

Motor Controllers

- A motor controller is a switching device which makes the motor turn-on or turn-off.
- It is used to change the direction of the motor's rotation.
- It is utilized to protect the motor from overloading.
- It is used to minimize the motor's drawn current during starting period.
- It is used to control the speed of the motor.

Parts and Function of Motor Controllers

- **Magnetic Contactor**

- is an electromechanical device which is similar to the concept of the ordinary relay but capable to hold large amount of current and voltages.

- It is designed for remote and automatic operation of electric motors and similar electrical equipment.

- Overload relay
 - is a device designed to protect the motor and the control apparatus from excessive current due to motor overloads.
 - Relays in which the time of operation is inversely proportional to the amount of current flowing are called Inverse Time Relays.
 - It takes some time to heat the metal strip to open the motor control circuit.

- Pushbutton Switch

- a type of heavy duty switch which is designed to control the current in the magnetic contactor's coil.
- It is also act as the indirect switch to activate the electric motor.

- Pilot/Indicating Lamps

- are group of lamps which the main function is to indicate the status of the electric motor.
- Red for Stop, Green for Run and Orange for Overload or Fault motor's circuits.

- Timer

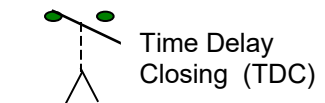
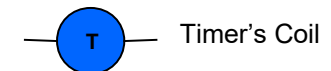
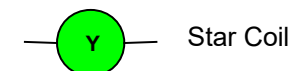
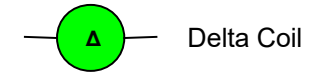
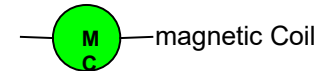
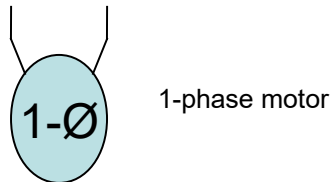
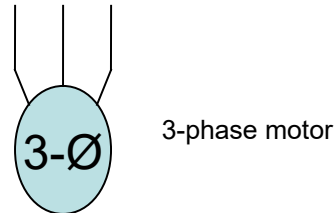
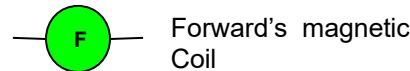
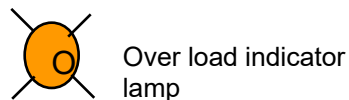
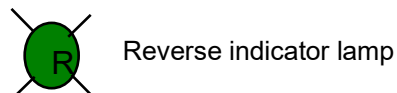
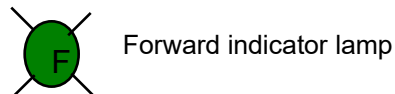
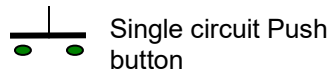
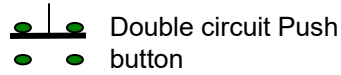
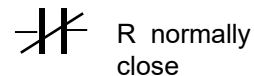
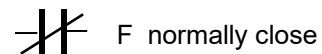
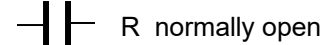
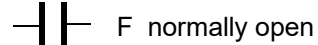
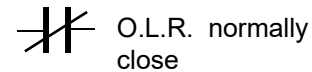
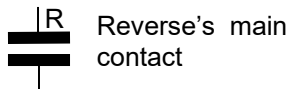
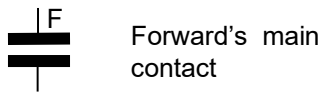
- An electrical relay which consist of timing device to delay the activation of the relay's contact terminals.
- There are two types of timer according to mechanical activation, the on-delay activated and off-delay activated timer.
- The timer is normally used in the motor controller for Star-Delta operation of the three-phase motor.

Typical Reduced Voltage Magnetic Starter

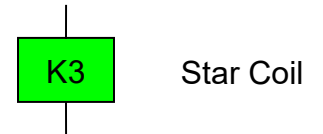
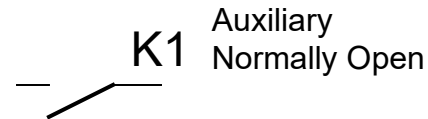
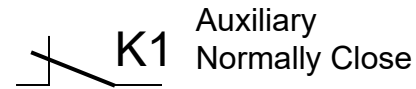
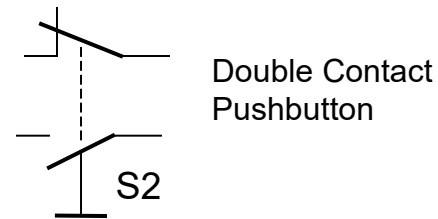
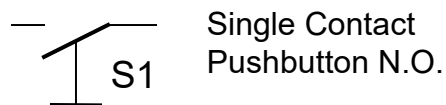
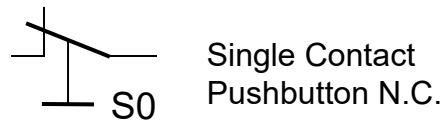
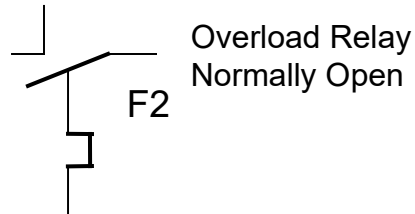
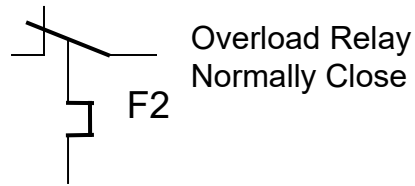
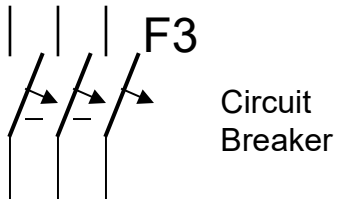
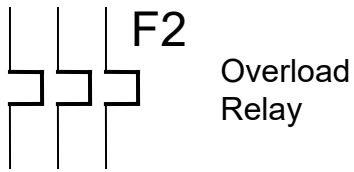
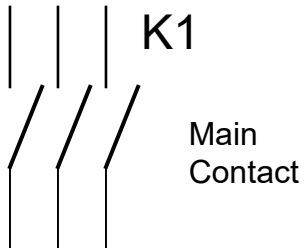
- Auto-transformer
 - a type of special transformer which is intended only for motor controller to reduce the starting current of the big motors.
- Resistor (Rheostat)
 - Primary Resistance Starting, an industrial type resistor which is momentarily connected in series with the motor's coil during the starting stage.
 - Secondary Resistance Starting, a resistor is inserted in the rotor circuit to decrease the line current in the wound motor.

- **Star-Delta Starting** – the motor is temporarily connected in star during the starting stage and would activate in delta connection for normal operation. This starting method is frequently used in medium size motors.
- **Part-winding Starting** – the motor's several windings are initially energized, then after few seconds the whole windings are activated to set into operation. This method is used to avoid the inrush of starting current.

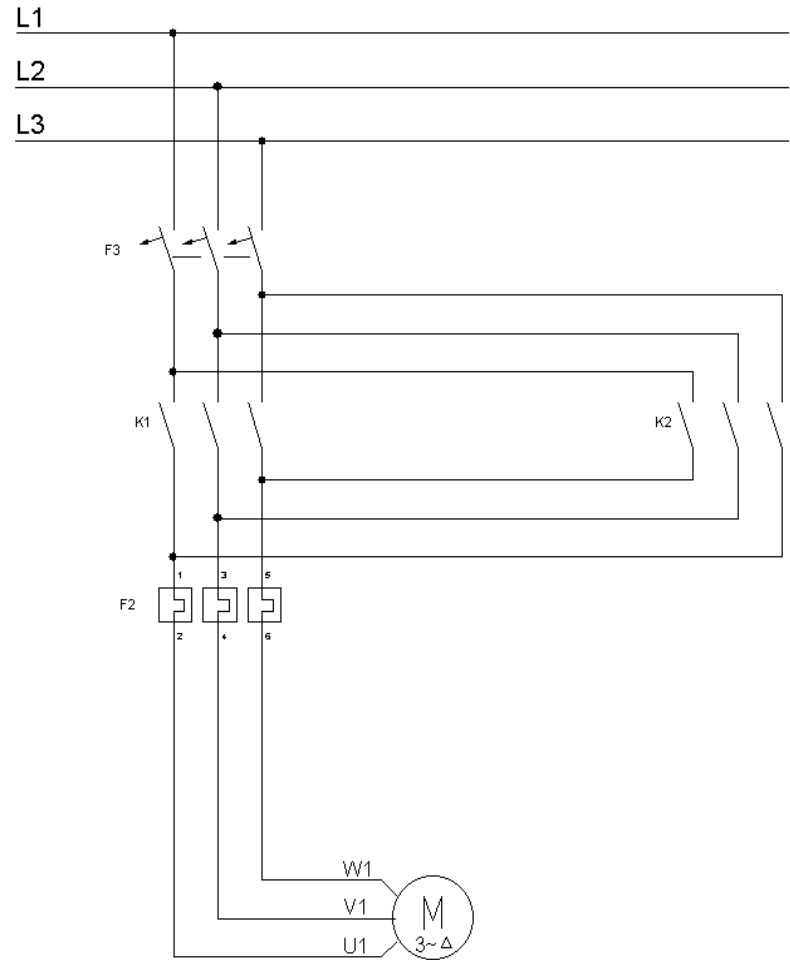
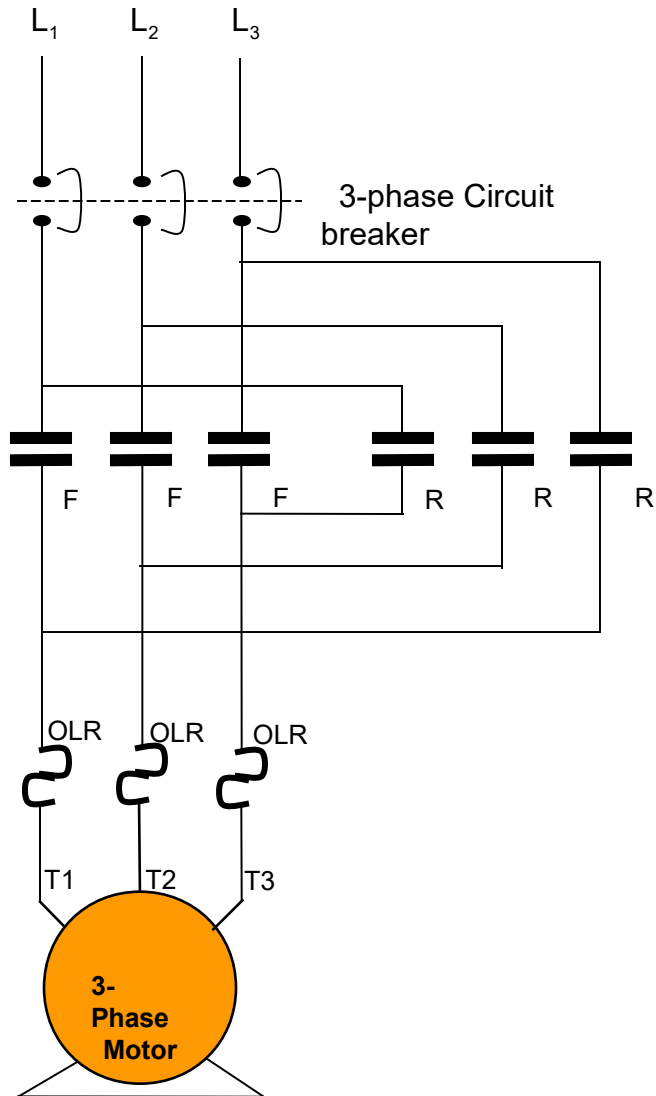
Motor Controllers Symbols (Western Format)



Motor Controllers Symbols (European Format)



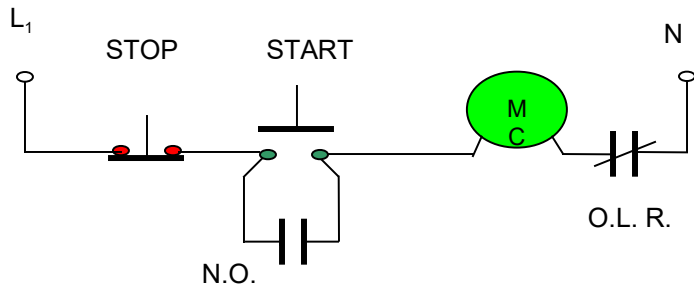
Power Circuits



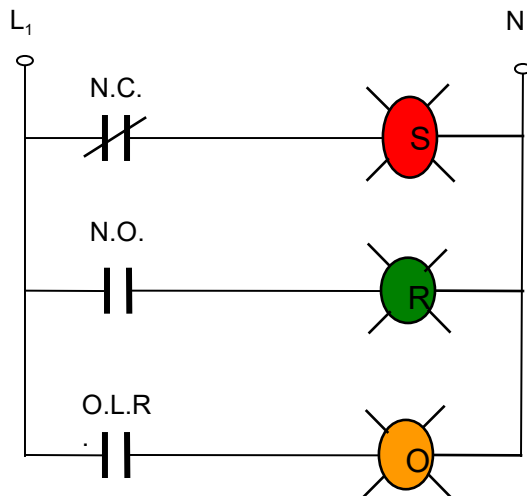
Work sheet # 1

Full-voltage Across the Line Magnetic Starter

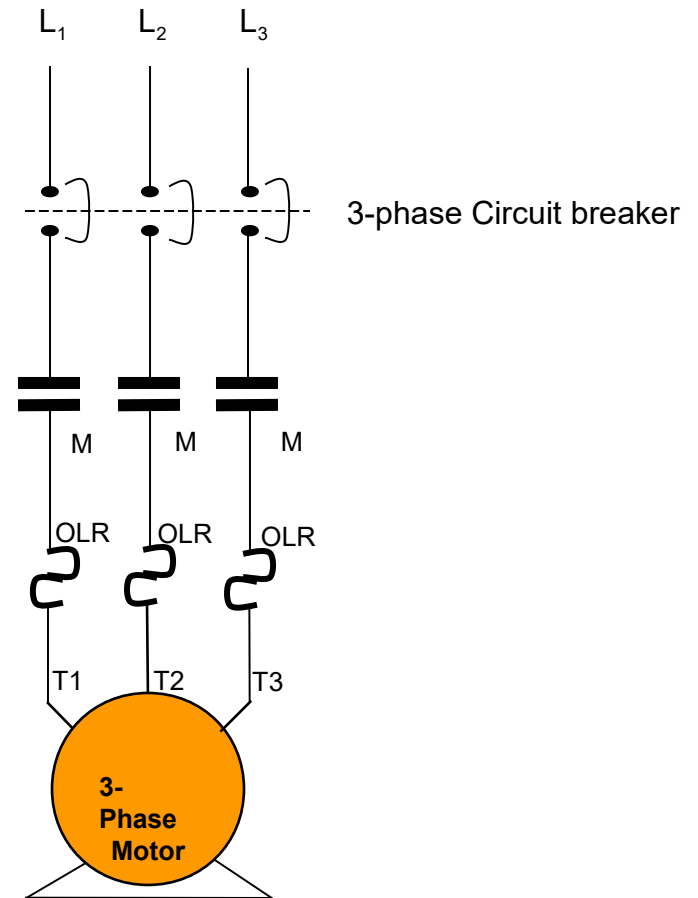
I. Control Circuit



II. Indicating Circuit



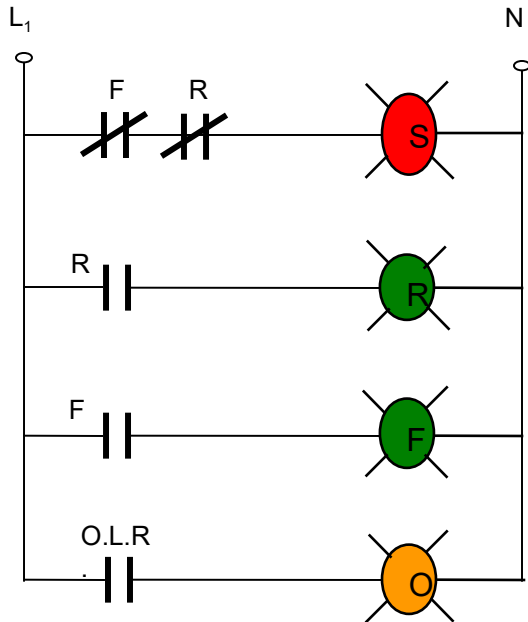
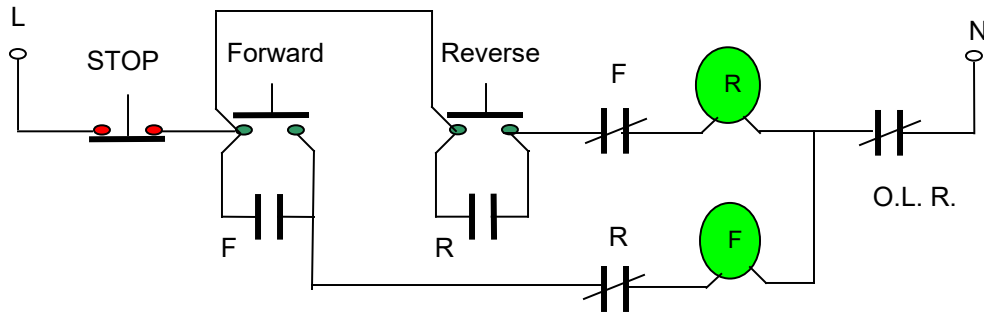
III. Power Circuit



Work sheet # 2

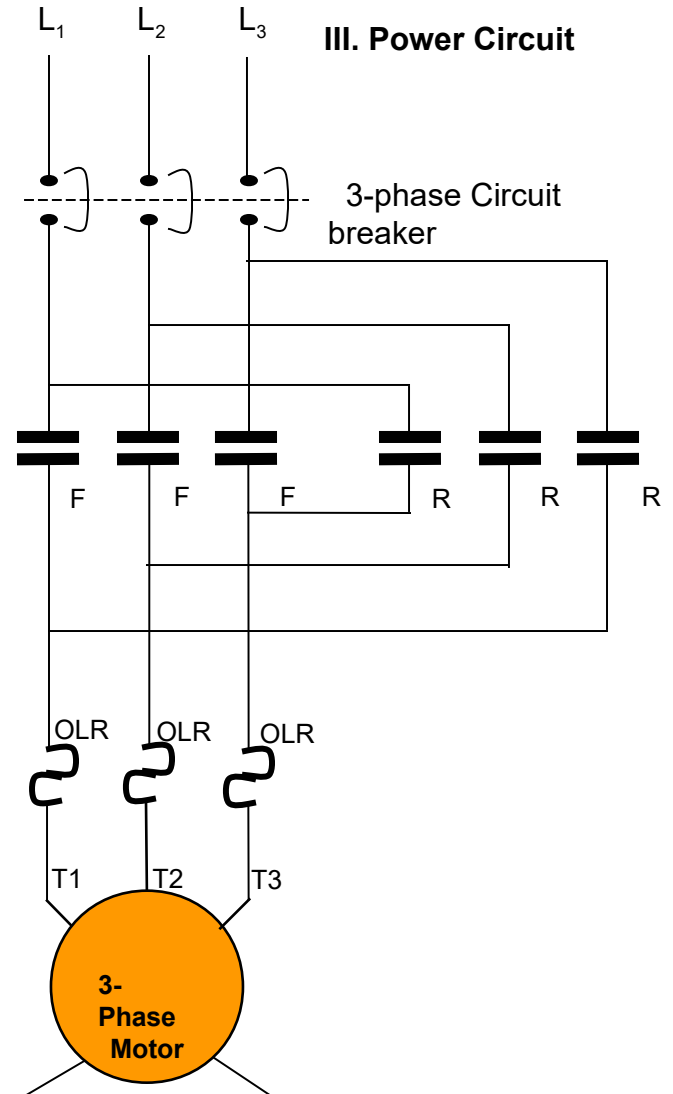
Full-voltage Reverse-Forward Magnetic Starter

I. Control Circuit



II. Indicating Circuit

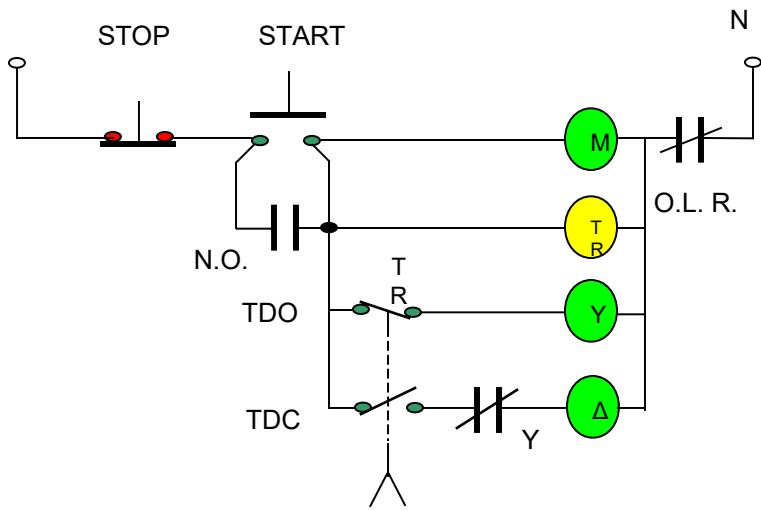
III. Power Circuit



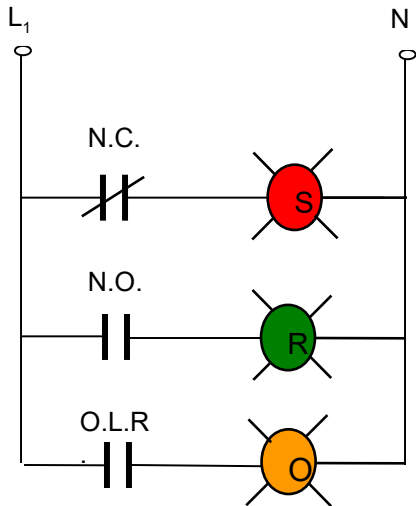
Work sheet # 3

Star- Delta Magnetic Starter

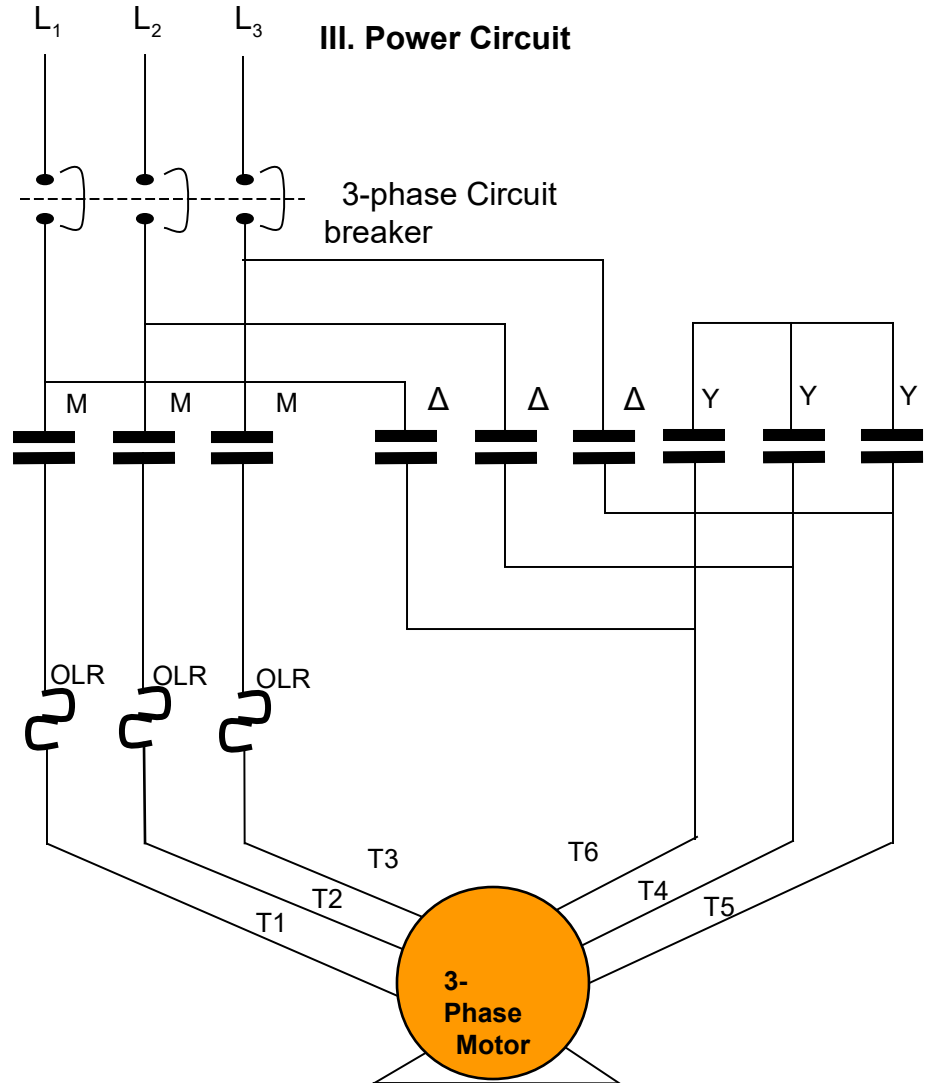
I. Control Circuit



II. Indicating Circuit

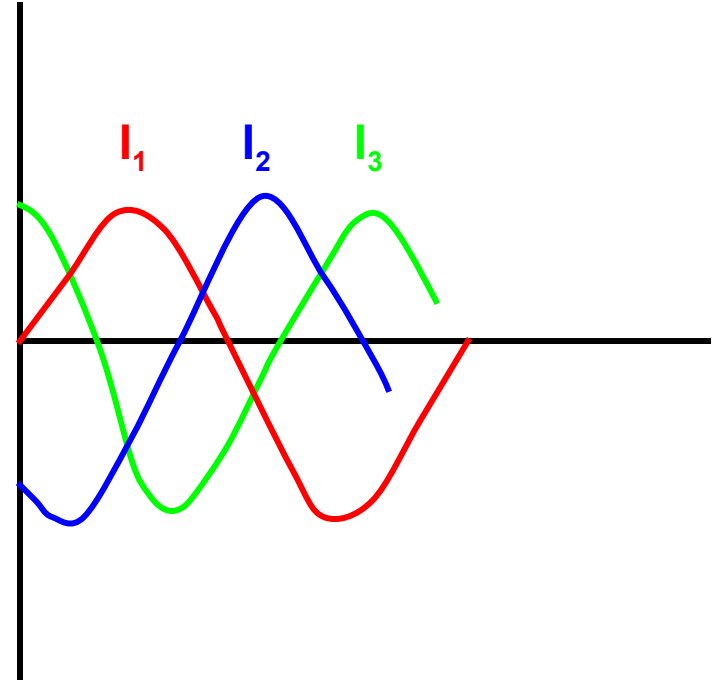


III. Power Circuit

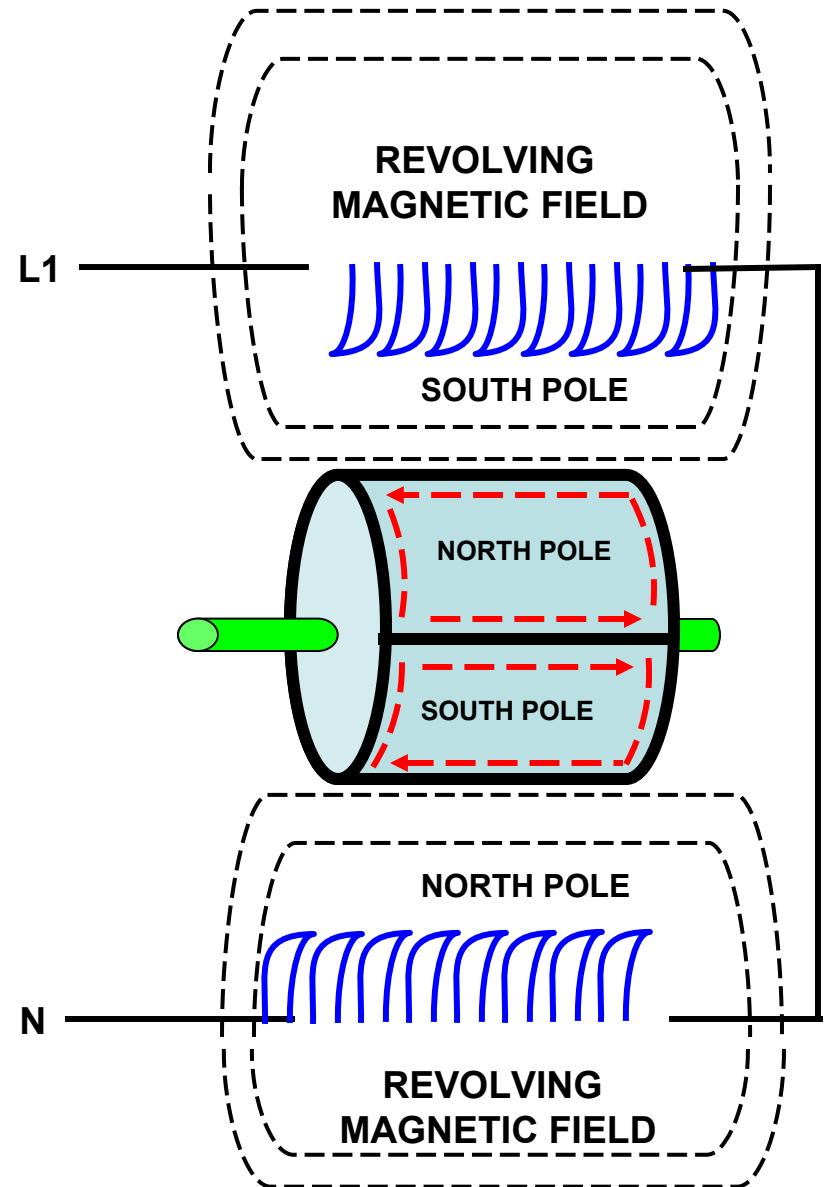


Alternating Current Motors

- **Principle of Operation** – practically most AC motors depend for their operation upon the production of a revolving magnetic field. This revolving field is set up by the rising and falling of current in the stator windings. The windings are so distributed that this shifting is uniform and continuous.
- Shifting of Current in 3-phase motor



- As the field revolves, it cuts the squirrel cage conductors (rotor) and voltages are set up in them as though the conductors were cutting the field. These voltages cause currents to flow in the rotor circuit which makes a loop to establish a magnetic fields (north and south) in the rotor core. These poles in the rotor are attracted by the poles of the revolving field set up by the current in the stator winding, and follow them around.



Parts and Function of an AC Motors

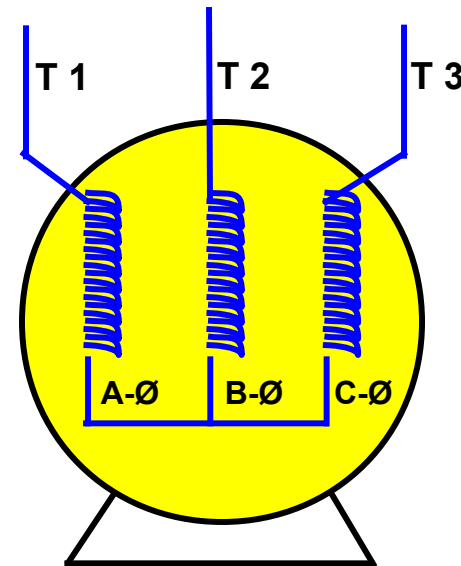
- Stator – the stationary part of the motor. It is the place where the windings are situated. Commonly it is made up of laminated sheet of steel core and with serrations or slots in it.
- **Rotor** – the rotating part of the motor. It is made up of copper or aluminum bars which are mounted on a core and connected by sturdy rings at the ends.
- **Frame** – the solid metallic body of the motor which hold the stator in place. It is intended to protect the windings and other vital parts from damage and frequent operation.

- **End plates** – the holder of motor's bearings and the part of motor which is fastened by screws or nuts and bolts in the frame to keep the rotor in correct position.
- **Capacitor** – the capacitor or the condenser in the single phase motor is the provider of a leading current to easily start the motor.
- **Centrifugal switch** – it is a special type of switch which is located inside the motor. It has two parts, the stationary part is connected to the end plate and the rotary part is attached to the starting coil through the shafting of the motor.
 - The function of this switch is to disconnect the starting winding from the main winding after a predetermined speed of more or less 75% through centrifugal force.

General Classification of AC Motors

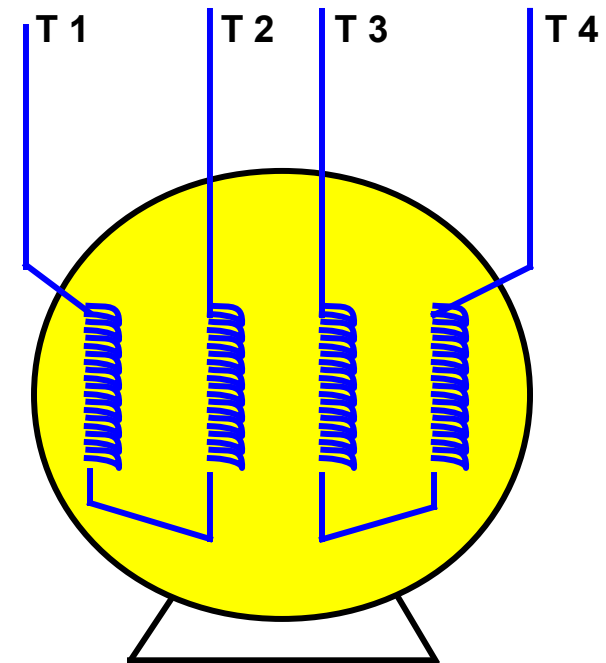
- Three-phase motor – it is a commonly used motor in the industry to drive machineries. It has 3-main windings which is powered by a three-phase line.

Construction of a 3-phase Motor



- Two-phase motor – it is a very rare type of motor used in the industry to drive machineries. It has 2-main windings which is powered by a two-phase line.

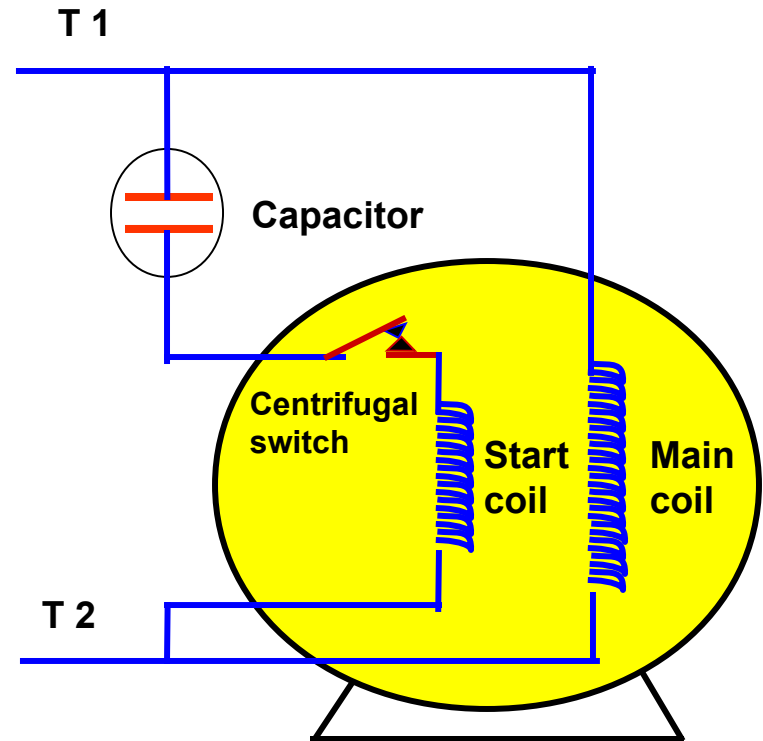
Construction of a 2-phase Motor



- Single-phase motor – it is a commonly used motor in the power tools and in all household appliances. It consists of two windings, run/main coils and the auxiliary coils. This motor is powered by a single-phase line.

- Generally, this motor needs a capacitor and sometimes a centrifugal switch for starting and running operation.

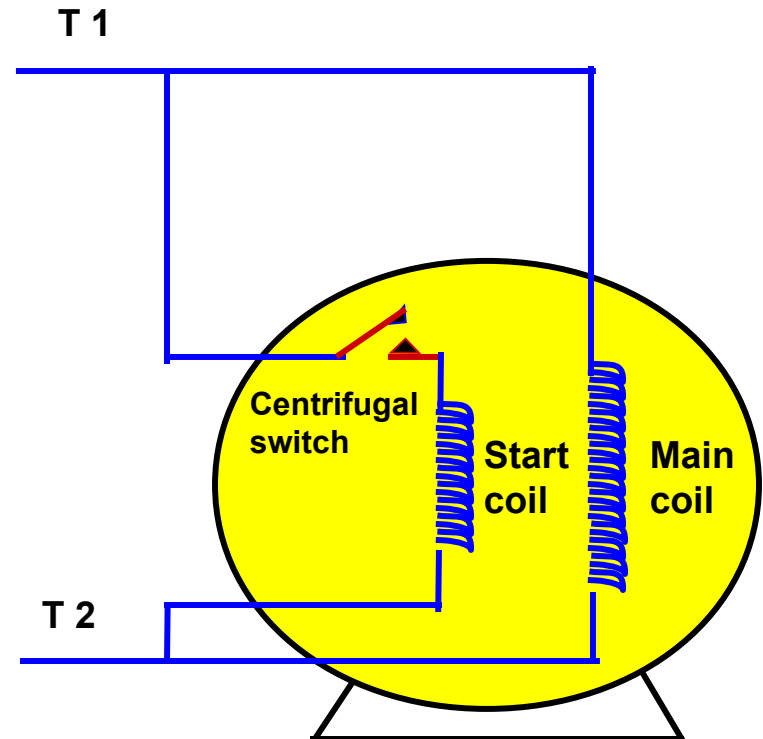
Construction of a Single-phase Motor



Types of Single Phase Motor

- **Split Phase Motor-** a type of single phase motor which consists of main winding, auxiliary winding and a centrifugal switch. The auxiliary winding is usually opened by the centrifugal switch when the motor attains a predetermined speed.

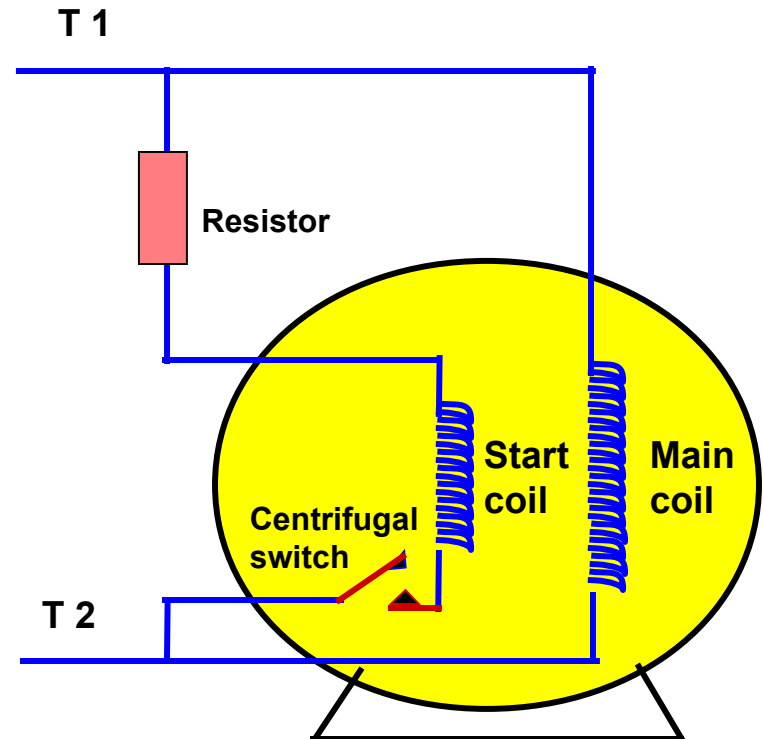
Part of Split phase motor



Types of Single Phase Motor

- **Resistance Start Motor-** is a form of a single phase motor having a resistance connected in series with the auxiliary (start) winding . The starting winding is disconnected when the motor has come up to a predetermined speed.

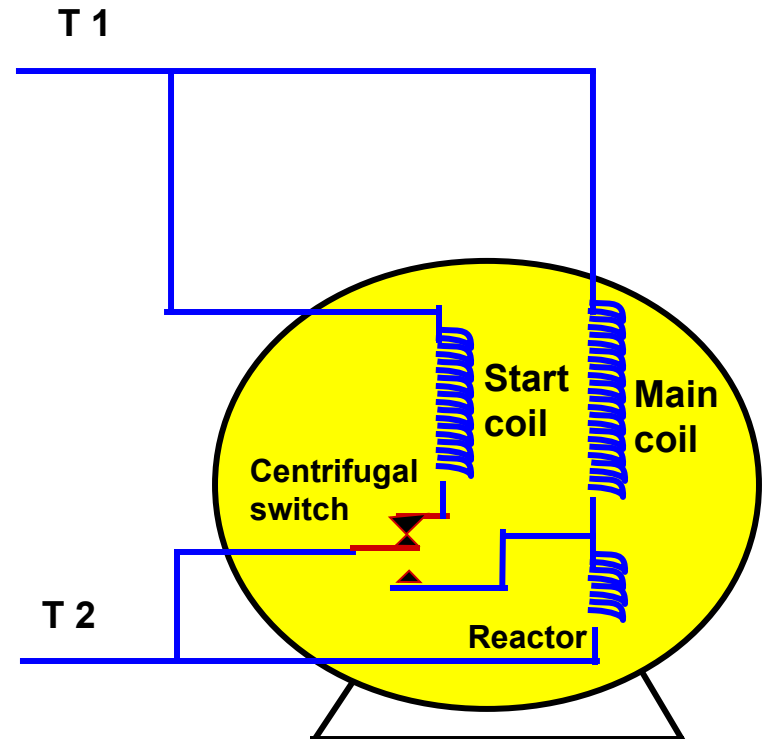
Resistance start motor



Types of Single Phase Motor

- **Reactor Start Motor-** is a kind of a single phase motor which has a reactor connected in series with the running (main) winding . After the motor has attained the predetermined speed, the reactor is shorted out of the circuit and starting winding is disconnected by the centrifugal switch.

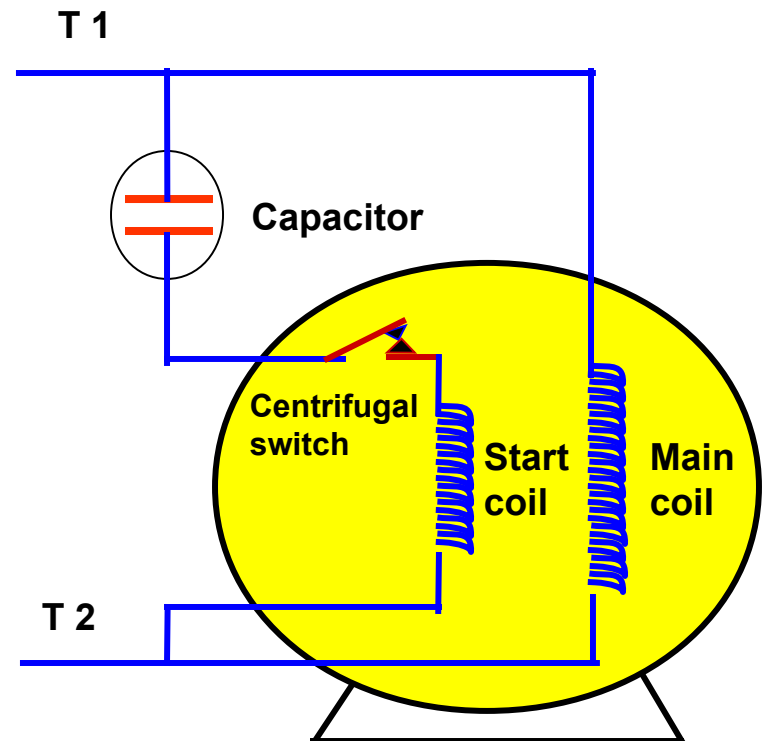
Reactor start motor



Types of Single Phase Motor

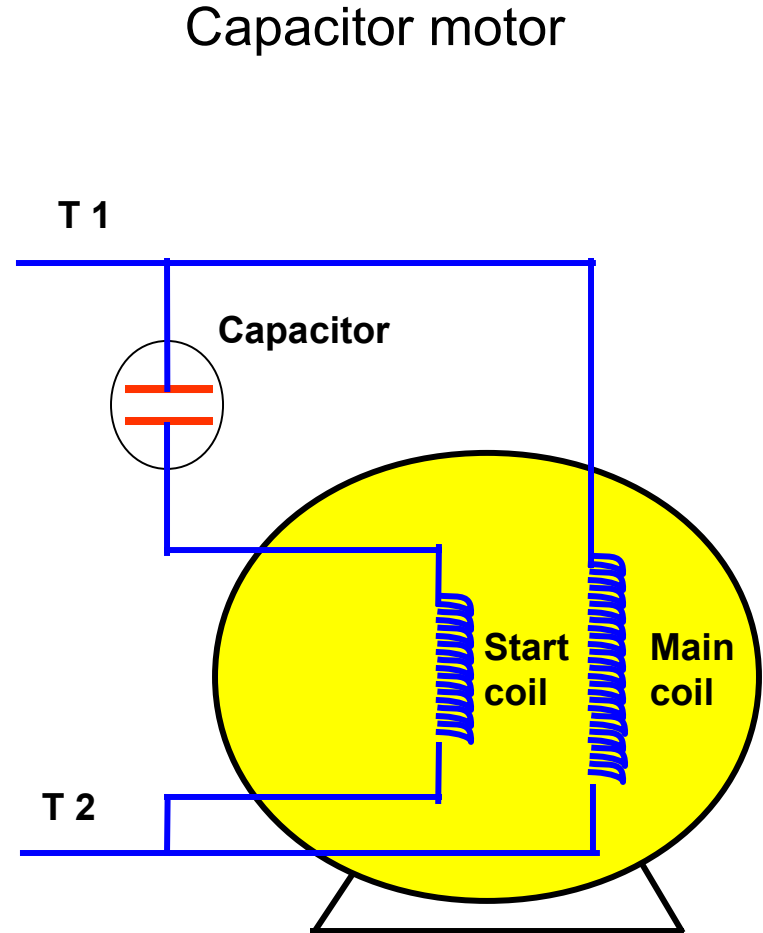
- **Capacitor Start Motor-** is a kind of a single phase motor having a capacitor connected in series with the auxiliary winding . The starting coil is disconnected from the circuit when the motor comes up to near normal speed.
 - It is used in water pump, machine drives, stationary grinder, etc.

Capacitor start motor



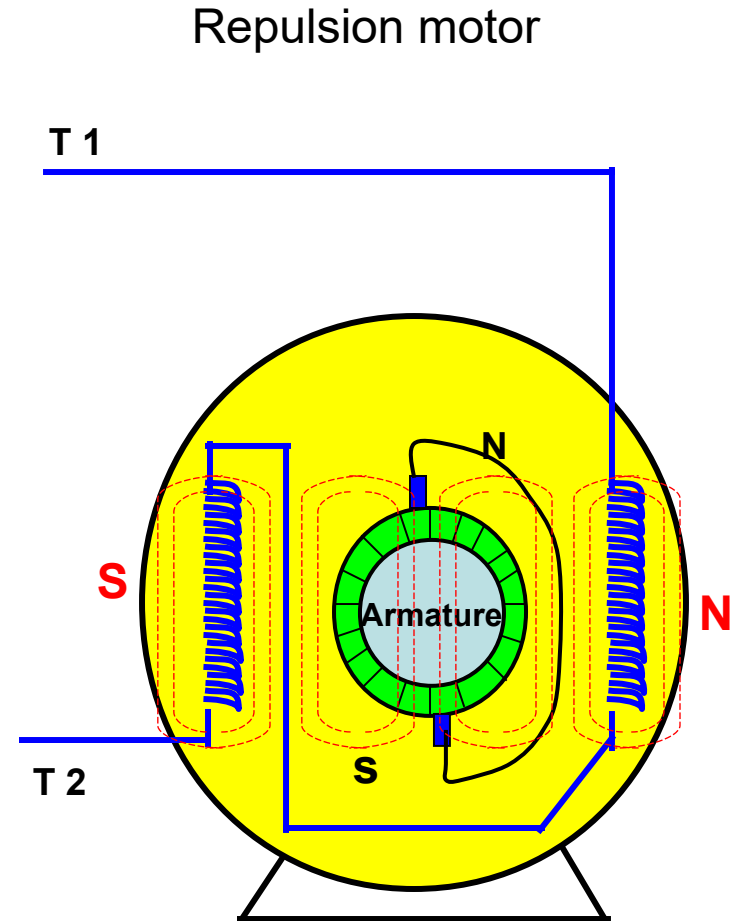
Types of Single Phase Motor

- **Capacitor Motor-** is a kind of a single phase motor having a capacitor connected in series with the auxiliary winding . The start coil is connected all times in the circuit as well as the running winding.
 - it is commonly used in electric fan and washing machine motors.



Types of Single Phase Motor

- **Repulsion Motor**- this motor is like that of any single phase motor but its rotor is like the armature of a DC motor, and the opposite brushes on its commutator are short circuited. The armature produces field poles with the same polarity to the adjacent stator field and are repelled by them, so this repulsion causes the armature to rotate. From this action the motor derives its name.

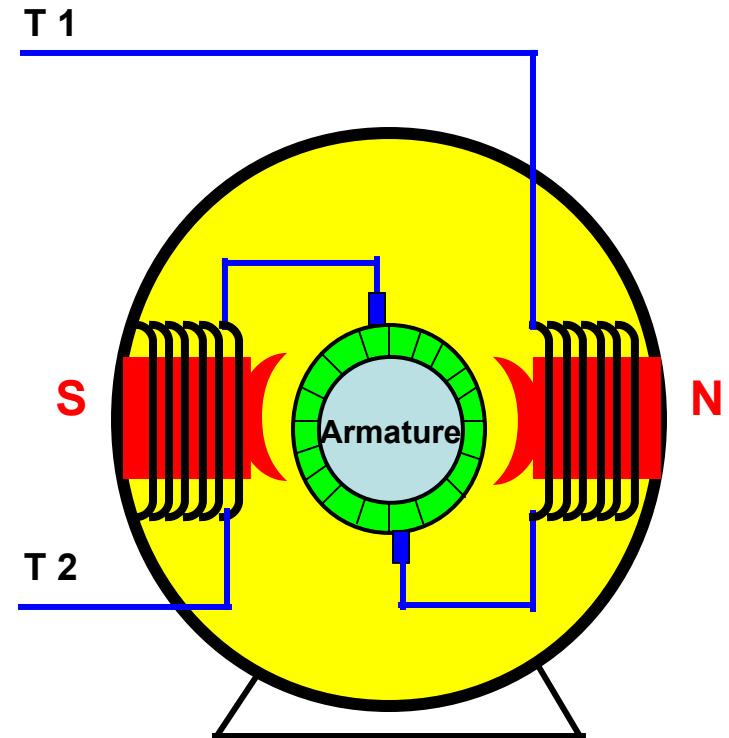


Types of Single Phase Motor

- **Universal Motor**- this kind of single phase motor is very similar to the characteristic of a DC motor. It could be activated by both AC and DC power supply, thus its name was termed universal motor. It has a commutator and brushes on its armature which are connected in series to its field windings. It has a varying speed with low speed to large load and high speed to small loads.

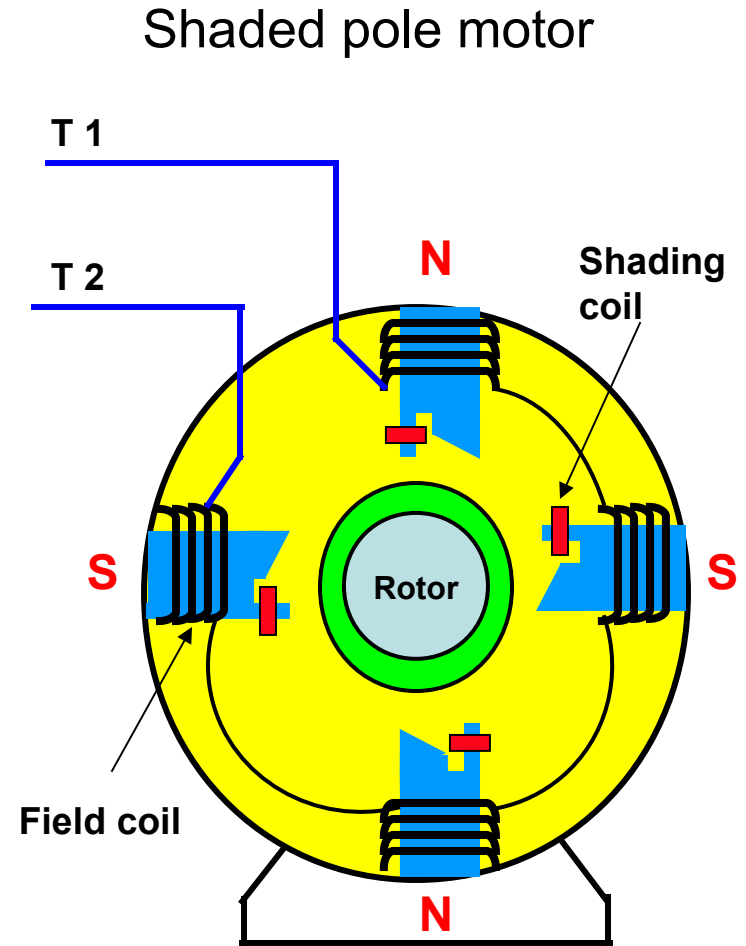
- Thus, it is best suited for light duty household appliances.

Universal motor



Types of Single Phase Motor

- **Shaded Pole Motor-** is a single phase induction motor with salient field poles. The shading coil of low resistance is wound on one tip of the stator poles which causes the motor to have weak rotating magnetic field. This motor is commonly used in aquarium pump and in some small electric fan.



Procedure for Analyzing Motor Troubles

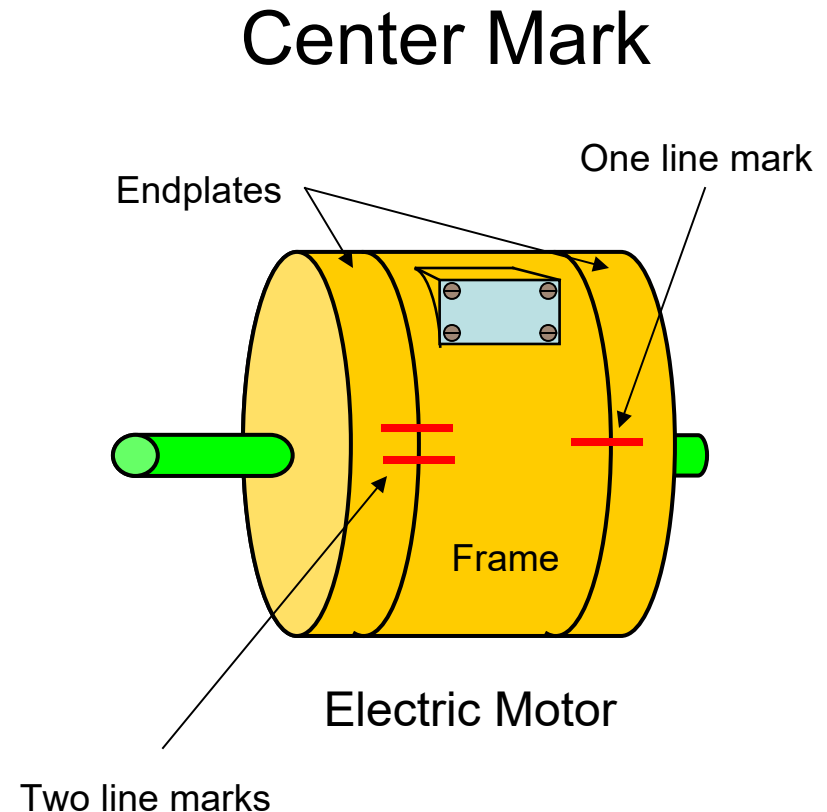
- Inspect the motor and look for the physical defects such as broken or cracked end plates, bent shaft, broken or burned leads.
- Test the motor for bearing troubles. Try to move the shaft up and down. If the shaft moves, it indicates that the bearing is worn. Or try to rotate by hand the rotor, it does not rotate freely it's the indicator of worn bearing or improper alignment of the shaft.
- Test the motor leads by the following: check for shorted circuit, check for grounded circuit, check for open circuit and check for coil' resistances.

Procedure for Analyzing Motor Troubles

- After the preliminary test and still you find no troubles, try to connect the motor to the power supply and let it run for a few seconds. Observe the motor: does it run slowly, does it run noisily, does it run severely hot, does it remain idle with humming or no motion at all?
- Any of the above indications are probable signs of motor's internal trouble, thus the motor must be opened and disassembled for better inspection.
- Once the motor is proven burned out or the winding is severely damaged, a rewinding is required to restore the condition of the motor.

Rewinding Procedure

- Before to disassemble the motor, a center mark must be scraped on the frame and endplates of the motor for re-assemble purposes.



Rewinding Procedure

1. **Taking Data** – is recording the specific and original data of the motor. The information is gathered before and during stripping the damaged windings.

The table listed right is the example of taken data obtained from the 3-phase motor.

Motor Data

HP : 1/8	SLOTS : 24
FREQUENCY : 60 Hz	STRAND : Single
RPM : 1640	GROUP : 12
NO. OF POLE : 4	COIL/GROUP : 2
CURRENT : 0.35A	TURNS/COIL : 410 T
VOLTAGE : 240 VAC	WIRE SIZE : #30AWG INSULATION : HF
PHASE : 3- Ø	COIL EXTENSION : 2cm
LEADS OUT : 6	TYPE OF WINDING : Full Lap
CONNECTION : WYE	PITCH : 1-6
WEIGHT : 2 kg	INSULATION Type/size: Mylar / 0.22 mm

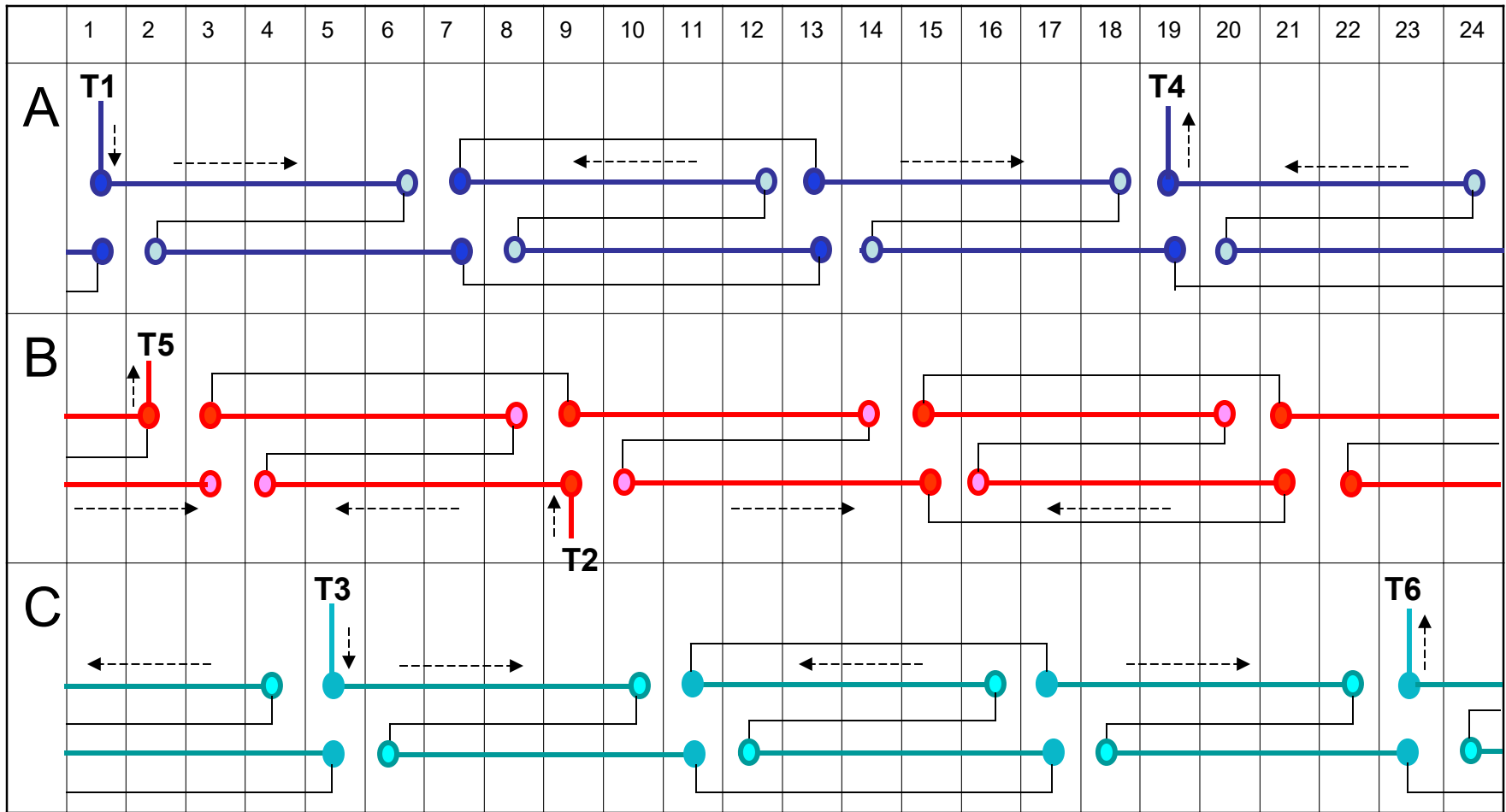
Rewinding Procedure

...Taking Data – you may take as many data as you want, but make it sure that your recorded information is easy to understand so that any motor repairman will be able to continue your work.

Nameplate Data

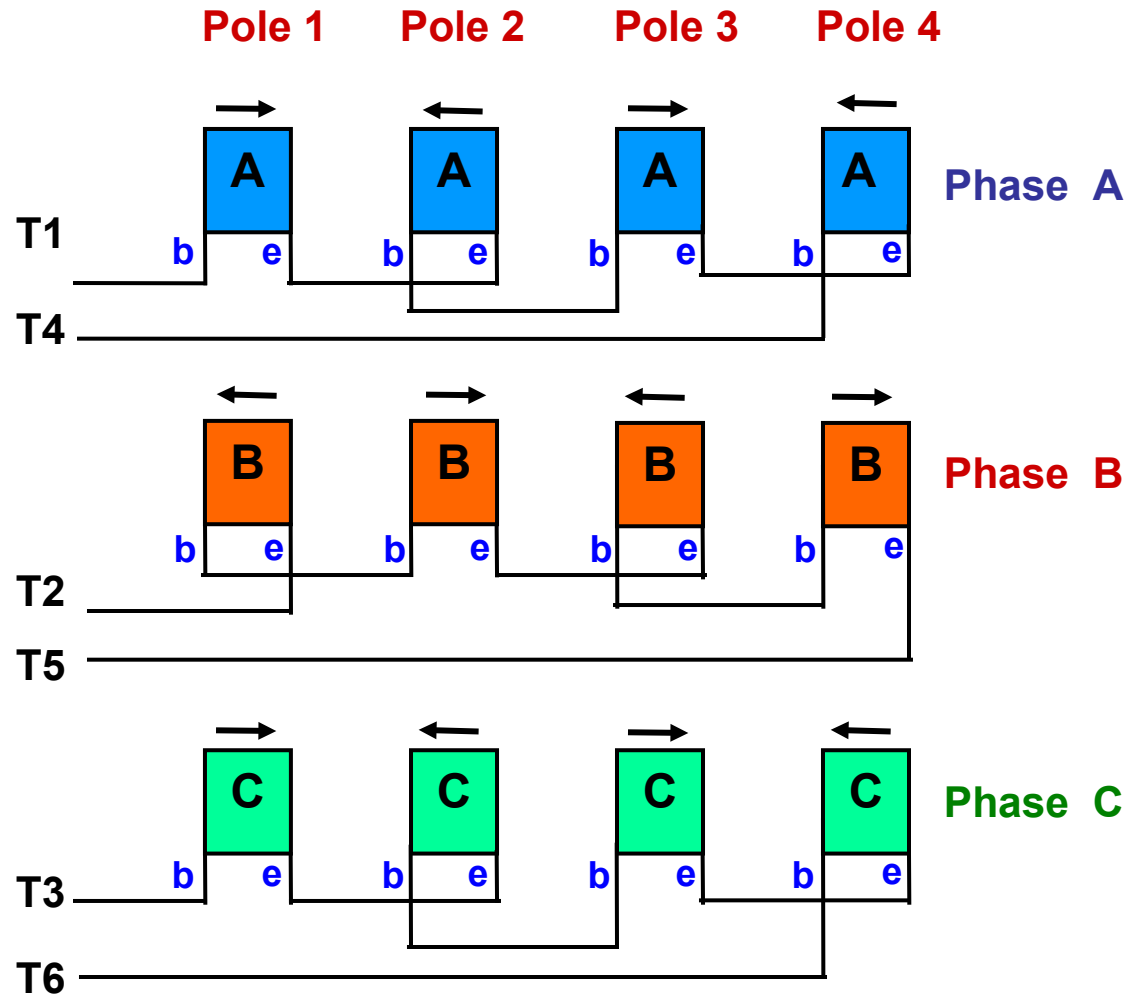
HP	: 2	Bearing No. : 134500
FREQUENCY	: 60	SERIAL NO. : 123456
RPM	: 1720	SERVICE FACTOR : 1.5
NO. OF POLE	: 4	CONNECTION : WYE
CURRENT	: 9A	WEIGHT : 20KG
VOLTAGE	: 230V	LEADS OUT : 6
PHASE	: 3-Ø	BRAND : BALDOR

Coil Lay-out and Connections

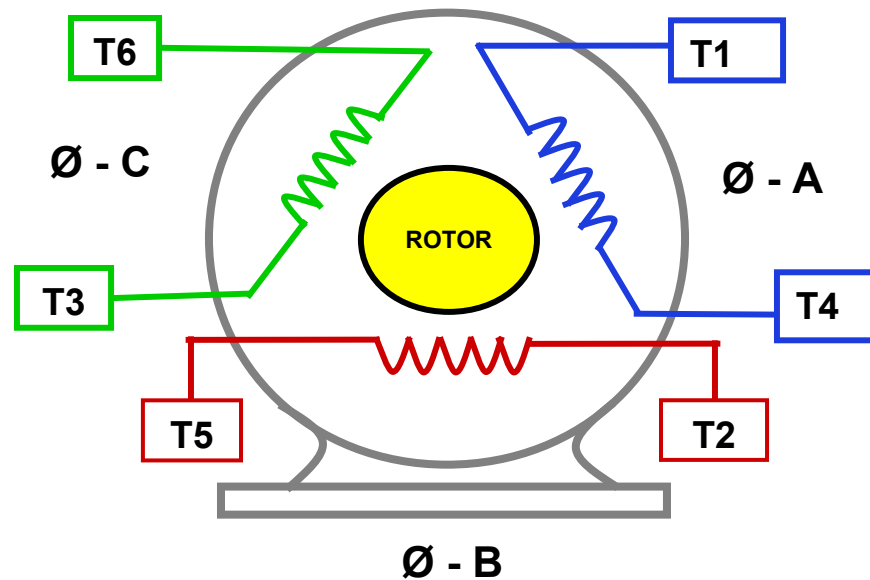


BLOCK DIAGRAM OF 3-Ø MOTOR

Pole and Phase Arrangement



Schematic Diagram of a 3-Ø Motor



Rewinding Procedure

2. Stripping the Winding

- a) Burn the old winding by using oven or torch to remove the varnish.
- b) Avoid not to damage the slot lamination.
- c) Cut the coils by using cold chisel or hacksaw.
- d) Remove the wedges before pulling out the wires.

Burn-out Oven

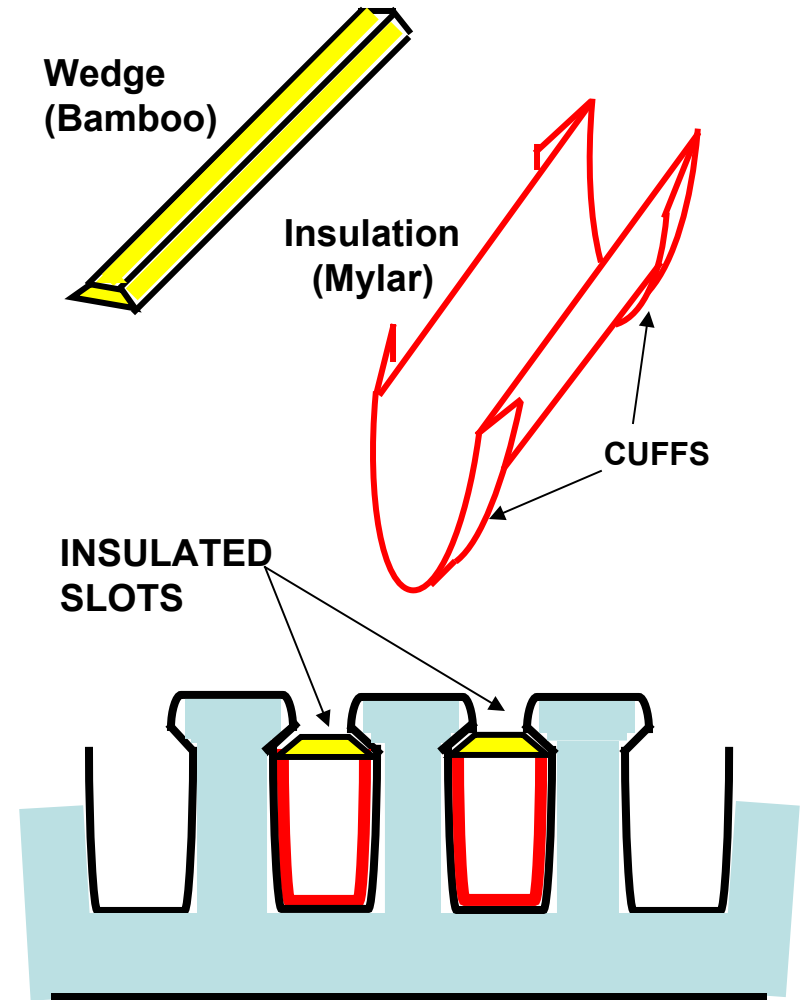


Rewinding Procedure

3. Insulating the Slots

- a) Clean first the slots.
- b) Copy the size and format of the removed slot insulation.
- c) Make the required length of wedge (bamboo) for slot lock.
- d) Insert the insulation inside the slot. Ensure that it is fitted correctly.

Slot Insulation



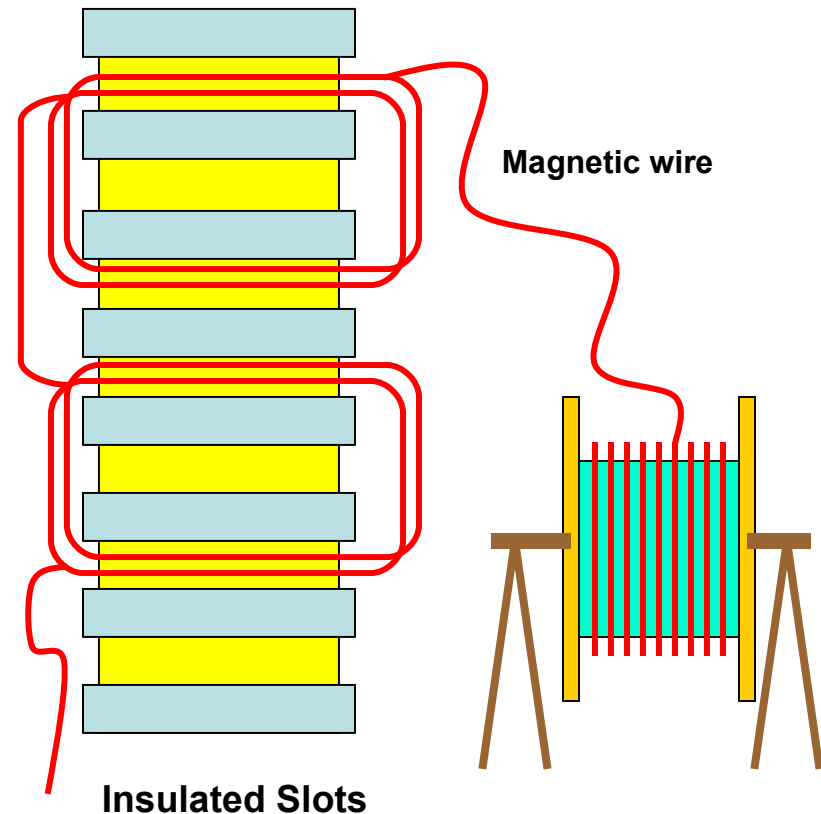
Rewinding Procedure

4. Winding the Coils

a) Hand winding- the wires are wound directly inside the slots, one turn at a time. Starting with the inner coil and until all the coil of one pole are wound.

This is normally used in the rewinding of wound rotors, armatures and other small motors.

Hand Winding



Rewinding Procedure

4. Winding the Coils

b) Form winding- this is the most common method of winding the coils. The wires are wound in the wooden, plastic or metal form then secured it, before inserting it part by part into the slots.

Form Winding
Machine

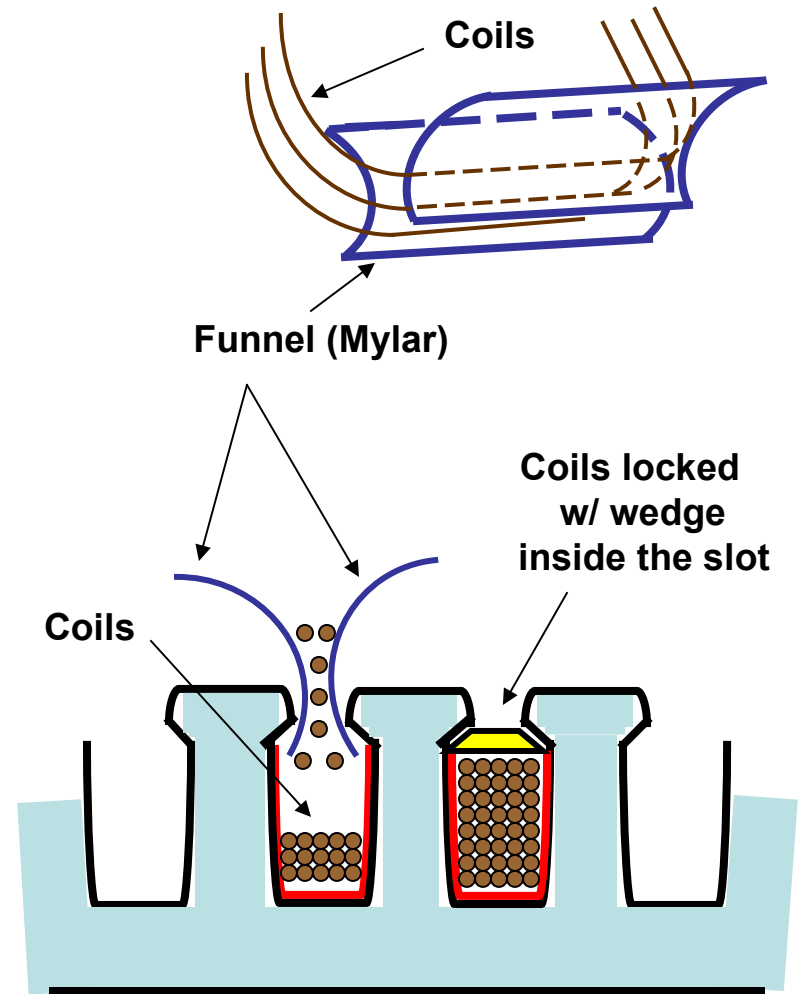


Rewinding Procedure

5. Inserting the Coils into the Slots

- a) By using the form winding method, the coils must be inserted part by part.
- b) Avoid forcing the coils to be fed in the slots simultaneously.
- c) Sometimes, it is advisable to use a funnel to ease the task.

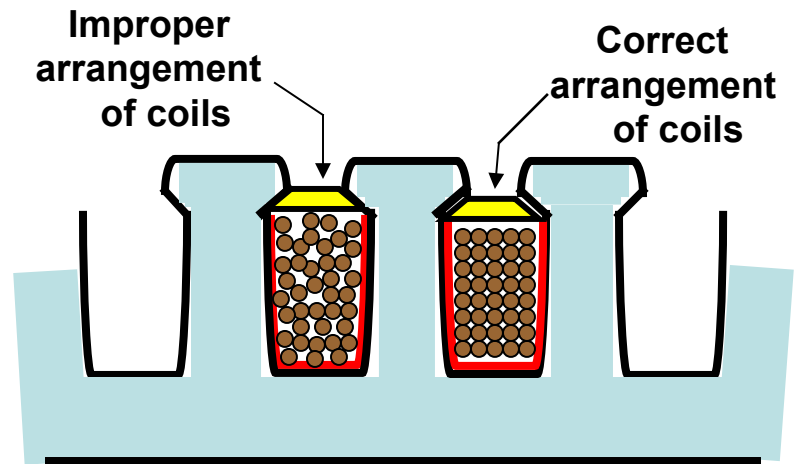
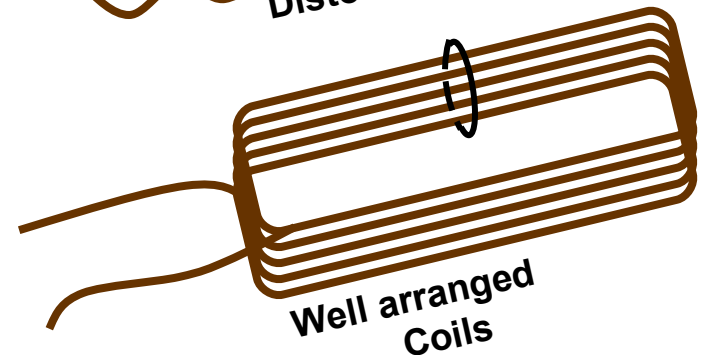
Inserting the coil



Rewinding Procedure

5.Inserting the Coils...

- d) Avoid overlapping or crossing the coils to maximize the space of the slots.
- e) Remove the kinks in the wire before inserting it into the slots.
- f) After all coils were inserted, put the wedge or slot lock. Be sure that no coil was wrongly placed outside the slot insulation.



Rewinding Procedure

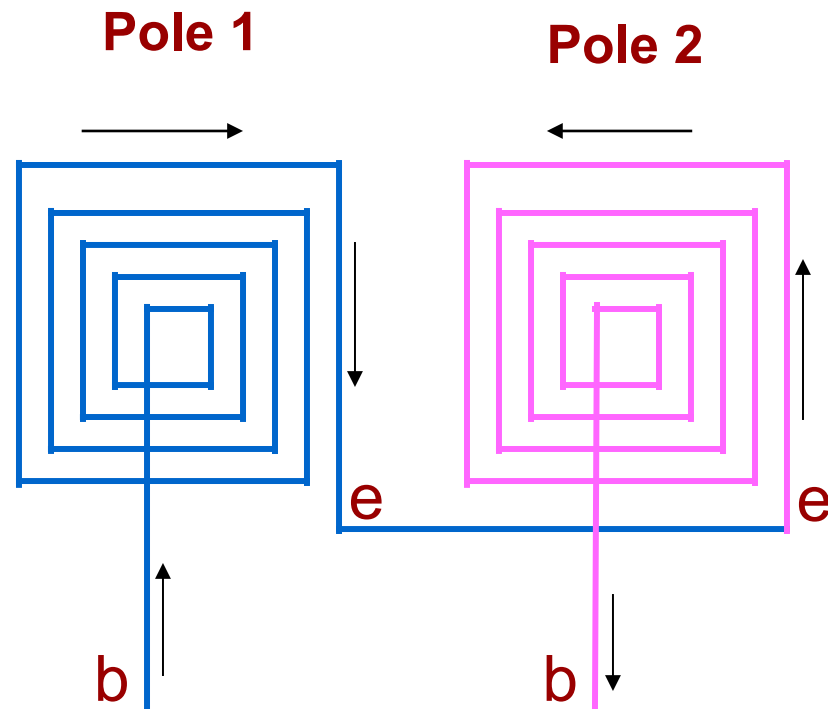
6. Connecting the Windings

a) After all coils are inserted, the next step is to connect them.

b) The coils must be connected in the set of Begin(b) to Begin and End(e) to End terminals in order to form an alternate polarity in the poles...

See the left diagram.

Connecting the coils



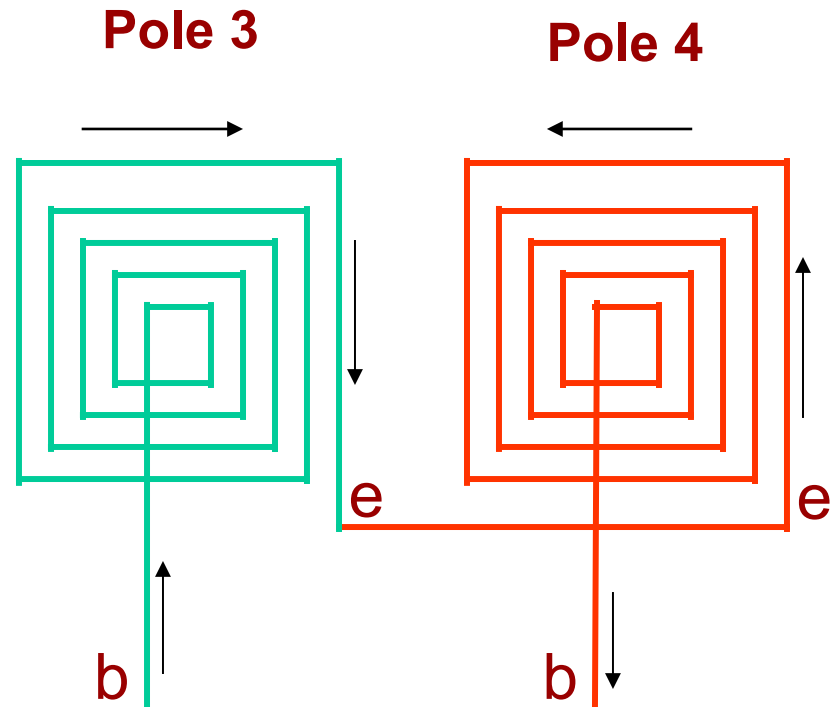
Rewinding Procedure

6. Connecting the Windings

... or the first pole is wound clockwise, the second pole is counter clockwise and the third is clockwise again and so on...

c) Care should be taken to alternate the direction of the winding for each pole.

Connecting the coils

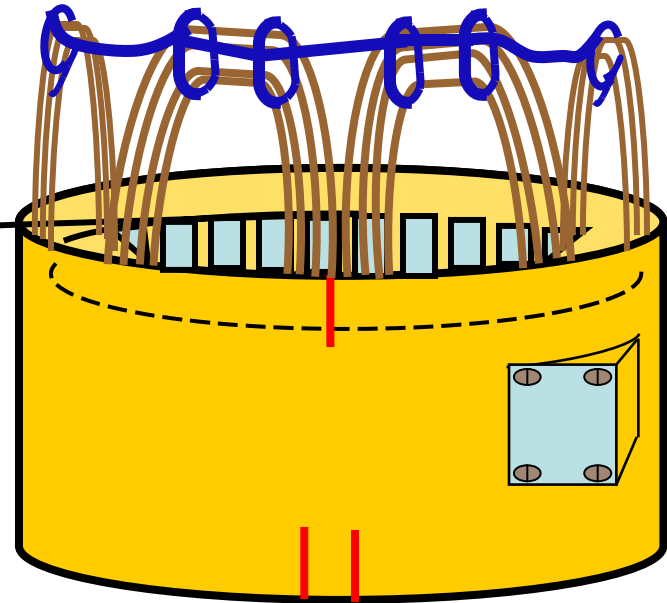


Rewinding Procedure

7. Lacing the Coils

a) After the coils were correctly soldered and connected. Motor thread or yarn is used to lace the winding to keep the coils in good shape and fit inside the casing. It also protect the coils not to be detached during the motor's running operation.

Lacing the coils



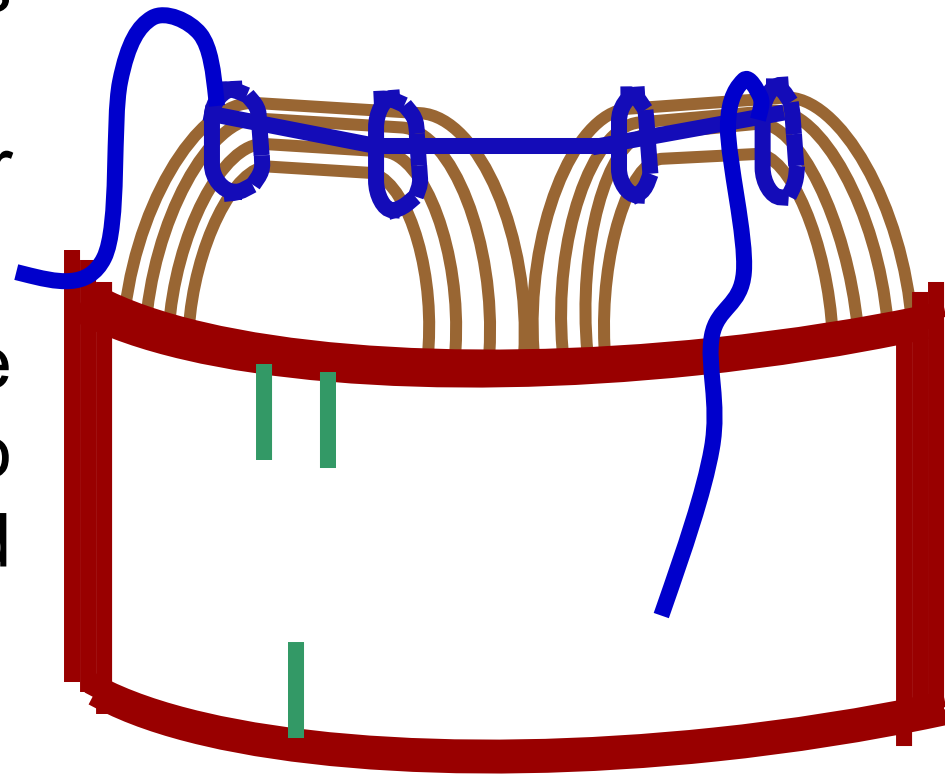
Electric Motor

Rewinding Procedure

7. Lacing the Coils...

- b) The thread used is a special type which is intended only for motor and transformer rewinding.
- c) The thread must be correctly tied in order to avoid loss of time and rewinding effort.

Lacing the coils

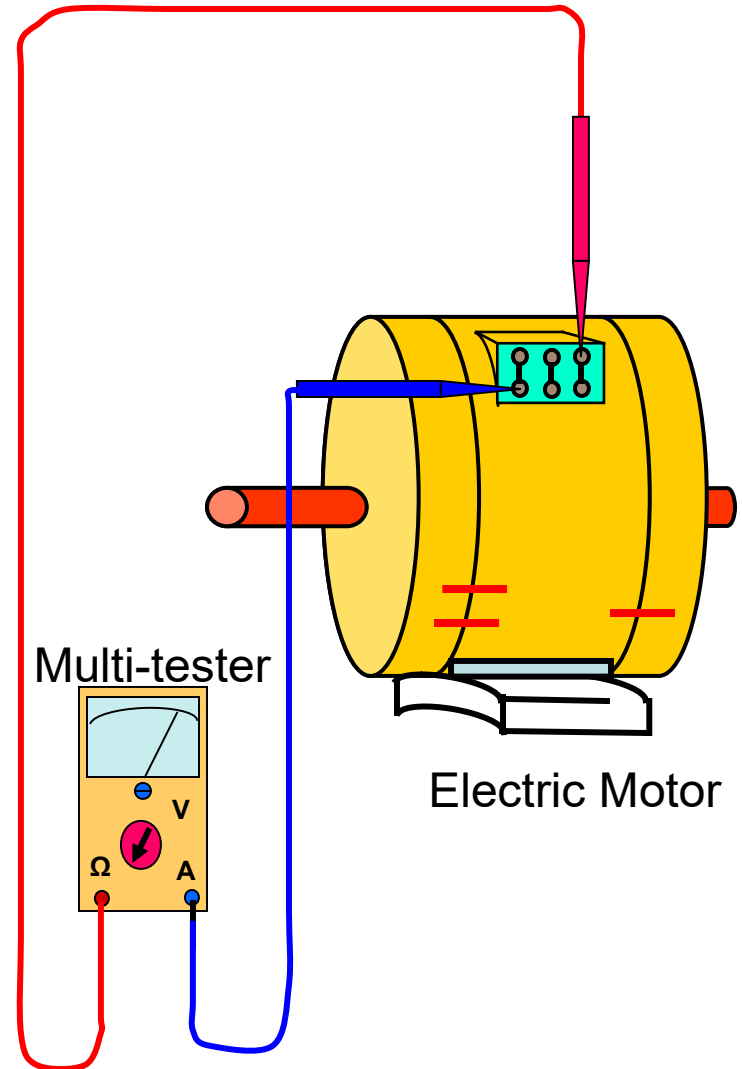


Rewinding Procedure

8. Testing the New Winding

- a) After the rewinding and connections of coils are completed, it is essential to test and check the motor.
- b) Using Ohmmeter; check the motor for Short circuits, Open circuits, Ground circuits and Incorrect connections and polarity.

Test the motor

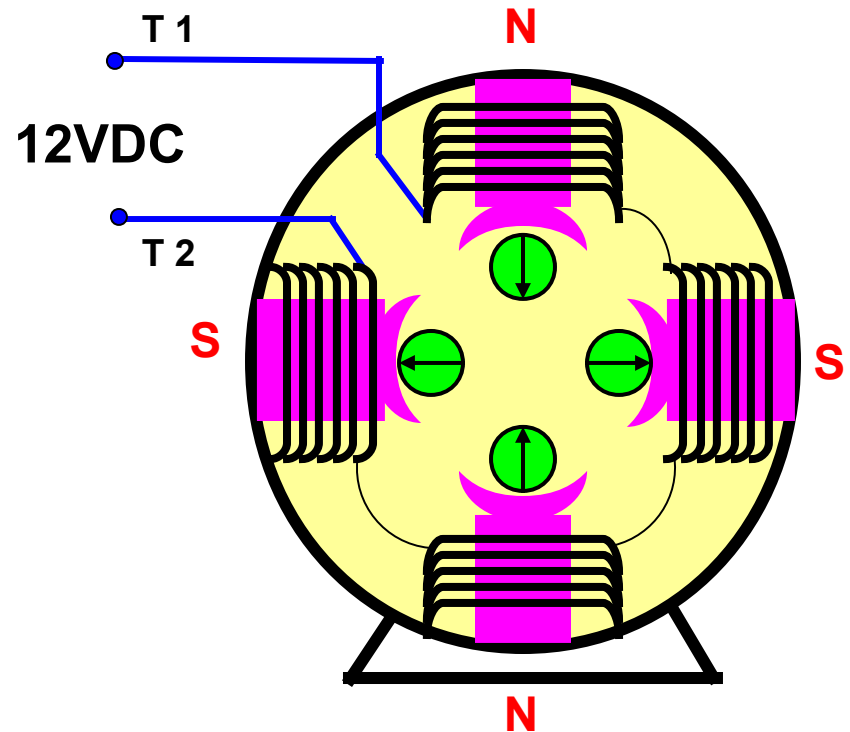


Rewinding Procedure

8. Testing the New Winding...

- c) Incorrect connections could be discovered by using compass method and nail method (for small motors).
- d) Using compass method, the winding of the motor must be connected to the low voltage direct current or low voltage alternating current.

The compass must be in alternate position to indicate the correct polarity of the motor



Rewinding Procedure

8. Varnishing and baking

- a) After the winding is thoroughly tested, the stator is let to dry to remove any kind of moisture. Then the stator winding is dipped into a container of insulation varnish.
- b) Varnish may also be applied by spraying or brushing. After that, let it drip the remaining varnish and put it inside the baking oven.
- c) The oven temperature must be in between 110°C to 140°C and the stator must be there for several hours to dry it completely.
- d) Varnishing and baking bonds the entire winding and it helps to increase the mechanical and dielectric strength of the wires.

