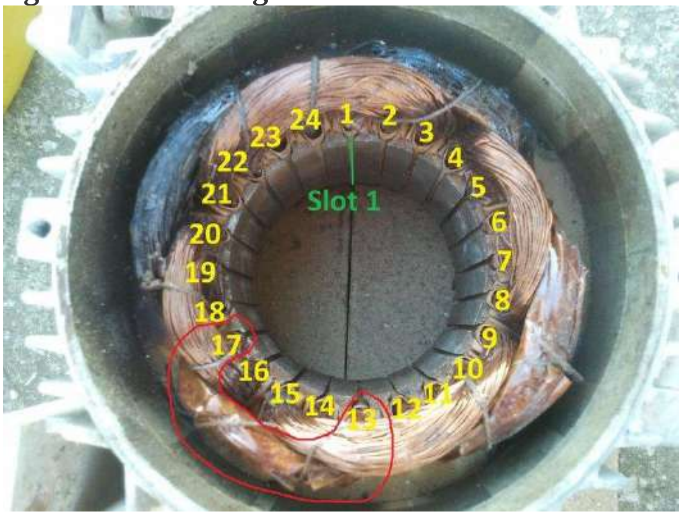

Count number of slots (gaps in stator, look at pictures).It has 24 gaps.

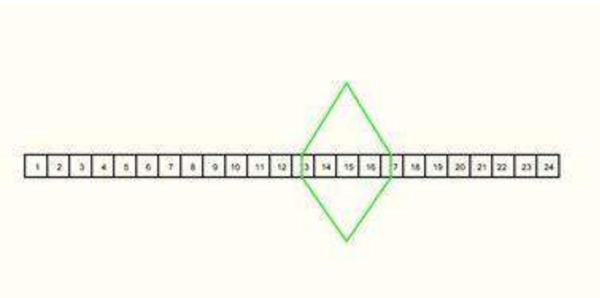
Step 12: Winding Diagram Fig 8.29

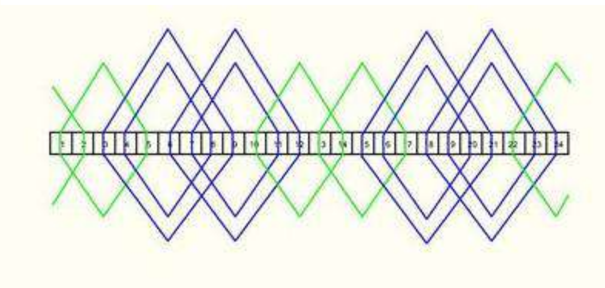


On Paper draw 1 square for each slot connecting each other

Step 13: Winding Diagram **Fig 8.30 and 8.31 and 8.32**

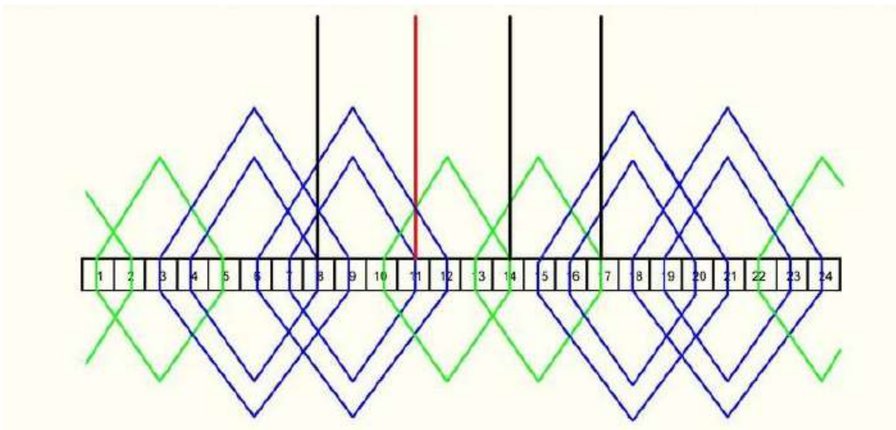






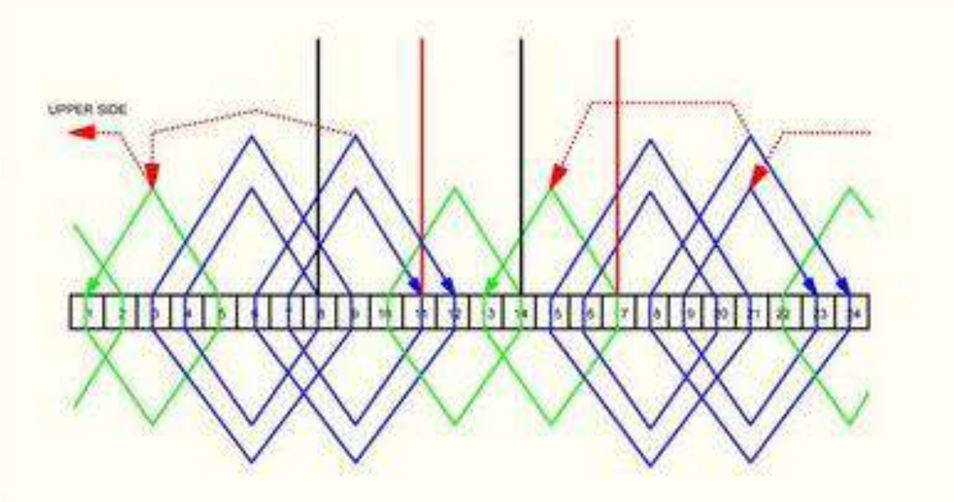
Each of coil is placed in 2 slots. Draw coils from your stator to your winding diagram.
Do same for all coils. There can't be 2 coils in one gap (if you have Single-layer winding). All of gaps needs to be full.

Step 14: Winding Diagram **Fig 8.33**



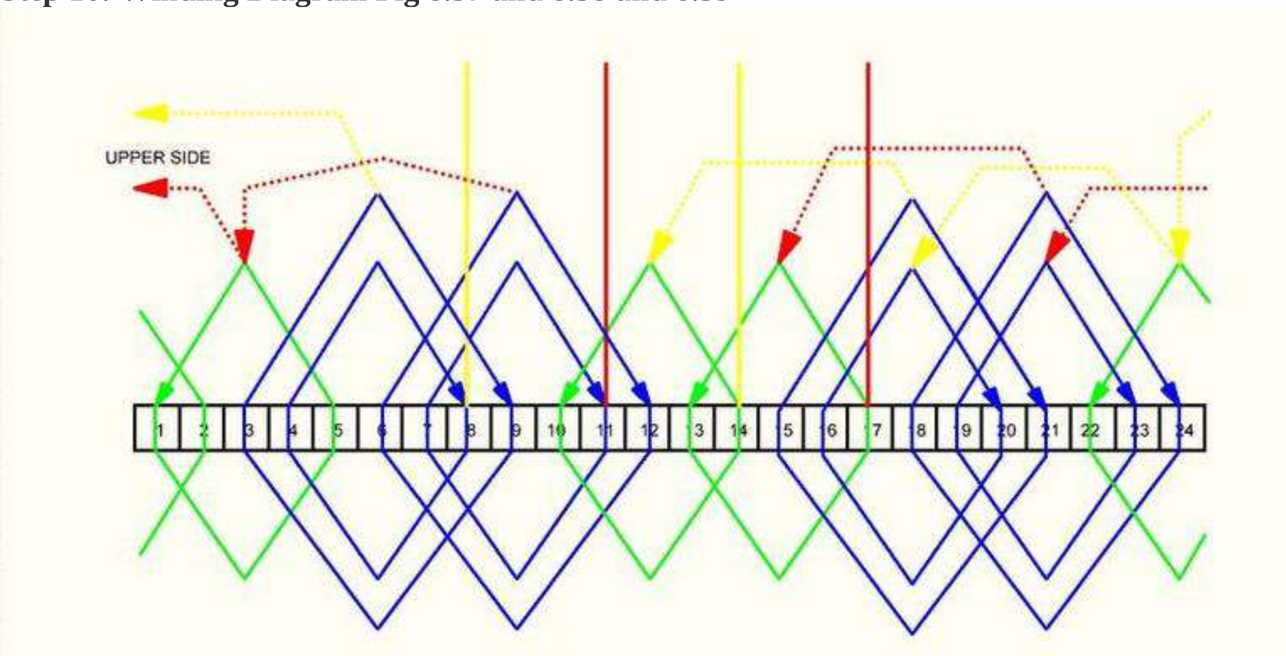
Mark output coil wires (wires that were connected on electrical clips).

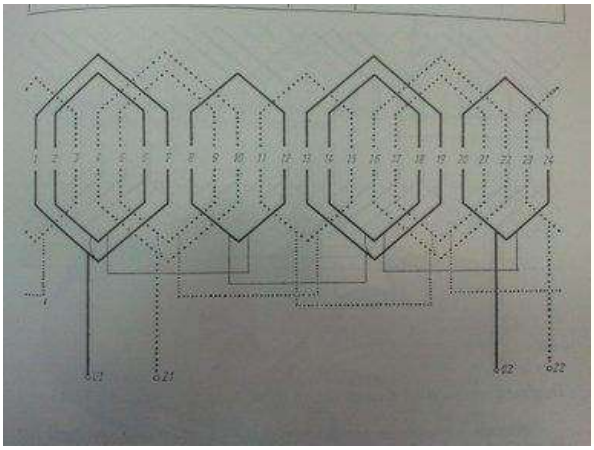
Step 15: Winding Diagram **Fig 8.34 and 8.35 and 8.36**

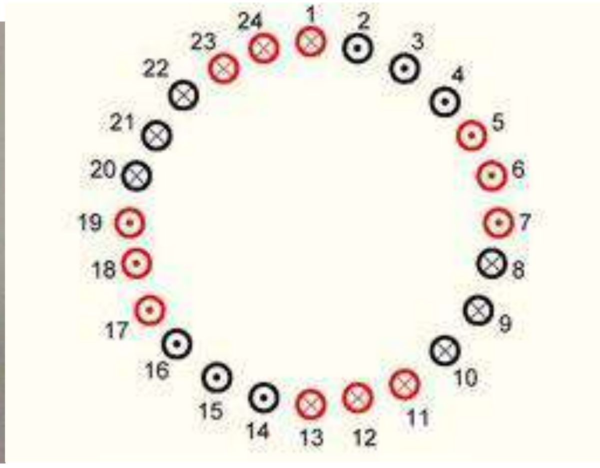


Heat up old winding, so you burn out old lacquer, but be careful, you must not damage copper wires.When you can clearly see hot coils are connected, chose one of the output wire and draw path of it with arrows.

Step 16: Winding Diagram Fig 8.37 and 8.38 and 8.39



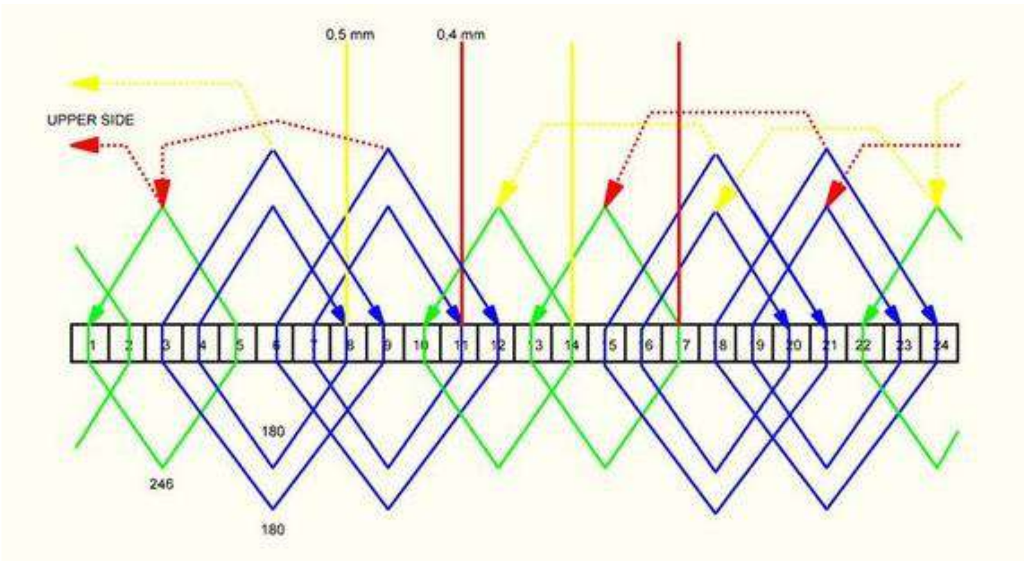




Make same thing for second pair of output wires.
If it is found same winding in the book (it is just rotated for 180°).

You can draw gaps in circle and mark **x** (wire in) and Dot **.** (wire out). Now you are able to draw path of magnetic field (picture 8.39).

Step 17: Winding Diagram Fig 8.40 and 8.41



Cut wires of different coils and count them and measure their diameter. Write number of wires in each coil in winding diagram.
Now the winding diagram is complete

Step 18: Winding Diagram (Skip This If it is One Wire Coil)

Be careful. If your coil is made out of 2 parallel wires, you can replace them with one wire. Measure diameter of 1 wire. Calculate plate of 1 wire and multiply with 2. Now calculate 1 wire from your plate. (New wire must have same plate as old 2 wires together).

Fig 8.42

Step 19: Cut of Winding **Fig 8.43 and 8.44 and 8.45**

Use hammer and Chisels to cut off old winding. Try not to damage stator lamellas. You can continue when you cut the old winding on one site (Picture 8.45).

Step 20: Pull Out Winding Fig 8.46 and 8.47 and 8.48 and 8.49

Heat up other side of old winding and pull it out using crowbar. Do these for all coils.

Step 21: Clean Gaps Fig 8.50 and 8.51

Until stator is hot, clean gaps with screwdriver or iron stick, but don't damage stators lamellas.

Step 22: Remove Pulley Fig 8.52 and 8.53 and 8.54 and 8.55



If you have one, remove screw or safety metal stick, and then pull pulley with puller from axis. If you need, heat pulley (not axis!!!!) with butan torch.

Step 23: Remove Front Cover Fig 8.56 and 8.57 and 8.58



Put cover on wood, so rotor doesn't touching the bottom. Put piece of wood on axis of rotor and hit it with hammer until rotor separates from cover.

Step 24: Removal of Bearings Fig 8.59 and 8.60 and 8.61

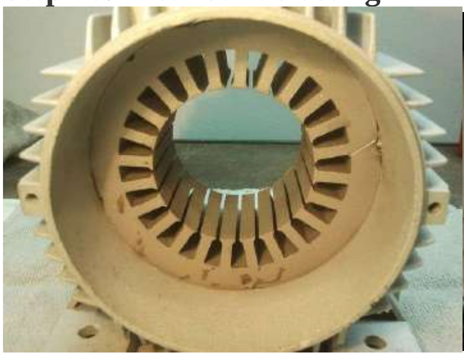


Use puller to remove bearings on both sides. You must not damage the axis of rotor.

Step 25: Clean Housing of Motor Fig 8.62and 8.63 and 8.64

Motor was covered with concrete so we decided to sandblast it.

Step 26: After Sandblasting Fig 8.65 and 8.66



Don't sandblast or scratch stator lamellas too much, they are made of iron which can rust.

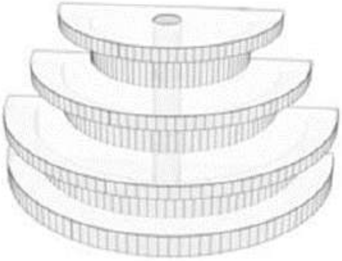
Step 27: Twisting Edges of Insulating Paper Fig 8.67 and 8.68 and 8.69

Put isolate paper on table, and place ruler on it, so you get about 4mm gap in which you will insert isolate paper and then twist it.

Step 28: Insert Isolate Paper in Stator Fig 8.70 and 8.71 and 8.72

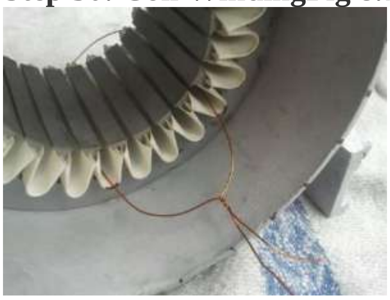
Measurelength of gap, and add about 16mm (depends of how you will twist paper). Cut it and twist it as in the pictures. Use screwdriver to bend it and insert it in gap. It should fit perfectly so you can’t pull it out. Picture 8.71, front side of motor, and picture 8.72, back side of motor.

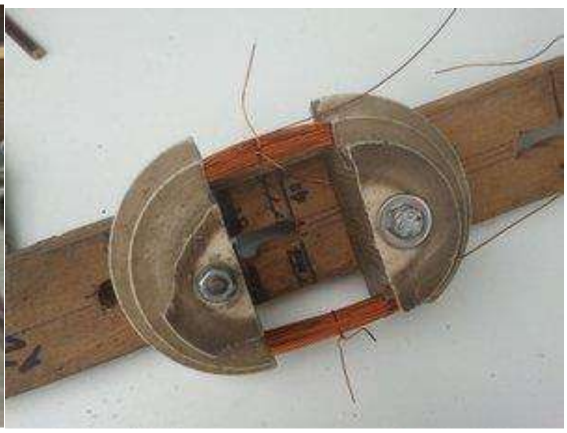
Step 29: Insert Isolate Paper in StatorFig 8.73 and 8.74



Do same thing for all gaps

Step 30: Coil WindingFig 8.75 and 8.76 and 8.77 and 8.78 and 8.79

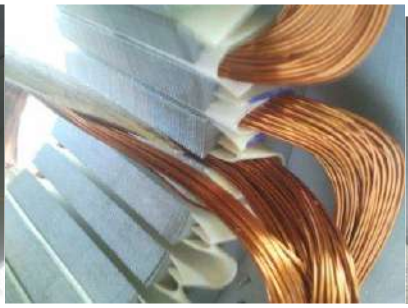
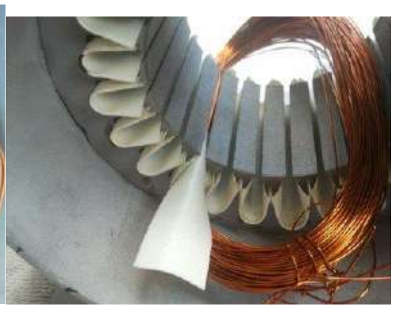




Make model of coil with one wire leaving a little bit more space. Put it on "Winder" to get distance. Put model off, and set winder to right distance, then start winding coil (you written numbers of wires in coils before). You can use same distance for winder for same coils.

You can make winder at home. I redraw my in fusion 360 so you are able to print it and make one for yourself.

Step 31: Place Coils in Stator Fig 8.80 and 8.81 and 8.82

Careful place coils in stator. This can take a long time to do. Be gently so you don't damage wires lacquer. Rotate coils so their end wires will come out on the side, where is the hole from stator to electrical clips.

Step 32: Wire Coils with Winding DiagramFig 8.83 and 8.84

Connect coils according to the winding diagram. Remove isolation, then solder copper wires and isolate them with heat shrinks. Connect normal wires with end coil wires, and isolate them with heat shrink (picture 8.82). Wire them to electrical clips.

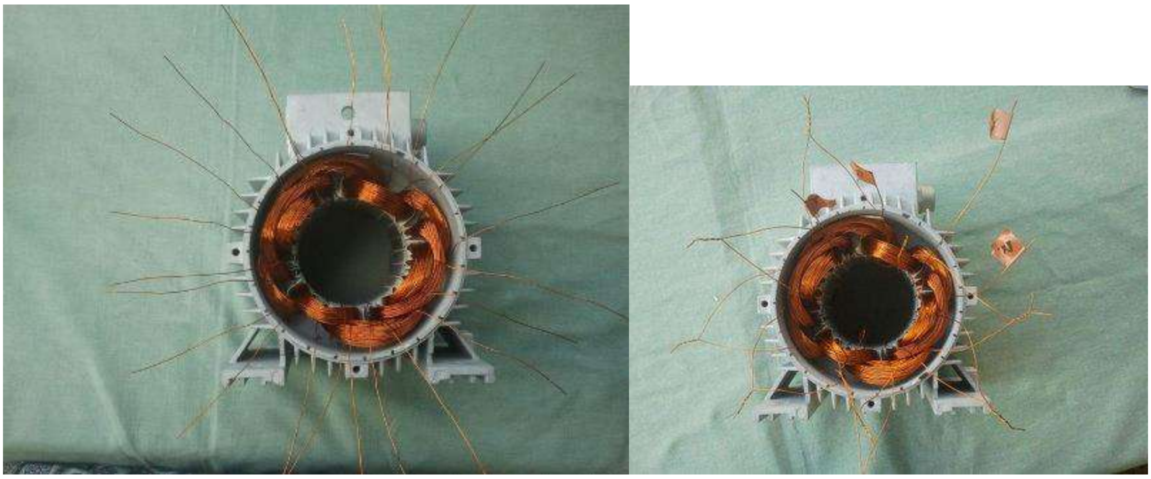
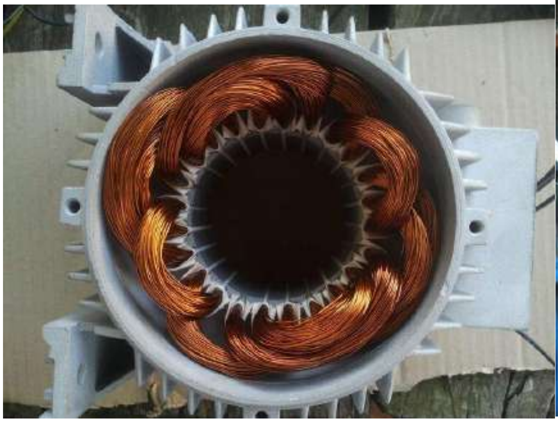


Fig 8.83 and 8.84

Step 33: Bind the Coils Fig8.85 and 8.86 and 8.87

Bind the coils with the stator lacing thread. Sew stator lancing thread around coils, as you can see on pictures

Step 34: Bind the Coils Fig 8.88 and 8.89




Do the same thing on other side of motor.

Step 35: Varnishing the Motor Fig 8.90 and 8.91


1. Heat up cooking oven to 100 °C. Put motor in it.
2. When motor heats up, spills lacquer on motors coils as you see on pictures
3. Turn motor around and do the same
4. You can reuse old lacquer.
5. Put motor in hot oven, and cook it for about 4 hours
6. Take motor out and clean edge (so cover will fit perfectly).

Step 36: Bearings

You can find appropriate bearing, by measuring old bearings diameters.

Step 37: AssemblingBearings Fig 8.92 and 8.93 and 8.94

Grease the axle of rotor with lubricant and mount bearings on axle.

Step 38: Fig 8.95 and 8.96

Grease the bearing bed with lubricant, on both covers. Place first cover on rotor (don't forget for spring washer). Then place stator over rotor on first cover, and screw it (don't forget to glue screws). After that place second cover on top of the stator and screw it (glue screws).**Step 39: Motor Fan**

Put clamp on rotors axle. Mount motors fan on rotor (you can heat it with an industrial fan, but dont overheat it because it becomes really soft and can change shape). If you have cracked fan, you can buy new one, they are cheap. I just wanted to show you that you can repair it.

Step 40: Fans Protective Cover Fig 8.97 and 8.98

I sandblasted it and repaired cracks, with soldering iron and iron mesh, witch i heated in plastic. I painted it in black and install it on motor (no screws needed).

Step 41: Capacitor Fig 8.99 and 8.100


Mount capacitor on motor with zip ties (drill holes in housing as i have done on pictures). If you don't have capacitor there is right value on motors inscription label on housing (for my motor is 20 microF). Lead wires to connection box of motor.

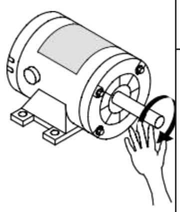
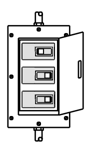
Step 42: Electrical Clips Fig 8.101 and 8.102

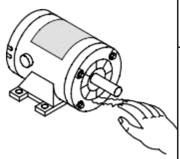

Lead power cable into connection box and tighten it, so you can't pull it out. wire clips as in picture 8.102

Step 43: Mounting Pulley Fig 8.103 and 8.104


Grease the rotors axle with lubricant, and mount on pulley.

Step 44: TestFig 8.105 and 8.106

Problem	Possible Cause	Suggested Test Tool	Corrective Action
Motor will not start 	Thermal cutout switch is open		Reset the thermal switch. Caution: Resetting the thermal switch may automatically start the motor.
	Blown fuse or open CB	Basic electrical tester, DMM , clamp meter, or Mega ohmmeter	TesttheOCPD.Ifvoltageispresentattheinput,butnottheo utputoftheOCPD,thefuseis blown or the CB is open. Check the rating of the OCPD. It should be at least 125 % of the motor'sFLC.
	Motor overload on starter tripped		Allowoverloadstocool.Resetoverloads.Ifresetov erloadsdonotstartthemotor, test thestarter.
	Low or no voltage applied to motor	Basic electrical tester, DMM or clamp meter	Checkthevoltageatthemotorterminals.Thevoltagemustbepr esentandwithin10%ofthe motor nameplate voltage. If voltage is present at the motor but the motor is not operating, removethemotorfromtheloadthemotorisdriving.Reapplypo wertothemotor.Ifthemotor runs, the problem is with the load. If the motor does not run, the problem is with the motor. Replace or service themotor.
	Open control circuit between incoming power and motor	Basic electrical tester, DMM or clamp meter	Check for cleanliness, tightness, and breaks. Test the circuit starting with the incoming power and moving to the motor terminals. Voltage generally stops at the problem area.
	Starting winding not receiving power	Basic electrical tester, DMM or clamp meter	Check the centrifugal switch to make sure it connects the starting winding when the motor is OFF.
Fuse, CB, or overloads retrip after service 	Blown fuse or open CB	Basic electrical tester, DMM , clamp meter, or Megohmmet er	TesttheOCPD.Ifvoltageispresentattheinput,butnottheo utputoftheOCPD,thefuseis blown or the CB is open. Check the rating of the OCPD. It should be at least 125 % of the motor'sFLC.
	Motor overload on		Allowoverloadstocool.Resetoverloads.Ifresetov erloadsdonotstartthemotor, test thestarter.

	starter tripped		
	Low or no voltage applied to motor	Basic electrical tester, DMM or clamp meter	Checkthevoltageatthemotorterminals.Thevoltagemustbepresentandwithin10%ofthe motor nameplate voltage. If voltage is present at the motor but the motor is not operating, removethemotorfromtheloadthemotorisdriving.Reapplypowertothemotor.Ifthemotor runs, the problem is with the load. If the motor does not run, the problem is with the motor. Replace or service themotor.
	Open control circuit between incoming power and motor	Basic electrical tester, DMM or clamp meter	Check for cleanliness, tightness, and breaks. Test the circuit starting with the incoming power and moving to the motor terminals. Voltage generally stops at the problem area.
	Motor shaft does not turn		Disconnectthemotorfromtheload.Ifthemotorshaftstill doesnotturn,thebearingsare frozen. Replace or service themotor.
Motor produces electric shock	Broken or discon nected ground strap		Connect or replace ground strap. Test for proper ground.
	Hot power lead at motor connecting terminals is touching motor frame		Disconnectthemotor.Openthemotorterminalboxandcheckforpoorconnections,damaged insulation,orleadstouchingtheframe.Serviceandtestmotorforground.
	Motor winding shorted to frame		Remove, service, and test motor.

Plug in the motor and measure its current. If it runs smooth than you finished.

Step 45: Conclusion

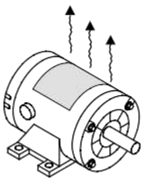
Rewinding the electric motor takes a lot of time, as specially if you are doing it for first time. But when you see finished product, wasted time pays off.

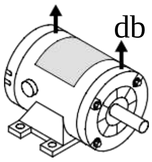
8.3Comparison between Starting and Running WindingsTable 8.4

S.NO	**Starting winding**	**Running windings**
1	In starting windingsmaller wire is used as conductor. Conductor size will be less	Inrunning windingconductor size will be more than the Starting Winding
2	Starting winding Gauge is Higher	Running windingconductor size is Lesser than the Starting Winding
3	the Starting winding is more resistive than running winding	Running windingResistance is Lesser than the Starting Winding
4	Start winding have less number of turns	Running winding have higher numbers of turns
5	Start winding have less inductance	Running winding have more inductance
6	In starting windingcurrent is in phase with applied voltage	In running winding current lags behind applied voltage
7	Capacitor is present in series with starting winding to provide 90 degree phase displacement.	Running winding is connected in parallel with the Supply along with the starting winding
8	It is also named as auxiliary winding	It is also named as mainwindings

8.4 Common faults and remedies in 1-phasemotors

Table 8.5

Problem	Possible Cause	Suggested Test Tool	Corrective Action
Motor overheats 	Starting windings are not being removed from circuit as motor accelerates		When the motor is turned OFF, a distinct click should be heard as the centrifugal switch closes as the motor slows down.
	Improper ventilation	Infrared thermometer	Clean all ventilation openings. Vacuum or blow dirt out of motor with low-pressure, dry, compressed air.
	Motor is overloaded	Basic electrical tester, clamp meter or DMM with clamp accessory	Check the load for binding. Check shaft straightness. Measure motor current under operating conditions. If the current is above the listed current rating, remove the motor. Remeasure the current under no-load conditions. If the current is excessive under load but not when unloaded, check the load. If the motor draws excessive current when disconnected, replace or service the motor.
	Dry or worn bearings		Dry or worn bearings cause noise. The bearings may be dry due to dirty oil, oil not reaching the shaft, or motor

			overheating. Oil the bearings as recommended. If noise remains, replace the bearings or the motor.
	Dirty bearings		Clean or replace bearings.
Excessive Noise db 	Excessive end play		Checkendplaybytryingtomovethemotorshaftinandout.A ddend-playwashersasrequired.
	Unbalanced motor or load		An unbalanced motor or load causes vibration, which causes noise. Realign the motor and load. Check for excessive end play or loose parts. If the shaft is bent, replace the rotor or motor.
	Dry or worn bearings		Dry or worn bearings cause noise. The bearings may be dry due to dirty oil, oil not reaching the shaft, or motor overheating. Oil the bearings as recommended. If noise remains, replace the bearings or the motor.
	Excessive grease		Ball bearings that have excessive grease may cause the bearings to overheat. Overheated bearings cause noise. Remove any excess grease.

8.5 Common faults and remedies in 3-phasemotors

Three phase induction motors are one of the most popular electric motors commonly found in processing plants or any manufacturing concern. They are used in situations where large power is required. The squirrel cage brand is the most popular and they perform various tasks wherever they are applied.

Because of the critical roles these motors play in any plant, a failure of the motor, inability to start, noisy operation and sundry other problems need to be remedied as soon as possible to avoid costly production downtime. The table below gives the commonly encountered problems in 3 phase squirrel cage induction motors, cause of problems and what remedy to apply to bring the motor back to production. This troubleshooting guide can also be applied to other types of three phase induction motors:

Table 8.6

Motor Problem	Cause	Remedy
Motor fails to start	Blown fuses	Replace fuse with proper type and rating
	Overload Trips	Check and reset overload in starter
	Improper power supply	Check to see that power supplied agrees with nameplate specifications and load factor
	Improper line connections	Check connections with wiring diagram supplied with motor
	Open circuit in winding or control switch	This is normally indicated by a humming sound when switch is closed. Check for loose wiring connections. Confirm that all

		control contacts are closing.
	Mechanical failure	Check to see that motor and drive turns freely. Check bearings and lubrication
	Short circuited stator	Indicated by blown fuses. Motor must be rewound
	Poor stator coil connections	Remove end belts. Locate poor connections with test lamp.
	Rotor defective	Check for broken bars or end rings
	Motor may be overloaded	Reduce motor load
Motor stalls	One phase may be open	Check supply lines for open phase
	Wrong application	Change type or size. Consult motor manufacturer
	Overload	Reduce load
	Low voltage	Check that nameplate voltage is maintained. Check connection.
	Open circuit	Fuses blown. Check overload relay, stator and push buttons
Motor runs and then dies down	Power failure	Check for loose connections to line, to fuses and to control
Motor does not come up to speed	Motor is applied for the wrong application	Consult manufacturer for right application of motor
	Voltage too low at motor terminals because of line drop	Use higher voltage on transformer terminals or reduce load. Check connections. Check conductors for proper size.
	Starting load too high	Check load motor is supposed to carry at start.
	Broken rotor bars or loose rotor	Look for cracks near the rings. A new rotor may be required as repairs are usually temporary not permanent
	Open primary circuit	Locate fault with testing device and repair.
Motor takes too long to accelerate and/or draws high current (Amps)	Excessive load	Reduce load
	Low voltage during start up	Check for high resistance. Adequate wire size.
	Defective squirrel cage rotor	Replace with new rotor
	Applied voltage too low	Improve voltage at terminals of transformer by tap changing.
Wrong rotation	Wrong sequence of phases	Reverse connections at motor or at switchboard.
Motor overheats while running under load	Overload	Reduce load
	Frame or bracket vents may be clogged with dirt and prevent proper ventilation of motor.	Open vent holes and check for a continuous stream of air from the motor.
	Motor may have one phase open	Check to make sure that all leads are well

		connected.
	Grounded coil	Locate and repair
	Unbalanced terminal voltage	Check for faulty leads, connections and transformers.
Motor vibrates	Motor misaligned	Realign
	Weak support	Strengthen base
	Coupling out of balance	Balance coupling
	Driven equipment unbalanced	Re-balance driven equipment
	Defective bearings	Replace bearing
	Bearings not in line	Line bearings up properly
	Balancing weights shifted	Re-balance motor
	Poly-phase motor running single phase	Check for open circuit
	Excessive end play	Adjust bearing
Unbalanced line current on poly-phase motors during normal operation	Unequal terminal volts	Check leads and connections
	Single phase operation	Check for open contacts
	Unbalanced voltage	Correct unbalanced power supply
Noisy Operation	Airgap not uniform	Check and correct bracket fits or bearing.
	Rotor unbalance	Rebalance
Hot bearings general	Bent or sprung shaft	Straighten or replace shaft
	Excessive belt pull	Decrease belt tension
	Pulley too far away	Move pulley closer to motor bearing
	Pulley diameter too small	Use larger pulleys
	Misalignment	Correct by realignment of drive
Hot bearings ball	Insufficient grease	Maintain proper quantity of grease in bearing
	Deterioration of grease or lubricant contaminated	Remove old grease, wash bearings thoroughly in kerosene and replace with new grease.
	Excessive lubricant	Reduce quantity of grease, bearing should not be more than 1/2 filled
	Overloaded bearing	Check alignment, side and end thrust.
	Broken ball or rough races	Replace bearing, first clean housing thoroughly

Short Answer Questions

1. Compare closed and open winding
2. State the Difference between Concentrated and Distributed Winding
3. How to identify the Single Phase Motor?
4. What are the Tools required in Rewinding?
5. What is Balanced and Un Balanced Winding

Essay Questions

1. Classify the AC armature winding
2. Explain the methods in the Trouble shooting of A. C. Windings
3. Compare Starting Winding with and Running winding
4. Explain about the Common faults and remedies in the 1-Ømotors
5. Explain about the Common faults and remedies in the 3-Ømotors

ELECTRICAL TECHNICIAN

SECOND YEAR

PART – B

Theory Paper – III

ELECTRICAL ESTIMATION & UTILIZATION

UNIT 1

DOMESTIC WIRING

1.1 Introduction

A network of wires connecting various accessories for distribution of electrical energy from the supplier meter board to the electrical energy consuming devices such as lamps, fans and other domestic appliances through controlling and safety devices is known as electrical wiring.

The supplier service cable feeding an installation terminates at meter board. The point at which the consumer's wiring is connected to the energy meter is known as point of commencement of supply or consumer's terminals. From consumer terminals onwards the supply cables are under the control of consumers and so laid out as per his selection.

1.2. Types of House wiring and their comparison in tabular form

1. Wooden casing capping
2. Cleat wiring
3. CTS(Cab Tyre Sheathed Batten Wiring)or TRS(Tough Rubber Sheathed) wiring
4. Lead (or metal) Sheathed wiring
5. Conduit wiring.

(A)Surface or Open type

(B)Recessed or Concealed type

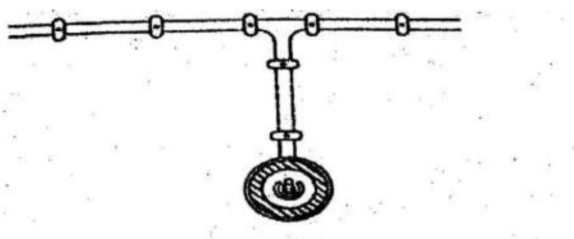
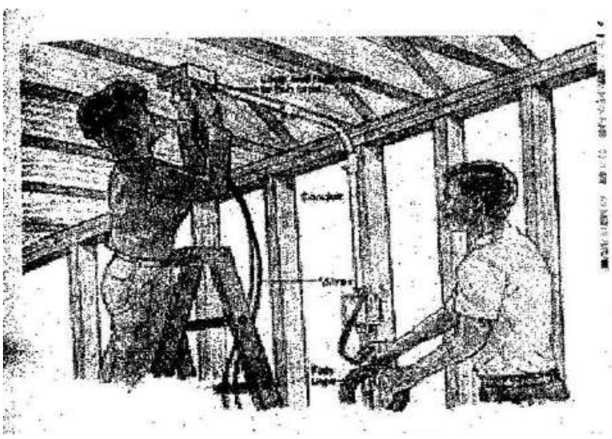


Fig.1.1 Cleat. Wiring



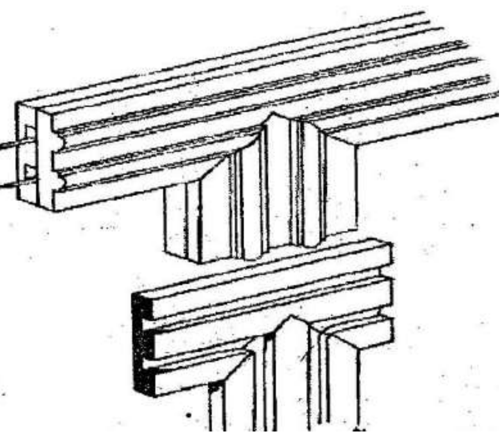


Fig.1.2 Conduit WiringFig.1.3Wooden Casing&Capping Wiring

Comparison of different wirings

S. No.	Base of comparision	Cleat wiring	Wood casing Capping wiring	CTS / TRS wiring	Lead sheathed wiring	Conduit wiring Metal	PVC
1	Material required	Cleats, VIR/ PVC Cables screws, boards, blocks, gutties etc.	Seasoned wood casting and capping VTR/ PVC cable, screws, boards blocks gutties etc.	wood battern CTS/TRS cables, screws nails, link clips boards block E gullies etc.	Seasoned wood batten, lead sheath cable, pales, screws, nails link clips boards, blocks etc.	Metal conduit VlR/PVC cables saddles, bends, elbows, junction boxes gullies etc.	PVC Conduits VIR/PVC cable, saddles, screws bends, elbowsjunction - boxes gullies etc..
2	Cost	Low	Costly	Medium	Costly	Very costly	Medium
3	life	short	Long	Long	Long	Very Long	Very Long
4	Mechanical Protection	Nil	Good	Fairly good	Good	Very good	Very good
5	Protection against fire	Nil	Nil	Poor	Good	Very good	Poor
6	Protection from dampness	Nil	Poor	Good	Good	Fairly good	Good
7	Appearance	not good	Fairly good	Good	Fairly good	Good	Good
8	Type of labour required	Semi-skilled	Highly skilled	Skilled	Skilled	Highly skilled	Skilled
8	Addition of points	very easy	Difficult '	easy	Difficult	Most difficult	Most difficult
9	No. of pointsthat can be done/day by electrician with a mate	6 to 8	3 to 4	4to5	3to4	2to3	4to5
10	Repair/fault	Very easy	Difficult	Easy	Difficult	Difficult	Difficult
11	Finding Applications	Temporary installation se.gmarriages	Residential buildings offices but replaced	Residential offices& commercial	Suitable for places exposed	Industries, workshops, public buildings	Residential commercial

	functions etc.	by CTS &PVC ' conduit wiring,	to sun & rain & damp places	&office buildings

1.3. Types of Materials and Accessories used in House wiring with a detailed estimate.

S. No.	Specification of material	Rate*	Remarks
	A. Electrical Material		
1	Double-pole iron clad switch fuse 15 A, 250-V	200/-	
2	Double-pole flush type switch fuse, with neon indicator 15 A, 250-V.	100/-	
3	I.C. cut outs 15 A, 250-V	25/-	
4	Porcelain cut out 15A, 250 V	10/-	
5	Teak-wood batten ; 12 x 6mm 25 x 6mm 37 * 6mm 50 x 6 mm	5/m 6/m 8/m 10/m	Not available in the market
6	Seasoned country wooden batten : 12 x 6 mm 25 x 6 mm 37 x 6 mm 50 x 6 mm	 2/m 4/m 5/m 6/m	
7	PVC conduit 1 mm thick : 12 mm dia length 25mm dia length	 30/ 32/	 1 length =10 feet = 3m -do-
8	Casing capping-teak wood	2 5/m	
9	Casing capping country wood	16/m	
	B. PVC Cables :		
10	Single core 1.5 sq. mm or 1/1.4 mm (1/18) 250V/440V aluminum conductor PVC cable	190 / 100m	

11	Single core 2.5 sq.mm or 1/1.8 mm (1/14) aluminum conductor PVC Cable	210 / 100 m
12	1.5 sq. mm or 1/1.4 mm (1/18) 250V/440V single core copper conductor PVC cable	250 / 100m
13	2.5 sq. mm or 1/1.8 mm (1/14) 250V/ 440 V single core copper conductor PVC cable	350 / 100m
14	1.5 sq. mm 250V/440V. multistrand flexible PVC cable	280 / 100m
15.	2.5 sq. mm 250V/440V multistrand flexible PVC cable 100m	400 /
16.	3-core 4.7 sq. mm or 3/1.4 mm (3/18) 250V/440V copper, PVC cable	350 / 100m
17.	3-strand 3.8 sq. mm or 3/1.27 mm (3/20] 250V/440 V copper, PVC cable	330 / 100m
18.	3-strand 3.14 sq. mm or 3/2.2 mm (3/22) 250V/440 V, copper, PVC cable	310/ 100m
19.	7-strand, 13.85 sq mm or 7/1.59 (7/16) 250V/440 V, copper conductor PVC cable	700 / 100m
20.	7-strand, 10.8 sq. mm or 7/1,4 mm (7/18) 250V/440V, copper conductor PVC cable.	675 / 100m
21.	7-strand, 8.9 sq. mm or 7/1.27 mm (7/20 250V/440V, copper conductor PVC cable.	(650 / 100m
22.	7-strand, 13.85 sq. mm or 7/1.59 mm. (7/16) 250V/440V, aluminum conductor weather proof cable.	700 /100 m
23.	7-strand 8.9 sq. mm or 7/1.27 nun (7/20) 250V/440V, aluminum conductor weather proof cable	650 /100m
	C. PVC Conduit Accessories	
24.	Conduit bends (solid) 12 mm dia 25 mm dia	 2/each 3/each
25.	Conduit bends (inspection) 12mm dia 25 mm dia	 2/each 4/each
26.	Elbows 12mm dia 25 mm dia	2/each 3/each
27.	Saddles 12mm dia 25mm dia	6/doz 9/doz

28.	Junction boxes 12 mm • 4-way 3-way 2-way	 3/each 2/each 2/each	
	D. Electrical Accessories:		
29.	i) Switches 5A, one way surface type ii) Switches 5 A, one way flush type iii) Switches 5 A, two way surface iv) Switches 5A, two-way flush type	10/eaeh 10/each 10/each 10/each	
30.	i) Switches 15A surface type ii) Switches 15 A flush type	18/each 20/each	
31.	i) Sockets 2-pin, 5A surface type ii) Sockets 2-pin, 5 A flush type iii) Sockets 3-pin, 5A surface type iv) Sockets 3-pin, 5A flush type v) Sockets 3-pin 15A surface vi) Sockets 3-pin 15 A flush type	10/each 10/each 15/each 15/each 25/each 25/each	
32.	Ceiling roses : 5 A 2 plate Ceiling roses : 5 A3 plate	. 10/each 12/each	
33.	Lamp holders i) Barten type (Brass) ii) Batten type (Bakelite) iii) Pendent (Brass) iv) Pendent (Bakelite)	 15/each 10/each 10/each 10/each	
	E. Hard-ware Material :		
34.	Nails .. 12 mm (1/2)" 25 mm (1") 60 mm (5^{11})	40/Kg 50/Kg 50/Kg	
35.	Screws 12mm (4 SWG) 25 mm (8 SWG) 60 mm (8 SWG)	30 35 75	per 100 -do- -do-
36.	Link-Clips..:. 25 mm 51 mm	10 12	 -do-
	F. Wooden Material :		
37.	Boards ... 10 * 10cm 18 x 10cm 30 x 20cm 45 x 30cm 60 x 45 cm	8 9 15 40 60	each - do - - do - - do - - do -

38.	Blocks ... 10 x 10cm 18 k 10 cm 30 * 20cm	5 10 12	- do - - do - - do -
39.	Round blocks .	3	
40.	Plugs/gutties 9 cip^2 x 4$_{cm}$^{2} x 50 mm	10/doz	- do -
	G. Earthing Material :		
41.	Copper plate60cm x 60cm x	1950 3.18mm	
42.	G.I. plate60cm x 60cm x	500 6.35mm	
43.	Copper wire(14, 12, .10, 8 gauge)	160/Kg	
44.	G.I. wire(14, 12, .10, 8 gauge)	50/Kg	
45.	G.I. Pipe 12mm/dia 25min dia	40/m 50/m	
46.	G.I. nuts &bolts (10 mm dia) withwashers	3/each	
47.	Cast iron cover 30 x 30cm	120	
48.	Funnel with mesh cover	20	
49.	Coal	6/Kg	
50.	Salt	5/Kg	
51.	Caution/Danger plate	50	
52.	Shock treatment chart	75	

1.4. 1-phase and 3-phase Service – Selection of Mains

The service mains or main switch and distribution boards should be provided at such a place which is readily accessible to the consumer.

The service mains installed in the consumers premises maybe broadly- classified into two groups they are:

1. Double - Pole Main Switch (D.P.Mains)
2. Triple -Pole Main Switch (T.P.Mains)

The type of mains used by a consumers will depends upon the nature of the supply i.e. D.P mains will be used for single - phase supply and T.P mains will be used for three -phase supply.

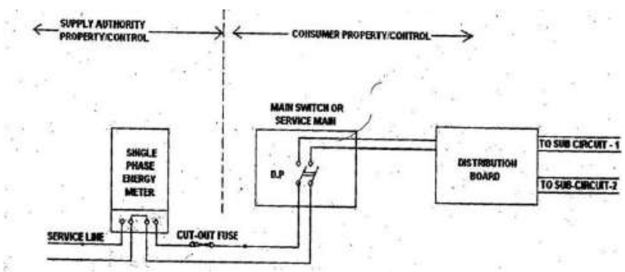


Fig.1.4 Electrical power supply to consumer

Selection of Service - Mains.

Most of the domestic and commercial consumers uses D.P. mains because they offer single-phase supply except, certain multi storied building, apartments, shopping complex etc. They use T.P mains because they offer three phase supply. whereas industrial consumers uses T.P mains and its rating/ size depends upon the load of the industry.

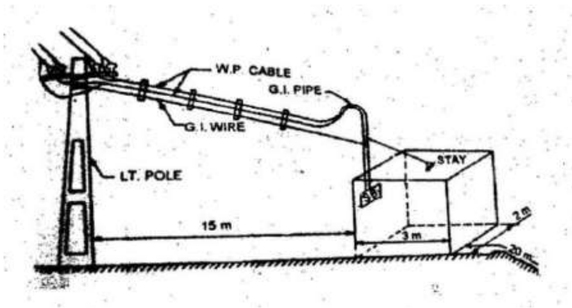


Fig.1.5 Three phase service mains

1.5. Designing number of Sub-circuits and Distribution Boards

For determination of number of sub circuits in an electrical installation ,the following ratings of the different loads may be assumed unless the ratings are given. or specified.

1.Fluorescent lamp :40 Watt

2.Incandescent lamp :60 Watt

3. Fan point :80 Watt

4.Socket outlet :100 Watt

5.Power socket :1000 Watt

Number of sub-circuits : The number of sub-circuits in house wiring may be decided depending upon the number of lights, fan points and the total connected load i.e. The number of points in sub-circuits ,may be 10 and the total connected load per sub-circuits i.e 800 Watt.(apprx)

In a power sub-circuits the number of socket outlets (3pin) may be two and the maximum load that can be connected is 3000 Watt.

Distribution Board : The size of distribution board depends on the number of sub circuits i.e. 2-way, 4-way, 5-way, 6-way etc. It is provided immediately after the main switch, a phase wire along with a neutral wire will be radiated from it to each sub-circuit to feed electricity to the load connected to that particular sub-circuit. The distribution board is a junction point of the feeding cables of all the sub-circuits of a wiring installations. Each sub circuit is connected through kit kat fuse or MCB. The rating of the fuse / MCB used for light load sub circuit is 5 A and power load sub circuit is 16A.

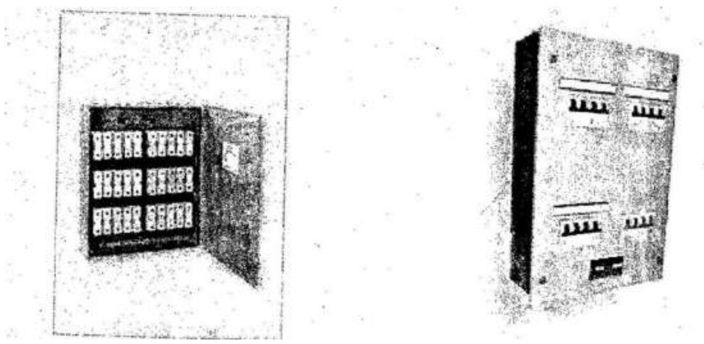


Fig 1.6 Distribution Board

Size of Conductors: The minimum size of conductors (Cable) used in house-wiring must not be less than one mm^2 14/0.3 mm copper or 1/1.4mm, 1.5 sq.mm aluminium.

1.6. Load points in a domestic installation and IE Wiring rulesPreparation of wiring Installation Plan / Wiring Layout

A residential building/domestic installation generally comprises of living rooms, Dining room, store room, kitchen, bathroom etc. The following table providesconcept for selection of number of load points/loads, illumination levels etc.

Table. Loads in Domestic Installtion

S.No	Location	Illumination	Normal	Lamp & Area waltage		Fan	Socket	Others
1.	Entrance, half ways varandahs.	100 lux	$6m^2$	20w, FL (or) 60 w, IL	1	5A-(1) 15-(1)	Bell Switch	
2.	Living room/ Drawing room 100w,IL	300 lux	$15m^2$	40w, FL (2) (or) Lamp - 2	2	15A-(2) 15A-(2)	Night Lamp - 1 Decoration	(2)
3.	Dining room / hall IL(1)	150 lux 100w,	$10m^2$ (or)	40w, FL(1)	1	5A-(2) 15A-(1)	–	
4.	Kitchen	200lux	$9m^2$	- do - fan	Exhause 15A-(1)	5A-(1)		
5.	Store room	70lux	$9m^2$	60w, IL	-	5A-(1)		
6.	Bathroom/ wc	100lux	$4m^2$	40w, IL	Exhause fan	5A-(1) 15A-(1)		
7.	Bed room	300 lux 100w,	$12m^2$	40FL or	1	5A-(2)	Bed light IL(1)	
8.	Study room	300lux	$10m^2$	40FL or	1	5A (2)	–	
9.	Stair case	70lux	$6m^2$	40w, IL	–	–	–	

FL - Flourescent Lamp IL - Incodescent Lamp

Wiring rules

1. The current rating of the cable used in wiring should be slightly greater than (1.5 time more) the load. The minimum size of cable for light load is 1sqmm' (copper conductor) and for power load 2.5 to 4 mm^2 (copper conductor).
2. Every live wire/line should be protected by a fuse of suitable rating and every sub circuit should be connected with the fuse of distribution board.
3. Every apparatus/load should be provided with separate switch.
4. In any building-light load wiring (i.e., lamp, fan, exhaust fan, 5A socket, T,V etc.,) and power load wiring (i.e., electric stove, mixer grinder, electric iron, motor, air conditioner etc) should be kept separately.
5. Every socket should be 3-pin type with suitable earthing.
6. ONE light load sub circuit may contain TEN load points or 800W total load.
7. ONE power load sub circuit may contain TWO load points or 3000W total load.
8. If the total load connected in wiring is more than 4500W, 3phas,400V supply is advised. If that is the case, the total load should be equally divided in each phase.
9. Mounting heights of various boards/loads

   Main board (MB)-1.75 - 2.75m

Distribution board (DB) -1.75 - 2.75m.

Preparation of wiring Installation Plan / Wiring Layout

Preparation of wiring layout or installation plan is an important task in electrical wiring. In this step, the engineer or technician decides the load points and their suitable places, where it is easily to accessible. For example, a ceiling fan should be fixed at a place where the maximum air circulated by it should be utilized by the consumer effectively. Its controlling switch and regulator should be fixed at a place where the consumer can access easily and safely.

The mounting places of the metre board, main board, distribution board and switch boards should be marked in the wiring installation planbased on the type of load points and the choice of the consumer, giving priority to the comfort and safety of the consumer. This task is carried based on general wiring rules and guidelines.

The number of sub-circuits for the lighting load and power load should be determined separately as per the I.E. rules (i.e the maximum load connected in a lighting sub-circuit should not exceed either 10 points or 800W). Whereas the load connected in a power sub-circuit (which is meant for the power load i.e. Geyser; fridge, mixer grinder, electric rice cooker, microwave oven, motor pump setetc.) should not exceed either two points or 3000 W.

1.7. Selection of Main Switch

The rating and type of the main switch of a particular wiring installation should be determined as per the total maximum load, load current, type of power supply (i.e. 1phase or 3 phase) safety of the consumer and type of wiring installation.

Types of Main Switches
1.DP-main switch ... for single phase installation (230 V) (16 A, 32 A, 250 Volts)
2. TPICN(Triple Pole Iron Clad with neutral link)... for three phase installations (440 V) (32 A, 64 A, 500 Volts)

1.8. Calculation of length of cable and labour cost

Selection of cable: The size and type of the cable should be determined as per the maximum load current of the sub-circuit.

Selection of Conduit: The size and type of the conduit should be determined as per the size and number of wires inserted into it.

Calculation of length of cable : The length of the cable inturn depends on the length of the conduit. In general practice, the length of cable required will be almost 3 times of the total length of the conduit.

Calculation of length of the conduit : The length of conduit is the sum of the length of Horizontal run ,Vertical ups, Down Drops And Passes through Walls

Horizontal run : The conduit laid horizontal on the walls and roofs.

Vertical up : The conduit is arranged vertically to reach alb load points above the horizontal run to reach the load points on the roof.

Calculation of labour cost

Electrical installation will be executed with the involvement of the labour. An electrician should accompany (a) Skilled (b) Semi Skilled and(c) Unskilled labour to complete an electrical wiring installation. In certain cases carpenter, mesons and plumbers are also work along with an electrician to complete his job effectively and efficiently within the given time.

The cost of the labour involved will be calculated by adopting any ofthe following methods

(a) Daily Wage

S.No	Type of Labour	Wage per/day	Total days worked	Amount
1. 2.	Electrician Helper	200 100	2 2	400 200
Grand Total				600

(b) Contract or Lumpsum

Work contract : In this, the material and the accessories are provided by consumer. Only installation work is carried by contract.

(c) Percentage of total cost of Material and Accessories

Some percentage of total cost of material and accessories is charged as labour cost based on the existing guidelines in PWD/R&B/Railways etc.

(d) The rates decided by Government departments / Schedule of labour rates prepared by Panchayath, Municipality, PWD, CPWD, Railways etc. will be considered as it is for fixing up of labour cost.

(e) No. of load points method

1.9. Preparation of detailed estimate in a standard proforma for Domestic wiring

Steps involved are

1. Load Calculation or preparation of load schedule
2. Determination of number of sub-circuits.
3. Determination of size of cable and conduit
4. Determination of size of main switch and distribution board.
5. Calculation of labour cost
6. Calculation of length of conduit and cable
7. Preparation of estimation in standard proforma

1.10. Estimation of wiring of small residential building, Office and Commercial establishments like Shops, sales counters, stores etc

Example 1:

A small residential building containing drawing room (3 m x 3m), hall (3m x 4m)has to be electrified with surface conduit wiring, Prepare

1.Load schedule

2.Electrical layout

Given Size of drawing room = 3 m x 3 m

Area = 9 m^2

Size of hall = 3 m x 4 m

Area = 12m^2

Surface conduit wiring is to be arranged.

Req :

1.Load schedule
2.Electrical layout

Solution

As per standard wiring rules for domestic wiring
A room of $10m^2$ may contain 1-Fan, 1 - Flourescent lamp, 1-Incandescent lamp, 1 - 5 A socket. Therefore The load can be assumed as below.

Load

Room	Fan	F/L		5 A Socket	Any other load
Drawing room ($9m^2$)	1	1	I	1	Bell -1
Hall ($12m^2$)	1	2	1	2	Refrigerator-1

(a) Load Schedule

S.No.	Load	Light Load			Power Load		
		Nos	Watts	Total	Nos	Watts	Total
1.	Fan	2	80	160	-	-	-
2.	F/L	3	40	120	-	-	-
3.	I/L	2	60	120	-	-	-
4.	Bell	1	15	15	-	-	-
5.	5 A Socket	3	100	300	-	-	-
6.	16 A Socket Refrigerator	-	-	-	1	200	200
Total		11	-	715	1	-	200

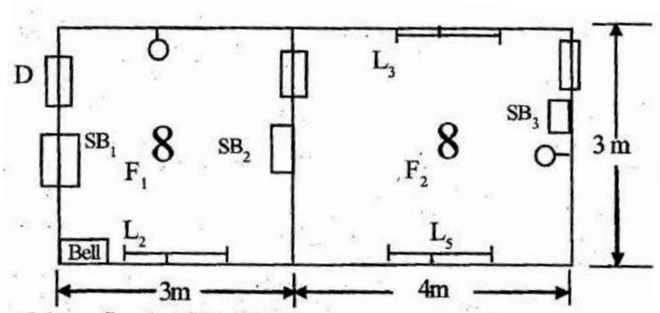
Total light load point = 11

Light load =715 Wats.

Total Power load points= 1

Power Loads =200 Watts.

(b)Electrical layout



5 A are fixed at SB_1, SB_2

16 A socket are fixed at SB_3

Example 2:

Estimate the quantity of materials required for a office of size 30mx14m x 8m.

CTS wiring system is to be provided with 14 tube lights and 6 fans ?

Ans: Given : Size of the office =30m x 14m x 8m

Type of wiring = CTS

Load details =As per load schedule.

Req :

Estimation of material & accessories for wiring.

Solution

a. Assumptions

Height of main board = 2.25m

Height of D/B = 2.25m

Height of wiring = 3.5m

Height of switch board = 1.5m

Height of lamp = 2.25m

Height of ceiling fan = 3m

Wattage of fluorescent lamp = 40W

Wattage of ceiling fan = 80 W

Wattage of 5A, socket = 100 W

(b) Load schedule, sub circuits, Distribution board. Load schedule

Load schedule

S.No.	Load	No.s '	Watts	Total watts
1	Fluorescent lamps	14	40	560
2	Ceiling fans	6	80	480
3	5A, sockets(assumed load)	4	100	400
Total		24		1440 W

sub circuits

Total load —1440W, (Light load only and no power load)

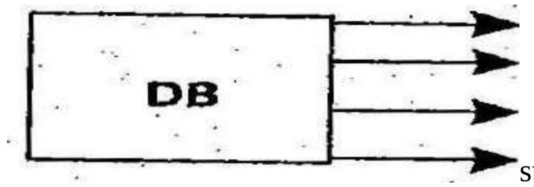
Load points = 24

As per IE rules 3- sub circuits to be arranged

[one light load sub circuit may contain 10-load points or 800W load].

Distribution Board

(3 + 1) or 4-way, 250V distribution board.

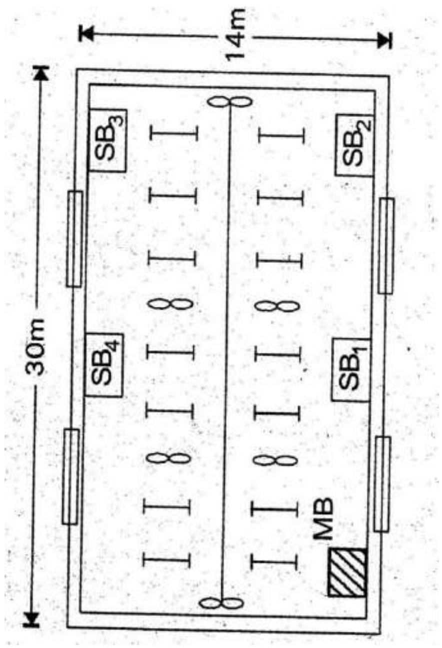


Main switch and cable

32A, 250V, **DPIC as** main switch,

3/20 CTS cable, copper conductor, 10A current capacity

(c) Layout of wiring and length of wiring



Horizontal length = 30 + 14 + 30 + 14 + 30 + 9 x 4 = 154m

Vertical length = 2 x 5 + 2 x4.5 = 19m

Total = 154 + 19 + 10% (154 +19)

= 173 + 17.9 = 200 m approx

Length of batten = 200m (length of wiring)

Length of cable = 3 x length of wiring =3 x 200 = 600m

= 600 + 20% of 600 (as wastage)

= 600 +120 = 720m.

d. Detailed Estimation

S.No	Specification	Quantity	Unit	Rate(Rs)	Amount(Rs)	Remark
1.	DPIC, 32A, 250V	1	each	150.00	150.00	
2.	4-way, 250v, distri-bution Board with fuse	1	each	100.00	1000.00	
3.	3/20 CTS cable .,	720m	meter	5.00	3600.00	
4.	T/W batten	200m	meter	5.00	1000.00	
5.	Link clips	10packets	each	10.00	100.00	
6.	5A, 250 v, 1-way switch	24	each	10.00	240.00	
7.	2/3 pin 5A, 250v sockets	4	each	10.00	40.00	
8.	Ceiling roses	20	each	10.00	200.00	
9.	T/W round blocks	34	each	5.00	170.00	
10.	Switch board (10 x 12)	3	each	30.00	90.00	For Fans &Lights
11.	Screws, nails,	15	Lump	Lump Sum	300.00	
	gutties, cement etc.		Sum(LS)			
12.	Earth set	1	each	600.00	600.00	
13.	Labour charges @ Rs 50/- Per point DB = 4 Pts MB= 4 Pts Load point=24/32P	32	each	50.00	1600.00	
			Total		9090.00	

Example 3

Estimate the quantity of material required for a shop of size 30 x 14mx 8m with 14 tube lights and 6 fans ?

Ans: Given

Size of the shop = 30m x 14m x 8m

Type of wiring = CTS (assumed)

Supply = 250V

Load details = as per load schedule

Req :

Estimation of material.

Sol :**(a)Assumption :**

Height of main board = 2.25m

Height of D/B = 2.25m

Height of wiring = 3.5m

Height of switch board = 1.5m
Height of lamp = 2.25m

Height of coiling fan = 3m

Wattage of fluorescent lamp= 40W

Wattage of ceiling fan = 80W

Wattage of 5A, socket = 100W

b.Load schedule and Sub circuits

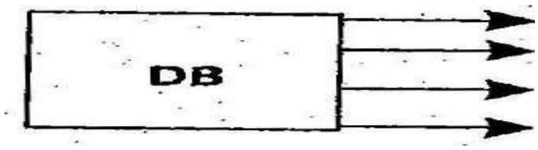
S.No	**Light load**				**Power load**
	Load	**Watts**	**No'**	**Total watts**	
1	Fluorescentlamps	40W	14	560W	
2	Ceiling fans	80W	6	480W	NIL
3	5A sockets (assumed)load	100W	4	400W	
			24	1440 W	

Here total load is 1440w and no of load points is 24 (light load only)

As per IE rules, Three subcircuits are to be arranged

[10 points - 1-subcircuit]

Layout of distribution board will be as below



spare

250V, 16A, (3 + 1) way D/B with fuse

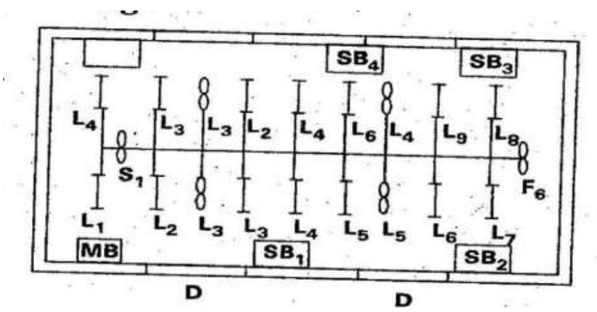
Main switch

1-Ph, 32A, 250V, DPIC

Cable for wiring

3/20, CTS, copper conductor

C .Layout of wiring and length of wiring



Layout of wiring

Length of wiring

Horizontal length = MB – SB_1 - SB_2 -SB_3 - SB_4 - MB- Between load

= 30 +14 +30 +14 +[9 x 10]+20

= 198m

Vertical length= at MB, SB_1, SB_2, SB_3, SB_4 and at loads(at 2places)

= 7 x 2 = 14m

Total length= (198 + 14) +10% (as wastage)

= 212 + 21.2

= 223.2 or 225m

Length of T/W batten required = 225m

Length of cable(CTS) = length of wiring x 3

= 225 x 3

= 675m

Add 20% as wastage= 675 + 135

= 810m

(d)Estimate

S.No	Description of materials	Quantity	Unit	Rate	Amount	Remarks
1	16A, 250v, DPIC main switch	1	each	150/-	150-00	
2	16A, 250v, (3 + 1) way DIB	1	each	200/-	200-00	
3	3/20 CTS cable, copper wire	810m	m	2/-	1620-00	
4	1", 2" Teakwood batten	225m	m	5/-	1125-00	
5	Link clips & nails	20P	each	10/-	200-00	
6	1-way switches	24	each	10/-	240-00	
7	5A, 250, V5 pin sockets	4	each	15/-	60-00	
8	Ceiling roses	20	each	10/-	200-00	
9	Round block	20	each	10/-	200-00	
10	T/W board 10'012' SB -4, MB-1, DB-1	6	each	50/-	300-00	
11	Earth sets	1	each	600	600-00	
12	Misc material	15	each	20/-	300-00	
13	Labour charge (load point wise) Load 24 x 50 =1200.0C MB4 x 50 = 200.00 **D/B**4.x 50 = 200.00				1600-00	

Short Answer Type Questions

1. Define Electrical Wiring.
2. What are the various types of House Wiring?
3. What are the types of service mains?.
4. Mention the mounting heights of
   Metre board
   Switch board
   Ceiling Fan
   D.P Main switch
5. Write short notes about
   1.Sub-circuit 2. Distribution board
6. Give the wattages of
   a. Ceiling fan
   b. Fluorescent lamp
   c. Incandescent lamp

d. Socket out let
e. Power Socket

7. Draw single line diagram of house wiring from service mains to a sub-circuit.
8. Expand the following
   SPT
   DP - Main
   DPIC
   ACSR

9. Expand the following
   CTS
   TRS
   PVP
   VIR

Long Answer Type Questions

1. Compare the various systems of wiring
2. What are the rules of wiring?
3. Write short note on
   Horizontal run
   Labour cost
   Vertical-ups
4. Estimate the quantity and cost of material required in standard proforma for a Hall of size 6m x 8m x 3m, in open type PVC conduit wiring system. Assume the missing data. The Hall is provided with light and fan points only.
5. Estimate the quantity of material and its cost for CTS using system in a House of size 6m x 5m x 3m. Assume the missing data. Provide one socket in Kitchen and Hall.

UNIT 2

POWER WIRING

2.1 Introduction to power wiring

In the previous section, electrical wiring installations for residential buildings were discussed. In this unit we will see how wiring installation is done in small industries upto 20 KW load and agricultural pump sets.

The wiring specially meant for high loads like Electric irons, Heaters, Geyser, Micro-wave, Motor, Air-Conditioner etc., is called power wiring, It is made by thick copper cable (minimum size - 2mm^2) and arranged in separate conduits. Power loads can be divided into groups.

(a) Domestic power loads - eg. Heater, Geyser, Air conditioner etc.
(b) Industrial load - eg: Lathe machine, Grinding machine, Agricultural pumpset, flour mill or the load which consume more than 5 A current.

Every motor must be controlled by main switch. A three phase motor needs an iron clad triple pole (ICTP) switch with fuse in each phase. In addition to main switch every motor also requires a starter for starting and stopping and also for protection. The typical single line diagram of power wiring is shown below in Fig.2.1.

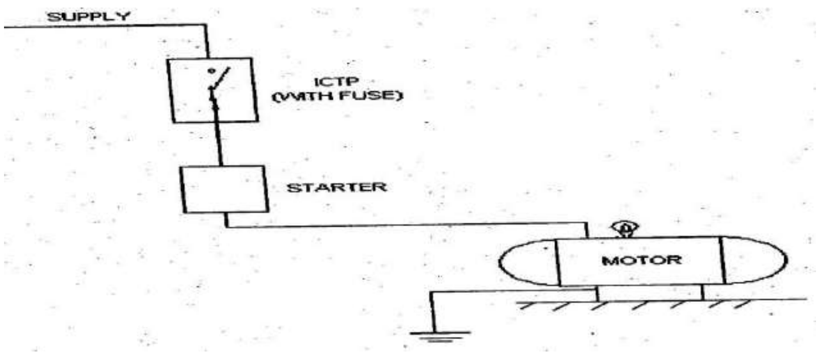


Fig.2.1 single line diagram of typical power wiring

2.2 Methods for power wiring

Metal surface conduit system of wiring should be preferred in industries, work Shops. The main board, distribution board and switch boards also must be strong enough to with stand the atmosphere in workshop. Flexible metal conduit should be used between starter, ICTP and motor terminals. The conduit used in power wiring Should be electrically continuous throughout its length and must be connected to the frame of the motor. The frame of the motor any how should be connected to the earth. The surface conduit facilitates the additions and alteration of connection. The metal conduit provides good mechanical strength, protection and also provides protection in case of fire accidents.

2.3. Types of Materials and Accessories used in Power wiring with a detailed estimate

The different types of electrical materials used in power (industrial) wiring /installation are listed in the table given below.

S. No.	Specification of material	
1	Triple-pole iron clad (ICTP) switch with fuse60 A, 500-V.	
2	60 A 500 - V ICTPN switch fuse unit	
3	32A, 500-V ICTPN switch fuse unit	
4	16A, 400/500-V ICTP switch fuse unit	
5	16A, 250-V ICDP switch fuse unit	
6	IC distribution fuse board 6-way 15 A per way	
7	IC distribution fuse board 4-way 15A per way	
8	Neutral link 8 way 4 way	
9	Metal conduit. 12 mm 19 mm 25 mm	
10	Conduit bends 12 mm 19 mm 25 mm	
11	Saddles 12 mm 19 mm 25 mm	
12	Couplers	
13	Bushings .-.	
14	Junction boxes 2-way 3-way 4-way	
15	1.5 mm^2 PVC single core, copper conductor with tough rubber or PVC sheathed (10A, 700-V) cable	
16	2.5 mm^2 PVC single core copper conductor with tough rubber or PVC sheathed (15A, 1100-V) cable	
17	4mm^2 PVC single core copper conductor with tough rubber or PVC sheathed (20A, 1100-V) cable.	
18	2.5 mm^2 (1/1.8 mm) PVC, two core aluminium conductor with tough rubber/ . PVC sheathed (15 A, 250-V) cable.	
19.	4mm^2 (1/2.24 mm) PVC core aluminium conductor with tough rubber / PVC sheathed (20A, 250- V) cable.	
20.	1.5 mm2 (1/1.4mm) PVC, three core copper/alumimum conductor with tough rubber or	

	PVC sheathed (10A,440/500V) cable	
21.	2.5 mm2 (1/1.8 mm) PVC three core copper / aluminium conductor	
	with tough rubber or PVC sheathed (12A-500-V) cable.	
22.	4mm2 (1/2 24mm) PVC, three core copper / aluminum conductor with tough rubber or PVC sheathed(17A,500-V) cable.	
23.	15 A tumbler switches	
24.	15A switch flush type	
	15A, 3-pin socket	
26.	Bus-bar chamber made of M.S sheets with four strips of aluminium bus-bars	
27.	Twin tube light fitting pendent type with downrods.	
28.	Ceiling roses 2-Plate	
29.	Copper wire 14 SWG	
30.	G.I. Wire 8 SWG	
31.	Clips for fixing earth wire	
32.	Earth set (pipe, salt, coal)	
33.	Caution or danger plate with painting	
34.	Shock treatment chart	

2.41-phase and 3-phase Service – Selection of starters

Starters are selected based on capacity and type of motor.
2-point ,3-point and 4-point starters, Rotor Rheostatic starter and drum type starters are best suitable for DC forcompound/shunt/series motors.
Direct on Line (DOL), Star-delta and auto transformers starters are used for AC motors.
They are selected based on HP rating as given below
up to 5 HP rating - DOL starter.
5HP to 15HP - Start Delta
Above 15HP- Auto Transformer starter
For DC machines –2-point/3-point/4-point/ Rotor Rheostatic starter and drum type starters

2.5 Designing number of control panel Boards

In Power wiring installations, the power supply to each motor should be given through a separate power sub-circuit and the live wires (phase and neutral) for supply to each motor should be taken directly from the Distribution board. So, the size of the distribution board depends upon the number of motors to be wired.
The distribution boards are available for single, phase supply with different current rating and number of ways.

Designing of Motor Control Panel

The motor control panel includes the motor ICTP switch, motor starter, measuring equipments (like Ammeters, Volt meter) and indicating lamps etc. It is made up of MS angle frame in which a wooden plank is inserted to provide the base for mounting of these iron clad type accessories and equipment etc.

The size and rating of these accessories, equipment and panel board depends on the type, size and rating of the motor.

The control panel board is must and should be connected to the earth without fail.

Determination of size of the cable:

HP	kW	Single Phase ampere	Three Phase ampere	Recommended Cable Size Sq.mm
0.125	0.095	1.20	0.4	1.0 Copper
0.25	0.19	2.00	0.8	1.0 Copper
0.5	0.37	3.70	1.0	1.5 Copper
0.75	0.55	5.00	1.3	1.5 Copper
1.00	0.75	6.50	1.9	1.5 Copper
1.50	1 10	11.50	. 2.6	1.5 Copper
2.0	1.50	-	3.7	1.5 C opper
3.0	2.20	-	4.8	1.5 Copper
5.0	3.70	-	7.8	1.5 Copper
7.5	5.50	-	11.2	2.5 Copper
10.0	7.50	-	15.5	4.0 Copper
12.5	9.30	-	19.0	4.5 Aluminium
15.0	11.0	-	22.0	6 Aluminium
20.0	15.0	-	29.0	10 Aluminium
25.0	18.5	-	35.0	16 Aluminium
30.0	22.0	-	40.0	16 Aluminium
35.0	26.0	-	47.0	2 5 Aluminium
40.0	30.0	-	53.0	25 Aluminium
50.0	37.0	-	650	35 Aluminium
60.0	45.0	-	80.0	50 Aluminium
75.0	55.0	-	94.0	70 Aluminium
100.0	75.0	-	127.0	95 Aluminium
125.0	90.0	-	152.0	15 0 Aluminium

Determination of the size of the conduit .

In Power wiring installations only the Heavy Gauge Metal Conduit should be used and the size of the conduit depends on the size and the number of the cables running inside it.

2.6.Preparation of wiring Installation Plan / Wiring Layout

In the Plan of a power wiring installation, it is very important to locate the mounting places of the main switch panel along with the distribution board of the motor to be installed and the motor control panel along with the suitable type of the starter to be used showing all the detailed measurements. The diagram or drawing so formed is called the Plan and Lay-out of the power wiring installation.

Single line diagram

Itis the diagram showing the mounting heights detailed distances and the number wires running between the main switch, distribution board, motor control panel and the motor terminals.

2.7.Selection of Main Switch

The rating and type of the main switch of a particular wiring installation should be determined as per the total maximum load, load current, type of power supply (i.e. 1phase or 3 phase) safety of the consumer and type of wiring installation.

Types of Main Switches

1.DP-main switch ... for single phase installation (230 V) (16 A, 32 A, 250 Volts)

2.TPICN(Triple Pole Iron Clad with neutral link) ... for three phase installations (440 V) (32 A, 64 A, 500 Volts)

2.8.Calculation of length of cable and labour cost

The length of conduit is the sum of the lengths of (a)Horizontal run (b)Vertical ups (c) Down drops and (d) Passages through walls. The heavy gauge M.S.type metal conduit should be used

2.8.1 .Calculation of labour cost

Electrical installation will be executed with the involvement of the labour. An electrician should accompany (a) Skilled (b) Semi Skilled and(c) Unskilled labour to complete an electrical wiring installation. In certain cases carpenter, mesons and plumbers are also work along with an electrician to complete his job effectively and efficiently within the given time.

The cost of the labour involved will be calculated by adopting any of the following methods

S.No	Type of Labour	Wage per/day	Total days worked	Amount
1	Electrician	200	2	400
2	Helper	100	2	200
Grand Total				600

(a) Daily Wage

(b)Contract or Lumpsum

Work contract: In this, the material and the accessories are provided by consumer. Only installation work is carried by contract.

(c) Percentage of total cost of Material and Accessories
Some percentage of total cost of material and accessories is charged as labour cost based on the existing guidelines in PWD/R&B/Railways etc.
(d) The rates decided by Government departments / Schedule of labour rates prepared by Panchayath, Municipality, PWD, CPWD, Railways etc. will be considered as it is for fixing up of labour cost.
(e) No. of load points method

2.9. Preparation of detailed estimate in a standard proforma for power wiring

To find out final estimated cost of a power wiring installation,some useful exercise should be done to calculate and tabulate the detailed estimation of the cost and quantity of the material and equipment in a standard proforma. This total process involves several steps which are mentioned below:

Step -1: Calculation of the full load and starting currents of the motor.

Step-2: Determination of the size and rating of the main switch, distribution board, motor switch and suitable type of the starter to be used.

Step-3: Determination of suitable type and size of the cables.

Step -4: Determination of the suitable size of the heavy gauge MS type metal conduit and metal flexible conduit.

Step -5: Preparation of installation plan lay-out and single line diagram.

Step -6: Calculation of total length of the conduit and the length of flexible conduit(i.e from motor base to motor terminal box, restricted to a maximum length of 1.5m) allowing a wastage of 10%.

Step 7 : Calculation of total length of the cables allowing a wastage of 10%.

Step -8: Calculation of the labour cost.

Step -9: Tabulation of the material and labour cost along with addition of10-15% of contingencies (i.e miscellaneous expenditure which includes rise in rates, transport cost and fringe benefits offered to the workmen)

2.10. Estimation of wiring of small Workshops and Irrigation pump sets etc

2.10. 1 Estimation of wiring of small Workshops

Example 1

Make an estimation of material required for installing of a 10HP, 400V, 50Hz 3phase motor in a workshop of size 30 x20 x 8m.

Given

Capacity of motor = 10HP, 400V, 50 c/s, 3phase

Size of work shop = 30 x 20 x 8m

Req

Detailed estimation for installing motor.

Step-1 : Selection of main board, distribution board, MCP

Main Board : Motor current =HP x 3 = 10x3=30A

Outer load = 5A

60A, 500V, TPICN is suitable

NOof load points -------- 1 - 10 HP motor

---------1- light load assumed.

60A, 2-way, 3phase, 500V D/B is suitable

MCP (Motor Control Panel) : Motor HP = 10HP

Current= 10 x 2.25= 22.5 A

Starter : Motor HP rating is 10HP

Y /Δ starter is suitable (5 HP —15 HP --Y /Δ starter is suitable)

Motor switch = 32A, 1CTP, 500V

Step-2 : Layout, single line diagram ,length of wiring and cable

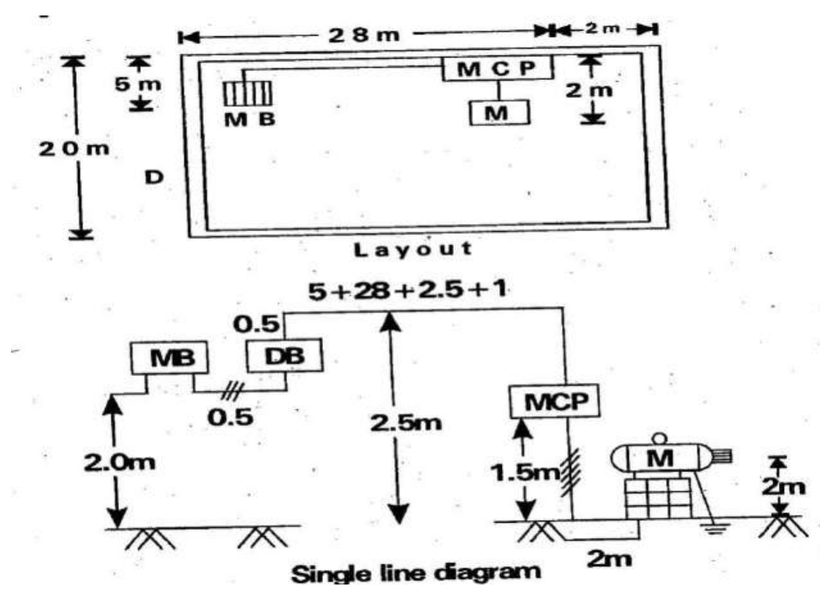


Fig 2.2Single Line Diagram

S.no	Description of the materials	Quantity	Unit	Rate	Amount	Remarks
1.	Main switch a) ICTPN 60A,500v b) ICTP 32A,500v	1 1	each each			
2.	3Φ,2-way, 60A Distribution board	1	each			
3.	Heavy gauge metal conduit	50m (25mm)	m .			
4.	Flexible conduit	2m	m			
5.	2.5mm^2 PVC cable	200m	m			
6.	Conduit bends	6	each			
7.	Saddles (50m x 2)	100	each			
8.	Wooden/Asbestos board (MB, DB, MCP)	3	each			
9.	Indicators	3	each			
10.	Earth set with ECC	2	each			
11. 12	Screws, nails, gutties, Labour charges	LS LS	each each			

Length of wiring:

MB — DB — MCP — M =0.5 + 5 + 28 + 2. 5 + 1 + 1.5 + 2 + 2 = 42.5m

Add10% as wastage = 42.5 + 4.25=46.75 or 50m

Length of cable=50 x 3 + 5.5 x 3 [MCP to motor line has six wires]

=150 + 16.5 = 166.5 m

Add 20% as wastage =166.5 + 32 = 200m approx.

Example 2

Ina workshop following motor to be installed.

(a) 20HP, 3ϕ,440v, 50Hz, SQIM (Squirrel Cage Induction Motor)
(b) 10HP, 3ϕ,440v, 50Hz, SQIM
(c) 5HP, 3ϕ,440v, 50Hz, SQIM
(d) 1HP, 1-ϕ, 230v, 50Hz, Induction Motor.

Draw single line diagram of wiring and indicate the ratings of main switch, conduit, conductor etc.

Ans: Given :

Rating of motorA- 20HP, 3ϕ,440v, 50Hz, SQIM

Rating ofmotor B- 10HP, 3ϕ, 440v, 50Hz, SQIM

Rating of motor C- 5HP, 3ϕ, 440v, 50Hz, SQIM

Rating of motor D- 1-HP, 1-ϕ, 230v, 50Hz, Induction motor

Req :

(a) Single line diagram of wiring
(b) Ratings of accessories for each motor

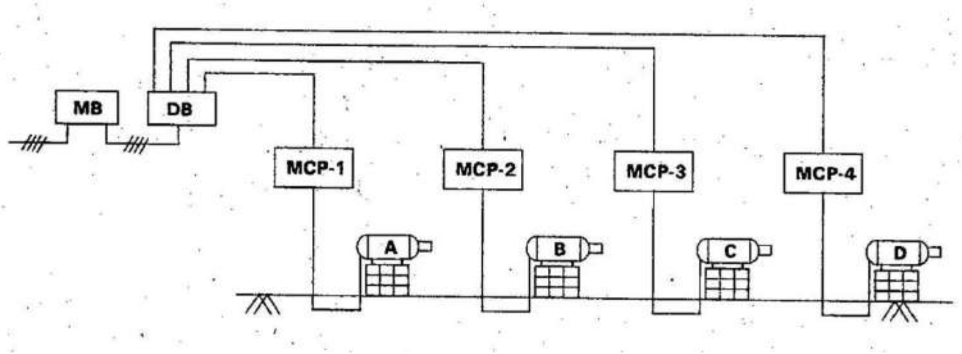


Fig 2.3 Layout/ single line diagram

Ratings of Accessories

Motor-A : 20HP, 3ϕ ,440v, 50Hz, SQIM

Motor current = HP x 3 = 20 x 3
= 60A

Motor switch = 62A, ICTP, 3ϕ ,500v

Starter = Auto T/F starter [HP > 1 SHP]

Cable for wiring = 10 rnm^2, PVC insulated copper conductor

Conduit= ϕ19 mm metal (Regid Type)

Motor-B : 10HP, 3ϕ, 440, 50Hz, SQIM

Motor current = HP X 3=10X 3

= 30A

Motor switch3ϕ,32A, 500V, ICTP

Starter = star-delta

Cable for wiring 6mm^2/PVC insulated Cu conductor

Conduit for wiring =19mm , metal-regid.

Motor-C : 5HP, 3ϕ, 440V, 50 Hz, IM

Motor current = HP x 3 = 5 x 3

= 15A

Motor switch =3ϕ,16A, 500v, ICTP

Starter =Star-Delta.

Cable for wiring =4mm^2, PVC insulated, Cu conductor

Conduit for wiring =ϕ19mm dia, metal-regid.

Motor-D : 1HP, 1ϕ,250v, 50Hz induction motor

Motor current =1HP x 3=1 x 3 = 3A

Motor switch = 1ϕ,16A, 250v, ICDP

Starter = DOL

Cable for wiring = 2mm^2/ PVC insulated Cu Conductor

Conduit for wiring = 19mm , metal-regid.

Example -3 : Give the rating of main switch for 5HP, 400v, 3ϕ,Induction Motor

Ans: There are two methods

(a) First method - Thumb rule --> HP x 3 = 5HP x 3 =11.15amp

(b) Second method - From formula

P = VI cosϕwatts, p = $\sqrt{3}$VI Cosϕ

Assuming Cosϕ= 0.8 x 5HP = 5 x 735.5 = 3677.5W

3677.5 =$\sqrt{3}$ x 400x I x 0.8

$$I_{FL} = \frac{3677.5}{\sqrt{3} \times 400 \times 0.8} = 6.76$$

Startingcurrent (I_s) =1.5 x I =10.14

32A, 500v, 3ϕ, ICTP can be selected as main switch.

[32A min size is 16A, main switch is available].

Example 4 : Draw the wiring diagram and estimate the material required for 8HP, 440v, 50Hz, SQIM is to be installed in a workshop of 20m x 10m x 5m. Assume any missing data.

Ans: Given

Motor details- 8HP, 34), 440v, 50Hz, SQIM

Size of work shop- 20m x 10m x 5m

Req : Wiling diagram, estimate

Sol

(a) Installation plan, wiring diagram /single line diagram:

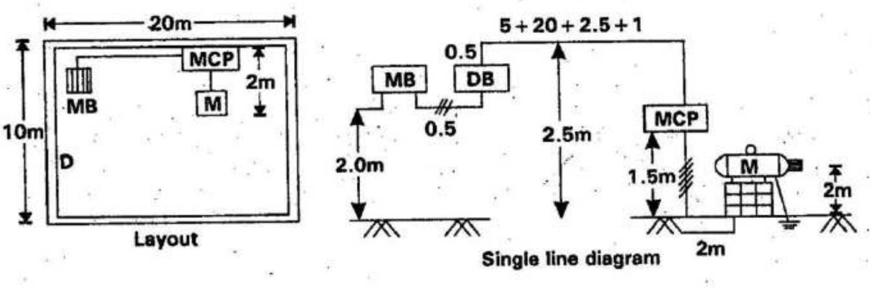


Fig 2.4

(b) Estimate:

(i) Selection ofAccessories:

Rating ofmotor = 8HP, 3ϕ,440v, 50Hz, SQIM

Motor current = HP x 2.25 = 8 x 2.25 = 18A

HenceMotor switch = 32A, 500v, 3ϕ, ICTP (Min. size)

Starter = STAR/DELTA [5HP to 15HP]

Main switch = 60 A ICTP-N,500V,3ϕ

Distribution Board = 2 way, 3ϕ, 60A (1 for motor, 1 for light lode)

Size of cable for light load = 1.5mm/PVC / insuslated copper wire

Size of metal conductor = 32mm, regid

Type of wiring = Surface type heavy guage metal conduit wiring –

(ii) Length ofwiring = MB - MCP - Motor

=0.5 +0.5 +0.5 +4 + 18+ 1 + 1.5 +2 +2 =30m

Add 10% as wastage - 30 + 3 = 33m

Length of cable= [IM - MB - DB] [4] + [DB - MCP] x 3 +[MCP - Motor] x 6

=1 x4+23.5 x 3 +5 x 6= 104.5m

Add 20% as wastage

104.5 + 21 = 125.5 or 130m

S No.	Description Of Material	Quantity	Unit	Rate	Amount	Remarks
1	Main switch a) ICPTN 60A,500V b) ICTP 32A,500V	 1 1	 Each Each			
2	3ϕ,2 way,60A Distribution board	1	Each			
3	Heavy gauge metal conduit 25mm	50m	m			
4	Flexible conduit	2m	m			
5	2.5 mm^2 PVC cable	200m	m			
6	Conduit bends	6	each			
7	Saddles (50m x 2)	100	each			
8	Wooden / Asbestos board MB,DB,MCP	3	each double the length of the wiring			
9	Indicators	3	each			
10	Each set with ECC	2	each			
11	Screws, nails, gutties	LS				
12	Labour charges	LS				

2.10.2 introduction to irrigation pump set wiring

Irrigation or agriculture pump set wiring is similar to power wiring estimation. But in agriculture motor switch board, indicating lamps and single phase preventor are being used. The electrical material mentioned for' power wiring holds good for the material required for the execution of the irrigation for pump set installation.

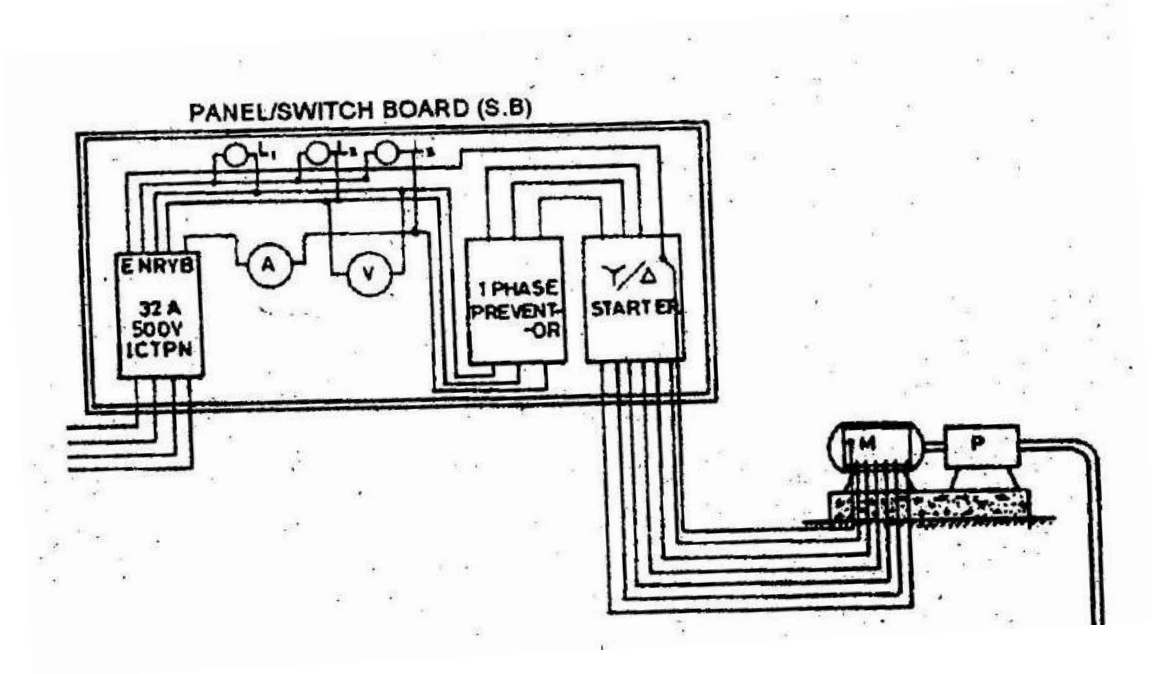


Fig 2.5 Agriculture motor and its control panel

2.10.3 Estimation of Irrigation pump sets

Example 1: Estimate the quantity of material required for wiring of agriculture pump set motor 400 V, 5 kW, 50 Hz, 3-phase using star-delta starter. The supply to the pump is to be taken from an overhead L.T. 3-phase pole, 15m away from pump shed (5m x3m). Use conduit wiring for motor connection and show the layout of the connection

Solution

Assumptions

1. The efficiency of the pump set motor is 85% at a P.F. of 0.8.
2. The height of the pump set is 3m.
3. The height of the switch board, starter is 1.5m, above ground level.
4. The height of horizontal run is 2.5m.
5. The cost of motor is not included in the estimation.
6. The cost of service wire is not included in the estimate.

(a) Selection of cable size and ICTP rating

Full load current of the motor = $\frac{rating}{\sqrt{3}\ x\ V_L x\ cos\phi\ x\ \eta}$

$= \frac{5\ X\ 1000}{\sqrt{3}\ X\ \ 400\ X\ \ 0.8\ x\ 0.85}$ = 10.61Amps

The starting current of the motor = 2 x Full load current

= 2 X 10.61

= 21.32 Amps

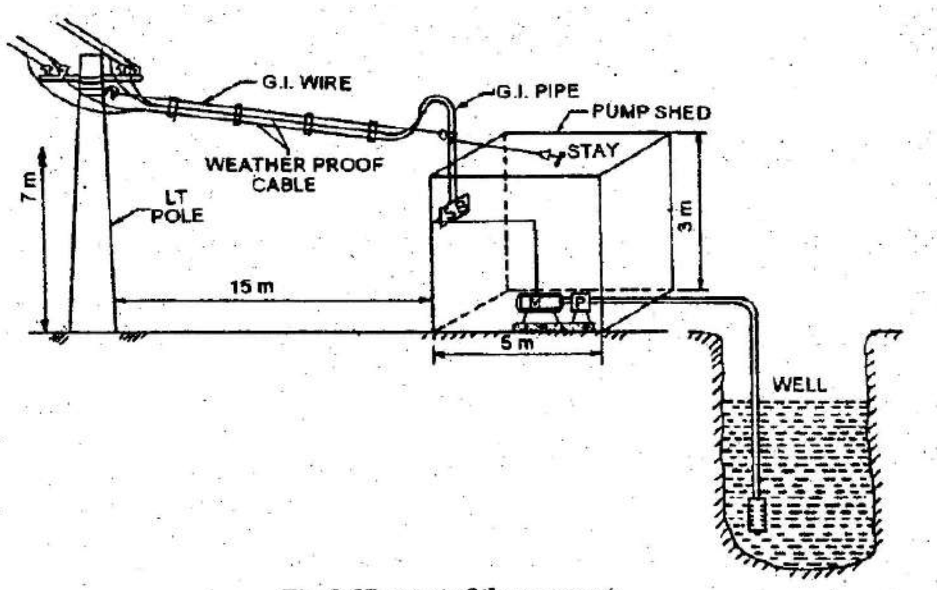


Fig. 2.6 Layout of the pumpset

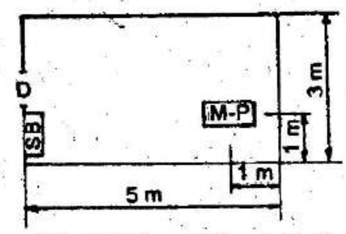


Fig. 2.7 Plan of Pumpshed

Wiring diagram

Hence 3.0 mm^2 copper conductor cable of current carrying capacity 22A to 4.0 mm^2. Alluminium conductor of current carrying capacity 23A is sufficient.

A 32A 500-V, ICTPN switch with fuses may be used.

(b)Size of Conduit

25.4 mm metal conduit (heavy gauge) is required from panel or switch board into motor base and flexible conduit of 25.4 mm size is sufficient from motor base to motor termination since, 6 cables are to be run through the conduit.

(c) Length

Length on the roof = 2.0 m

Length from SB to motor base (1 + 4 + 2.5 + 1) = 8.5 m

Total = 10.5 mm

10 % wastage = 1.05

= 11.55 m

= 12.0 m (say)

Flexible conduit from motor base to motor terminals 0.75 m

1.0 m (say)

(d) Length of the cable (single core copper)

Length from ICTPN to starter (0.5 x 3) = 1.5 m

Length from starterto motor terminals

(1+4 +2.5 +1 + 0.75)x 6 =55.5m

57.0 m

15% wastage and end connections = 8.55m

65.55m

66m (say)

1.0 mm^2copper conductor cable for lamps = 2.0 m

(e) Labour cost :

One electrician with one helper can complete the work in one day

Labour cost = (electrician rate + helper rate) x no. of days

= (300 + 150) x 1

= Rs. 450.00

Schedule of Material and Cost

S. No.	Specification of material	Qty	Rate /Each	Amount
1	32A,440-V ICTPN switch fuses	1 No.	2500	2500
2	Star – Delta starter,16A,, 500 V	1 No.	1500	1500
3	I-phase-preventer (with timer)	1 No.	500	500
4	25.4mm conduit (heavy guage)	12m	50	600
5	25.4mm flexible conduit	1m	40	40
6	3.0mm^2 copper conductor for cable	66m	15	990
7	1.0mm^2copper conductor cable	2m	10	20

8	Angle Iron Frame 50 x30 cm	1No	300	300
9	Conduit bends 25.4 mm	3No	20	60
10	Saddles 25.4 mm	25 No	5	125
11	Conduit coupler 25.4 mm	1 No.	25	25
12	Wooden Gutties	2 doz.	30	60
13	Earth wire G.I.S SWG	20 m	3	60
14	Earth pipe perforated 25.4 mm	2.75 rat	75	75
15	Coal	20 kg	5	100
16	Salt	20 kg	5	100
17	Funnel with wire mesh	1 No.	50	50
18	fixing	1 No.	500	500
19	Lugs for connecting leads to motor	6 No	10	60
20	Stay set	1 No.	500	500
21	Nails/Screws	1/2 kg	75	75
22	Batten holders (brass)	3 No	20	60
23	Lamps (0W/25W,250-V)	3 No	10	30
24	Switches 5 A	3 No	10	30
25	Ammeter (0-10 A/25A)	1 No.	500	500
26	Voltmeter(0-500V)	1 No	300	300
27	Panel board steel 50 x 30 cm	1 No	500	500
28	Cement	2 kg	20	20
29	Danger plate	1 No	25	25
30	Shock treatment chart	1 No	50	50
31	Labour cost		1500	1500

Example 4

Estimate the material required for the erection of irrigation pump set of 7.5 HP, 3-Phase, 400 -V. Assuming the distance from pole to the pump set shed is 15m and pump shed to pump set is 20m which IC available inside the well.

Solutions

Assumptions

1. The efficiency of the motor is 85% at a pl. of 0.8.
2. The height of the pump shed is 3m.
3. The height of the switch board and starter is 1.5m.
4. The height of the horizontal run is 2.5m.

5. The cost of motor and starter is not included in the estimate.

(a) Selection of cable size and ICTPN

$$\text{Full load current of the motor} = \frac{Power\ rating}{\sqrt{3}\ x\ V_L x\ cos\phi\ x\ \eta}$$

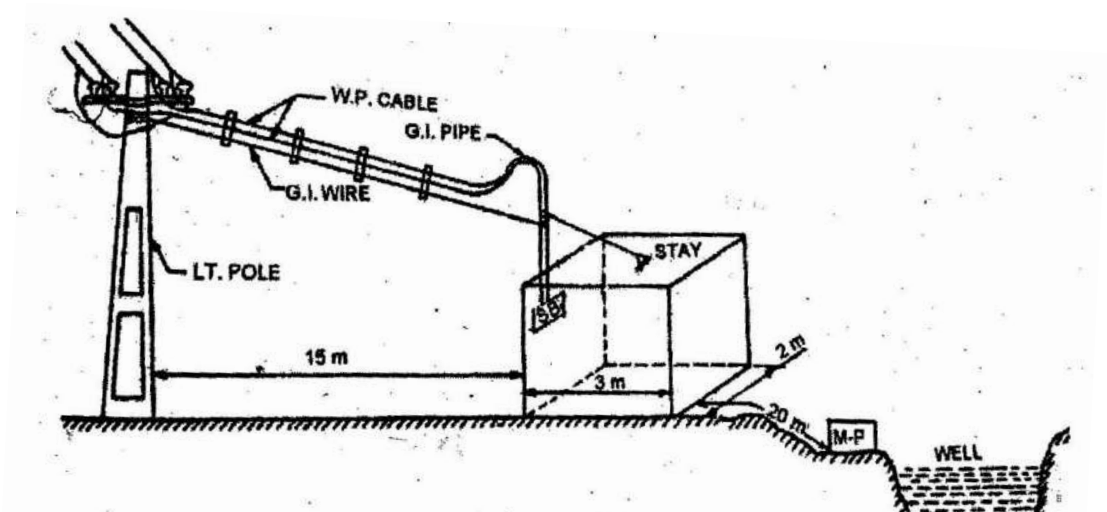
$$= \frac{7.5\ X\ 735.5}{\sqrt{3}\ X\ \ 400\ X\ \ 0.8\ x\ 0.85} = 11.7\text{Amps}$$

The starting current of the motor = 2 x Full load current

= 2 X 11.7

= 23.4 Amps

4.0 mm^2 copper conductor cable of current capacity 25A is sufficient and 32A, 500-V ICTPN switch with fuses may be used.



Layout of the Pump

(b)Size and length of Conduit

25.4 mm metal conduit (heavy gauge) is required

Length on the roof			=	2.0 m
Length from SB to motor base (1 + 3+ 2.5 + 20)	=	26.5 m		
	Total		=	28.5 mm
	10 % wastage		=	2.85
			=	31.35 m
			=	32.0 m (say)
Flexible conduit from motor base to motor terminals				1.0 m

(c) Length of the cable (single core multi strand copper)

Length from starterto motor terminals

(1+3 +2.5 +20 + 0.75)x 6 = 163.50m

20% wastage and end connections = 32.7m

Total 196.2m

200.00m

1.0 mm^2copper conductor cable for lamps and neutral = 2.0 m

(2.5 mm^2 single core copper conductor cable)

Length form ICTPN to starter (0.5 x 3) = 1.5 m

Say = 2.0m

7/1.27 mm ('or' 7/20 SWG) Aluminium conductor

W.P twin core cable from L.T. Pole to S.B (15+2) x 2 = 34.00m

15 % sag and end connections = 4.1 m

Total : 38.1 m

Say 40.00 m

(d) Labour cost :

One electrician and one helper can complete the work in one and half day

Labour cost = (electrician rate + helper rate) x no. of days

= (300 + 150) x 1.5

= Rs. 675.00

Schedule of Material and Cost

S. No.	**Specification of material**	**Qty**	**Rate /Each**	**Amount**
1	32A,500-V ICTPN switch fuses	1 No.		
2	I-phase-preventer (with timer)	1 No.		
3	25.4mm conduit	32m		
4	25.4mm flexible conduit	1m		
5	4.0 mm^2 copper single core cable	200m		
6	2.5 mm^2 copper single core cable	2m		
7	1.0mm^2, single core cable	2m		
8	7/1.27mm W.P. (2-core) alluminium cable	40m		
9	Angle Iron Frame 50 x30 cm	1No		
10	Panel board box 50x30x20 cm	1No		

11	Conduit bends 25.4 mm	6No		
12	Saddles 25.4 mm	100No		
13	Conduit coupler 25.4 mm	10 No.		
14	Wooden Gutties	1 doz.		
15	Brass batten holders	3 No.		
16	Earth wire: G.I.S SWG	40 m		
17	Earth pipe perforated	2.75m		
18	Coal	20 kg		
19	Salt	20 kg		
20	Funnel with wire mesh	1 No.		
21	Lugs for connecting leads to motor	6 No		
22	Stay set	1 No.		
23	Nails/Scews	1kg		
24	Lamps (0W/25W,250-V)	3 No		
25	Switches 5 A	3 No		
26	Ammeter (0-30 A)	1 No.		
27	Voltmeter(0-500V)	1 No		
28	Cement	5 kg		
29	Danger plate	1 No		
30	Shock treatment chart	1 No		
31	Labour charges for earthing(civil work)	1 set		
	Labour cost			

Short answer type questions

1. Give any four examples for power loads.
2. Expand ICDP, ICTP, ICTPN switches and GI. wire.
3. Draw a single line diagram of power wiring to install a motor for a workshop.
4. What type of wiring system is best suited for Industrial wiring?
5. What are the types of starters suitable forAC motors and DC motors?
6. What Are the Types of Main Switch?
7. What type of accessories should be used in power Wiring?
8. Define power wiring

Long answer type questions

1. In a flour-mill of size 4m x6 m x 3.5 m, one 10 HP, 440 V,3Φ,50 Hz. Squirrel cage Induction motor is to be installed, prepare the estimate of the material and its cost along with layout of the wiring.

2. Estimate the material required for the erecting of irrigation pump setof 5 H.P, 3Φ, 400 V, the distance between pole to the pump set is 25m and pump set to pump set shed is 15m, which is available inside the well. Assume the missing data, if any.
3. How to calculate the length of cable and labour cost.
4. what are the steps involved in calculating final estimated cost of power wiring?

UNIT 3

Low Tension Distribution Lines and Village Electrification

3.1 Types of Overhead (OH) Distribution Lines

Overhead lines are many types. They can be divided on the basis of :
1.Working or line voltage
2.No.of conductor /wires on OH line
3.Disposition of conductors/ arrangement of conductors on OH line.
Low voltage line or LT line - 230V to 400V
(a) Working /line voltage classification based on :
Medium voltage line - 400V to 6.6kV
High voltage line or HT line – l1kV to 33kV
Extra high voltage line - 66kV to 132kV
Very high voltage line - 220kV to 400kV etc
(b)Classification based on number of wires on OH line :
2-wire --- 1Φ, for 230V, AC or D.C
[1-ph, 1-N] [1-Positive, 1-Negative]
3-wire ---- 3Φ ,AC 11kV/33kV
[1-Red, 1-Yellow, 1-Blue]
4-wire ---3Φ ,1-N, AC for 400V
5-wire --- 3Φ,1-N, AC, street light control
[3-3ph, 1-Neutral, 1-street light control]
6-wire ---3Φ double circuit for 66kV and above

(c) Classification based on disposition or arrangement of wires :

Vertical disposition : In cities, narrow streets, the wires are arranged vertically on OH line. The top wire is neutral.
Horizontal disposition : It is general arrangement of wires on OH line.The wires are arranged on cross arms with separate insulators. The length of cross arm is depends on the line voltage.

3.2 Major components of Overhead lines

Supports : poles or towers are used as supports. The type, size, height depends on line voltage the region or area of location.
Insulators : Pin, shackle, disc and reel type insulators are used for support the line/wire. They also protect the leakage of current to ground.
Cross arms and clamps : Steel angle sections are used on pole structure to support the insulators and conductors.
Conductors : ACSR (Aluminum conductor steel reinforced) conductors and AAC (All aluminum conductor) are used in OH line
Guys and stays : These are angular supports to pole to support the pole at terminations (end of OH line) curves, weak soil places.

Lightning arrestors : These are arranged at top of the pole and they divert lightning stroke and discharges to earth.

Fuses and Isolators : In order to isolate different parts of OH fuses and isolators are fixed on certain poles.

Earth wire : It runs at top of OH line and is perfectly earthed at different poles [Every 5th pole of LT dist line/ alternate pole of 11kv line/each pole of 33kv line].

Guards : These are arranged below the OH line if the line is crossing' the streets/crossing over the telephone line/or crossing over the railway track etc.

Span : The distance between two successive poles is called span. It is measured in 'meters'.

Barbed wire/anti-climbing device : These are protecting devices to avoid climbing of the un authorized persons/insects/snakes. They arranged over some part of OH line support..

3.2.1 Insulators

The insulators are made from porcelain /glass/rubber and arranged between conductors and cross-arm structures to prevent short circuit between conductors. The wires are rigidly attached to line support through insulator. They are following types.

(a) Pin Insulators : Pin insulators are commonly used on cross arm/poles where horizontal /vertical. Type configuration of conductors. They are many type-single shed, double shed, Triple shed etc. They can be used in 1Φ,3Φ(230/400v) LT and 11 kv,33kv-HT- OH lines.

(b) Shackle Insulators : These are used at terminations, angles, cut points of OH line. But its usage is limited for LT [230v/400v] OH lines, They are also used in vertical configuration of conductors. The shackle insulators are attached to cross arm /poles by v-clamps and bolts.

(c)Strain Insulators /Disc insulators : These are also called string insulators. Each disc withstand for 11kv.

(d)Stay insulator or egg insulators : These are used in stay sets. They stops the flow of fault current (if any) in stay wire and thus protects near by people.

(e)Reel Insulator : Reel insulators are not insulators. They are made by iron. They are used to carry Neutral/Earth Wire on OH line.

3.2.2 Poles

Poles are used to support the OH line, insulators cross arms etc. They are also called line supports. The various types of poles presently used in erection of OH lines are as given below **:**

S.No.	Type of Pole	Purpose	Max. span
(a)	Steel tubular polesorrolled steel joint poles	for 11 k V to33 kV	with max. span of50 - 80 m
(b)	Steel rail poles	for l lk V to33 kV	with max. span of50 - 80 m
(c)	RCC(Re-inforced cement concrete)poles	for upto 33 kV	with max. span of200 m.
(d)	PSCC(Pre-stressed cement concrete)poles	for upto 33 kV	with max. span of200 m
(e)	Angular pole structures	for upto 66 kV	with max. span of240 m.
(f)	Towers	for 132 kV &above	300 m to 375m

The first 'four' types of pole supports are used in OH distribution lines. The common length /height of poles are 8m, 9m and 10m. One sixth ($1/6^{th}$or $1/5^{th}$) of pole length is buried in ground to have good structure.

3.2.3 Cross Arm

Cross arms are mounted on the top of the poles. They support the insulators and line conductors. They also helps to maintain the distance between conductor to conductors and prevents arcing due to swinging of conductors. They are made by MS-(mild steel) channels or angles.

The length and shape of cross arm will depends on voltage, purpose and location of the OH line..

3.3 Types of Materials and Accessories used in Overhead lines with a detailed estimate

Example 1: Prepare the quantity of various materials and accessories required for1km length of 11kv line with 7/2.59 ACSR conductor on PSCC poles of 8m height with 80m span. Assume any missing data.

Ans: Given

Length of 11kv OH line = 1km =1000m

Span = 80m

Size of conductor= 7/2.59, ACSR

Height of pole8m

Type of pole= PSCC

Req :

Estimate of OH line for 1km length

Sol

Type of OH line = 3Φ, 3-wire, 11kv

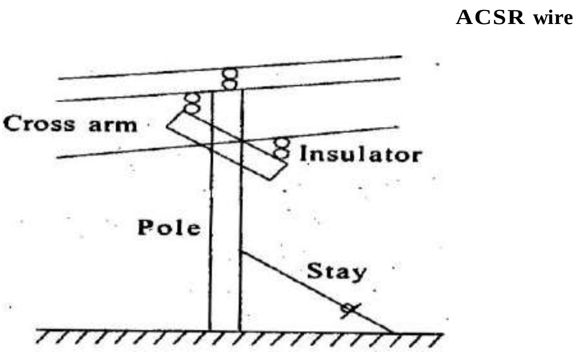
(a)No. of poles $= \frac{\text{Length of OH line(1000m)}}{\text{Span(80m)}} + 1 =$ 13.5 or 14 poles

(b)Length of ACSR conductor =3 x 1000 = 3000m

Add 4% as wastage= 3000 + 4% of 3000=3.12km

(c) No. of Insulators = No.of poles x 3 = 14 x 3 = 42

(d) layout of OH line and pole structure



(e) Estimate

S.No.	Specifications of materials	Quantity	Remarks
1	PSCC poles, 8m long with cross arms	14	
2	ACSR conductors (7/2.59)	3.12 km	
3	Insulators	42	
4	(a) Pin - 36		
4	(b) Disc - 6		At ends of OH line
5	Earth sets		
6		3	At every fifthpole
5	Lightning arrestor	14	On each pole
6	Danger plates	14	On each pole
7	Barbed wire	28kg	2kg per each pole
8	Cement concrete	L.S.	
9	Misc-material like Nuts, Bolts etc.	As required	

3.4. Estimation in a standard proforma for 1-phase and 3-phase Overhead lines – simple problems

Example 1: A main road has a street light line of 1.5km. It is to be electrified by fluorescent lamps of 40w. Estimate the quantity of materials, cost of the street light line. Take span as 80m.Assume the type of OH line is 1Φ, 2wire (1-Ph, 1-N).

Ans: Given

Length of OH line = 1.5km =1.5 x 1000 = 1500m

Span = 80m

Purpose of OH line = Street lighting with 40w, fluorescent lamps

Types of OH line = 1Φ, 230v, 2wire (1-Ph, 1-N)

Req : Estimate of materials and accessories

Sol

(a)No. of poles $= \frac{\text{Length of OH line(1500m)}}{\text{Span(80m)}} + 1 =$ 19.75 or 20 poles

(b) Length of ACSR conductors =Length ofOH line x 2=1500 x2 =3000m

Add 4% as sag/wastage = 3000 + 120 = 3120m or 3.121km

(c) No. of insulators

Each pole will have two (2) insulators (2-wire OH line)

For - Phase line/wire- Pin insulator

For - Neutral line/wireReel /insulator.

At - ends of OH line- shackle insulators

Total insulators = No.of poles x No. of insulators per pole

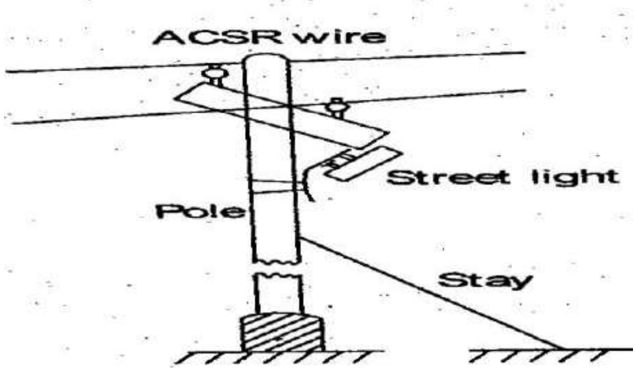
= 20 x 2 = 40

Reel/insulators = 18

Pin insulators = 18

Shackle insulators = 4

(d)layout of OH line and pole structure



(e)Estimate

S.No.	Specifications of materials	Quantity	Remarks
1	RCC poles of 8m long with cross arms.	20	
2	ACSR conductor (7/2.59)	3.12km	
3	Insulators	40	
4	Stay sets	10	
5	Earth set	4	Every fifth pole
6	Fluorescent lamp sets with fittings	20	One an each pole
7	Cement and concrete	LS	
8	Misc, materials like	As required	
	Nuts, bolts, fittings etc.		

Example 2 : A road has a straight length of 3km is to be electrified by fluorescent lamps of40w. The span is 50m. Estimate quantity of material and their cost. The type of OH line is 1Φ, 2wire (1-Ph, 1-N). Assume any missing data.

Ans: Given

Length of OH line = 3km = 3 x 1000 = 3000m

Span = 50m

Purpose of OH line = Street lighting with 40w, fluorescent lamps

Types of OH line = 1Φ, 230V, 2wire (1-Ph, 1-N)

Req :

Estimate of materials and accessories

Sol :

(a)No. of poles $= \frac{\text{Length of OH line(3000m)}}{\text{Span(50m)}} + 1$

=61poles

(b) Length of ACSR conductors = Length ofOH line x 2 = 3000 x 2 = 6000m

Add 4% as sag/wastage = 6000 + 240 = 6240m or 6.24km

(c) No. of insulators

Each pole will have two (2) insulators(2-wire OH line)

For - Phase line/wire- Pin insulator

For - Neutral line/wireReel /insulator.

At - ends of OH line- shackle insulators

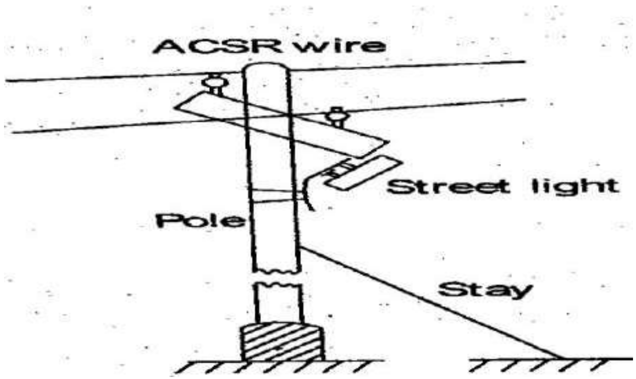
Total insulators = No.of poles x No. of insulators per pole
= 61 x 2 = 122

Reel/insulators = 59

Pin insulators = 59

Shackle insulators = 4

(d)layout of OH line and pole structure



(e)Estimate

S.NO.	Specifications of materials	Quantity	Remarks
1 2 3 4 5 6 7 8 6 7 8	RCC poles of 8m long with cross arms. ACSR conductor (7/2.59) Insulators Stay sets Earth set Fluorescent lamps with fittings Cement and concrete Misc, materials like Nuts, bolts, fittings etc.	61 6.24km 122 30 12 61 LS As required	Every fifth pole One an each pole

Example 3 : A 11KV ,3Φ,3wire OH line is to be laid for 2Km length with PSCC poles. Write the estimation of materials required. Assume span between poles is 80m.Assume any missing data.

Ans: Given :

Length of 11KV OH line = 2Km = 2000m

Span between poles = 80m

Size of conductor = 7/2.59, ACSR

Type of pole = PSCC

Req :

Estimate Of OH line for 2Km length

Sol :

(a)No. of poles =<u>Length of OH line(2000m)</u>+1

Span(80m)

=26poles

(b) Length of ACSR conductors = Length ofOH line x 2 = 2000 x3 = 6000m

Add 4% as sag/wastage = 6000 + 240 = 6240m or 6.24km

(c) No. of insulators

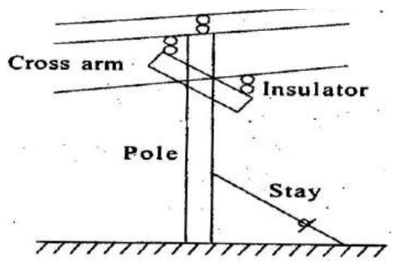
Each pole will have three (3) insulators(3-wire OH line)

Total insulators = No.of poles x No. of insulators per pole

= 26 x 3 =78

(d)layout of OH line and pole structure

ACSR wire



(e)Estimate

S.No.	Specifications of materials	Quantity	Remarks
1	PSCC poles, 8m long with cross arms	26	
2	ACSR conductors (7/2.59)	6.24 km	
3	Insulators	78	
4	(a)Pin - 72		
	(b)Disc - 6		
5	Earth sets	6	Atevery fifth pole
6			
7	Lighting arrestor	26	At each pole
8	Danger boards	26	At each pole
9	Barbed wire	52kg	
	Cement concrete	L .S	2kg on each pole
	Misc-material like Nuts, Bolts etc.	As required	

3.5. Preparation of detailed estimate for the quantity of materials required for Village Electrification

Village Electrification

The scheming of utilization of electrical energy in the villages is based on the village electrification broadly known as Rural Electrification. Rural electrification includes provisions of electric supply to non-electrified villages (i.e. these villages, where there is no electricity is available previously) by erecting distribution line, street lights and installation of suitable distribution transformers based on the load survey of the particular village.

3.5.1 Load survey

The load survey is performed to determine the approximate maximum load of a village including the load particulars of all types of consumers.

Each village or town will have one or more of the following types of

loads

1.Domestic loads

2.Industrial loads

3.Agriculture loads

4.Commercial loads

5.Street light loads

6. Churches, Mosques, Temples, Hotels etc

The 11 kV line is to be traced with minimum length. The length must be as straight as possible. The following obstacles may be encountered.

1.Private property, where right of entry is refused to the department of electricity.

2.Existance of ponds etc.

3.Existing telephone lines

4.Existing railway tracks

5.Horticultural obstacles etc.

3.5.2 Location of the Transformer

The transformer substation (pole mounted or plinth mounted transformer sub stations) has to be located preferably nearer to or at the centre of the load points.

If the village has sufficient agricultural load, domestic and industrial load , then it is better to install two transformer of suitable ratings at load points. One transformer for agriculture load as this load will be outside the village and the second transformer near the village to meet both domestic and industrial loads.

Example: Prepare an estimate for the quantity of the material required for village electrification.

Solution

Let us consider small village plan.

Load Survey: The total number of houses (including all types of loads 132 housesof people are willing to take the supply. The average load per each house is approximately 500 watts.

Load estimation: The different types of load particulars in the village are given below:

1. Domestic Load $= \frac{132\ X\ 500}{1000}$ = 66 KVA
2. Rice Mills $= \frac{3\ \ X\ 10HP\ X\ 735.5\ W}{0.8\,pf\ \ X\ 1000}$ = 18.38 KVA
3. Street Lights $= \frac{135\ No.X\ 40\ w}{1000}$ = 1.4 KVA
4. Agriculture pump sets $= \frac{1325\ No.X\ 7.5\ HP\ X\ 735.5W}{0.8\,pf\ X\ 0.8(\eta)X\ 1000}$ = 215 KVA

Total = 300.78 KVA

Taking a delivery factor 1.5. the capacity of the transformer = 1.5 x 300.78

= 451.17

It is proposed to install two transformers of ratings 200 kVA and 250 kVA (instead of a single transformer of 450 kVA.)

The line to be tapped for village electrification is at a distance of 1 km from the village.

The number of poles = $\frac{Total\ Distance}{Span} + 1$

Total distance = 1000+500+1000+500+500+250+250+250+350+250

= 4580 m

Assuming span = 50m

Number of poles = $\frac{6280}{50} + 1$

= 97+1

= 98

Within the village certain length needs single phase 3-wire and certain length three-phase 5-wire, certain length need 3-phase, 4-wire, whereas agriculture motors need 3-phase, 3-wire only.

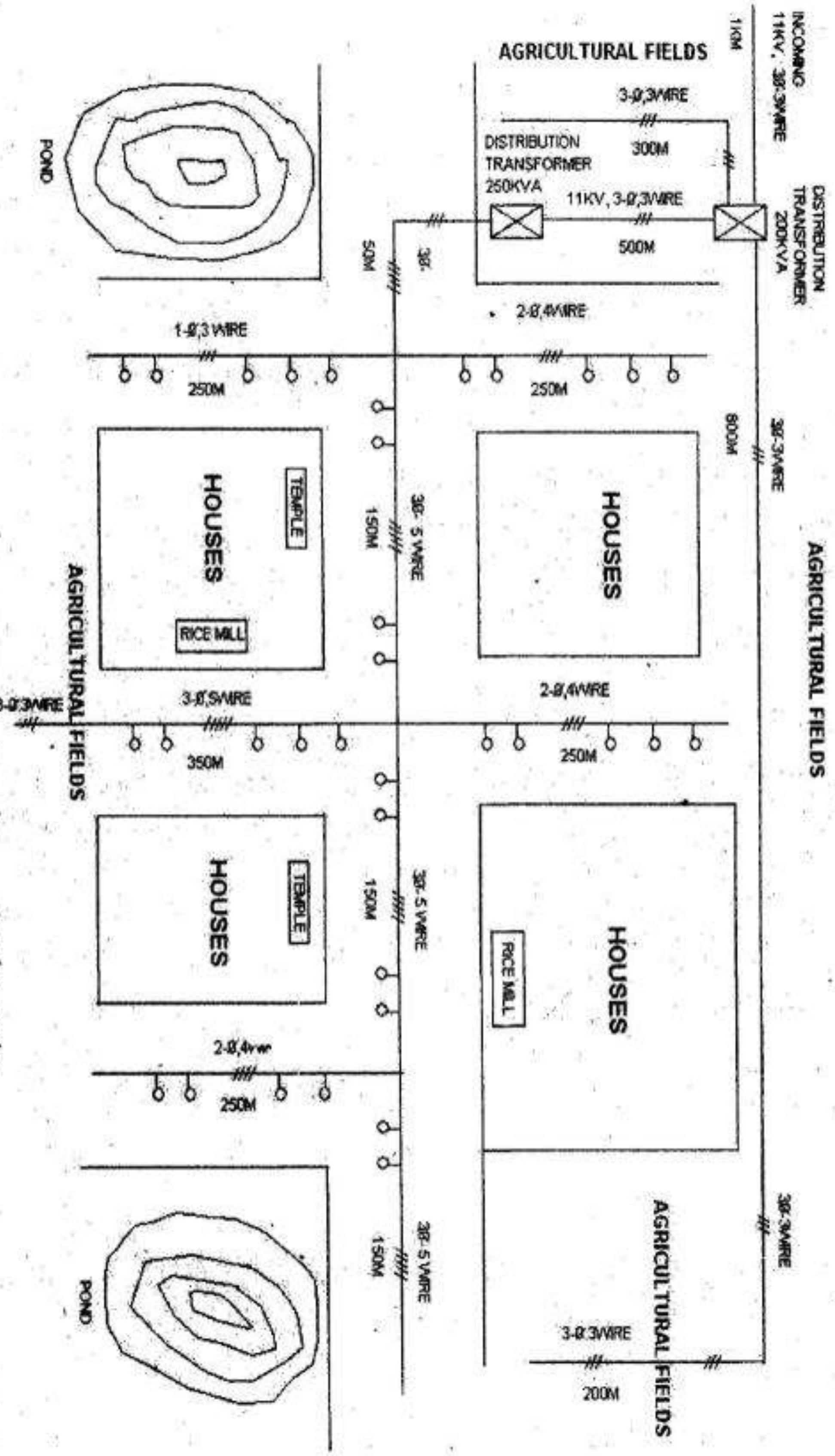
Length of 3-phase ,5-wire = 200+300 = 500 m

Length of 3-phase ,3-wire = 1000+500+1000+500 = 3000 m

Length of 2-phase ,4-wire = 250+250+250 = 750 m

Length of 1-phase ,3-wire = 250 = 250 m

Total = 4500 m



Plan and distribution scheme of a Small village (Say, Yelkanty, Medak District)

11KV pin insulator for 1000m $=(\frac{1000}{50}+1)x3 = 63$

LT Pin insulators (for 500m) =10 x 5 = 85

LT Pin insulators (for 2000m) = 40 x 3 = 120

LT Pin insulators (for 750m) = 15 x 4 = 60

LT Pin insulators (for 250m) = 5 x 3 = 15

Total LT pin insulators = 273

Length of ACSR conductor for 11 kV = 1000 x 3 = 3000 m

Length ofAAR conductor = (500x5)±(2000x3)+(750 x 4) + (250x3) = 12250m

Schedule of material

S. No.	**Specification of material**	**Qty**	**Remarks**
1	Transformer 250KVA 11 KV /440-V 3-Phase ,out door type with all accessories and oil filled	1 No.	Pinth mounted
2	Transformer 200KVA 11 KV /440-V 3-Phase ,out door type with all accessories and oil filled	1No.	Pole mounted
3	Rolled steel (joist) poles 175mm x 100 mm x 11 mm long	4 No	For H- Structure
4	PSCC poles 9 or 10 m long	98 Nos	
5	ACSR conductor 7/2.21	3000 m	For 11 KV line
6	AAC conductor 7/2.21	14000 m	
7	11KV pin insulators with pins	63 Nos	
8	Disc insulators with pins (3+6+3+5+3+5+3+3+3)	34 Nos	For dead end and H-Structure
9	L.T. pin insulators with pins	273 Nos	
10	M.S cross arms (angle iron) 1.52 m x75 mm x37 mm	123 Nos	(98+2500/50)
11	M.S flat cross arm clamps with nuts and bolts	123 Nos	
12	Top insulator brackets	25 Nos	
13	M.S channels 2m long 100 x 50 x 6 mm	2 Nos	For T/F flatform
14	M.S angles50 x50 x 6 mm – 2m long (3x2=6)	6Nos	For GOS HG fuses
15	M.S flat 50x6 mm- 2 m long	2 Nos	T/F belting
16	11 KV gang operating AB switch with 25 mm dia operating pipe and handle	2 sets	
17	11 KV Horn gap fuse units	2 sets	For two substations
18	ICTPN 200 A 500 V with rewireable fuses	3 Nos	
19	Stay sets(complete)	100 No.	
20	Earthing sets (complete)	10 sets	
21	Earth wire 8 SWG, GI	30 m	For earthing
22	Knee bracing sets	25	Cross arm supports

23	11 KV Lighting arresters	6 Nos	
24	Distribution of cable box	3 Nos	
25	Barbed wire	50kg	For fencing
26	Binding wire(alluminium)	3kg	
27	3 1/2 core 120 mm^2 conductor PVC insulated PVC Sheathed Cable	30 m	From T/F to DB
28	95 mm^2, single core alluminium conductor, PVC insulated ,PVC sheathed cable	75 m	From DB to LT Line
29	Nuts and bolts of different size(GI)	50kg	
30	Danger plates with paint	10 Nos	
31	Eye screw Nuts and bolts	4 Nos	One at each end for earth wire
32	Caradle guard	1 Nos	
33	Cement	2 bags	Pole foundation
34	sand	L.S.	
35	Plinth(Stones, Cement Etc.,)	1 No	For plinth T/F
36	Alluminium Paint	4 Lts	For steel poles
37	Sundries such as thimbles ,washes, solders etc.. to complete the work	L.S.	
38	Empire Tape	2 Rolls	
39	Alluminium Lugs	20 Nos	

Short Answer Type Questions:

1.What is the highest transmission line voltage in India till the end of the year 2019
2.How the OH distribution lines are classified based on voltage
3. How the OH distribution lines are classified based on disposition
4.What are the distribution voltages of LT and HT line.
5.What are the types of poles used in OH lines
6. How much of a pole length is to be buried in ground to have a good structure.
7.Define vertical disposition
8.List the types of insulators used in OH line
9.what is the purpose of poles and cross arm in OH line.

Long Answer Type Questions:

1.What are the major components of OH lines.
2.Write short notes on a) Insulators b) poles
3.Write short notes on
   a) Load survey
   b) village/rural electrification
   c) Location of a distribution transformer

UNIT 4

DISTRIBUTION SUBSTATIONS

4.1Types of Transformer Substations

Substation is Defined as assembly of apparatus used to change the one or morethan one electrical parameter of the Electrical supply.

The Generation of Electricity in Power Generating station is taking place at faraway place form consumer load centers due to various reasons . The voltages i.e11kv or 33 kv is stepped upto 132 kv,220kv or 400 kV and transmitted to load centre in India (where as in USA stepped upto 765 kV or 1050 kV). At load centers the high voltage is stepped down to 33 kv, 11Kv or 440v/230v and distributed. These voltage transformations are carried out at substations. Substations are of different types, they are

A.Based on Purpose

Step-up substations

Primary gird substations

Secondary substations

Distribution substations

Bulk supply and industrial substation

Mobile substations

Mining substations

Cinematograph substations

B. Based on Location

Outdoor

Indoor

Underground (basement)

C. Pole, Plinth mounted or open or Kiosk type substation

4.2Various components required in Erection of asub station

1.Poles **:**Steel(or PSCC) poles are required to carry the transformer and switch gear etc.
2.Transformer :11/0.4 kv, 3-phase (distribution)transformer.
3.Transformer plat form :MS channels are used for plat form preparation.
4.Insulator :Pin type (or disc type) insulators of 11 kv are used. `
5.Cross -arms :To erect the insulators gang operating switch.
6.Fuses : Horn gap fuses are usually provided on 11Kv side. Semi enclosed rewirable fuses are used on 400-V side.
7.Gang operating switch (GOS) :Used for On and Off the 11kV line.
8.Stays :Stays are provided to support the poles and structure.
9.Distribution Box :The consumers are supplied through distribution box.
10.Jumpers :ACSR conductor is used to connect the 11 kV lines.
11.AnticlimbingDevice : A barbed wire is found round the pole to prevent the climbing of unauthorized people.
12.Fencing :Fencing is provided around the poles with steel mesh to prevent the entry of animals, children's into transformer substation yard.
13.VIR **(**Vulcanised Indian Rubber) Cable **:**To connect transformer secondary to OH distribution line through distribution box (LT fuses).

14. LT fuses :High current rating fuses are provided in the distribution box only
15. Earthing :As per IE rules the pole mounted substation should be earthed at two or more places.
16. Danger Plates :Danger plates are provided on each pole specifying the voltage as a caution to the public.
17.Isolators :Isolators are provided to isolate the live line.

18.Lighting Arrestors :Lighting arrestors are provided on line to prevent the transformer and associated equipment from lighting strokes.

4.3 Preparation of detailed estimate of the quantity of materials and accessories required for Pole mounted substation

4.3.1 Supports for pole mounted sub station

Pole mounted substations are smallest among all the sub-stations and are located in thickly populated areas. Such sub stations are simple and cheap. All the equipment is out door type and mounted on the poles. Transformers of low rating such as 25,63,100 and 200 kVA are mounted on MS channels (or double channels) which are rigidly fastened to a two pole or H-type structure as shown in figure 4.1. The type of poles chosen for this type of sub stations are steel I section or steel rail poles of 10 m or 9m long.

For transformers of capacities 250, 300 and 400 kVA a platform is constructed on 4-pole structure. The type of poles may be of the same as mentioned above. If the area is not available for 4-pole structure and the constructional or erection charges are to be reduced then a two pole (H-type) structure with a struct (same pole piece) supporting the transformer will be placed in between the poles.

For transformers of rating upto 100 kVA can also be erected as shown in fig. 4.1This type of structure will be chosen when the area is not available for two pole structure and transformer erection is must. Fig. 4.1 shows a distribution transformer mounted on a pole. The h.v. system consists of the wires on the upper cross arm of the pole. Wires would lead from that system to the primary of the transformer. Other wires would carry the low voltage power from transformer secondary to the customer homes.

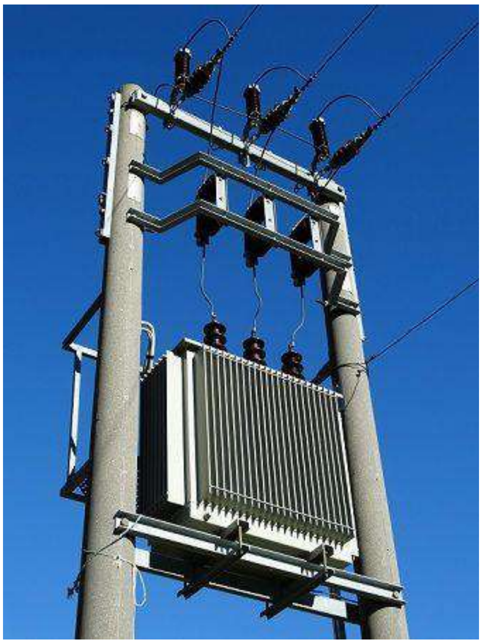
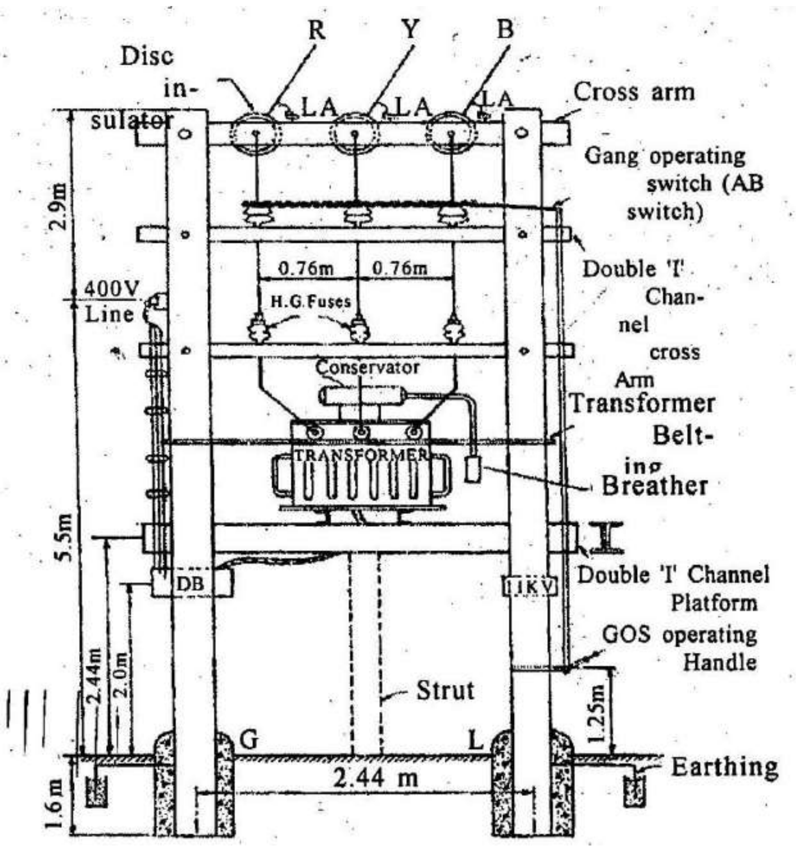


Fig 4.1 Pictorial view of Pole mounted sub-station

Exmaple 1: Draw the layout and make a list of material required for installing a Pole mounted Substation.

Ans:



Estimate of material and accessories for pole mounted substation

S. No.	Specification of Material	Qty.	Remarks
1	63 kVA, 11/0.4 kV transformer unit with Bushings	1 No.	
2	PSCC poles 10 m long	2 No.	For H-structure
3	Cross-arms - M.S channel 100 x 50 x 6 mm - 2m long With clamps	2 No. 5 No.	For supporting For OH line, GOS and
4	M.S. flat 50 x 6m ; 2m long	2 No.	For transformer belting
5	11 kV Gang Operating Air - brake, triple-pole 25 mm dia. Operating pipe & handle	1 Set	
6	11 kV lightning arrestors	3 No.	
7	11 kV disc insulators	3 No.	For dead end
8	11 kV horn-gap fuse unit (with post insulators &	1 set	For 3-phases
9	ICTPN, 100A, 500-V with fuses (rewirable)	1 No.	
10	ACSR or AAR conductor	18 m	Form OH line to
11	Stay sets (complete)	2 No.	
12	Earthing sets (complete)	2 No.	
13	3core, 50 mm, aluminum conductor, PVC insulated, PVC sheathed cable	30m	From T/F secondary to D.B.
14	Binding wire aluminum, Barbed wire, Nuts and bolts of different size, Danger plate, Cement, Sand, etc	LS	

4.4 Preparation of detailed estimate of the quantity of materials and accessories required for Plinth mounted substation

4.4.1 Support for Plinth Mounted sub station

For transformer of capacities exceeding 250 kVA are also installed on a foundation or plinth with a fence or wall surroundings it. This type of stations are called plinth-mounted or foundation mounted sub station and are used where sufficient space is available. Some times even less than 250kVA(i.e.. say 100KVA) transformers also of plinth mounted type, illustrated a 100 kVA distribution transformer installed on a plinth as shown in Fig.4.3.

Fig 4.3 plinth mounted substation

Example 2 : Draw the layout and make a list of material required for installing a Plinth mounted Substation.

Ans: Layout of Plinth mounted Substation

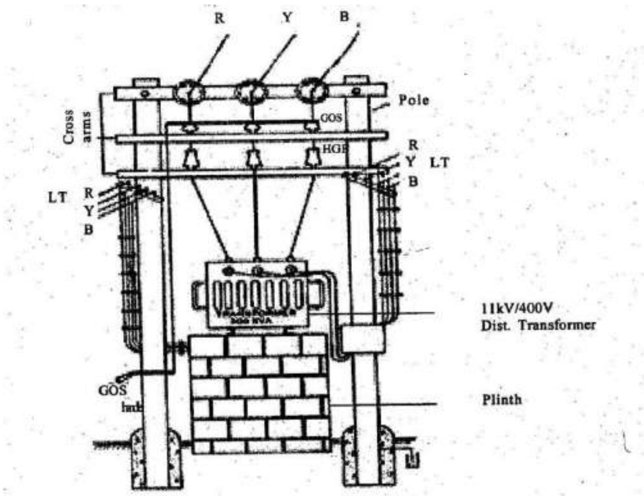


Fig.4.4Layoutofplinthmounted Substation

Estimate of material and accessories for plinth mounted substation

S. No	Specification of Material	Qty.	Remarks
1	300 kVA, 11 kV/400-V distribution transformer unit with all mountings accessories	1 No:	
2	PSCC poles/steel poles 11 m long	2 No.	For H-structure
3	11 kV Gang operating AEC switch with25 mm clia. operating pipe and handle	1 set	
4	11 kV horn-gap fuse units	1 set	For 3-phases
5	M.S. channels 100 x 50 x 6 mm long	4 No.	For Fixing GOSHG fuses 11 kV insulators & OCB
6	11 KV lighting arrester	3 Nos	
7	Cross arm clamps	8 Nos	
8	Binding wire alluminium	1 kg	
9	Barbed Wire	25kg	
10	Nuts and bolts of different size	L.S.	
11	Danger Plates	1No.	
12	Cement	Half bag	
13	Sand	L.S.	
14	Miscellaneous(red oxide, alluminium paint, tape, thimble etc.,)	L.S.	

4.5 Preparation of detailed estimate in a standard proforma for Pipe and Plate Earthing

Connecting an equipment (body) to earth through a conductor(thick wire)is called earthing. This is done for safety reasons. By earthing, we can by pass fault currents to earth.

There are four important methods of earthing.
(a) Pipe earthing(b) Plate earthing
(c) Rod type earthing (d) Strip type earthing

4.5.1 Pipe Earthing

In pipe earthing a GI pipe of 38mm dia, 2m long is buried in a pit of 2.5m depth, 30cm dia. The pit is filled with alternative layers of coal, salt and sand.

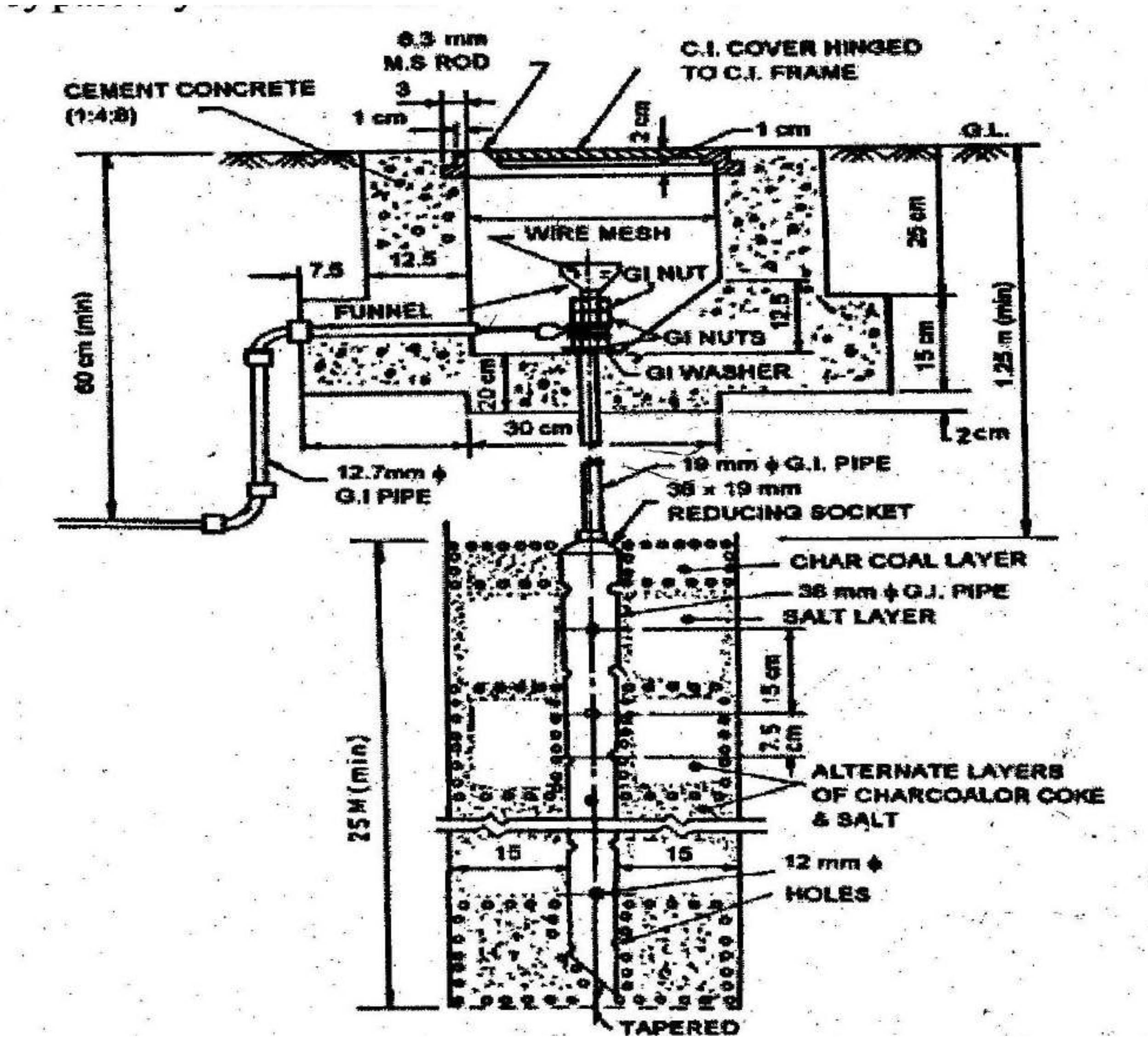


Fig.4.5 Pipe Earthing

A funnel is arranged at the top of earth pipe to pour water in order to provide humid in summer.

A GI wire of 8 SWG is connected at the bottom of rod and brought out and fitted at common earth point in the main board.

Estimation of Pipe Earthing

S.No.	Specification of material	Qty	Remarks
1	38 mm dia**GI.** pipe perforated	2.5 m	
2	19 mm dia**G I.** pipe	1m	
3	12.7 mm dia**G I.** pipe	2 m	
4	G I wire 8 SWG	6m	
5	G I(38 x 19 mm) reducing socket	1 No	
6	G Ilugs	2 No	
7	Nuts, bolts, locknut and washer for 19mm	2 sets	
8	**G.I.** bends 12.7 ram	2 No	
9	30x30 cm cast ironframe with hinges	1 No	
10	30 x 30 cm cast iron cover	1 No	
11	Funnel with wire mesh	1 No	
12	Charcoal or Coal (pieces)	20kg	
13	Cement concrete	L.S.	
14	Caution plate painted	1 No	L.S. = Lump Sum

4.5.2 Plate earthing

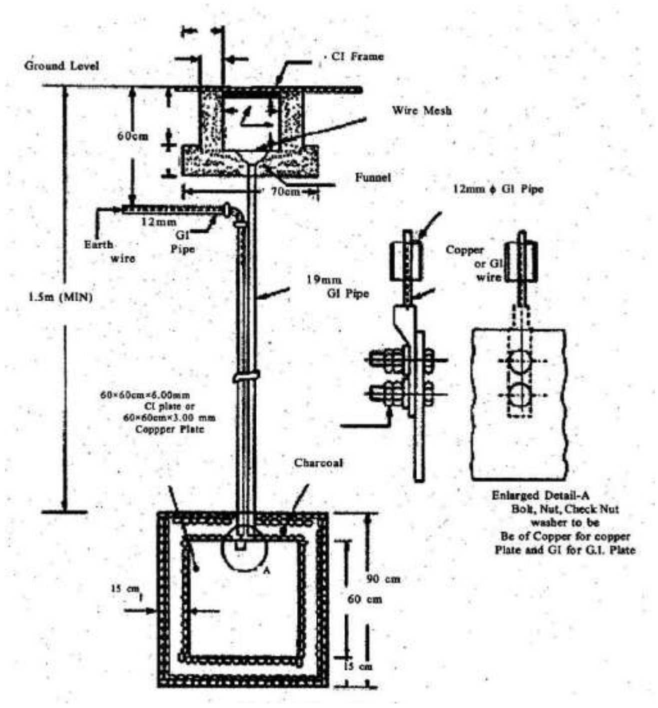


Fig.4.6 Plate Earthing

In Plate earthing a copper plate of 60cm x 60cm x 3.15mm or a GI plate of 60cm x 60cm x 6.30mm is burried in the ground at 1.5m depth. An earth wire of 8 SWG in firmly connected to' plate' and brought out from the pit through GI pipe. The earth wire is connected at main board.The the pit is filled with alternate layers of sand ,salt and coal.

Estimation of Plate Earthing

S.No.	Specification of Material	Qty.	Remarks
1	**G.I.** Plate 60 cm x 60cm x 6.30 mm	1No.	
2	G.I. wire (8 SWG)	4 m	
3	12.7 mm GI pipe	2m	
4	19mm GI Pipe	1.5 m	For watering
5	GI nuts, bolts, check nut and washers	6sets	Four at point 'A' and two for funnel
6	GI bend12.7	1 No.	For connecting earth wire
7	GI lugs	3No.	
8	Cast iron frame with hinges 30 x 30 cm	1 No.	
9	Cast iron cover 30 x 30 cm	1 No.	
10	Funnel with wire mesh	1 No.	LS = Lump Sum
11	Charcoal or coke	20 kg	
12	Salt	20kg	
13	Cement concrete	L. S.	
14	Caution plate painted	_ 1 No.	

Short Answer Type Questions

1. Define sub-station.
2. What are the types of Transformer sub-stations
3. Define earthing
4. what are the different methods of earthing.

Long Answer Type Questions

1. Write the various components of Transformer sub-station.
2. Write a short notes on
3. (a)Pole mounted sub-station (b)Plinth mounted sub-station

4. Draw a neat diagram of a pole mounted sub-station and label its parts.
5. Draw a neat diagram of a Plinth mounted sub-station and label its parts.
6. Prepare estimation of the material for a pole mounted sub-station
7. Prepare a schedule of material for a plinth mounted substation.
8. Draw a neat diagram of plate earthing and label its parts.
9. Draw a neat diagram of pipe earthing and label its parts.

UNIT 5

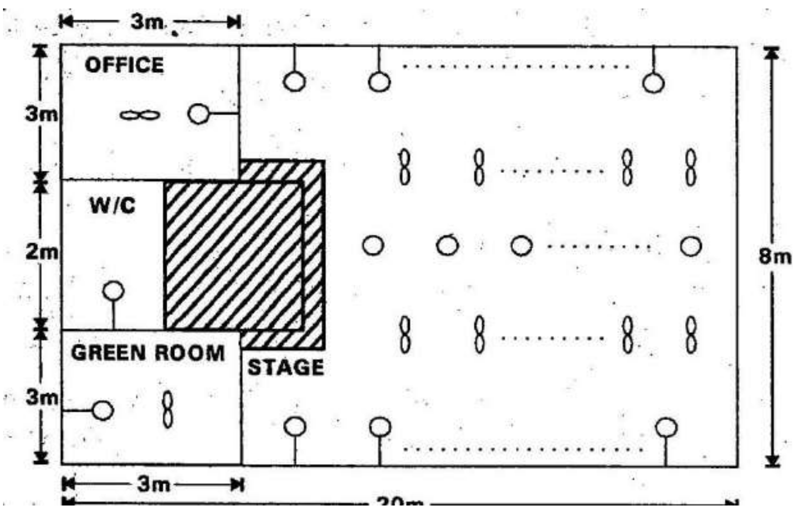
Theatre / Auditorium Wiring & Public address system (Field-visit)

Auditorium is the place where number of people assemble for various activities like meetings, functions etc.
Ex. Theatergoerz ground for party meetings/functions

5.1Basic Requirements of an Auditorium

1.Main distribution board -200 A, 3-Φ, 500 V,
2.Sub distribution boards -50 A, 3-Φ500 V,4 way
3.Change over switch -100A, 3-Φ ,500v, 4 pole
4.Film projector -1-Φ,250v, 2000w
5.Slide projector- 1-Φ,250v, 200w
6.Center auditorium light- 500w, 250v, 1- Φ
7.Ceiling fans located in auditorium/balcony/open places
8.Lighting located in auditorium/balcony/open places/ corridors
9.Sewage water pump
10.Drinking water pump
11.ICTP-N, 500v, 200A, 3-Φmain switch
12.15A, 1-way switches
13.6A,1-way and 2-way switches
14.6A,5 pin socket
15.15A,5-pin socket etc.

5.2 General Wiring Layout of an Auditorium



5.3 Preparation of detailed estimate for electrification of small auditorium in standard proforma

Electrical wiring installation of aAuditorium havethe following circuits

(a) One circuit for cabin i.e., projector and its accessories.
(b) One circuit for lights in auditorium /hall.
(c) One circuit for outside display and decoration.
(d) One circuit for stage/screen area.
(e)One circuit for PA system.
(f)Two circuits for fans, bathrooms, verandahs and other open places.
(g) Spare two circuits should be 3-Φ ,4-wire system.

Different lighting methods used in an auditorium

The following methodsof lighting is used in various places of aauditorium.

1.Stage - special lighting.
2.Audience area - (auditorium), indirect lighting.
3.Verandahs, bathrooms and other area - general lighting.
4.Displays, show case area - Decorative lighting.

Steps involved inPreparation of estimation for electrification of small auditorium in a standard proforma.

1.Preparation of the plan and electrical layout of the auditorium.
2.Determination of number of load points.
3.Determination of size and rating of the equipment and accessories.
4.Preparation of load schedule.
5.Preparation of the estimates of material and accessories in the standard proforma..

Example 1: Estimate the quantity of material and cost of wiring of a mini auditorium-of size 20 m x 8 m in surface conduit wiring. Assume any missing date.

Ans:

Given :

Size of mini auditorium(area) = 20 m x 8m =160m^2

No. of load points(light/fan) =*Total area of auditorium /10=160/10
=16

*Thumb rule

In total auditorium 16 lamps, 16 fans and 2 No's -5A, sockets, 2No's - 15A sockets may be arranged.

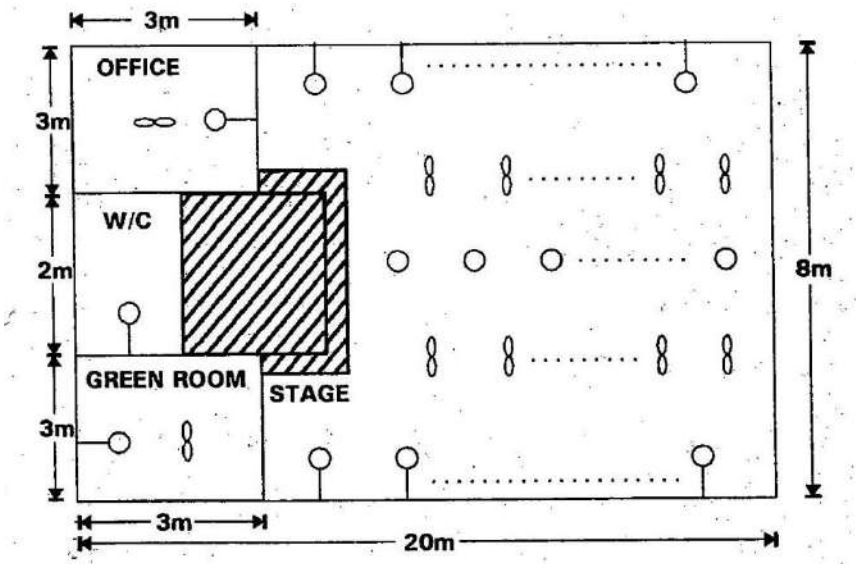


Fig.5.1 wiring plan

Load Schedule

S.No	**Lamps**	**No's**	**Walt**	**Total**
1	Lamp	16	100w	1600w
2	c/fan	16	80w	1280w
3	5A sockets	2	100w	200w
4	15A sockets	2	1500w	3000w
	TOTAL	36		6080w

Estimate of Materials and Accessories

S.No	Specification	Qty.	Unit	Rate	Amount	Remark
1	60A. 500v, ICTP-N	1No	each	300	300=00	
2	60A, 500V, 3Φ, 10 way D/B	1	each	1500	1500=00	
3	1" conduct (PVC, rigid)	160m	m	5	800=00	Conduit length= Area of Building = 8 x 20 = $160m^2$
4	1.5mm^{2}pvc/cu cable	480 = 500m	m	7	3500	
5	Sadles 1" size	160 x 2 =320	each	3	960=00	
6	6A, 250v, 1-way switches	32	each	15	480=00	
7	15A, 250v, 1-way switches	4	each	25	200=0	
8	6A, 250v, socket	2	each	15	30=00	
9	15A, 250v, socket	2	each	25	50=00	
10	Ceiling roses	32	each	2	64=00	
11	Boards for MB/DB/SB	5	each	50	250=00	
12	L'S.T'S. BandsJunction Boxes	LS	LS	LS	2500=00	
13	Screw, Nails/guties/cement	LS	LS	LS	500=00	
14	Labourcharges	L.S	L.S	L.S	7000=00	

Note : 1. Here length of wiring was calculated based on the area of building.

2. Length of cable for wiring = length of wiring x 3.

3. No. of load point are also selected on the basis of area of building.

5.4.Public Address system - Major components of P.A. system

The orderly arrangements of various equipment like microphones, amplifier, speakers etc., is called PA system or public address system. It is used intheatre, cinema hall, meetings, cultural activities etc., so that all audience can enjoy the music systems.

The main types of PA systems are :

1. Outdoor PA system used in open air grounds,
   Ex.Public meetings, Advertisements etc.
2. Indoor PA system used in indoor i.e., inside of (closed) buildings

Ex. Auditoriums, Theatres etc.,

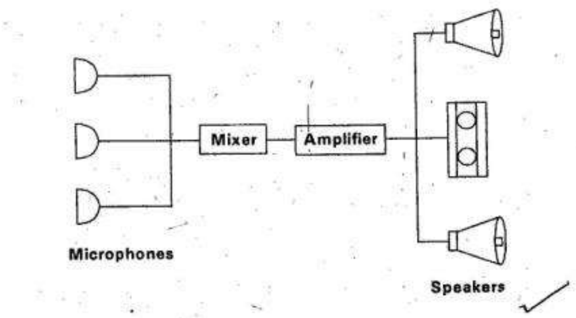
3. Special PA systems used in musical concerts

Ex. Orchestras (DJsystems) etc.

5.4.1 Major components of public address System

1. Microscophones.
2. Mixers.
3. Amplifiers.
4. Speakers/sound column/horns/ and other materials are as below.
   a. Coaxial cables
   b. Shielded cables
   c. Twin cord cable
   d. Conduct pipes, bends, cables (for indoor PA system)
   e. Matching Transformers.

Layout of PA system



5.4.2 General specifications of main equipment used in PA system

1.Amplifier:

Output power: 500w/350w/250w/160w/120w/100w/80w/60w/40w 500w/40w.

Input channels: (5 +2)/.... /(2 + 1)

Frequency response:50Hz to 15KHz,± 3dB

Speaker output parts : 4W, 8W, 16W, 70V, 100V

1. Mixers :

No. of channel: 14/ 12/ 10/8

Frequency response :30Hz to 20kHz

Output: 10dB to + 17dB

2. Microphones :

Type: Dynamic, condenser, pizo-electric etc.

Frequency response :50Hz to 15kHz

Impedance: 300 to 1000 ohms.

3. Loud speaker :

Type:Column type, horn type

Output power: 16w to 600W

5.5. Prepare a detailed estimate and layout of Public Address system for a Hall, Open ground

How the equipment of PA system is selected for auditoriums, open places etc.

1. PA system is different for indoor and outdoor applications
2. In indoor PAsystem (like theatres, auditorium etc.) Audio-amplifier, dynamic microphones,mixture, sound column and shielded cables are used.
3. Butin outdoor PA system, Audio power amplifiers. Dynamic microphones mixers, soundcolumn, horns, twin cord cables etc., are used.
4. . The rating and quantity of equipment are depends on size of auditorium/ open ground.

The main equipments used in Indoor PA system

100 to 250w PA amplifier - 1No

Dynamic microphones - 2 to 4No

8-channel mixer - 1 No

Sound column of 32w-6 to 12 No's

[Double the capacity of Amplifier selected i.e., Total wattage / rating of speakers = 2 x amplifier rating]

The main equipment used in outdoor PA system

250w PA amplifier	-	1No
250w power amplifier	-	1No
Dynamic microphones	-	4 to 8 no's
12-channel mixer	-	1No
Sound column of100w	-	6-8 No's
Horns of 32w	-8No's and shielded cables, Twin cords etc.	

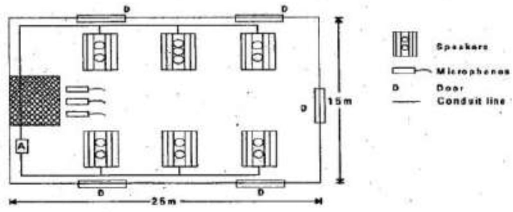
5.5.1 Public Address System For A Hall :

Example 1 : Install a PA system in a hall of 25 m x 15 m. Assume any other data?

Given :Size of hall =25m x 15m=375m^2

Type of PA system = Indoor (Hall).

Layout of PA system in Hall



2. Equipment and material

Amplifier- PA Type, 250w, 1No

Loud speaker - Column type 100w each, 6Nos

Micro phones - Dynamic type, 4 No's

Conduct length - 5 + 25 +15 = 65 or 70m (see layout)

(circumference)

3. Estimate

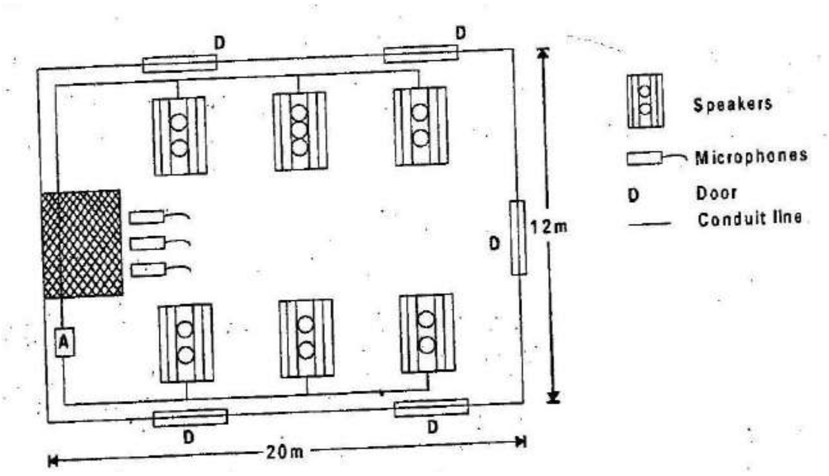
S.No	Specification	Qty.	Unit	Rate	Amount	Remark
1	250w, PA amplifier	1	each	10,000	10,000-00	
2	Dynamic microphone	4	each	800	3,200-00	
3	Sound column 100w	6	each	1,000	6,000-00	
4	3/4" PVC conduit	70m	m	5	350-00	Asper layout wiring lengthx2 Asper length
5	Saddles	140	each	2	280-00	
6	Shielded cable	70m	m	5	350-00	
7	Screw, nuts cement etc.,	LS	LS	100	100-00	
8	Labour charges		LS	800	800-00	

Example 2: Estimate the quantity of material required and its cost for PA system is to be providedpermanently in assembly hall of size 20 x 12m. Assume any other required data.

Size ofhall= 20 m x 12m=240m^2

Type of PA system = Indoor (Hall)

Sol **: 1.Layout of PA system in Hall**



2.Equipment and material

(a)Amplifier- PA Type, 250w, 1No

(b) Loud speaker - Column type 100 each, 6Nos

(c) Micro phones - Dynamic type, 4 No's

(d) Conduit length - 20 + 20 +12 = 42 or 50 (see layout)

3. Estimate

S.No	Description	Qty	Unit	Rate	Amount	Remark
1	250w, PA amplifier	1	each	10,000	10,000-00	
2	Dynamic microphone	4	each	800	3,200-00	
3	Sound column100w	6	each	1,000	6,000-00	
4	3/4" PVC conduit	50m	m	5	250-00	As per layout wiring lengthx2 As per length
5	Saddles	100	each	2	200-00	
6	Shielded cable	50m	m	5	250-00	
7	Screw, nuts cement etc.,	LS LS	LS LS	100 800	100-00 800-00.	
8	Labour climes	LS	LS	800	800-00.	

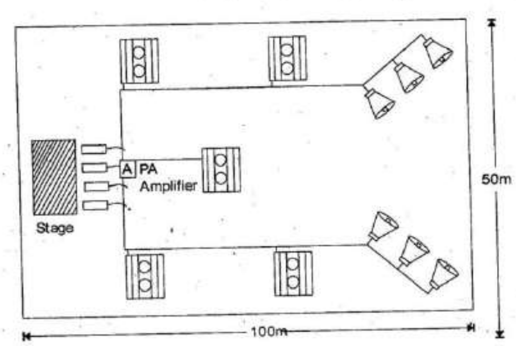
5.5.2 Public Address system for Open Ground

Example 1 : Estimate the quantity of material and equipment for arrangement of sound system in a college ground of size of 50m x 100m. Assume any other-missing data.

Size of ground = 50m x 100m=5000m^2

Type of sound system / PA System = Outdoor (open ground)

1. Layout of PA system



2.Equipment and material:

PA amplifier - 250w, 1 No.

Power amplifier-250w, 1No.

Microphones Dynamic type 8 No.

Mixer 12 way.

Column speakers 200w.

Horns 32w, 6No's.

Line output Transformers - 6 sets.

Twin cord cable, poles /supports /stands - for speakers.

Length wire/cable =100m + 100m + 50m + 50m = 300m(see layout).

3.Estimate

S.No	Description	Qty	Remark
1	250w, PA amplifier	1 No	
2	250w power amplifier	1 Nosystem	Used in outdoor PA
3	Dynamic microphones	8 No’s	
4	Sound column, 200w	5 No's	
5	Horn speaker, 32w	6 No's	

6	Twin cord wire/cable	300m	
7	stands /supports for fixing of speakers	7 sets	
8	Misc .items	7 sets	

Short Answer Type Questions

1. What is an auditorium ?
2. What are the different wiring circuits used in an Auditorium?
3. What are the different types of lighting methods used in an Auditorium?
4. Draw a general wiring layout of an Auditorium.
5. What is a Public Address System (PA-system)?
6. What are the different types of PA-system?
7. Draw a general layout of PA-system.
8. What are the main equipments used in Outdoor PA-system?

Long Answer Type Questions

1. What are the basic requirements of an Auditorium?
2. What are the major components of a PA system?
3. List out the main components used in a PA-system along with the specifications.
4. Estimate the quantity of material required and its cost for PA system is to be provided permanently in seminar hall of size 30m x 12m. Assume any other required data.
5. Estimate the quantity of material and equipment for arrangement of sound system in a open ground of size of 60m x 90m. Assume any other-missing data.

UNIT 6

IE RULES

6.1 Extracts from IE Rules 1956

The main aim of framing Indian Electricity Rules is to

1. Safeguard the consumer from electric shock
2. Minimize the fire risk
3. Ensure Satisfactory operationof equipment and apparatus used

Preliminary

Rule I Short title and commencement

1. These rules may be called as the Indian Electricity Rules 1956.
2. They shall come into force on 26th June 1956.

Rule 2 Definition

1. In these rules, unless the context other wise requires,

a) The act means in Indian Electricity Act 1910.

b) "Accessible" means with in physical reach without the use of any appliance or special effort.

c) "Apere" means unit of electric current and is unvarying electric current which when passed through a solution of nitrate of silver in-water, in accordance with the specification set out in Annexure I, deposits silver at the rate of 0.001118 of a gram per second.

d) "Apparatus" means electrical apparatus and includes all machine, fittings accessories and appliances in which conductors are used. "Authorized" person means a person authorized under Rule 3.

e) "Bare" means covered with insulating material.

f) "Cable" means a length ofinsulated single conductor (solid or straded) or of two or more such conductors each provided with stranded) or two or more such conductor each provided with its own insulation which are laid up together and insulated conductors or may not be provided with an overall mechanical protective covering. "Flexible cable" means a cable consisting of one or more cores each formed a group of wires, the diameter and the physical properties of the wires and the insulating material being such as to afford flexibility

g) "Circuit' means an arrangement of conductor or conductors for the purpose of conveying. energy and forming a system or branch of a system.

h) "Circuit breaker" means a device capable of making and breaking the circuit under all conditions. and unless otherwise specified so designed as to break the current automatically under abnormal condition.

i) "Concentric cable" means a composite cable comprising an inner conductor which is insulated and one or more outer conductors which are insulated from one another and are disposed over the insulation of and more or less around the inner conductor.

j) "Conductors" means any wire cable bar tube rail or plate used for conducting energy and so arranged as to be electrically connected to a system.

k) "Conduit" means rigid or flexible metallic tubing or mechanically strong and fire resisting non metallic thing into which a cable or cables may be drawn for the purpose of affording it or them mechanical protection.

l) "Covered" with insulating material means adequately covered with insulating material of such quality and thickness as to prevent danger.

m) "Cut -Out" means any appliances for automatically interrupting the transmission of energy through any conductor when the current rises above predetermined amount and shall also include fusible cut-out.

n) "Danger" means danger to health or danger to life or any part of body for shock bum, or other injury to person, or property., or form fire or explosion attendant upon the generation , transmission, transformation , conversion, distribution or use of energy.

o) "Dead" means at or about earth potential and disconnect from any live system. Provided that apparatus separated from a live conductor by a spark gap shall not be deemed to be dead.

Note : The team dead is used only with reference to current carrying parts when the parts to be dead.

p) "Earthen" or connected with earth means connected with the general mass of earth in such manner as to ensure at all times and immediate " discharge of energy without danger.

q) "Earthing system" means the electrical system in which all the conductors are earthen.

r) Electrician means a person over 21 years of age who is competent for the purpose of the rule in which the term is used and who has been appointed in writing by the leases owner, or manager of installation.

s) "Enclosed sub-station" mean any premises or enclosure or part thereof being large enough to admit the entrance ofa person after the apparatus there in in position, containing apparatus for transforming or converting energy to or from voltage at or above medium voltage (other than transforming or converting solely for the operation of switch gear or instruments) with or without any other apparatus for switching controlling other wise regulating the energy and includes the apparatus therein.

t) "Enclosed switch station" mean any person or enclosure or part thereof being large enough to admit the entrance of a person after the apparatus there in is in position, containing apparatus for switching, controlling or otherwise regulating energy at or above medium voltage but not for transforming or converting energy (other than for transforming on converting solely for the operation of switch gear on instruments) and includes the apparatus therein.

u) "Guarded" means covered shielded fenced or otherwise protected by means of suitable casing , bather rails or metal screen to remove the possibility of dangerous contact or approach by a person or objects to a point of danger. "Hand held portable apparatus" means a apparatus which is so designed as to be capable of being held in the hands and moved while connected to a supply of electricity

v) Inspector" means an electrical inspector appointed under section 36.

w) "Installation" means any composite electrical unit used for the purpose of generation transforming, transmitting, converting, and distributing and utilizing energy.

x) "Intrinsically safe" as applied to apparatus or associated circuits shall denote that any sparking that may occur in normal working is incapable of causing explosion of inflammable gas or vapour.

y) "Lighting arrester”" means a device which has the property of diverting to earth any electrical surgeon of excessively high amplitude applied to its terminal and is capable of interrupting follow current if present and restoring itself thereafter to its original operation conditions. "Linked switch" means a switch with all poles mechanically lined so as to operate simultaneously.

z) "Live means electrically charged.

aa) "Metallic" covering means mechanically strong metal covering one or more conductors.

ab) "Neutral conductor" means the conductor ofmultiwire system the voltage of which is normally intermediate between the voltages of the other conductors of the system and shall also include return wire of the single phasesystem.

ac)"Occupier" means the owner or person in occupation of the premises where energy is used or proposed to be used.

ad)"Ohm" means a unit electric resistance and is the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14.4521 gram in mass of an uniform cross sectional area and of a length 106.3 centimeter the aforesaid unit is represented by the resistance between the terminals of the instruments marked government of India ohm standard verified, to the passage of an electric current when the coil of wire, forming part of the aforesaid instruments and connected to the aforesaid terminals is in parts at a temperature of 30°C.

ae) "Open sparking" means sparking which owing to the lack of adequate provision for preventing the ignition of inflammable gas external to the apparatus would ignite such inflammable gas.

af) "Over head line" means any electric supply line which is placed above ground and in the open air but excluding live rails of traction system.

ag) "Portable apparatus" means an apparatus which so designed as to be capable of being moved while in operation.

ah) "Portable hand lamp" means a portable light fitting provided with suitable handle guard and flexible cord connected to a plug.

ai) "Span" means the horizontal distance between two adjacent supporting points of an overhead conductor.

aj) "Street box" means totally enclosed structure either above or below ground containing apparatus for transforming switching, controlling or otherwise regulating energy.

ak) "Supplier" mean a license a non-license or any other supplier of energy including the government.

al) "Switch" mean **a** manually operated device for opening and closing for changing the connection of a circuit.

(ala) "Switched board" means an assembly including the switch gear for the control of electrical circuits electric connection and the supporting frame.

am) "Switch gear" shall denote switches circuit breaker cut coil and other apparatus used for the operation regulation and control of circuits.

an) "System" means an electrical system in which all the conductors and apparatus are electrically connected to a common source of electric supply

ao) "Transportable apparatus" means apparatus which is operated in a fixed position but which is so designed as to be capable of being moved readily from one place to another.

ak) "Volt' means a unit of elect° potential measured in volts between any two conductors or betweenany part of either conductor and the earth as measured by a suitable voltmeter and is said to be

Low : Where the voltage does not exceed 250 volts under normal in volts between any two conductors or between any part of either conductor and the earth as measured by a suitable voltmeter and is said to be
Medium : Where the voltage does not exceed 650 volts under normal conditions subject however to the percentage variation allowed by these rules.
High : Where the voltage does not exceed 33,000 volt under normal conditional subject, however to the percentage variation allowed by these rules.
Extra High: Where the voltage exceeds 33,000 volt under normal condition subject however to the percentage variation allowed by these rules.
(aq) "Voltage" means a unit of electro-motive force and is the electric pressure which when steadily applied to a conductor the resistance of which is will produce a one ampere.

6.1.2 Code of Practice by AP TRANCO to supply electrical energy

Rules 47. Testing of Consumer installation:

1. Upon receipt of an application for anew or additional supply of energy and before connecting the supply or reconnected the same after a period of six months, the supplier shall inspect and test the applicant installation. The supplier shall maintain a record of test result obtained at each supply point to a consumer in a form to be approved by the inspector.

2. If as a result of such inspection and test the supplier is satisfied that the installation is likely to constitute danger, he shall deserve on the applicant a notice in writing requiring him to make such modification as are necessary to render installation safe. The supplier may completed and he has been noticed by the applicant.

6.2 IE rules connected with Domestic and Industrial wiring

Domestic wiring

1.The minimum size of conductor used in domestic wiring must not be of size less than 1/1. 12mm in copper or 1/1.40 mm (1.5mm) in aluminium wire.

2.For flexible wires the minimum size is 14/0.193 mm.

3.The height at which meter board main switch board are to be fitted should be equal to 1.5 meters form ground level.

4.The casing will be run at a height of 3.0 meters from ground level.

5.The light brackets should be fixed at a height of = 2 to 2.5 meter from ground level.

6.The max No. of points in a sub circuit is restricted to a maximum of 10.

7.The maximum load in a light load sub circuit is 8800w.

8.Flexible cable should not be used in the work shop, and other places where they are liable to mechanical damage, unless they are mechanically protected by conduits or sheath.

9.3-core flexible cable is used for connecting of 1-phase appliances the third core is used for earthing of appliance.

10.In general "looping wiring system" is done to avoid the joint phase are live conductor is looped at the switches and neutral conductor at the points.

11.Separate and distinct circuits for lighting, fan, heating and power wiring shall be kept.

12.In the wiring system no bare are twist joint shall be done. If in any case joint is required it should be made by a connector of suitable current carrying capacity injunction box of approved type and design.

13.The third pin of all wall sockets must be earthed with minimum size of earthed conductor of GI SWG or Aluminium 4 mm^2.

14.Proper distribution of load should be done at the main distribution board and also at the branch D.B.

15.The land should be arranged in such a way that it is balanced on all the phases in case of 3-phase, 4-wire system or poly phase system.

16.Distribution board should be located at convenient points, preferably at load centre.

17.The main switch or switch gear should be located at a place where easily a accessible to disconnect the supply when required.

18.The phase positive neutral or negative and earth should be distantly marked at the main and branch D.B.S as per the I.E. rule, 32 of 1956.

19.All the main switch gear should be of metal Glade and must be fixed on metal frame.

20.All the metal boards must be double earthed for medium, high and extra high voltages.

21.All the switch boards must be fixed with "danger notice plate" in Hindi and in local language for medium, high and extra high installation.

Industrial wiring or power wiring

1.In a power sub circuit the load is normally exceed restricted to 3000 watts and number of outlets to 2 on each sub circuit

2.All equipment used in power wiring shall be of iron clad construction and wiring shall be of the armored cable or conduit type.

3.Wood work shall not be used for mounting of Iron Clad switch control of distribution gear.

4.Looping of conductors and use of the joints shall not be allowed.

5.The length of flexible conduit used for connection between the terminal boxes of motors and starters, switches and motor shall not be exceed 1.25 meters.

6.Every motor regardless of its size shall be provided with a switch fuse placed near it.

7.In addition of switch fuse all motor shall be provided with suitable means for starting and stopping (starter) placed at convenient places . The starters are used to limit the starting current to a desirable value. Direct on in starters , star delta starters, auto transformer starter (or rotor resistance starter in case of slip ring induction motor) are used for ac motors of ratings upto one bhp above 1 bhp and below 15 bhp and above 15 bhp respectively.

8.The circuit enclosing VIR and PVC cables are usually run on surface rather than laying them in covered trenches. This is because it facilitates addition and alterations.

9.Though the cables for more than one motor can be enclosed in open conduit but using separate conduit for every motor is preferred.

10.The minimum cross sectional area of conductor that can be used for power wiring is 1.25 mm for copper conductor cables and 1.50 mm for Al conductor cables (refer ISI recommendation) . Hence VIR or PVC cables of size lower than 3/0.915 mm copper or 1/1.80 mm Al can not be used for motor wiring.

11.The current rating of cables for supply to motor may be based upon the normal full load current of motor but the rating of the fused should be based upon the starting current i.e. fuse should be capable carrying the starting current of motor. Since in no case the rating of fuse should be greater than twice the rating of cables. So for deciding the rating of fuse stand cable, following two points should be kept in view.

(a)For motors above 15 bhp which have starting current lower than twice their normal full load, the current rating of the cable should be based on normal full load current of motor current rating and fuse should be based upon motor starting current.

(b)For motor below 15bph which have a very heavy starting current a fuse should be current rating to carry the starting current of motor safely and cable should be of current rating not lower than half of current rating of use.

12.The conduit used in power wiring shall be electrically continuous throughout and connected to the frame of the motor. The frame of the motor shall be earthed by the owner by two separate and distinct connections to earth.

13.The wire used to earthing conductor shall be of copper or galvanized iron. The cross sectional area of copper earthing wire should be not smaller than half of the largest current carrying conductor used in wiring. The cross-sectional area of GI wire, if used as an earthing conductor should be such that its conductivity is not less than that of copper conductor.

Since supplier provides and maintains only a suitable earthed terminals at or near the point of commencement of supply at the consumer premises so the consumer is required to provide his own earthing system with an independent electrode.

14.The main switch or switch gear should be located at a place where easily accessible to disconnect the supply when required.

15.The phase positive neutral or negative and earth should be distintly marked at the main and branch D.B.S as per the I.E.rule, 32 of 1956.

16.All the main switch gear should be of metal clad and must be fixed on metal frame.

17.All the metal boards must be double earthed for medium, high and extra high voltages.

18.All the switch boards must be fixed with "danger notice plate" in Hindi and in local language for medium, high and extra high installation.

Equipment to be earthed

i.Earth pin of 3-pin lighting plug socket and 4 pin power plug sockets should be permanently and efficiently earthed.

ii. All metal casing or metallic coverings containing or protecting any electric supply line or protecting any electric supply line or apparatus, such as iron clad switches, iron clad distribution fuse boards, GI pipes and conduits enclosing VIR or PVC cables the downrods of electric fans, should be connected to earth.

iii. The metal casing of portable apparatus such as heaters, refrigerators, hand lamps, soldering irons, electric drills etc, should be connect to earth. Ifany of them is installed in a fixed position a separate direct connection to the earth should be provided in addition to the earth wire in the connecting cable.

iv. The frame of every generator, stationary motor, and so far as is possible, portable motor and the metallic parts (not intended as conductors) of all transformers, an d any other apparatus used for regulating or controlling energy and all medium voltage energy consuming apparatus should be earthed by two separate and distinct connections with earth.

v. The neutral conductor of a 3-phase, 4-wire system and the middle conductor of a 2- phase, 3-wire system should be earthed by not less than two separate and distinct connections with earth at the generating station and at the substation. It may also be earthed at one of more points along the distribution system or service line in addition to any connection with earth, which may be at the consumer's premises.

vi. In the case of a system comprising electric supply line having concentric cables, the external conductor of such cables should be earthed by two separate and distinct connections with earth.

vii. Ina D.C. 3-wire system the middle conductor should be earthed at the generating station.

viii.Fabricated steel transmission line towers, tubular steel or rail poles carrying overhead conductors should be earthed. For this purpose a continuous earth wire is provided and connected with earth at four points in every mile (1.61 km), the spacing between the points being as nearly equidistant as possible, alternately, the metal work should be connected to an effective earthing device at each individual support.

ix. Stay wires provided for overhead lines should be connected to earth by connecting at least one strand to the wire.

6.2.1 Indian Electricity rules regarding Insulation resistance and permissible voltage drops

1.I.E. Rules No. 48 the insulation resistance between the wiring of an installation and earth should be of such value that the leakage current may not be exceed 21/5000 the part or 0.02 percent of the full load current.

2.The permissible voltage drop in a lighting circuit is 2% of the supply voltage plus on volt.

3.The max permissible voltage drop in a power or industrial circuit should not be more than 5% of the declared supply voltage.

4.The insulation resistance should not be more than 0.5M ohm/No of outlets.

5.In any case the value should not be more than 0.5M ohm and, need not to be more than one mega ohm.

6.In case of PVC wires insulation resistance must be 12.5Mohm/No of outlets.

7.The earth resistance should not exceed the value of one ohm. Higher than this value shows that conduit or switch has not been properly earthed.

6.3 Testing of Electrical Installation as per IE Rules

Before any new electrical installation or an addition to an existing installation is to be connected to the supply main, a number of tests have to be carried out to ensure that there are no defects in the installation which may cause danger. The various tests to be conducted are

1. Insulation resistance between conductor and earth.
2. Insulation resistance between conductors
3. Wiring continuity (or oc test) test.
4. Polarity testing of single pole switch.
5. Earth continuity test

6.3.1 Insulation resistance between conductor and earth

This test is conducted on cables to identify the leakage current

As per IE Rules 48 the leakage currant should not exceed 1/1500 the part(0.02%)of the full load current . For this test DC Voltage not less than twicethe working voltage but not greater than 500v should be applied.

Before conducting the test ensure the following

Energy meter output terminals should be connected.

- Put the main switch ON
- All fuses in the main switch should be in position.

- All other fuses (on distribution board) should be in position.
- All switches should be in 'ON' position.
- All the lamps and fans should be in their position.
- Outlet points should be short circuit.
- Live and neutral wire should be short circuited (S.C) near Energy meter.

Connect the megger to the installation. Now rotate the handle of the megger until it slips, at which it generates the specified voltage and the readingson the dial should be noted. The insulation resistance measured in mega ohm should not be less than 50MΩ divided by the number of outlets.

Insulation Resistance : 50 mega-ohm number of outlets(switches+ sockets)

However the whole installation need not be required to have resistance greater than one mega-ohm . Ifany appliances are not connected during the test must be tested separately and the insulation resistance between the frame and live part must not beless than 0.5 mega ohm.

6.3.2 Insulation Resistance between conductors

The insulation resistance between line and neutral in a single installation and between all the pairs possible in a 3-phase 3-wire or 4-wire installation. The aim of this test is to ensure that the insulation between any two conductors is sound.

The connection diagram for this test is same as previous test except the following
1.The short circuit near the meter out put is removed.
2.All the lamps form the holders and the appliances or apparatus from the outlets (sockets) are removed
Rest of all things remain as it is. Main switch ON main fuses and D.B. fuses in position . The megger L and E terminals are connected to two terminals (line and neutral) between which the insulation resistance is to be measured.

The insulation resistance so measured should not be less than50MΩ divided by the number of outlets(i.e. must not be less than 1mega ohm) . In case of PVC insulation the insulation resistance should be less than 12.5MΩ divided by the number of outlets.

When fluorescent mercury vapour, or sodium vapour lamps are used, low readings (<1 MΩ) may be obtained owing to choke or transformer present between line and neutral. Low readings may also be obtained due to Transformer or motor windings. In such case the insulation resistance must not be less than 35M ohm.

6.3.3 Wiring Continuity Test

The object of this test is to ensure the continuity of the wirings of the circuit or sub-circuit i.e. any opening (O.C) in the wiring can be detected.Before conducting the test ensure the following

- Put the main switch OFF.
- Remove all the fuses from the distribution board.
- All the lamps, fans etc, should be in the circuit.
- All the switches should be in the OFF position.

6.3.4 Polarity Testing of Single-Pole switch

All the switches should he connected in the live or phase wire (not in neutral) of the circuit to make the lamp or appliance quite dead when the switch is made off .if the switch is connected in the neutral ,the lamp holder or appliance will remain live even when the switch is off. Which may lead to shock and hence accidents. The neutral must be continuous and unbroken.

To verify whether the switches are connected in the live or not, a simple test should be conducted. Before testing ensure the following:

- All the lamps should be removed from the holders.
- All the appliances should be disconnected.
- All switches should be put in 'ON' position and their covers should be opened.
- The main switch should be in 'ON' position.
- The distribution board fuses should be in position.

A test lamp with long leads is used, one end of the lamp is connected to earth, the other end is touched to the feed terminal of each switch. If the test lamp glows**,** the switch is connected in live and if the lamp does not glows, the switch is connected in neutral.

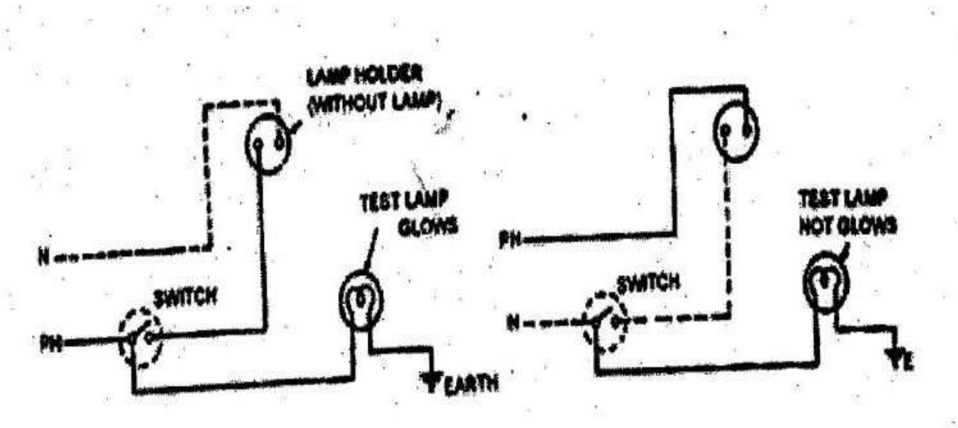


Fig.6.1 Polarity testing of single pole switch

However when a new installation is being test, the supply will not available and the test have to be conducted without supply. In this case the supply is replaced by battery and the test lamp by an ohm-meter 'or' a bell. If the switches are connected correctly the bell will ring otherwise no.

Another simplest method of testing is by means of the tester. When the tester is touched to the feed terminal of the switch the tester lamp will glow if the switch is connected in the live. The tester lamp will not glow if the switch is connected in neutral.

6.3.5 Earth Continuity Test

In wiring installations, the earthing or equipment earthing of metal conduits, metallic envelopes, switch covers etc is must be provide the safety tohuman life. The resistance of the electrical continuity along the earthing lead (excluding added resistance) measured from the earth electrode to any point in the earth conductor should not exceed one ohm.

Before conducting earth continuity test ensure the following

- Main switch should be 'OFF'
- All switches be in 'ON' position.
- Lamps must be in the lamp holders

One end of the earth continuity tester is connected to an independent earth and the other end is connected to the switch covers or metal coverings. The earth resistance tester should measure a resistance less than one-ohm. Higher than this value indicates that the equipment earthing is not proper.

Another method for the earth continuity test is to apply a D.C. test consisting of a ohm-meter and a battery. One end of the ohm-meter is connected to the earth and the other end is connected to the farthest part of the installation (if the installation is large each sub-circulation can be measured separately). The ohm-meter reading should be less than one-ohm.

6.4 Steps Involved for Obtaining a Domestic Service Connection

To obtain a new service connection either to a house or to an industry the following steps should be followed

Step I Apply in form A or Appendix XVIII

Application for service connection form A which can be had free of cost from any section office. This form when filled in and submitted will also serve as an agreem6nt between you and the Board.

Please remember to enclose with your application documentary evidence in support of the ownership of the premises. In case you are tenant a consent letter from your landlord is essential.

Step II Register you application with the section officer

Application for release of service connection has to be registered with the section officer at the consumer services centre by paying application fee. Alternatively you may pay it in cash to be concerned assistant accounts officer (revenue) and obtain receipt for the same. It can also be paid by in any banks in the name of Assistance Officer, A.P.S.E.B Board. This receipt along with the application form maybe delivered to the section officer.

As and when a prospective consumer hands over application along with payment receipt ,the section officer will

Note : Tick whichever is applicable

(i) In case of SC, ST, necessary community certificate should be produced.

(ii) In case of partnership location, head office names and addresses of all partnership and a copy of partnership deed should be enclosed.

(ii) In case of company names of present director and copy of memorandum of articles of association should be furnished.

Registers the application and will have the serial No. of the registration of application and an acknowledgment for the application . Please insist on obtaining the receipt of the application. This is very important document which indicates the seniority of your application . preserve it safely.

Step III. Boards Technical personnel will visit your premises. Please await communication form the section officer

The section officer on receipt of your application will inspect your premises and prepare an estimate for extending electric service connection. He sanction the estimate with a week from the date of receipt of application wherever there are no extensions and cost is upto Rs.2000/-, and load is upto 5kW. If minor extensions are involved sanction is to be accorded by assistant divisional engineer (upto Rs.10000/-) and takes one month. The section officer will be glad to advise you as to how best your installation work should be carried out the conditions under which power would be supplied.

Step IV Payment of Service Connection and Security Deposit Charge

You will receive communication form the security officer intimating to you

(i) The charges to be paid for extending service connection to your premises.

(ii) Service line charges as applicable

(iii)Security deposit being the approximate amount of energy consumption charges for a period of three months based on the contracted load. Please pay the service connection classes and security deposit and also furnish the certificate of completion of wiring for your installation by a licensed electrical contractor.

The service connection charges and the security deposit may be 'paid in the shape of crossed demand draft drawn in favor of the. Divisional Engineer, "Operation and Assistant Accounts Officer (Revenue) A.P.S.E Board, of your area respectively. After paying the deposit please get the service connection line ready upto the proposed tapping pole and intimate the section officer.

Now await the communication from the section officer for release of supply to your premises

The release of service will be taken up in the order of payment of service connection charges and security deposit.

Step V Release of service

The Board technical staff will test and inspect the installation for safety and verification of the connected load and if found in order the supply will be released to your premises. We have fixed certain reasonable time intervals for disposal of application at each stage and it will be our constant Endeavour to keep up to limits.

Step VI Bills and Payment

How to and when to pay yo¯ur bills, when adjustment bills are issued how adjustments are made, and procedures for removing difficulties.

The slab cards, pass books are issued to the consumer on the same day of the release of the service under domestic and non-domestic categories by the field engineers. It can be utilized fora period of 5 year. The slab amount is fixed based on the connected load of the service, The amount is payable upto 14th of the succeeding month without discharge.

The meter readings are taken once in every 2 months and adjustment bills is prepared and issued after one year based an actual consumption. If any amount is due from the consumer as per adjustment bill will be payable with in month after the issue of the adjustment bill. If however the consumer has already paid in excess of the actual, consumption by way of slab assessment , the excess amount will be placed at the credit of the consumer and will be adjusted in the future slab amounts.

Any representations from the consumer regarding dispute of meter reading , issue of adjustment bills, revision of slab amounts etc, will be considered and disposed of based on the field reports. The consumers are requested to approach the section officer if they feel there are mistakes in meter readings. For any missing credits or omission payments or adjustments bill in course of the year they may approach the assistance account officer of the concerned revenue office.

Short Answer Type Questions

1. What is the main aim of framing Indian Electricity rules?
2. List the different types of tests to be conducted for testing of new Electrical Installation before connecting to the supply?
3. List the steps involved for obtaining domestic service connection
4. Define the following as per IE rules
   (a) Ampere (b) Cable (c) Cut-out (d) Danger(e) Earthed
5. Define the following as per IE rules
   (a)switch(b)system(c)Neutral conductor(d)supplier(e)voltage

Long Answer Type Questions

1. Write the IE rules regarding Domestic wiring.
2. Write the IE rules regarding power wiring /Industrial wiring.
3. Explain the Insulation resistance test between the conductor and earth.
4. Explain the Insulation resistance test between conductors
5. Explain the polarity test of single pole switch.
6. Explain the earth continuity test

UNIT 7

CONTRACTING

7.1 Tender

Tender is an offer from a contractor or company or firm to supply different materials/accessories or undertake certain work at reasonable rate. It accompanies with EMD, CMD etc.

7.1.2 Quotation

Quotation is an offer from a party or company in a prescribed format to make supply or undertake some work at certain rates. It provides information about each unit cost.

7.1.3 Tender Form

Tender form is a prescribed agreement format given: o a contractor by an organization. It is used to take up various tasks in that' company. In that tender form, the contractor should provide Complete information about the work to be taken, time to complete the work, cost of work etc., It accompanies with EMD Tamest Money Deposit),CMD(Caution money deposit) etc

7.1.4 Earnest Money Deposit

Earnest Money Deposit" means the amount required to be remitted by a tenderer along with his tender indicating his willingness to implement the contract.

7.1.5 Estimation

The process of preparing Estimate in prescribed format is called estimating. It contains a table of information about the complete details quantity, costs f different materials to execute a work. The standard format of estimate is as below.

S.no	Description of materials/accessories	Quantity	Units	Rate	Amount	Remarks

7.1.6 Estimate

Estimate is a table of information containing the complete information of electrification work, materials, accessories labour charges etc. for an electrical project. The standard format of estimation is as below.

S.no	Description of materials/accessories	Quantity	Rate	Amount	Remarks

Short Answer Type Questions

1. Define

(a)Tender (b)Tender form(c)Quotation(d)Estimation(e)Estimate

2. Give the standard proforma of Estimate

UNIT 8

UTILISATION OF ELECTRICAL ENERGY

8.1 Illumination

The source of light can be divided into two categories:

1. Natural
2. Artificial

The Artificial source of light can be further subdivided into

(a) Non electrical sources of light
(b) Electrical sources of light.

The natural sources of light Sun, Moon, Stars, candles, oil lamps etc., are called non electrical sources of light where as the electrical sources of light are incandescent lamps, mercury vapour lamps, fluorescent lamps etc.,

Luminous flux per unit area is called illumination. The units for Illumination are lumens/m^2 or metre candle or lux.

8.2 Requirements of Good Lighting

A good lighting is one under the influence of which the eyes of persons, using the light do not feel any strain. The good lighting provides comfort while working under it.

The factors to be taken care while planning a lighting scheme are

(a)Illumination level.

(b)Absence of glare.

(c)Contrast.

(d)Shadows.

(e)Colour rendering.

8.3Level of Illumination for various applications

The visibility of objects depends upon the magnitude of light falling over them and the light reflected by them. It depends on various factors. The level of illumination is different for different applications. They are given as below. Place of application along with Level Illumination in lumens/m^2 is mentioned below.

(a) Domestic

Place of Application	Level Illumination in lumens/m^2
(i) Drawing room	80 to 200
(ii) Bed room	50
(iii) Toilet	100
(iv) Veranda	50

(v) Study room 150

(vi) Entrance 100

(vii) Living Room 300

(viii)Dining Room 150

(ix)Stair case 100

(b) Educational Institution

(c) Place of ApplicationLevel Illumination in lumens/m^2

(i)Library 150

(ii)Indoor sports 500

(iii)Class rooms150 to 200

(c)Factories/Workshops

(i)Fittings shop200 to 250

(ii)Machine shop100 general lighting,200local lighting

(iii)Stores 100 to 200

(iv)Compound 25 to 50

(d) Others

(i)Street lighting 15 to 30

(ii)Flood lighting 15

(iii)General lighting 100

8.4 Standard Definitions in lighting

1. **Luminous flux:** Rate of flow of luminous energy is called flux or luminous flux. The unit for luminous flux is lumens. It is denoted by **Φ**

2. **Plane Angle: Two** converging straight lines meeting at a point subtend a plane angle. The unit of plane angle is radian or degrees.

3. **Radiant: Radiant:** is the angle subtended at the centre of a circle by an arc whose length is equal to the radius of the circle.

4. **Solid Angle: A** solid angle encloses a volume e an infinite energy a line lying on a surface meeting at point. It is denoted by ω. And the unit is Steradian.

5. **Steradian :**Is the angle subtended at the centre of a sphere by an area on the surface of the sphere which is numerically equal to the square of the radius.

6. **Candle Power:** Candle power is the ratio of brightness of a source of light to that a standard candle .

A standard candle gives a luminous flux of 4π lumens

1 CP = one lumen/steradian.

7. Luminous Intensity: The luminous flux per unit solid angle by a point source °flight in a particular direction is the luminous intensity of the source. The luminous flux per unit solid angle emitted by a point source of light in a particular direction is the luminous intensity of the source Luminous intensity measured in candlepower or lumen/steradian. Brightness is the luminous intensity per unit area.

8. Illumination : Luminous flux per unit area is called illumination.

9. Brightness : It is the luminous intensity per unit area

10.Luminous efficiency : It is the out put in lumens per watt of the power consumed by the source.

11.Depreciation factor : It is the ratio of illumination produced by a source under normal working condition to the illumination produced by the source under ideal conditions.

12.Reflection factor (R.F): It is the ratio of the total light reflected to the incident light falling over a surface..

13.Utilization factor : It is the ratio of part of the light being usefully employed to the total light emitted by a source.

14.Space height ratio : It is the ratio of space between lamps to the height of these lamps form the working surface.

15. MHCP :(Means Horizontal Spherical Candle Power): The mean of candle power measured at different points on a horizontal surface or plane gives M.H.C.P.

16. MSCP :(Mean Sperical Cattle Power) . If the mean is taken along all planes in all direction (along a total solid angle gives means spherical power of the source.

17. Glare : Glare is the sensation experienced by human eye when some rays of light enter the eye directly from a source. eg. Drivers use dipper at night when facing other vehicles to avoid glare. In case of a lighting scheme this glare can be of two types :

(i) **Direct glare:** Glare due to direct rays of the source

(ii) **Indirect glare:** Glare due to reflected rays of the source. Glare not only causes under fatigue, but can be a cause of industrial accident.

8.5 Laws Of illumination

The light received by any surface depends on the two factors for a given source a point.

I. The distance of the surface from the some.

II. The angle made by normal to the surface, to the light flux.

Two different laws deals with the factors mentioned as above.The first law is calledInverse Law, and the second one is Known as Lambert's Cosine Law.

Inverse Law

Illumination at a surface is inversely proportional to the square of its distance from the source.

$$E \propto \frac{1}{d^2}$$

E - Illumination on the surface

d - distance between source and the surface

Lambert's Cosine Law

As per Lambert's law, the illumination of a surf-ace inclined at an angle is proportional to cosine of the angle.

E α Cos Ө

E - illumination on the surface

Ө -Angle between the flux and normal to the surface

The illumination at a point (E)

$$E = \frac{\Theta}{d^2} = \text{Cos}\ \Theta\ lux$$

8.6. Designing of lighting scheme

Suppose is desired to have E lumen /m^2 in a hall area A m^2. Obviously total flux required on the working place in Ex A lumens. To send this much flux the output of the source should be higher taking into consideration the depreciation factor, coefficient of utilization etc. If the value of these coefficients is given

Then output of the source necessary

$$\frac{\text{Lumens required}}{\text{Dep. Factors x coefficient of utilization}}$$

Example 1:Itis desired to illuminate a drawing hall with an average illumination for 200 flux. The hall is 30 x 20 m^2. The lamps are to be fitted 4m room ground floor. Find the number of lamps and wattage/lamp for the lighting scheme. Given efficiency of the lamps available as 25 lumens watt, depreciation factor 0.8 and coefficient of utilization 0.75 space height ratio between 0.8 and 1.2. Give satisfactory arrangement.

Solution:E, required

= 200 Lux or Lumens /m^2

Floor area=30 x 20

= 600 m^2

Total flux = Ex A

= 200 x 600

= 120,000 Lumens

Desired light output $= \dfrac{\phi}{D.F.X\ c.u.}$

$= \dfrac{120000}{0.8.X\ 0.75}$

= 200000 Lumens

Wattage of lamps $=\frac{\phi}{\eta}$

$=\frac{200000}{25}$

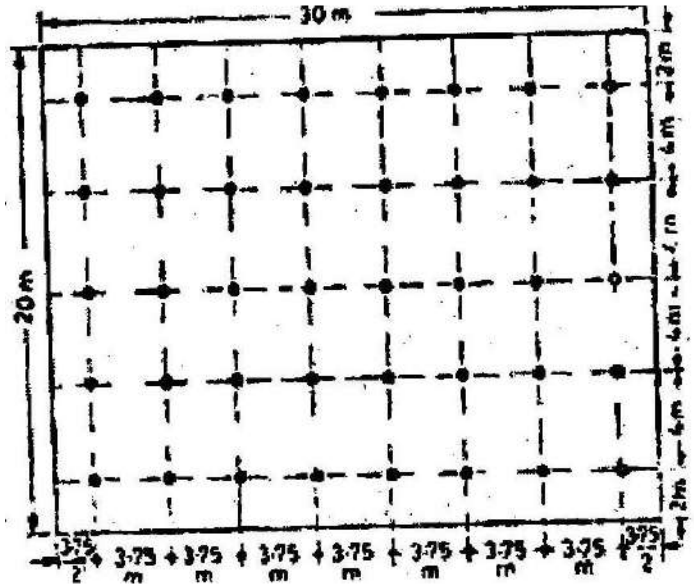
=8000 watts

If we take 200 W lamps, then

Number of lamps = $\frac{8000}{200}$= 40 Ans.

Rating / lamp= 200 W

Taking five rows of eight lamps we have total distribution of40 lamps.



Now lengthwise spacing comes to be 30/8 = 3.75 m
Widthwise spacing comes to be 20/5 = 4 m

The lamps near the walls are kept at half the calculated spacing to keep uniformity of light. If for example this distance is kept equal, the length between two adjacent lamps will be more as compared to illumination on the wall.

Now space height ratio lengthwise comes to be height$\frac{3.75}{Height}$

$\frac{3.75}{4}$

= 0.94 Approx.

Widthwise space height ratio $=\frac{4}{4}=1$

8.7 Types of Lamps

An electric lamp converts the electrical energy into light energy. It is an artificial method of producing light. Electric lamps, in board sense may be classified into three groups.

1. Incandescent or Filament Lamps
2. Arc Lamps
   (a) Carbon — Arc Lamps
   (b) Flame —Arc Lamps
   (d) Magnetic —Arc Lamps
3. Electric Discharge Lamps
   (a) Sodium Vapour Lamps
   (b) Mercury Vapour Lamps
   (c) Neon Lamps
   (d) Fluorescent Lamps
4. LED Lamps

8.8 Neon sign lamps

This is also known as Neon tubes These are belongs to cold cathode discharge category. The electrodes are in the form of iron shells and are coated inside. Although the main constituent of the gases inside the tube is neon, but the combination of other gases produces different colours e.g. mercury and neon produces blue colour where as argon, neon and mercury produces bluish green colour. Fig 8.2 shows a neon sign display circuit. The required voltage goes increasing with the number of display letters or the length of the sign tube required to represent some figures (like rotating fan, etc), a 5 kV network is used. The Transformer has a high leakage reactance which controls the magnitude of current and hence stabilizes the arc in the lamp. A choke is also used to restrict the current. A capacitor is used to improve the power factor of the highly inductive circuit. This type of lamps are mostly used for commercial advertisements.

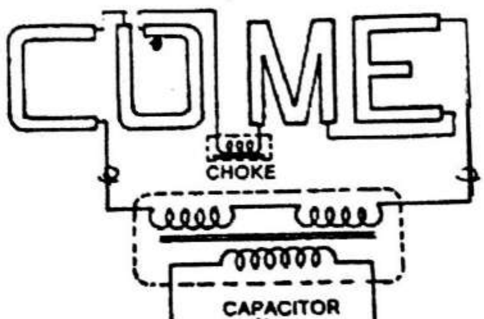


Fig. 8.2 Neon Sign Display Circuit

8.9Flasher for Moving Lights

For decoration proposes in marriages, functions etc., moving lights are used. The moving effect is usually obtained by means of flasher, which consist of a wooden cylinder which rotates into the two balls bearings at the two ends. The wooden cylinder is connected to the motor through a belt or a coupling. The speed of the motor and the selection of pulley should be so made that the wooden cylinder rotates about 100 r.p.m. The wooden cylinder is provided with a copper rings (to which the live wire is connected through a brush) and 3 copper segments120 parts form each other and each end of these segments is permanently connected alternately with the brushes 1,2 and 3 in turn. The brush No.1connected to amps L1, the brushes No2 and 3 are connected to lamps L2 andL3 respectively . Shows the instant when the copper segment No.1 makes contact with brush No. 1 it lights all the lamps L I . As the cylinder rotates through 1 /3rd of the revolution of the circuit No.1 goes off and just the same instant circuit No.2 becomes alive and lights all the lamps L2 and after further1/3rd of the revolution, the circuit No.3 becomes alive and lights all the lampsL3 and such system of lighting the lamps is repeated and it so appear that the lights move from right to left. Such removing effects of light can be used to show waving, flag, flickering light etc.

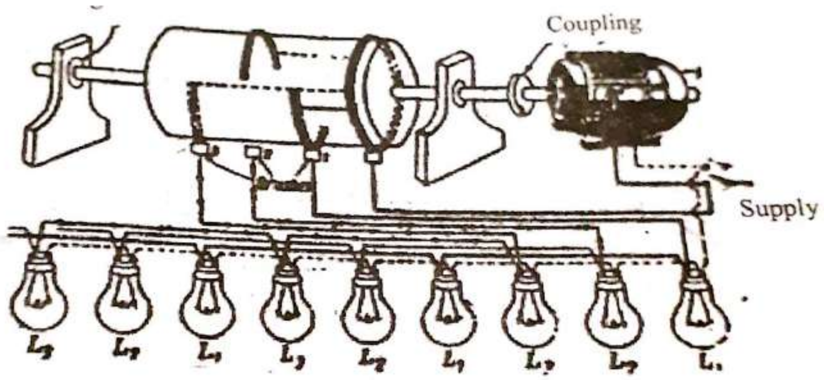


Fig 8.3 Flasher for moving lights

8.10 Circuit diagram and working of a Refrigerator and Air conditioner

Electric circuit of Refrigerator is shown below Fig.8.4

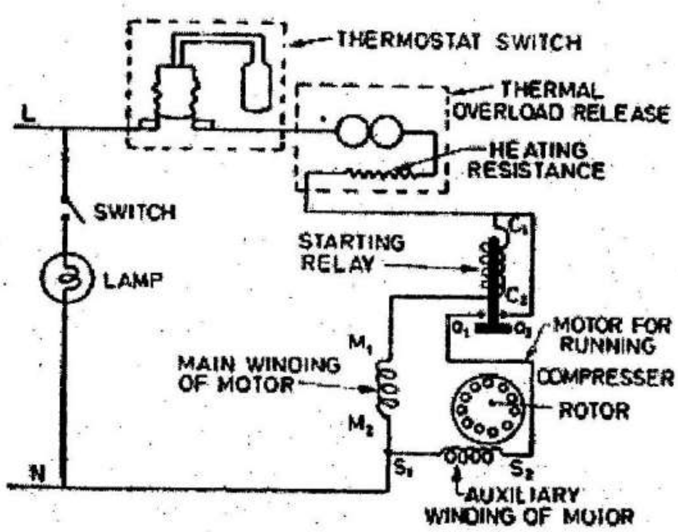


Fig.8.4 Circuit diagram of Refrigerator

The various components involved in the electric circuit are

1.Lamp and switch: When the door of the refrigerator remains closed the switch is in series with the lamp (push button type) remains off but as soon as the door is open as a result the switch gets released and therefore it comes in the on position and therefore lamp becomes on .. As soon as the door is opened which might even at night time, the lamp should becomes on .so that various commodities placed in the refrigerator are traced.

2.Thermostatic switch : The idea of providing this switch is to maintain requisite temperature in the refrigerator. As soon as it is reached, the thermostat switch should function and the supply to the motor should automatically get switched off and motor should stop thus stopping the further cooling process, so long as this temperature is maintained. But as soon as the temperature rises, thermostat should function in a way that electric supply to the motor is again revised and motor starts working till the requisite temperature in the refrigerator is attained.

Thermostat switch is provided with an arrangement so that it could be set at different settings for attaining any pre-requested temperature inside the refrigerator. In the freezer, the temperature might remain between -23°C to -18°C .while the temperature inside the remaining part of the refrigerator might vary between3°C to 5°C .

3.Thermal overhead releases: The purpose of providing this device is that as soon as the temperature of the compressor rises beyond certain value, excessive current flows in the motor. The supply to the motor should get switched off so as to avoid any damage to the motor compressor unit. It is nothing else but a device having a bimetallic strip along with resistance connected in series with the motor circuit and mounted on the casing of the compressor unit . If the excessive currents flows does not flow but temperature of the bimetallic strip which shall again open out thus disconnecting the supply to the motor again. Thus thermal overload release is protective device for compressor motor unit.

4.Starting relay: The function of the starting relay is to start the motor by putting starting winding(auxiliary winding) of split phase single phase induction motor connected across the supply. The main winding M_1 , M_2 as show in in figure is directly connected across the supply through coil of starting relay, thermal overload and thermostat switch

5.Electric Motor: Electric motor used is single phase induction motor of split phase type. It is fractional horse power motor. The size of the motor depends upon the capacity of the refrigerator. One 'Ton' capacity of the refrigeration requires approximately 1HP motor 'Ton' is the unit of of 50 calories /minute. Domestic refrigerators are named by their horse power motor and they are not rated for continuous rating but for intermittent rating as the refrigerator motor works for some time and then it stop and remains stopped for some time again. It is because of this reason, that motor is likely to get burnt if some, how it doesnot stop but continues running due to some fault in thermo static switch or due to some other reason.

Working: When refrigerator is connected across the supply , the current passes through the thermostat switch, thermal overload release coil C_1, C_2 of starting relay ,the main winding M_1, M_2 of the motor . Since to start with the motor is at rest, it draws a very heavy current .This heavy current flows through coil c_1c_2 of the starting relay. This coils gets energized and it pulls up the plunger, short circuiting the contacts a_1, a_2 and putting auxiliary windings, S_1,S_2 also in circuits. since both the main windings and auxiliary windings are energized, the motor starts running. As soon as the motor picks up the normal speed the current drawn the main winding of motor becomes normal. At normal current plunger in the coil c_1, c_2 cannot remind pulled and it is released down, opening the contacts a_1, a_2, thus auxiliary windings gets it to put auxiliary winding in circuit at the time of starting the motor and to disconnect it as soon as the motor starts working at normal speed.

In case starting relay fail to close motor will not start as explained above. But once it fails then auxiliary winding shall also keep on drawing the current resulting is increased current draw by the motor. In that case either the fuse shall be blown off or thermal overload shall trip out.

8.10.1 Air Conditioner

The principal of working of air conditioner is same as that of water cooler except that in case of water there is only one fan for cooling the condenser but in air conditioner there is one more fan (blower) which circulates the cooled air in the room. In case of small air conditioner both these fans are mounted on one shaft, one at each end of the shaft but in case of large air conditioner ,separate motor is used for each. Electric diagram of air conditioner is as shown in figure Fig 8.5

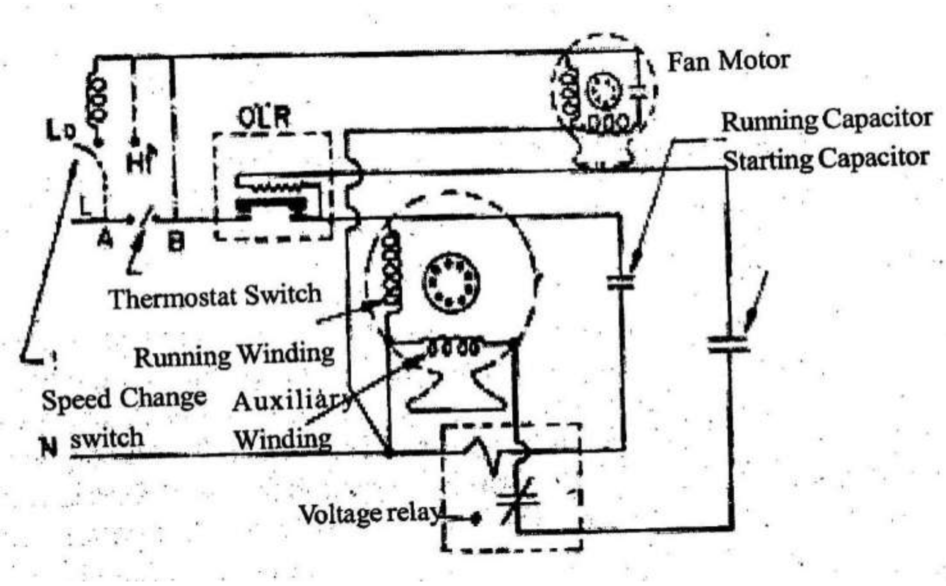


Fig. 8.5 Circuit diagram of Air Conditioner

Dotted line in a diagram should be considered for the said purpose. The supply is connected to thermostat switch through point A. As a result of this the fan motor gets connected across the supply and fan motor starts working even if the compressor motor is in off position due to operation of thermostat switch. The speed of fan motor is low if the speed change switch is in LLo position as the inductance gets connected in series with the motor. The speed of this fan motor becomes high if speed change switch in Hi position as no inductance is connected in series with motor..

If the thermostat switch gets in on position the compressor motor starts running as the supply is being fed to both running and auxiliary windings. The compressor motor used is capacitor start and capacitor run as already indicated. After the motor has picked up its normal speed, The voltage relay trips and auxiliary winding goes out of circuit where as main winding still continues getting supply voltage. OLR is over load release, which functions when the supply voltage falls down. Thus the compressor motor gets disconnected from the supply and becomes quite safe.

Short Answer Type Questions

1. Define the following

(a) Illumination	(b) Reflection factor
(c) Luminous flux	(d) Plane angle
(e) Solid angle	(f) Steradian
(g) Candle power	(h) Luminous intensity
(i) Brightness	(j) Luminous efficiency
(k) MHCP	(1) MSCP
(m) Glare	

2. Define the following
   (a) Depreciation factor
   (b) Utilization factor
   (c)Space-height ratio
3. State the laws of Illumination.
4. What are the different types of lamps?
5. Draw the electric circuit of a refrigerator.
6. Draw the electric circuit of air conditioner.
7. Define Refrigeration.
8. What are the parts of a Refrigerator?
9. Define air conditioning.
10. Write the applications of different types of lamps

Long Answer Type Questions

1.Draw the connection diagram of neon sign board for "GOD".

2.Explain Flasher for moving lights with diagram and its applications

3.Write the faults and remedies of refrigerator

4.Explain neon sign Lamps with diagram

5.Explain the working of Refrigerator with circuit diagram

6.Explain the working of Air conditioner with circuit diagram

ELECTRICAL TECHNICIAN

PART – B

FIRST YEAR

THEORY PAPER – II

ELECTRICAL ENGINEERING MATERIALS AND WIRING

PERIODS PER WEEK: 4 **PERIODS PER YEAR: 135**

Sl. No.	Name of the Unit	No. of Periods	Weightage in Marks	Short Answer Questions	Essay type Questions
1	Electrical Engineering Materials	6	3	--	1/2
2	Conducting & Semi-Conducting materials	16	10	2	1
3	Magnetic Materials	15	6	--	1
4	Insulating Materials	15	8	1	1
5	Wiring Tools & Wiring Accessories	28	12	3	1
6	Wiring Joints & Wiring Systems	28	13	2	1 1/2
7	Wiring Circuits	15	8	1	1
8	Earthing systems	12	8	1	1
	TOTAL	**135**	**68**	**10**	**8**

ELECTRICAL TECHNICIAN

PART – B

FIRST YEAR

THEORY PAPER – III

ELECTRICAL MEASURING INSTRUMENTS AND ELECTRONIC DEVICES

PERIODS PER WEEK: 4 **PERIODS PER YEAR: 135**

Sl. No.	Name of the Unit	No. of Periods	Weightage in Marks	Short Answer Questions	Essay type Questions
1	Introduction to Measuring Systems	15	5	1	1/2
2	Indicating Instruments	25	12	--	2
3	Integrating Instruments	15	8	1	1
4	Special Instruments	15	8	1	1
5	Digital Instruments	10	5	1	1/2
6	P-N Junction Diode	15	10	2	1
7	Transistors	15	8	1	1
8	Applications of Electronic Devices and Integrated Circuits	25	12	3	1
	TOTAL	**135**	**68**	**10**	**8**

ELECTRICAL TECHNICIAN

PART – B

SECOND YEAR

THEORY PAPER – I

ELECTRICAL MACHINES AND POWER SYSTEMS

PERIODS PER WEEK: 4 **PERIODS PER YEAR: 110**

Sl. No.	Name of the Unit	No. of Periods	Weightage in Marks	Short Answer Questions	Essay type Questions
1	D. C. Generators	20	8	1	1
2	D. C. Motors	15	8	1	1
3	A. C. Fundamentals	15	8	1	1
4	Transformers	15	8	1	1
5	Alternators	5	5	1	1/2
6	Three Phase Induction Motors	10	8	1	1
7	Single Phase Induction Motors	10	8	1	1
8	Power Systems – Generation – Transmission – Distribution	20	15	3	1&1/2
	TOTAL	**110**	**68**	**10**	**8**

MODEL QUESTION PAPER
ELECTRICAL TECHNICIAN
ELECTRICAL MACHINES AND POWER SYSTEMS
SECOND YEAR: THEORY PAPER -I

Time: 3hours **Max Marks :50**

SECTION - A **10 x 2 =20**

NOTE: 1. Answer any FIVE questions.
2. Each question carries SIX Marks.

1. State the different types of D.C. Generator.
2. Write the working principle of D.C. Motor.
3. Define the terms Form factor and Peak factor of an alternating quantity.
4. State the different losses occurred in Transformer.
5. Define Voltage Regulation of an alternator.
6. State the applications of Three phase slip-ring induction motor.
7. Write the applications of Stepper motor.
8. Write different types of Conventional energy sources.
9. State the different type of equipment’s used at substations.
10. Expand the following terms.
   (a). ACSR (b). HG (c).PSCC (d).OCB.

SECTION - B **6 x 5 =30**

NOTE: 1. Answer any FIVE questions.
2. Each question carries SIX Marks.

11. An 8-Pole DC Generator has 960 conductors and flux per pole 20 milli Weber and running at 1000 rpm. Calculate the EMF generated in LAP and WAVE winding.
12. Explain the working of Three-Point starter with a neat sketch.
13. Write the advantages of Poly Phase Systems over Single phase systems in six aspects.
14. Explain OC and SC test on a single Transformer.
15. (a). State any three advantages of an alternator.
   (b). Draw the single line diagram of Power System.
16. Draw and explain the working of a STAR/DELTA starter.
17. Explain the operation of Single Phase Induction Motor.
18. Explain the working of Thermal Power station with a neat sketch.

MODEL QUESTION PAPER
ELECTRICAL TECHNICIAN
DOMESTIC APPLIANCES AND REWINDING
SECOND YEAR: THEORY PAPER –II

Time: 3hours **Max Marks :50**

SECTION - A **10 x 2 =20**

NOTE: 1. Answer any FIVE questions.
2. Each question carries SIX Marks.

1. State the different types of Tools required for dismantling of Electrical domestic appliances.
2. Name the main parts of Electrical Mixer.
3. State the different types of Pump sets.
4. Write the different types of Electric Lamps.
5. Draw the wiring circuit of Fluorescent tube light.
6. What are the tests to be done before proceeding for Rewinding?
7. Name the different insulating materials used while rewinding of a machine.
8. Define the term Front Pitch in a DC Machine.
9. Write the types of AC windings.
10. What are the defects in Universal Motor?

SECTION - B **6 x 5 =30**

NOTE: 1. Answer any FIVE questions.
2. Each question carries SIX Marks.

11. (a). Classify the different types of Electrical Domestic appliances.
(b). State the faults and remedies in Hair Dryer.
12. Explain the working of Electric Iron with a neat sketch.
13. Explain the construction of an Electric Geyser with a neat sketch.
14. Explain the working of Ceiling fan.
15. Explain the working of Servo Voltage Stabiliser with a neat sketch.
16. Explain the General procedure for rewinding of a machine.
17. Draw and develop the single layer LAP winding diagram for 4-pole DC generator having 24 slots.
18. Explain the procedure for servicing of a three phase induction motor.

MODEL QUESTION PAPER
ELECTRICAL TECHNICIAN
ELECTRICAL ESTIMATION AND UTILISATION
SECOND YEAR: THEORY PAPER –III

Time: 3hours **Max Marks :50**

SECTION - A **10 x 2 =20**

NOTE: 1. Answer any FIVE questions.
2. Each question carries SIX Marks.

1. What are the different types of starters used for AC Motor?
2. State the power rating limitations in a sub circuit.
3. Define SAG.
4. What are the different types of Insulators used in Over Headlines?
5. Define Substation.
6. State the different lighting methods used in auditorium.
7. What are the Major Components in a Public address system?
8. Write any two IE rules employed in an internal wiring system.
9. What is meant by Quotation?
10. Define Space-Height ratio.

SECTION - B **6 x 5 =30**

NOTE: 1. Answer any FIVE questions.
2. Each question carries SIX Marks.

11. Explain the General rules for wiring.
12. Estimate the quantity of materials and its costs for a conduit wiring system in a house of size 6m x 5 m x 3m. Assume any missing data. Provide one power socket at each hall.
13. Draw and estimate the materials required for Installation of an agriculture Motor with 5HP, 440Volt and 50Hz three phase motor.
14. A 11KV three phase OH line is to be layed for 3KM's length with PSCC poles with a span of 50 Metres. Prepare the estimation of materials required.
15. Prepare an estimation of materials for a Pipe earthing system.
16. Estimate the quantities of materials and its costs for PA system to be provided in an Assembly hall of size 30m x 15m. Assume any missing data.
17 (a). Explain the polarity test of a single pole switch.
(b). State the Laws of Illumination.
18. Draw the connection diagram of NEON sign board for ELECTRICAL.

*****