ELECTRIC MOTOR REPAIR

ILLUSTRATIONS AND STUDY QUESTIONS

PREFACE

For many years there has been a need for an intensely practical, nontheoretical book on electric-motor repair and rewinding that could be used by men with little background of electrical knowledge. This has been only too evident in my contacts with workers over a period of many years in motor repair shops and with learners during ten years as an instructor in motor repair and armature winding in the New York City vocational high schools. It is with the hope of satisfying this pressing need that this book has been written. Inclusion of more than 900 illustrative drawings should make it particularly valuable as a direct working guide, not only to the student but to the repairman at the bench, and in helping the student to a clearer understanding of the text.

Because the troubleshooter and repairman must learn to do satisfactory work in the shortest possible time, I have tried to point out the best and quickest methods for testing and repairing. The summary headed *Troubleshooting and Repair* at the end of each discussion should be especially helpful.

ELECTRIC MOTOR REPAIR

ELECTRIC MOTOR REPAIR

A PRACTICAL BOOK ON
THE WINDING, REPAIR, AND TROUBLESHOOTING OF
A-C AND D-C MOTORS AND CONTROLLERS

by

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CHAPTER I

Split-phase Motors

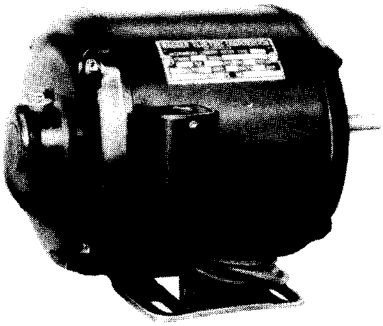


FIG. 1-1.—A split-phase motor. (*Wagner Electric Co.*)

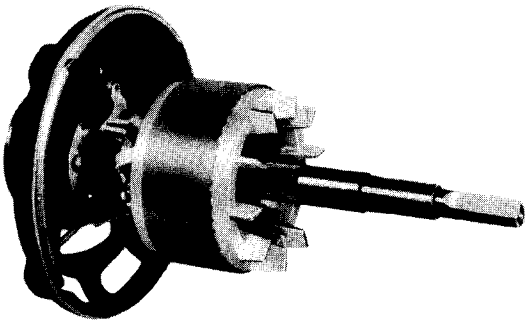


FIG. 1-2.—A complete rotor of a split-phase motor. (*Wagner Electric Co.*)

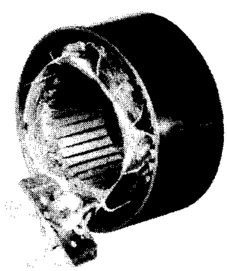


FIG. 1-3.—A stator of a split-phase motor mounted inside the frame. (*General Electric Company.*)

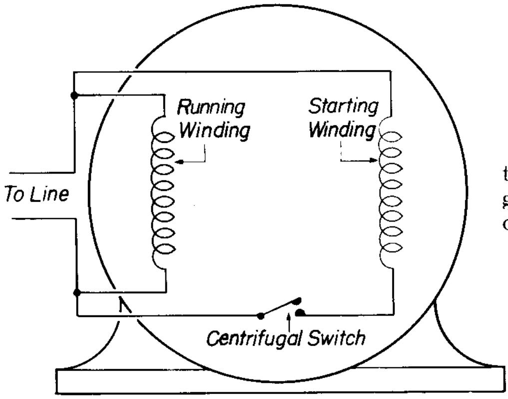


FIG. 1-4.—A circuit of the two windings and the centrifugal switch when the motor is operating at full speed.

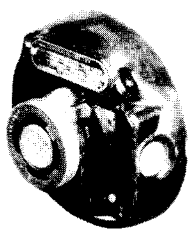
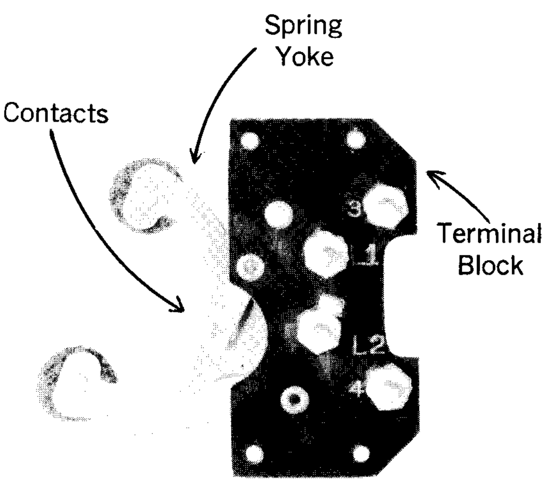


FIG. 1-5.—One end plate of a fractional-horsepower a-c motor. (*General Electric Company.*)



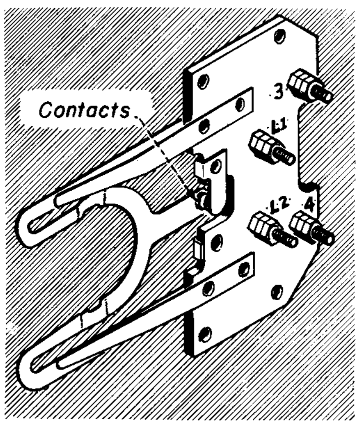


FIG. 1-6.—Two variations of the stationary section of one type of centrifugal switch which consist of a U-shaped yoke mounted on a terminal block.

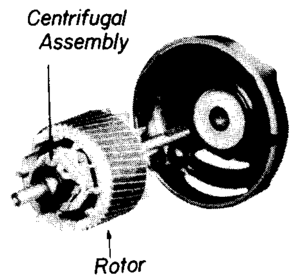
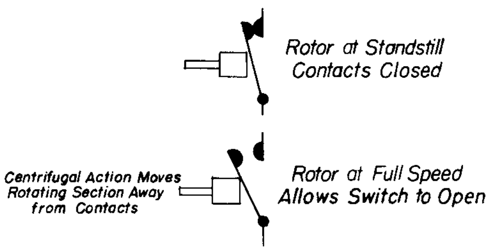


FIG. 1-7.—The rotating mechanism of a centrifugal switch. (*General Electric Company.*)

FIG. 1-8.—Steps in the operation of a centrifugal switch.



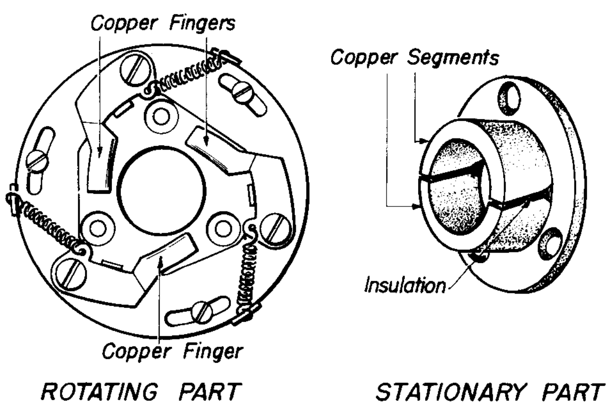


FIG. 1-9.—The rotating and stationary parts of one type of centrifugal switch.

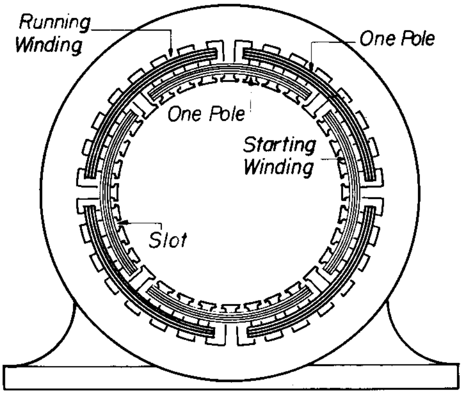


FIG. 1-10.—The two windings of a split-phase motor. Note the four sections or poles in each winding.

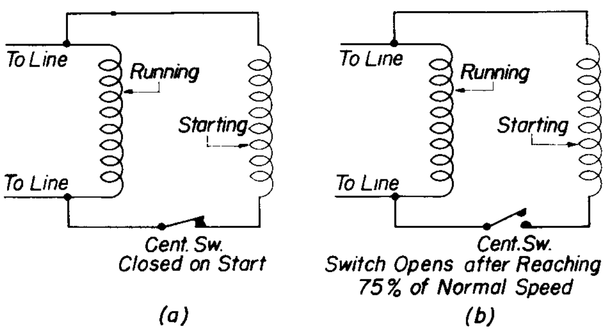


FIG. 1-11.—The change in motor circuit caused by a centrifugal switch.

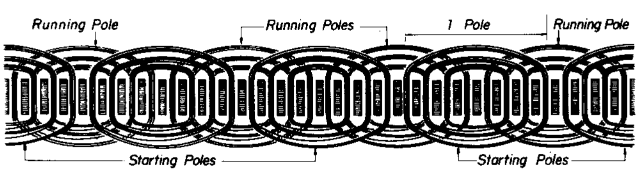


FIG. 1-12.—A diagram of the stator in Fig. 10 with slots and windings shown as they would look if rolled flat. The starting-winding poles are located between two running-winding poles.

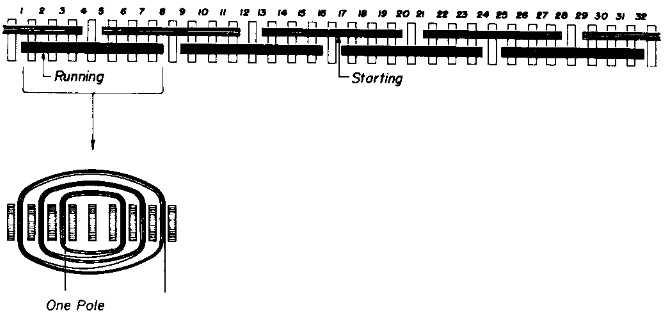


FIG. 1-13.—Each pole consists of three coils, and each coil is wound in two slots separated by other slots.

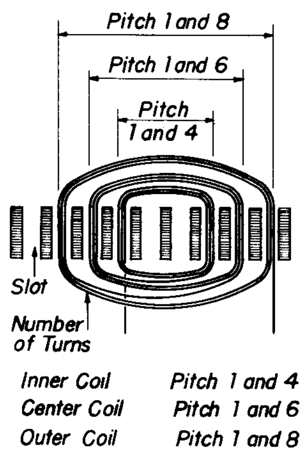


FIG. 1-14.—The pitch, or span, of the three coils forming one pole.

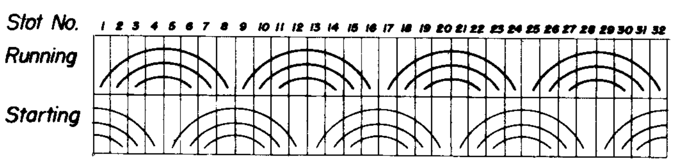


FIG. 1-15.—The method of recording the pitch of the coils in a 32-slot, four-pole motor. The number of turns in each coil can be recorded alongside each coil in the diagram if so desired.

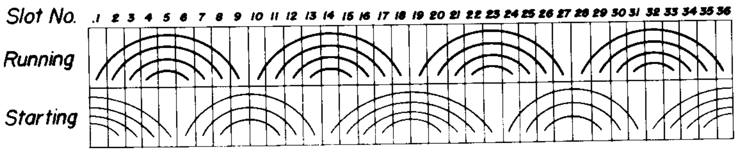


FIG. 1-16.—Pitch data of a 36-slot, four-pole motor. The poles of the starting winding are not the same; one pole has four coils while the next has three.

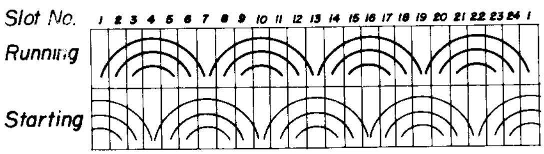


FIG. 1-17.—Pitch data of a 24-slot, four-pole motor. The outer coils of adjacent poles are in the same slot.

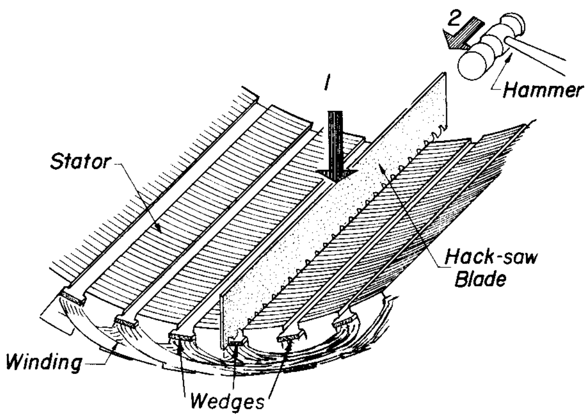


FIG. 1-18.—The method of forcing a hack-saw blade into a wedge.

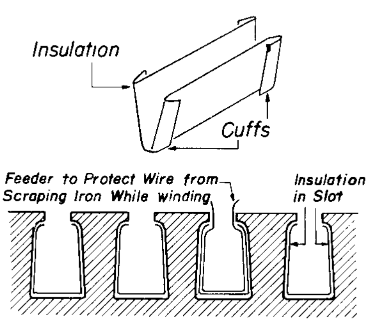


FIG. 1-19.—An insulating strip and its placement in slot before winding.

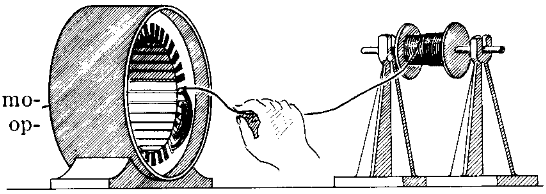


FIG. 1-20.—The position of the motor and wire spool during winding operation.

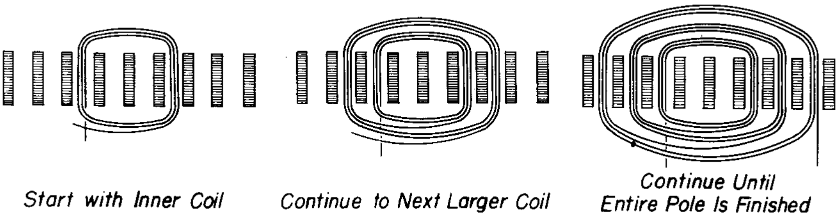


FIG. 1-21.—The procedure for winding one stator pole by hand.

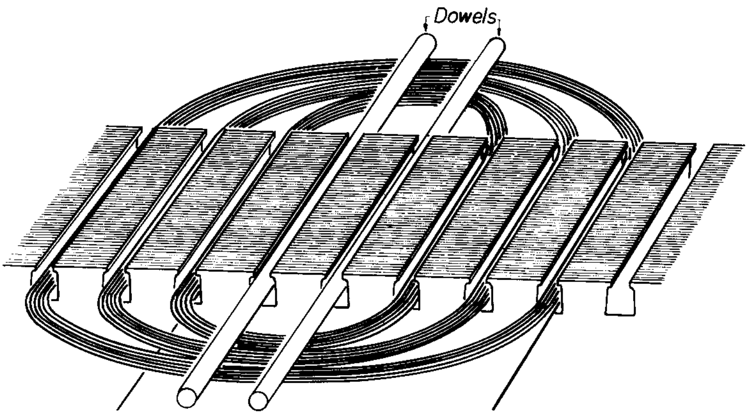
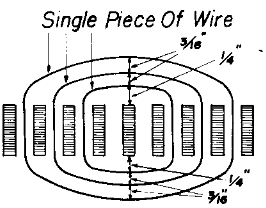


FIG. 1-22.—Wooden dowels may be placed in empty slots to hold coils in position while winding.

FIG. 1-23.—Properly spaced single turns of wire determine the size of the wooden forms shown in Fig. 1-24.



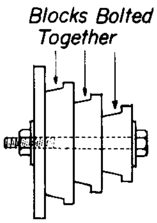


FIG. 1-24.—Wooden blocks provide forms on which to wind coils.

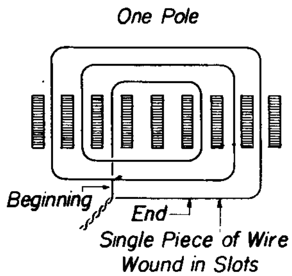


FIG. 1-25.—The method of determining the size of the skein.

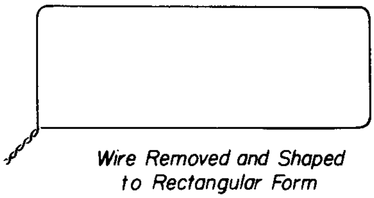


FIG. 1-26.—The size of the skein obtained from a single wire.

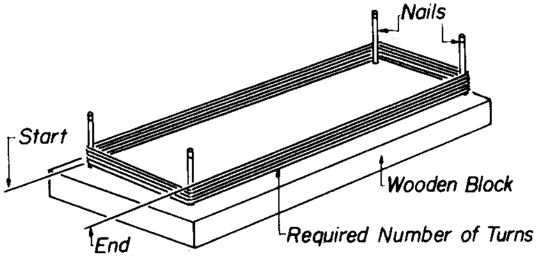


FIG. 1-27.—A coil wound around nails to form a skein.

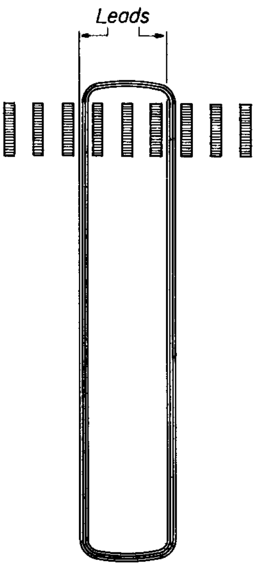


FIG. 1-28.—After it is removed from the nails, the skein is placed in slots of the lowest pitch.

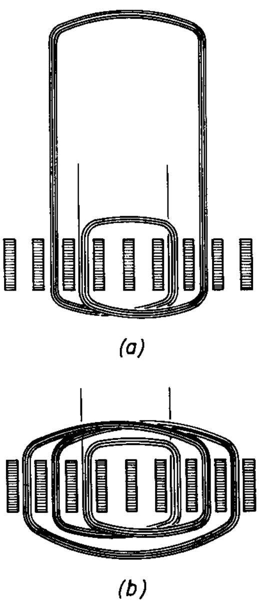


FIG. 1-29.—The skein is twisted and placed in the slot of next pitch (*a*) and twisted again to form final pole (*b*).

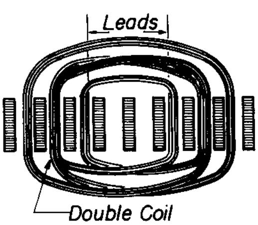


FIG. 1-30.—A skein winding with a double coil in the center.

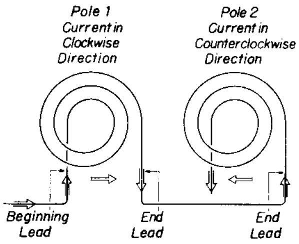


FIG. 1-31.—The connection of adjacent poles to obtain opposite polarity.

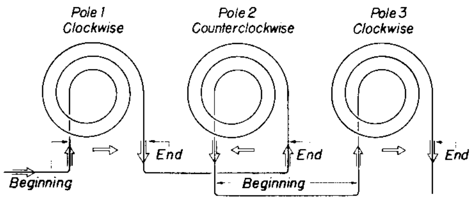


FIG. 1-32.—The connections of three poles.

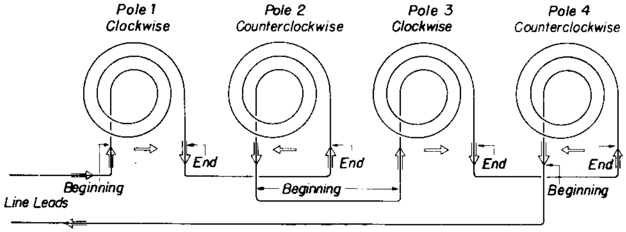


FIG. 1-33.—Four poles connected together and to the line.

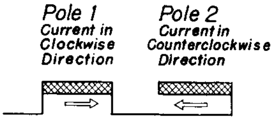


FIG. 1-34.—A block diagram of circuit of Fig. 1-31.

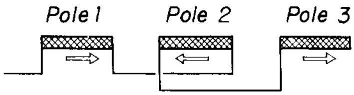


FIG. 1-35.—Continued from Fig. 1-34. The beginning of pole *2* connects to the beginning of pole *3*.

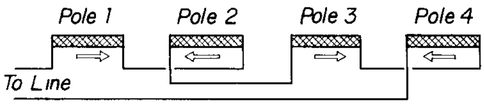
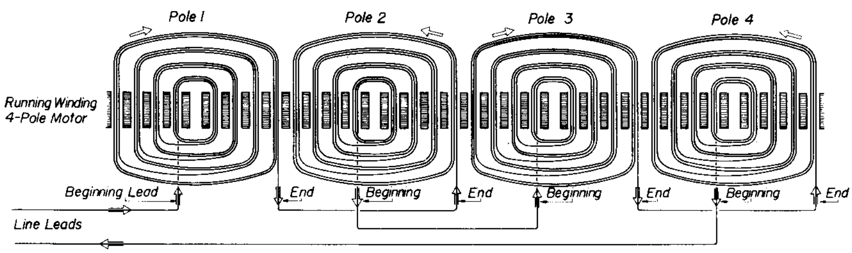


FIG. 1-36.—The end of pole *3* connects to the end of pole *4*. The line is connected to the beginning of pole *1* and pole *4*.



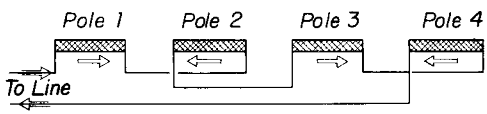


FIG. 1-37.—Four poles of the running winding. The poles are connected so that the current through pole *1* is in a clockwise direction; through pole *2*, in a counterclockwise direction; pole *3*, clockwise; pole *4*, counterclockwise.

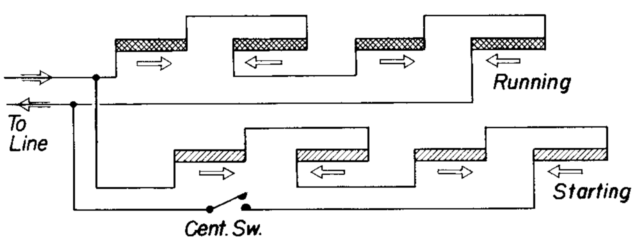


FIG. 1-38.—A four-pole split-phase motor connection.

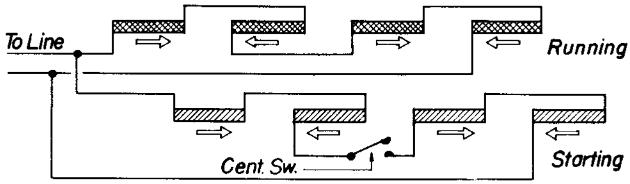


FIG. 1-39.—A four-pole, split-phase motor showing the centrifugal switch connected in the center of the starting winding.

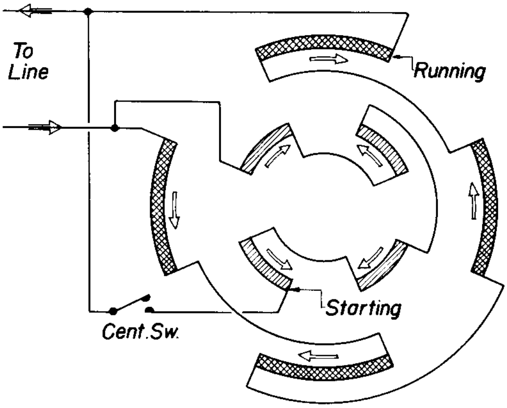
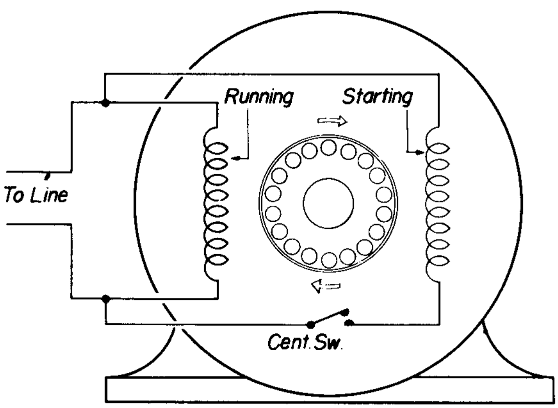


FIG. 1-40.—A four-pole split-phase motor connection shown in a circular diagram.

FIG. 1-41.—A split-phase motor with four leads brought outside the frame for reversing.



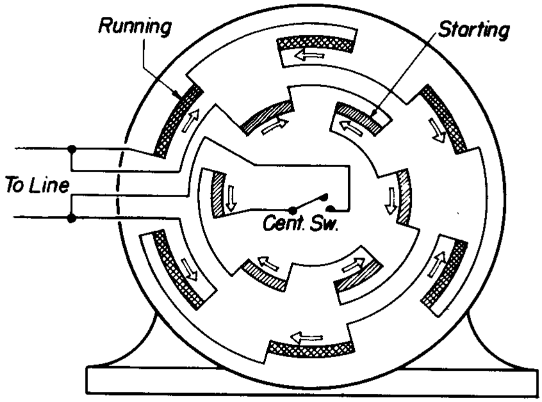


FIG. 1-42.—The connections of a six-pole split-phase motor.

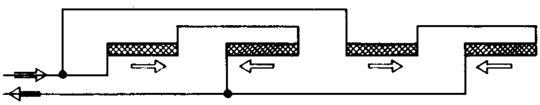


FIG. 1-43.—A two-circuit connection of a four-pole running winding.

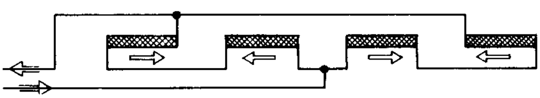


FIG. 1-44.—Another method for connecting a two-circuit, four-pole running winding.

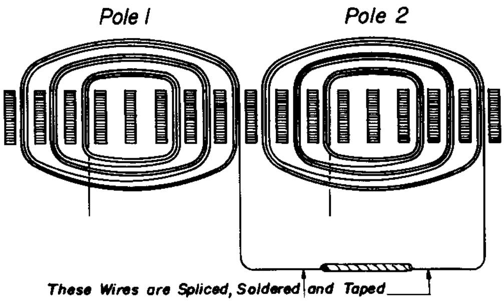


FIG. 1-45.—One method of connecting wires between poles.

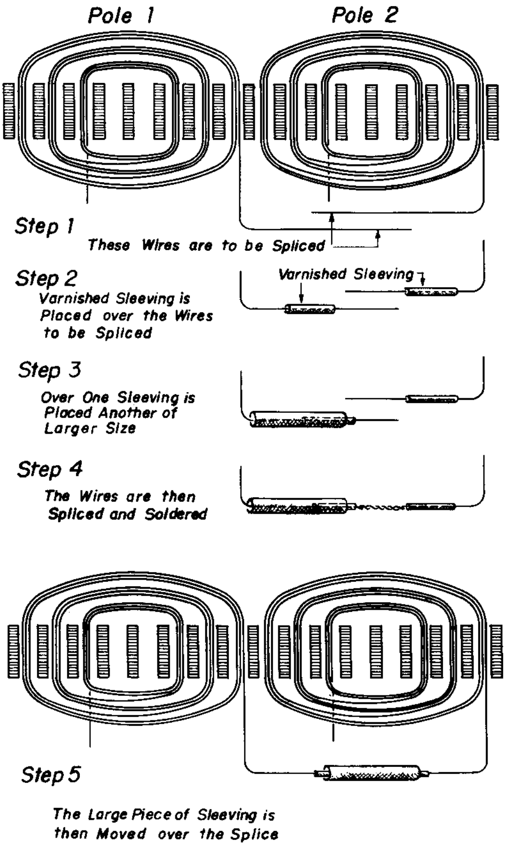
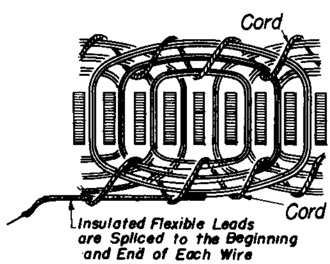


FIG. 1-46.—A method of connecting leads together.

FIG. 1-47.—The lead is tied to the winding with cord so that it cannot be broken off. The windings are also tied to one another to prevent unraveling.



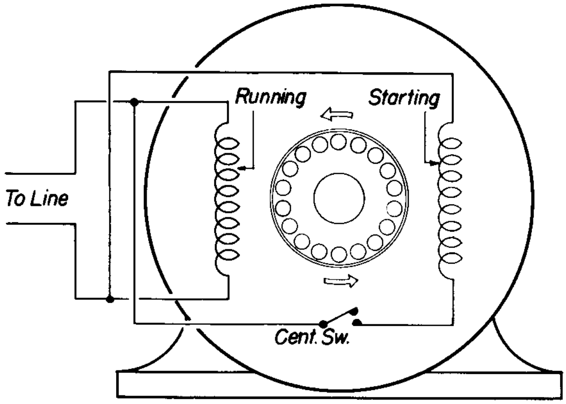


FIG. 1-48.—The motor shown in Fig. 1-41 connected for reversed rotation.

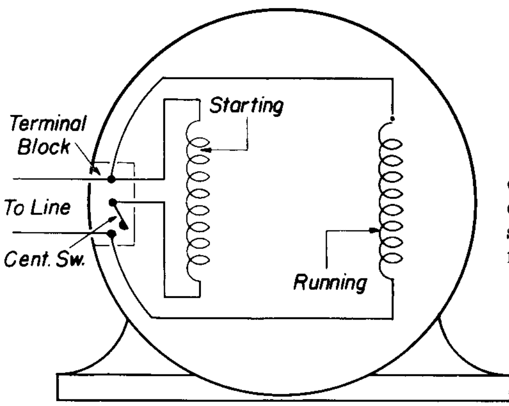


FIG. 1-49.—The connections of the terminal block on the end plate. The centrifugal switch is mounted on the terminal block.

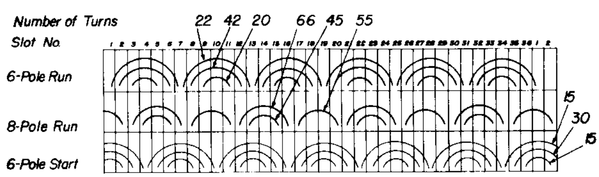


FIG. 1-50.—A coil layout of a two-speed, three-winding split-phase motor.

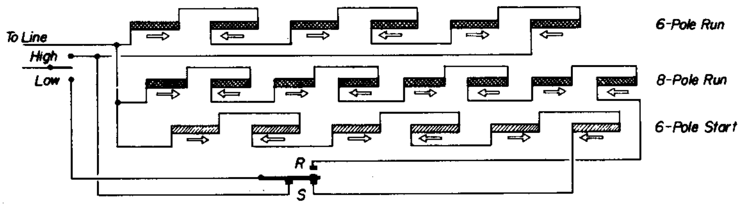


FIG. 1-51.—The wiring of a two-speed split-phase motor.

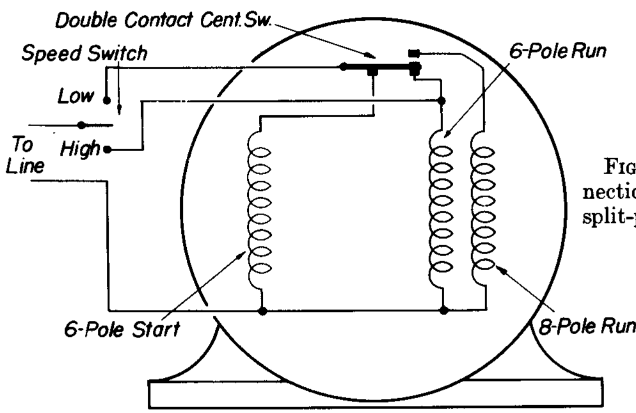


FIG. 1-52.—The connections of a two-speed split-phase motor.

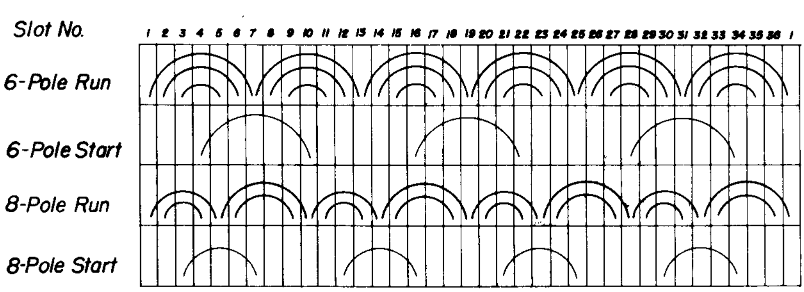


FIG. 1-53.—A typical layout of a two-speed split-phase motor using four windings. The starting windings are consequent pole connected.

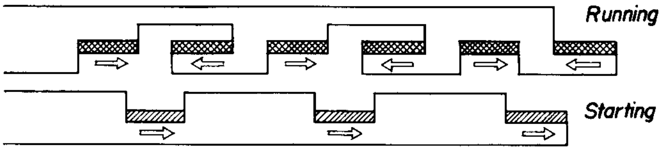


FIG. 1-54.—The starting and running winding of the six-pole part of a two-speed motor. The starting-winding poles are connected for like polarity. There are only three wound poles; three more poles of opposite polarity are formed in the stator frame.

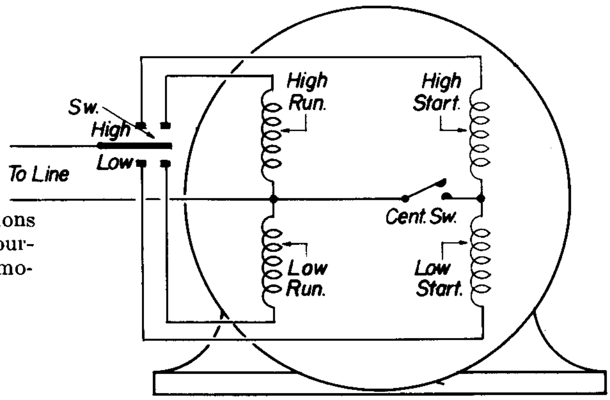


FIG. 1-55.—Connections of a two-speed, four-winding split-phase motor.

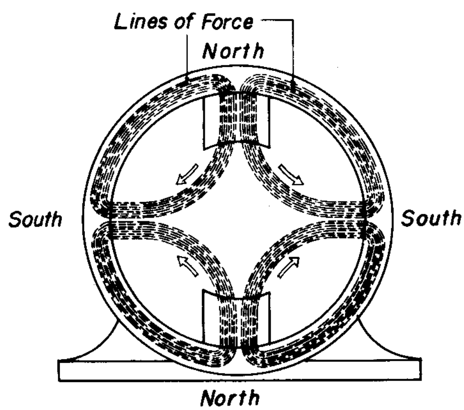


FIG. 1-56.—If the two poles of a two-pole motor are connected so that like polarity results, two more poles will be formed by the lines of force entering the frame.

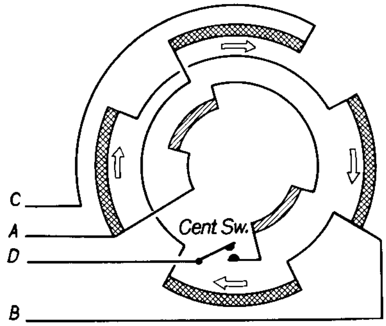


FIG. 1-57A.—Circular diagram of a two-speed, two-winding, split-phase motor.

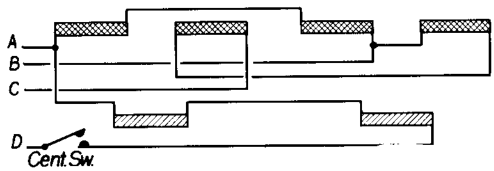


FIG. 1-57B.—Straight-line diagram of motor of Figure 1-57A.

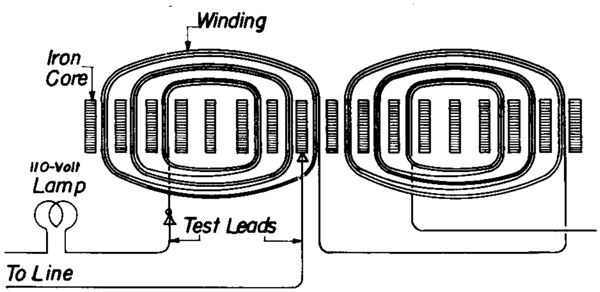


FIG. 1-58.—To determine whether winding is grounded, connect one test lead to the winding and the other test lead to the core. The lighted lamp indicates a ground.

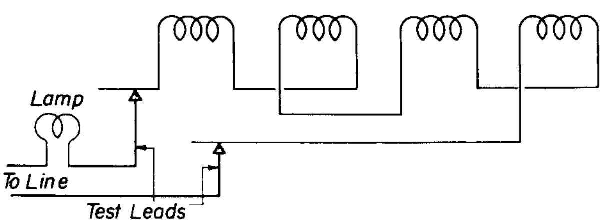


FIG. 1-59.—A circuit for testing winding for opens.

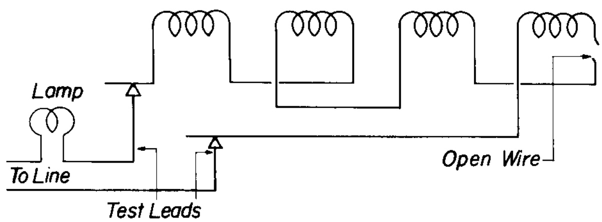


FIG. 1-60.—The effect of a defective pole. If the circuit is open, the lamp will not light.

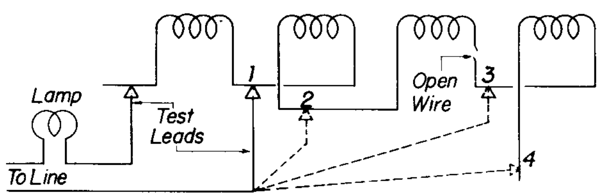


FIG. 1-61.—The method of determining which pole is open-circuited.

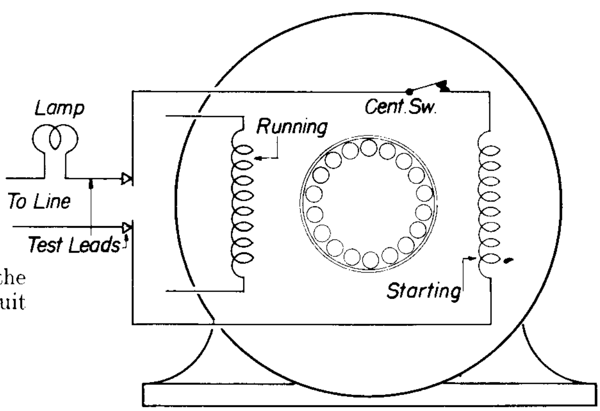


FIG. 1-62.—Testing the starting-winding circuit for opens.

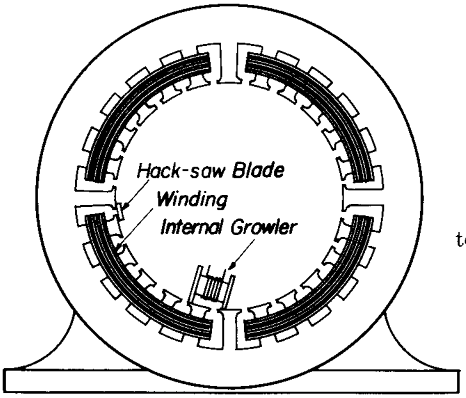


FIG. 1-63.—The growler method of testing for shorts in the stator.

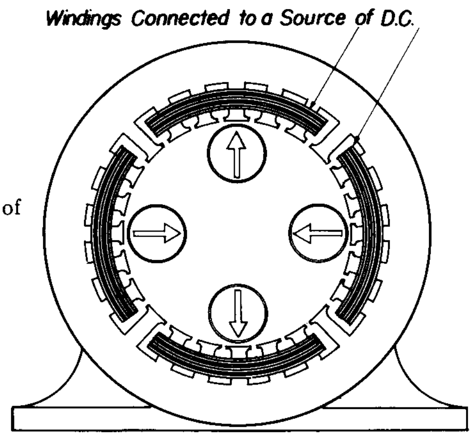


FIG. 1-64.—The compass method of testing for reversed poles.

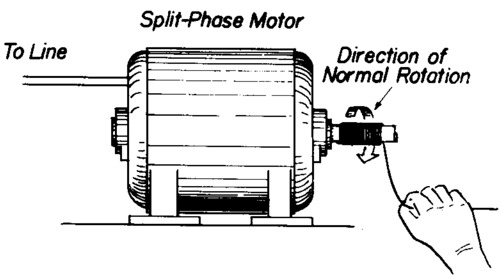


FIG. 1-65.—Starting the motor by mechanical means.

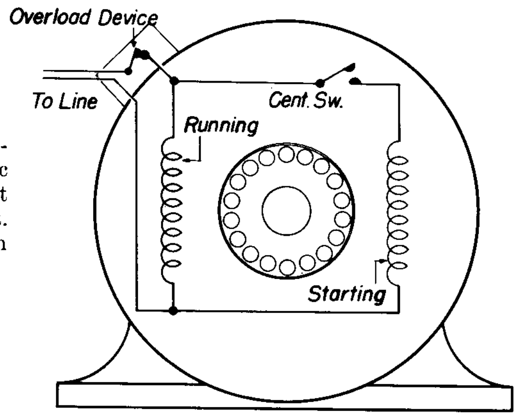


FIG. 1-66.—An overload device, consisting of a bimetallic element that will open circuit on overload or short circuit. It is connected in series with the line.

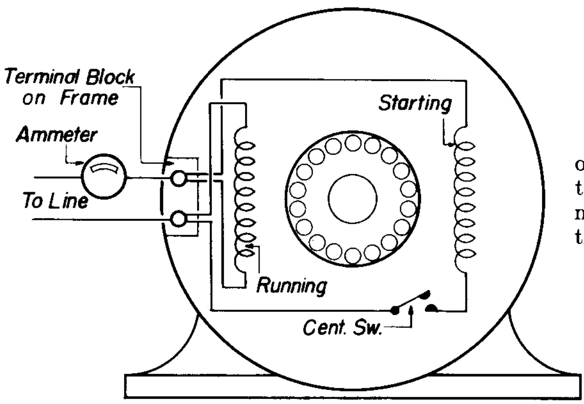


FIG. 1-67.—The method of connecting an ammeter in circuit to determine the current flowing through the motor.

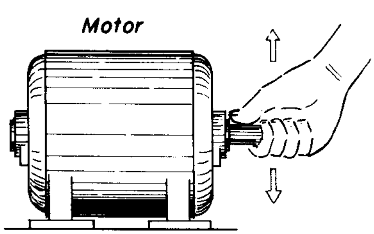


FIG. 1-68.—The bearings are tested by trying to move the shaft vertically.

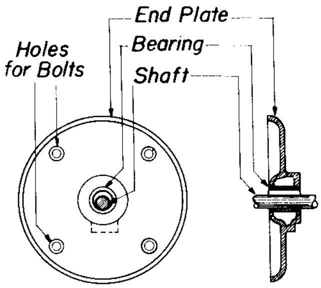


FIG. 1-69.—If the shaft can be moved vertically, it indicates a worn bearing or worn rotor shaft.

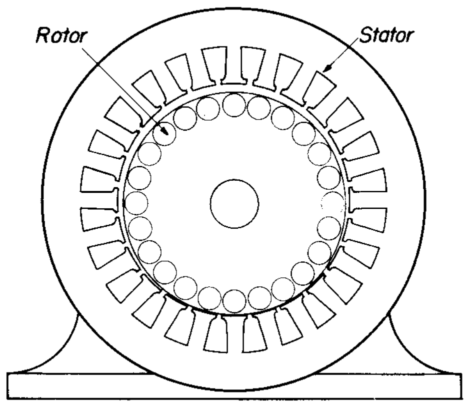


FIG. 1-70.—A worn bearing may cause the rotor to rub on the stator core.

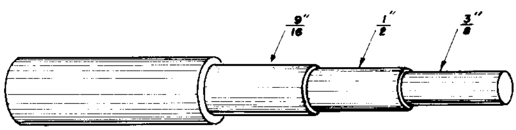


FIG. 1-71.—The tool used for forcing bearings out of end plates.

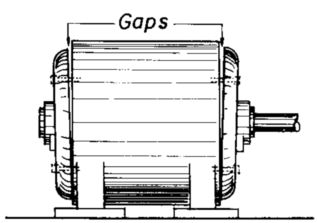


FIG. 1-72.—A motor showing end plates not mounted properly. This prevents the rotor from turning. Use a mallet to tap plates into position.

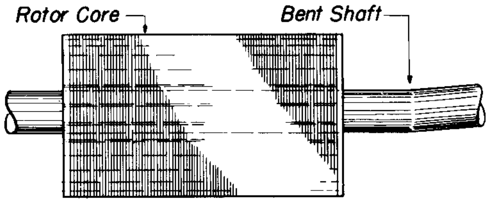


FIG. 1-73.—The bent shaft of a rotor.

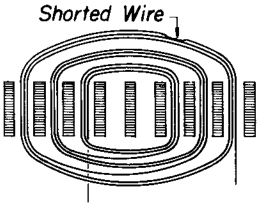


FIG. 1-74.—Two coils making electrical contact.

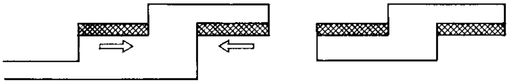


FIG. 1-75.—A connection mistake often made by beginners.

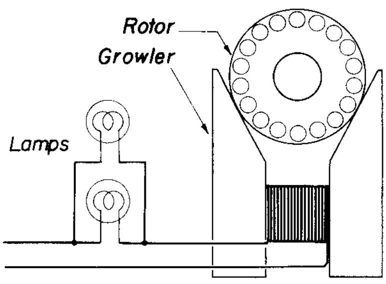


FIG. 1-76.—The rotor under test placed between the open ends of the growler core.

CHAPTER 2

Capacitor Motors

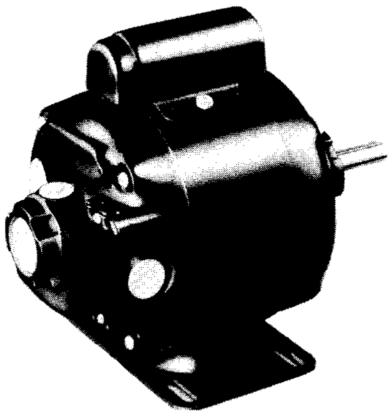


FIG. 2-1.—Fractional-horsepower capacitor motor. (*General Electric Company.*)

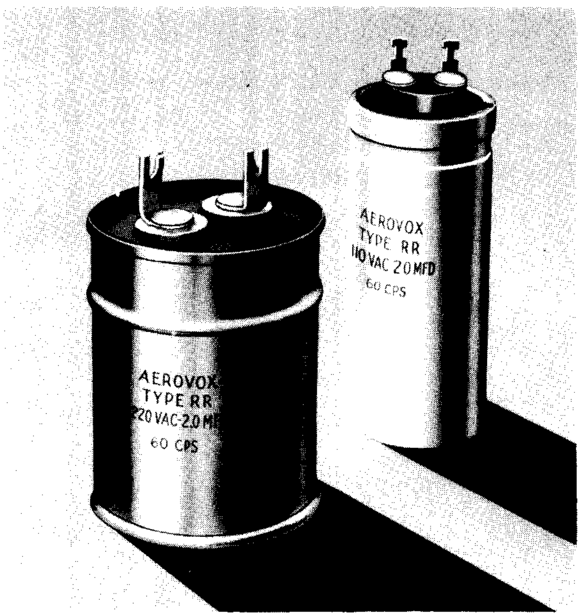


FIG. 2-2.—Paper capacitors.

FIG. 2-3.—An oil-filled capacitor.

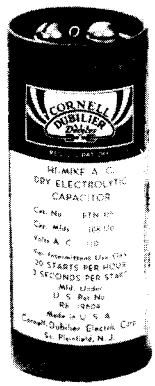


FIG. 2-4.—An electrolytic capacitor.

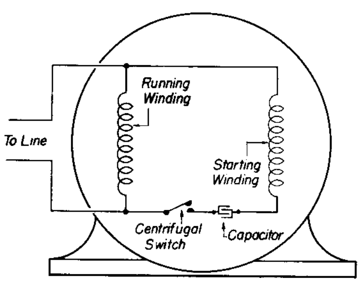


FIG. 2-5.—Connections of a capacitor-start motor.

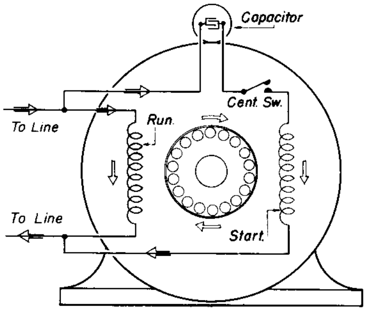


FIG. 2-6.—Single-voltage capacitor-start motor connected for clockwise rotation. Note direction of current in the windings.

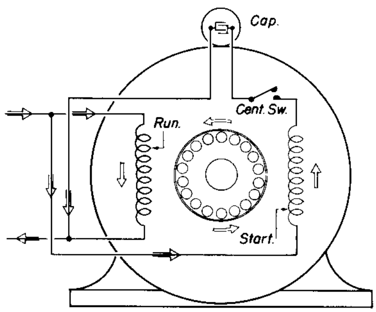


FIG. 2-7.—Single-voltage capacitor-start motor connected for counter-clockwise rotation. The direction of the current in the starting winding has changed from that shown in Figure 2-6.

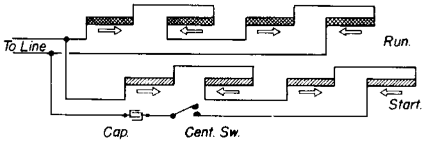


FIG. 2-8.—Straight-line diagram of a four-pole capacitor-start motor.

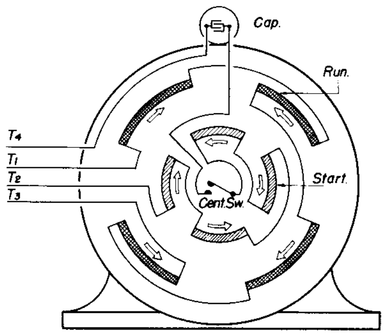


FIG. 2-9.—Connection diagram of a four-pole capacitor-start motor.

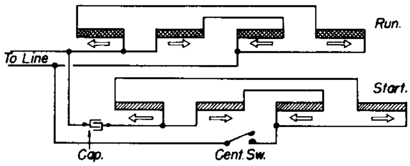


FIG. 2-10.—Straight-line diagram of a four-pole, two-circuit capacitor-start motor.

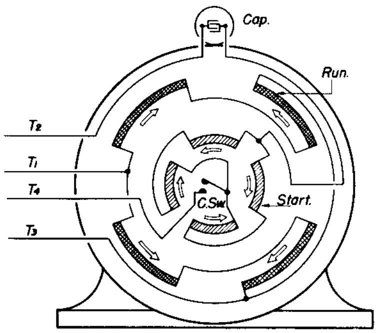


FIG. 2-11.—A four-pole, two-circuit capacitor-start motor.

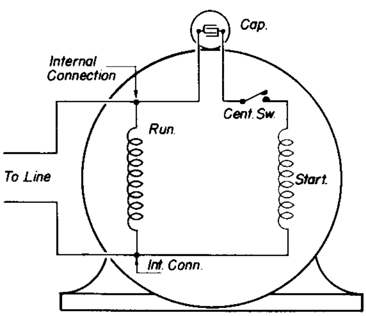


FIG. 2-12.—Nonreversible capacitor-start motor.

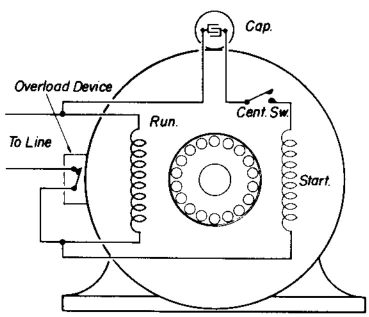


FIG. 2-13.—Capacitor-start motor with bimetallic overload device connected in series with the line.

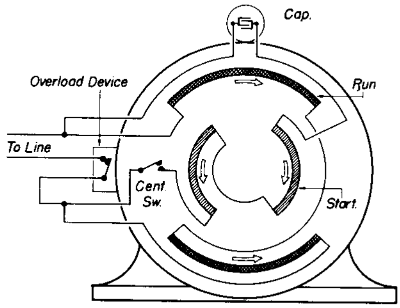


FIG. 2-14.—Connection diagram of a two-pole capacitor-start motor with an overload device.

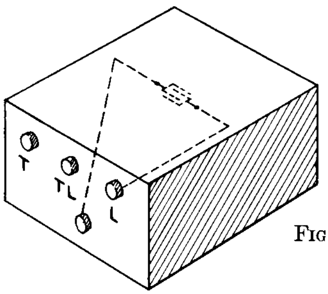


FIG. 2-15.—Capacitor with terminal block attached.

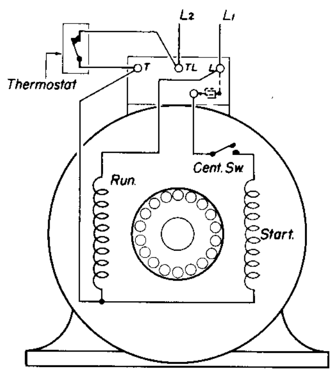


FIG. 2-16.—Capacitor-start motor with a terminal block capacitor.

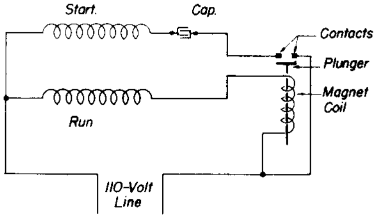


FIG. 2-17.—Diagram of a capacitor-start motor using a magnetic switch instead of a centrifugal switch.

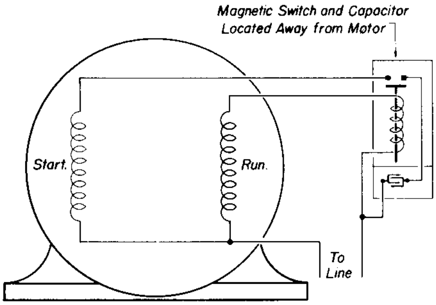
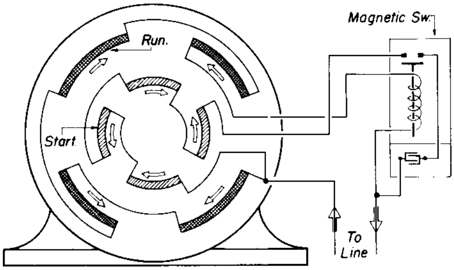


FIG. 2-18.—Capacitor-start motor using magnetic switch.

FIG. 2-19.—Connections of four-pole capacitor-start motor using a magnetic switch.



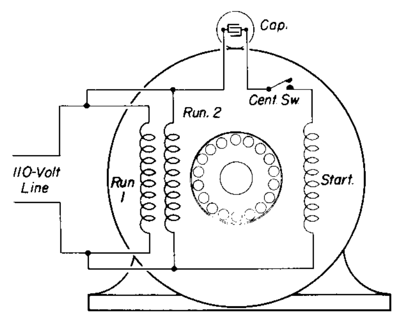
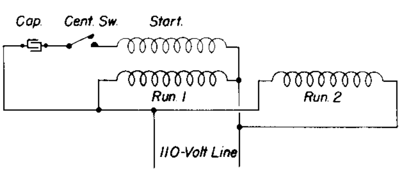


FIG. 2-20.—A two-voltage capacitor-start motor connected for 110-volt operation. The running windings are connected in parallel.

FIG. 2-21.—A schematic diagram of a two-voltage capacitor-start motor connected for 110-volt operation.



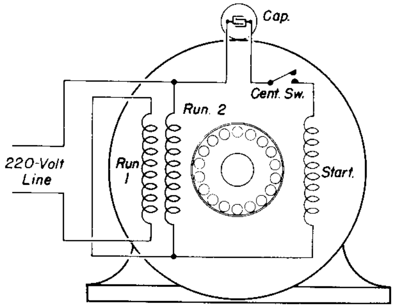


FIG. 2-22.—A two-voltage capacitor-start motor connected for 220 volts. The running windings are connected in series.

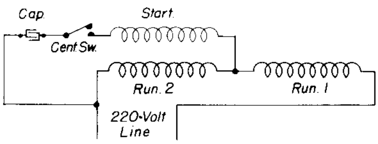


FIG. 2-23. A schematic diagram of a two-voltage capacitor-start connection for 220 volts.

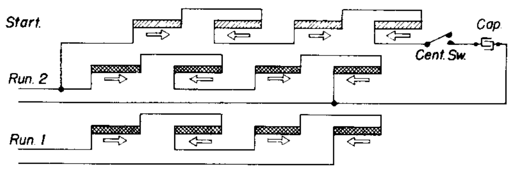


FIG. 2-24.—A straight-line diagram of a four-pole, two-voltage capacitor-start motor.

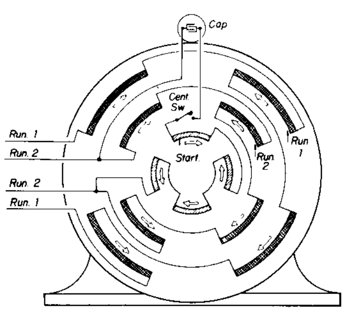


FIG. 2-25.—A wiring diagram of a four-pole, two-voltage, nonreversible capacitor-start motor. The starting winding is connected across one running winding.

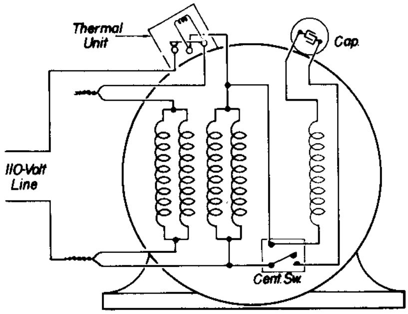


FIG. 2-26.—A two-voltage capacitor-start motor with thermostatic protection. Each running winding is two-parallel-connected.

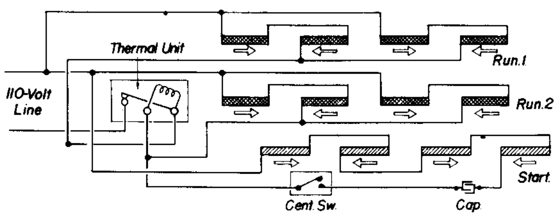


FIG. 2-27.—A connection diagram for a two-voltage capacitor-start motor. The running windings are connected two-parallel for 110-volt operation.

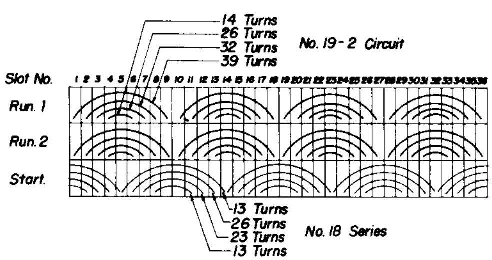


FIG. 2-28.—The layout of coils for the two-voltage motor of Figure 2-27. The running windings are similar.

Figures 2-26; 2-27; 2-28

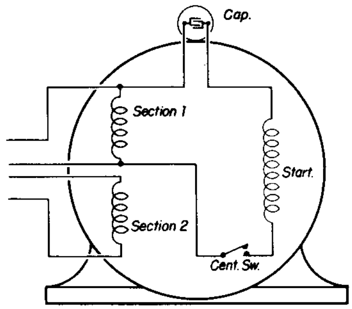


FIG. 2-29.—A two-voltage motor having one running winding of two sections.

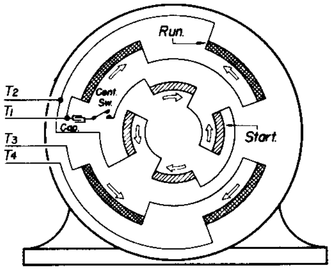


FIG. 2-30.—A four-pole two-voltage motor diagram with two sections in the running winding.

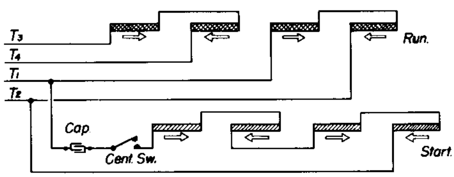


FIG. 2-31.—A straight-line diagram of the motor of Figure 2-30.

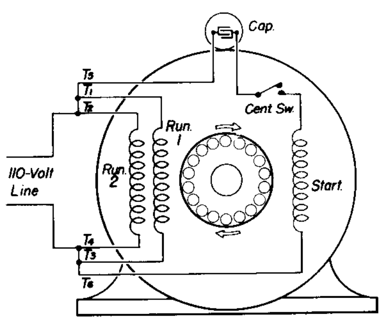


FIG. 2-32.—A two-voltage capacitor-start motor connected for clockwise rotation on 110 volts.

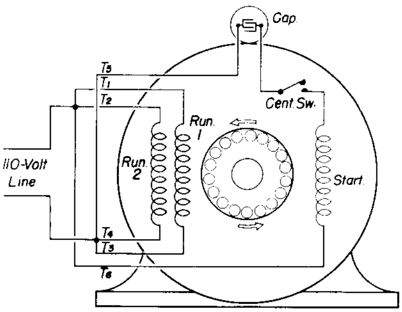


FIG. 2-33.—A two-voltage capacitor-start motor connected for counter-clockwise rotation on 110 volts.

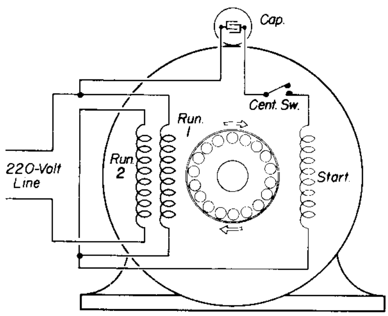


FIG. 2-34.—A two-voltage capacitor-start motor connected for clockwise rotation on 220 volts.

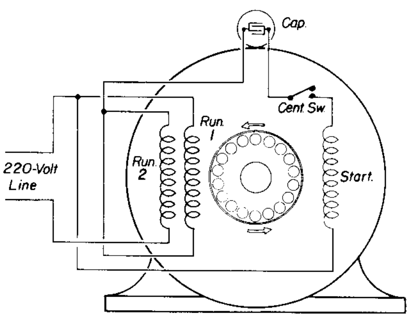


FIG. 2-35.—A two-voltage capacitor-start motor connected for counter-clockwise rotation on 220 volts.

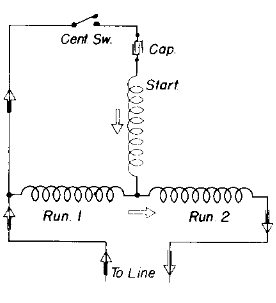


FIG. 2-36.—A schematic diagram of a three-lead, reversible capacitor-start motor showing how current in starting winding flows when it is connected across running winding.

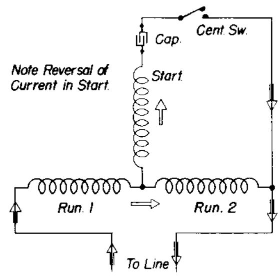


FIG. 2-37.—Same as Figure 2-36, except that starting winding is connected across running winding 2.

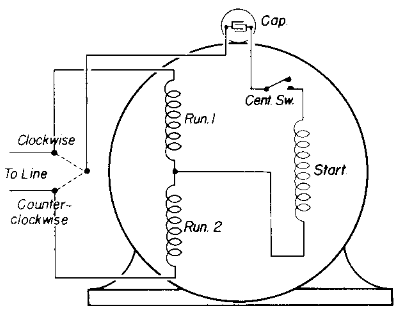


FIG. 2-38.—A wiring diagram of a three-lead, reversible capacitor-start motor.

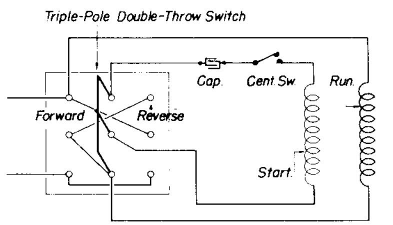


FIG. 2-39.—A capacitor-start motor using a triple-pole, double-throw switch for reversing.

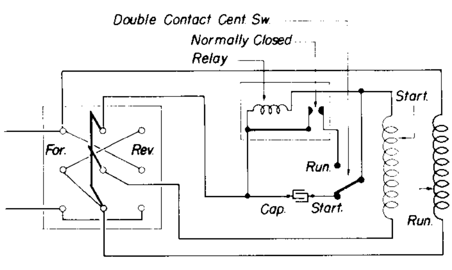


FIG. 2-40.—An instantly reversible capacitor-start motor with triple-pole, double-throw switch for reversing.

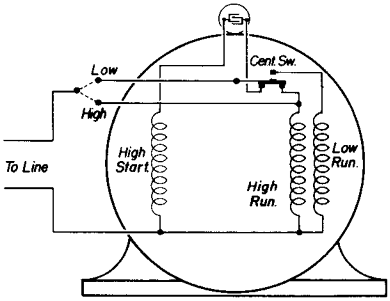


FIG. 2-41.—A two-speed capacitor-start motor. This motor always starts on high speed.

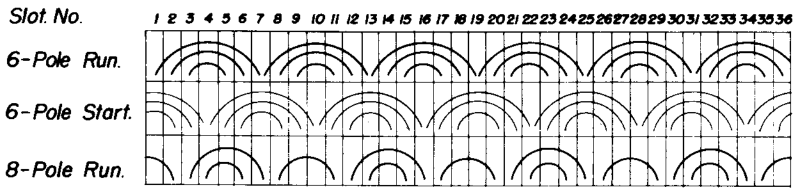
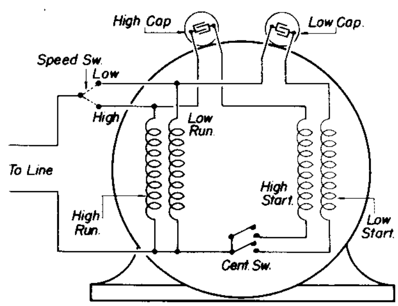


FIG. 2-42.—A typical layout of coils in a two-speed capacitor-start motor.

FIG. 2-43.—A two-speed capacitor-start motor using two capacitors.



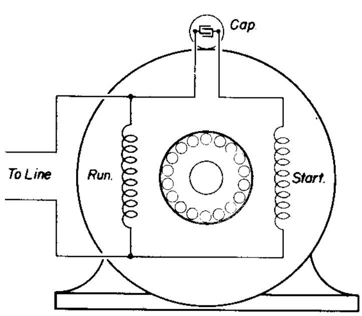


FIG. 2-44.—A single-value capacitor-run motor with the capacitor mounted on the motor.

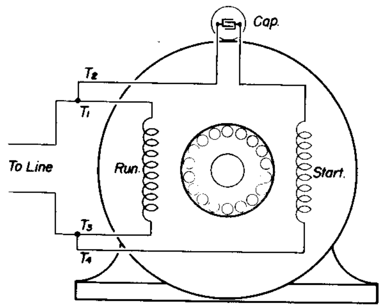


FIG. 2-45.—An externally reversible, single-value capacitor motor. To reverse, interchange leads T_3 and T_4

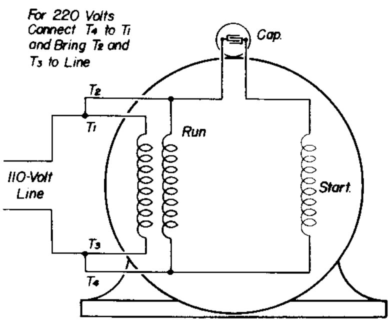


FIG. 2-46.—A two-voltage, single-value capacitor-run motor connected for 110-volt operation.

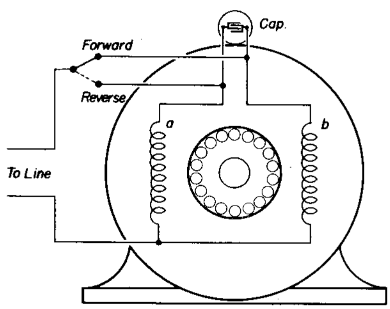


FIG. 2-47.—A single-value, three-lead, reversible capacitor-run motor.

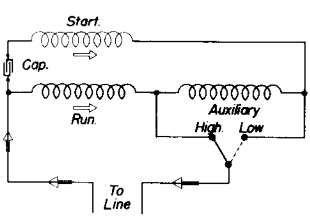


FIG. 2-48.—A schematic diagram of a two-speed capacitor-run motor with switch in high-speed position.

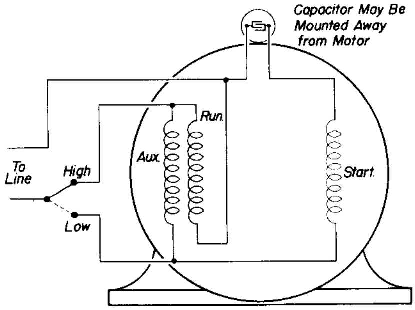


FIG. 2-49.—A two-speed, single-value capacitor-run motor.

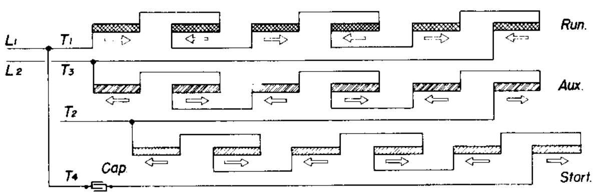


FIG. 2-50.—A two-speed, six-pole, single-value capacitor-run motor connected for high-speed operation. For high speed: line L_1 connects to T_1 and T_4; line L_2 connects to T_3 For low speed: line L_1 connects to T_1 and T_4; line L_2 connects to T_2.

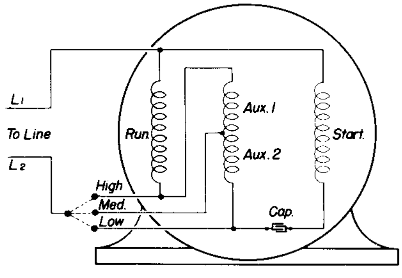


FIG. 2-51.—A schematic diagram of a three-speed, single-voltage capacitor-run motor.

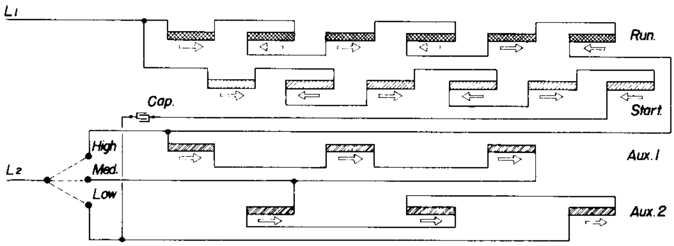


FIG. 2-52.—A wiring diagram of a three-speed capacitor-run motor. Note the consequent-pole connection on the auxiliary connection.

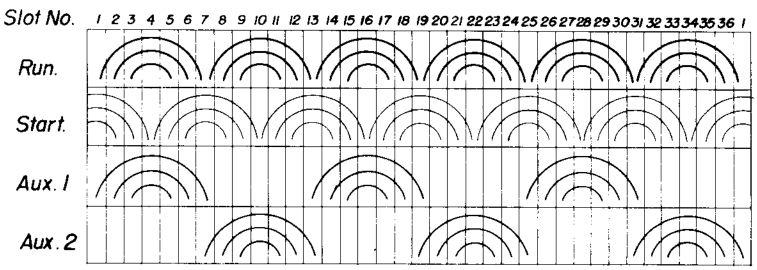


FIG. 2-53.—A typical layout of a three-speed capacitor-run motor.

FIG. 2-54.—An autotransformer consisting of a coil of wire wound on a laminated core. The coil is tapped at several points to obtain different voltages.

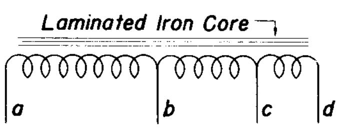
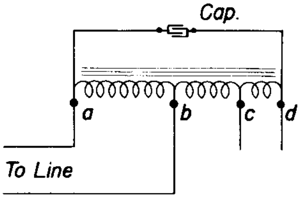


FIG. 2-55.—A voltage approximately twice the line voltage will be produced across the capacitor with this connection.



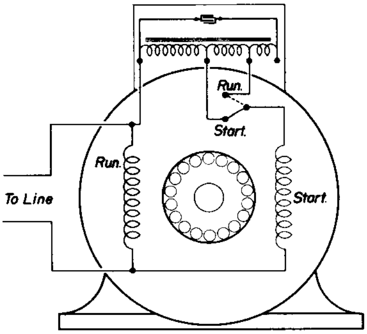
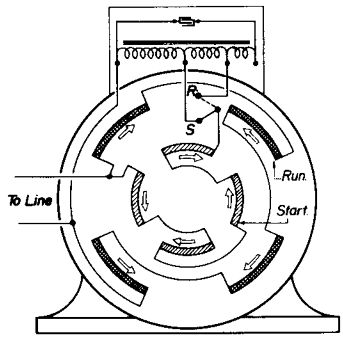


FIG. 2-56.—A two-value capacitor-run motor using a capacitor transformer to change the effective capacitor value.

FIG. 2-57.—Stator connections for a two-value capacitor-transformer type of motor.



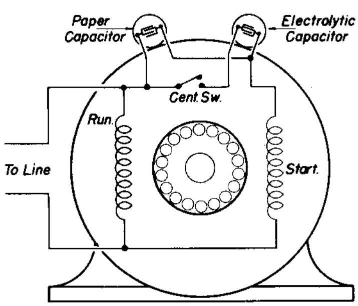
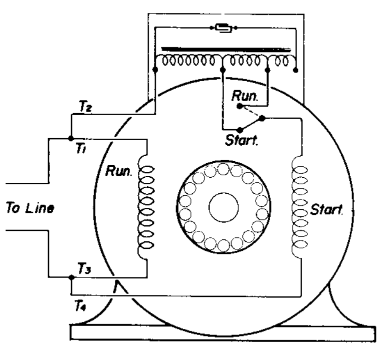


FIG. 2-58.—A two-value capacitor-run motor using two capacitors.

FIG. 2-59.—A two-value capacitor-run motor externally reversible.



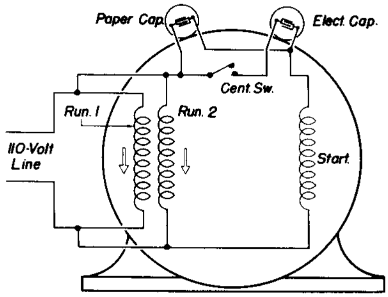


FIG. 2-60.—A two-voltage, two-value capacitor-run motor connected for 110-volt operation.

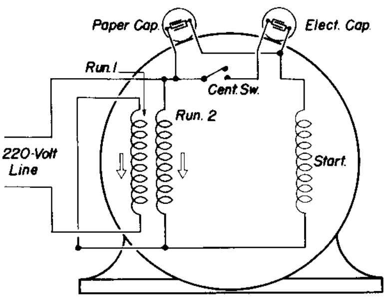


FIG. 2-61.—Connections of two-voltage, two-value capacitor-run motor for 220-volt operation.

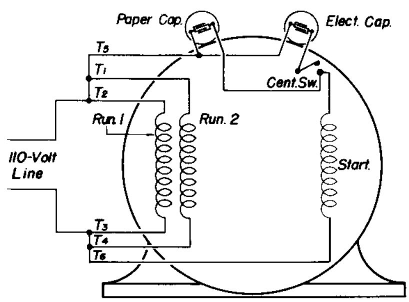


FIG. 2-62.—To reverse this two-value motor, interchange leads T_5 and T_6.

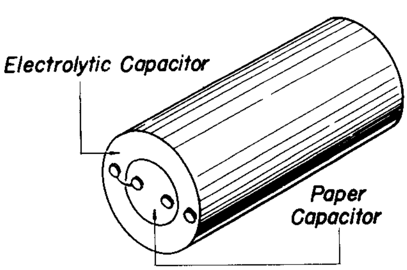


FIG. 2-63A.—A two-unit capacitor.

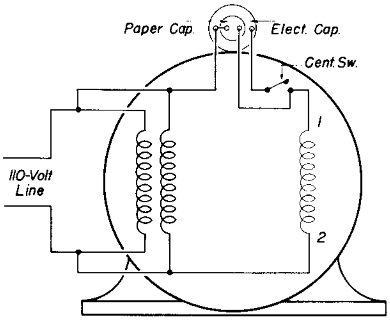


FIG. 2-63*B*.—A two-voltage, two-value capacitor-run motor with a two-unit capacitor mounted on top For 220-volt operation, connect running windings in series. To reverse, interchange leads *1* and *2*. These leads are brought to terminals on the centrifugal-switch plate.

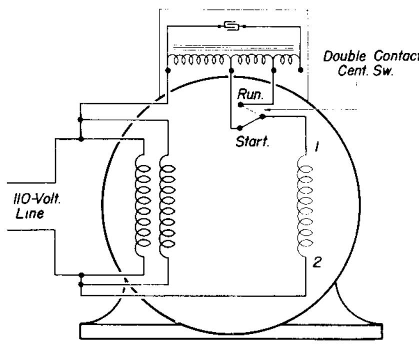


FIG. 2-64.—A two-voltage, two-value capacitor motor with a capacitor transformer mounted on the motor. To reverse, interchange leads *1* and *2*. These leads are generally connected to terminals on the centrifugal-switch plate. For 220 volts, connect running windings in series externally.

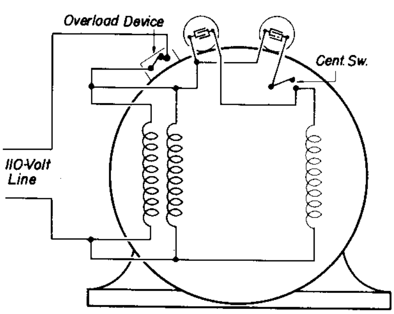
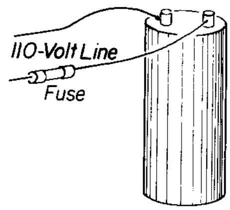


FIG. 2-65.—A two-voltage, two-value capacitor motor with overload device.

FIG. 2-66.—Steps in testing a capacitor: Step 1. Connect the capacitor to a line for an instant.



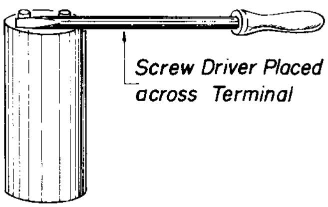
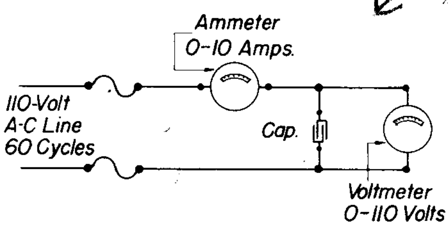


FIG. 2-67.—Step 2. Remove line wires and short-circuit the terminals. A spark should be visible.

FIG. 2-68.—A circuit for capacity test.



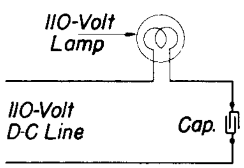
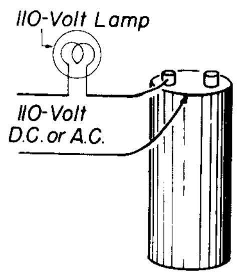


FIG. 2-69.—Testing a capacitor for short circuit: If the lamp lights, the capacitor is shorted. Note the use of direct current.

FIG. 2-70.—Testing a capacitor for ground.



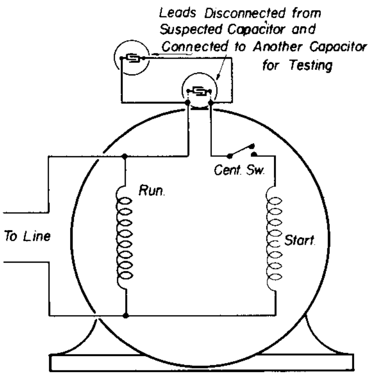


FIG. 2-71.—Testing a capacitor motor for a defective capacitor by the substitution method.

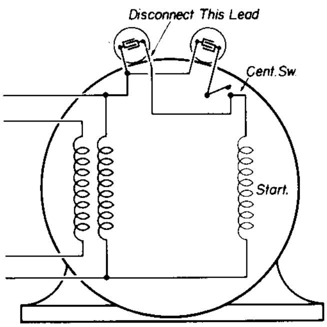


FIG. 2-72.—Changing a two-value motor into a capacitor-start motor. This can also be done if the two capacitors are in one container.

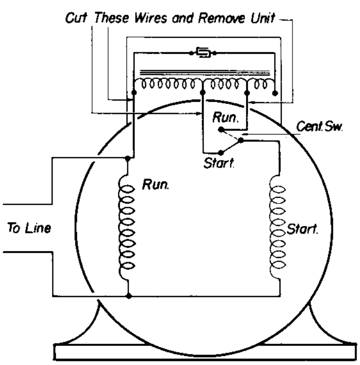


FIG. 2-73.—Temporary repair of a two-value capacitor motor.

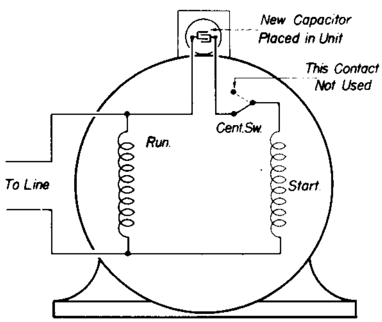


FIG. 2-74.—A capacitor transformer replaced with an electrolytic capacitor and the motor changed to a capacitor-start type.

CHAPTER 3

Repulsion-type Motors

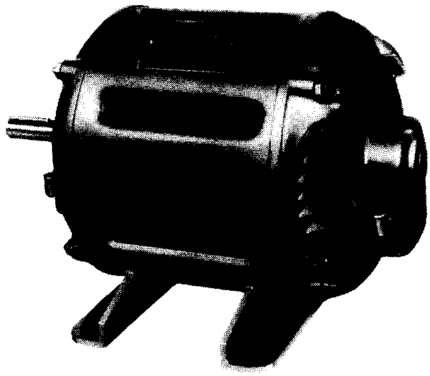


FIG. 3-1.—A repulsion induction motor. (*Wagner Electric Company.*)

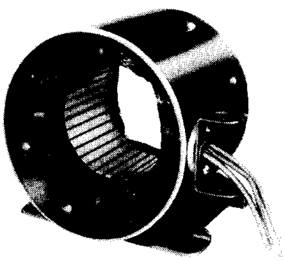


FIG. 3-2.—The stator of repulsion induction motor. (*Wagner Electric Company.*)

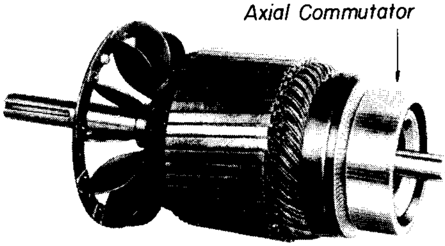


FIG. 3-3.—The rotor of a repulsion induction motor. The axial commutator has bars parallel to the shaft. (*Wagner Electric Company.*)

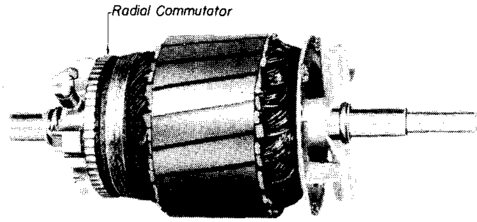


FIG. 3-4.—A rotor having a radial commutator with bars perpendicular to the shaft. (*Wagner Electric Company.*)

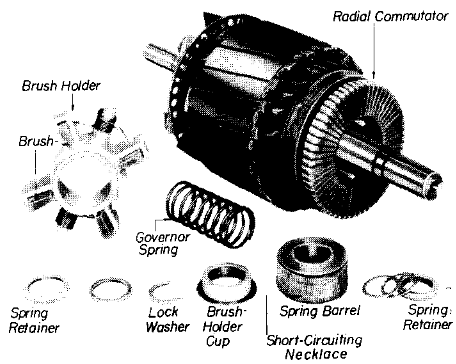


FIG. 3-5.—A partly dismantled rotor and parts of the centrifugal mechanism. (*Wagner Electric Company.*)

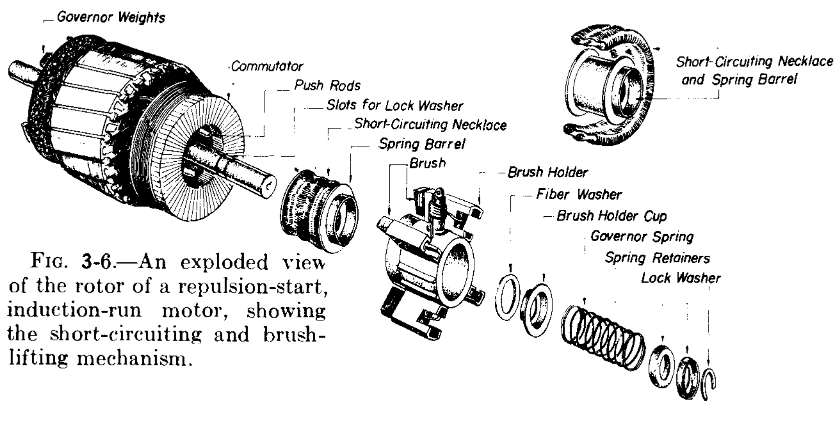


FIG. 3-6.—An exploded view of the rotor of a repulsion-start, induction-run motor, showing the short-circuiting and brush-lifting mechanism.

Figures 3-4; 3-5; 3-6

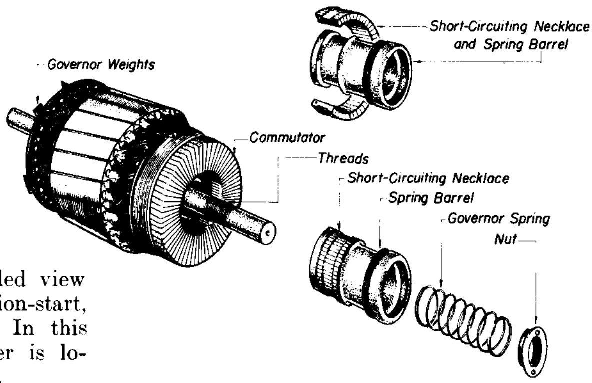


FIG. 3-7.—An exploded view of the rotor of a repulsion-start, induction-run motor. In this type, the brush holder is located in the end plate.

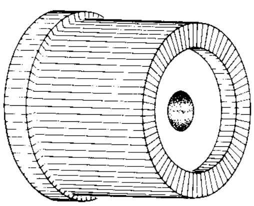


FIG. 3-8.—A commutator for a brush-riding, repulsion-start, induction-run motor.

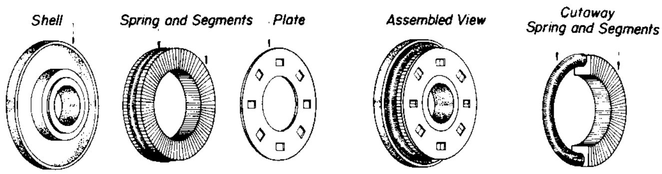
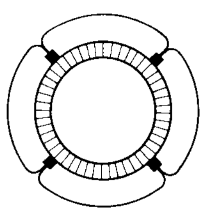


FIG. 3-9.—The assembly of the short-circuiting device of a brush-riding, repulsion-start, induction-run motor.

FIG. 3-10.—Four brushes are used on this four-pole motor. All brushes are connected together by a one-piece metal brush-holder rigging and the pigtails on the brushes.



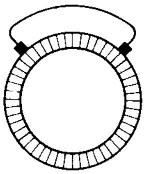


FIG. 3-11.—Two brushes may be used for a four-pole motor if the armature is wave-wound or cross-connected.

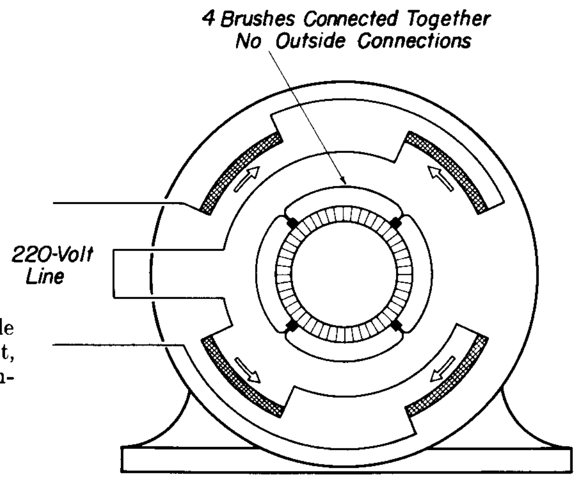


FIG. 3-12.—A four-pole stator of a repulsion-start, induction-run motor, connected for 220 volts.

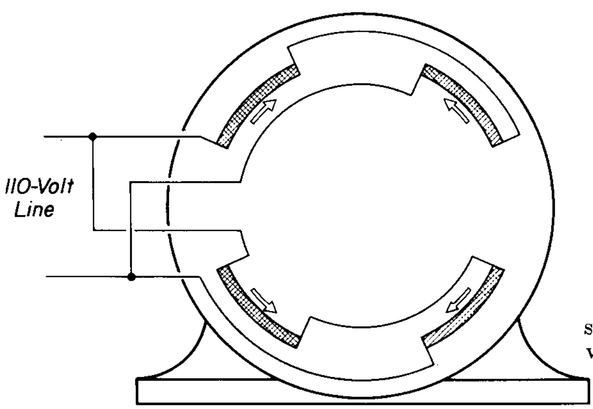


FIG. 3-13.—A four-pole stator connected for 110 volts.

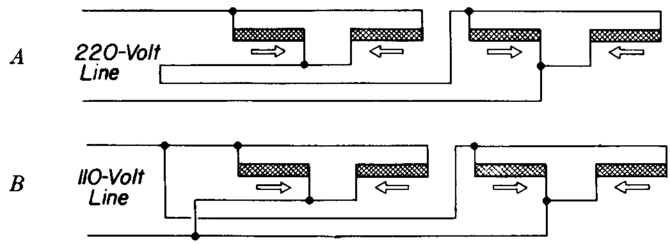


FIG. 3-14.—*A*. A two-circuit connection for 220-volt operation. *B*. A four-circuit connection for 110-volt operation.

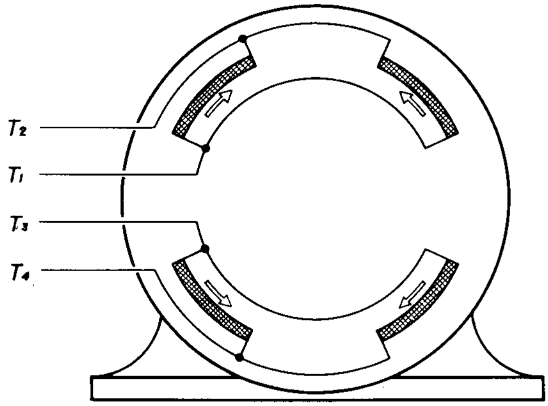


FIG. 3-15.—A two-voltage motor. For 220 volts: connect T_2 and T_3 together; T_1 to line lead, and T_4 to line lead.

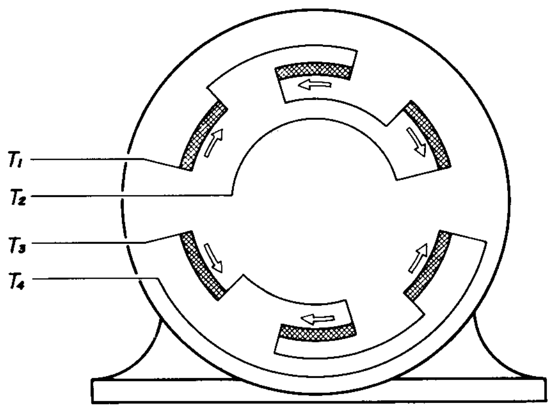


FIG. 3-16.—A six-pole stator connected for 110 or 220 volts.

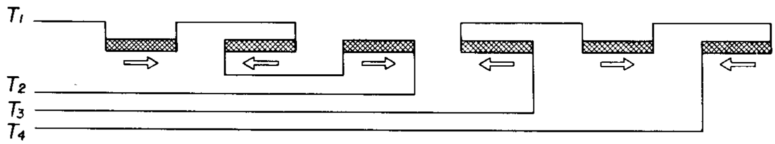


FIG. 3-16*A*.—A straight-line diagram of a six-pole stator with alternate connection.

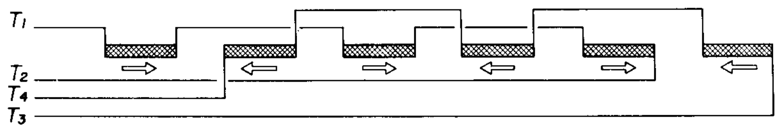


FIG. 3-16*B*.—Same as Figure 3-16*A*, except that the skip- group method of connection is used.

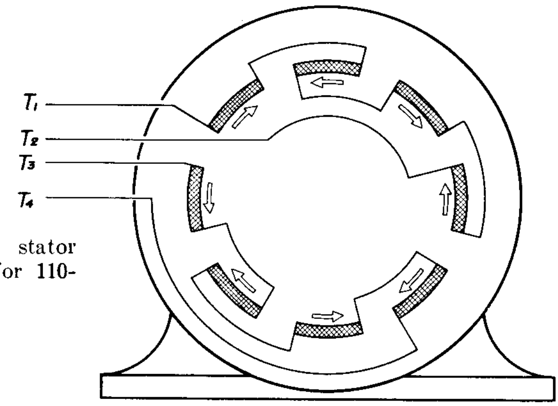


FIG. 3-17.—An 8-pole stator which can be connected for 110- or 220-volt operation.

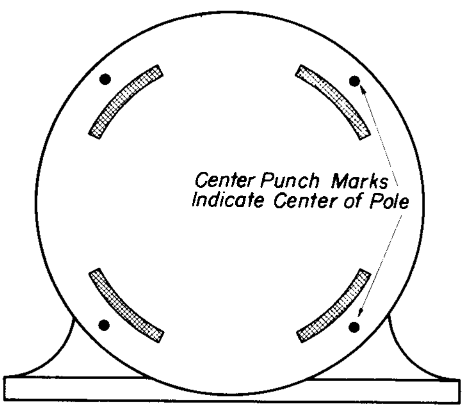


FIG. 3-18.—Recording the position of the poles in a repulsion motor.

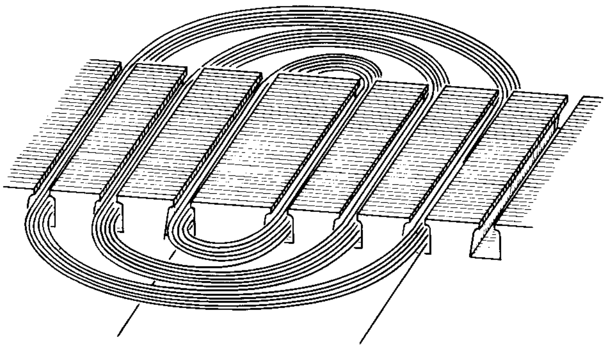


FIG. 3-19.—The core section at the center of the pole. It is wider than other sections.

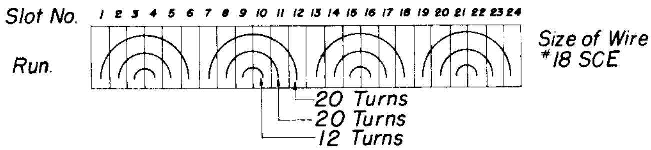


FIG. 3-20.—The method of recording data for a 24-slot, repulsion-start, induction-run motor.

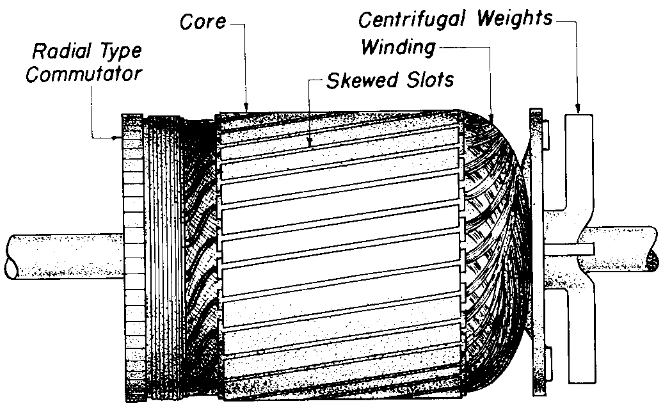


FIG. 3-21.—The armature of a repulsion-start, induction-run motor.

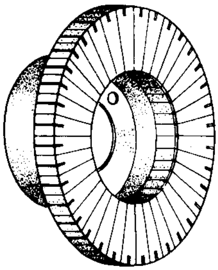


FIG. 3-22.—A radial commutator that is pressed on the armature shaft.

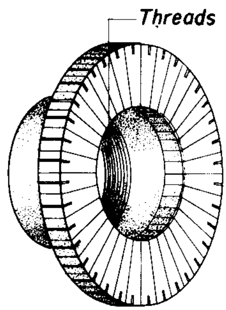


FIG. 3-23.—A radial commutator that screws onto the armature shaft.

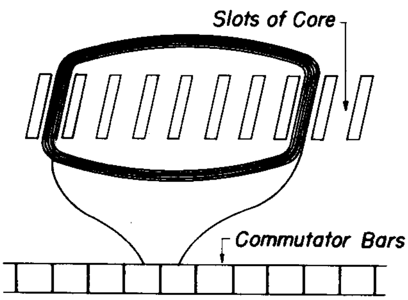


FIG. 3-24.—A lap winding with one coil per slot.

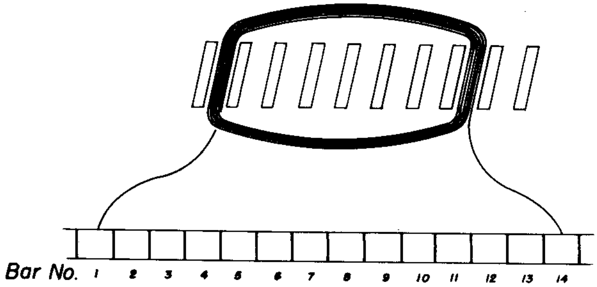


FIG. 3-25.—A wave winding with one coil per slot.

Figures 3-22; 3-23; 3-24; 3-25

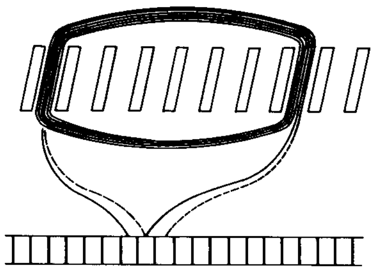


FIG. 3-26.—A lap winding with two coils per slot.

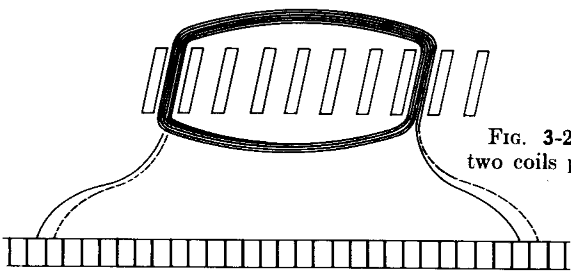


FIG. 3-27.—A wave winding with two coils per slot.

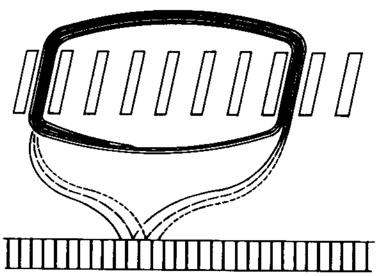


FIG. 3-28.—A lap winding with three coils per slot.

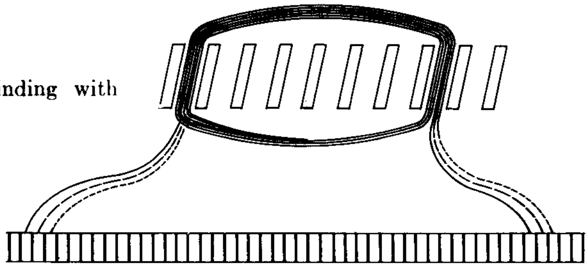


FIG. 3-29.—A wave winding with three coils per slot.

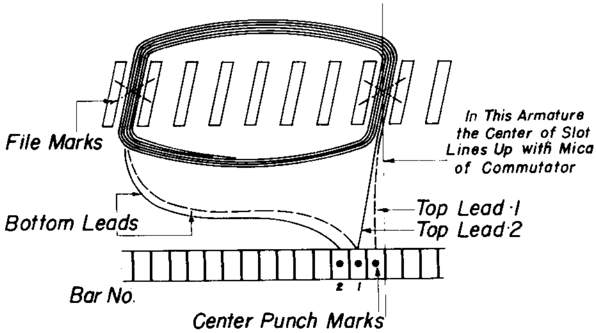


FIG. **3-30.**—Step 1. Record the data for a two-coil-per-slot repulsion armature.

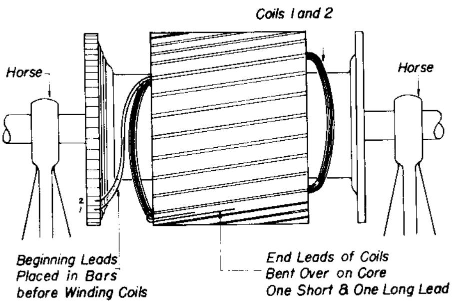


FIG. **3-31.**—Step 2. Place beginning leads in adjoining commutator bars according to data and wind the proper number of turns, using two wires in hand. Cut the wires at the last turn and bend them over the core.

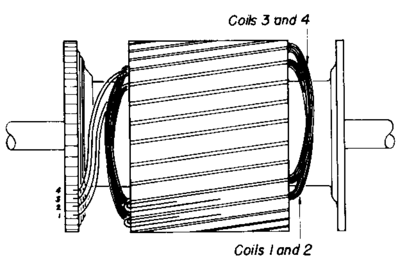


FIG. **3-32.** Step 3. Place the beginnings of coils *3* and *4* in bars *3* and *4* and start winding the coils, beginning one slot away from the first coils and using the same pitch as before.

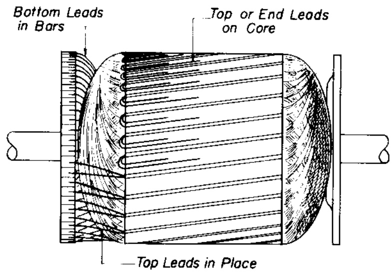


FIG. 3-33.—Step 4. Place the top leads in the commutator bars after the armature is completely wound. For a lap winding, the top leads are placed in bars adjacent to the bottom leads of the same coil.

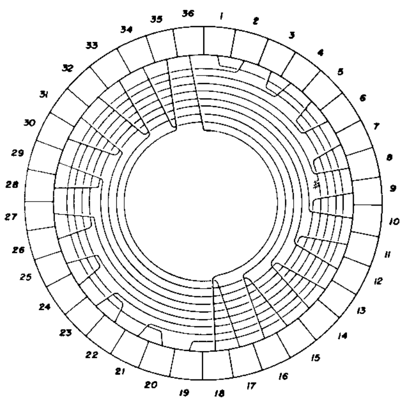
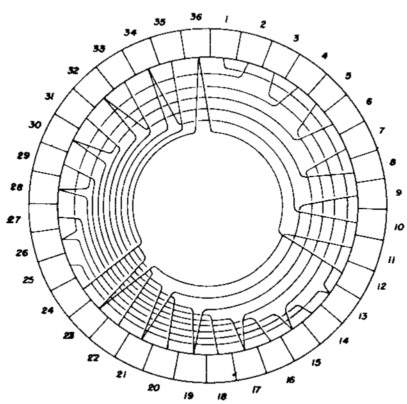


FIG. 3-34.—Cross connections of commutator bars for a four-pole motor having 36 bars, pitch 1 and 19.

FIG. 3-35.—Cross connections of commutator bars for a six-pole motor having 36 bars, pitch 1 and 13.



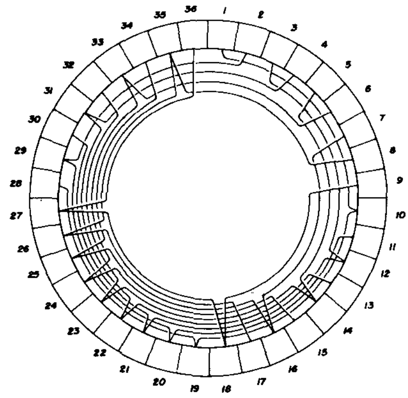


FIG. 3-36.—Cross connections of commutator bars for an eight-pole motor having 36 bars, pitch 1 and 10.

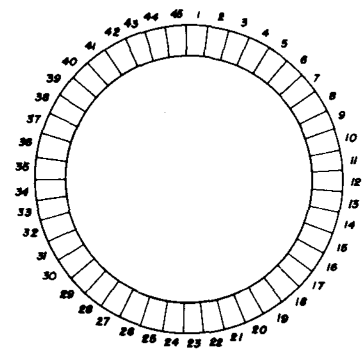


FIG. 3-37.—A four-pole, wave-wound armature must have an odd number of bars in the commutator. If there is an even number of bars, two must be shorted.

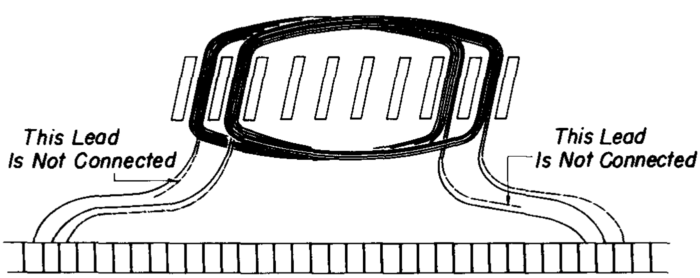


FIG. 3-38.—A wave connection showing dead coil. This coil must remain unconnected when there are more coils than bars.

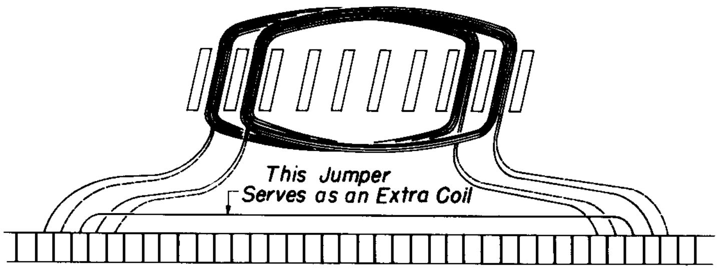


FIG. 3-39.—The method of placing a jumper between two bars to take the place of a coil. This is used when there is an even number of coils and one bar more than the number of coils.

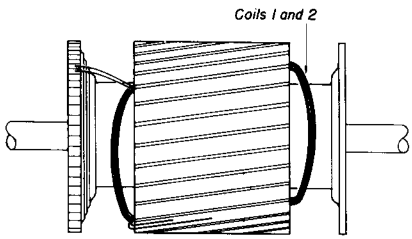


FIG. 3-40.—The first two coils of a wave-wound armature in place. Note that this armature is wound exactly as a lap armature, except that the beginning leads are placed away from the center of the coil.

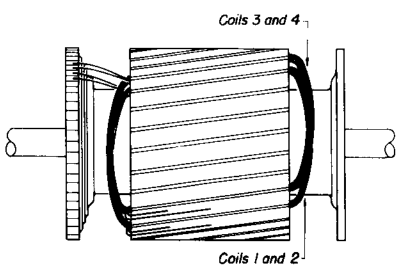


FIG. 3-41.—The next two coils placed in the slots exactly as the first two coils, except that they are started in the next slot. The end leads are cut off and left on the core.

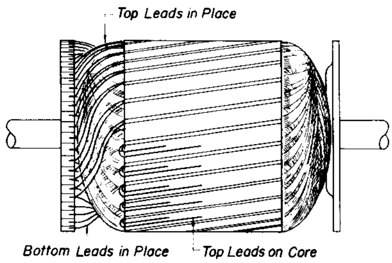


FIG. 3-42.—How the top leads are placed in bars for a wave winding.

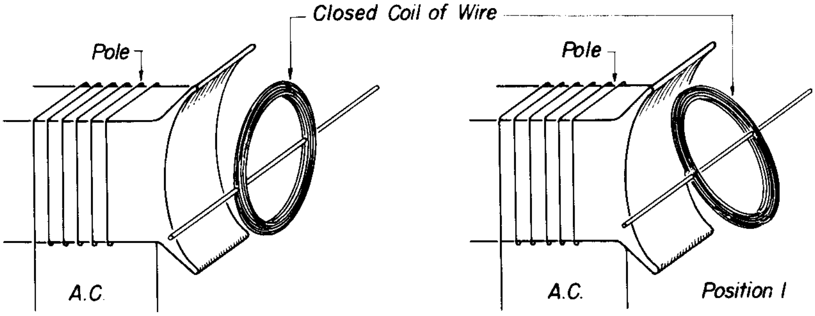


FIG. 3-43.—If the coil is in a vertical plane, it will not move. If the coil is tilted off the vertical, it will tend to move.

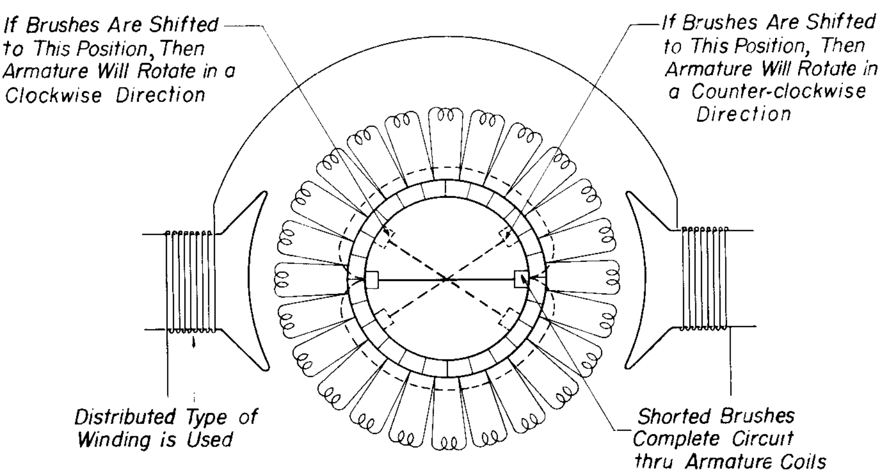


FIG. 3-44.—Two closed circuits in an armature similar to two coils. No motion takes place if brushes are in a vertical or horizontal position.

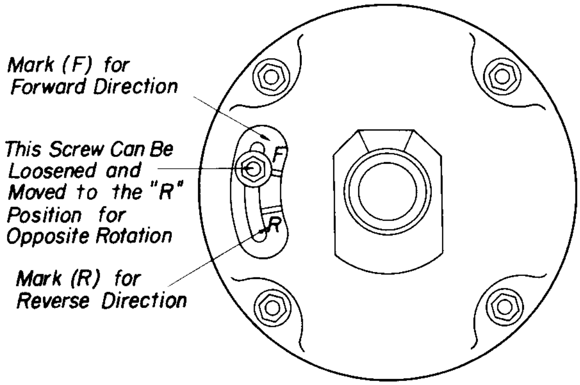


FIG. 3-45.—An end plate showing how the brush holder is moved to reverse the motor.

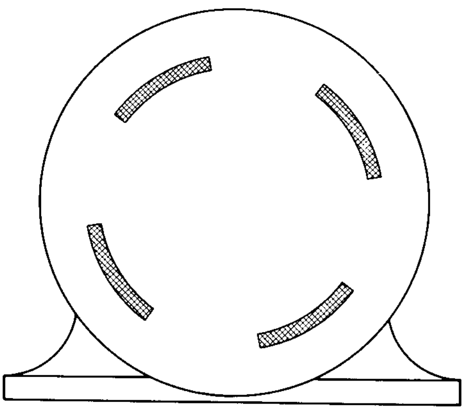


FIG. 3-46.—A frame with field poles off center.

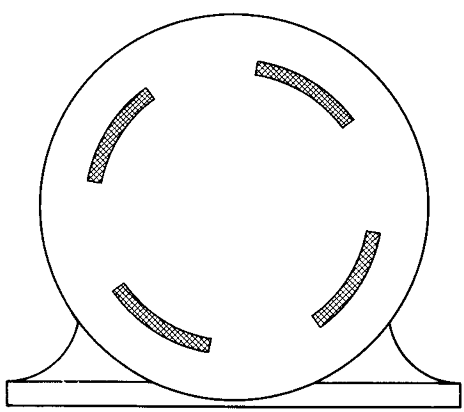


FIG. 3-47.—The position of the frame in Figure 3-46 reversed. This will cause the motor to run in the opposite direction.

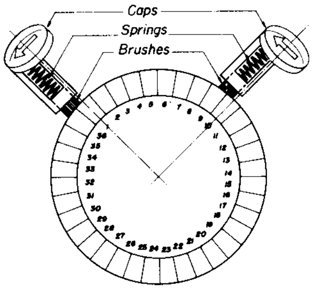


FIG. 3-48.—A cartridge type of brush holder with both brushes in position for counterclockwise rotation.

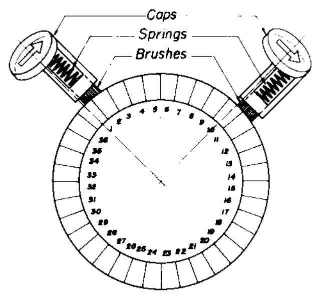


FIG. 3-49.—A cartridge type of brush holder with both brushes in position for clockwise rotation.

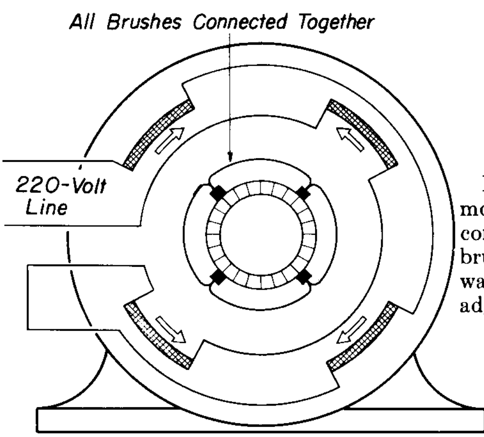


FIG. 3-50.—A four-pole repulsion motor. Note that the motor can be connected for two voltages. Four brushes are used. If the armature is wave-wound or cross-connected, two adjacent brushes may be used.

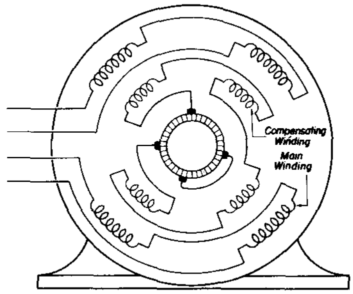


FIG. **3-51**.—A compensated repulsion motor.

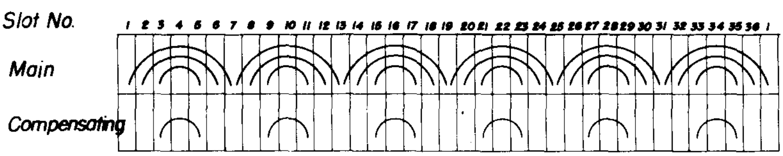


FIG. **3-52**.—A layout of a six-pole compensated repulsion motor. Note the location of the compensating winding in relation to the main winding. The compensating winding is generally wound into the slots first.

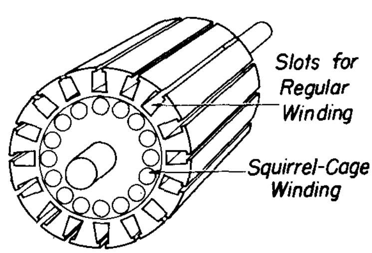


FIG. **3-53**.—An armature of a repulsion-induction motor. Note slots and squirrel-cage winding.

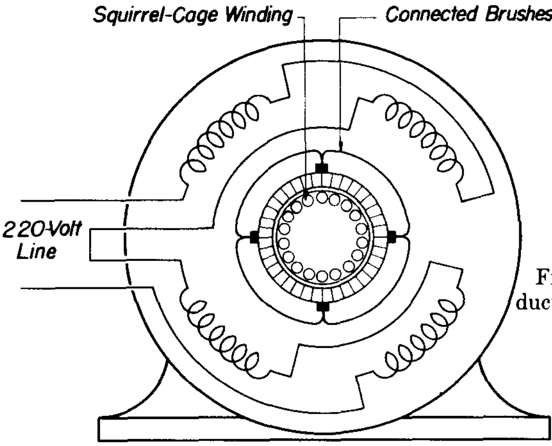


Fig. 3-54.—A typical repulsion-induction motor.

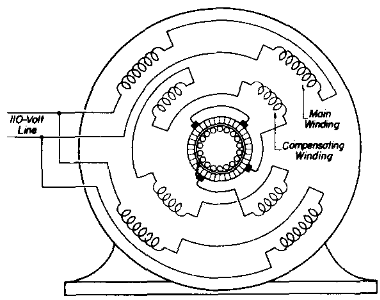


Fig. 3-55.—A diagram of a compensated repulsion-induction motor.

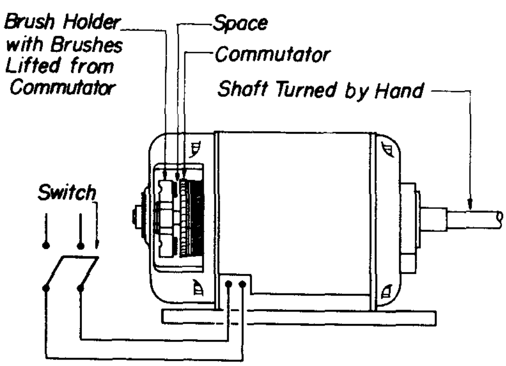
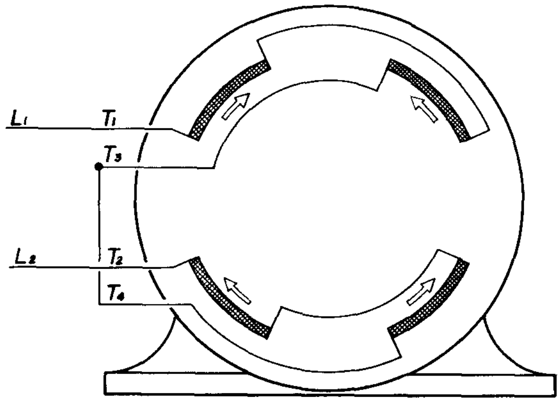


Fig. 3-56.—Testing a repulsion motor for a shorted armature. Lift the brushes from the commutator; throw the switch on and turn the armature by hand. If it turns freely, the armature is not shorted.

Figures 3-54; 3-55; 3-56

FIG. 3-57.—A wrong connection for 220 volts. The current flows through two adjacent poles in the same direction. The motor hums and does not run. To remedy, connect T_3 and T_2 together; T_1 to L_1 and T_4 to L_2.



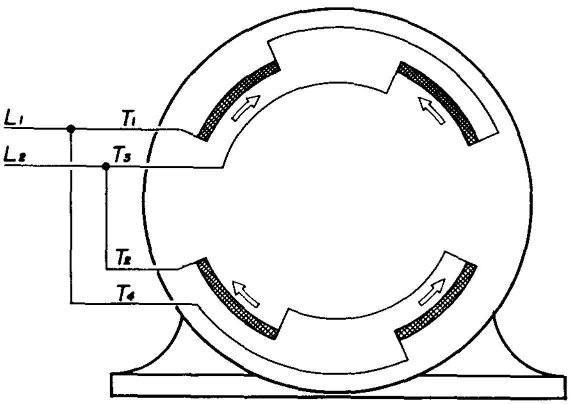
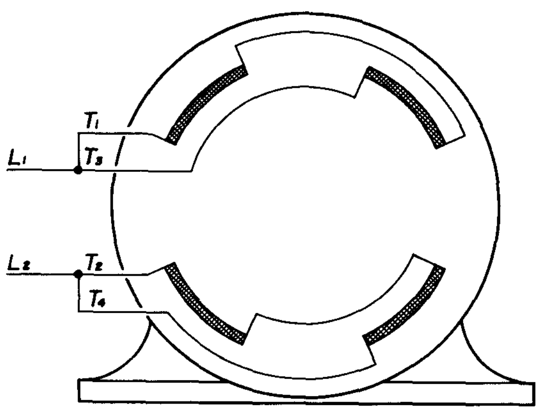


FIG. 3-58.—Although connected for 110 volts, adjacent poles have the same polarity. Remedy by connecting T_1 and T_2 to L_1 and T_3 and T_4 to L_2.

FIG. 3-59.—A common mistake. There is no complete circuit across the line, and the motor neither operates nor hums.



CHAPTER 4

Polyphase Motors

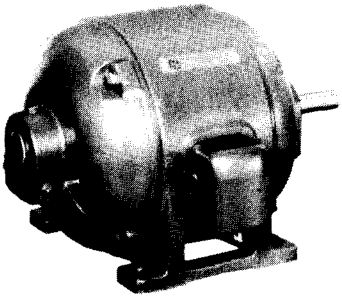


FIG. 4-1.—A three-phase motor. (*General Electric Company.*)

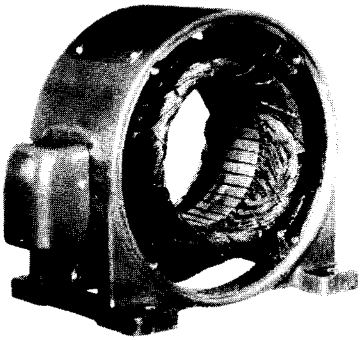


FIG. 4-2.—A stator of a three-phase motor showing the coil assembly and the laminated iron core. (*General Electric Company.*)

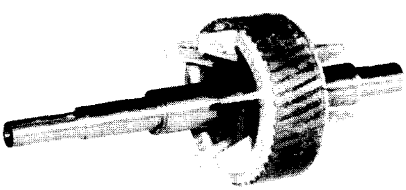


FIG. 4-3.—A squirrel-cage rotor of a three-phase motor. (*General Electric Company.*)

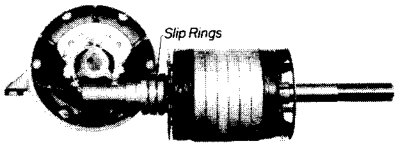


FIG. 4-4.—A wound rotor and an end plate of a three-phase motor. (*Wagner Electric Company.*)

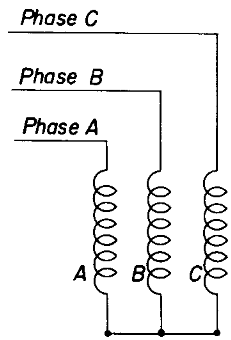


FIG. 4-5.—The coils of a three-phase motor connected to produce three windings, or phases.

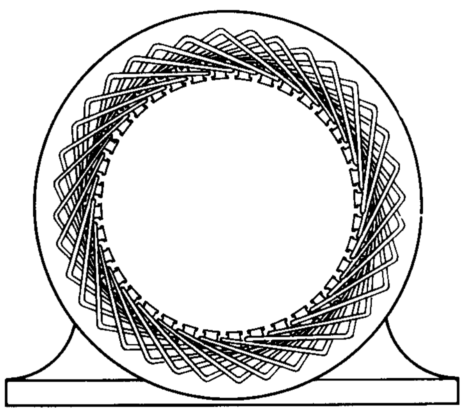


FIG. 4-6.—A stator of a three-phase motor with all the coils in their slots.

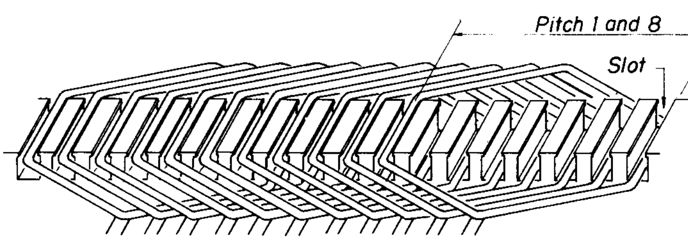


FIG. 4-7.—A portion of a three-phase winding as it would appear if the slots were laid flat.

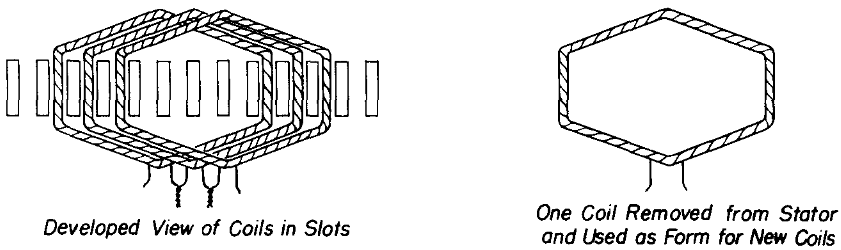


FIG. 4-8.—A simplified diagram of the coils and slots. *A* shows three coils connected in series; *B* shows one coil removed.

FIG. 4-9.—Two types of slots found in the stators of three-phase motors.

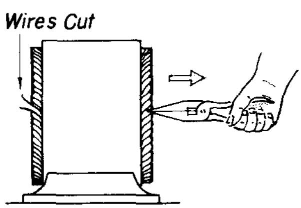
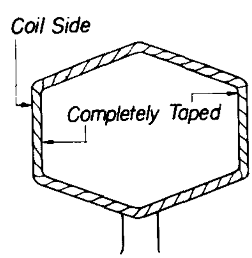


FIG. 4-10.—Stripping the stator by cutting each coil on one side and pulling from the other side.

FIG. 4-11.—A diamond-shaped coil used on open-slot stators.



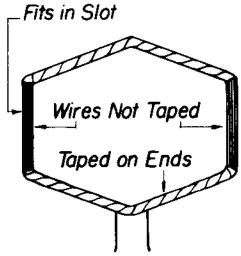
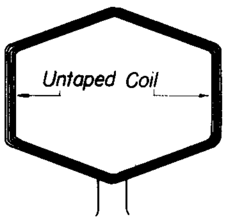


Fig. 4-12.—A coil used in semiclosed slots.

Fig. 4-13.—An untaped coil used in semiclosed slots.



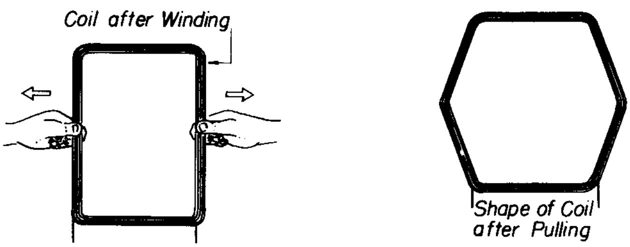


Fig. 4-14.—The coils of small motors may be wound in a rectangular shape, which is later formed into a diamond shape by pulling at the center of opposite ends.

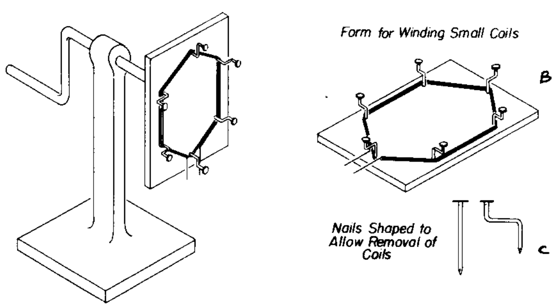


Fig. 4-15.—The method of winding coils on a special form.

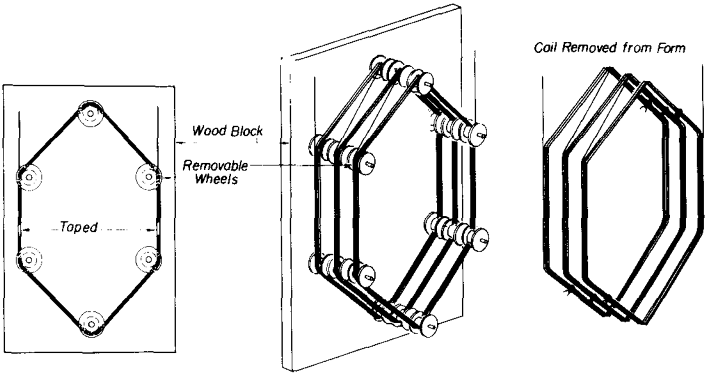
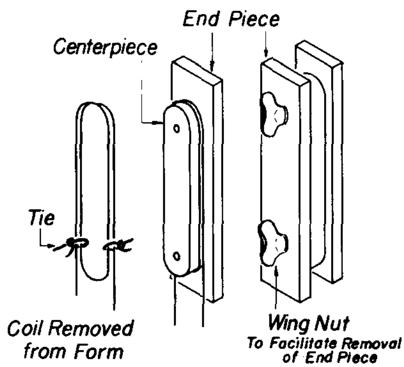


FIG. 4-16.—A special form for single or gang winding.

FIG. 4-17A.—Form for winding coils that are to be taped completely.



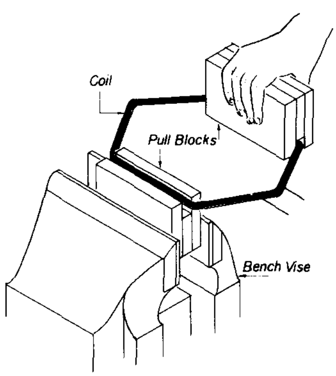


FIG. 17B.—Shaping coils by means of pull blocks.

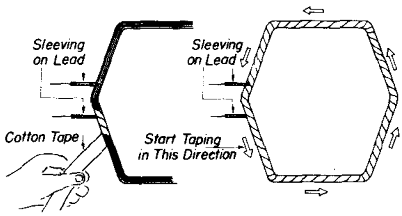


FIG. 4-18.—Taping coils to fit open slots.

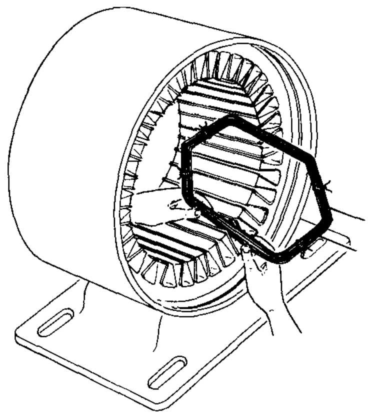


FIG. 4-19.—One side of a coil spread so that it can be fed into the slot.

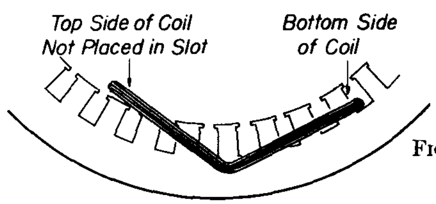


FIG. 4-20.—Starting to place coils in slots.

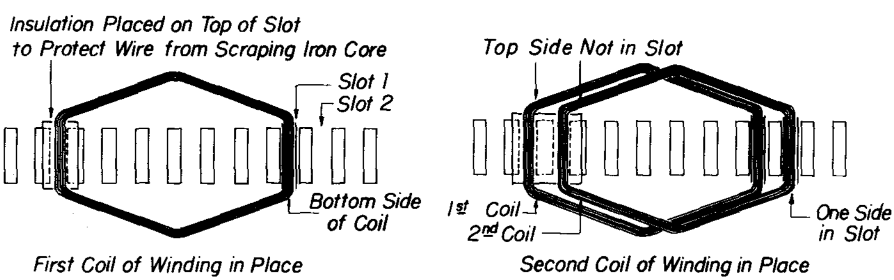


FIG. 4-21.—The method of placing one side of each coil in slot.

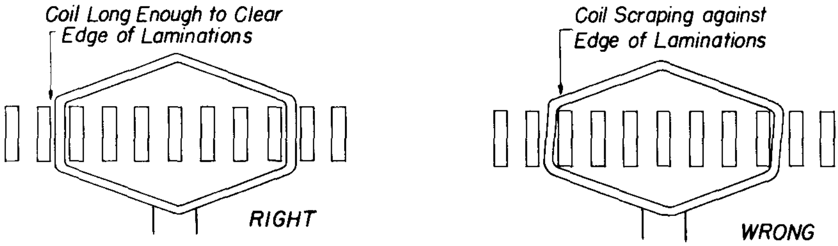


FIG. 4-22.—The sides of each coil must extend beyond the edge of the slot.

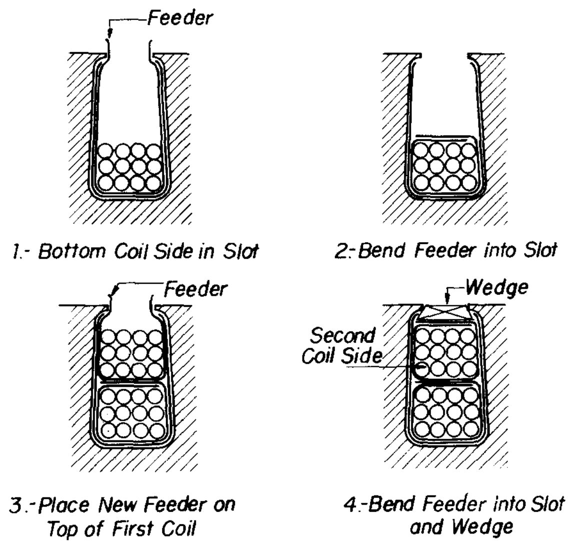


FIG. 4-23.—The method of placing the sides of two coils in a slot with insulation formed by the feeders.

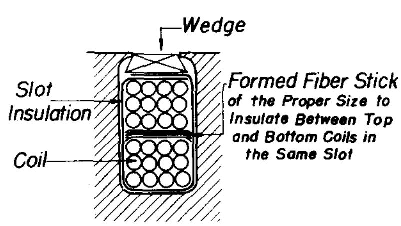


FIG. 4-24.—Placing a fiber stick or insulation paper between coils. The insulation between coils should extend at least ½ in. beyond slot ends.

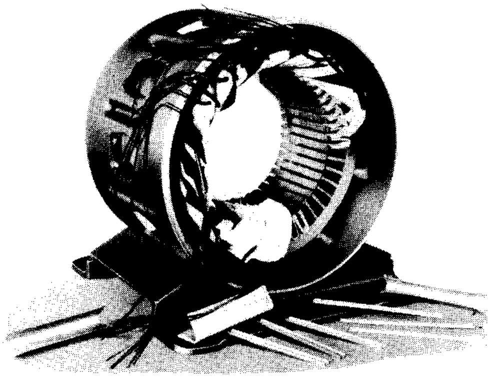


FIG. 4-24A.—A partially wound, three-phase stator showing slot insulation.

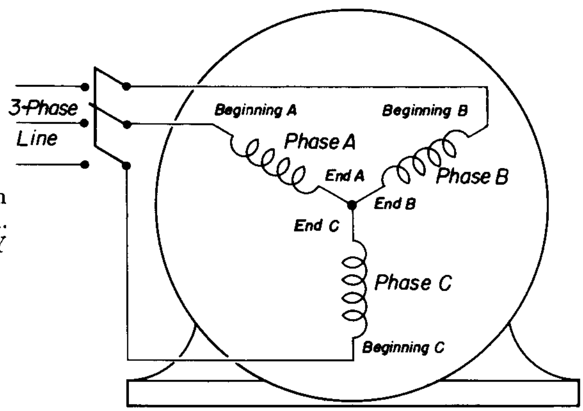


FIG. 4-25.—A diagram of a star connection. This is also called a Y connection.

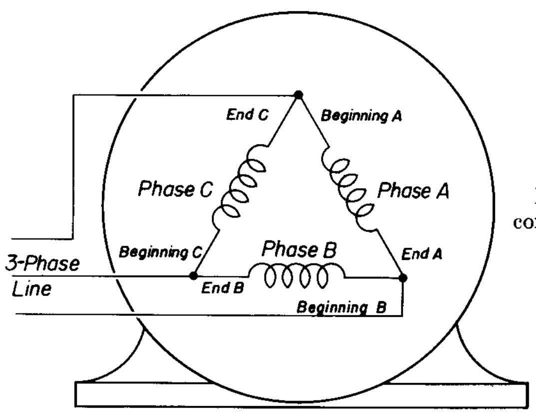


FIG. 4-26.—A diagram of a delta connection.

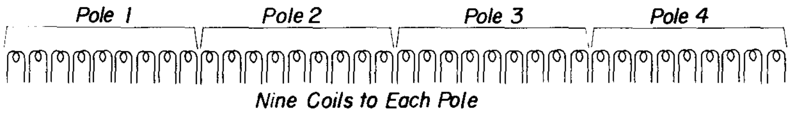


FIG. 4-27.—A 36-coil, three-phase motor with coils divided into poles.

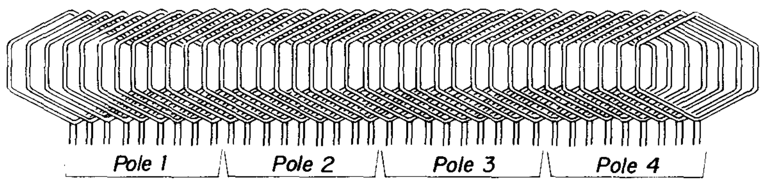


FIG. 4-28.—The true shape of coils shown in Figure 4-27.

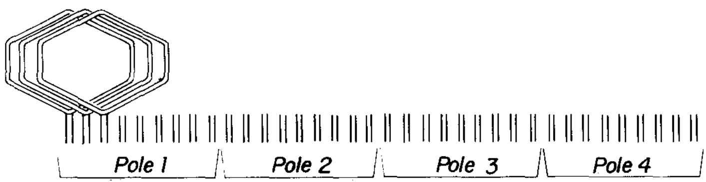


FIG. 4-29.—A simplified diagram of the coils in a three-phase, four-pole motor

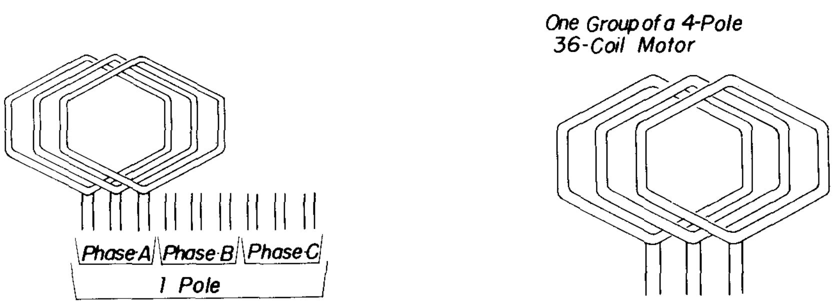


FIG. 4-30.—Three groups in one pole. Each group has three coils.

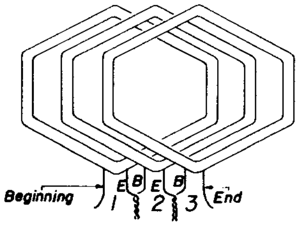


FIG. 4-31.—How the coils in a group are connected together.

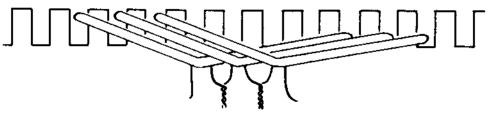


FIG. 4-32.—A side view of the coil connections shown in Fig. 4-31.

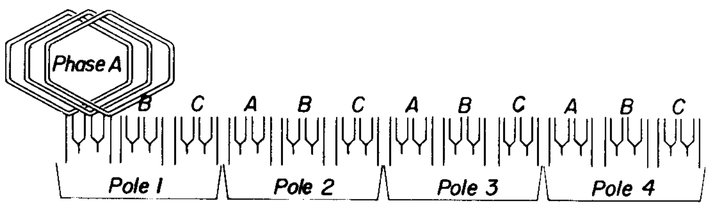


FIG. 4-33.—Coils connected in twelve groups of three coils each. Note that all poles are alike.

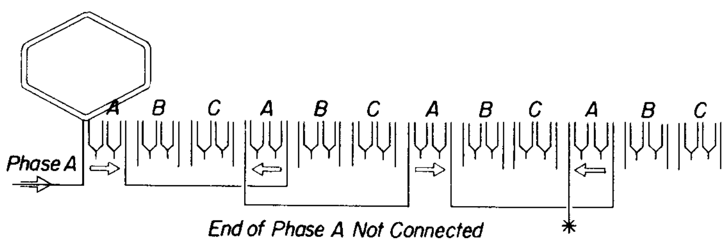


FIG. 4-34.—Connections of groups of phase *A*.

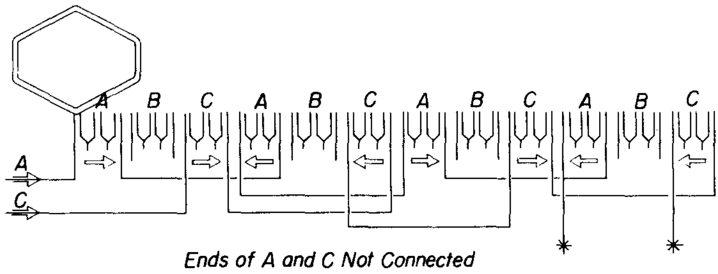


FIG. 4-35.—Phase C connected exactly like phase A and connected before phase B to simplify connections.

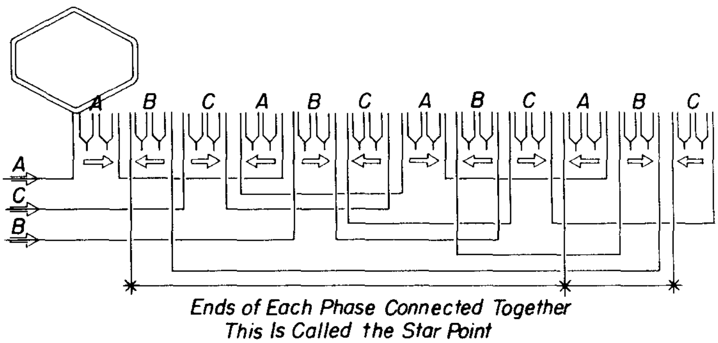


FIG. 4-36.—The current flow in the B phase is opposite to the current flow in both the A and C phases. This is shown by the arrows under each group.

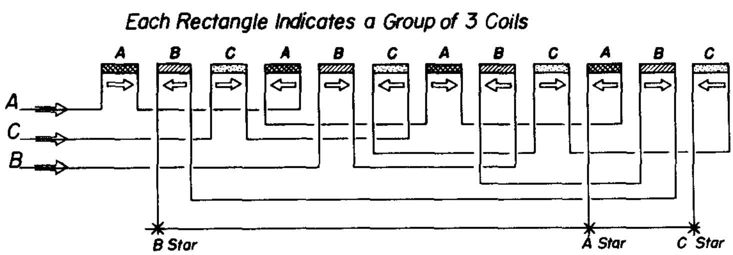


FIG. 4-37.—A diagram similar to Figure 4-36, except that rectangles are used instead of coils.

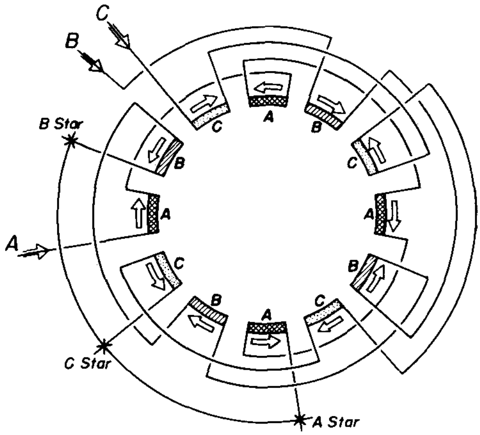


FIG. 4-38.—A circular diagram of the preceding illustration. A four-pole series star connection.

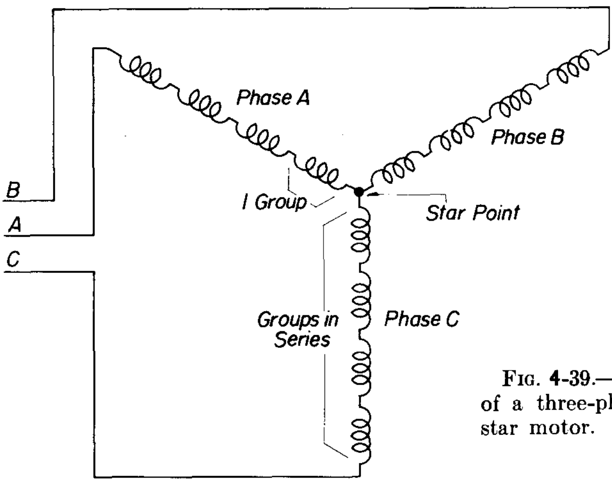


FIG. 4-39.—A schematic diagram of a three-phase, four-pole, series star motor.

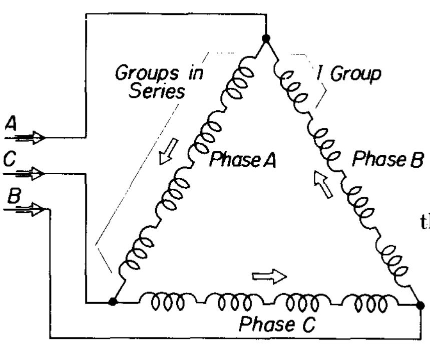


FIG. 4-40.—A schematic diagram of a three-phase, four-pole, series delta motor.

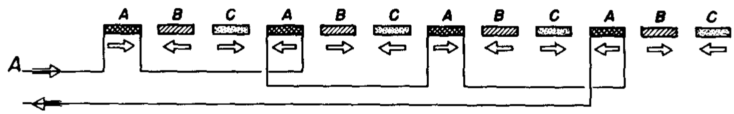


FIG. 4-41.—The *A* phase connection in a four-pole, series delta motor.

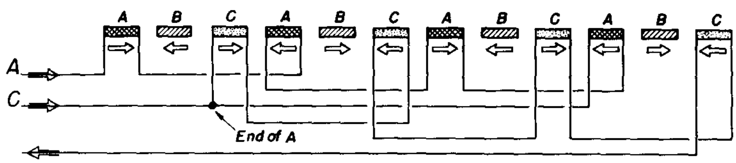


FIG. 4-42.—The *C* and *A* phase connections in a four-pole, series delta motor. The end of the *A* phase is connected to the beginning of the *C* phase.

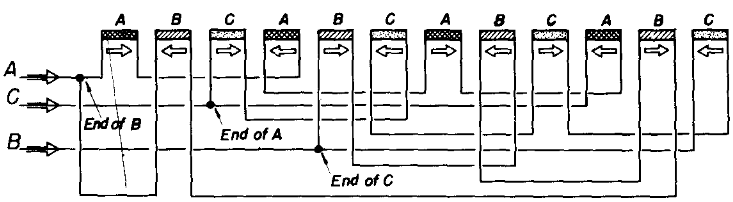


FIG. 4-43.—A complete diagram of connections for a three-phase, four-pole, series delta motor.

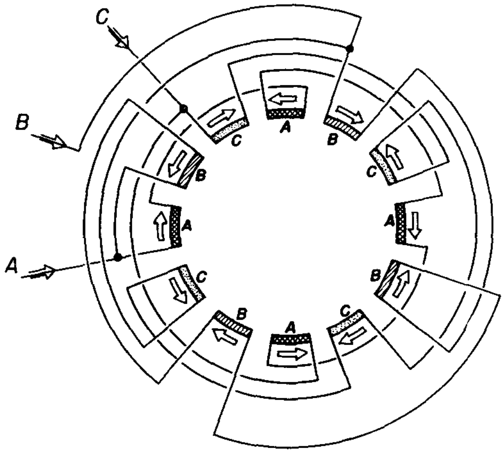


FIG. 4-44.—A circular diagram of a four-pole, three-phase, series delta motor.

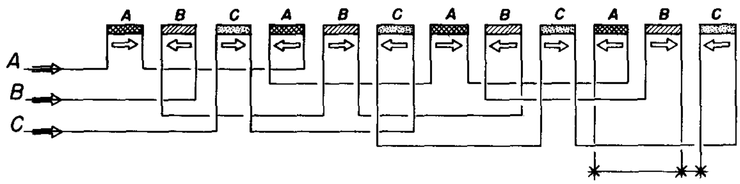


FIG. 4-45.—A three-phase series star connection in which the *A* phase is connected first, then the *B* phase, and finally the *C* phase.

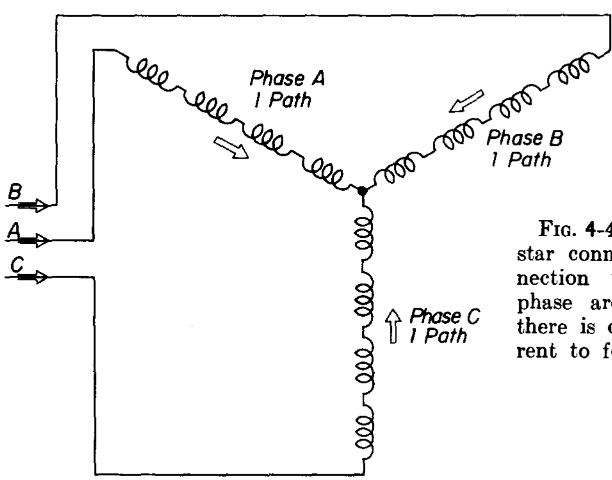
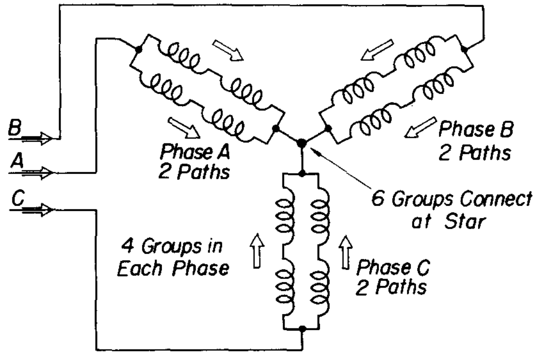


FIG. 4-46.—A four-pole, series star connection. In this connection the groups of each phase are connected so that there is one path for the current to follow.

FIG. 4-47.—A four-pole, two-parallel star connection. In this connection the groups are connected so that there are two paths in each phase for the current to follow. There are four groups in each phase, and this forms a four-pole motor.



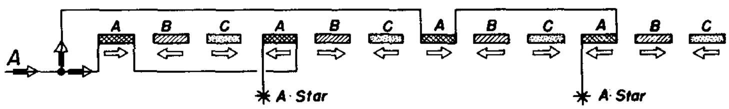


FIG. 4-48.—A diagram of connections for the *A* phase of a two-parallel star connection. Two wires from the *A* phase connect to the star point.

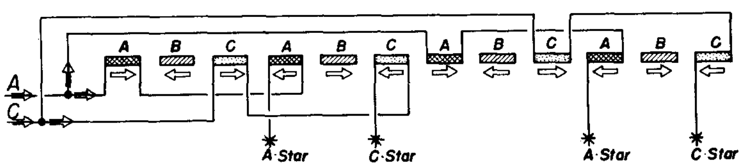


FIG. 4-49.—The connections for the *C* and *A* phase of a two-parallel star connection. So far, four leads are connected to star points.

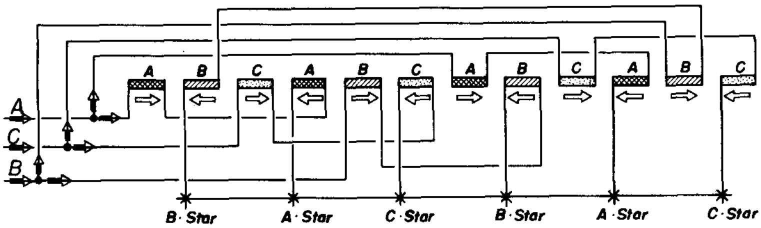
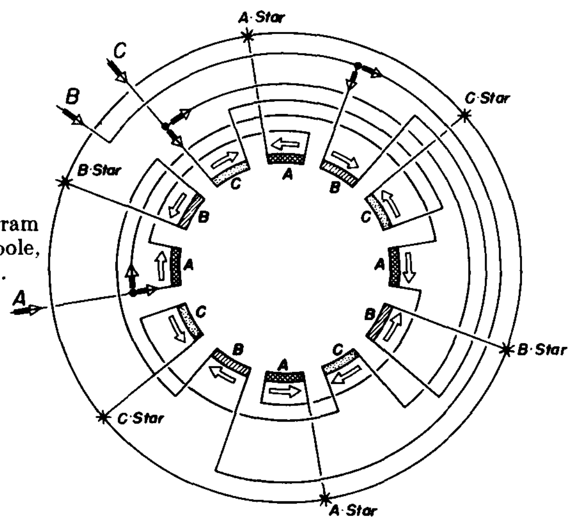


FIG. 4-50.—A complete diagram for a three-phase, four-pole, two-parallel star connection.

FIG. 4-51.—A circular diagram of a three-phase, four-pole, two-parallel star connection.



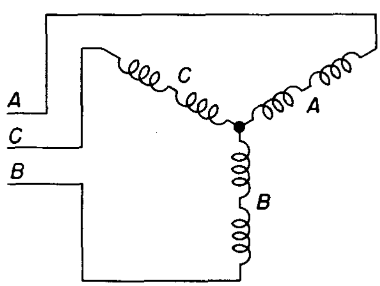


FIG. 4-52.—A two-pole, series star connection. If only one group is connected to each line, then it is a series star connection.

Figures 4-50; 4-51; 4-52

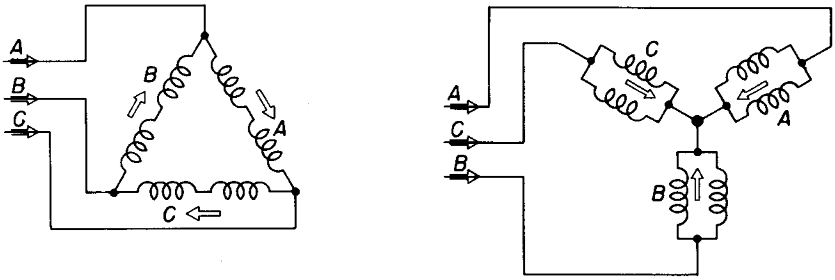


FIG. 4-53.—Both methods of connection shown above have each line lead connected to two groups, but the parallel star connection has six groups connected together.

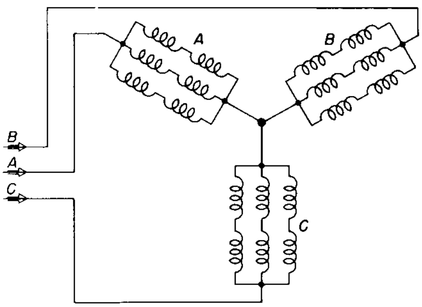


FIG. 4-54.—A three-parallel star connection. Each line lead connects to three groups.

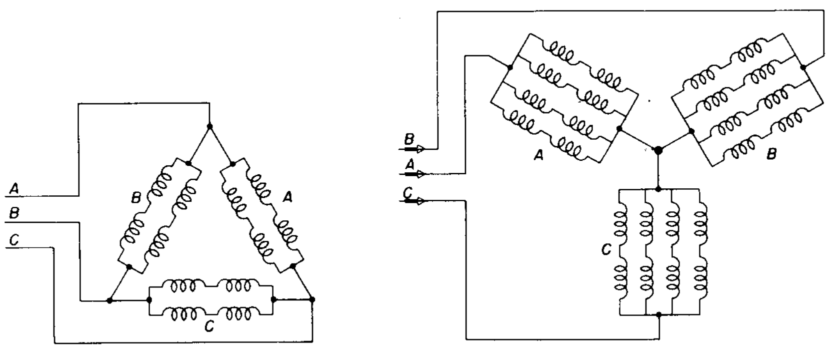


FIG. 4-55.—(*A*) shows a four-pole, two-parallel delta connection with each line lead connected to four groups. (*B*) shows an eight-pole, four-parallel star connection. Both methods of connection shown have each line lead connected to four groups, but the four-parallel star connection has twelve groups connected together.

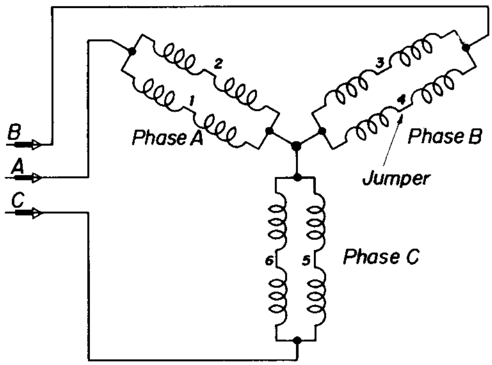


FIG. 4-56.—The four-pole, two-parallel star connection has six jumpers.

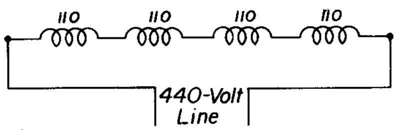


FIG. 4-57.—Four coils connected in series for 440-volt line. The voltage in each coil is 110.

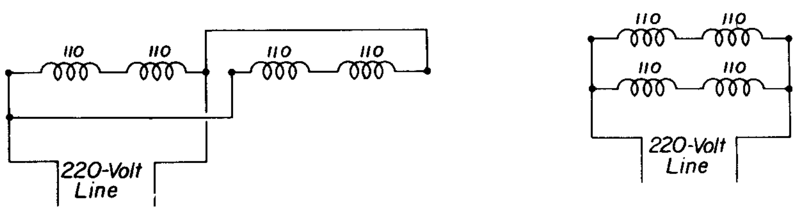


FIG. 4-58.—Four coils connected two-parallel for a 220-volt line. Each coil still receives 110 volts.

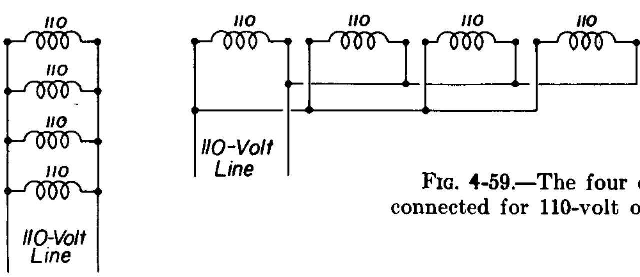


FIG. 4-59.—The four coils of Figure 4-58 connected for 110-volt operation.

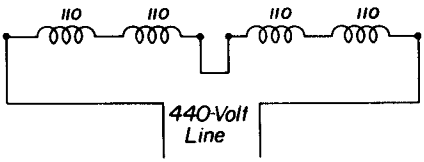


FIG. 4-60.—Series connection of coils for 440-volt operation.

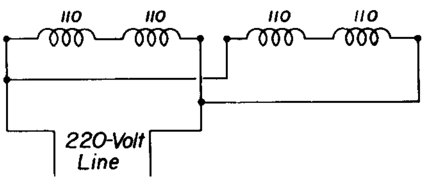


FIG. 4-61.—Two sets of coils in parallel for 220-volt operation.

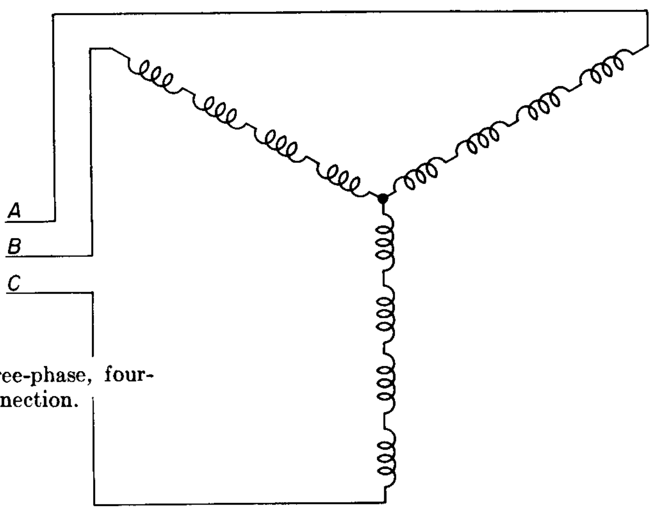


FIG. 4-62.—A three-phase, four-pole, series star connection.

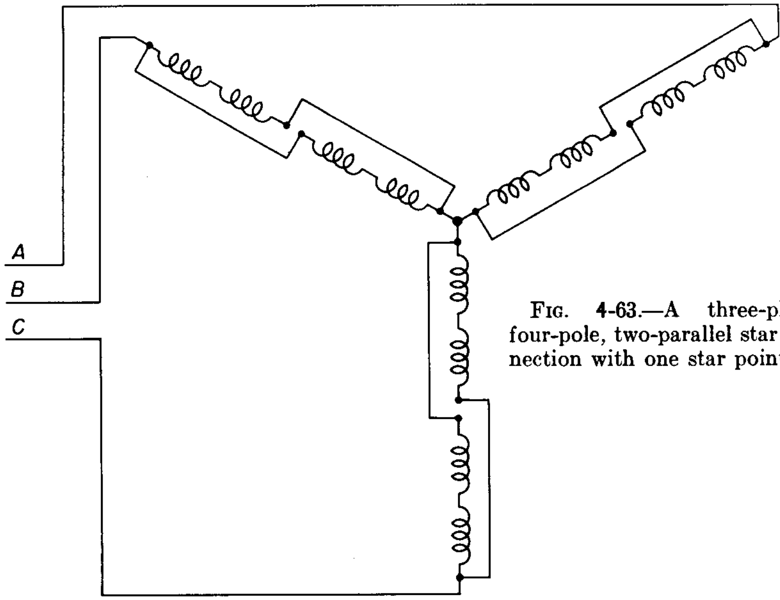


FIG. 4-63.—A three-phase, four-pole, two-parallel star connection with one star point.

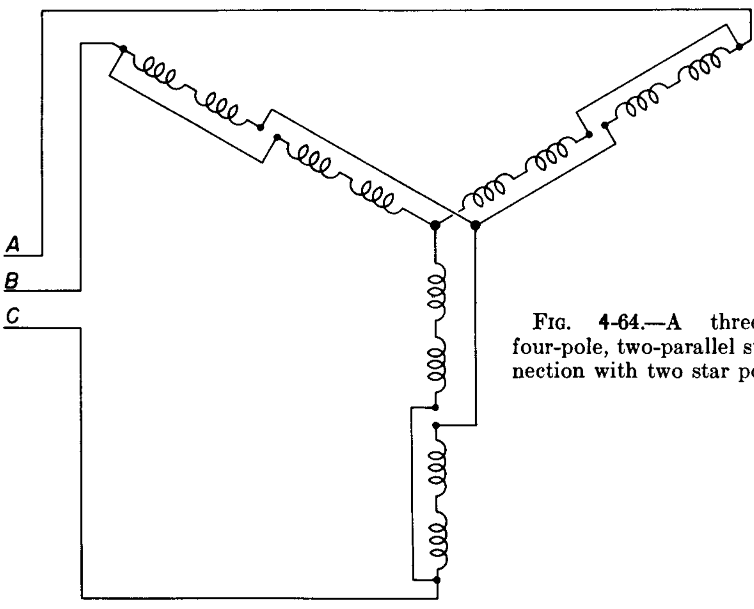


FIG. 4-64.—A three-phase, four-pole, two-parallel star connection with two star points.

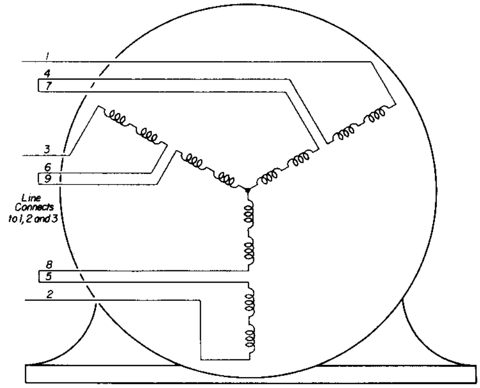


FIG. **4-65.**—A two-voltage star motor with groups connected in series for high-voltage operations.

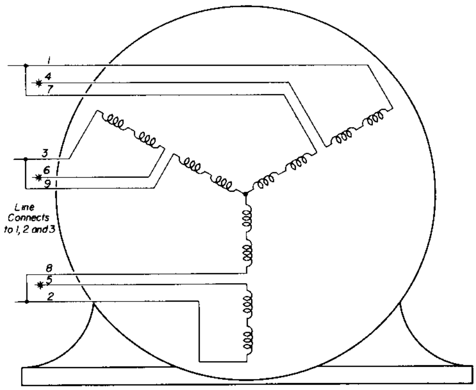


FIG. **4-66.**—A two-voltage star motor with groups connected in parallel for low voltage. The common connection of *4*, *5*, and *6* forms an external star.

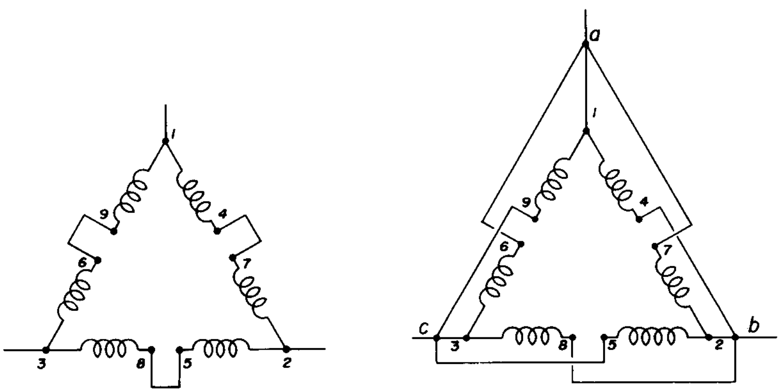


FIG. **4-67.**—(*Left*) A two-voltage delta connection with groups in series for high-voltage operation. (*Right*) A two-voltage delta connection with groups in parallel for low-voltage operation.

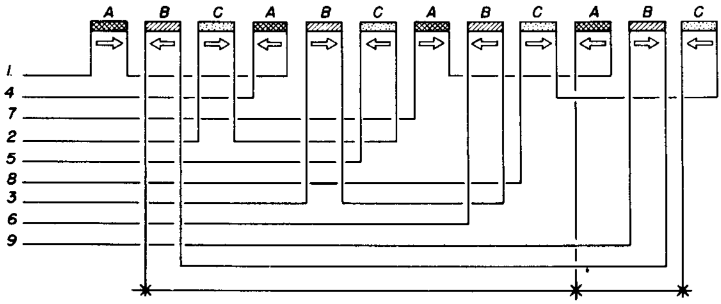


FIG. 4-68.—A three-phase, four-pole, two-voltage, star-connected motor.

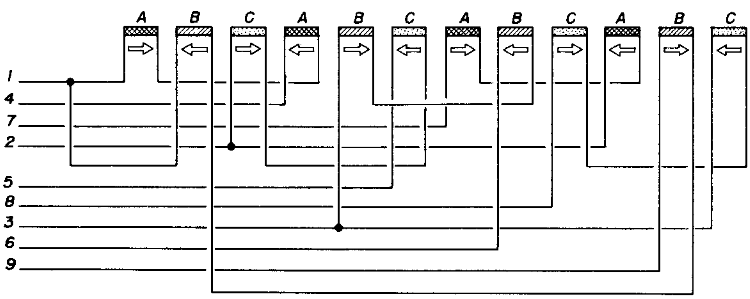


FIG. 4-69.—A three-phase, four-pole, two-voltage, delta-connected motor.

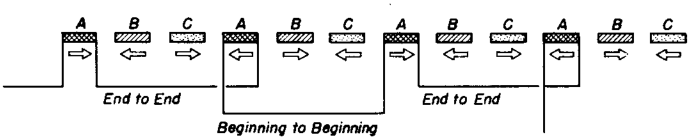


FIG. 4-70.—Short jumpers between groups of phase A.

Figures 4-68; 4-69; 4-70

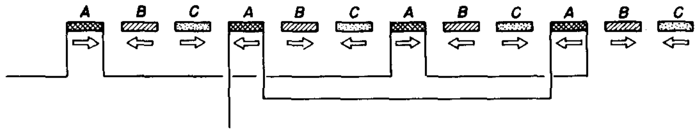


FIG. 4-71.—Long jumpers between groups of phase *A*.

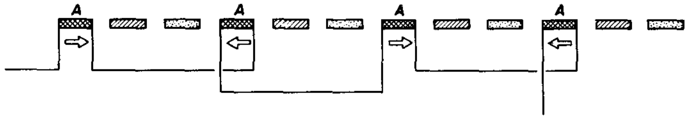


FIG. 4-72.—A four-pole motor with *A* phase connected in the usual way.

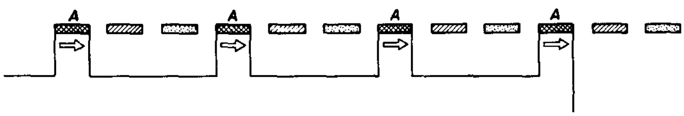


FIG. 4-73.—Groups connected so that eight poles will be formed instead of four. All the arrows point in the same direction.

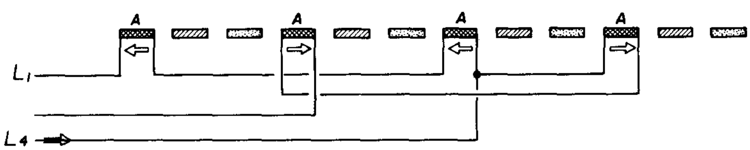


FIG. 4-74.—The *A* phase connected in parallel for four-pole operation. The current flows through the groups in the direction of the arrows. Long jumpers are necessary in two-speed motors.

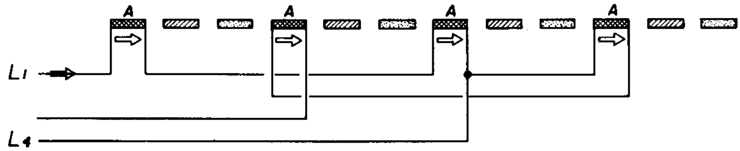


FIG. 4-75.—The *A* phase connected series delta for eight-pole operation. The current flows through the groups in the direction of the arrows. This type of motor is used for constant torque at both speeds.

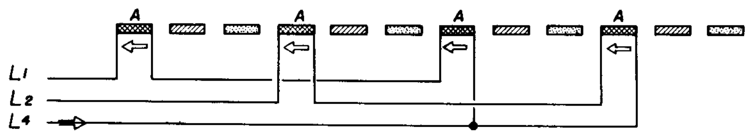


FIG. 4-76.—A two-parallel connection for eight-pole operation at low speed.

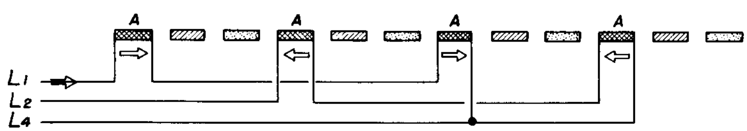


FIG. 4-77.—The groups of the *A* phase are connected in series for four-pole operation at high speed.

Figures 4-75; 4-76; 4-77

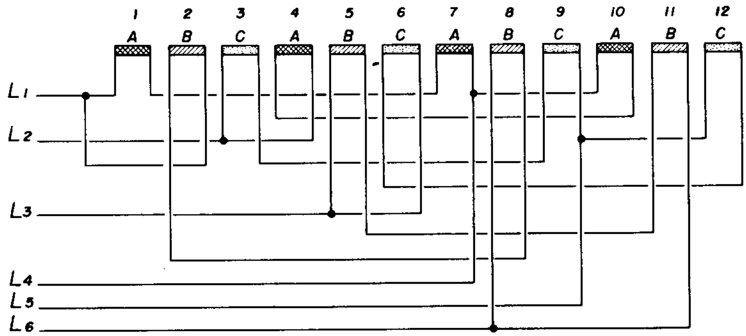
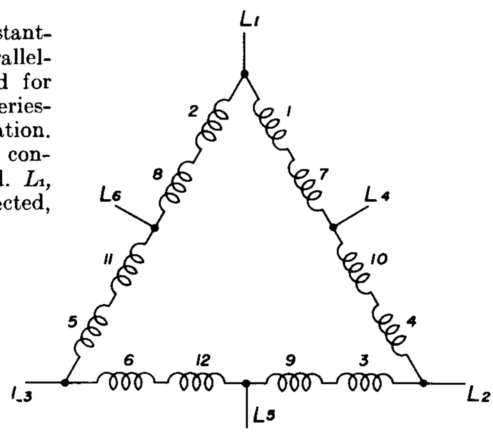


FIG. 4-78.—A four-pole, constant-torque two-speed motor. The parallel-star connection (above) is used for high-speed operation; the series-delta (*right*) for low-speed operation. L_4, L_5, L_6 to line; L_1, L_2, L_3 connected together, for high speed. L_1, L_2, L_3 to line; L_4, L_5, L_6 not connected, for low speed.



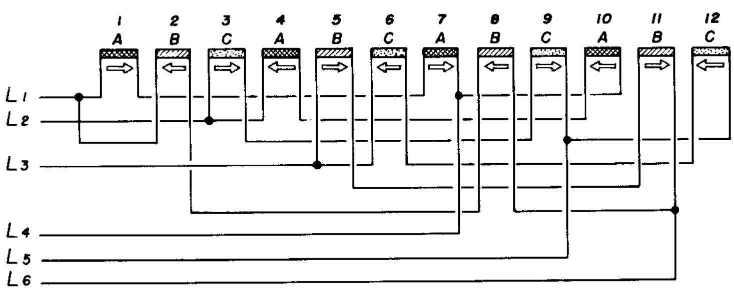


FIG. 4-79.—A two-speed constant horsepower motor. The series-delta connection is used for high-speed operation; two-parallel star for low speed. L_4, L_5, L_6 to line; L_1, L_2, L_3 connected together for low speed. L_1, L_2, L_3 to line; L_4, L_5, L_6 not connected for high speed.

FIG. 4-80.—A method of arranging groups in drawing.

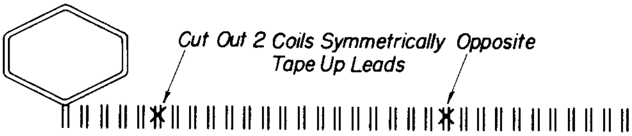


FIG. 4-81.—A four-pole, 32-coil motor, but two coils are not in circuit.

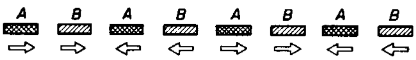


FIG. 4-82.—A two-phase, four-pole, 48-coil motor. Note direction of arrows.

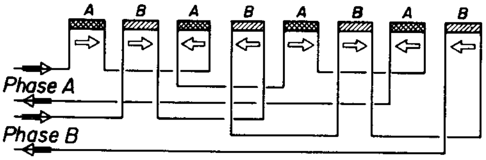


FIG. 4-83.—A two-phase, four-pole motor. Note that the two phases are connected alike.

Figures 4-80; 4-81; 4-82; 4-83

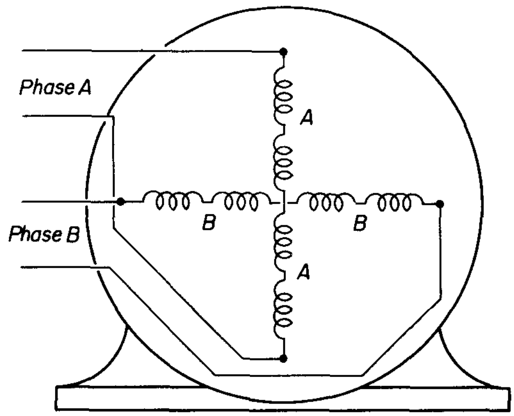


FIG. 4-84.—A two-phase, four-pole series connection.

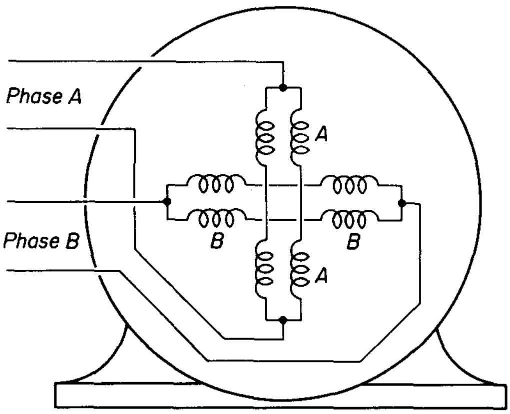


FIG. 4-85.—A two-phase, four-pole, two-parallel connection.

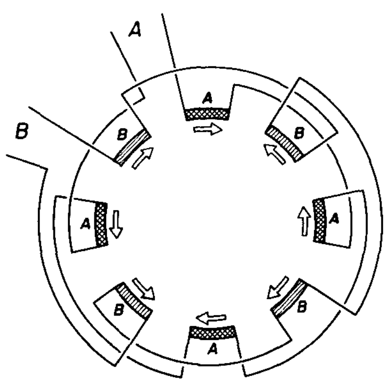


FIG. 4-86.—A two-phase, four-pole, series connection with eight groups.

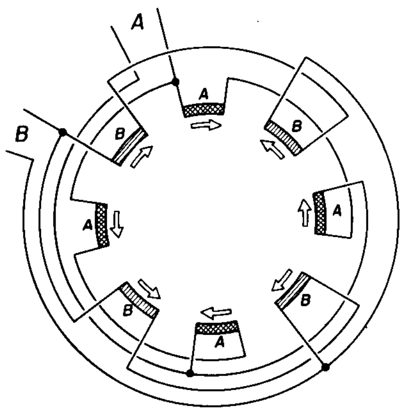


FIG. 4-87.—A two-phase, four-pole, two-parallel connection.

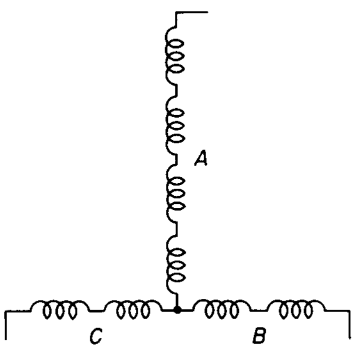


FIG. 4-88.—The end of the *A* phase is connected to the center of the *B* phase to form a T, or Scott, connection. One half of the *B* phase becomes the *C* phase, and the other half remains the *B* phase.

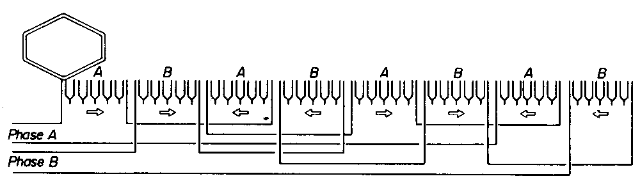


FIG. V-89.—A two-phase, 48-coil series motor to be connected Scott for three-phase operation.

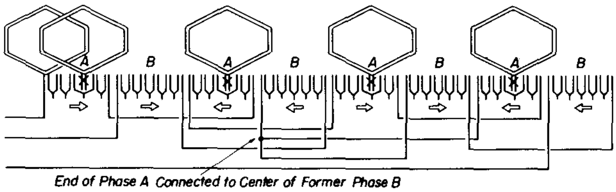


FIG. 4-90.—The circuit of a three-phase motor formed by Scott connection.

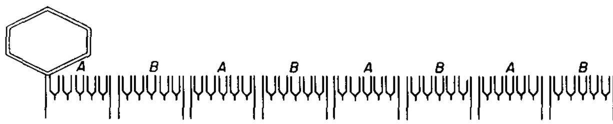


FIG. 4-91.—A two-phase, four-pole motor with jumpers removed.

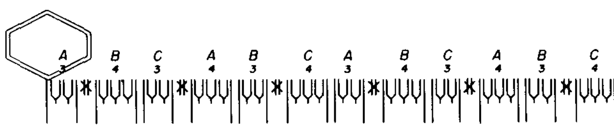
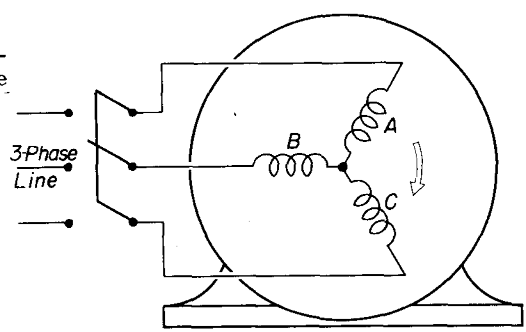


FIG. 4-92.—Laying out groups for a three-phase, four-pole, 42-coil, series star connection.

FIG. 4-93.—A three-phase motor connected to a three-phase line.



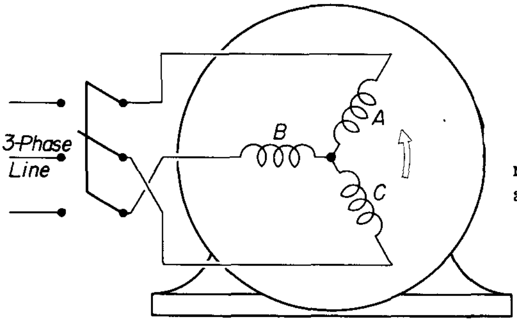


FIG. 4-94.—To reverse the direction of rotation, interchange any two motor leads.

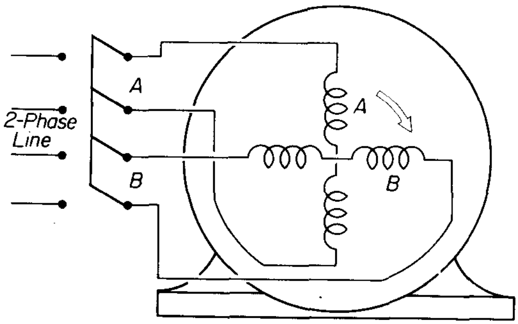


Fig. 4-95.—A two-phase motor connected to a two-phase line.

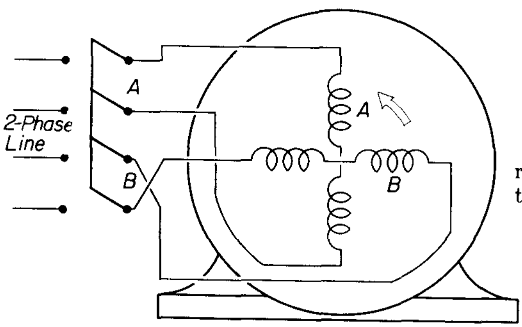


FIG. 4-96.—To reverse the direction of rotation, interchange the leads of one phase.

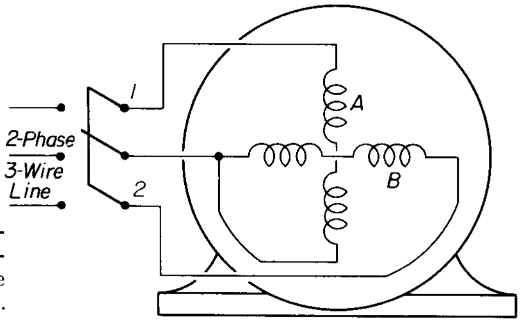


FIG. 4-97.—To reverse the direction of a three-wire, two-phase motor interchange the outer two motor leads, *1* and *2*.

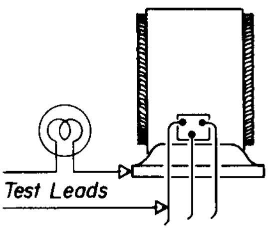


FIG. 4-98.—Testing a polyphase motor for grounds.

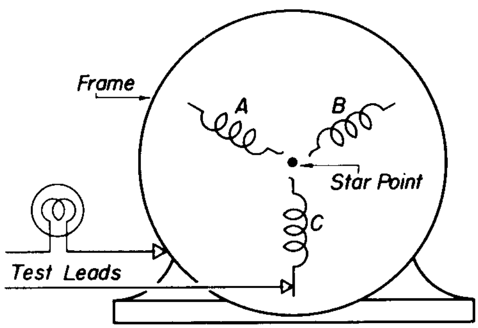


FIG. 4-99.—A star-connected motor. Disconnect the star point to locate a grounded phase.

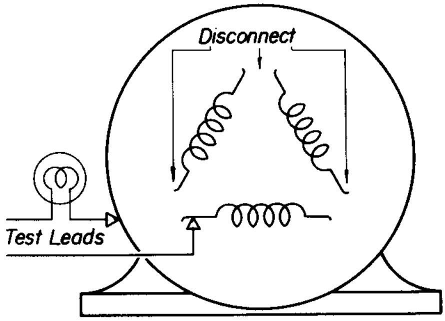


FIG. 4-100.—In a delta-connected motor disconnect phases to locate a grounded phase.

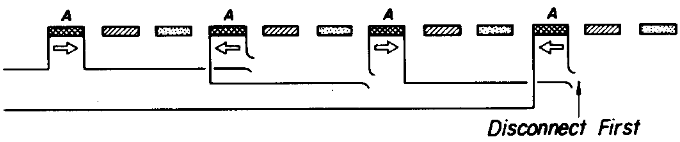


FIG. 4-101.—To locate the grounded group, disconnect jumpers between groups of that phase.

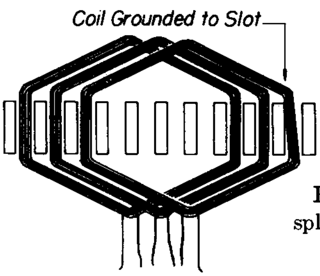
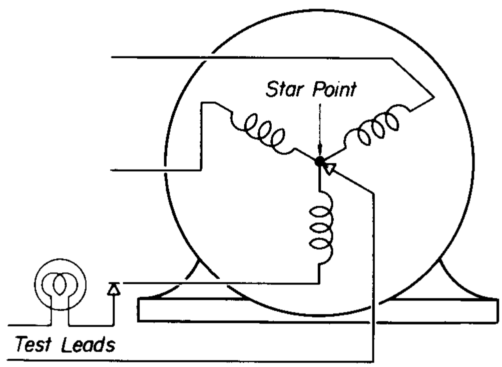


FIG. 4-102.—To find a grounded coil, disconnect splices and test each coil separately.

FIG. 4-103.—A test to determine the open phase in a star motor.



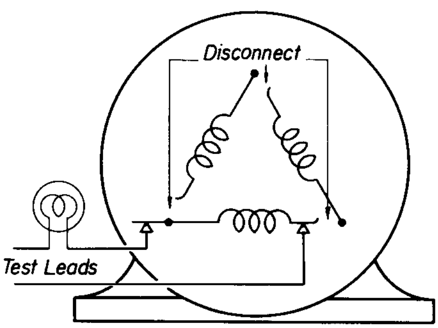


FIG. 4-104.—Determining the open phase in a delta motor.

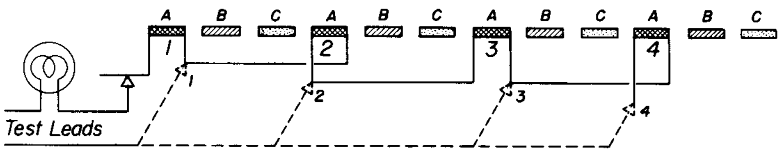


FIG. 4-105.—Consecutive tests for locating an open group.

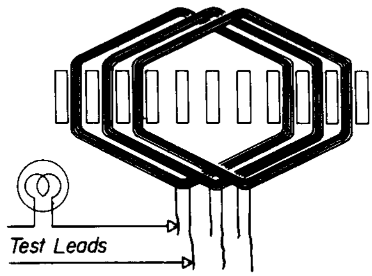


FIG. 4-106.—A group with splices disconnected to locate an open coil.

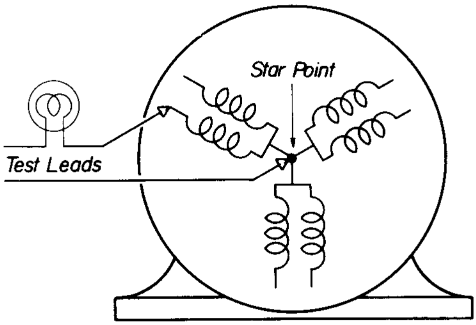
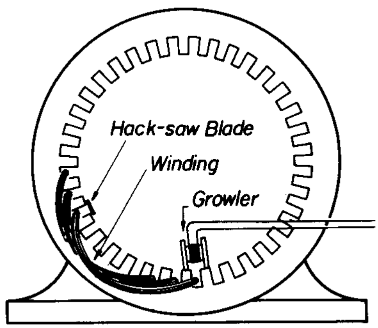


FIG. 4-107.—Locating an open in a two-parallel star motor.

FIG. 4-108.—The use of an internal growler to locate a shorted coil.



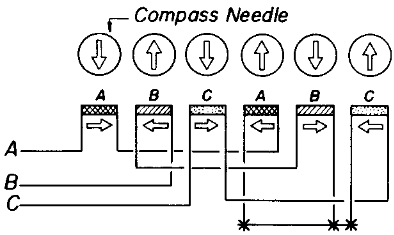


FIG. 4-109.—The correct method of connecting a three-phase, two-pole star motor is indicated by the compass needle.

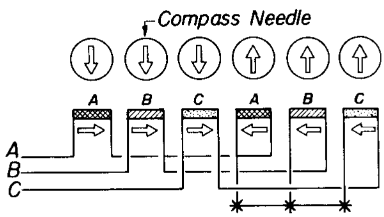


FIG. 4-110.—An incorrect connection of phase *B*. Reverse this phase.

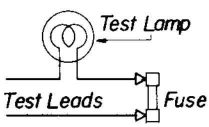


FIG. 4-111.—Testing a fuse with a test lamp.

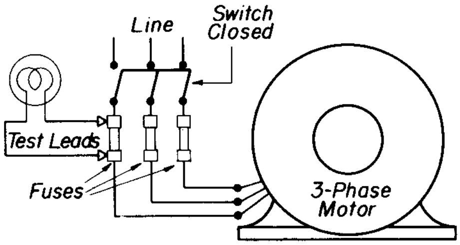


FIG. 4-112.—A test lamp placed across a burned-out fuse will light.

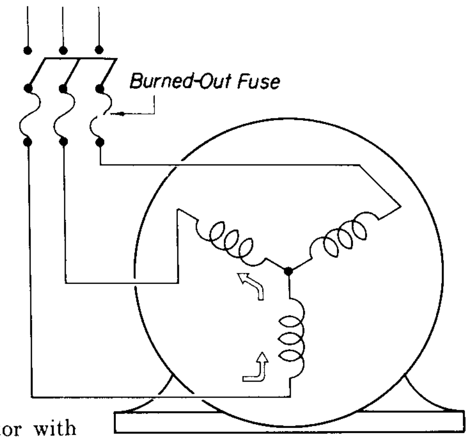


FIG. 4-113.—A star-connected motor with burned-out fuse in one phase. Current through the other two phases will overload the coils and burn them out.

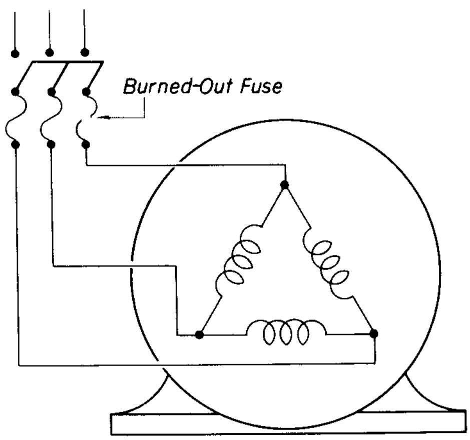
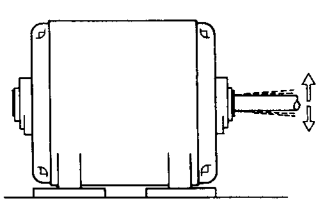


FIG. 4-114.—A delta-connected motor with burned-out fuse in one phase. Current will flow in one of the phases.

FIG. 4-115.—Lift the shaft up and down. Movement indicates worn bearing of shaft.



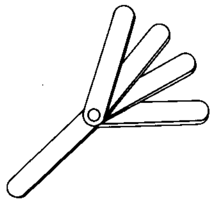


FIG. 4-116.—A feeler gauge, which has thin metal strips of different thickness.

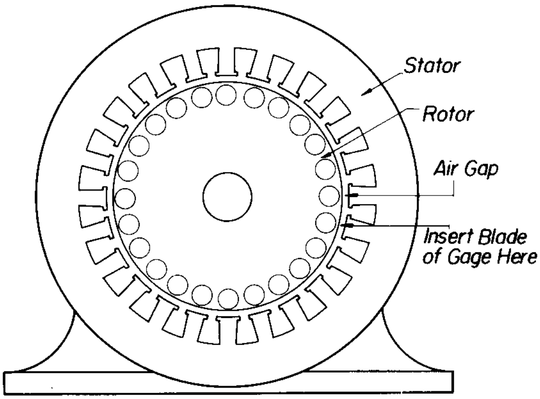


FIG. 4-117.—The air gap should be the same around the entire motor. This is checked with a feeler gauge.

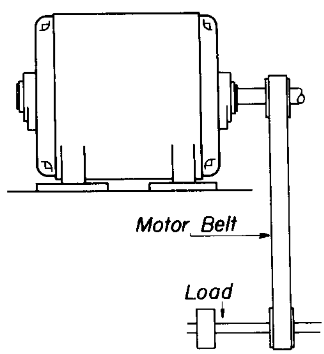


FIG. 4-118.—Disconnect belt and try to move load in order to see if load is free to turn.

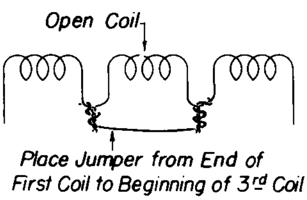


FIG. 4-119.—The method of jumping out one coil of a group of three coils.

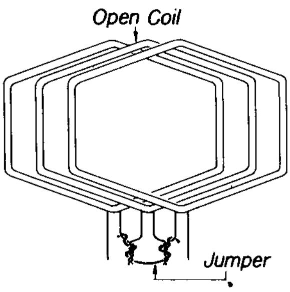


FIG. 4-120.—The method of jumping out one coil of a diamond-shaped group.

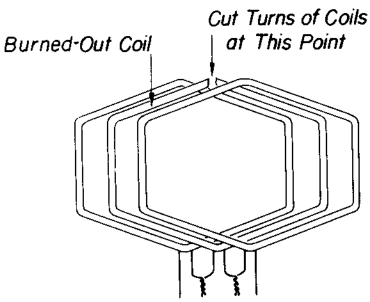


FIG. 4-121.—Cutting turns of a burned-out coil.

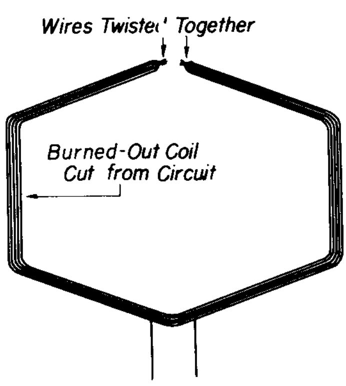


FIG. 4-122.—A coil cut and wires twisted together on both sides.

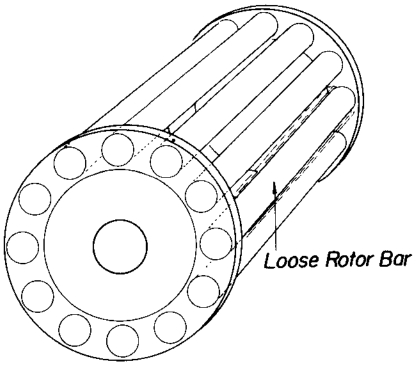


FIG. 4-123.—Rotor bars are welded or cast on end rings. One or more bars may loosen, thus causing poor operation of motor.

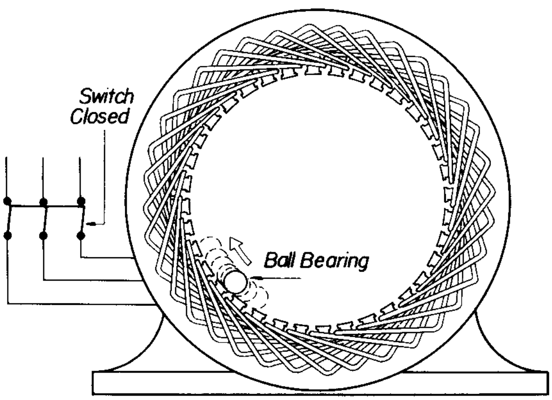


FIG. 4-124.—The ball bearing should rotate around the core of the stator if internal connections are correct.

CHAPTER 5

Alternating-current Motor Control

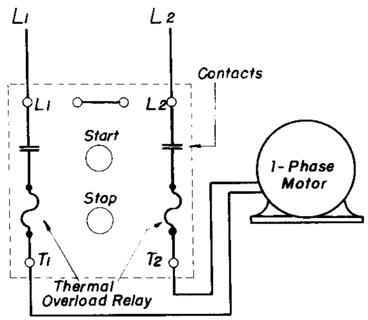


Fig. 5-1.—A pushbutton switch starter connected to a single-phase motor.

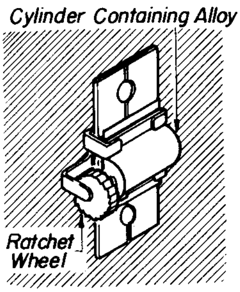


Fig. 5-2.—A thermal relay of the molten-alloy type.

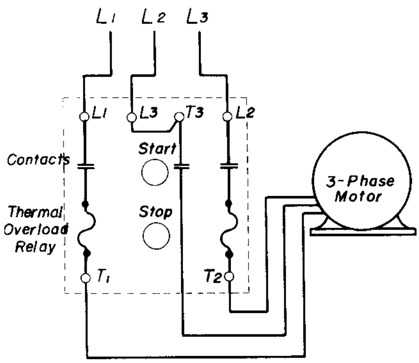


Fig. 5-3.—A pushbutton switch starter connected to a three-phase motor.

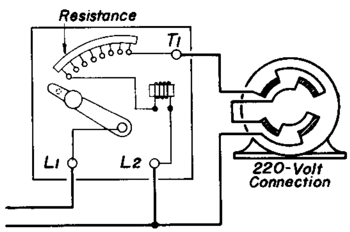


Fig. 5-4.—A manual resistance starter connected to a repulsion induction motor.

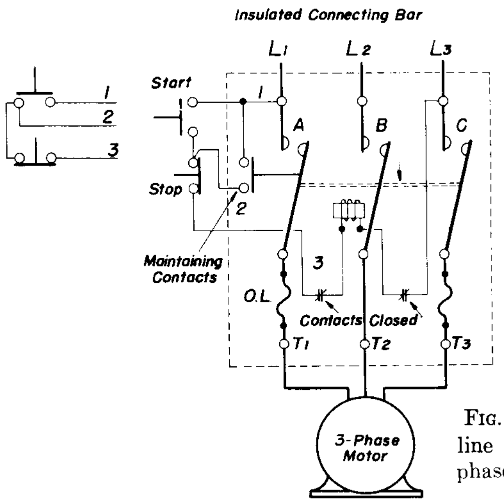


FIG. 5-5.—A magnetic across-the-line starter connected to a three-phase motor.

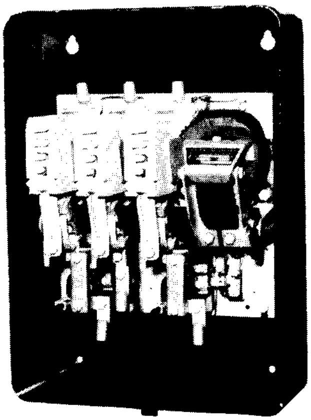


FIG. 5-6.—A magnetic starter for an a-c motor. (*General Electric Company.*)

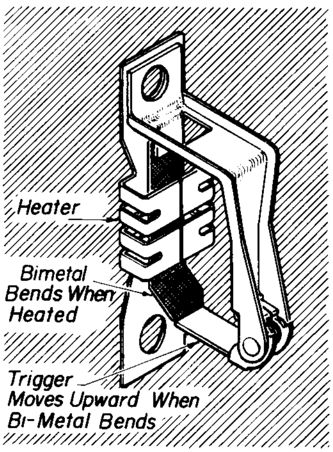


FIG. 5-7.—A thermal relay manufactured by the General Electric Company.

FIG. 5-8.—A START-STOP station. (*General Electric Company.*)

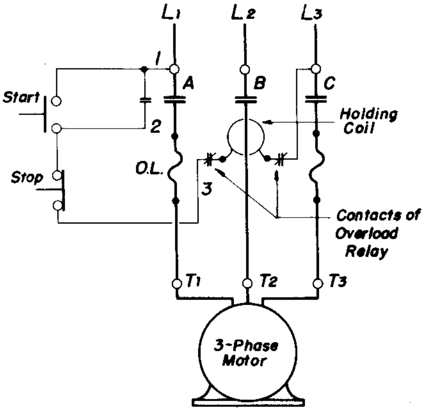


FIG. 5-9.—A simplified diagram of a magnetic across-the-line starter.

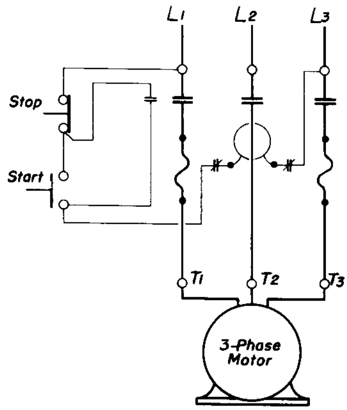


FIG. 5-10.—An across-the-line starter with a slightly different connection of the STOP and START buttons.

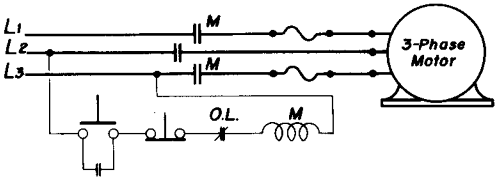


FIG. 5-11.—A line diagram of a magnetic across-the-line starter.

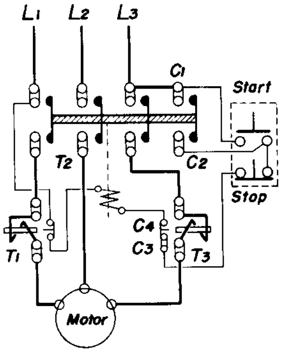


FIG. 5-12.—An across-the-line starter. (*Allen-Bradley Co.*)

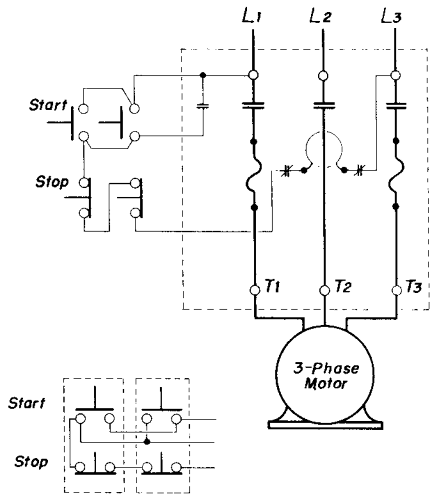


FIG. 5-13.—A magnetic switch controlled by two START-STOP stations.

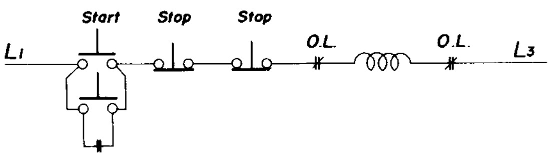


FIG. 5-14.—A control circuit for two START-STOP stations.

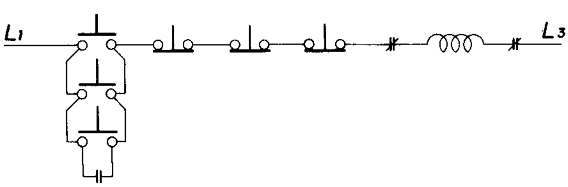


FIG. 5-15.—A control circuit for three START-STOP stations.

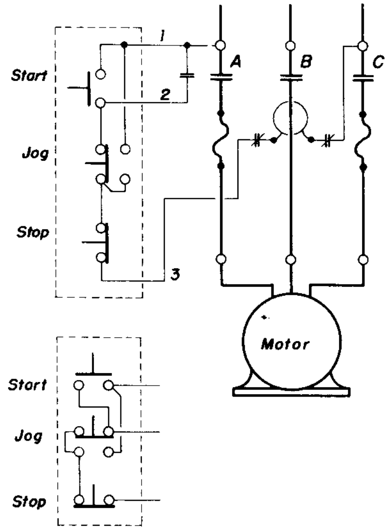


FIG. 5-16.—A START-JOG-STOP station connected to a magnetic switch.

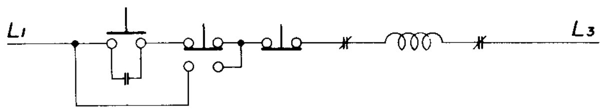


FIG. 5-17.—A control circuit of a START-JOG-STOP station.

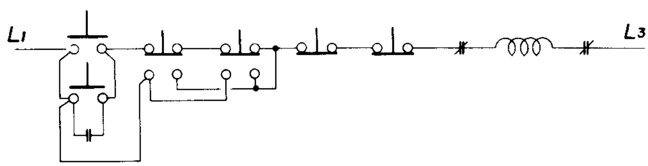


FIG. 5-18.—A control circuit for two START-JOG-STOP stations.

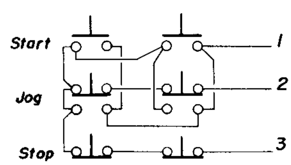


FIG. 5-19.—Two START-JOG-STOP stations with four wires between stations.

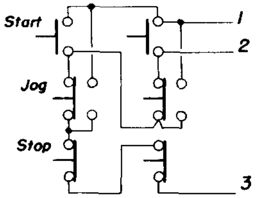


FIG. 5-20.—Two START-JOG-STOP stations with three wires between stations.

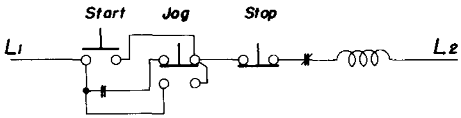
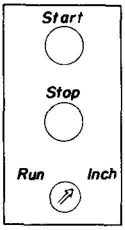


FIG. 5-21.—Another method of connecting a START-JOG-STOP station.

FIG. 5-22.—A panel of a station in which the START button can be used for inching or jogging.



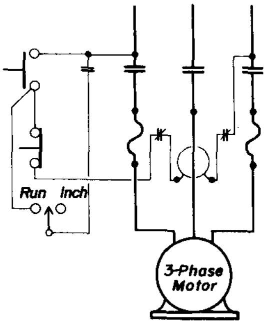
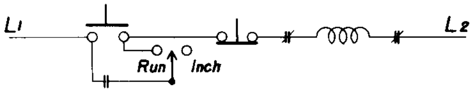


FIG. 5-23.—A magnetic switch operated by a START-STOP station with selector switch for jogging.

FIG. 5-24.—A line diagram of control circuit for Figure 5-23.



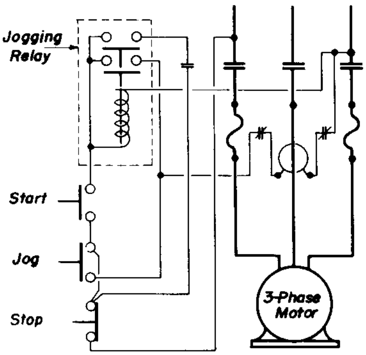


FIG. 5-25.—A magnetic switch operated by a START-JOG-STOP station with a jog-relay attachment.

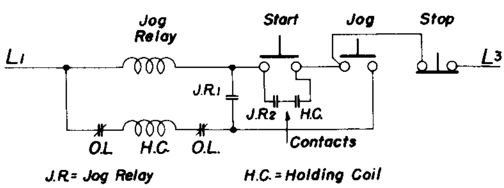
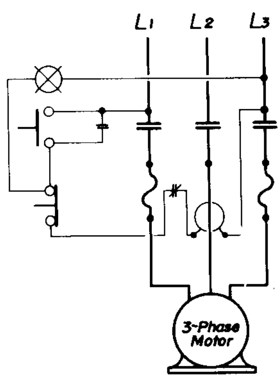


FIG. 5-26.—An elementary diagram of Figure 5-25.

FIG. 5-27.—A pushbutton station with indicating light.



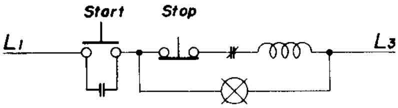


FIG. 5-28.—A simple control circuit of a START-STOP. station with an indicating light.

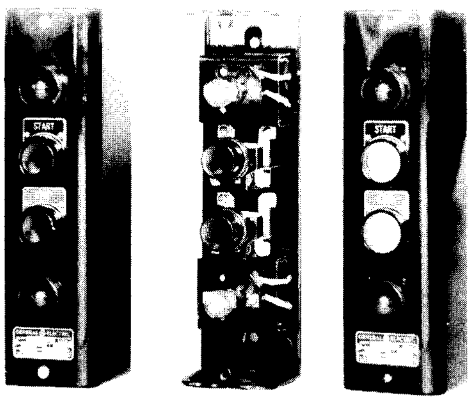


FIG. 5-29.—Two pushbutton stations with indicating lights. (*General Electric Company.*)

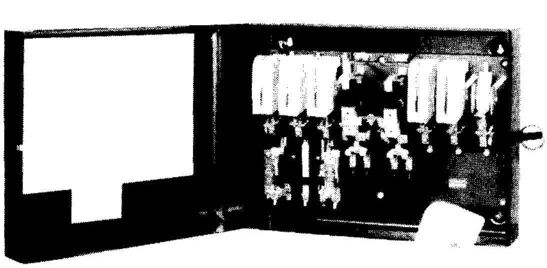


FIG. 5-30.—An a-c magnetic reversing panel with overload protection by thermal relays. (*General Electric Company.*)

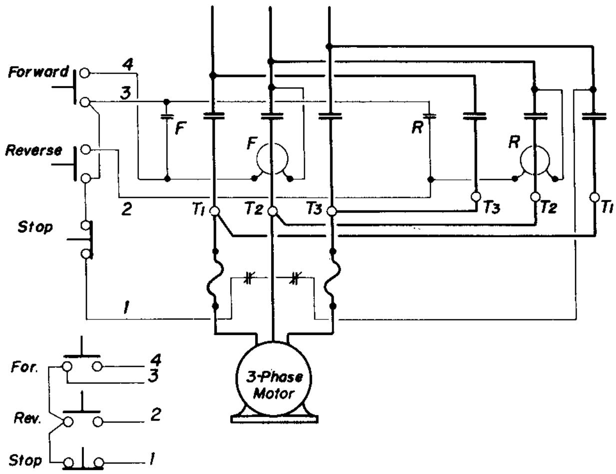


FIG. 5-31.—A reversing magnetic switch operated by a FORWARD-REVERSE-STOP station.

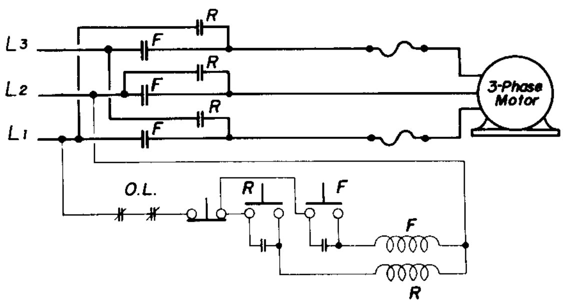


FIG. 5-32.—An elementary diagram of Figure 5-31.

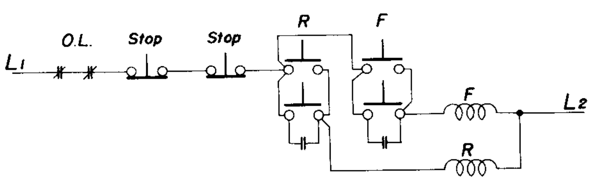


FIG. 5-33.—A line diagram of control circuit for two FORWARD-REVERSE-STOP stations.

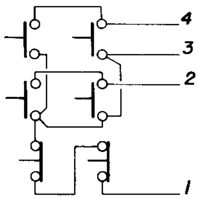


Fig. 5-34.—A connection for two FORWARD-REVERSE-STOP stations to a reversing magnetic switch.

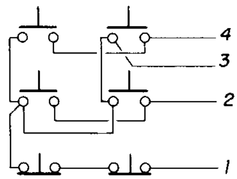


Fig. 5-35.—The true position of the stations of Figure 5-34.

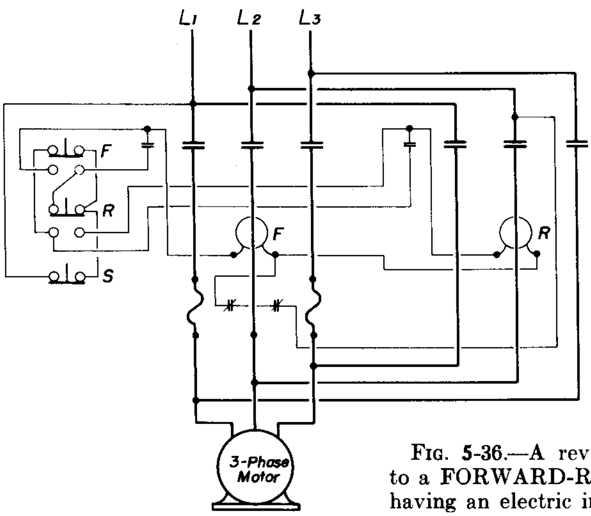


Fig. 5-36.—A reversing switch connected to a FORWARD-REVERSE-STOP station having an electric interlock.

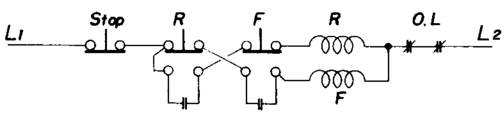


Fig. 5-37.—A control circuit of a FORWARD-REVERSE-STOP station having an electrical interlock.

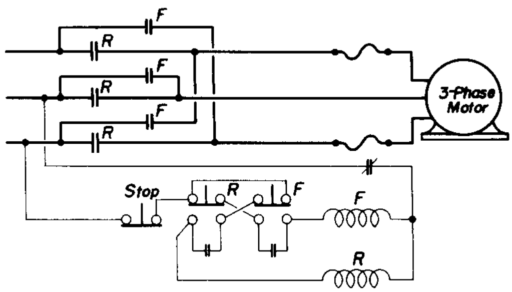


FIG. 5-38.—An elementary diagram of Figure 5-36.

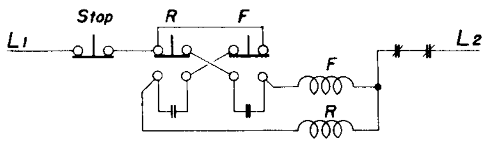
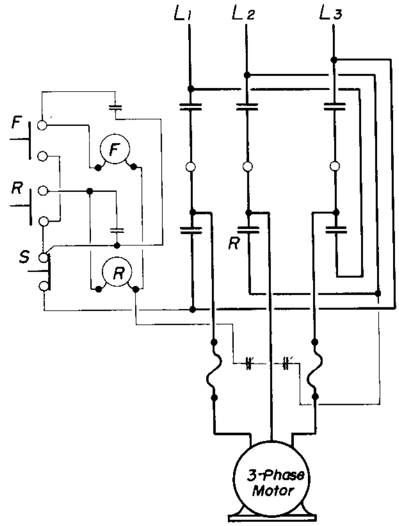


FIG. 5-39.—Another method of connecting the circuit of Figure 5-37.

FIG. 5-40.—A magnetic reversing switch in a vertical, instead of a horizontal, position.



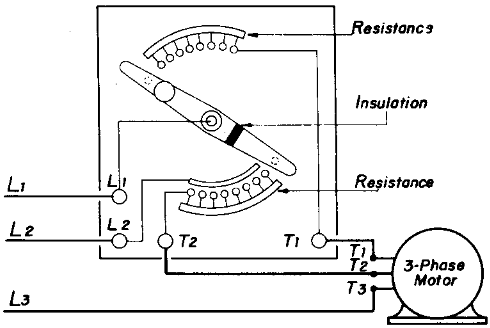


FIG. 5-41.—A manual resistance starter of the rheostat type.

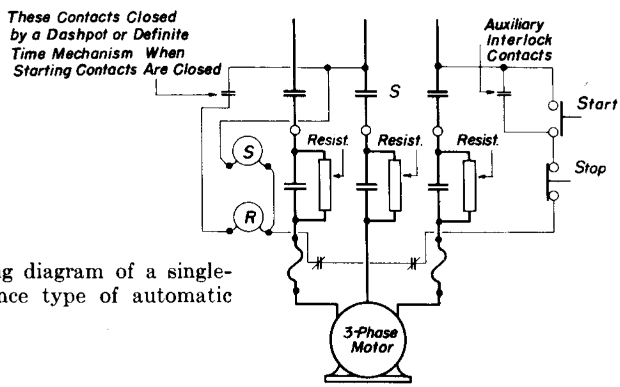


FIG. 5-42.—A wiring diagram of a single-step, primary-resistance type of automatic starter.

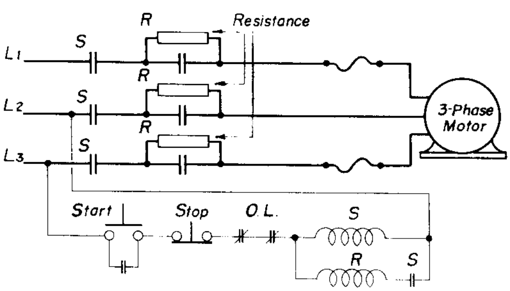


FIG. 5-43.—An elementary diagram of a primary-resistance automatic starter.

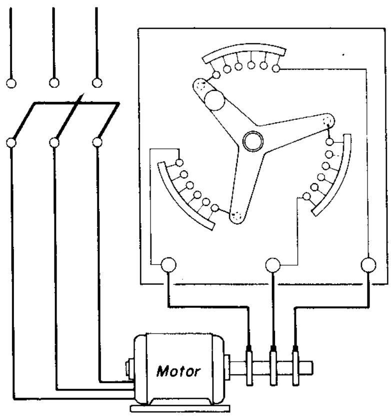


FIG. 5-44.—A secondary-resistance starter connected to a wound motor. A 3-pole manual switch is used for the stator.

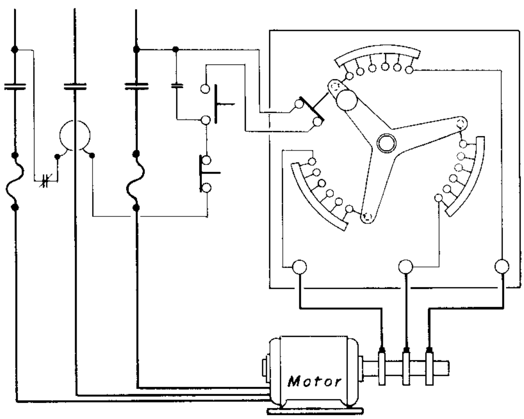


FIG. 5-45.—A resistance starter connected to a magnetic switch.

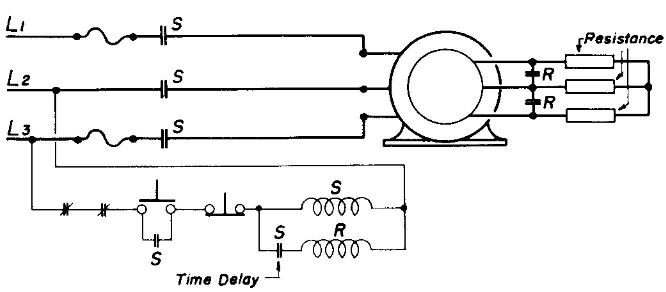


FIG. 5-46.—An elementary diagram of an automatic two-step resistance starter for a wound-rotor motor.

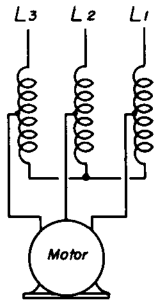


FIG. 5-47.—The connection of a start position of a compensator.

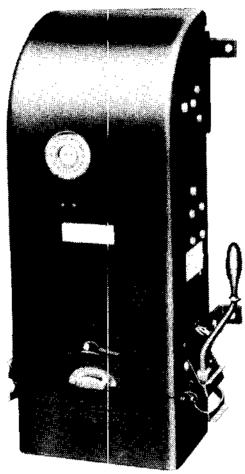


FIG. 5-48.—A typical manual auto-transformer compensator.

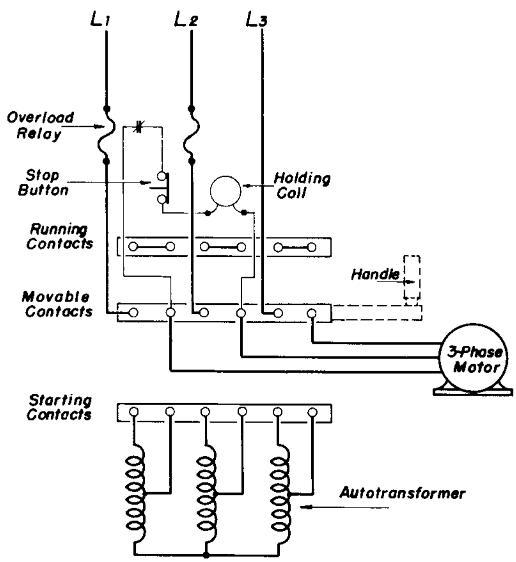


FIG. 5-49.—A diagram of a three-phase compensator.

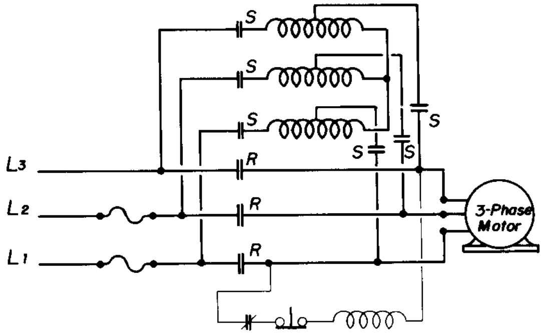


FIG. 5-50.—An elementary diagram of a three-phase compensator.

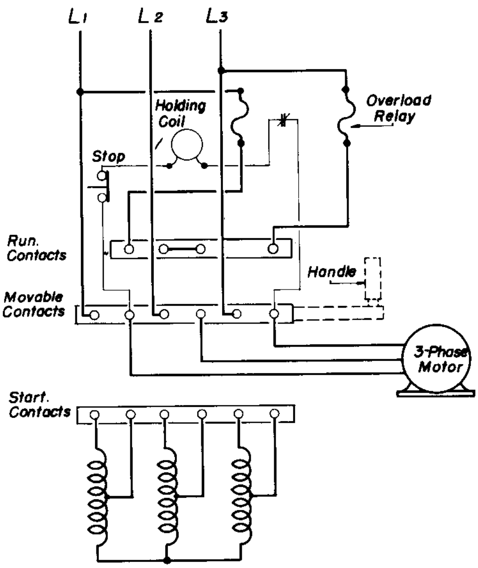


FIG. 5-51.—A three-phase compensator with the overload relay connected in the running circuit.

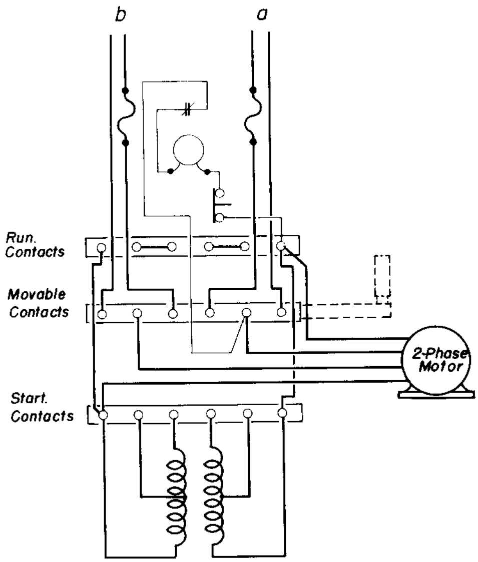


FIG. 5-52.—A two-phase compensator with two autotransformers.

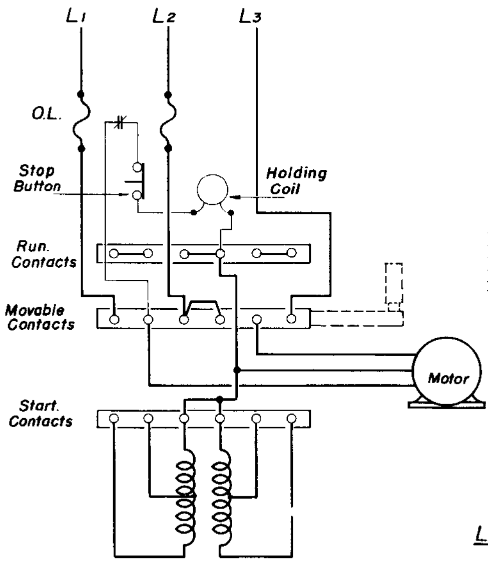


FIG. 5-53.—Operating a three-phase motor with a two-coil compensator. These coils are connected open delta.

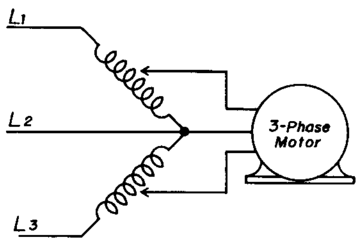


FIG. 5-54.—A line diagram of a two-coil, three-phase compensator on START position. Note the open-delta connection.

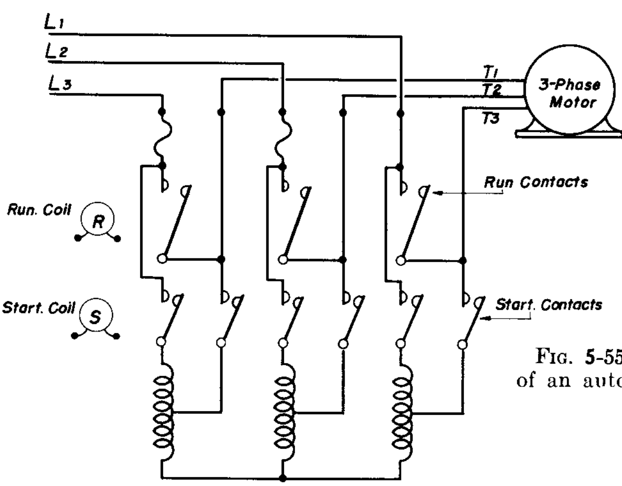


FIG. 5-55.—The motor circuit of an automatic compensator.

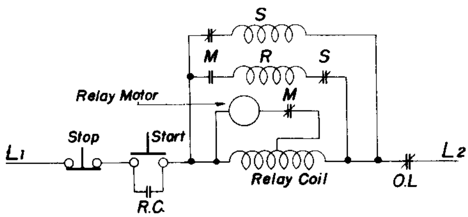


FIG. 5-56.—A control circuit for an automatic compensator. A motor-driven relay is used.

FIG. 5-57.—Each phase of a delta-connected motor receives the full line voltage.

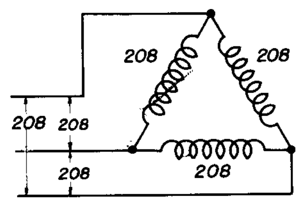
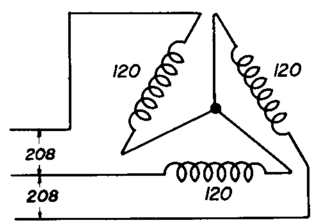


FIG. 5-58.—If a delta-connected motor is connected star, each phase will receive 58 per cent of line voltage.



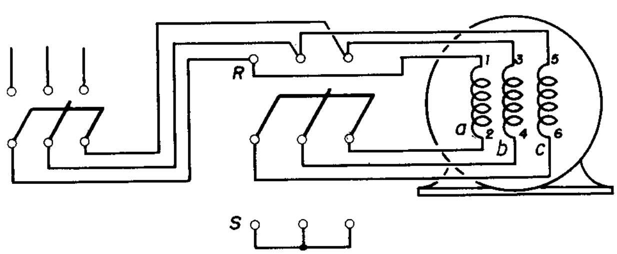


FIG. 5-59.—A star-delta connection for reduced-voltage starting.

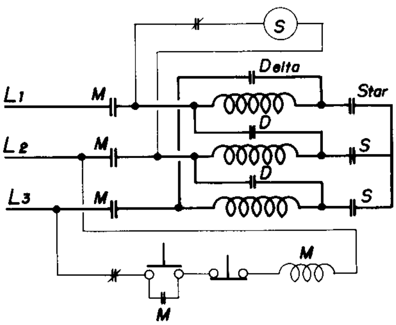


FIG. 5-60.—A star-delta automatic control.

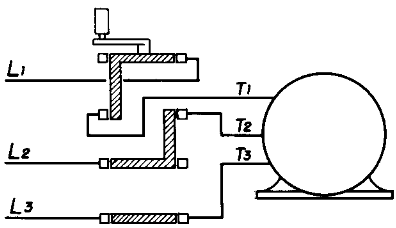


FIG. 5-61.—A three-phase motor connected to a manual reversing-drum switch for clockwise rotation.

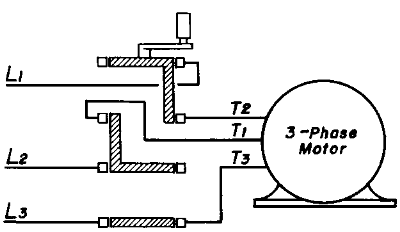


FIG. 5-62.—A drum switch connected to a three-phase motor for counterclockwise rotation.

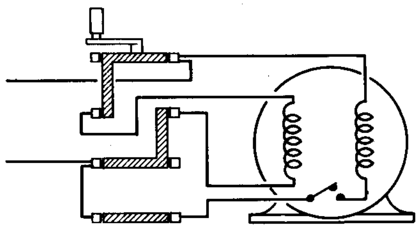


FIG. 5-63.—A drum switch for reversing a split-phase or capacitor motor.

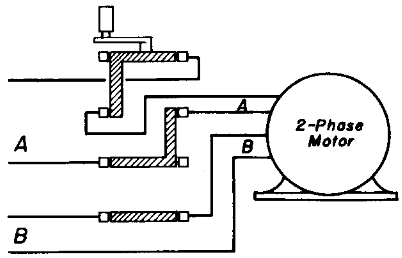


FIG. 5-64.—A drum switch for reversing a two-phase motor.

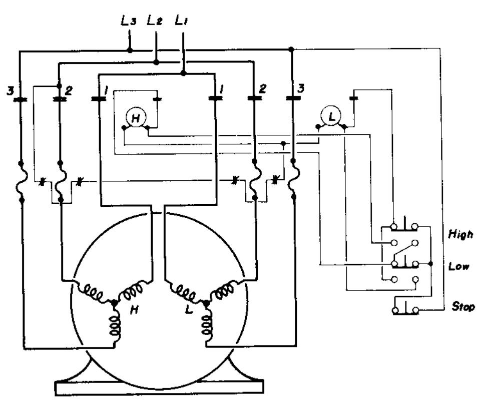


FIG. 5-65.—A two-speed controller for two sets of three-phase windings.

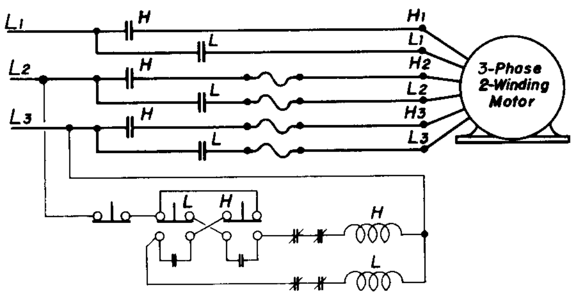


FIG. 5-66.—A line diagram of a two-speed, two-winding controller.

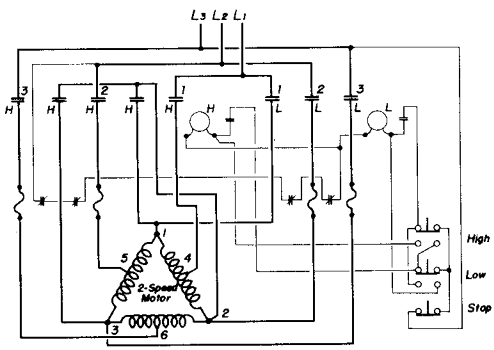


FIG. 5-67.—A connection diagram of a nonreversible, two-speed, single-winding, three-phase, squirrel-cage motor controller with constant torque.

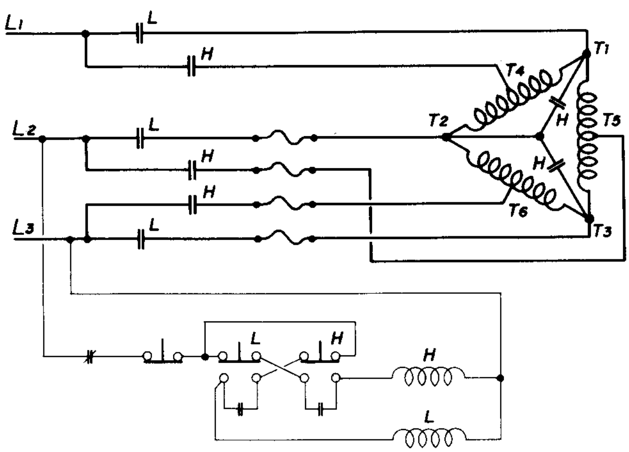


FIG. 5-68.—A line diagram of a two-speed, single-winding, three-phase motor controller.

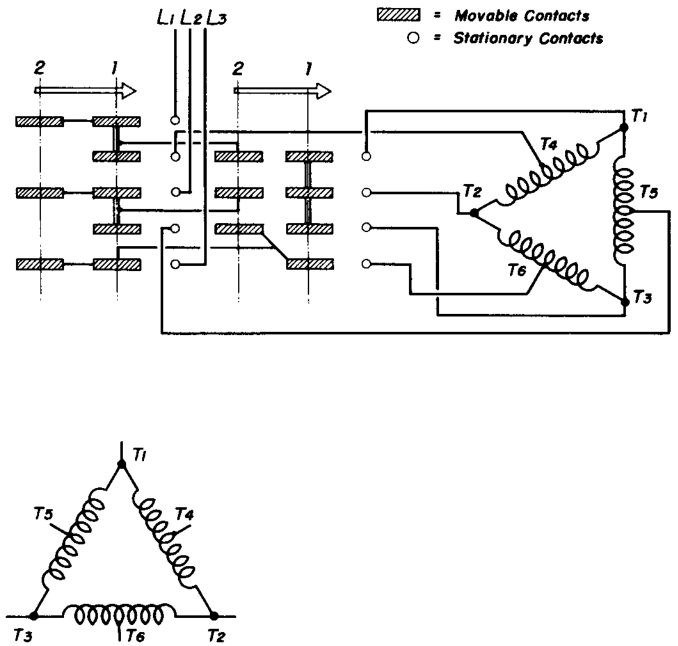


FIG. 5-69.—A simple cam switch for a single-winding, two-speed, constant-horsepower motor.

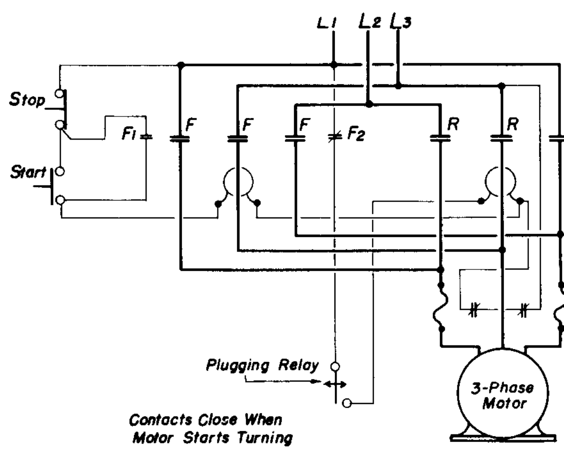


FIG. 5-70.—A controller using a plugging relay for braking.

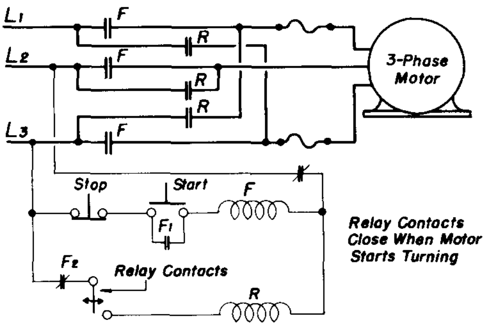


FIG. 5-71.—A line diagram of a controller with a plugging relay.

CHAPTER 6

Direct-current Armature Winding

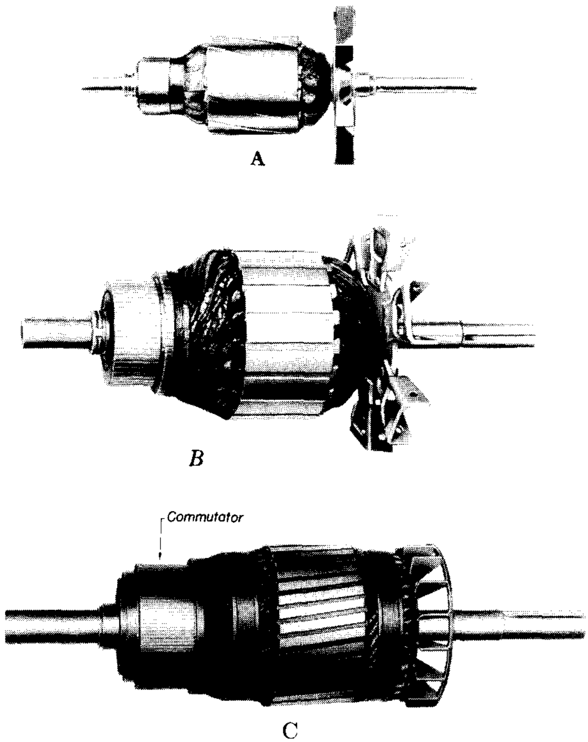


FIG. **6**-1.—Different type of d-c armatures. (*A, General Electric Co.; B* and *C, Century Electric Co.*)

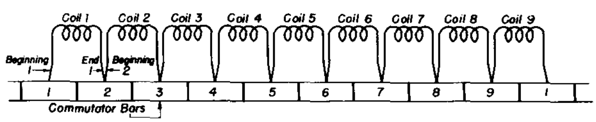


FIG. **6**-2*A*.—A schematic diagram of a simple loop winding that consists of nine coils and nine commutator bars. The end lead of each coil and the beginning lead of the next coil are placed in the same commutator bar. The end lead of the last coil is placed in the same bar as the beginning lead of the first coil.

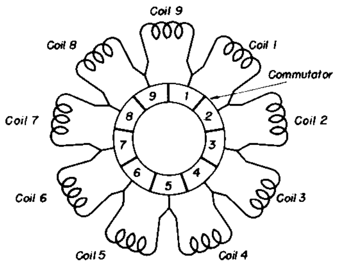


FIG. 6-2*B*.—A circular schematic diagram showing all the coils of a nine-coil armature connected to the commutator bars.

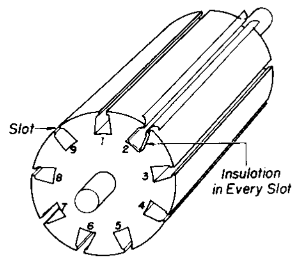


FIG. 6-3.—Slots in the armature into which the coils are wound.

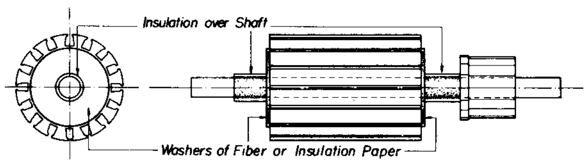


FIG. 6-4.—In addition to the slot insulation, the insulation shown above is necessary to protect the winding from grounding.

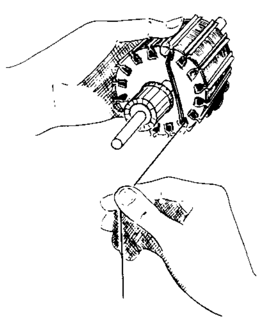


FIG. 6-5.—A small armature can be held in one hand during winding.

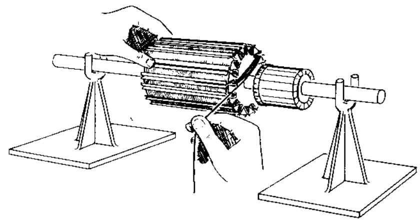


FIG. **6-6**.—Large armatures are supported by horses during winding.

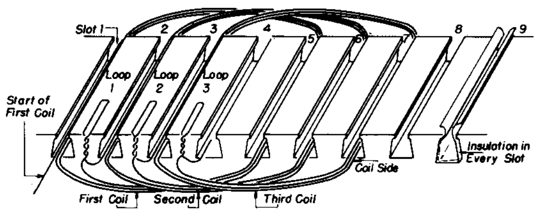


FIG. **6-7**.—The start of a loop winding. The entire armature is wound before the loops are connected to the commutator. Note that the first coil is wound into slots *1* and *5*. This is the pitch or span of the coil.

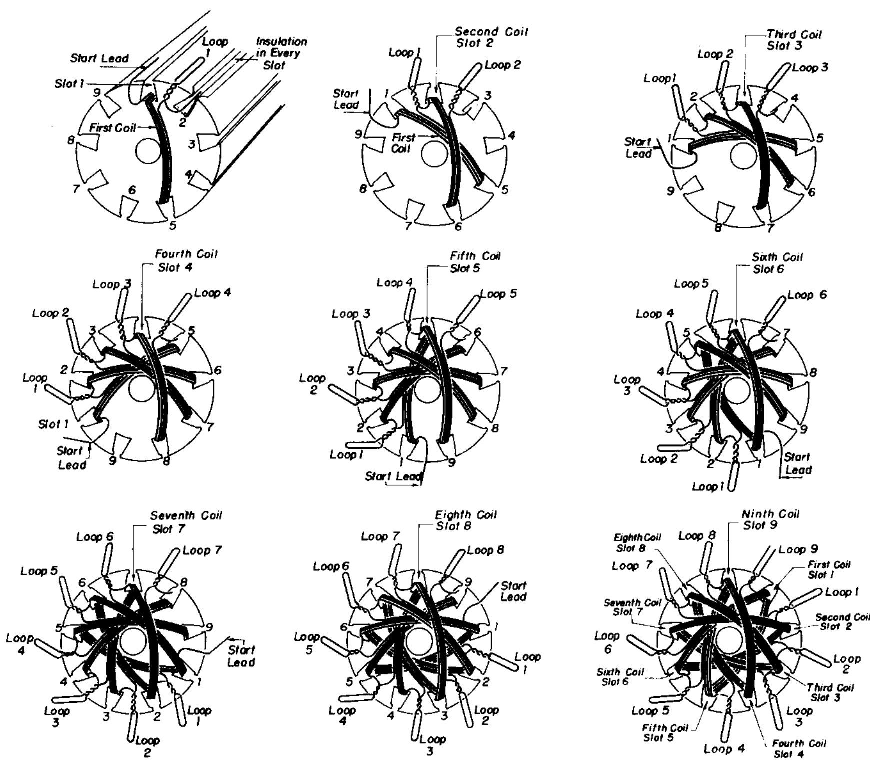


FIG. **6-8**.—Steps in winding the coils of a nine-slot armature.

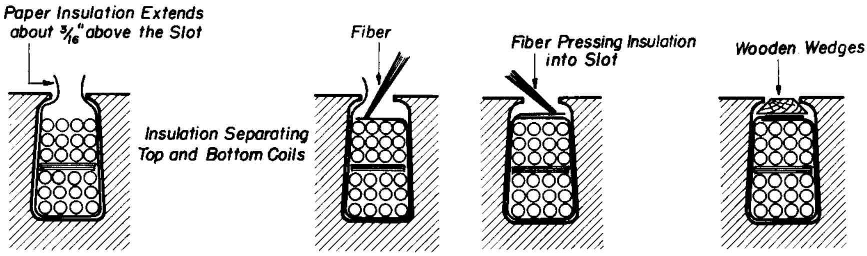


FIG. 6-9.—A method of folding insulation into slot and locking it in place with a wooden wedge.

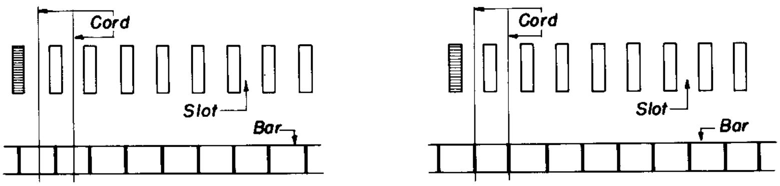


FIG. 6-10.—A simple method of determining the alignment of slot and commutator bar.

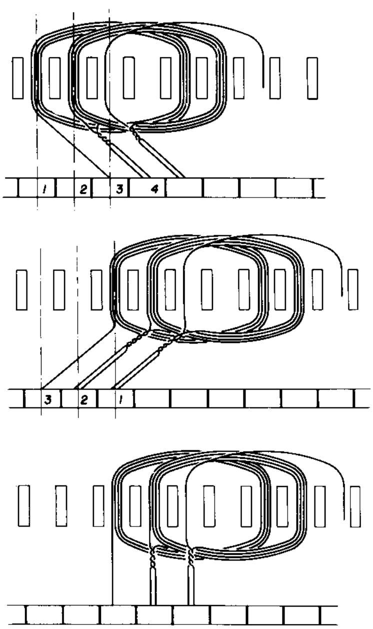


FIG. 6-11.—Three conditions of lead swing.

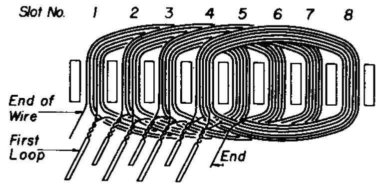


FIG. **6-12.**—A two-coil-per-slot winding with short and long loops for identification.

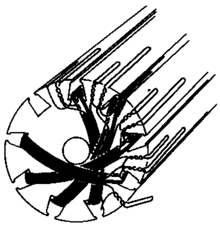


FIG. **6-13.**—A loop armature having twice as many loops as slots after four coils have been wound.

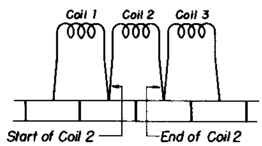


FIG. **6-14.**—A simplex lap winding in which the start and end of a coil are connected to adjacent bars.

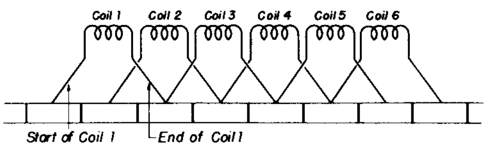


FIG. **6-15.**—In a duplex lap winding, the end lead of each coil is connected two bars away from the beginning lead.

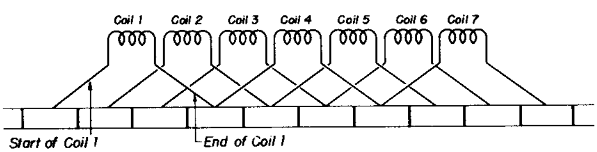


FIG. **6-16.**—In a triplex lap winding, the end lead of each coil is connected three bars away from the beginning lead.

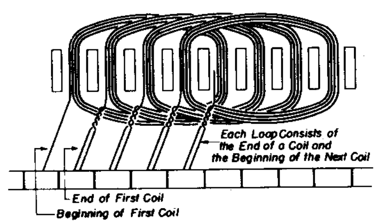


FIG. **6-17.**—A lap winding with one coil per slot has the beginning and end of the same coil connected to adjoining bars. The loops are connected to the commutator bars in succession.

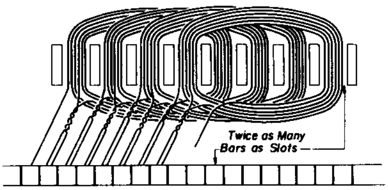


FIG. **6-18.**—A lap winding with two coils per slot. The beginning and end of each coil is connected to adjoining bars.

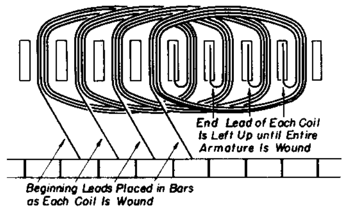


FIG. **6-19.**—A lap winding of one coil per slot with beginning leads in place.

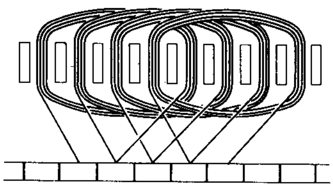


FIG. **6-20.**—A lap winding of one coil per slot after the end leads are placed in the commutator bars.

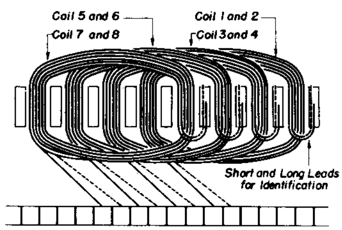


FIG. **6-21.**—A method of winding an armature having two coils per slot. The bottom or beginning leads are placed in the commutator bars as each coil is wound. The top leads are placed in the bars after the armature is wound.

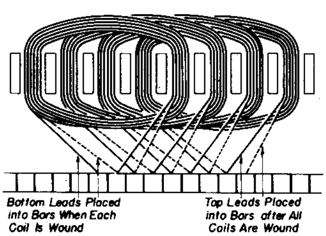


FIG. **6-22.**—The connections after the top leads are placed in the bars to produce a simplex lap winding with two coils in each slot.

Figures **6**-18; **6**-19; **6**-20; **6**-21; **6**-22

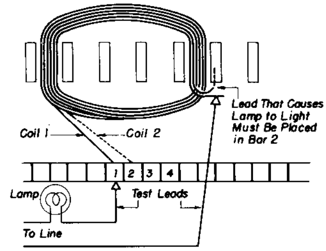


FIG. **6-23**.—Lamp method of determining in which bars top leads must be placed to produce a simplex lap winding.

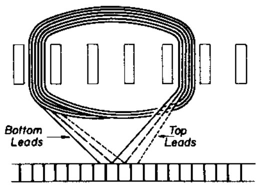


FIG. **6-24**.—A lap winding with three coils per slot.

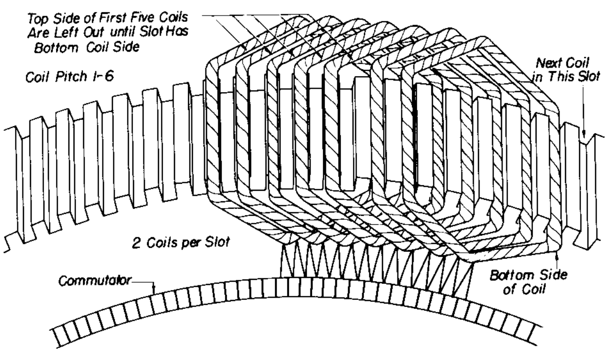


FIG. **6-25**.—A lap winding with two coils per slot.

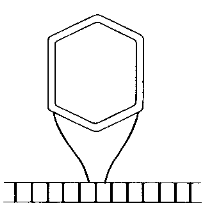


FIG. **6-26**.—In a lap winding leads face each other and are connected to adjacent bars.

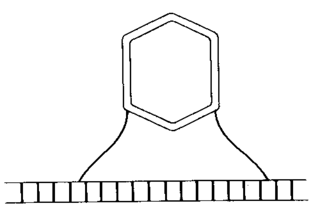


FIG. **6-27**.—In a wave winding, leads face away from one another and must be a definite number of commutator bars apart.

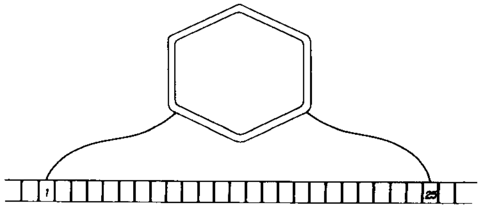


FIG. **6-28**.—Lead connections for a four-pole, 49-bar armature. According to the formula, the leads should be **24** bars apart; hence, they are placed in bars *1* and *25*.

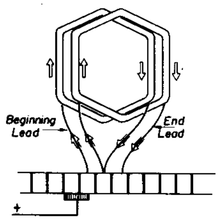
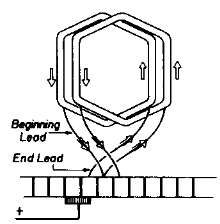


FIG. **6-29**.—A simplex progressive lap winding. The current flows in a clockwise direction.

FIG. **6-30**.—A retrogressive lap winding. The leads cross one another even though they are connected to adjacent bars. The current flows in a counterclockwise direction.



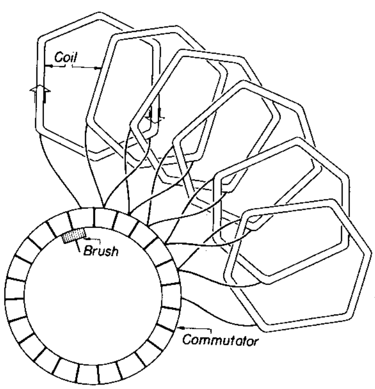


FIG. **6-31**.—A simplex, progressive lap winding.

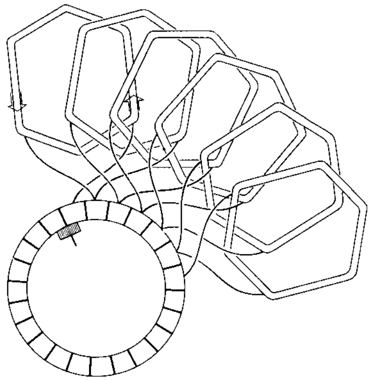


FIG. 6-32.—A simplex, retrogressive lap winding.

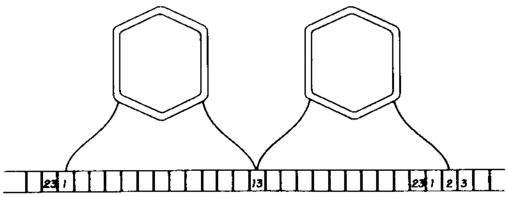


FIG. 6-33.—A four-pole, simplex, progressive wave winding with a commutator pitch of 1 and 13. The current travels through two coils before reaching the bar adjacent to the start.

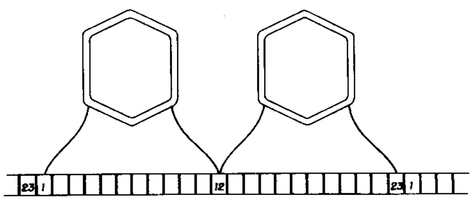


FIG. 6-34.—A four-pole, simplex, retrogressive wave winding with a commutator pitch of 1 and 12.

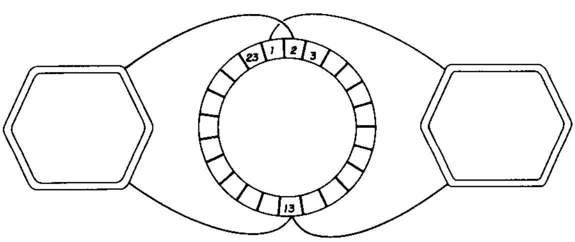


FIG. 6-35.—A four-pole, simplex, progressive wave winding with a commutator pitch of 1 and 13.

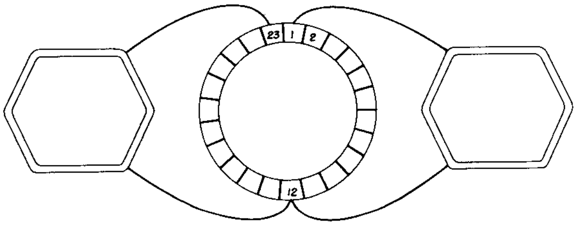


FIG. 6-36.—A four-pole, simplex, retrogressive wave winding with a commutator pitch of 1 and 12.

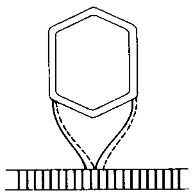


FIG. 6-37.—Two coils of a progressive lap winding.

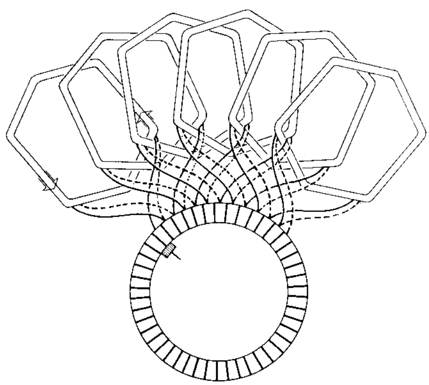


FIG. 6-38.—Several coils of a retrogressive lap winding with two coils per slot.

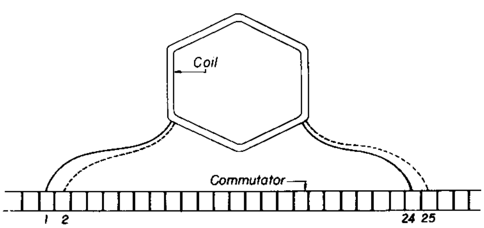


FIG. 6-39.—Wave-wound coils.

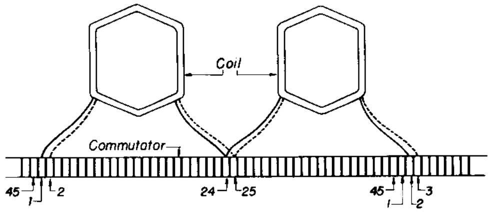


FIG. 6-40.—A progressive wave winding, two coils per slot.

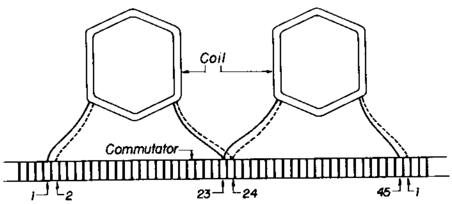


FIG. 6-41.—A retrogressive wave winding, two coils per slot.

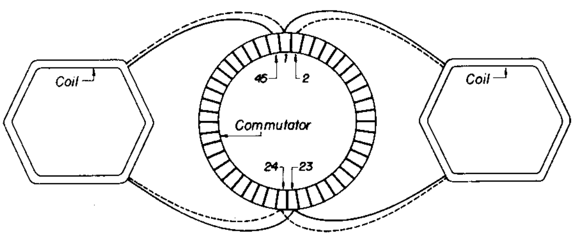


FIG. 6-42.—A retrogressive wave winding.

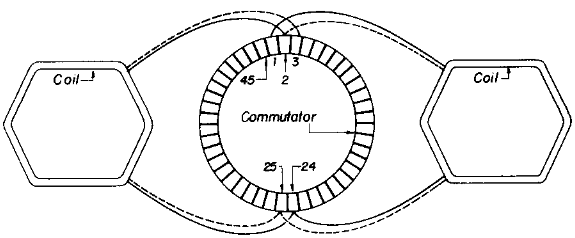


FIG. 6-43.—A progressive wave winding.

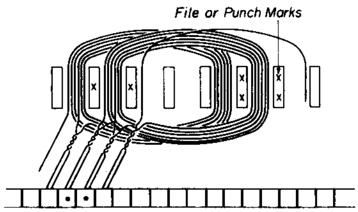


FIG. 6-44.—Pitch and lead data of a lap winding may be marked on the armature.

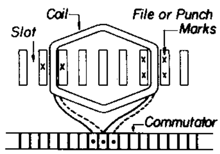
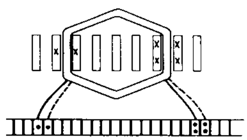


FIG. 6-45.—Pitch and lead data of a lap winding marked at the slots and bars of one particular coil.

FIG. 6-46.—Pitch and lead data of a wave winding marked at the slots and bars of a particular coil.



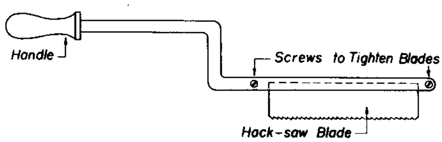


FIG. 6-47.—A tool for cutting slots in commutator bars.

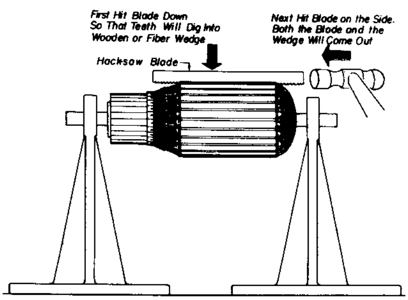


FIG. 6-48.—Method of removing wedges from armature or stator slots.

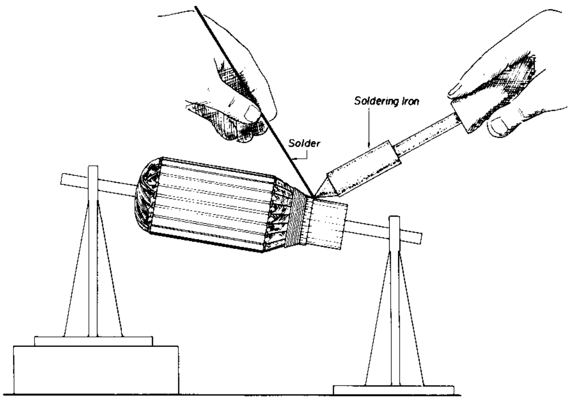


FIG. 6-49.—Soldering leads to the commutator. The soldering iron is held slightly above the horizontal.

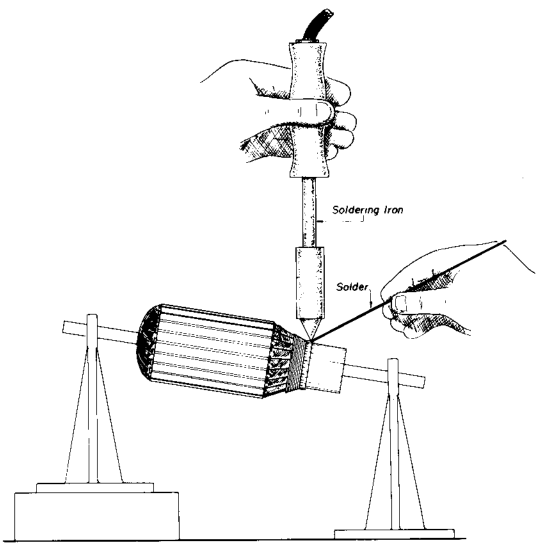


FIG. 6-50.—Holding the iron vertically prevents the solder from spanning two bars.

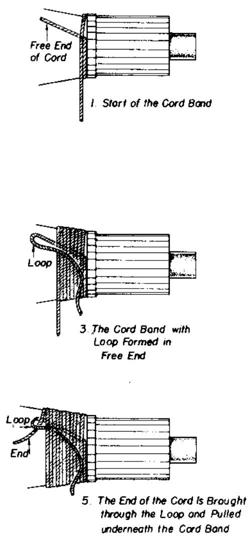


FIG. **6-51**.—A method of winding a cord band on an armature.

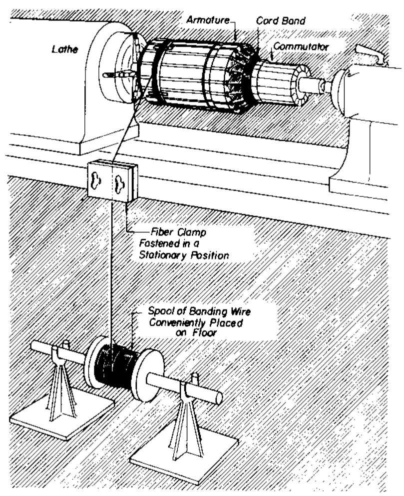
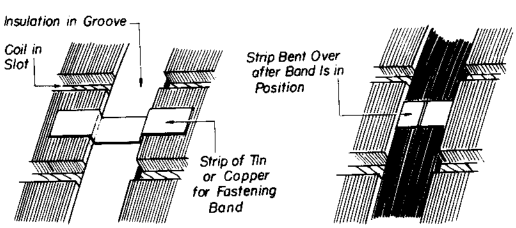


FIG. **6-52**.—A method of banding an armature with steel wire.



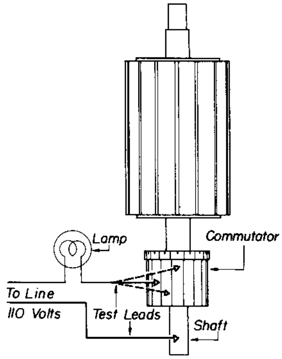


FIG. 6-53.—A test for a grounded commutator.

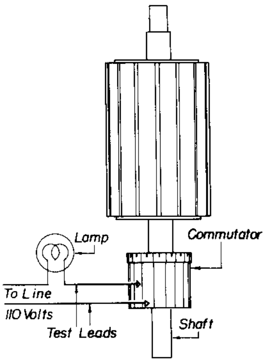


FIG. 6-54.—A test circuit for finding shorts between bars.

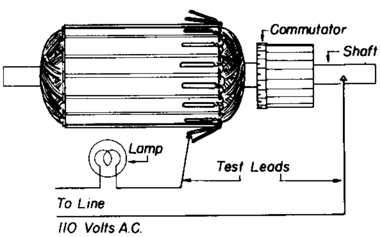


FIG. 6-55.—Testing the winding for grounds before the leads have been connected to the commutator.

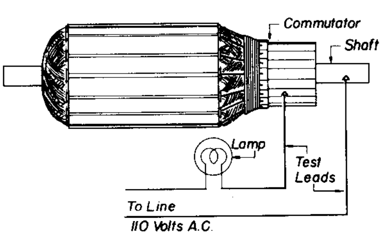


FIG. 6-56.—Testing the completed armature for grounds after the leads have been connected to the commutator.

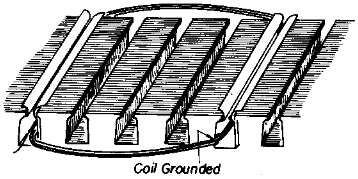


FIG. 6-57.—The coil may contact the iron core due to torn or improperly cut slot insulation.

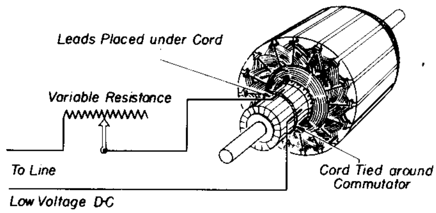


FIG. 6-58.—A variable resistance is placed in series with the line in order to obtain a normal deflection on the meter.

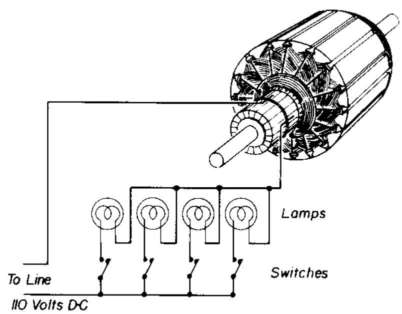


FIG. 6-59.—Lamps placed in series with 110 volts of direct current to supply current to the armature for testing. Switches *1, 2, 3,* and *4* may be connected in the circuit, depending on the size of the armature tested and the amount of current necessary.

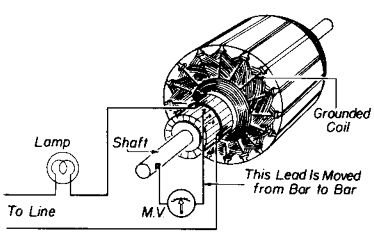


FIG. 6-60.—Testing an armature for grounds. One meter lead is moved from bar to bar until the lowest reading is indicated on the meter. The grounded coil is connected to this bar.

Figures 6-57; 6-58; 6-59; 6-60

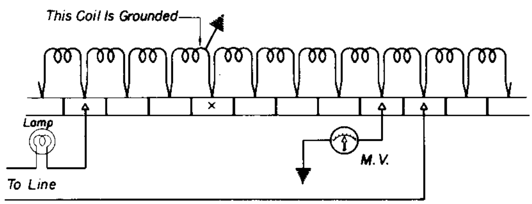


FIG. 6-61.—A schematic diagram of the test circuit shown in Figure 6-60.

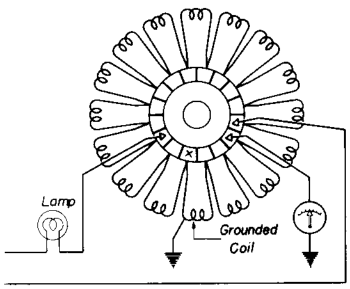


FIG. 6-62.—A complete circuit of ground test.

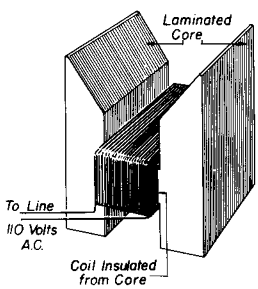
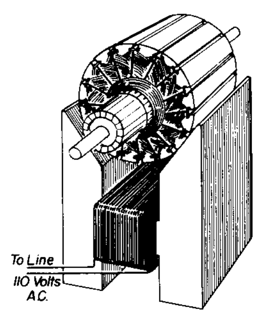


FIG. 6-63.—A growler consisting of a laminated core on which a coil of wire is wound.

FIG. 6-64.—An armature in position on a growler for test purposes.



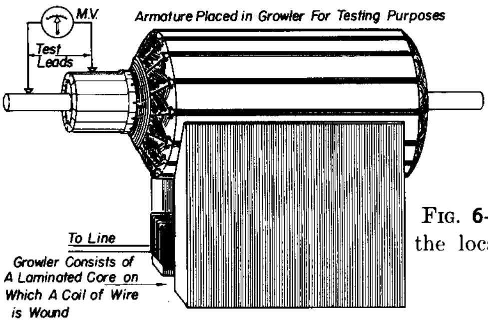


FIG. 6-65.—The growler test to determine the location of a grounded coil.

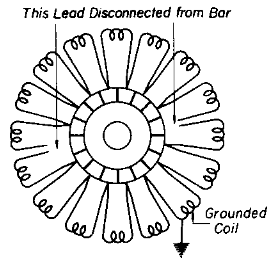


FIG. 6-66.—Locating a grounded coil by the trial method. The leads are disconnected on opposite sides of the commutator, and in this case, the bottom half of the armature will test grounded.

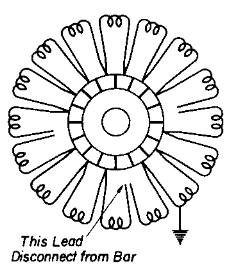


FIG. 6-67.—Disconnect a lead in the center of the grounded group and test in which quarter grounded coil is located.

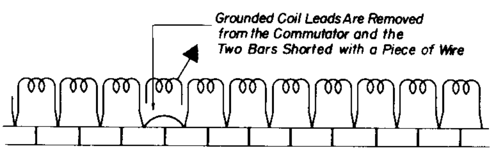
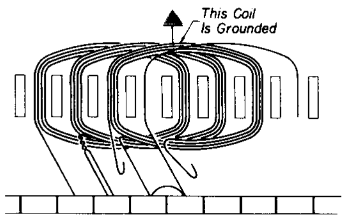


FIG. 6-68.—Schematic diagram showing how a grounded coil is disconnected from the commutator.

FIG. 6-69.—Disconnecting a grounded coil from a loop winding.



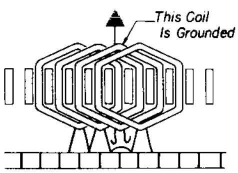


FIG. 6-70.—Disconnecting a grounded coil from a lap winding.

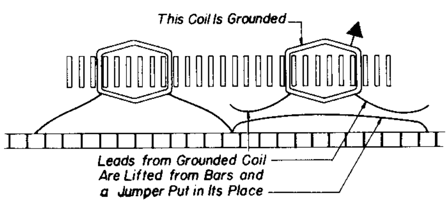


FIG. 6-71.—Disconnecting a grounded coil from a wave winding.

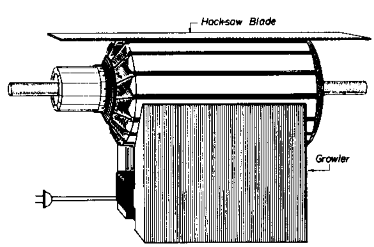


FIG. 6-72.—Testing an armature for shorts by placing a hack-saw blade over the top slot.

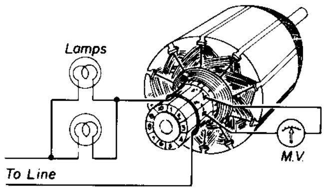


FIG. 6-73.—Testing an armature for shorted coils by using the bar-to-bar test. A shorted coil will be indicated by a low or zero reading on the meter.

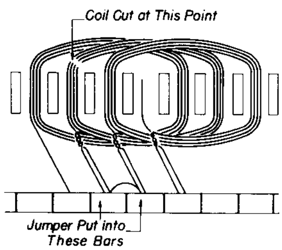


FIG. 6-74.—Cutting the shorted coil and connecting a jumper between the two bars connected to the coil.

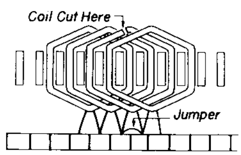


FIG. 6-75.—Cutting out a shorted coil on a form-wound armature.

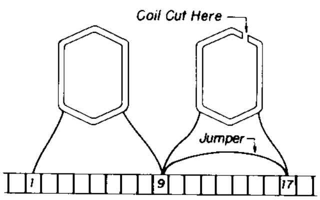


FIG. 6-76.—Cutting out a shorted coil on a four-pole wave winding.

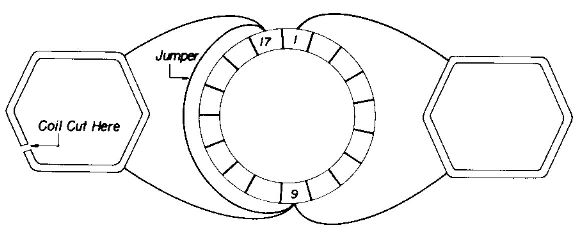


FIG. 6-77.—Cutting out a shorted coil on a wave winding.

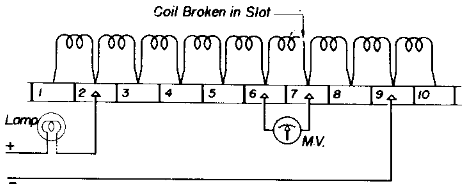


FIG. 6-78.—A method of locating an open coil. The meter will not show a reading until it bridges bars *6* and *7*. The meter completes the circuit from positive to negative.

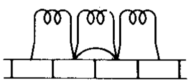
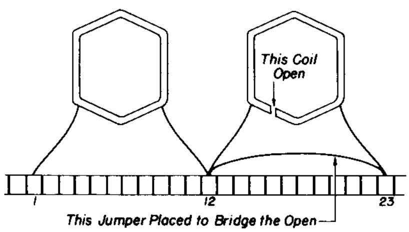


FIG. 6-79.—A method of jumping out an open coil on a lap winding.

FIG. 6-80.—A method of repairing a wave-wound armature having an open coil.



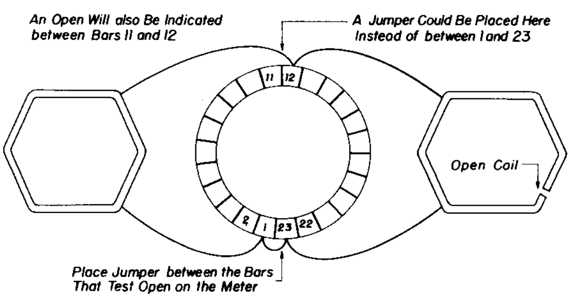


FIG. 6-81.—A quick method of closing an open on a four-pole wave winding.

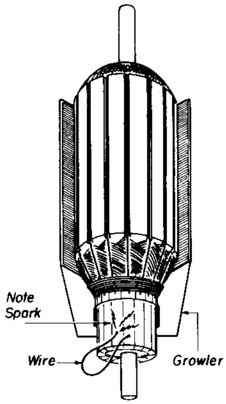


FIG. **6**-82.—If two bars are shorted with a piece of wire, a small spark indicates a complete circuit through the coil.

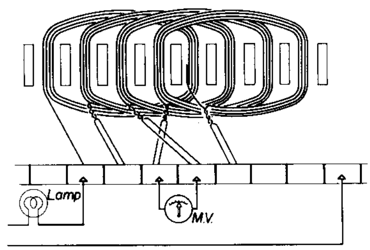


FIG. **6**-83.—Loops placed in wrong bars.

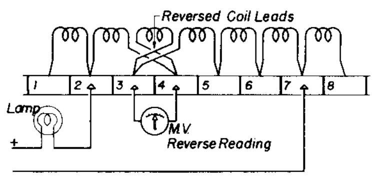


FIG. **6**-84.—A test of a loop winding for reversed coils. Between bars *3* and *4* the meter will indicate reversed reading; between bars *2* and *3* a double reading; between bars *4* and *5* a double reading. All others will be normal.

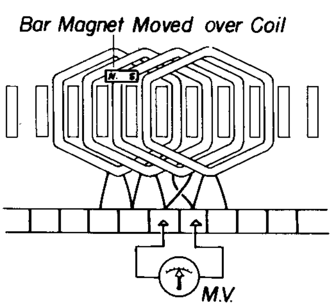


FIG. **6**-85.—A method of testing for reversed coils by running a bar magnet over each coil and noting the meter needle. When the reversed coil is reached, the needle will reverse.

Figures **6**-82; **6**-83; **6**-84; **6**-85

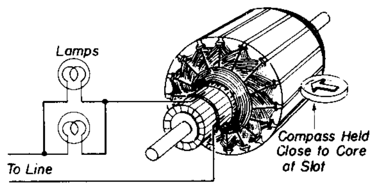
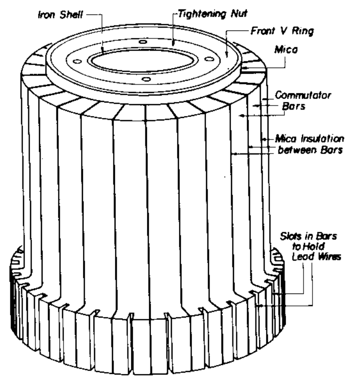


FIG. 6-86.—Test for a reversed coil by using a compass. The armature is turned slowly until the reversed coil is alongside the compass. The needle will reverse at this point.

FIG. 6-87.—A typical commutator.



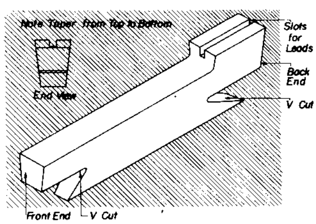


FIG. 6-88.—A commutator bar before it is mounted.

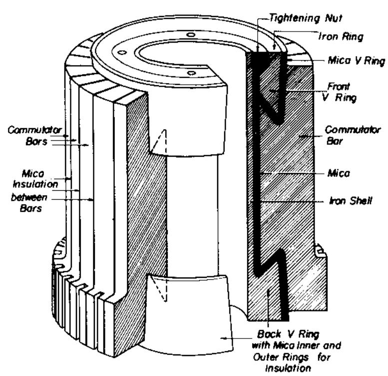


FIG. 6-89.—A commutator with a portion removed to show section and assembly.

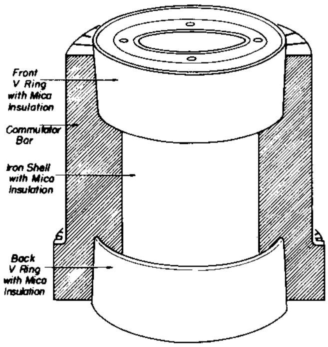


FIG. **6-90**.—A commutator with half the bars removed and the front and back V ring in place.

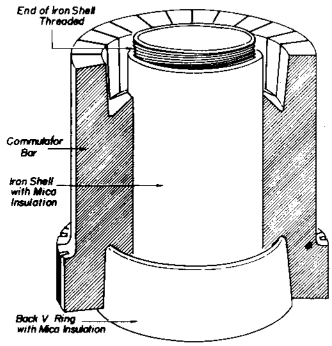


FIG. **6-91**.—A commutator with the front V ring and half the bars removed.

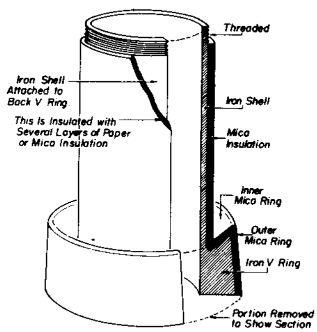


FIG. **6-92**.—A back V ring with shell attached to iron core.

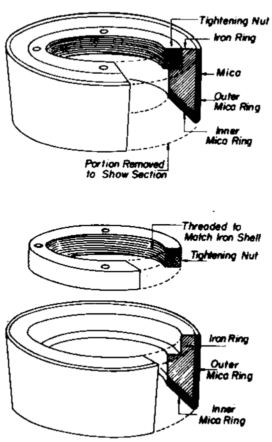


FIG. **6-93**.—A front V ring and tightening nut.

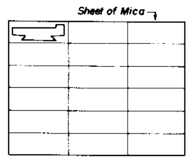


FIG. 6-94.—The mica sheet marked off into small strips of mica.

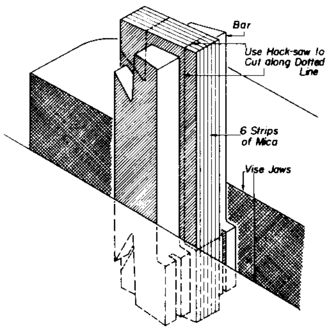


FIG. 6-95.—Rectangular strips of mica stacked between two commutator bars and placed in a vise before being cut.

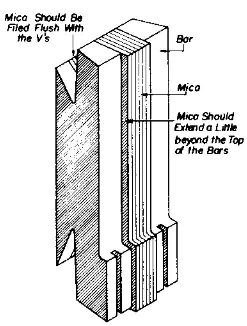


FIG. 6-96.—The appearance of mica segments after they have been cut and filed to the same shape as the commutator bars.

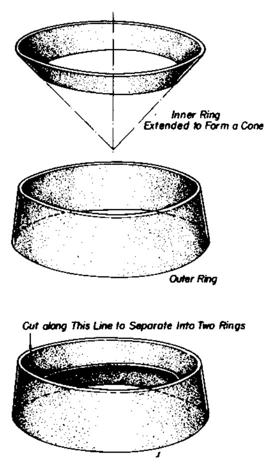


FIG. 6-97.—A mica V ring consists of an inner and outer ring.

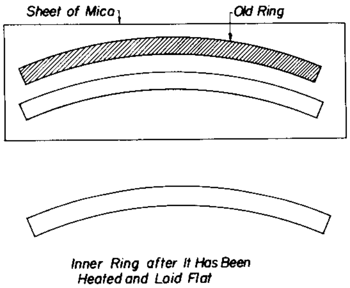


FIG. 6-98.—Using the old V ring as a template to mark off the outline of the new ring.

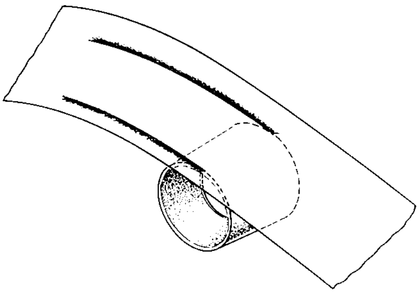


FIG. 6-99.—A method of making a template by placing a piece of paper over the mica ring and pressing at the edges so that it will leave a mark on the paper.

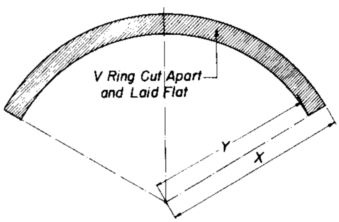


FIG. 6-100.—The appearance of a section of a cone cut through and laid flat.

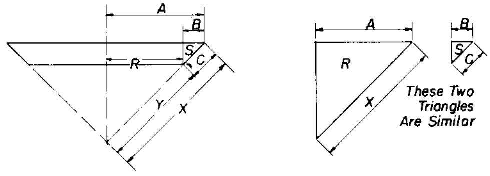
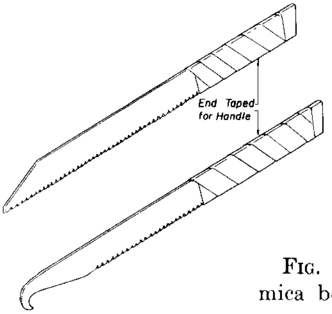


FIG. 6-101.—Distances *A, B,* and *C* obtained from actual measurement on the iron V ring. These are necessary in order to get the radius x.



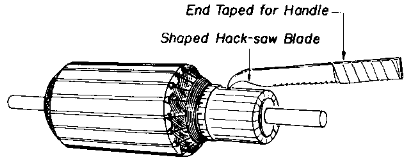


FIG. **6-102.**—Special tools for removing the defective mica between bars.

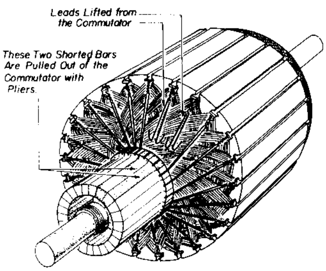


FIG. **6-103.**—A step in removing shorted bars.

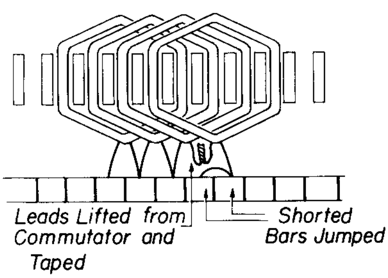
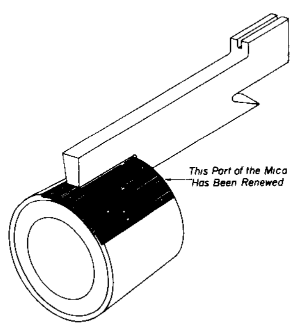


FIG. **6-104.**—A quick repair that can be made if two bars are shorted.

FIG. **6-105.**—A patch placed on the outer V ring.



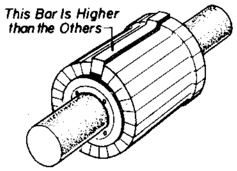


FIG. 6-106.—A high bar in a commutator.

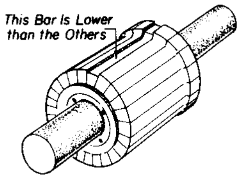


FIG. 6-107.—A low bar in a commutator.

FIG. 6-108.—(Left) A commutator correctly undercut. (Right) An improperly undercut commutator.

CHAPTER 7

Direct-current Motors

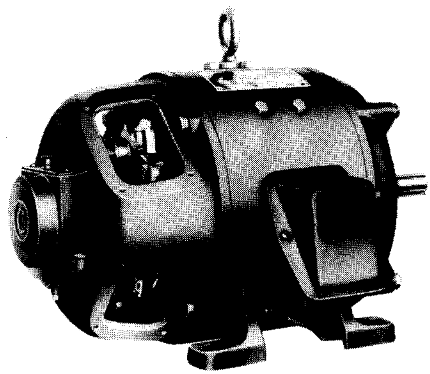


FIG. 7-1.—A d-c motor. *(Century Electric Co.)*

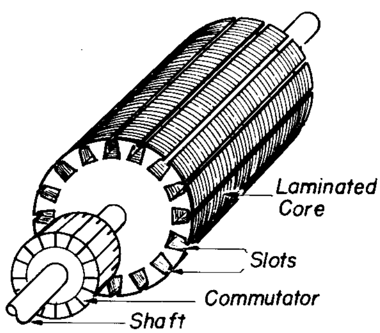


FIG. 7-2.—The armature of a d-c motor before windings are inserted in slots.

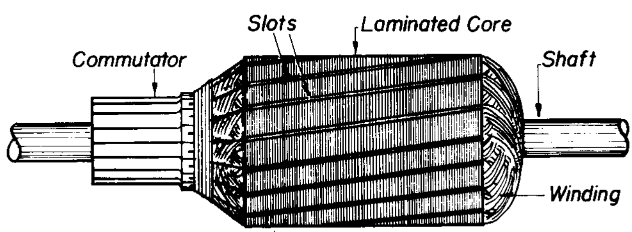


FIG. 7-3.—The armature with skewed slots and windings in place.

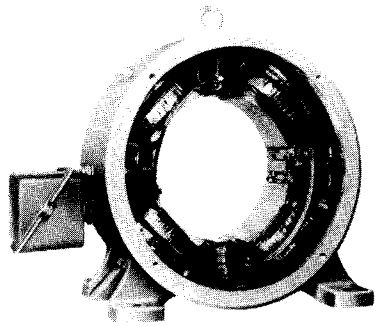


FIG. 7-4.—A complete field assembly and frame of a d-c motor. (*Century Electric Co.*)

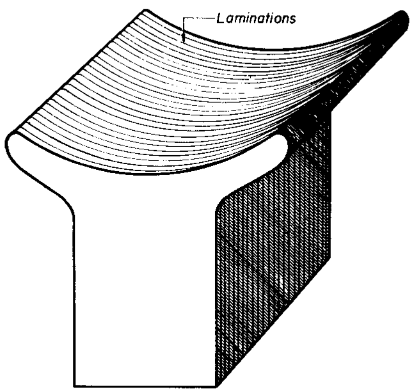


FIG. 7-5.—A laminated field core.

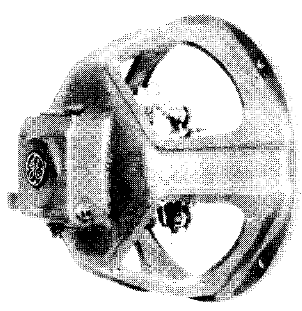


FIG. 7-6.—An end plate of a d-c motor. The brush rigging is visible through the openings. (*General Electric Co.*)

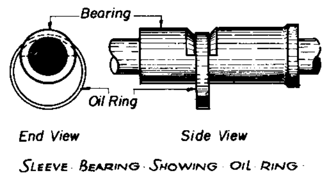


FIG. 7-7.—Construction of sleeve bearing and oil ring.

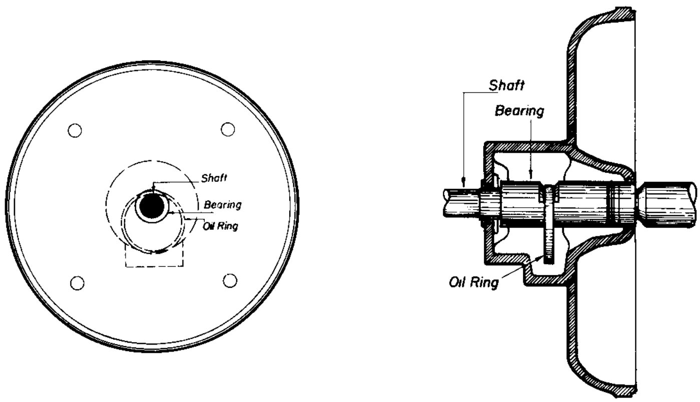


FIG. 7-8.—A sleeve bearing assembled on an end plate.

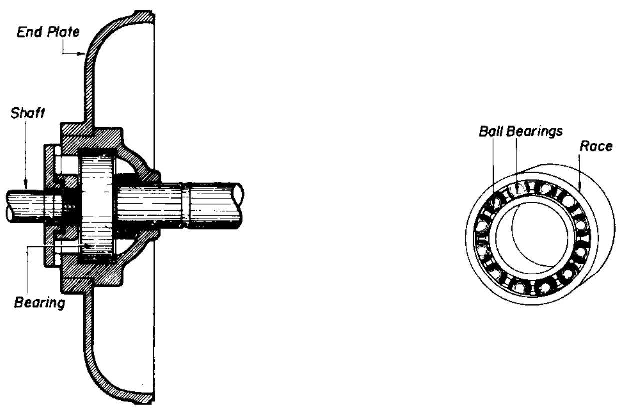


FIG. 7-9.—The ball bearing at right mounted in the end plates as shown.

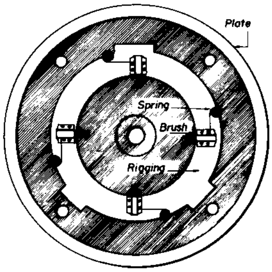
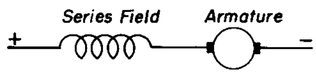


FIG. 7-10.—The brush rigging attached to the end plate.

FIG. 7-11.—The field and armature connection of a series motor.



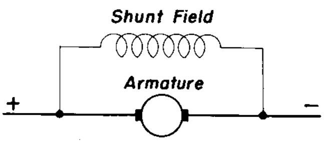
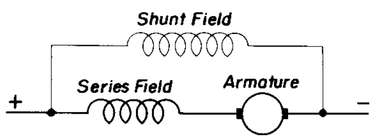


FIG. 7-12.—The field and armature connection of a shunt motor.

FIG. 7-13.—The field and armature connection of a compound motor.



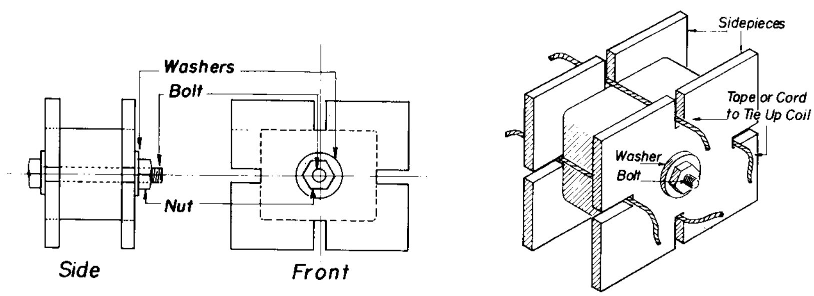


FIG. 7-14.—The construction of a form on which to wind d-c field coils.

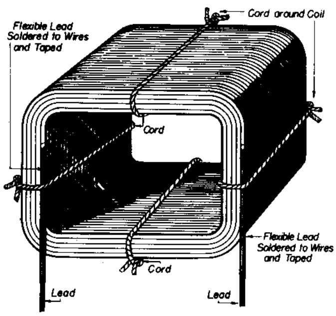


FIG. 7-15.—A field coil after removal from form. The cord holds the turns in place.

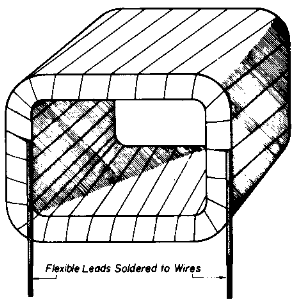


FIG. 7-16.—A series-field coil is taped after flexible leads are soldered to the beginning and end of the coil. The coil is usually taped with a layer of varnished cambric and a layer of cotton tape.

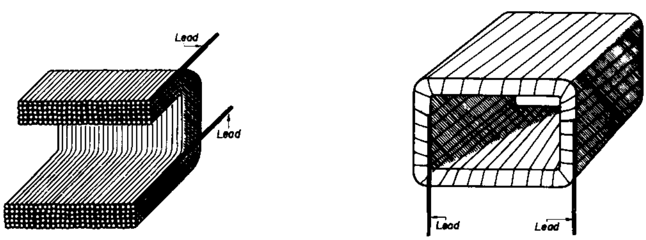


FIG. 7-17.—A cutaway view of a shunt-field winding and the same winding after taping.

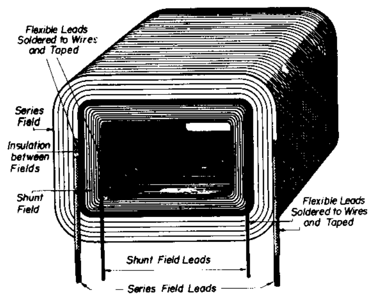


FIG. 7-18.—The arrangement of windings in a compound field coil.

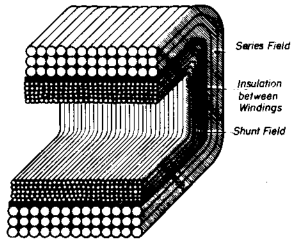


FIG. 7-19.—A cutaway view of a compound-field coil.

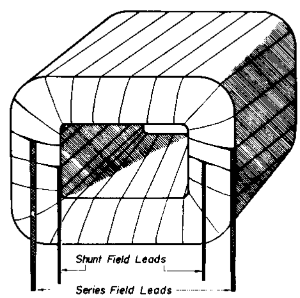


FIG. 7-20.—A compound-field coil and its leads after taping.

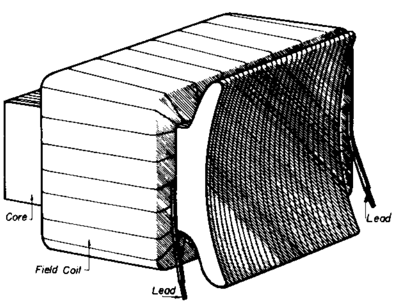


FIG. 7-21.—A field coil assembled on its core.

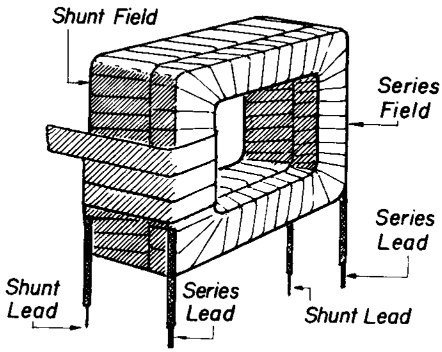


FIG. 7-22.—A compound field for a large motor. The shunt and series fields are wound and taped separately, then placed side by side and taped again.

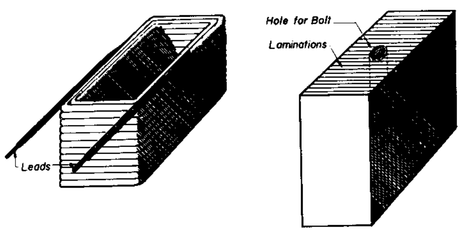
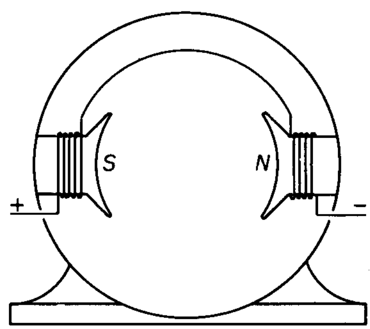


FIG. 7-23.—An interpole field and its core.

FIG. 7-24.—In a two-pole motor, the fields are connected to form a north and south pole.



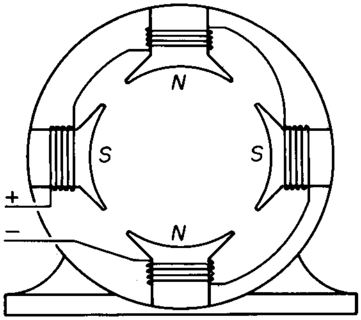


FIG. 7-25.—North and south poles alternate in a four-pole motor.

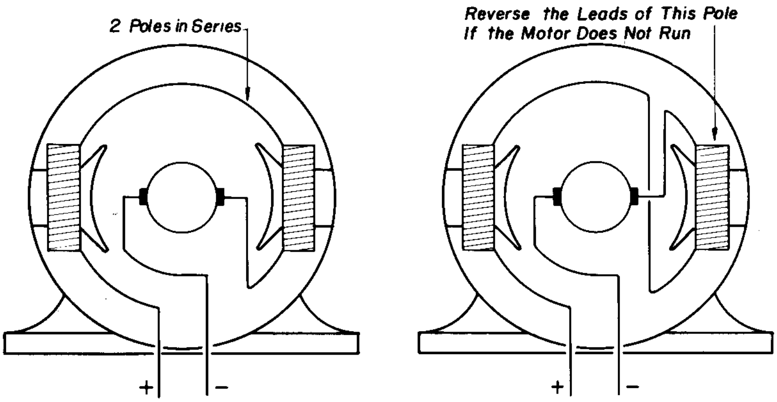


FIG. 7-26.—A test for correct field polarity on a small two-pole motor.

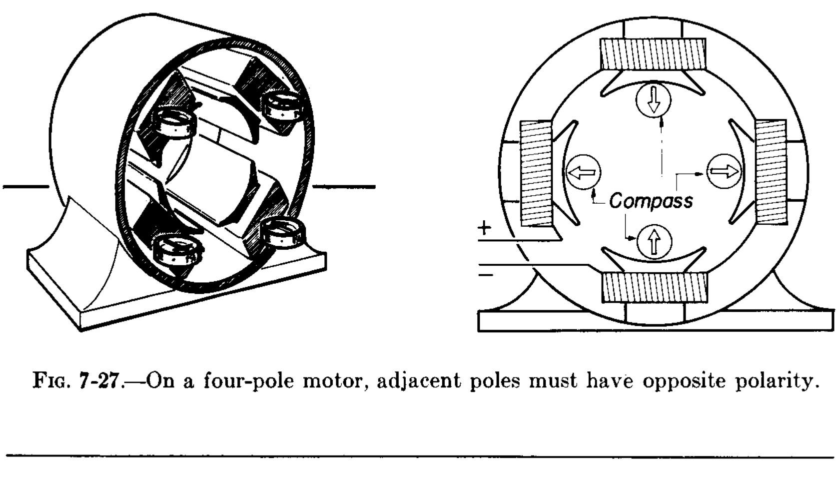


FIG. 7-27.—On a four-pole motor, adjacent poles must have opposite polarity.

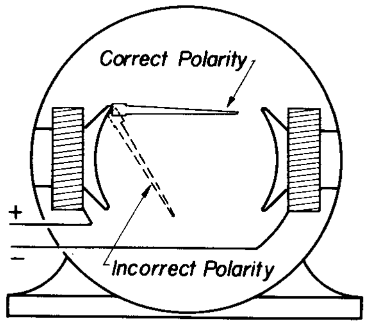


FIG. 7-28.—Testing polarity of the field coils with a nail.

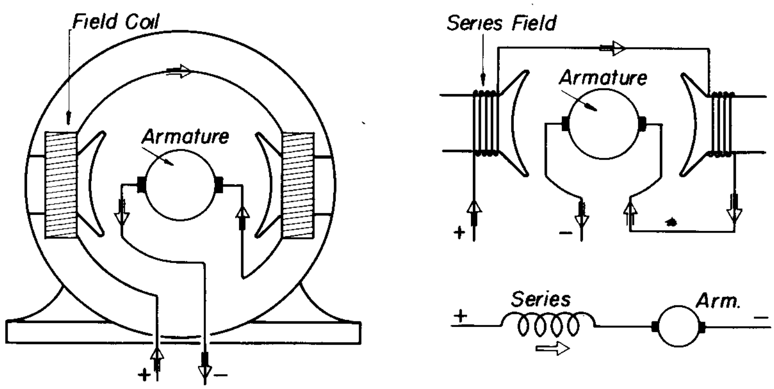


FIG. 7-29.—Several methods of showing the connections of a two-pole series motor.

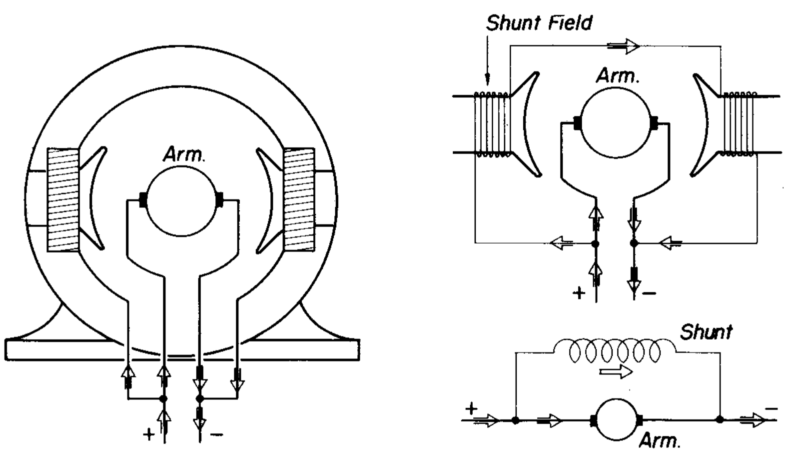


FIG. 7-30.—Three methods of showing the connections of a two-pole shunt motor.

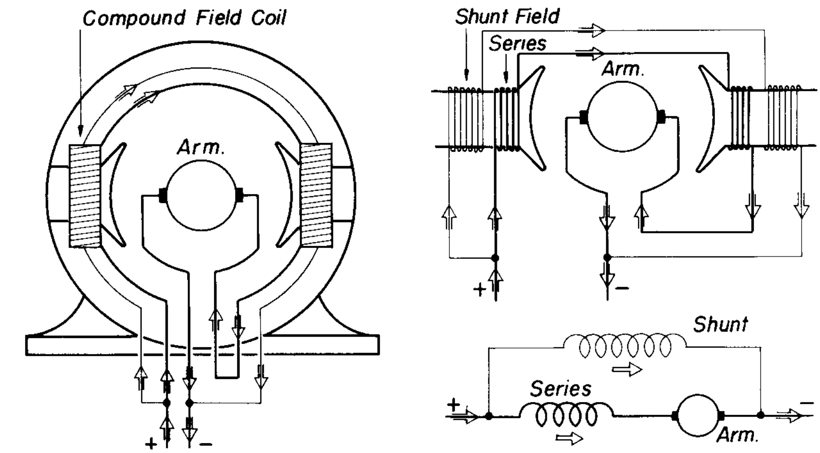


FIG. 7-31.—Three methods of showing the connections of a two-pole compound motor.

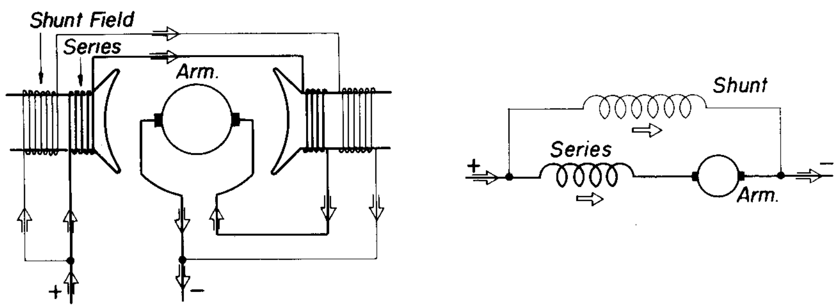


FIG. 7-32.—A two-pole cumulatively compounded motor. If the current flow is in the same direction in both fields, it is called a *cumulative connection.*

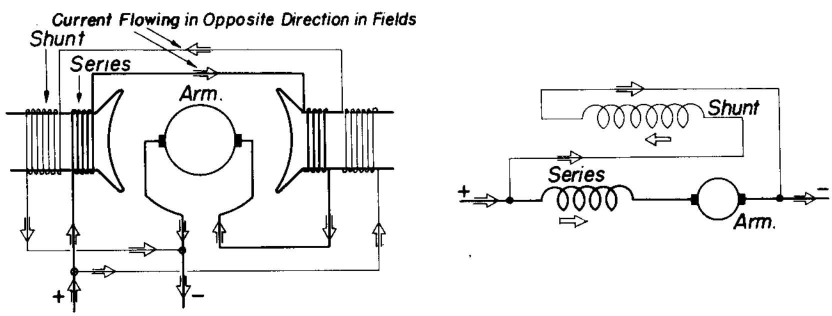
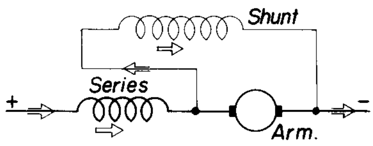


FIG. 7-33.—A long-shunt, differentially connected compound motor with the current flow in opposite directions in the fields. When the shunt field is connected across the line, it is called a *long shunt.*



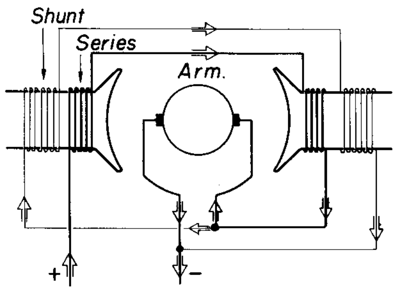
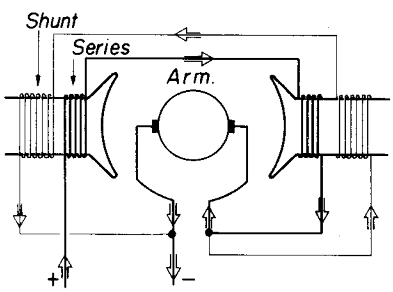


FIG. 7-34.—A short-shunt cumulatively compound motor. The current in both the series and shunt fields flows in the same direction.



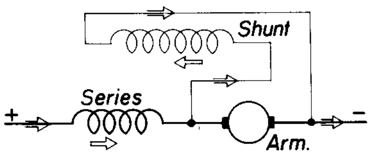


FIG. 7-35.—A two-pole, short-shunt differentially compounded motor.

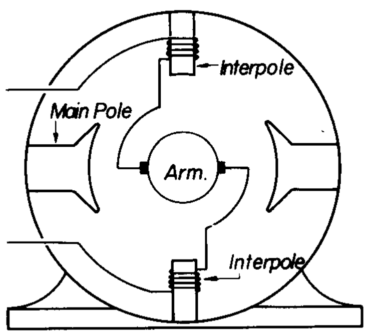


FIG. 7-36.—Method of connecting the interpole in a two-pole motor.

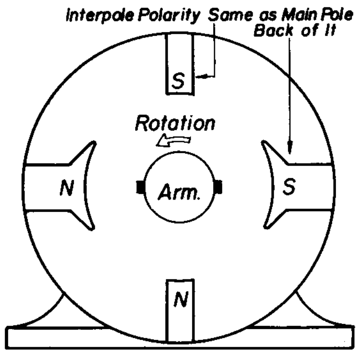


FIG. 7-37.—The polarity of the interpole for counterclockwise (c.c.w.) rotation of a two-pole motor.

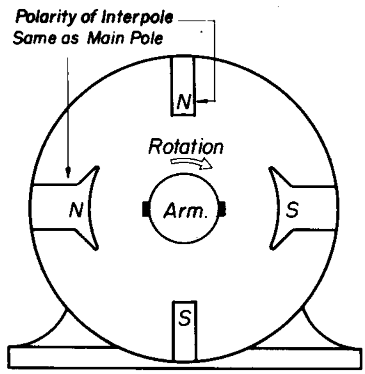


FIG. 7-38.—The proper interpole polarity for clockwise (c.w.) rotation of a two-pole motor.

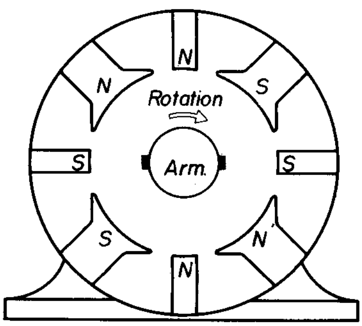


FIG. 7-39.—The polarity of the interpole for clockwise (c.w.) rotation of a four-pole motor.

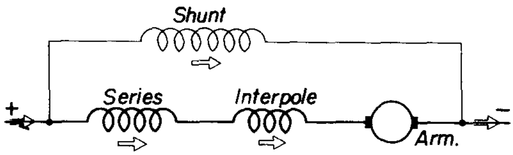


Fig. 7-40.—A schematic diagram of a compound-interpole motor.

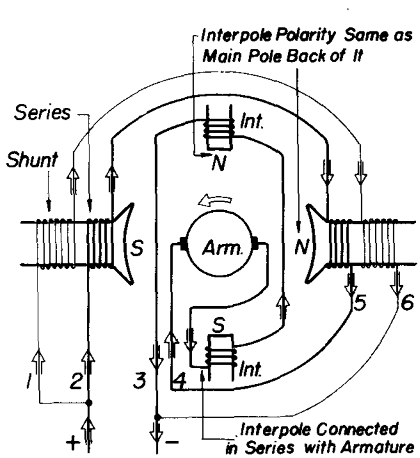


Fig. 7-41.—A two-pole compound-interpole motor. With the polarity indicated, the motor will run counterclockwise.

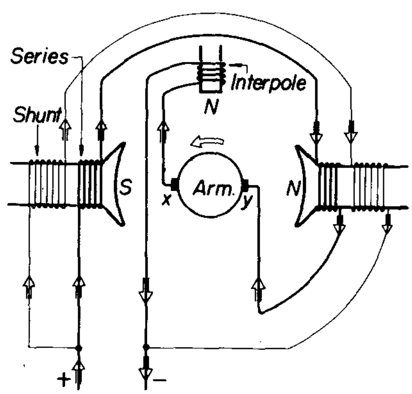


Fig. 7-42.—A two-pole compound-interpole motor using one interpole connected in series with the armature.

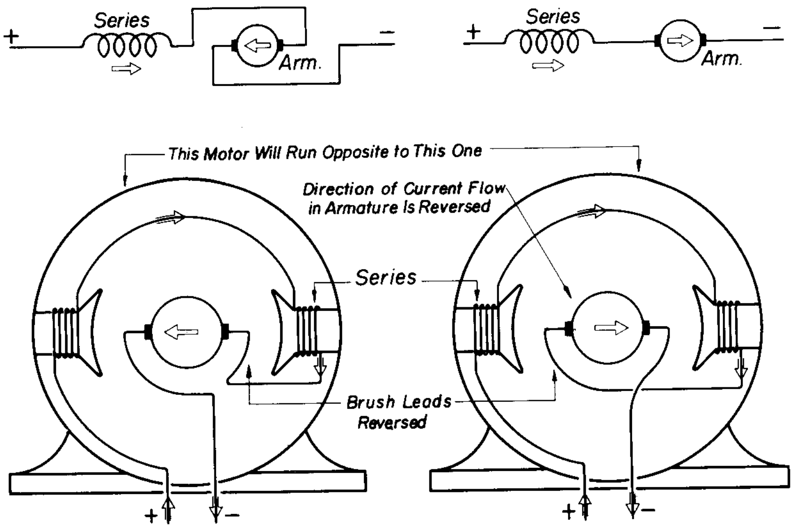


FIG. 7-43.—The direction of rotation of a two-pole series motor changed by reversing the current flow in the armature.

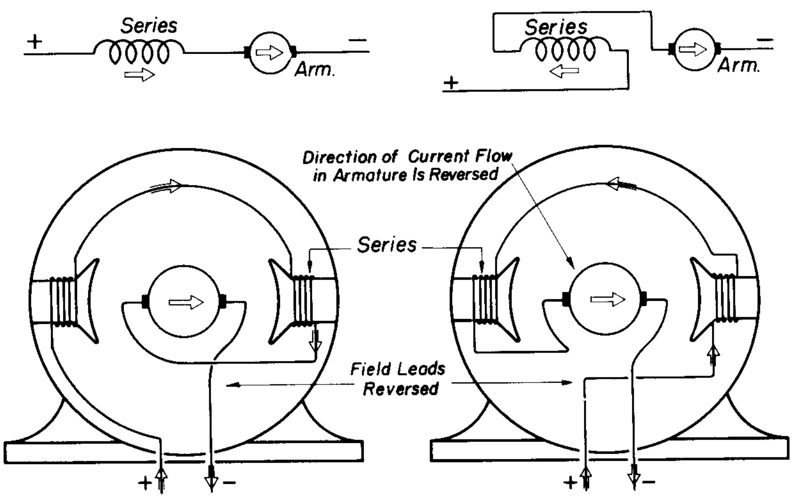


FIG. 7-44.—The direction of rotation of a two-pole series motor changed by reversing the current flow in the field poles.

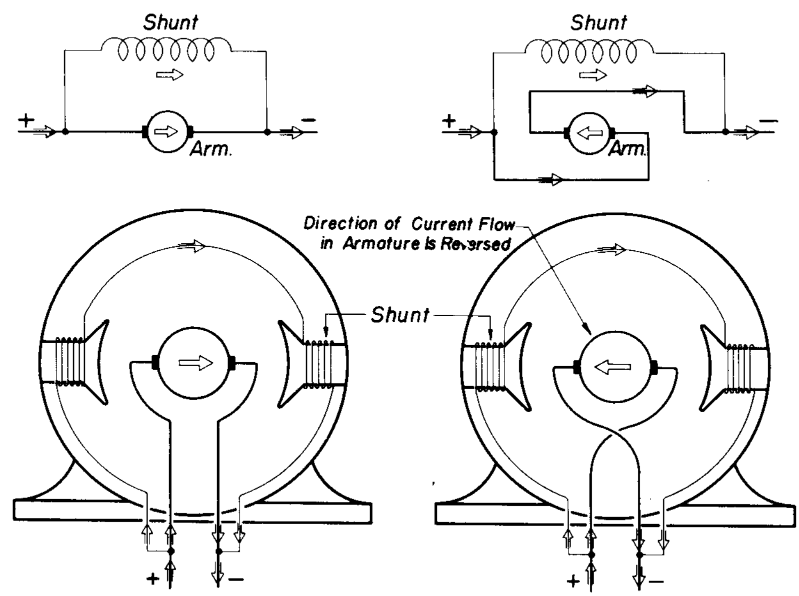


FIG. 7-45.—A two-pole shunt motor reversed in the armature circuit.

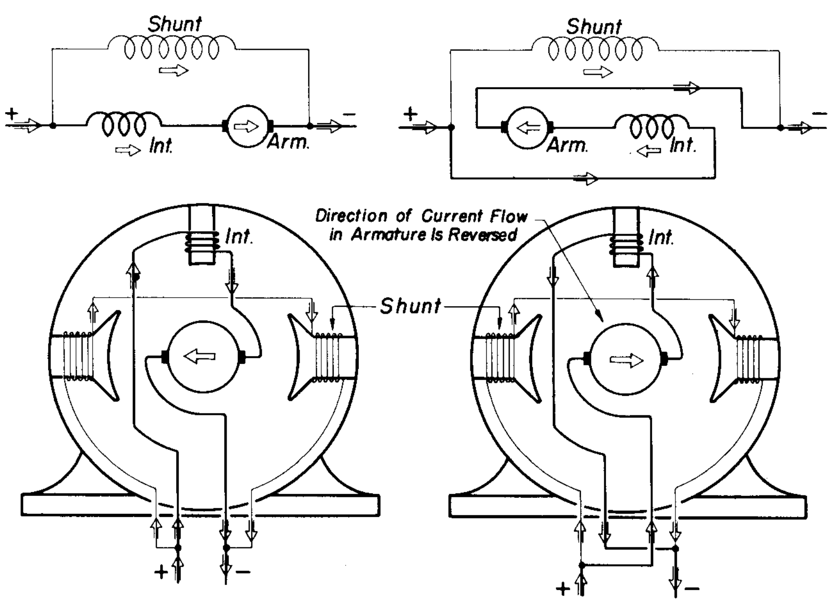


FIG. 7-46.—A two-pole shunt-interpole motor. The armature and interpole leads are reversed as a unit. The field polarity remains the same.

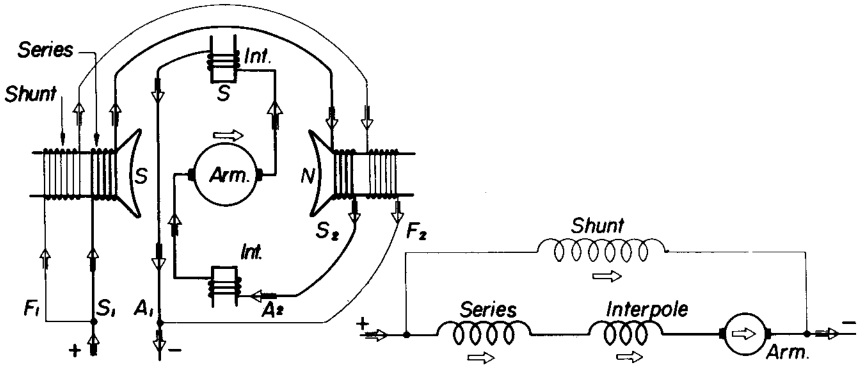


FIG. 7-47.—A two-pole compound-interpole motor with six wires brought out of the motor. Wires F_1 and S_1 are sometimes connected together inside the motor, and one wire is brought outside.

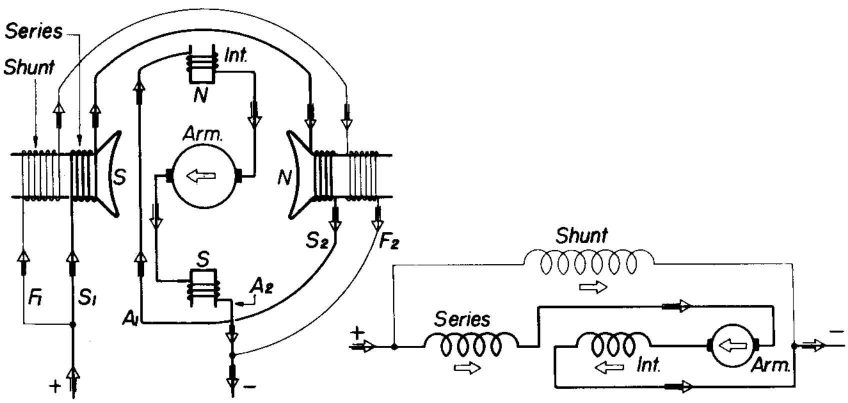


FIG. 7-48.—A two-pole compound-interpole motor with the armature circuit reversed for opposite rotation from that of Figure 7-47.

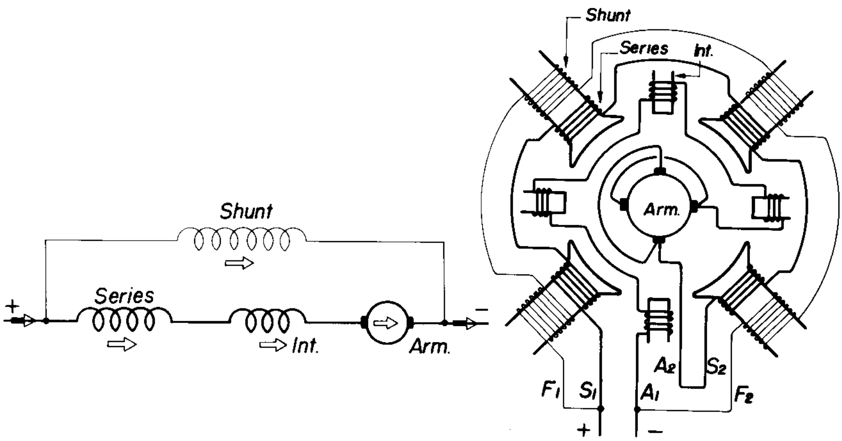


FIG. 7-49.—A four-pole compound-interpole motor. To reverse, interchange leads A_1 and A_2.

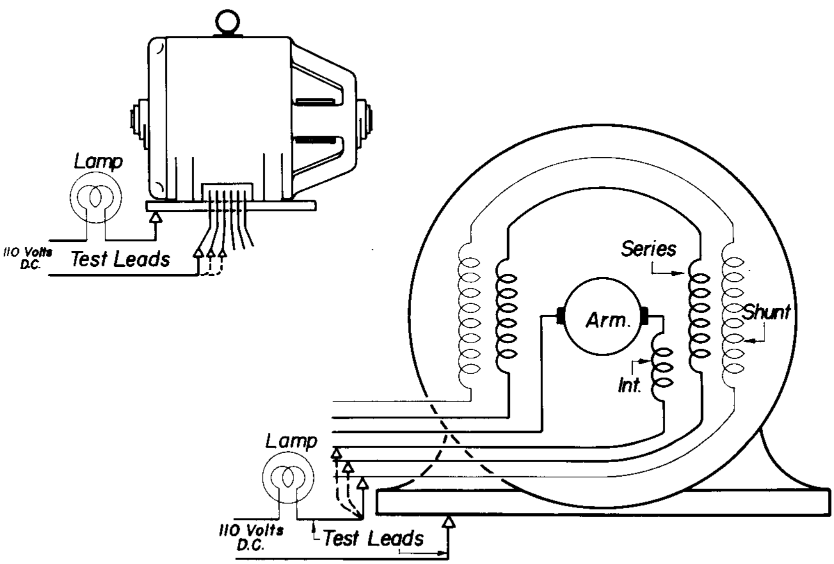


FIG. 7-50.—Testing a compound motor for grounds.

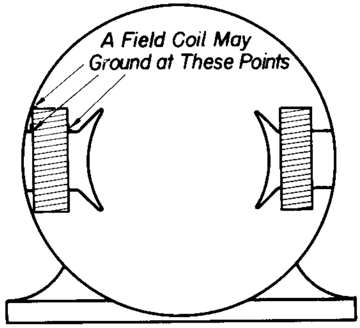


FIG. 7-51.—The positions where the field most often grounds.

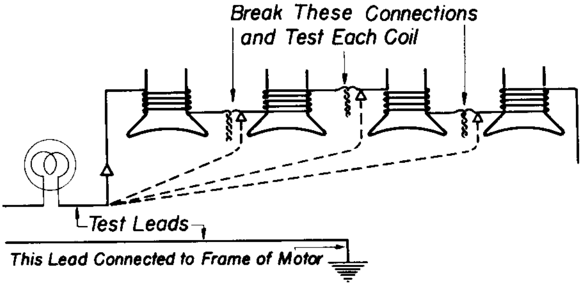


FIG. 7-52.—To locate the grounded field coil, each coil is given a ground test.

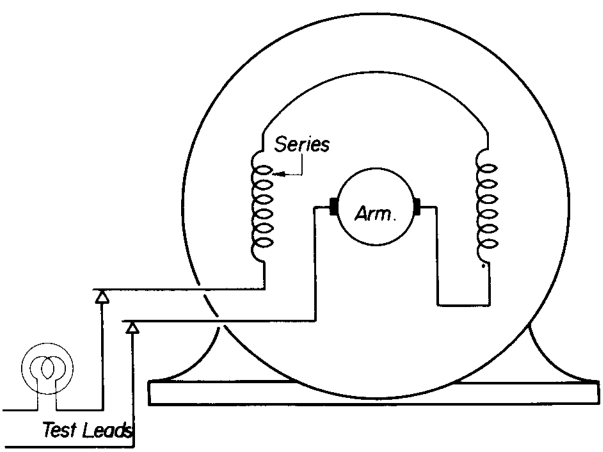


FIG. 7-53.—The test for an open in a series motor. If the lamp does not light, the trouble may be the brushes, the field, or the connections.

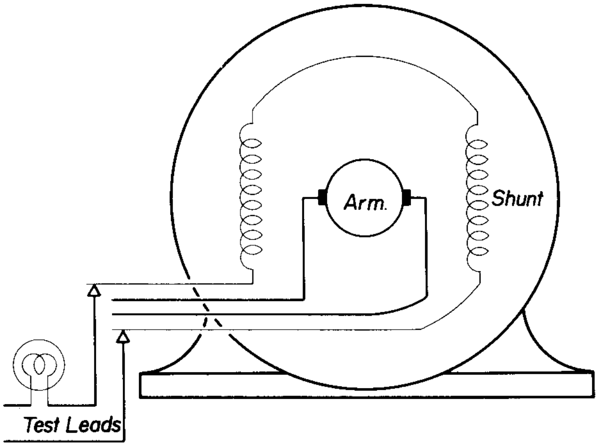


FIG. 7-54.—The test of a shunt motor for opens.

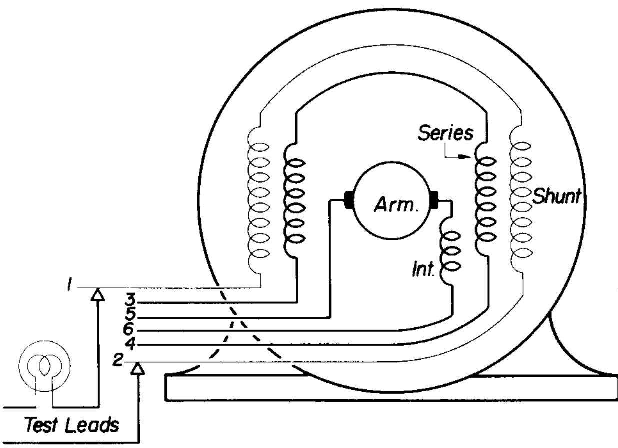


FIG. 7-55.—The test of a compound motor for opens. There are three complete circuits: 1 and 2, 3 and 4, 5 and 6.

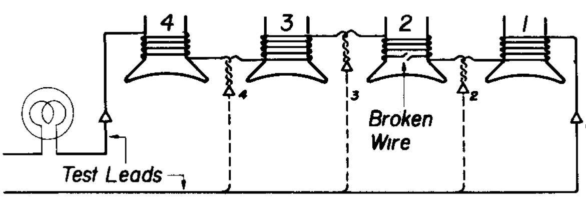


FIG. 7-56.—The test for locating an open field coil in a four-pole motor.

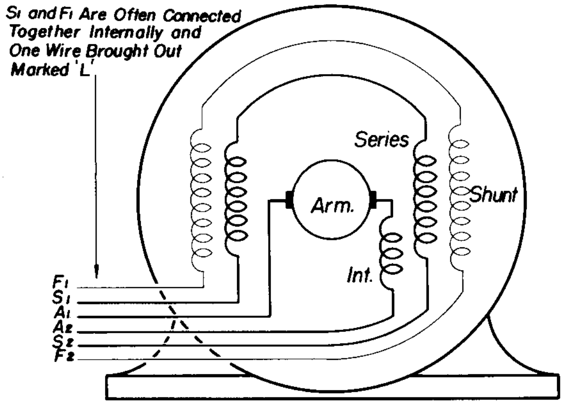


FIG. 7-57.—Typical markings on the leads of a compound motor.

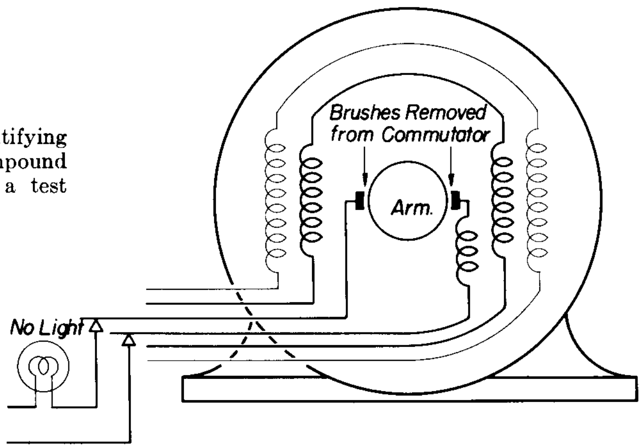


FIG. 7-58.—Identifying the leads of a compound motor by use of a test lamp.

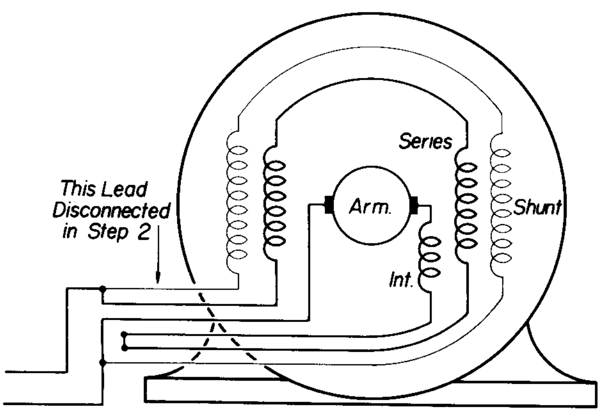
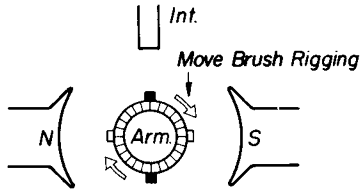


FIG. 7-59.—The test to determine whether a motor is cumulatively connected.

FIG. 7-60.—The test for interpole polarity in a two-pole motor. All connections are removed except the armature and interpole. The brushes are shifted 90 degrees, and if the armature turns in the same direction in which the brushes were moved, the polarity is correct.



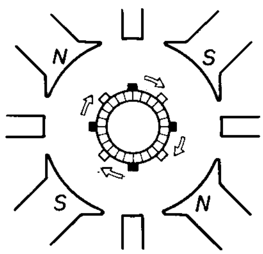


FIG. 7-61.—The test for correct interpole polarity in a four-pole motor.

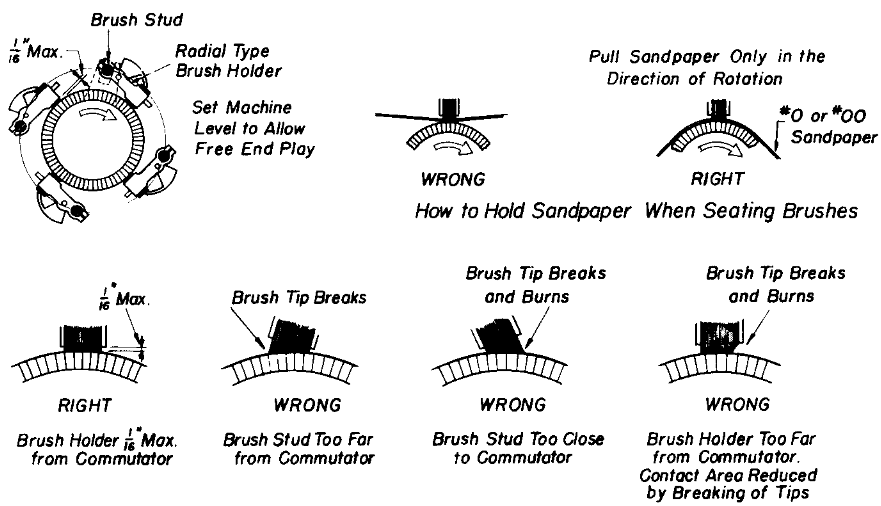


FIG. 7-62.—The correct and incorrect positions of a carbon brush.

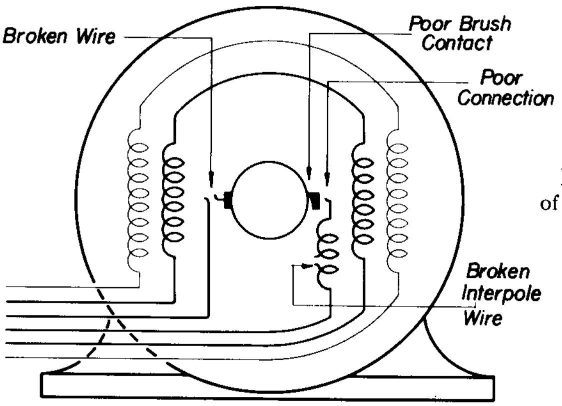
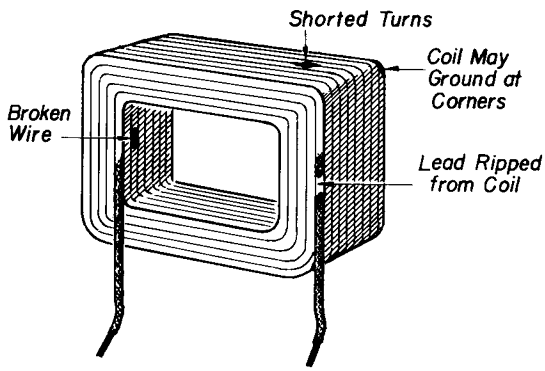


FIG. 7-63.—Possible causes of an open armature circuit.



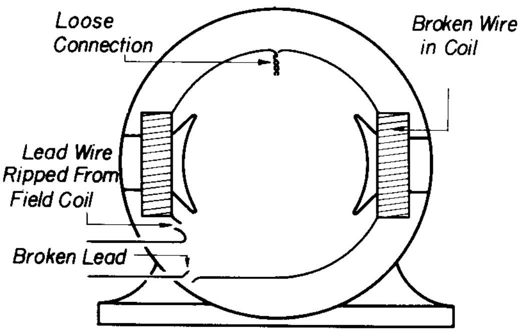


FIG. 7-64.—Possible locations of opens in the field circuit and coil.

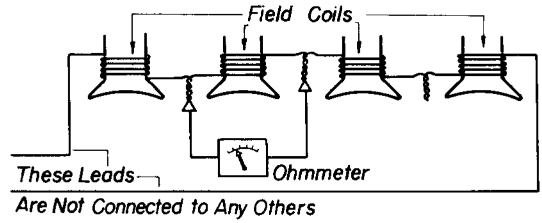


FIG. 7-65.—The ohmmeter method of detecting a shorted coil.

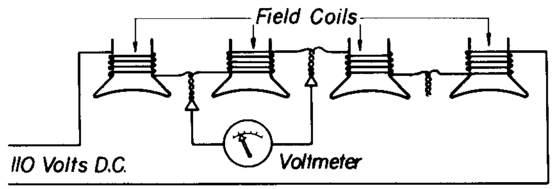


FIG. 7-66.—The voltmeter method of locating a shorted coil.

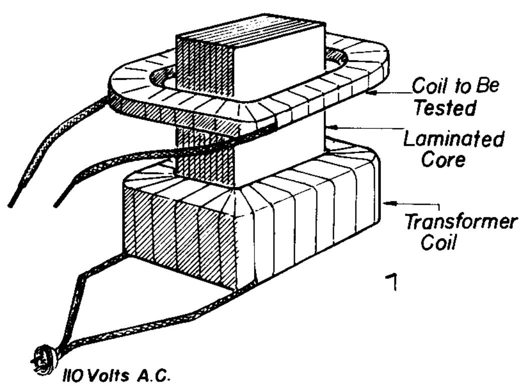


FIG. 7-67.—A transformer used for testing shorted coils.

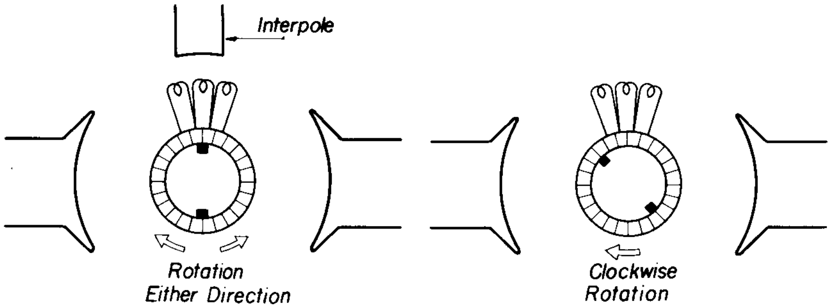


FIG. 7-68.—The correct brush positions for interpole and noninterpole motors.

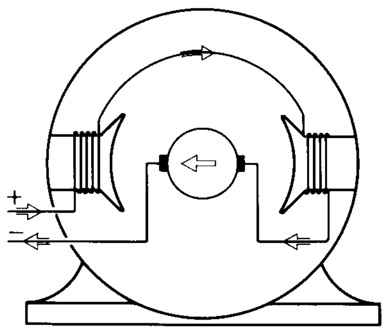


FIG. 7-69.—The same amount of current flows through all elements of a series motor.

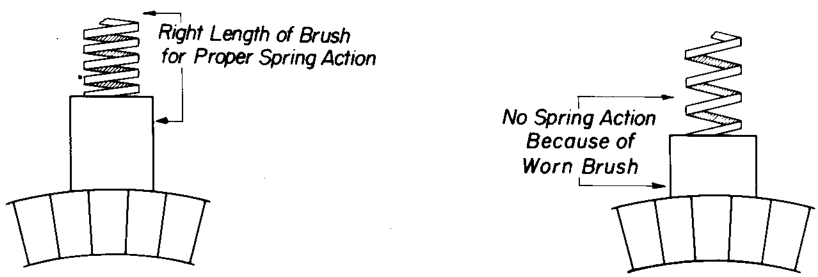


FIG. 7-70.—Two diagrams showing the tension in the springs with brushes of different length.

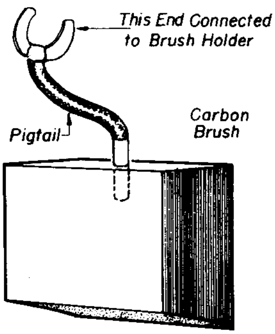


FIG. 7-71.—A common type of pigtail brush.

CHAPTER 8

Direct-current Motor Control

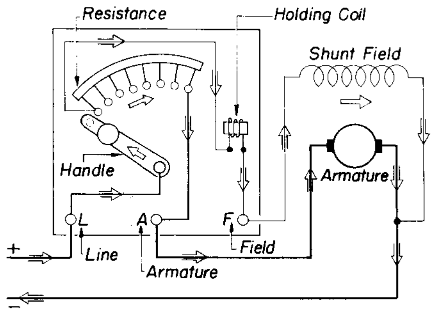


FIG. 8-1.—A three-point starting box connected to a shunt motor.

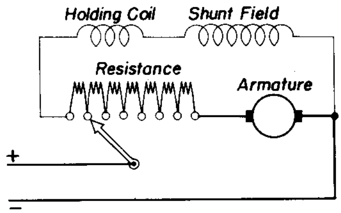


FIG. 8-2.—A simplified diagram of Figure 8-1.

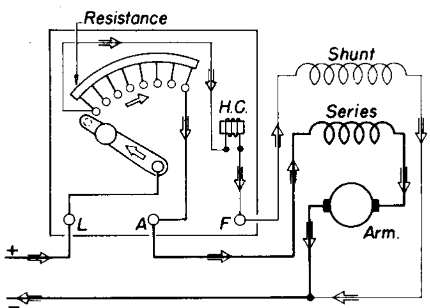


FIG. 8-3.—A three-point starting box connected to a compound motor.

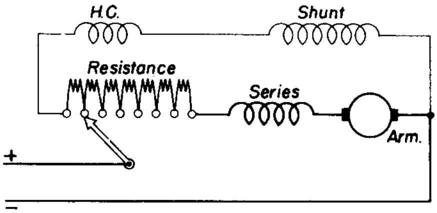


FIG. 8-4.—A simplified diagram of Figure 8-3.

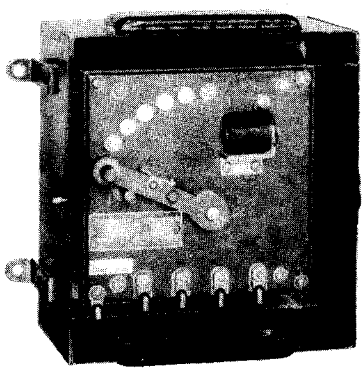


FIG. 8-5.—A four-point starting box. (*General Electric Company.*)

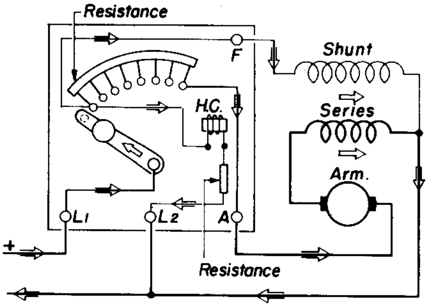


FIG. 8-6.—A four-point starting box connected to a compound motor.

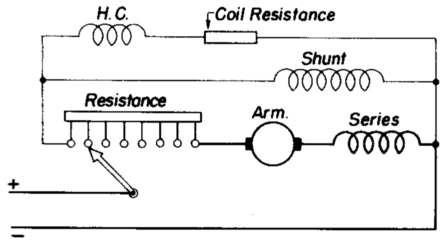


FIG. 8-7.—A schematic diagram of the current paths for a four-point box connected to a compound motor.

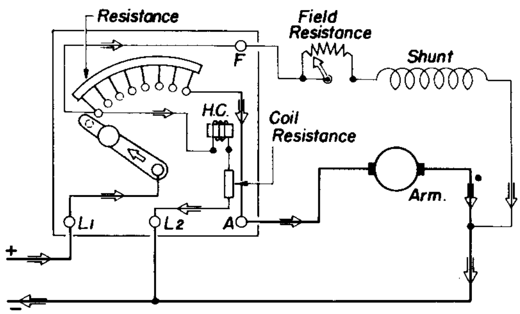


FIG. 8-8.—A four-point box with a variable field resistance added for speed control.

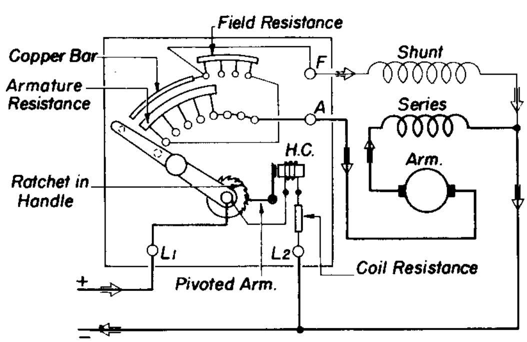


FIG. 8-9.—A four-point speed-regulating rheostat connected to a compound motor.

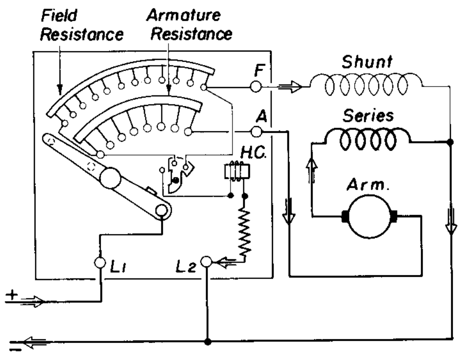
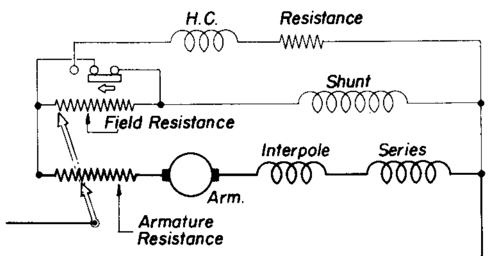


FIG. 8-10.—A four-point starting box and speed-regulating rheostat connected to a compound motor.

FIG. 8-11.—A simplified diagram of Figure 8-10.



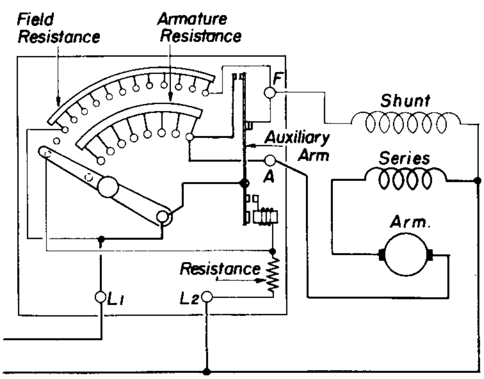
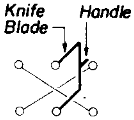


FIG. 8-12.—A combination starter and speed regulator.

FIG. 8-13.—A double-pole, double-throw knife switch.



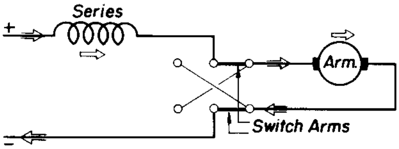


FIG. 8-14.—A double-pole, double-throw switch connected to reverse the armature current of a series motor. Note the direction of current in the armature with the switch thrown to the right.

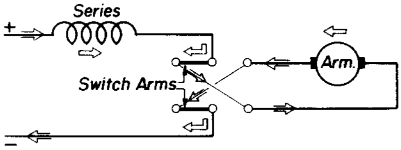
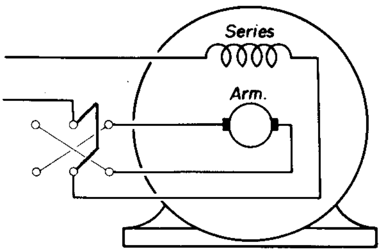


FIG. 8-15.—A circuit of Figure 8-14 with the switch thrown in the opposite direction.

FIG. 8-16.—A series motor connected to a double-pole, double-throw switch for reversing.



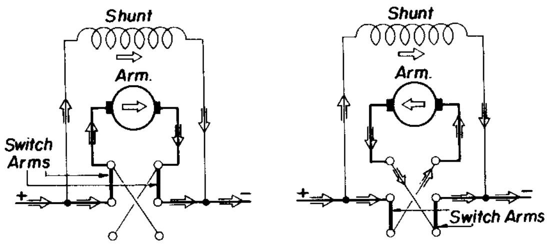


FIG. **8-17.**—At (*A*) with the switch thrown up, the armature current of a shunt motor is flowing to the right. At (*B*) with the switch thrown down, the armature current is flowing to the left.

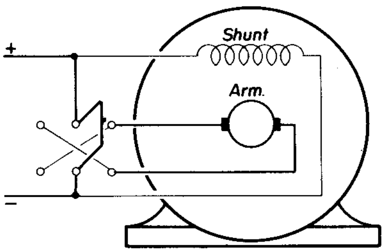


FIG. **8-18.**—A shunt motor connected to a double-pole, double-throw switch.

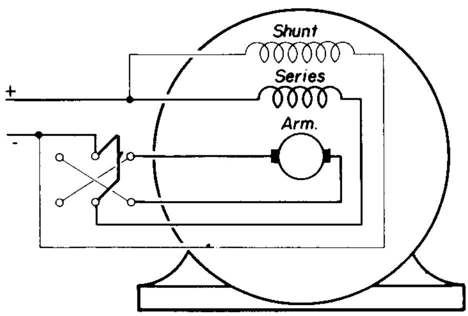


FIG. **8-19.**—A compound motor connected to a reversing switch.

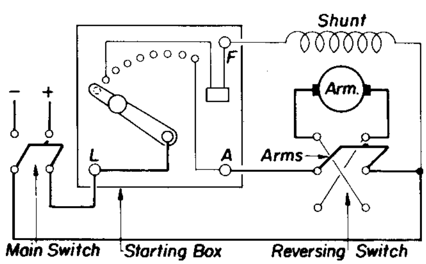


FIG. **8-20.**—A shunt motor connected to three-point box and reversing switch.

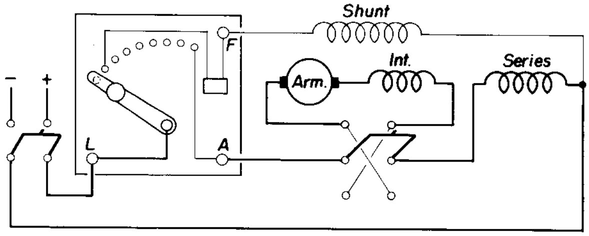


FIG. 8-21.—A compound motor connected to three-point box and reversing switch. Note that the armature and interpole are reversed as a unit.

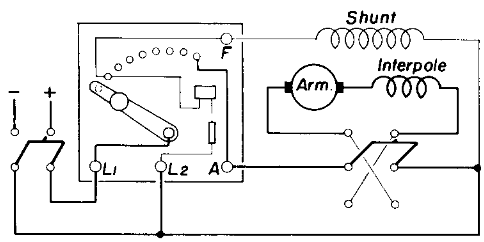


FIG. 8-22.—A shunt motor connected to a four-point box and reversing switch.

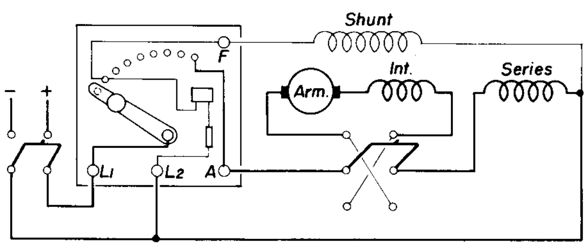


FIG. 8-23.—A compound motor connected to a four-point box and reversing switch.

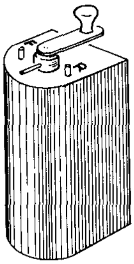


FIG. **8-24.**—General appearance of a small drum switch.

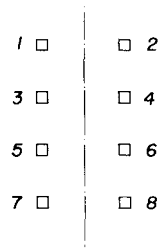


FIG. **8-25.**—Stationary contacts of a drum switch.

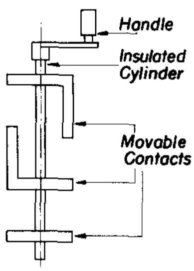


FIG. **8-26.**—Movable contacts of a drum switch.

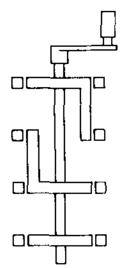


FIG. **8-27.** — The position of the contacts for forward rotation.

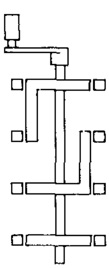


FIG. **8-28.** — The position of the contacts for reverse direction.

Figures **8**-24; **8**-25; **8**-26; **8**-27; **8**-28

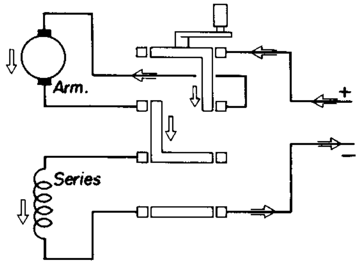


FIG. **8-29.**—A series motor connected to a drum switch for clockwise direction.

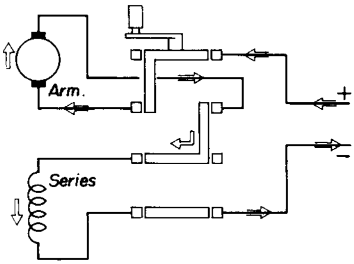


FIG. **8-30.**—A drum switch connection for counterclockwise rotation of a series motor.

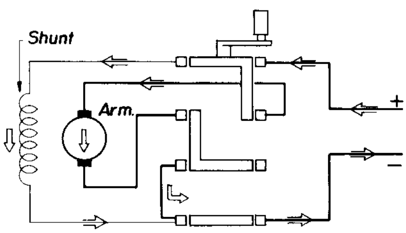


FIG. **8-31.**—A shunt motor connected to a drum switch.

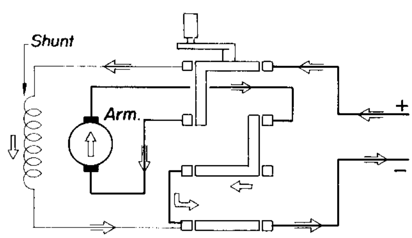


FIG. **8-32.**—A shunt motor of Figure 8-31 reversed by drum switch.

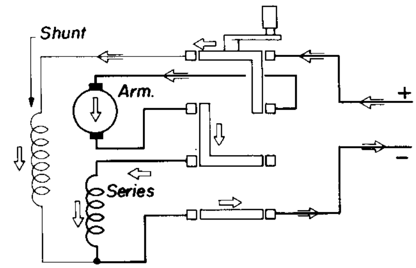


FIG. 8-33A.—A compound motor connected to a drum switch for clockwise direction.

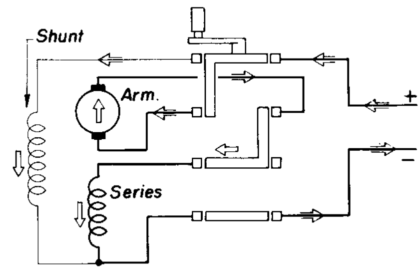


FIG. 8-33B.—A compound motor connected for counterclockwise direction.

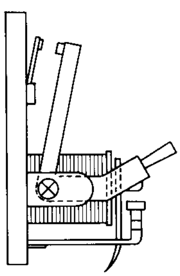


FIG. 8-34.—A magnetic circuit breaker.

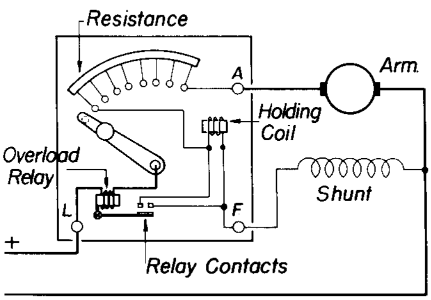
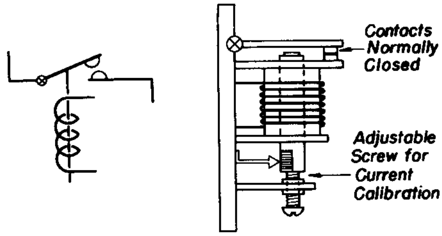


FIG. 8-35.—An overload relay connected in a three-point starting box.

FIG. **8-36**.—An overload relay with a plunger to open the contacts.



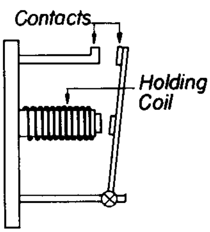


FIG. **8-37**.—A d-c magnetic contactor.

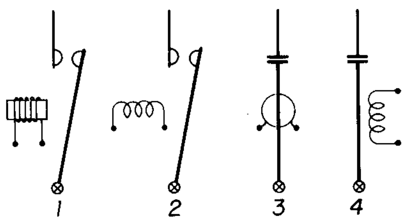


FIG. **8-38**.—Methods of denoting a magnetic contactor.

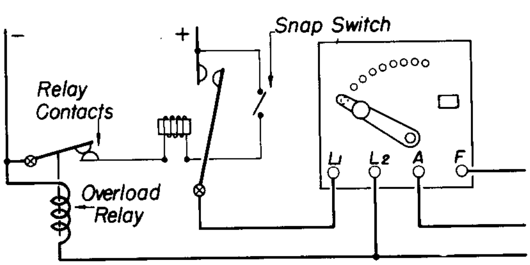


FIG. **8-39**.—A magnetic overload relay used in conjunction with a magnetic contactor.

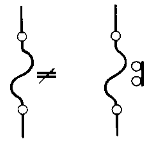


FIG. 8-40.—Methods of denoting a thermal relay. The figures to the right indicate contacts.

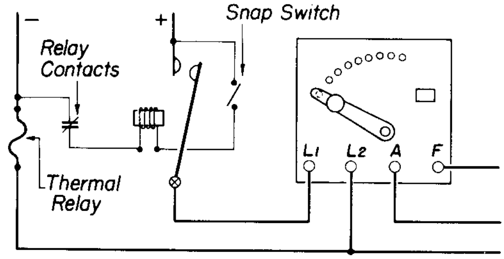


FIG. 8-41.—A thermal overload relay used with a magnetic contactor.

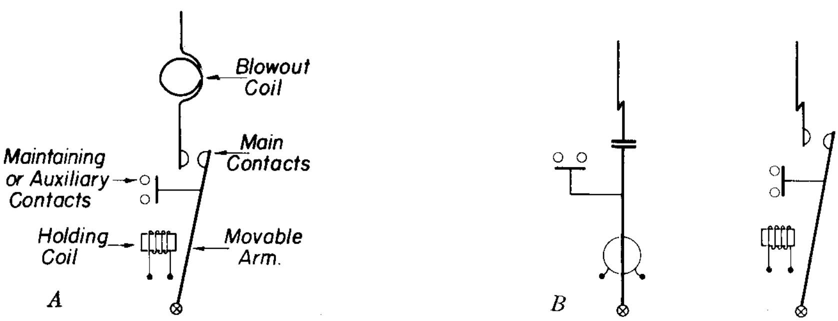


FIG. 8-42.—(*A*) The parts of a magnetic switch. (*B*) Methods of denoting a magnetic switch.

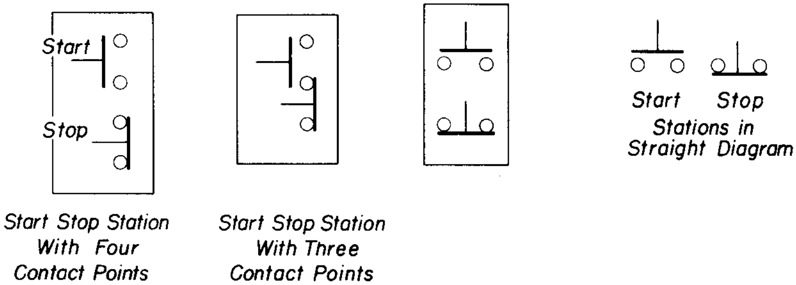


FIG. 8-43.—Methods of showing four-contact and three-contact, start-stop, pushbutton stations.

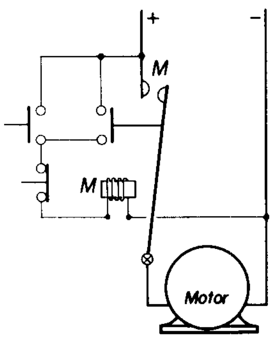


FIG. 8-44.—A start-stop station connected to a magnetic switch.

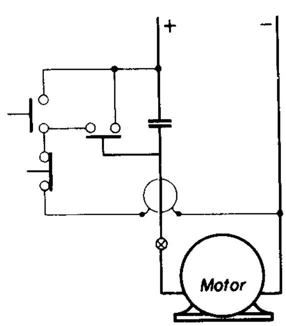


FIG. 8-45.—A start-stop station connected to a magnetic switch similar to that in Figure 8-44.

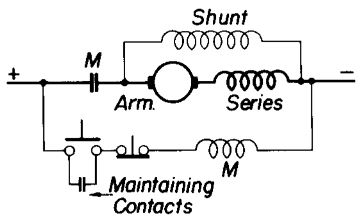


FIG. 8-46.—An elementary diagram of a start-stop station connected to a magnetic switch.

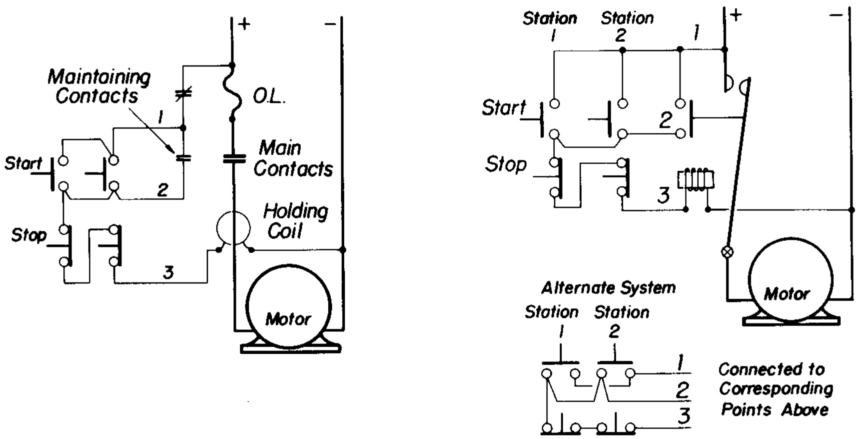


FIG. 8-47.—Two start-stop stations connected to a magnetic switch. (*A*) and (*B*) show different representations of the magnetic switch; and (*C*) shows the pushbutton station in another position.

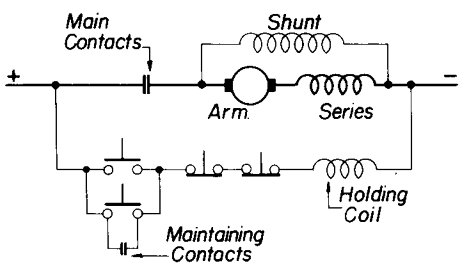


FIG. 8-48.—An elementary diagram of two start-stop stations connected to a magnetic switch.

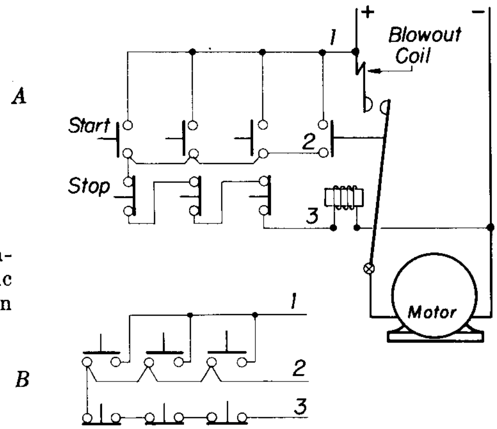


FIG. 8-49.—Three start-stop stations connected to a magnetic switch. (B) shows the station in another position.

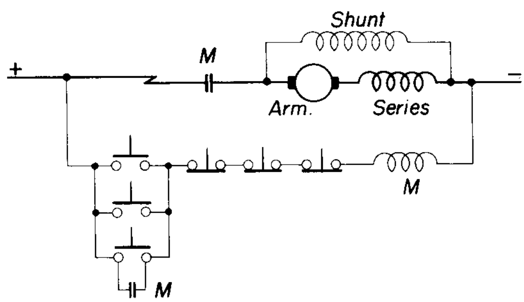


FIG. 8-50.—An elementary diagram of three start-stop stations connected to a magnetic switch.

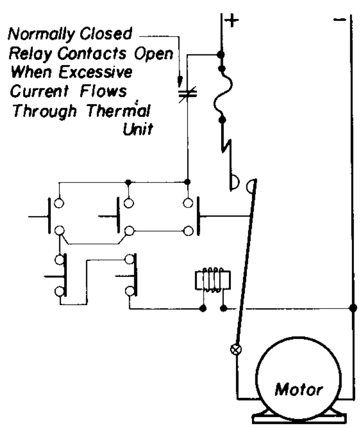


FIG. 8-51.—Two start-stop stations controlling a magnetic switch having a thermal relay.

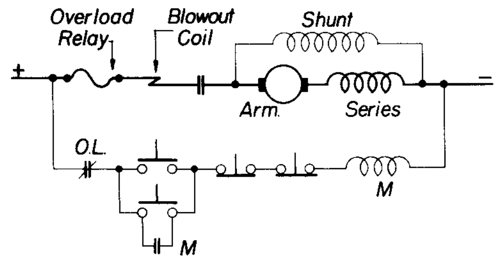


FIG. **8-52**.—An elementary diagram of the connection of Figure **8-51**.

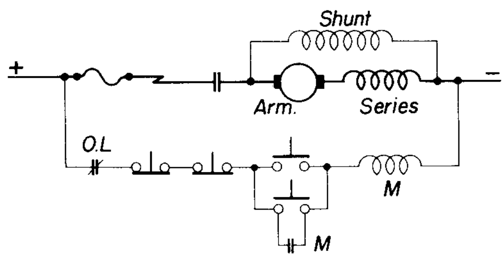


FIG. **8-53**.—The connection of Figure **8-51** with the start-stop station reversed.

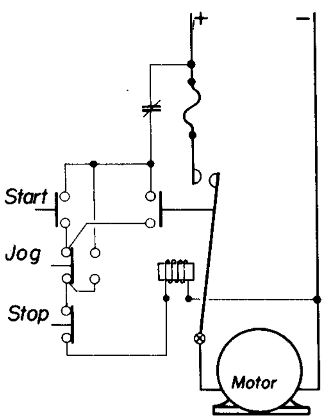


FIG. **8-54**.—A start-jog-stop station connected to a magnetic switch.

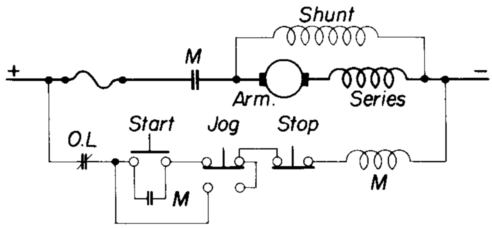


FIG. **8-55**.—A line diagram of a start-jog-stop station connected to a magnetic switch.

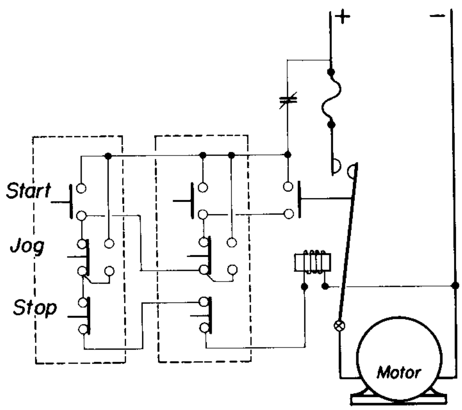


FIG. **8-56**.—Two start-jog-stop stations connected to a magnetic switch.

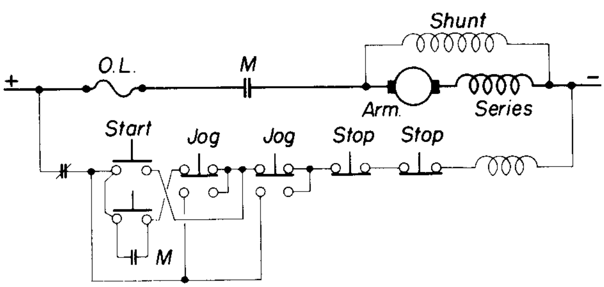


FIG. **8-57**.—A simple diagram of two start-jog-stop stations connected to a magnetic switch and operating a compound motor.

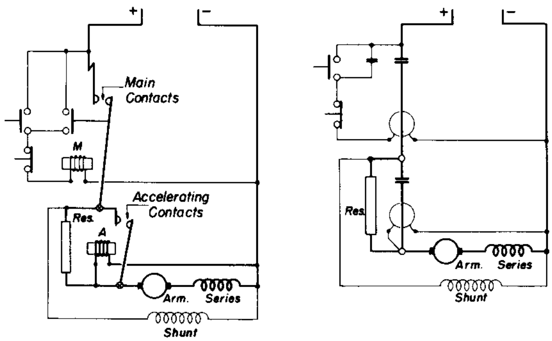


FIG. 8-58.—Diagrams of a simple counter e.m.f. starter operated by a magnetic switch.

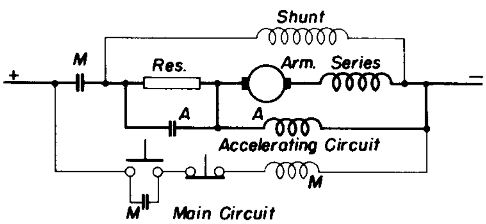


FIG. 8-59.—An elementary diagram of a counter e.m.f. starter connected to a compound motor.

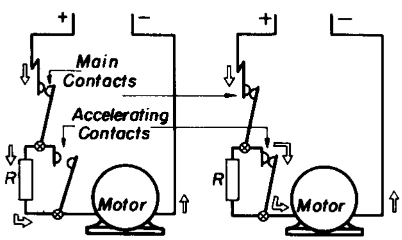


FIG. 8-60.—Positions of the accelerating contact of a counter e.m.f. starter when the motor starts and after acceleration.

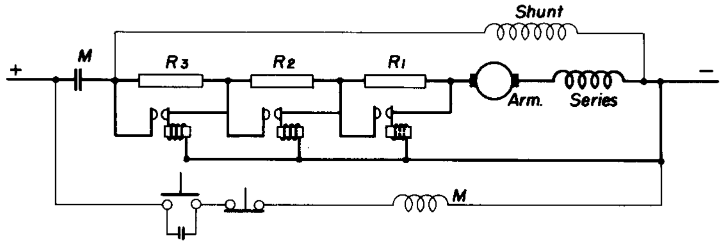
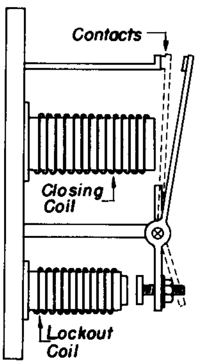


FIG. 8-61.—A counter e.m.f. starter with three steps of acceleration connected to a compound motor.

FIG. 8-62.—A two-coil lockout contactor used in current-limit starters.



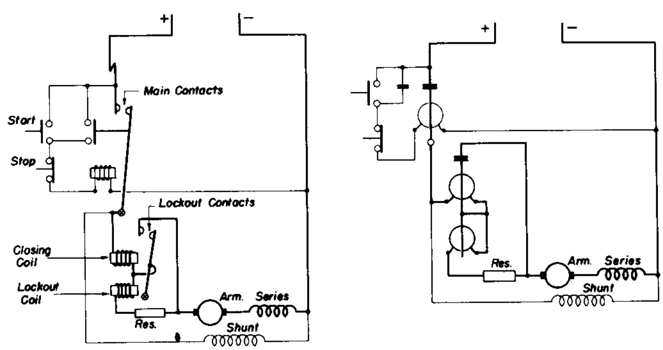


FIG. 8-63.—Different representations of a two-coil lockout starter with one step of acceleration connected to a compound motor.

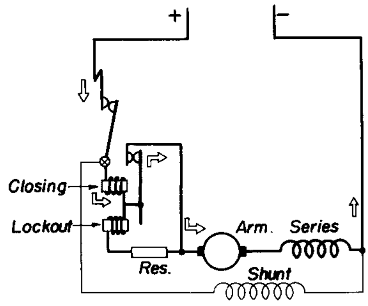


FIG. 8-64.—Position of the accelerating contact of a two-coil lockout starter when a motor is drawing normal current.

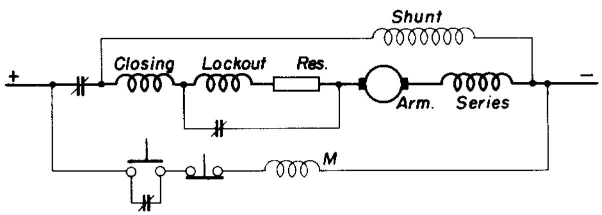


FIG. 8-65.—An elementary diagram of a two-coil lockout starter connected to a compound motor.

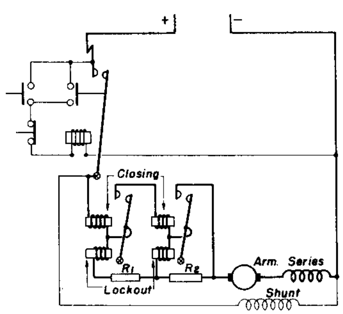


FIG. 8-66.—A two-coil lockout controller with two steps of acceleration.

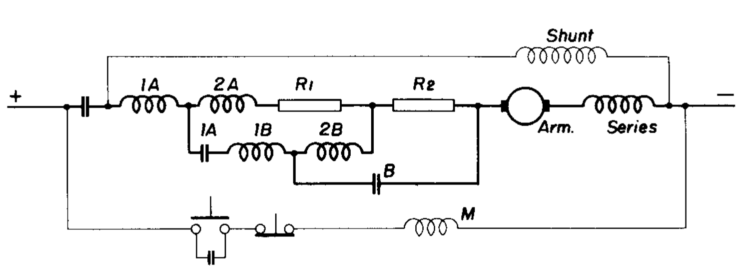


FIG. 8-67.—An elementary diagram of a two-step, two-coil lockout starter connected to a compound motor.

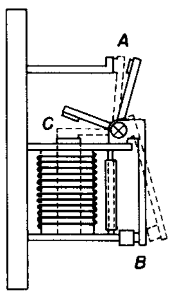


FIG. 8-68.—A single-coil lockout contactor.

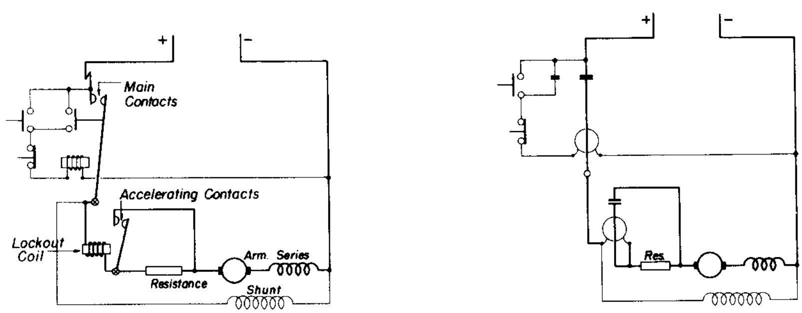


FIG. 8-69.—Different representations of a single-coil lockout starter with one step of acceleration connected to a compound motor.

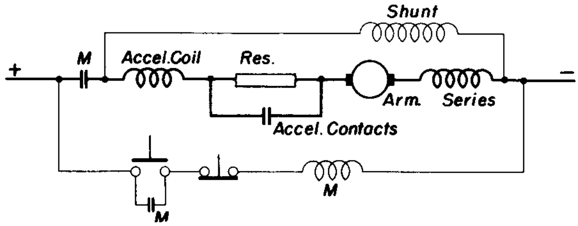


FIG. 8-70.—An elementary diagram of a single-coil lockout starter connected to a compound motor.

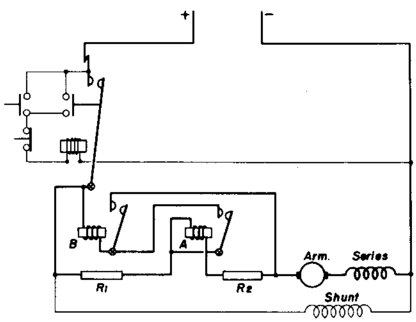


FIG. 8-71.—A single-coil lockout starter with two steps of acceleration.

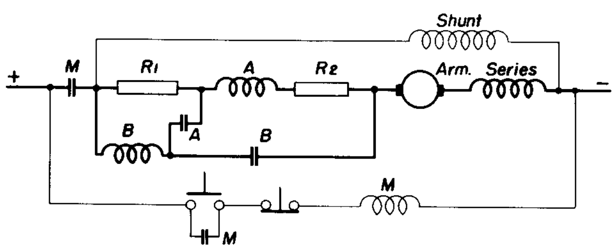


FIG. 8-72.—A simplified diagram of Figure 8-71.

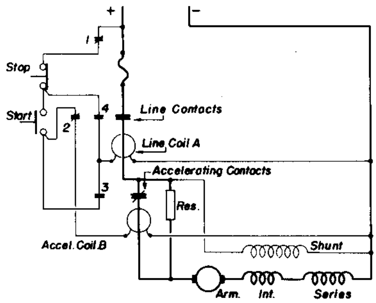


FIG. 8-73.—A wiring diagram of a definite magnetic time starter connected to a compound motor.

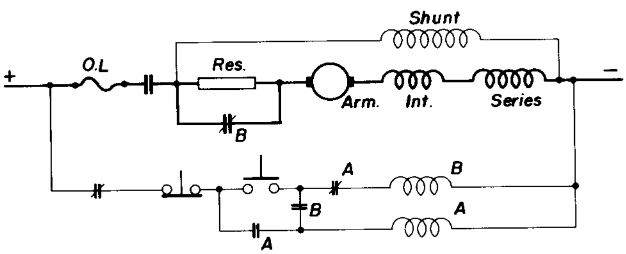


FIG. 8-74.—An elementary diagram of the connection of Figure 8-73.

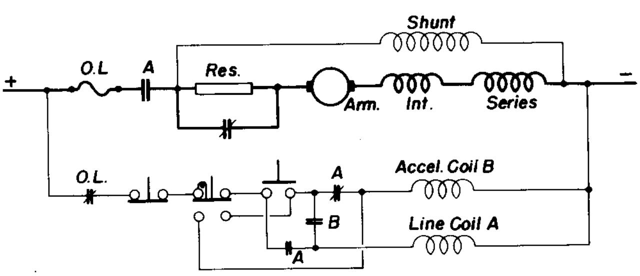


FIG. 8-75.—A wiring diagram of a definite magnetic time starter with a start-jog-stop station.

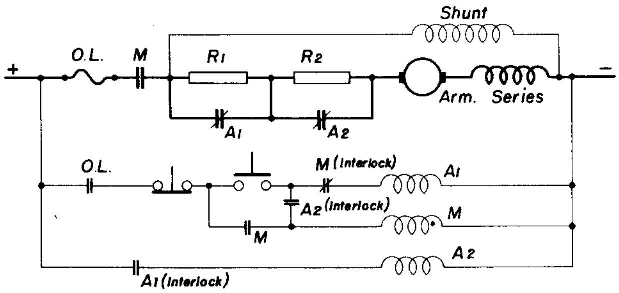


FIG. 8-76.—An elementary diagram of a definite magnetic time starter having two steps of resistance.

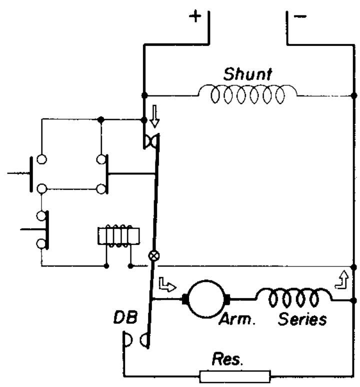


FIG. 8-77.—A starter equipped with dynamic braking. Contacts are shown in position while motor is operating. Note the flow of current in the armature.

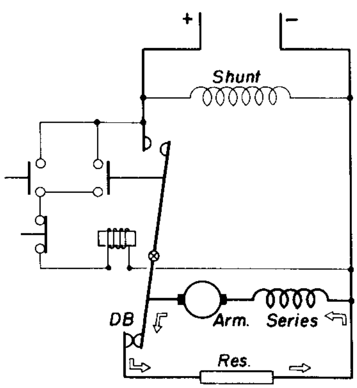


FIG. 8-78.—Position of the dynamic braking contacts when the current is shut off.

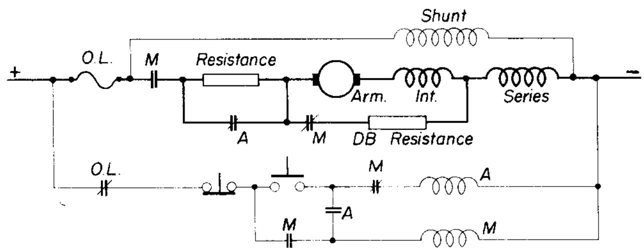


FIG. 8-79.—A wiring diagram of a magnetic time delay starter with dynamic braking connected to a compound motor.

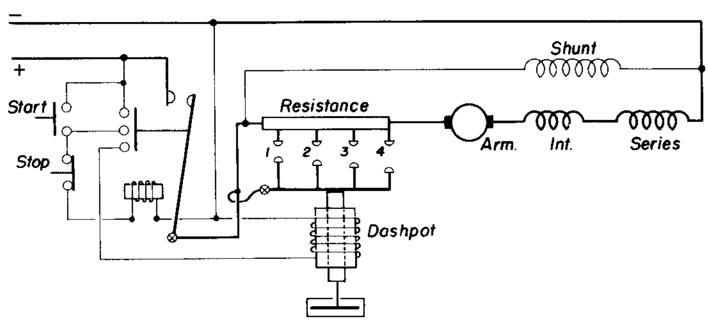


FIG. 8-80.—A starter using dashpot acceleration.

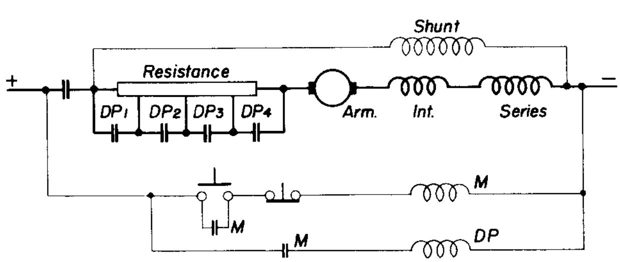


FIG. 8-81.—A line diagram of a dashpot starter.

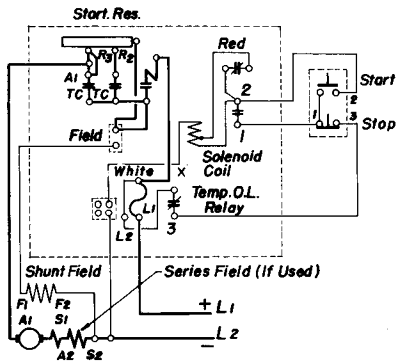
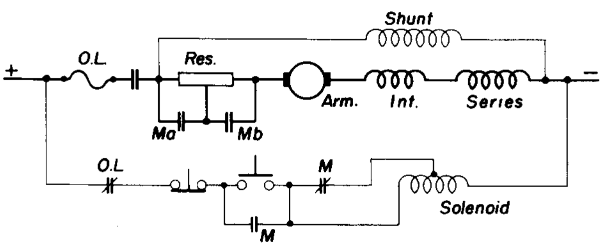


FIG. 8-82.—Wiring diagrams of a definite mechanical time starter.



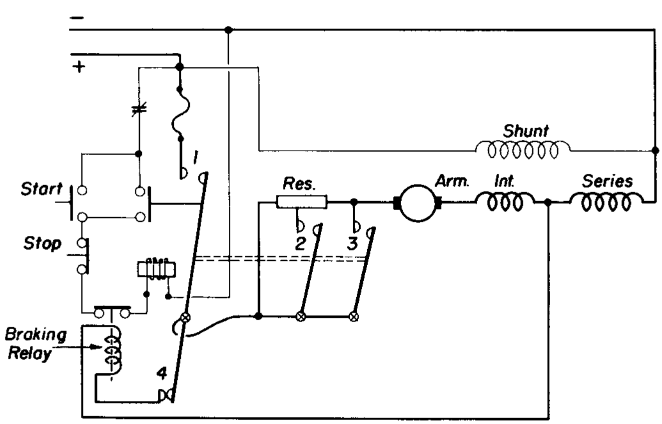


FIG. 8-83.—A geared timing starter with dynamic braking.

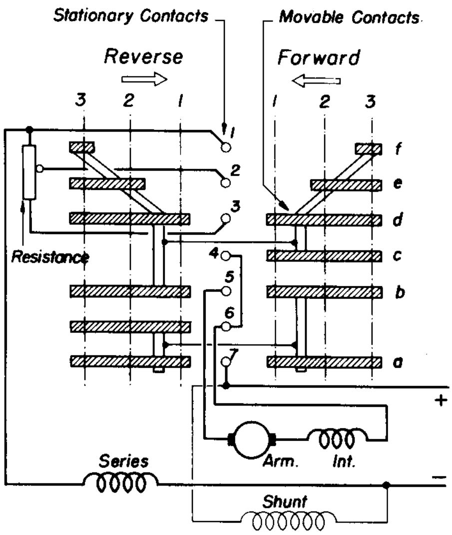


FIG. 8-84.—A typical simple type of drum controller connected to compound motor.

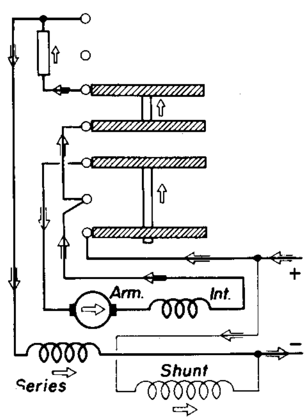


FIG. 8-85.—First position of the controller of Figure 8-84.

CHAPTER 9

Universal, Shaded-pole, and Fan Motors

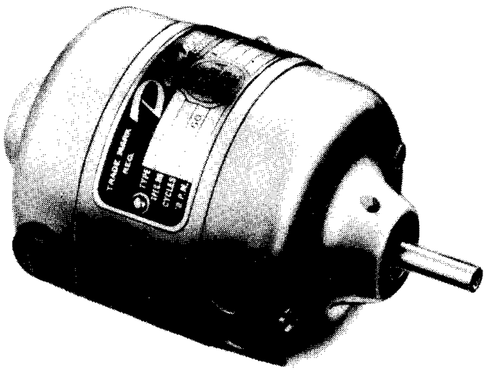


FIG. 9-1.—A universal motor. (*The Dumore Company.*)

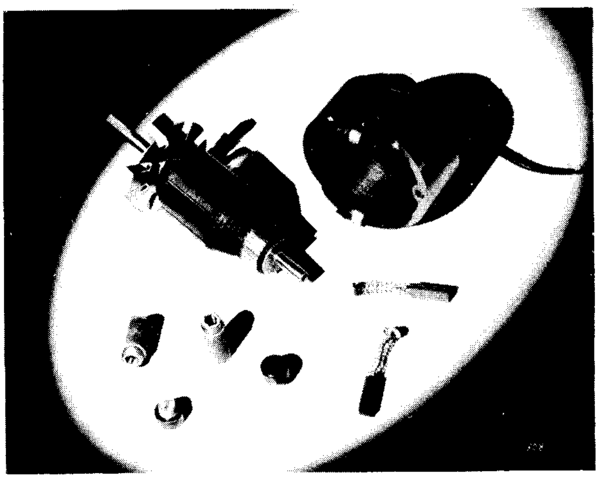


FIG. 9-2.—Parts of a universal motor. (*The Dumore Company.*)

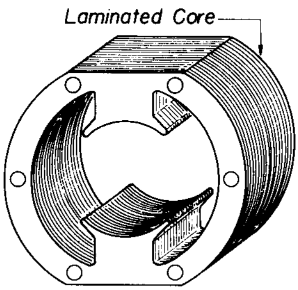


FIG. 9-3.—Field core of a two-pole universal motor.

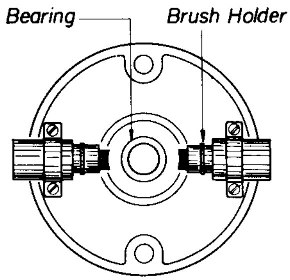


FIG. 9-4.—End plate showing the brush holders and bearing.

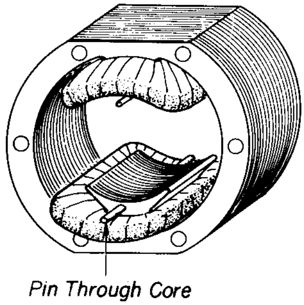


FIG. 9-5.—Pins through the core hold the field coils in place.

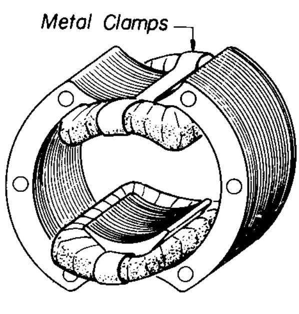


FIG. 9-6.—Method of securing coils to the core by using metal clamps.

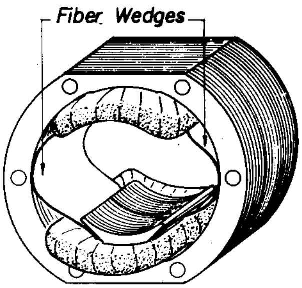


FIG. 9-7.—Using fiber wedges to secure field coils to the core.

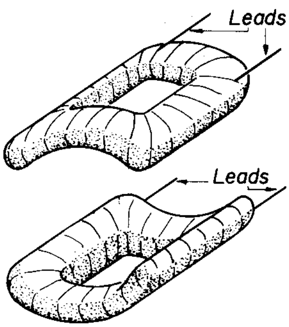


FIG. 9-8.—Shape of coils after removal from the core.

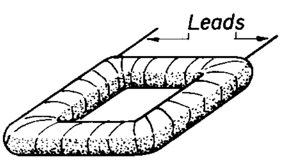


FIG. 9-9.—Shape of coil after it is flattened to obtain coil dimensions.

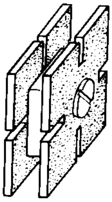


FIG. 9-10.—Form for winding field coils.

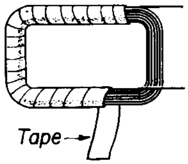


FIG. 9-11.—Taping a field coil.

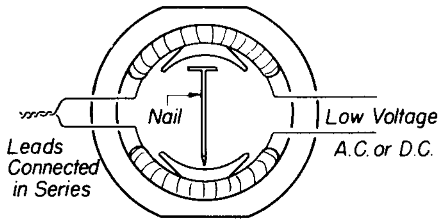
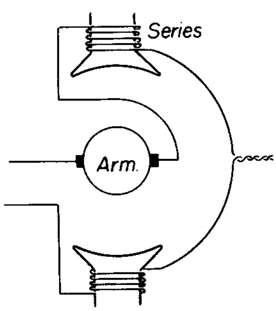


FIG. 9-12.—Testing fields for proper polarity. If the nail stands between the energized coils, their polarity is correct.

FIG. 9-13.—Series connection of a universal motor.



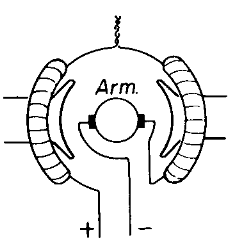


FIG. 9-14.—Series connection showing taped field coils.

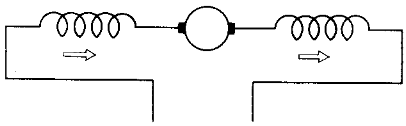


FIG. 9-15.—Schematic connection of a universal motor. Note the armature is connected between the field poles.

FIG. 9-16.—Motor connection for clockwise rotation.

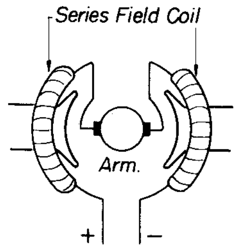
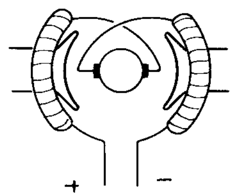


FIG. 9-17.—Motor of Figure 9-16 connected for counterclockwise rotation by interchanging armature connections.



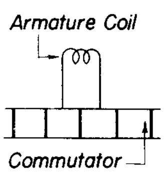
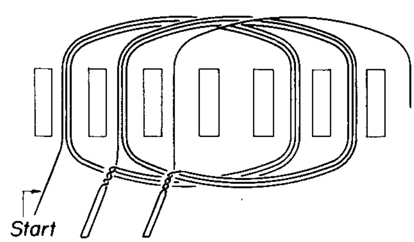


FIG. 9-18.—In a lap-wound armature, each coil connects between adjacent bars.

FIG. 9-19.—A loop winding showing loops at the end of each coil.



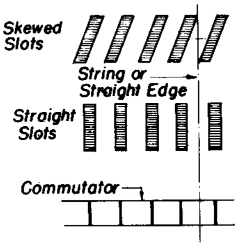
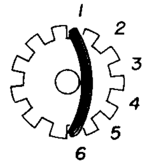


FIG. 9-20.—Lining out the center of slots to the commutator to determine lead throw.

FIG. 9-21.—View of the armature from the end opposite the commutator to determine the coil pitch.



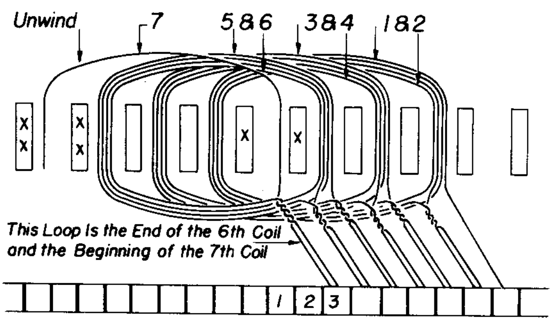


FIG. 9-22.—Coils being unwound turn by turn to record the position of the leads to the commutator bars.

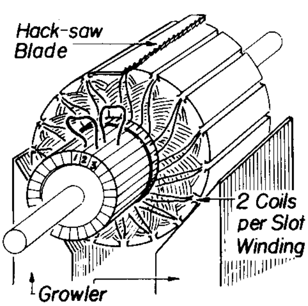


FIG. 9-23.—The hack-saw blade vibrates if bars *1* and *2* and *2* and *3* are shorted while the armature is in the growler. This determines the lead throw of the coils.

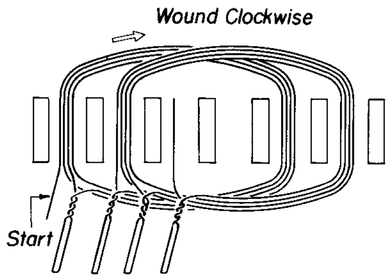


FIG. 9-24.—Coils in an armature wound in a clockwise direction.

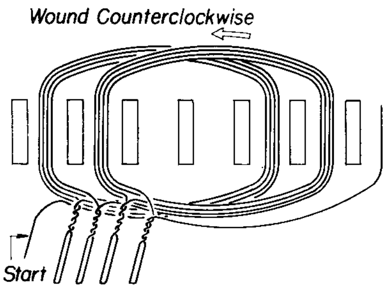


FIG. 9-25.—Coils wound in a counterclockwise direction.

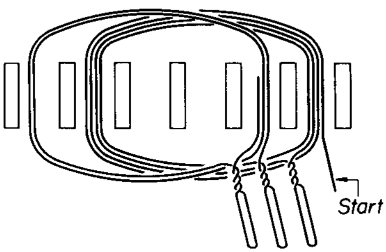


FIG. 9-26.—Loops for making connections to commutator shown on the right side of the coils.

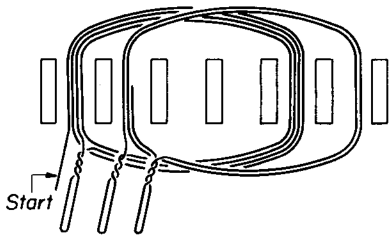


FIG. 9-27.—Loops shown on the left side of each coil.

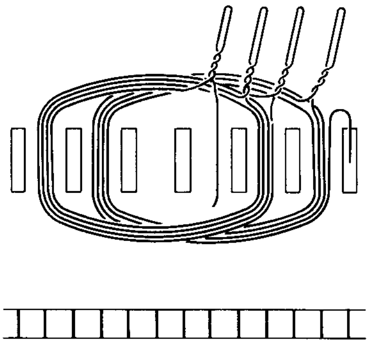


FIG. 9-28.—In some armatures the loops are made at the rear of the slots and brought back through the slots to the commutator.

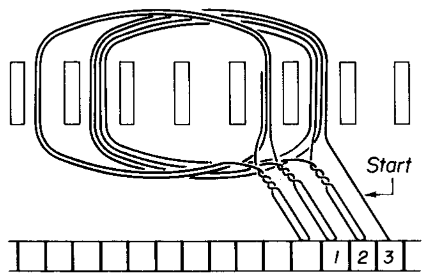


FIG. 9-29.—Leads connected several bars to the right of each coil for clockwise rotation.

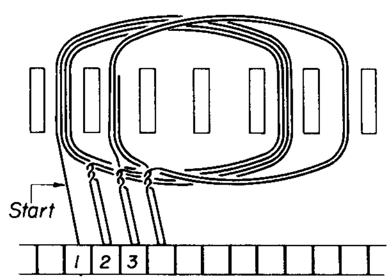


FIG. 9-30.—Leads connected to the right of each coil for clockwise rotation.

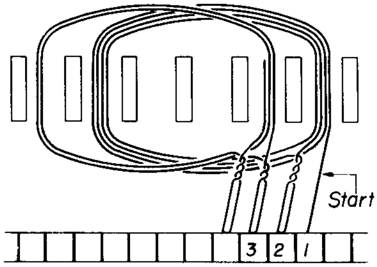


FIG. 9-31.—Leads connected several bars to the left for counterclockwise rotation.

Figures 9-28; 9-29; 9-30; 9-31

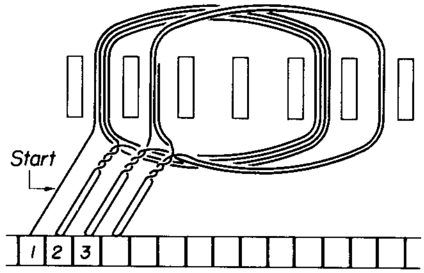


FIG. 9-32.—Leads connected to the left of each coil for counterclockwise rotation.

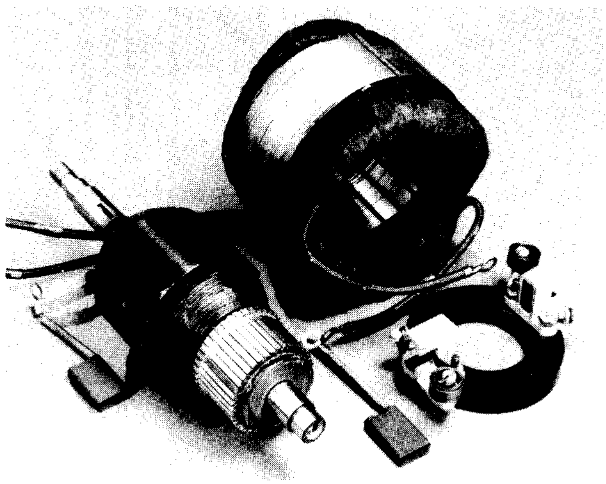


FIG. 9-33.—Parts of a distributed-field universal motor. (*Westinghouse Elec. Co.*)

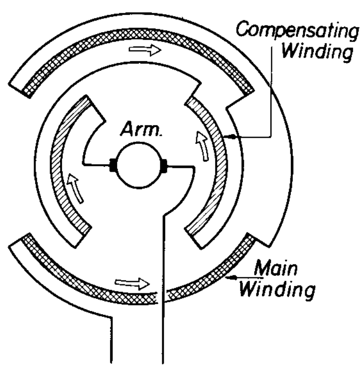


FIG. 9-34.—Connections of a compensated universal motor. Note that the compensating winding is located 90 electrical degrees from the main winding and connected in series with the armature and main winding.

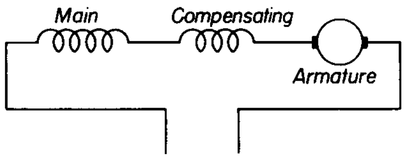


FIG. 9-35.—Schematic diagram of a compensated universal motor.

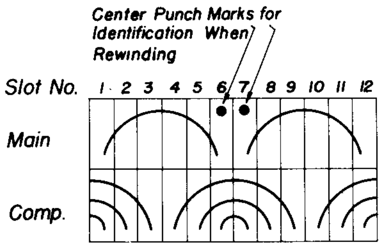


FIG. 9-36.—Recording the windings of a twelve-slot, two-pole, compensated universal motor. Note the center-punch marks in the slots to locate the windings in the proper slots.

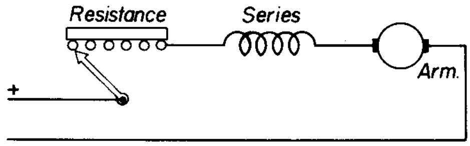


FIG. 9-37.—Speed of a small universal motor controlled by connecting a variable resistor in series with the motor.

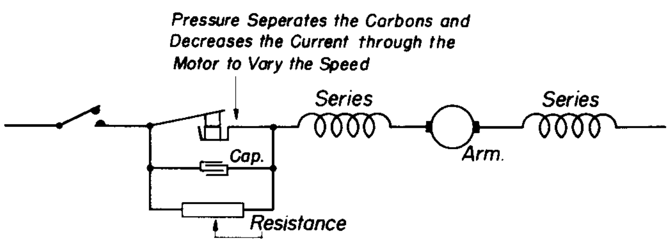


FIG. 9-38.—Speed control of a universal motor by a variation in contact resistance between two carbon blocks.

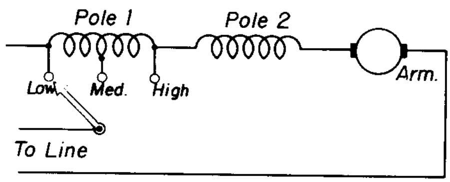


FIG. 9-39.—Three speeds are obtained by tapping one field pole.

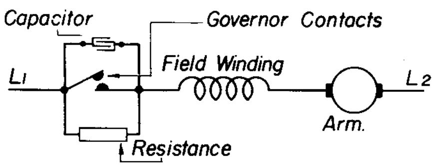


FIG. 9-40.—Speed control of a universal motor by means of a centrifugal governor.

FIG. 9-41.—A shaded-pole motor. (*Emerson Elec. Mfg. Co.*)

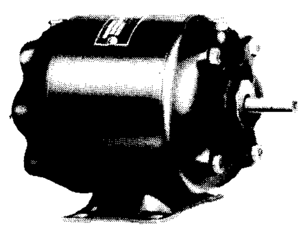
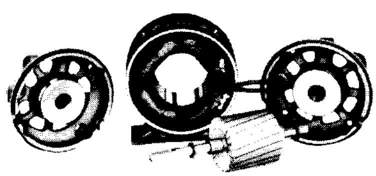


FIG. 9-42.—Construction of the field and armature of a shaded-pole motor. (*Emerson Elec. Mfg. Co.*)



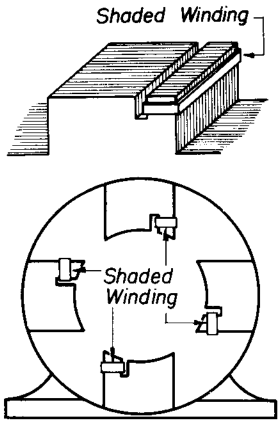


FIG. 9-43.—A four-pole, shaded-pole motor showing the field poles and shading windings.

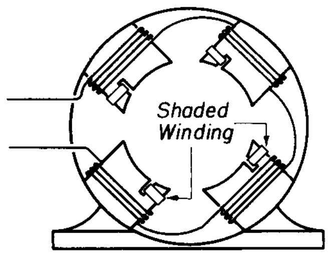


FIG. 9-44.—A four-pole, shaded-pole motor with the field poles connected in series for alternate polarity.

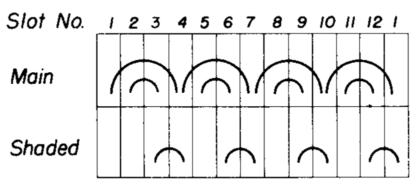


FIG. 9-45.—Recording the windings of a four-pole, twelve-slot, distributed shaded-pole motor.

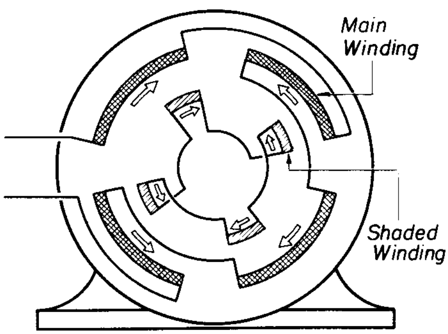


FIG. 9-46.—Connection diagram of a four-pole, distributed shaded-pole winding.

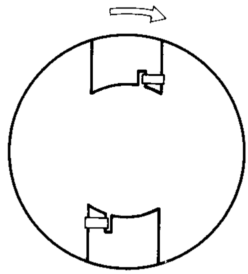


FIG. 9-47.—Position of the poles and shading coils before the stator is reversed.

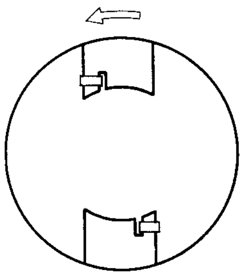


FIG. 9-48.—Position of the poles after the stator is reversed end for end. Compare with Figure 9-47.

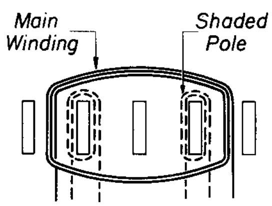


FIG. 9-49.—One pole of a twelve-slot, reversible shaded-pole motor. Note the two shading coils.

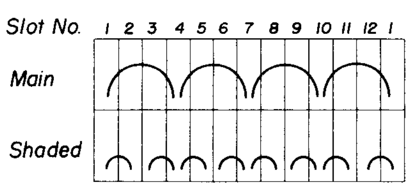


FIG. 9-50.—Coil layout of a reversible shaded-pole motor.

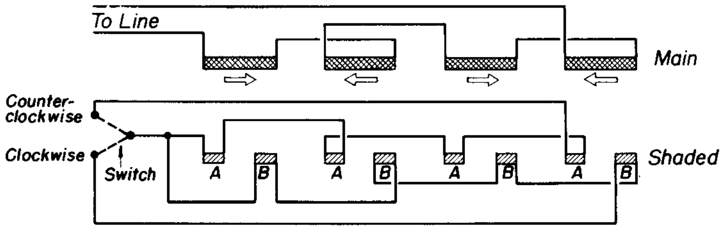


FIG. 9-51.—Wiring diagram of a reversible shaded-pole motor. To reverse a shaded-pole motor, one series of shading coils is opened and the other series closed.

FIG. 9-52.—Reversible shaded-pole motor with two main poles for each shaded coil.

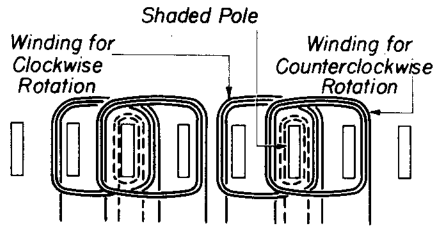
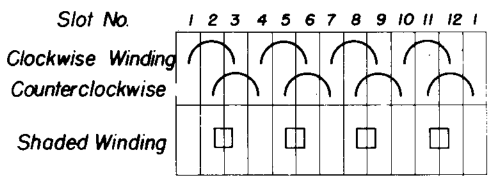


FIG. 9-53.—Method of recording the layout of the coils of a twelve-slot, four-pole, reversible shaded-pole motor having two sets of main poles.



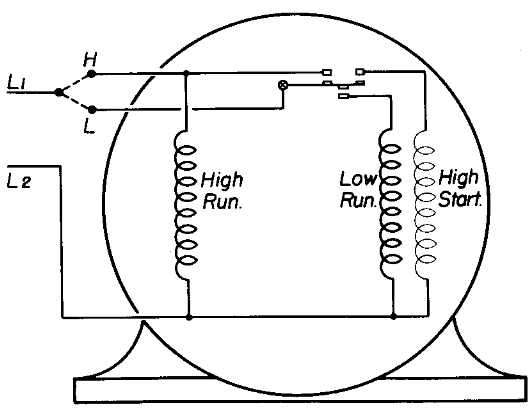


FIG. 9-54.—A two-speed, split-phase fan motor with two running windings and one starting winding.

Figures 9-51; 9-52; 9-53; 9-54

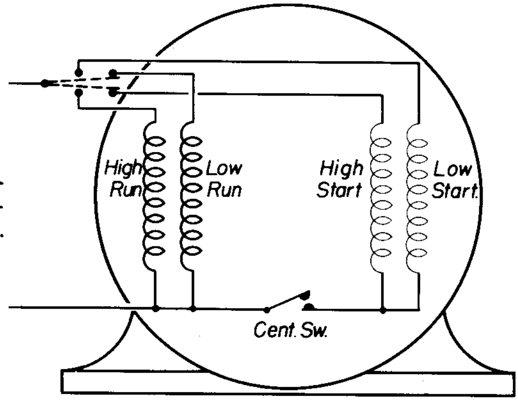


FIG. 9-55.—A two-speed, split-phase fan motor with two running and two starting windings.

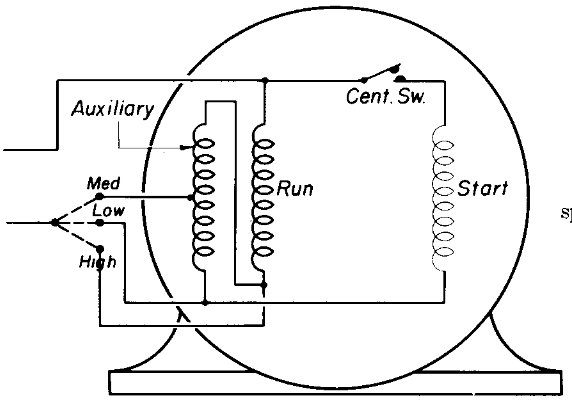


FIG. 9-56.—A three-speed split-phase motor.

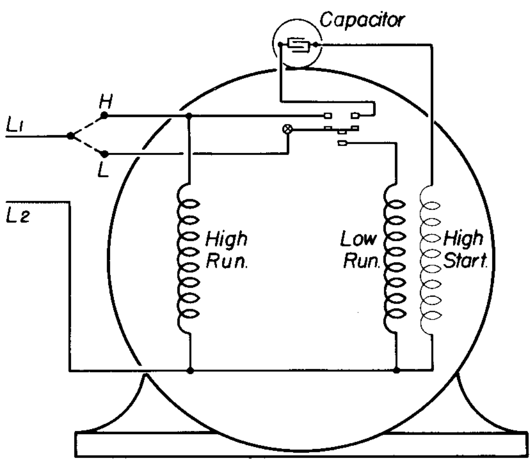


FIG. 9-57.—A two-speed, capacitor-start fan motor.

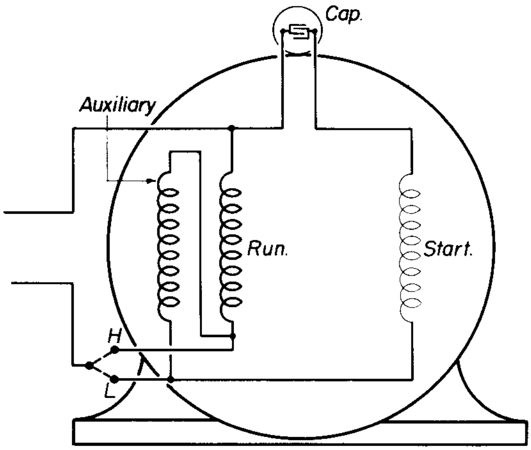


FIG. 9-58.—A two-speed, capacitor-run fan motor.

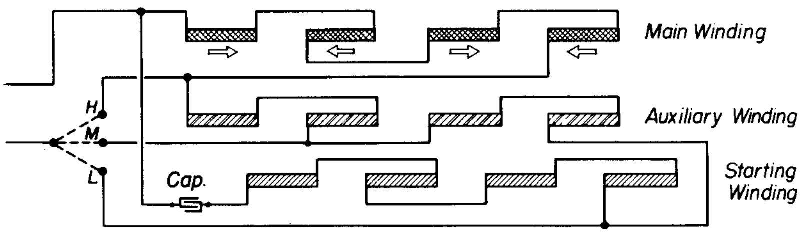


FIG. 9-59.—Wiring diagram of a three-speed, capacitor-run motor.

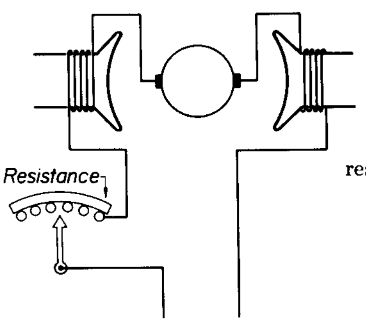


FIG. 9-60.—Universal fan motor with a series resistance for speed control.

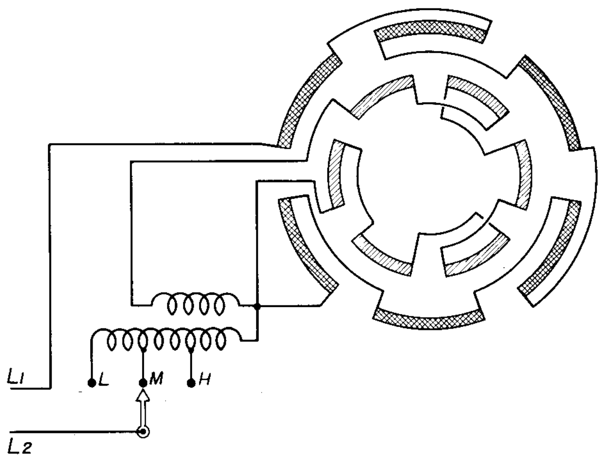


FIG. 9-61.—A split-phase motor using an autotransformer for speed control.

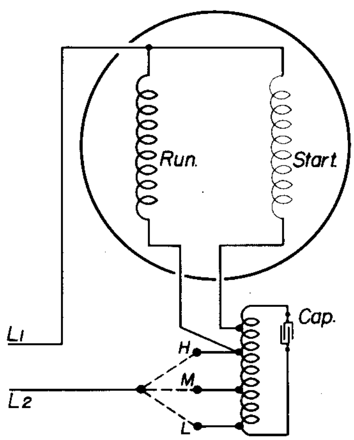


FIG. 9-62.—Diagram of a capacitor motor used for fan service.

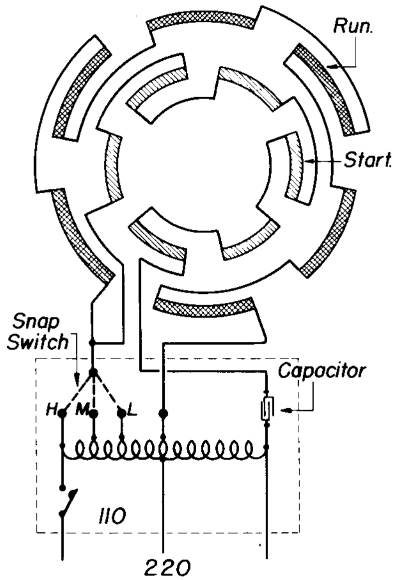


FIG. 9-63.—Unit-heater three-speed motor. The speed is varied by impressing various voltages from an autotransformer to the running and starting windings.

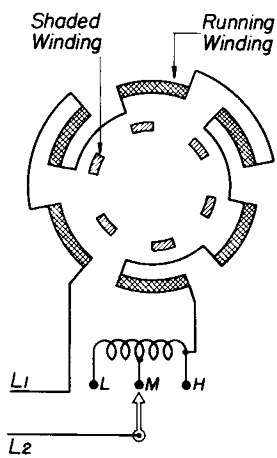


FIG. 9-64.—Shaded-pole fan motor with speed control varied by means of a choke coil.

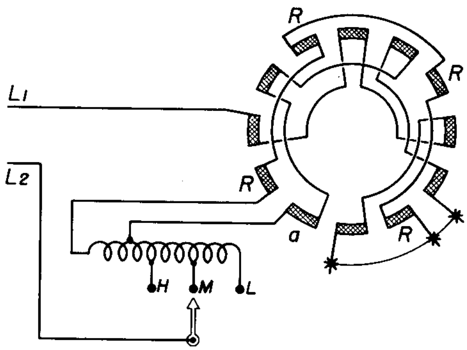


FIG. 9-65.—A single-phase motor wound as a three-phase motor. By using resistance wire for the coils of one winding and a tapped-choke coil in series with another, this motor can be run at various speeds on a single-phase line.

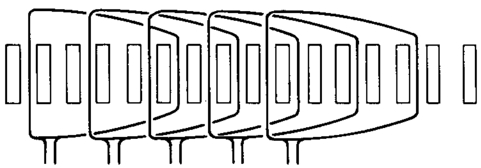


FIG. 9-66.—Basket winding for a 48-slot, 24-coil, three-phase motor.

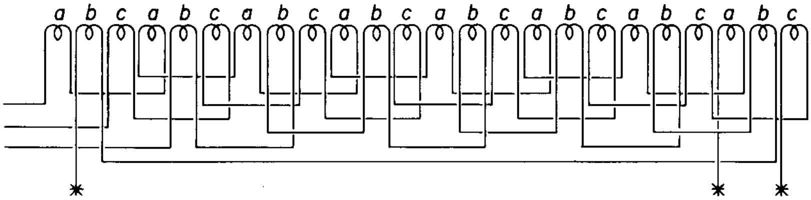


FIG. 9-67.—A 48-slot, eight-pole, three-phase motor connected series star.

CHAPTER 10

Direct-current Generators; Synchronous Motors and Generators; Synchros; Electronic Control of Motors

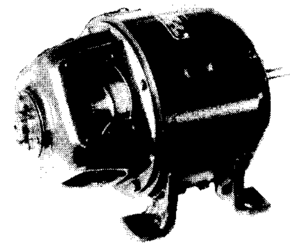


FIG. 10-1.—A d-c generator. (*General Electric Company.*)

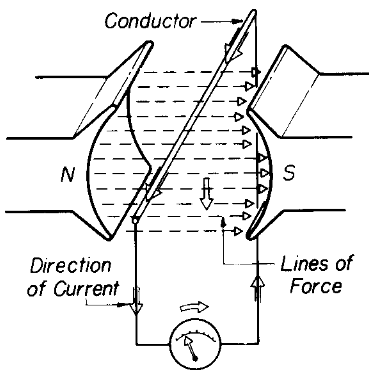


FIG. 10-2.—A potential is induced in the conductor when it cuts lines of force.

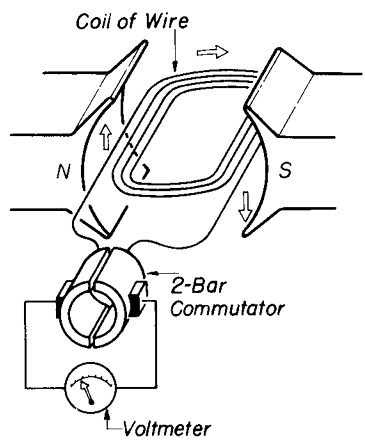


FIG. 10-3.—A coil of wire used as the conductor and rotated in a magnetic field. The leads of the coil are connected to a commutator to produce direct current.

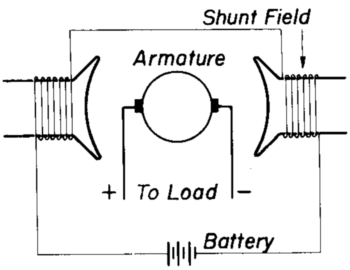


FIG. 10-4.—A separately excited shunt generator.

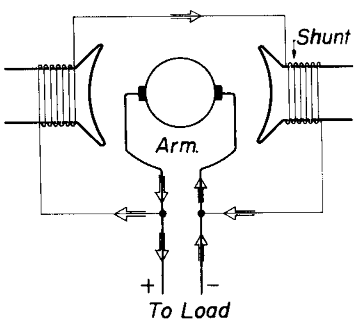


FIG. 10-5.—A self-excited shunt generator.

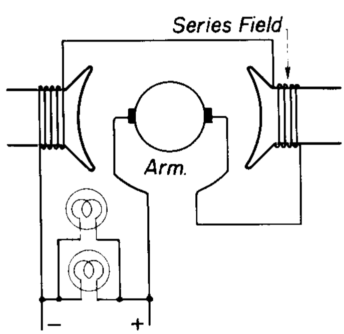


FIG. 10-6.—A self-excited series generator.

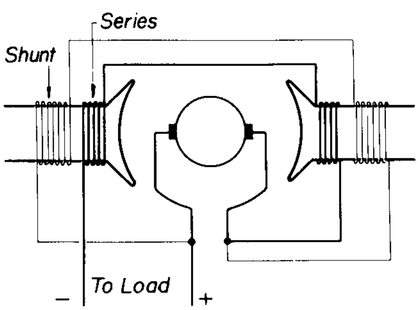


FIG. 10-7.—A short-shunt cumulative compound generator.

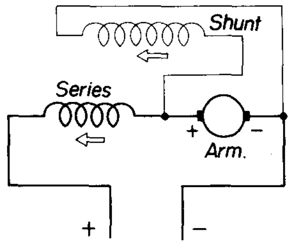


FIG. 10-8.—Wiring of a compound short-shunt generator.

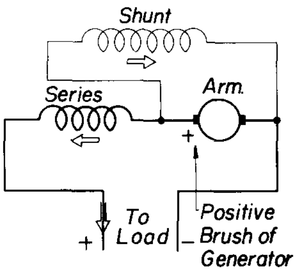


FIG. 10-9.—A short-shunt differential generator.

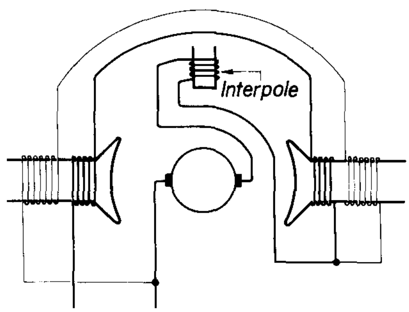


FIG. 10-10.—A short-shunt cumulative generator with interpole.

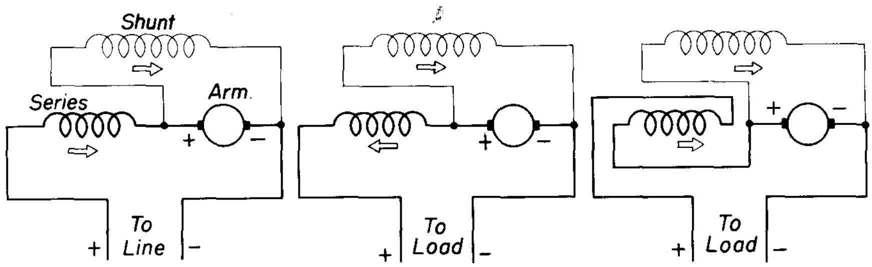


FIG. 10-11.—At the left is shown the direction of flow of the two field currents of a compound motor. This motor is cumulative, but if used as a generator, it will be differential, as shown in the center. If the series field is reversed, as shown at the right, the generator will be cumulative.

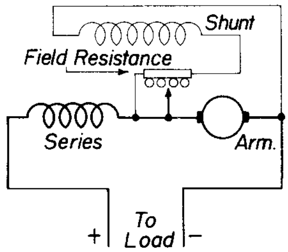


FIG. 10-12.—A short-shunt cumulative generator with field rheostat for voltage control.

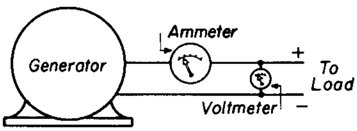
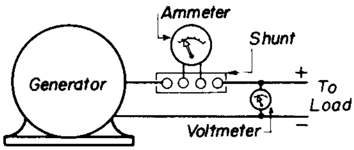


FIG. 10-13.—A voltmeter and an ammeter properly connected in a generator circuit.

FIG. 10-14.—An ammeter with external shunt connected in generator circuit.



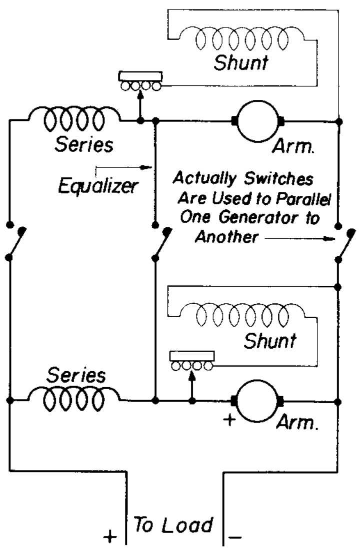


FIG. 10-15.—Two compound generators connected in parallel.

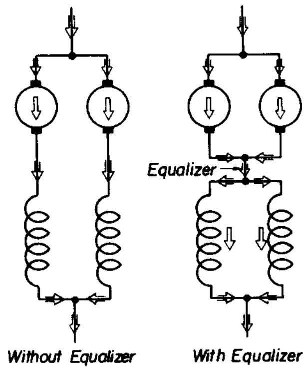


FIG. 10-16.—A diagram showing how the load is divided equally between two generators if equalizer is used.

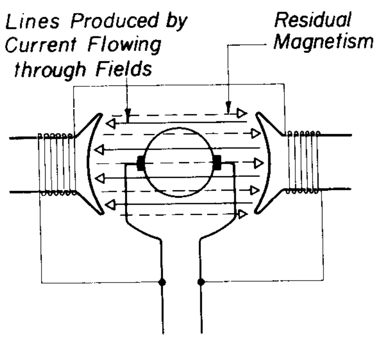


FIG. 10-17.—An incorrect connection of shunt field in a generator. The residual lines of force oppose the lines caused by the field current and prevent build-up of the field strength.

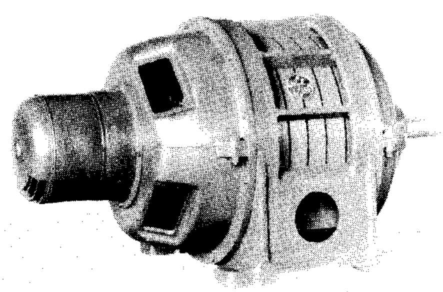


FIG. 10-18.—A synchronous motor for general-purpose application. (*General Electric Company.*)

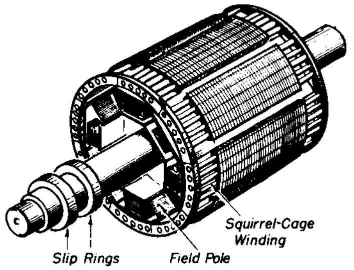


FIG. 10-19.—A rotor of a synchronous motor.

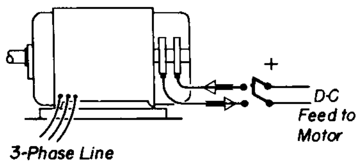


FIG. 10-20.—Synchronous-motor power connections.

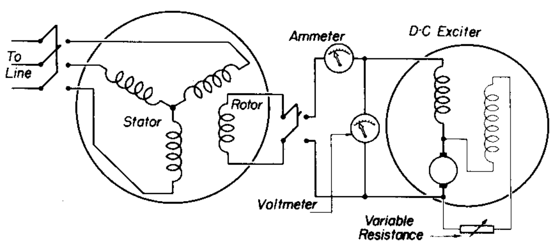


FIG. 10-21.—A synchronous motor showing rotor supplied from a small exciter.

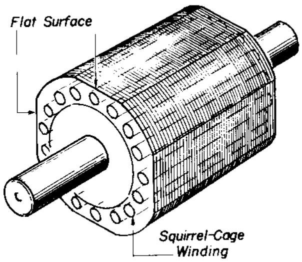


FIG. 10-22.—A flat-faced rotor of a self-starting, nonexcited, split-phase synchronous motor.

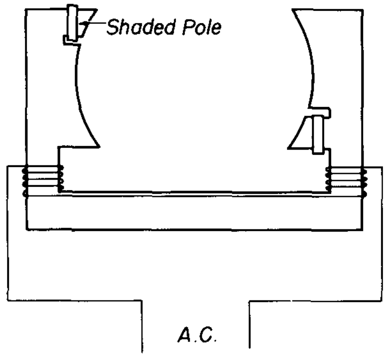


FIG. 10-23.—A stator with shaded poles for a synchronous clock motor.

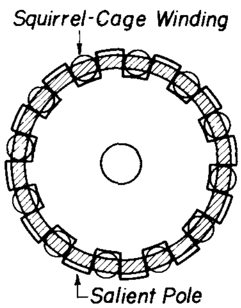


FIG. 10-24.—A rotor for a self-starting synchronous motor.

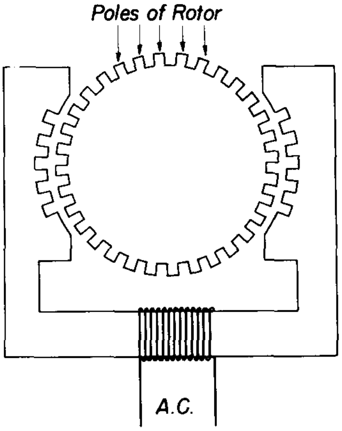


FIG. 10-25.—A synchronous clock motor having 32 poles.

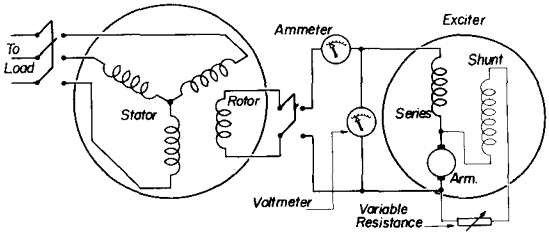


FIG. 10-26.—Synchronous-generator connections.

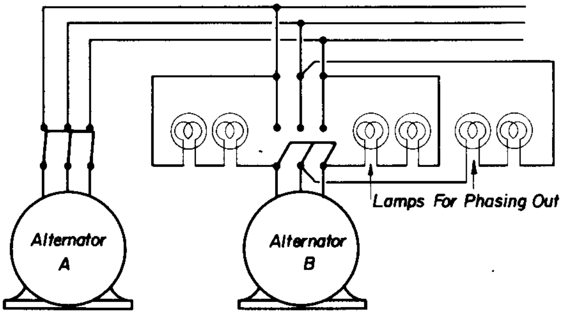


FIG. 10-27.—The "all dark" method of synchronizing two alternators.

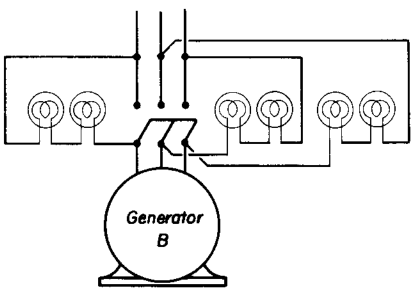
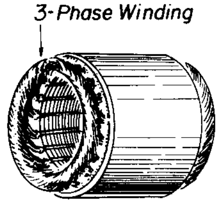


FIG. 10-28.—The "one dark and two bright" method of synchronizing.

FIG. 10-29.—A stator of a synchro.



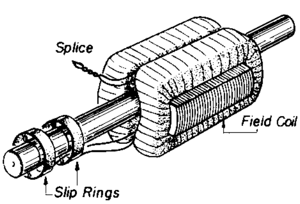


FIG. 10-30.—A rotor of a synchro.

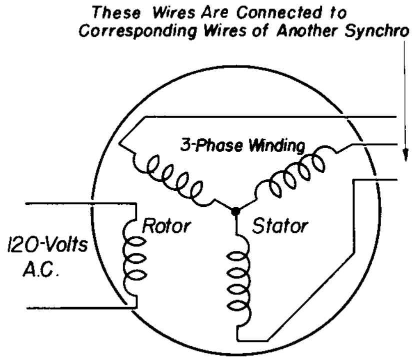


FIG. **10-31**.—Connections of a synchro showing a three-phase winding on the stator and a single-phase winding on the rotor.

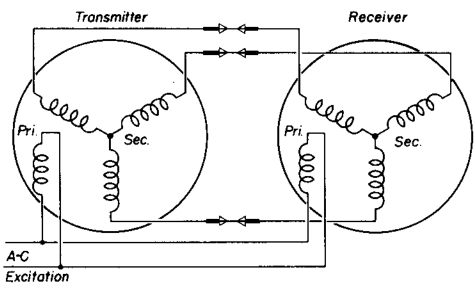


FIG. **10-32**.—Two synchros connected for operation. The receiver will remain motionless until the transmitter is turned.

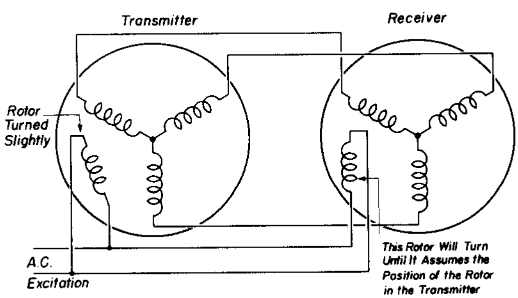


FIG. **10-33**.—The rotor of the transmitter has been turned slightly, causing the receiver to turn.

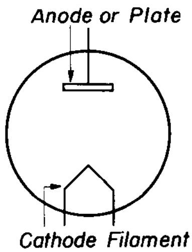


Fig. 10-34.—The symbol of a two-element vacuum-tube diode.

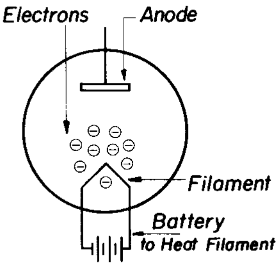


Fig. 10-35.—Heated filament emits electrons.

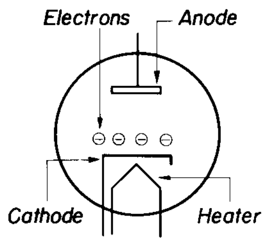


Fig. 10-36.—A diode with an indirectly heated cathode.

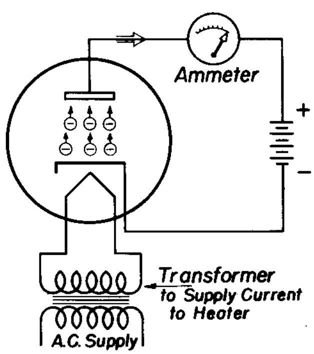


Fig. 10-37.—Electrons will flow from the cathode to the anode when the anode is given a positive charge.

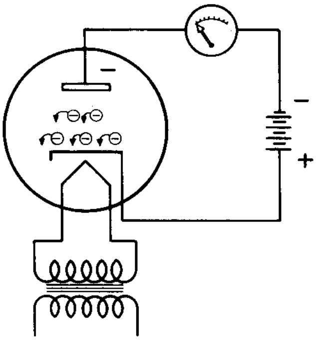


FIG. 10-38.—When the anode is made negative, the electrons will be repelled.

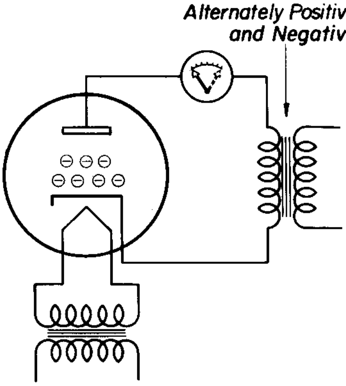


FIG. 10-39.—This tube acts as a rectifier permitting current to flow only when the anode is positive.

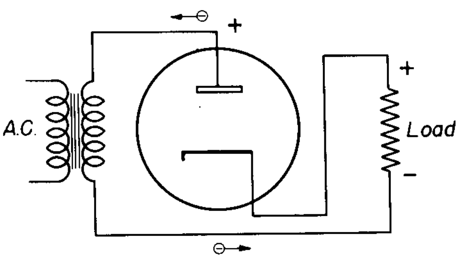


FIG. 10-40.—A half-wave rectifier circuit.

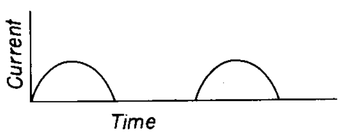


FIG. 10-41.—A pulsating current produced by a half-wave rectifier.

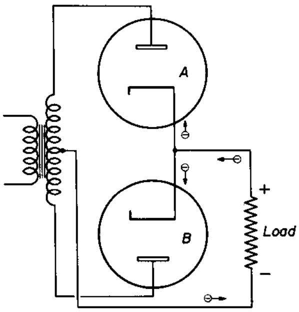


FIG. 10-42.—A full-wave rectifier circuit.

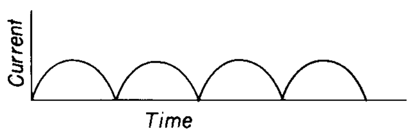
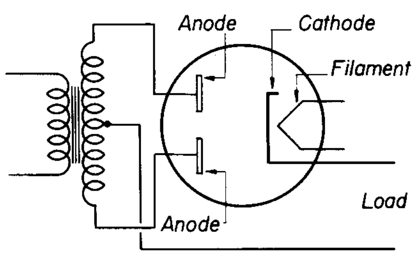


FIG. 10-43.—A pulsating current produced by a full-wave rectifier.

FIG. 10-44.—A full-wave rectifier in one envelope.



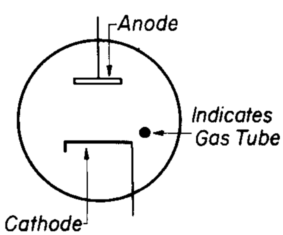


FIG. 10-45.—The gas-diode symbol.

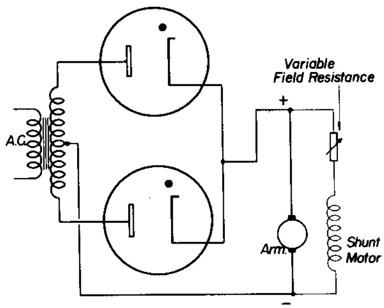


FIG. 10-46.—A d-c motor can be operated from an a-c source by using a full-wave rectifier.

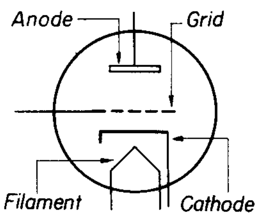
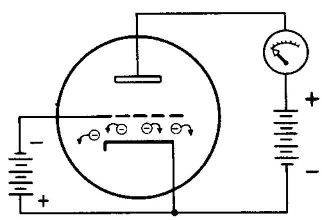


FIG. 10-47.—The three-element vacuum-tube triode symbol.

FIG. 10-48.—Electrons will not reach the plate because the negatively charged grid repels them.



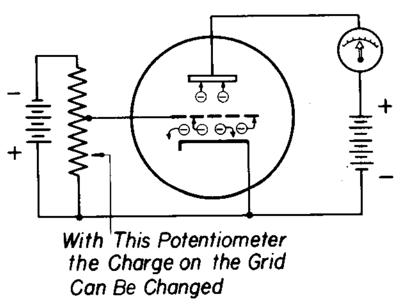


FIG. 10-49.—If the negative charge on the grid is reduced, some electrons will flow to the anode.

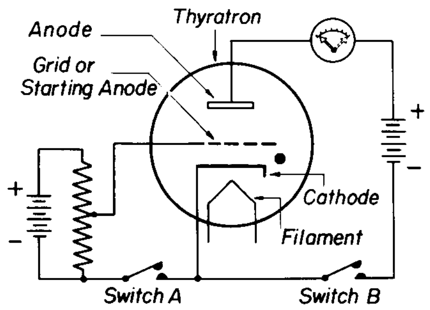


FIG. **10-50.**—To stop the current flow in the anode circuit, open switch *B*.

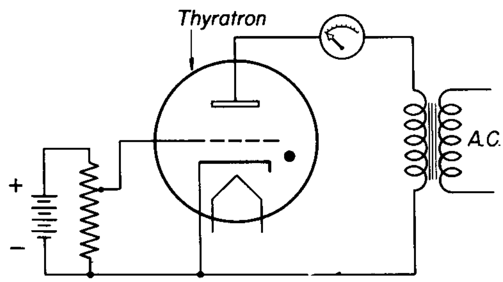


FIG. **10-51.**—Current will flow only when the anode is positive and when the voltage is of the proper value. This may be for less than half a cycle.

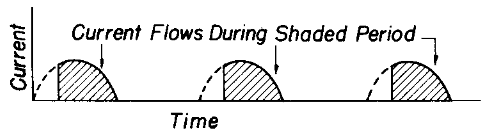


FIG. **10-52.**—A curve showing how current can be made to flow in a thyratron for a portion of a half wave.

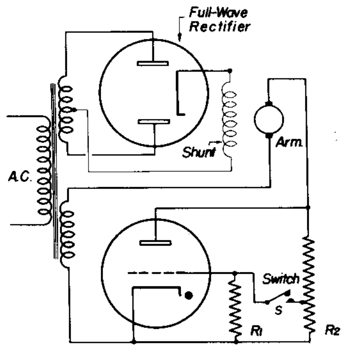


FIG. 10-53.—A circuit showing a thyratron used on alternating current to operate a d-c motor.

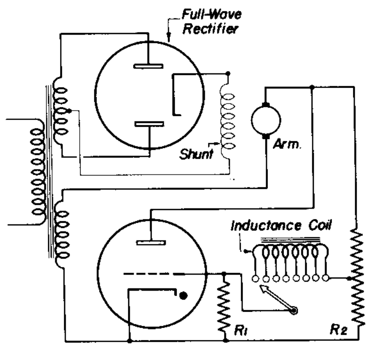


FIG. 10-54.—Different speeds can be obtained by varying an inductance in the grid circuit of the thyratron.

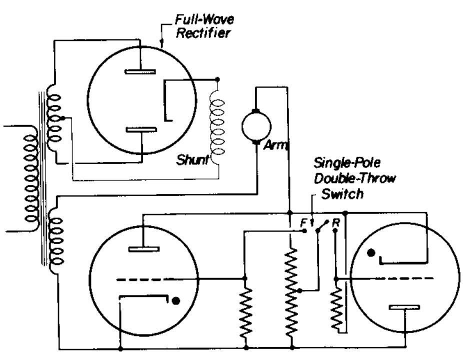


FIG. 10-55.—Two thyratrons permit reversing the direction of rotation of a d-c motor with a simple switch.

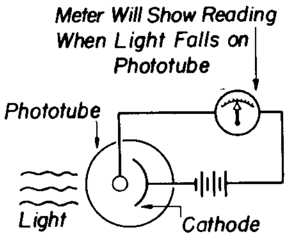


FIG. 10-56.—A basic phototube circuit.

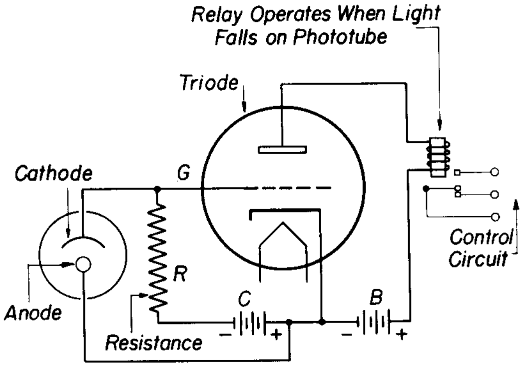


FIG. 10-57.—A circuit showing how a phototube controls a relay.

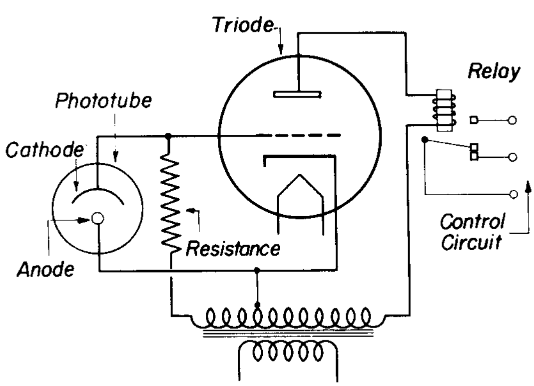


FIG. 10-58.—A phototube circuit using a-c supply.

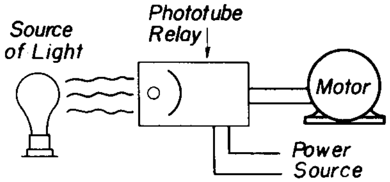


FIG. 10-59.—The motor operates when the light source is interrupted.

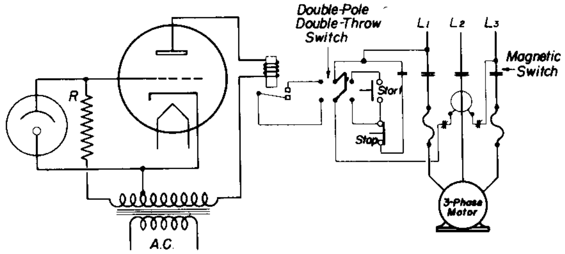


FIG. 10-60.—A circuit showing a phototube operating a magnetic switch.

STUDY QUESTIONS

Foreword

This section contains study questions for each chapter in *Electric Motor Repair*. They are arranged to follow the sequence of information found in the repair book. Complete explanations or illustrations or both are necessary for the correct answers.

For those who are studying the repair book without benefit of an instructor these questions should prove of value. First, they serve to test the student's knowledge gained in studying the book because he will have to check his answers by referring to the book. Second, these questions test the student's ability to apply the knowledge gained from the book to practical jobs. Third, by successfully answering these questions, the student will be preparing himself for examinations in which similar questions may be asked. And fourth, by answering these questions correctly, the student will gain confidence in his ability to tackle more difficult problems in motor repair work.

From the instructor's point of view, the questions can be used as a basis for discussion during school periods. Weekly quizzes, which are given to test the student's knowledge and comprehension of the subject, may be based on these questions, and daily or weekly assignments may be made from them.

Motor repair men, helpers, apprentices and all others interested in electric motor repair will find these questions valuable as a guide to show them how much knowledge they have of the subject.

CHAPTER I

Split-phase Motors

1. (a) What is a split-phase motor? (b) What are its characteristics? (c) Give several applications.

2. List the main parts of a split-phase motor and give a brief description and function of each.

3. (a) What is a squirrel-cage winding? (b) Describe two types of squirrel-cage windings. (c) Draw all the parts of a rotor.

4. (a) What is a centrifugal switch? (b) Where is the switch located? (c) Draw a diagram to show how this switch operates.

5. Name at least seven steps usually taken in repairing a split-phase motor.

6. (a) How should the end plates and frame be marked before disassembling for repair? (b) Why is this necessary?

7. (a) List all of the information necessary in taking data for the rewinding of a split-phase motor. (b) What would be the consequence if incorrect data were taken?

8. (a) What is meant by the pitch of a coil? (b) How is it recorded? Illustrate.

9. (a) Draw a simple circuit of the connections of a split-phase motor. (b) Explain the diagram.

10. Draw a chart showing how the windings and other information of a 36-slot split-phase motor can be recorded.

11. (a) Show separate diagrams of a split-phase motor winding when the motor is at a standstill and when it is running. (b) What is the difference between the two illustrations?

12. (a) What is meant by a "pole of the winding"? (b) Show a drawing of one pole of a running winding having four coils with pitches 1-3, 1-5, 1-7, and 1-9.

13. (a) How is wire size recorded? (b) Name several types of insulation with which wire is covered. (c) What may happen to a motor if the winding is replaced with the wrong size of wire? (d) Why?

14. How are measurements taken to obtain the size of a skein coil?

15. Describe and give an example of how to change a hand winding to a skein winding.

16. (a) What precautions must be taken when coils are placed into the slots of a stator? (b) What consequences may result from poor and careless workmanship?

17. Draw a straight-line diagram of a four-pole series split-phase motor showing the running and starting windings and the centrifugal switch. Trace and explain the circuit.

18. Draw a circular-form diagram of the motor referred to in Question 17. Place arrows under each pole to indicate direction of flow of current.

19. What is meant by a two-parallel or a two-circuit connection? Why is it used?

20. (a) Draw a circular-form diagram of a two-circuit winding for a six-pole split-phase motor. (b) Repeat (a) for a three-circuit winding. (c) What method may be used to determine whether the poles of the motor are connected correctly?

21. Explain three methods that may be used in changing the speed of a split-phase motor.

22. (a) Show a schematic and straight diagram of a two-speed split-phase motor which has one starting and two running windings. (b) Explain in detail the operation of this motor. (c) Describe the centrifugal switch used with this motor.

23. (a) What troubles may result if the starting winding in a single- or two-speed motor is permitted to remain in the circuit while the motor is in operation? (b) Explain how you arrive at your conclusions.

24. (a) What tests should a split-phase motor be given in order to detect faults? (b) When and why should these tests be made?

25. Draw two or more diagrams that will illustrate what is meant by a "ground."

26. (a) What test is recommended to determine whether a motor winding is grounded? (b) Explain where and how grounds usually occur and the precautions which should be taken to prevent them.

27. Assuming that an open circuit exists in the starting-winding circuit of a split-phase motor, explain the procedure to find the "open" and the measures taken to correct the fault.

28. (a) What is meant by a short-circuit in a motor? (b) How do short circuits occur? (c) Where do they take place?

29. (a) What are some of the indications that there is a short circuit in a motor? (b) What means are employed to test for short circuits?

30. What is an internal growler? Explain its construction and use.

31. Name and explain the various methods which are used for testing poles for correct polarity. Draw diagrams to illustrate.

32. List some of the reasons why a split-phase motor may fail to start. Explain each reason.

33. Explain three practical tests for determining whether the starting winding has an open circuit.

34. (a) What is meant by "end play"? (b) What is its cause and how can it be remedied? (c) How much end play can be allowed in a split-phase motor?

35. Explain and diagram the "overload device" that is used to some extent on split-phase motors.

36. (a) Show how the overload device is connected in the circuit of a split-phase motor. (b) What troubles may occur in this device and how would you remedy them?

37. (a) Explain how a motor is tested for bearing troubles. (b) How are sleeve and ball bearings removed and new ones put in?

38. (a) What troubles could worn bearings cause in a motor? (b) How would you detect that these troubles are due to worn bearings?

39. What is meant by a "reamer"? Name several kinds and explain the purposes of each.

40. Give several reasons why a motor may run slower than its normal speed. Explain each reason.

41. (a) Explain several methods of testing for loose rotor bars in a motor. (b) How would a motor with this defect operate?

42. List and explain the conditions that may cause a motor to run too noisily.

43. How can you tell which two leads belong to the starting winding and which two leads to the running winding, assuming that the leads cannot be traced to their respective windings?

44. What information is usually found on the name plate of a motor? Explain each item.

45. When a defect in the winding of a split-phase motor causes it to run at lower-than-normal speed, or not at all, describe in detail the procedure used in diagnosing the trouble and the steps recommended to correct the fault.

CHAPTER 2

Capacitor Motors

1. (a) Give a general description of a capacitor motor. (b) What are its characteristics and uses? (c) How does it differ from a split-phase motor?

2. (a) Explain the construction of a paper capacitor, an oil-filled capacitor, and an electrolytic capacitor. (b) In what ways do they differ from each other and for what purpose is each used?

3. (a) How are capacitors rated? (b) What precautions must be taken in the use of each? (c) How would you go about ordering a new one?

4. (a) Name the main parts of a capacitor-start motor and give the function of each. (b) Draw a diagram showing the construction of each part.

5. (a) What type of capacitor is generally used on a capacitor-start motor? (b) What difficulties might be encountered if another type of capacitor were used? Explain.

6. Draw straight-line and circular diagrams of a four-pole capacitor-start motor. Show arrows under each group to indicate the direction of the flow of current.

7. (a) Draw a circular diagram of a six-pole, two-circuit capacitor-start motor. (b) What will be the approximate speed of this motor if the frequency is 60 cycles? 50 cycles?

8. (a) Draw a diagram of a capacitor-start motor with an overload device in the circuit. (b) Explain the operation of this circuit.

9. (a) What troubles may be encountered in a capacitor-start motor in which the overload device is defetcive? (b) What procedures are recommended to determine the exact nature of the defect?

10. (a) Explain and diagram the operation of a magnetically operated switch used to open the starting-winding circuit of a capacitor-start motor. (b) Why is it used instead of a centrifugal switch?

11. (a) What are some of the reasons for manufacturing capacitor motors that will operate on either of two voltages? (b) What is the advantage over single-voltage motors?

12. (a) Describe the construction of a two-voltage motor, with the emphasis on the description of the windings. (b) Explain how the main windings are used as an autotransformer.

13. (a) Sometimes it is necessary to reverse a capacitor-start motor by simply throwing a switch; show how this can be done with a three-pole double-throw knife switch. (b) What will happen if the switch is thrown quickly from one position to the other?

14. (a) What is the principle of operation of an instant-reversal motor? (b) Prepare a connection diagram for this motor and a three-pole double-throw switch. (c) What will happen if the switch is thrown quickly from one position to another?

15. (a) Prepare a diagram for a two-speed capacitor-start motor having two main windings and one starting winding. (b) Explain the operation.

16. What is meant by a single-value capacitor-run motor? By a two-value capacitor-run motor?

17. (a) Draw a simple diagram of a single-value capacitor-run motor. (b) Give several characteristics and applications of this motor. (c) What type capacitor is used with this motor?

18. (a) What is meant by slip in a motor? (b) What does slip depend upon and how can it be controlled?

19. Draw a diagram of a two-speed, six-pole single-value capacitor-run motor connected for high-speed operation. Explain the circuit.

20. (a) Draw a schematic diagram of a three-speed, single-value capacitor-run motor which utilizes the principle of slip for speed control. (b) In what ways is this motor similar to the motor in Question 19?

21. (a) What is meant by a two-value capacitor-run motor? (b) What are some of its characteristics and applications? (c) How does it differ from a single-value motor?

22. Explain the different methods used for obtaining the two values of capacity for a two-value capacitor-run motor.

23. (a) Describe the capacitors which are used on the two-capacitor type of two-value motor. (b) Which type of two-value capacitor motor would you use if you had your choice? Why?

24. (a) Draw a diagram of a two-capacitor type two-value capacitor-run motor and fully describe the circuit and operation. (b) What will happen if the electrolytic capacitor is defective? If the paper capacitor is defective?

25. (a) Draw simple diagrams of a two-voltage two-value capacitor-run motor using a capacitor-transformer unit and a two-capacitor unit. (b) How many leads are brought out of the motor if it is to be externally reversible?

26. (a) Explain how capacitors are tested for short circuits. (b) What would happen if you tried to start a capacitor motor with a shorted capacitor?

27. (a) Describe how to test a capacitor for capacity in microfarads. (b) What effect would a capacitor which has lost some of its capacity have on the starting and running of a capacitor motor?

28. (a) Prepare a diagram showing how to change a two-value capacitor-run motor into a capacitor-start motor. (b) Why would a changeover of this kind be undertaken?

29. Describe the operation of a capacitor motor which has (a) a shorted pole in its running winding; (b) dirty centrifugal switch contacts; (c) an open in one circuit of a two-circuit capacitor motor.

30. What are some of the causes of smoke issuing from a capacitor motor? Explain each cause.

CHAPTER 3

Repulsion-type Motors

1. Name the different types of repulsion motors and give the characteristics and applications of each.

2. (a) What construction features are common to each type of repulsion motor? (b) Describe the different types of commutators used on repulsion motors.

3. (a) Name and describe the main parts of the repulsion-start induction-run motor. (b) Why is this motor so named?

4. Explain in detail the principle of operation of a repulsion-start induction-run motor.

5. (a) Describe the construction and operation of two types of centrifugal short-circuiting mechanisms used on repulsion-start induction-run motors. (b) Why are different types of mechanisms used on different motors?

6. (a) Name the different parts of the brush-lifting type of centrifugal mechanism and prepare a diagram showing the order in which they are placed on the armature. (b) What function does the governor spring have? (c) How is the pressure of the spring varied?

7. What troubles are likely to occur (a) when the short-circuiting necklace becomes dirty and does not make good contact with the commutator? (b) when the brushes do not lift off the commutator?

8. (a) Describe the construction of the stator core and the stator winding of a repulsion-start induction-run motor. (b) How does it differ from that of a split-phase motor?

9. (a) Draw a diagram of the stator connection for a six-pole repulsion-start motor. (b) In making the internal connections how would you make sure that the polarity is correct?

10. (a) Prepare a sketch of the stator winding of a four-pole motor having 24 coils. (b) In winding the stator why is it important that each pole be in exactly the same coils as in the original winding?

11. (a) Explain how to take and record data for the stator winding of a repulsion-start motor. (b) Show a sample data chart. (c) Explain in detail how to wind one pole of the motor of Question 10.

12. (a) What precautions should be taken when replacing commutators on repulsion motors? (b) What information is needed when ordering a new commutator?

13. (a) What data should be taken while stripping an armature of a repulsion-start motor? (b) Show a data chart with sample data. (c) Why is it necessary to record the name-plate data?

14. (a) Describe a step-by-step procedure for winding an arma-

ture for a repulsion-start motor. (b) What advantage is there in putting bottom leads into the commutator as each coil is wound, rather than waiting until the entire armature is wound?

15. (a) Show a diagram of six coils of a two-coil-per-slot lap-wound armature connected to a commutator. (b) Repeat for a wave-wound armature.

16. (a) How are armatures with cross-connections tested for short circuits? (b) Explain why a growler short-circuit test cannot be used. (c) Where are short circuits likely to occur in this armature and what steps would you take to eliminate them in each case?

17. (a) Explain the formula for determining the commutator pitch for a wave-wound armature. (b) Give several examples of how to find the pitch. (c) Why don't wave-wound armatures have cross connections?

18. (a) Show by diagram why the rotation of a repulsion-start motor can be reversed by shifting the brushes. (b) How do you determine the amount of shift necessary?

19. (a) What is meant by the neutral point in a repulsion-start motor? (b) How is this point located? (c) Why is it necessary sometimes to locate the neutral point? (d) What is the false neutral point and how is it recognized?

20. (a) What would happen if there were an open between brush connections? (b) Will the operation of the motor be affected if the brush holders are grounded in a repulsion-start motor? Why?

21. (a) How does the repulsion motor differ from the repulsion-start induction motor? (b) How can you recognize the difference by inspection?

22. (a) What is a compensating winding and how is it connected in the circuit? Illustrate in a diagram. (b) Why do some repulsion motors have a compensating winding?

23. (a) Show a diagram of a four-pole compensated-repulsion motor; a two-pole motor; a six-pole motor. (b) What factors regulate the speed of these motors?

24. (a) How can the repulsion-induction motor be distinguished from the other types of repulsion motors? (b) Is this possible just by inspection? Why?

25. (a) What are some of the reasons why a repulsion motor will refuse to start when the switch is closed? (b) Explain how current will flow in the motor if the brushes are not connected to the line.

26. How many line wires are used for a repulsion motor? (b) for a single-phase motor?

27. (a) Explain why the wrong brush-holder position may prevent a repulsion-type motor from starting. (b) How do you determine the correct position of the brushes? (c) What will happen if the brushes are not moved sufficiently?

28. (a) What effect will worn bearings have on the operation of a repulsion-type motor? (b) How are worn bearings detected? (c) Explain how they are removed and replaced.

29. (a) How will a dirty commutator affect the operation of a repulsion-start induction-run motor? (b) How will it affect the other types of repulsion motors?

30. (a) Describe the operation of a repulsion-start induction motor that has a defective governor spring. (b) How do you determine the correct spring tension?

31. Of all the single-phase motors that you have studied, which in your opinion has the highest starting torque? the lowest starting torque? Explain your answer.

32. (a) What are some possible troubles if a repulsion-type motor does not start when the switch is put on? (b) if it blows a fuse when the switch is put on?

33. (a) List several causes of sparking at the commutator in a repulsion-start induction motor. (b) What procedure would you follow to determine the exact cause of sparking?

34. (a) Draw a diagram of a dual-voltage eight-pole stator of a repulsion-induction motor. Show connections for both voltages. (b) How do you identify the four leads coming out of the motor in order to make the right connection?

35. If you were called upon to repair a repulsion-start induction motor which has stopped running, list the steps you would take in order to put the motor into running condition.

CHAPTER 4

Polyphase Motors

1. (a) What is meant by a polyphase motor? (b) Describe the general construction of a polyphase motor, listing and illustrating the main parts.

2. (a) Give some of the characteristics and applications of a three-phase motor. (b) What advantages does this motor have over a split-phase motor?

3. (a) Describe briefly the operation of a three-phase motor. (b) How many windings does this motor have? (c) Show by a single diagram how these windings are connected.

4. (a) Name at least eight steps involved in rewinding a three-phase motor. (b) How would you know that the motor needs rewinding?

5. (a) What information is needed when recording data for rewinding? (b) Show a data sheet for polyphase motor.

6. (a) Show a diagram of the slot assembly and coils of a portion of a three-phase stator. (b) How many coil sides are in each slot?

7. (a) What is a gang winding? (b) Why is this winding used? (c) Prepare a diagram of a four-coil gang winding.

8. (a) What is meant by a diamond coil? (b) Draw this coil and explain why this type of coil is used on most medium-sized polyphase motors.

9. (a) Describe how a coil is taped. Diagram. (b) Why are the coils in some motors taped? (c) What is meant by half lap? full lap?

10. (a) What are the two main types of three-phase windings? (b) Explain how these windings are connected and show a simple diagram of each.

11. (a) How is the number of coils in each pole found? (b) Find the number of coils in each pole of a two-pole, 24-slot motor; a four-pole, 36-slot motor; and a six-pole, 48-slot motor.

12. (a) Explain what is meant by a pole-phase group. (b) Illustrate a four-coil group. (c) Why is phase-group insulation needed?

13. (a) How do you determine the number of groups in a three-phase motor? (b) How many groups are there in a three-phase, six-pole motor? in a three-phase, eight-pole motor? in a two-phase, two-pole motor?

14. (a) Outline the procedure in making the internal connections of a three-phase star-connected motor. (b) Determine the number of groups, the coils per group, coils per phase and coils per pole, assuming a 24-slot single-circuit, four-pole motor.

15. Draw a straight-line diagram of a two-pole, single-circuit, star motor showing groups only. Show the direction of current flow in each phase.

16. (a) Draw a circular diagram of a single-circuit, six-pole, star-connected motor. (b) How can you tell by inspecting the diagram that it is connected properly?

17. (a) Describe the procedure in connecting the phases of a delta-connected three-phase motor. (b) How does this differ from a star-connected motor?

18. Draw a diagram showing the connections of a six-pole, single-circuit delta motor. Show all coils and current direction in all groups.

19. (a) Make a circular diagram of a four-pole, series delta motor. (b) Explain how the current in each phase is traced.

20. Draw schematic diagrams of the following: two-, four-, six-pole series star; two-, four-, and six-pole series delta.

21. Explain what is meant by a two-parallel or two-circuit connection and show the difference between this and a series connection by means of schematic diagrams.

22. (a) What procedure is used to determine the type of connection already in a three-phase motor for which data are to be taken? (b) What is wrong with just tracing the circuit through each phase in order to determine the connection?

23. Give several specific examples of how you would identify a parallel-star and parallel-delta winding prior to stripping a three-phase motor.

24. (a) How would you go about determining the number of poles in a three-phase motor? (b) Describe several methods for doing this. (c) Why is this information and that of Question 23 necessary when data are being taken?

25. (a) Why are many motors made so that they can be connected for either of two voltages? (b) What is meant by a dual-voltage motor? (c) How can you recognize a motor as being a single- or two-voltage motor?

26. Draw a straight-line diagram of a four-pole, two-voltage star-connected motor. Number the leads and show the connections for low and high voltage.

27. Assuming nine leads coming from a two-voltage, three-phase motor, how can you tell which is which in order to connect for either voltage? Explain.

28. (a) Explain the difference between short and long jumpers. (b) Give diagrams of both. (c) Why should one be used in preference over the other and what other names are given to these connections?

29. (a) What factors govern the speed of a three-phase motor? (b) Give the formula to determine the speed of an induction motor. (c) Diagram several examples using this formula.

30. (a) What is meant by a consequent-pole connection? (b) Explain the principle involved in this connection. (c) Draw a diagram showing how consequent poles are formed.

31. (a) Show a straight-line diagram of a four- and eight-pole constant-torque motor. Show how many leads are brought from this motor. (b) Make the external connection for high speed and trace out the circuit. Place current-direction arrows under each group.

32. (a) What is meant by odd grouping? (b) Why do some motors have odd grouping? (c) Show by diagram how the number of coils for each group in an odd-grouped motor is determined and show the grouping for a three-phase, eight-pole, 36-coil motor.

33. (a) How does a two-phase motor differ from a three-phase motor? (b) What advantage has one over the other? (c) Describe the construction of a two-phase motor. (d) Show a schematic diagram of a four-pole, single-circuit, two-phase motor.

34. Explain how to determine the number of groups in a two-phase motor. How are the number of coils-per-group found? Compute these for a two-phase, six-pole, 36-coil motor.

35. (a) Show a circular diagram of a six-pole, two-phase, single-circuit motor. (b) Show the direction of the flow of current in each group of a two-phase motor. (c) What is the rule for the direction of arrows in each group?

36. (a) Name and describe several methods for converting a two-phase motor to a three-phase motor. (b) Why are many two-phase motors changed to three-phase?

37. (a) Describe in detail and show by diagram how to reconnect a two-phase motor to a three-phase star motor. (b) What would happen if some coils were not removed from the circuit in this reconnecting operation?

38. (a) Describe the procedure in rewinding a two-phase motor to operate satisfactorily on three-phase current. (b) Explain how you arrive at different wire size and number of turns.

39. (a) On what voltage should a three-phase motor operate if it is changed from a star to a delta motor? Assume a 220-volt star motor. (b) Explain how you arrived at the result.

40. What changes are necessary when a three-phase motor is rewound for a different voltage? Assume a three-phase, single-circuit star, 220-volt motor having 36 coils, 30 turns of No. 18 magnet wire to be rewound to operate on 440 volts. Make all computations.

41. (a) Explain in detail how to change the speed of a three-phase motor by reconnecting the winding. List a step-by-step procedure for doing this. (b) Explain why a speed change by this method is not always possible.

42. (a) Explain how to change the speed of a three-phase motor by rewinding it. (b) How is the new size wire and number of turns computed?

43. (a) Show by means of diagrams how a two-phase and three-phase motor are reversed. (b) How is a two-phase, three-lead motor reversed?

44. (a) Explain and make a diagram to show how a three-phase motor is tested for grounds. (b) Where are grounds most likely to occur? Explain some of the reasons why the winding becomes grounded.

45. (a) Explain how to locate an open in a three-phase motor. (b) Explain what you would do if an open coil could not be closed.

46. (a) Why won't a three-phase motor start if one phase is open? What will happen if one phase opens while the motor is running?

47. (a) Explain how short circuits in a three-phase winding are found. (b) How do you know when a three-phase motor is shorted? (c) How would you repair a three-phase motor if just one coil is

found to be shorted? if one group is shorted? if an entire phase is shorted?

48. (a) What may be some of the sources of trouble in a polyphase motor if it fails to start when the switch is thrown? (b) Explain each defect.

49. (a) What effect will worn bearings have on the operation of a polyphase motor? (b) Explain how to test for worn bearings.

50. (a) What is meant by "single phasing"? (b) How can you tell that a three-phase motor is "single phasing"? (c) What harm will there be in a three-phase motor if it runs this way?

51. (a) List and explain the troubles that may cause a polyphase motor to run excessively hot. (b) What effect will this heat have on the winding?

CHAPTER 5

Alternating-current Motor Control

1. (a) What is the function of a starter or controller? (b) Why is it necessary to have starters in most installations? (c) Name the main types of starters used for a-c motors.

2. (a) Explain what is meant by an "across-the-line" starter. (b) Name several applications for this type of starter. (c) What characteristics of the motors make it possible to use "across-the-line" starters?

3. (a) Why is it necessary to have reduced-voltage starters for some motors? (b) Give several specific applications where this type of starter would be necessary.

4. (a) Show a simple diagram of a pushbutton switch starter and explain its operation. (b) For approximately what size motors are these starters used and why?

5. Explain the operations of and diagram several types of thermal overload devices commonly used on pushbutton switch starters.

6. (a) Explain the construction of the holding coil on a magnetic across-the-line starter. (b) Why is the shading coil needed?

7. (a) What are the advantages of a magnetic across-the-line starter over a manual across-the-line starter? (b) Explain why these advantages are important.

8. (a) Describe the construction of a simple start-stop pushbutton station. (b) Explain the operation of a station having three contacts; four contacts.

9. (a) Explain how a start-stop pushbutton station should be connected to a magnetic switch. (b) Show a diagram of this connection. (c) How many wires should there be between station and starter?

10. (a) Show by a diagram the connection for a start-stop station to a magnetic switch to control a three-phase motor. (b) Explain the operation and trace out the circuit.

11. Explain the reaction of the starter if the maintaining contacts do not close when the start button is pressed.

12. (a) Connect two start-stop stations to control a three-phase magnetic switch. (b) How are the maintaining contacts always connected? (c) How should the stop buttons be connected? (d) How should the start buttons be connected?

13. (a) What is meant by jogging or inching a motor? (b) Give several applications where jogging is used.

14. (a) Draw a diagram of a three-phase magnetic starter connected to a station having a jog button. (b) Explain the operation of the starter when the jog button is pressed.

15. (a) What is the purpose of a pilot or indicating lamp on a start-stop station? (b) Show how it is connected in the circuit.

16. (a) What is a reversing magnetic starter? (b) Give some applications for which a starter of this type is used.

17. (a) Explain the construction and operation of a reversing magnetic starter. (b) Show a diagram of this starter. Label all parts and explain their function.

18. (a) Connect a magnetic-reversing, three-phase starter to a forward-reverse-stop station, and explain the circuits when each button is pressed. (b) What is likely to happen if the reverse button is pressed while the forward contacts are in?

19. (a) What is meant by a mechanical interlock as used in a reversing starter? (b) Give a specific example of how a mechanical interlock is used to prevent the forward and reverse contacts from operating at the same instant.

20. (a) Draw a diagram of a reversing magnetic starter connected to forward-reverse-stop station having an electrical interlock. (b) Trace each circuit and explain how the interlock operates.

21. (a) Why must some a-c motors be started with reduced voltage? (b) Give the names of several starters that start motors at a reduced voltage.

22. (a) What is a primary-resistance starter? (b) Describe the construction and operation of a primary-resistance starter of the manual type. (c) Show this type connected to a three-phase motor.

23. (a) Describe the construction and operation of an automatic primary-resistance starter. (b) Connect this starter to a three-phase motor and explain the circuit when the start button is pressed.

24. (a) What is the purpose of the definite-time mechanism used on the automatic primary-resistance starter? (b) How does it operate? (c) How is the time interval changed on these devices?

25. (a) Draw a diagram of a secondary-resistance starter and label all parts. (b) Explain its principle of operation.

26. (a) Show a three-phase slip-ring motor connected to a secondary-resistance starter. (b) Explain the circuit and operation. (c) Describe the construction of a three-phase slip-ring motor and its principle of operation.

27. (a) Show by diagram how an automatic secondary-resistance starter is connected to a three-phase slip-ring motor. (b) Explain how the timing mechanism operates.

28. (a) What is a three-phase autotransformer starter? (b) What is a three-phase compensator? (c) What advantage does a compensator have over a resistance starter? (d) Give some applications of this starter.

29. (a) Diagram the construction and principle of operation of a three-phase compensator. (b) Why are three transformers used?

30. (a) Show a diagram of a three-phase compensator connected to a three-phase motor. (b) Explain the sequence of operation.

31. (a) What is the purpose of having the contacts of a compensator immersed in oil? (b) What would happen if one transformer should open while the motor is running? (c) List and explain some of the things that may go wrong with a compensator.

32. (a) What is the purpose of the holding coil in a compensator? (b) How is it connected? (c) How many connection terminals does a three-phase compensator usually have? (d) How are they marked? (e) How do you go about ordering a compensator for a new installation?

33. Describe briefly an automatic compensator, and explain its advantage over the manual type.

34. (a) Explain the star-delta method of reduced-voltage starting. (b) How many wires must be brought out of a motor started in this way? (c) What are these wires connected to inside the motor?

35. (a) Connect a three-phase motor so that it can be started star and run delta. Use a three-pole double-throw switch. (b) Trace out and explain the circuit.

36. (a) Show diagrams of a small drum switch operating a three-phase motor; capacitor motor; split-phase motor. (b) Where are these drum switches used?

37. (a) What types of two-speed starters are in common use? (b) What applications require the use of two-speed starters for three-

phase motors? (c) What construction features of the motor permit it to operate on speeds?

38. (a) Connect a two-speed starter to a three-phase motor having two sets of windings. (b) Explain in detail the sequence of operation.

39. (a) What is meant by "plugging" a three-phase motor? (b) How is this accomplished? (c) Why is plugging necessary in some applications?

40. (a) Show a diagram of a starter that uses a plugging relay. (b) Explain the operation of the relay and the entire circuit.

41. What procedure would you follow in locating the source of trouble if a motor does not start when the main contacts of an across-the-line starter close?

42. (a) What may be the trouble if the main contacts of a magnetic starter do not close when the start button is pressed? (b) Explain how you would remedy each trouble.

43. What trouble usually causes a fuse to blow or the overload relays to operate when the start button is pressed?

44. (a) List some other troubles, besides those listed above, which may be encountered in automatic starters. (b) How would you remedy these faults?

CHAPTER 6

Direct-current Armature Winding

1. (a) Show by diagram the construction of a typical armature. Label all the parts. (b) How are the commutator and the laminations placed on the shaft?

2. (a) Name the operations involved in the process of armature winding. (b) Which operations in your opinion are more important than others?

3. (a) By means of simple schematic diagrams show how the coils in an armature are connected to the commutator. (b) How many commutator bars are necessary for an armature with nine coils? Why?

4. (a) Why is it necessary to insulate an armature before winding? (b) Where is the insulation placed? (c) Explain how the insulation should be cut so that the armature will be properly insulated.

5. (a) What is meant by pitch of a coil? loop winding? coil throw? (b) Diagram each.

6. (a) What is meant by lead swing? (b) Show the methods used in determining the position of the leads in the commutator. (c) Why is it necessary to put leads into the correct commutator bars? (d) What effect would an incorrect lead swing have on the operation of a motor?

7. (a) What is meant by a two-coil-per-slot winding? Show in a diagram. (b) In an armature of this type how many slots will there be if the commutator has 18 bars? 36 bars? (c) How many bars should the commutator have if there are eleven slots in the armature?

8. (a) Diagram and explain how you would wind a nine-slot, two-coil-per-slot armature. (b) How many loops will this winding have?

9. (a) Give the names of the two main types of armature windings. (b) In what way do they differ?

10. (a) Define a simplex lap winding and draw a simple diagram of it. (b) Explain the drawing.

11. (a) Explain how duplex and triplex lap windings differ from the simplex winding. (b) Show diagrams of these windings. (c) Which of these windings are most frequently used on small armatures? Why?

12. Show by diagrams several coils of a simplex lap winding that does not have loops and explain how the leads are placed into the commutator bars.

13. Show a circular diagram of a one-coil-per-slot wave winding having 23 slots and a pitch of 1 and 7. Trace the winding through half the coils.

14. (a) What is the difference between a coil winding and a hand winding? (b) Why are these two types of winding used? (c) Can all armatures be hand wound? Explain.

15. (a) What is meant by commutator pitch? (b) Give the formula for determining commutator pitch for a wave-wound armature. (c) Determine the pitch for a 59-bar, four-pole armature.

16. (a) Explain the difference between a progressive and retrogressive winding. (b) What effect has each one on the operation of a motor?

17. (a) What instruments can be used to measure wire size? (b) How is it recorded? (c) What different types of insulation are used on magnet wire?

18. (a) What information should be recorded before an armature is rewound? (b) Show a typical data sheet.

19. (a) Describe how the position of the leads on the commutator may be recorded by marking the commutator and the slots of the armature. (b) Diagram this for a loop, lap, and wave winding.

20. (a) Explain how the leads are soldered in the commutator bars. (b) What precautions should be taken to prevent solder from flowing behind the commutator?

21. (a) What is the purpose of cord and wire bands on armatures?

(b) Describe how cord and steel bands are placed on armatures. Show by a diagram.

22. (a) What is meant by a shorted commutator? (b) Diagram and explain how a commutator is tested for short circuits. (c) At what point during the winding process should the commutator be tested for shorts?

23. (a) Give some of the causes of grounds in a winding. (b) Where do the grounds usually occur? (c) Show by means of a diagram how the winding is tested for grounds.

24. (a) What is a growler? (b) How is a grounded coil located by means of the growler? (c) Explain the construction and operation of a growler.

25. (a) What is meant by a bar-to-bar meter test? (b) Show by diagram how the winding is connected to the line wires for such a test. (c) How is the amount of current flow to the winding controlled?

26. Explain and show separate diagrams of how a grounded coil is removed from the circuit of a loop-, lap-, and wave-wound armature. (b) Why is it necessary to remove a grounded coil from the circuit? (c) Is it always possible to do this? (d) If not, what must be done?

27. (a) Show by diagram the growler hack-saw blade test for a shorted armature. (b) Why can't this test be used on an armature having equalizer connections?

28. (a) Show by diagram the bar-to-bar meter test for locating a shorted coil. (b) Describe how an armature can be tested for shorts by means of the growler-meter method. (c) What precautions must be observed in these tests?

29. (a) Under what conditions is it advisable to eliminate shorted coils from the armature circuit? (b) When is it not advisable? (c) Why is it not always possible to cut out a shorted coil?

30. (a) How does a shorted coil show itself in the operation of a motor? (b) Why is it not advisable to run a motor with a shorted coil for any length of time?

31. (a) Describe and show by a diagram the bar-to-bar meter test for locating an open in an armature. (b) What precautions must be taken with the meter in this test?

32. (a) Describe the bar-to-bar test for a reversed coil in a loop winding. (b) How would you make this test using a growler?

33. (a) Describe how to test for reversed coils in a two-in-hand lap winding and wave winding. (b) How would you remedy this condition when it has been found? (c) What effect does a reversed coil have on the operation of a motor?

34. (a) Describe the construction and function of the commutator. (b) What material is the commutator bar made of? (c) Why must the bars be insulated from the rings?

35. (a) Explain how a commutator is disassembled preparatory

to insulating it. (b) What information must be taken while it is being disassembled? Why?

36. (a) What is a mica V ring? (b) Explain the three methods that can be used to make these rings. (c) Why must heat be used to shape the rings? (d) Can this be done without heating the mica?

37. (a) Describe the complete process of assembling a commutator. (b) What are some of the precautions to be taken while doing this?

38. (a) What is commutator cement and how is it used? (b) How do you go about ordering a new commutator? (c) How can you tell when an armature needs a new commutator?

39. Assuming that the entire commutator has to be reinsulated, how would you go about it when the commutator is connected to a good winding?

40. (a) What is meant by high bars? low bars? (b) What is their cause and how is it remedied?

41. (a) What is a commutator stone? (b) When is it used? (c) What precautions must be observed in using it? (d) Why can't sandpaper be used as a substitute?

42. (a) What is meant by high mica? (b) How is it caused and what is the remedy? (c) What effect will it have on the operation of a motor?

CHAPTER 7

Direct-current Motors

1. (a) Name the main parts of a d-c motor. (b) Describe the construction of each part and give the function of each. (c) Diagram an armature and label each part.

2. (a) Show a simple drawing of a sleeve bearing and an oil ring. (b) What is the purpose of the oil ring? (c) How is oil conducted along the shaft resting in the bearing?

3. (a) Describe and diagram a ball bearing. (b) Why are ball bearings used in some motors and sleeve bearings in others? (c) What advantage has one over the other?

4. (a) What is meant by brush rigging? (b) Why is this movable on some motors and not on others? (c) Why are the brushes insulated from the end brackets?

5. (a) Describe the construction of a series motor and give some of its characteristics and applications. (b) Make a simple diagram of this motor.

6. (a) Describe the construction of a shunt motor and give its characteristics and applications. (b) Show a simple diagram of this motor and explain the circuit. (c) In what ways is this motor different from the series motor?

7. (a) How does the compound motor differ from the series and shunt motors in construction, characteristics, and application? (b) Make a simple diagram of this motor.

8. (a) Describe the method used for winding series-field coils. (b) What is the general construction of the series-field coil? (c) Make a diagram of the form used for winding these coils.

9. (a) Describe in detail how a compound-field coil is wound. (b) Make a diagram of this coil. (c) What precautions must be taken when winding it?

10. (a) What is an interpole field? (b) How is it wound? (c) Why is heavy wire used in its construction?

11. (a) Describe and diagram three methods for testing coils to determine if they have correct polarity. (b) Which of these methods do you prefer? Why?

12. How would you test for correct field-coil polarity while the motor is completely assembled?

13. (a) Make several diagrams of a shunt motor. (b) Explain the circuit and trace out the connections.

14. (a) Draw a diagram of a two-pole compound motor. (b) Show arrows on all connecting wires to indicate the direction of current flow in the field poles.

15. (a) Name four different types of compound motors in general use. (b) Which one is mostly used in industry? Why?

16. Draw the following diagrams: (a) two-pole, long-shunt cumulative motor; (b) two-pole, long-shunt differential motor; (c) two-pole, short-shunt cumulative motor; (d) two-pole, short-shunt differential motor.

17. What is an interpole? What purpose does it serve in a motor? How many interpoles are there in a four-pole motor?

18. Draw the poles of a two-pole interpole motor showing the polarity of all the poles, assuming main pole polarity and counterclockwise rotation.

19. Draw a simple diagram showing how interpoles are connected in a motor.

20. Draw the same diagram as in Question 18 for a four-pole interpole motor.

21. (a) Describe the procedure for connecting a two-pole, cumulatively connected, compound-interpole motor for a proper polarity, assuming main pole polarity and counterclockwise rotation. (b) Diagram to show the direction of current in each field coil.

22. (a) How is the direction of rotation of any d-c motor re-

versed? (b) How is a series motor reversed? (c) Diagram to show how a series motor is reversed.

23. (a) Show by diagram how an interpole motor is reversed. (b) What precautions must be taken in reversing an interpole motor?

24. Draw a diagram of a six-pole compound-interpole machine showing the polarity of all the poles and show how this motor is reversed.

25. (a) List some of the tests that should be given to a motor before it is installed. (b) Which of these tests do you consider the most important? Why?

26. (a) Explain and diagram the procedure for making a ground test on a motor. (b) What is meant by a ground?

27. (a) Show by means of a diagram where grounds in a field coil are most likely to occur. (b) When a ground is indicated in the field of an eight-pole motor, show how to find the coil in which the ground is located. (c) What would happen if the series and shunt field of a compound motor were grounded?

28. (a) Why must permanently installed motors be grounded to earth? (b) Find the section referring to this in the electrical code.

29. (a) How are shunt motors tested for open circuits? Where are these opens usually located? (b) What would happen if the field should open while the motor is running? when the motor is started?

30. (a) What markings are usually put on the leads of a compound motor? (b) Why are these markings necessary?

31. (a) How are the six leads of a compound motor identified when the markings are missing? (b) Give the procedure in making this test.

32. (a) How are the leads of a compound motor identified when only five wires are brought out of the motor? (b) Will it be necessary to open the motor for this test? Why?

33. (a) Give the steps in testing a compound motor to determine whether it is connected cumulatively or differentially. (b) What difference will it make in the operation of a motor?

34. (a) Describe one method of locating properly the brush holders in the neutral position for an interpole motor and a noninterpole motor. (b) Why will the wrong location cause the armature to spark?

35. (a) Describe three other methods for setting the brushes on neutral. (b) Which of these methods would you use? Why?

36. (a) With what pressure should carbon brushes press against the commutator? (b) How is this pressure measured? (c) What effect will improper pressure have on the operation of the motor?

37. (a) How are brushes made to fit the curvature of the commutator? (b) Why are different grades of brushes used on different motors?

38. (a) What are some of the causes of open circuits in the armature circuit of a d-c motor? (b) Explain how to locate the open.

39. (a) What is meant by a motor "running away"? (b) What is the usual cause of this and how can it be prevented?

40. (a) What are some of the symptoms of a shorted armature in the operation of a motor? (b) What will the consequences be if a motor is allowed to run this way?

41. (a) Assuming that a motor with one or two shorted coils had to be put into operation very quickly, what would you do? (b) What would you do if two or more commutator bars were shorted?

42. (a) How does an open armature coil manifest itself while the motor is running? (b) How can you locate the open by inspecting the commutator?

43. (a) Name some of the conditions that may cause armature opens and explain how you would effect a repair. (b) How would you know that the open is repaired?

44. What importance has the name-plate data on a motor?

45. Explain what is meant by counter electromotive force.

46. Explain why a series motor must always run with a load.

47. (a) What are some of the reasons for sparking at the commutator? (b) Explain why each of these causes produces sparking and give the remedy for each.

48. (a) Why will incorrect lead swing cause sparking at the brush? (b) What other effect will this have on the motor?

49. (a) What is meant by high bars? low bars? (b) To what are these conditions due and how are they remedied?

50. Describe some of the defects that may cause a motor to run noisily.

51. (a) How is a motor tested for defective bearings? (b) Describe how sleeve and ball bearings are removed and then replaced.

CHAPTER 8

Direct-current Motor Control

1. (a) Name some of the functions of a starting box and controller. (b) What is the difference between the two? (c) Why is it necessary to use these devices?

2. Explain why a small motor can be started by placing full voltage across it while large motors must be started with reduced voltage.

3. (a) Describe the construction and operation of a three-point starting box. (b) Draw a diagram of all its internal connections and label all parts. (c) Why is it called a three-point box?

4. (a) Why is the holding coil of a three-point box called a no-field release? (b) What is the function of the holding coil? (c) How are the terminals of the box marked?

5. (a) Show a diagram of a three-point starting box connected to a compound motor. (b) Explain this circuit.

6. (a) Describe the construction and operation of a four-point starting box. (b) Draw a diagram of the internal connections of this box. Label all parts.

7. (a) Why is the starting box in Question 6 called a four-point starting box? (b) What are some of the essential differences between a three-point and a four-point starting box? (c) What are the reasons for using a three-point box on some applications and a four-point box on others?

8. (a) What is the function of the holding coil on a four-point box? (b) Why is this coil called a no-voltage release coil?

9. (a) Draw a diagram of a four-point starting box connected to a shunt motor; to a compound motor. (b) Trace out and explain the circuit.

10. (a) What is a speed-regulating rheostat? (b) Make a connection diagram of a four-point, speed-regulating rheostat. (c) Describe its operation. (d) Where would you use a rheostat of this kind?

11. (a) What is meant by a combination four-point starting box and speed-regulating rheostat? (b) Show by means of a diagram the internal wiring of this device and explain fully how it operates. Label and describe its various parts.

12. Connect a double-pole, double-throw switch in the armature circuit of a shunt motor; in the field circuit of a shunt motor; in both instances. Explain the circuits.

13. (a) Diagram to show a two-pole, compound-interpole motor with a double-pole, double-throw switch connected in the armature circuit for reversing. (b) What precaution must be taken in reversing this motor? Why?

14. By means of a double-pole, double-throw switch, reverse a shunt motor connected to a three-point starting box. Explain exactly how you would start and stop this motor.

15. Draw a diagram of a four-point starting box connected (a) to a shunt motor and use a double-pole, double-throw switch for reversing; (b) to a compound motor and use a double-pole, double-throw switch for reversing.

16. (a) Show a sketch of the external appearance and internal construction of a small drum-type switch. (b) Show all contacts, label all parts, and explain the operation. (c) What is this switch used for?

17. (a) What is an overload relay? (b) Show by diagram several devices that can be used to protect a motor from overloads. (c) How can you tell that a motor is overloaded?

18. (a) Show a simple sketch of a magnetic circuit breaker and explain its construction and operation. (b) Why is this device used?

19. (a) Explain with a diagram the construction and operation of a thermal relay. (b) What is the difference between a thermal relay and an overload relay? (c) What troubles can develop on a thermal relay?

20. (a) Explain what is meant by a pushbutton station and show a sketch of a station having a start-and-stop button. (b) Why is a pushbutton station used?

21. (a) Draw a diagram of a magnetic switch and small d-c motor connected to a start-stop pushbutton station. (b) Trace out and explain the connection fully. (c) Show an elementary diagram of this connection.

22. Explain what may be the trouble when the magnetic switch does not stay closed when the finger is removed from the start button.

23. What is the purpose of using several start-stop stations to operate one magnetic switch?

24. (a) Explain the use of a jog or inch button in a pushbutton station. (b) Show all the contacts in a station having a start, a jog, and a stop button.

25. (a) Draw a diagram of a start-jog-stop station connected to a magnetic switch to operate a small motor. (b) Explain the circuits when each button is pressed. (c) Show one elementary diagram of this connection.

26. (a) What may be the trouble if the magnetic switch does not operate when the jog button is pressed? (b) Explain.

27. (a) Why is resistance needed in the motor circuit in order to start a medium-sized or large-sized motor? (b) What will happen if the motor is started without resistance? Why?

28. (a) Explain the principle of the counter electromotive force controller. (b) Give an application of this controller.

29. (a) Show a diagram of a counter electromotive force controller with one step of resistance connected to a compound motor. (b) Explain the operation of this circuit.

30. (a) What is a lockout controller? (b) Why is it called by this name? (c) Why is it also known as current-limit starter? (d) Where would this type of controller be used?

31. (a) Connect a two-coil lockout controller with one step of

resistance to a compound motor. (b) Explain the operation of the circuit.

32. Show in a diagram a two-coil lockout controller with two steps of resistance connected to a compound motor. Show the complete circuit with magnetic switch and start-stop station.

33. (a) Diagram a single-coil lockout contactor. (b) Explain the principle of operation of this contactor. (c) What is the difference between this and the two-coil lockout contactor?

34. (a) Draw a wiring diagram of a single-coil lockout controller with one step of resistance connected to a compound motor. (b) Explain the operation.

35. (a) What is meant by a definite magnetic time controller? (b) Explain the principle of operation of this type of controller. (c) Diagram one of these controllers and label the parts.

36. (a) Draw a diagram and explain the circuit of a definite magnetic time starter connected to a compound motor. (b) Show also an elementary diagram of this starter.

37. (a) What advantages does this starter have over the lockout type of starter? (b) Why do you consider these advantages?

38. (a) Show in a diagram what is meant by dynamic braking. (b) Why is dynamic braking needed in many instances? (c) Give several instances where it is necessary.

39. Draw a diagram of a definite magnetic time controller equipped with dynamic braking.

40. (a) List and explain as many troubles as you can which may cause a definite magnetic time starter to function improperly. (b) How do you regulate the time element in this starter?

41. Explain the difference between a definite magnetic time starter and a definite mechanical time starter.

42. (a) Describe by means of a diagram a definite mechanical time controller using dashpot acceleration and explain the operation. (b) Explain the operation of a dashpot.

43. (a) What are some of the things that may go wrong with the controller of Question 42? (b) Explain each trouble and the remedy for it.

44. Show a typical diagram of a simple type of drum controller and describe the circuit when the handle is at the first point of acceleration. Assume this controller is used with a compound motor.

45. A manufacturer desires to use a five-horsepower compound motor to operate a machine in his factory. The motor is to be operated from two places. How would you determine the type of controller to be used and how would you order it?

46. (a) Describe some of the troubles which occur on three- and four-point starting boxes. (b) Explain how you would detect and remedy these troubles.

CHAPTER 9

Universal, Shaded-pole, and Fan Motors

1. What is a universal motor? Name some of its characteristics and applications.

2. (a) Name and describe the main parts of a universal motor. (b) Show simple sketches of each part. (c) How would you proceed in taking apart a universal motor for repairs?

3. (a) Explain the operation of a universal motor. (b) What characteristics of construction make it possible to operate on either alternating or direct current?

4. (a) What procedure should be followed when it is necessary to rewind the field coils of a universal motor? (b) How do you determine the size of wire to use? (c) Do you count the number of turns in each field or do you weigh the coil for rewinding? Why?

5. (a) Explain by means of a diagram how to make a form for winding field coils. (b) How are the right measurements for making the form obtained? (c) What would happen if the form were made too small? too large?

6. (a) Show by diagram how to reverse the direction of rotation of a universal motor. (b) Is it always necessary to take the motor apart to reverse it? Explain.

7. (a) Why does severe sparking generally occur when the rotation is reversed on some types of universal motors? (b) How can the sparking be eliminated?

8. Name and explain some important features that are common to all universal motors.

9. (a) What information must be recorded before an armature can be rewound? (b) Draw a chart with a sample recording. (c) What might be the result if the wrong information is recorded?

10. (a) Describe in detail how to determine the correct lead throw on a small armature. (b) What would happen if the armature was rewound with wrong lead throw? Why?

11. (a) Describe how to determine correct lead throw by using a growler. (b) What are some other functions of a growler?

12. (a) What precautions should be taken with respect to the position of the leads in the commutator? (b) What would happen if the leads are placed one or more bars out of the way?

13. (a) What is meant by a compensated universal motor? (b) Describe the single-field compensated universal motor.

14. (a) Describe the two-field compensated universal motor. (b) What function does the compensating field serve in this motor?

15. (a) What precautions should be taken when stripping the stator of a compensated universal motor? (b) List all the information that should be recorded.

16. (a) Describe briefly how the stator of a compensated universal motor is rewound. (b) Why is the compensating winding located 90 electrical degrees from the main winding?

17. Diagram and explain the layout of the coils of a two-field compensated universal stator having four poles and 24 slots.

18. Show by diagram how the speed of a universal motor may be regulated by using a variable resistance in the motor circuit.

19. (a) How may different speeds be obtained by tapping one field of a universal motor? (b) Explain the principle of operation of this type of speed control.

20. (a) Explain how speed may be controlled by means of a centrifugal device. (b) Diagram and explain the circuit.

21. (a) What are some of the troubles that may cause a universal motor to spark excessively? (b) Explain and give a remedy for each trouble.

22. List as many troubles as you can that may cause the universal motor to (a) run hot; (b) to smoke; (c) to have poor torque.

23. When a universal motor runs slower than it should, it is an almost certain sign that it is defective. Explain how you would diagnose the trouble of such a motor and repair it.

24. (a) Explain the principle of operation of a shaded-pole motor. (b) What is the purpose of the shaded coil? What will happen to the operation if the shading coil opens?

25. (a) Show a connection diagram of a six-pole shaded-pole motor. (b) How do you test for correct polarity? (c) Why isn't it necessary for the shaded coils to be insulated from ground?

26. (a) What precautions should be taken in rewinding the field coils of shaded-pole motors? (b) Some shaded-pole motors have an iron bridge between pole pieces. What is this for?

27. (a) Show by diagram how a shaded-pole motor is reversed. (b) How can you tell just by looking at the stator in which direction the motor will rotate?

28. (a) What may be some of the reasons for a shaded-pole motor failing to start? (b) Why is it particularly important that the bearings of a shaded-pole motor be in perfect condition?

29. (a) Explain how a shaded-pole motor is tested for grounds, short circuits, opens. (b) Describe how you locate and eliminate all of these defects.

30. List the possible troubles of a shaded-pole motor when it runs too hot; when it has very poor starting torque.

31. (a) Make a connection diagram of a two-speed, split-phase fan motor having two running windings and one starting winding.

(b) How many leads are brought out of this motor? (c) How can you tell which is the correct lead for connecting?

32. (a) Show by diagram the connections of a two-speed split-phase motor having one running and one starting winding. (b) Explain how two different speeds are obtained from this motor. (c) Explain the principle of consequent connections.

33. Many split-phase fan motors have a transformer in the base of the stand to control the speed. Show by means of a diagram how this transformer is connected to the motor.

34. Many fans are driven by capacitor motors and are controlled for speed by means of a transformer, as in the case of the motor in Question 33. Show how three different speeds can be obtained from this connection.

35. Explain with a diagram how the speed of a shaded-pole motor is varied.

36. (a) What is meant by a basket winding? (b) Diagram this type of winding.

CHAPTER 10

Direct-current Generators; Synchronous Motors and Generators; Synchros; Electronic Control of Motors

1. (a) What is the difference between a motor and a generator? (b) Since both look alike, how can you identify them?

2. (a) How are d-c generators rated? (b) List all the information generally found on a generator name plate.

3. (a) Describe the construction of a d-c generator. (b) How does it differ from that of a d-c motor?

4. (a) Show by a simple sketch how a potential is induced in a conductor when it cuts lines of force. (b) Explain the principle involved.

5. What factors will cause a change in the amounts of voltage generated in a d-c generator? Why?

6. (a) How can the direction of the generated voltage be changed? (b) Explain your answer.

7. (a) What are the three essentials necessary to cause a voltage to be generated? (b) Explain why each of these is necessary.

8. (a) Name several ways of producing the flux necessary in the generation of electricity. (b) How is the direction of this flux changed?

9. (a) What is meant by a separately excited generator? a self-excited generator? (b) Diagram each one.

10. (a) Explain in detail the operation of a self-excited generator. (b) Explain what is meant by the "building-up process."

11. (a) Explain with a diagram the connection and operation of a self-excited series generator. (b) What happens to the generated voltage when load is added or taken away?

12. (a) Show a diagram of a self-excited, shunt generator and explain its operation. (b) What are the characteristics of this generator?

13. (a) Describe the most common type of compound generator. (b) Show a diagram of this generator and describe its operation.

14. (a) What is meant by an over-compounded generator? flat-compounded generator? under-compounded generator? (b) Describe the characteristics and uses of each.

15. How would reversed interpole polarity affect the operation of an interpole generator? Explain.

16. How does direction of rotation affect the operation of a d-c generator?

17. It is necessary sometimes to change a compound motor to a compound generator. Show with a diagram how this is accomplished.

18. (a) What kind of device is used to regulate the voltage generator? (b) How is it connected in the circuits? Explain how it is used in the circuit.

19. (a) What is an ammeter? voltmeter? (b) Show by diagram how both of these are connected in a generator circuit. (c) What is an ammeter shunt?

20. What is meant by paralleling generators and why is it done?

21. In order to connect two generators in parallel, what three conditions are necessary? Why?

22. (a) What is an equalizer connection? (b) What is the reason for having this when two generators are paralleled? (c) Explain with diagram.

23. (a) Draw a diagram of two compound generators in parallel. (b) Explain all the connections.

24. (a) If a generator refused to generate, what troubles would you suspect? (b) How would you remedy them?

25. Why would wrong field-pole connections prevent a generator from building up?

26. (a) What may be some of the troubles if the voltage does not build up completely? (b) How do you proceed to locate the fault?

27. (a) How is the neutral point of the brushes located in a compound interpole generator? (b) How would you know that you have the correct position?

28. (a) What would cause the armature to spark while the generator is operating? (b) Give remedies for each of the troubles.

29. What are some of the characteristics and uses of a synchronous motor?

30. (a) Describe and diagram the construction of a synchronous motor. (b) What methods are used to excite it?

31. (a) What is an amortisseur winding? (b) What purpose does it serve? (c) In what type of motor is it used?

32. Show a complete connection diagram of a synchronous motor having external excitation.

33. (a) Describe the construction of a synchronous motor with a rotor that is not externally excited. (b) Explain its operation. (c) What happens if you overexcite or underexcite the rotor field?

34. (a) What types of motors do electric clocks use? (b) Describe two of these types and explain their operation.

35. What troubles are usually encountered on clock motors and how are these troubles remedied?

36. Show a complete wiring diagram of a synchronous generator and explain its operation.

37. What effect will varying the exciting currents have on a synchronous generator?

38. Explain with diagram the "all dark" and "one dark and two bright" methods of synchronizing two alternators.

39. What would happen if the synchronizing switch is closed when the lamps of the "all dark" method are not entirely dark?

40. (a) Explain what is meant by a "synchro." (b) Explain its use and characteristics.

41. (a) In what way does a synchro resemble a synchronous generator? (b) How do they differ? (c) Describe the construction of the synchro and show a simple diagram of the windings.

42. (a) How does a synchro operate? (b) Draw a diagram of two synchros, one of which is the transmitter and one the receiver. (c) Trace out and describe in detail the function of each.

43. What effects would two reversed phase wires have on the operation of the synchros?

44. Electronic controls have tubes which contain anodes and cathodes. What are these terms and what are their functions in the tubes?

45. (a) Describe a two-electrode tube and explain how this tube operates. (b) Make a simple diagram of this tube.

46. (a) What is the purpose of coating the filaments with barium oxide? (b) What other materials are used for this purpose?

47. (a) What is meant by an indirectly heated cathode? (b) Show a diagram of this type of tube.

48. (a) What is one of the chief functions of the two-element

tube? (b) Explain by diagram how rectification is obtained when the anode is alternately positive and negative. (c) What is this rectification called?

49. (a) Explain the difference between half-wave and full-wave rectification. (b) Which is more desirable?

50. (a) Show a diagram of a full-wave rectifier using two diodes and explain fully the circuits. (b) Draw the curves of the output of a full-wave rectifier and explain how it differs from that of a half-wave rectifier.

51. (a) Show how it is possible to run a small d-c motor from an a-c line by using a full-wave rectifier. (b) Explain the circuit.

52. (a) What is meant by a grid in a tube? (b) Explain its function in a triode. (c) Show by diagram its symbol.

53. Explain by diagrams how the grid in a triode controls the flow of electrons to the anode.

54. Explain the following terms: ionization; space; charge; starting anode; bias; trigger-type tube; phase-shift control.

55. (a) Show by diagram how to operate a small d-c motor on alternating current by using thyratron tubes. (b) Explain the circuit.

56. Explain the construction and operation of a phototube.

57. (a) Show by diagram a circuit containing a phototube operating a relay. (b) Explain in detail the entire operation of this circuit.

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