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ELECTRIC MOTORS FOR FARM USE.	VT 003 004

ILLINOIS UNIV., URBANA, COLL. OF AGRICULTURE

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BETWEEN 2 AND 8 HOURS ARE REQUIRED FOR USE OF THIS TEXTUAL OR REFERENCE MATERIAL ON ELECTRIC MOTORS. IT WAS DEVELOPED BY AN AGRICULTURAL EDUCATION-AGRICULTURAL ENGINEERING SPECIALIST ON THE BASIS OF CONFERENCES WITH SUBJECT MATTER SPECIALISTS, TEACHER EDUCATORS, SUPERVISORS, AND TEACHERS. THE OBJECTIVES AND SUBJECT MATTER CENTER AROUND THE FOLLOWING QUESTIONS -- (1) WHAT ARE THE ADVANTAGES OF ELECTRIC MOTORS, (2) WHAT FACTORS SHOULD I CONSIDER IN SELECTING AN ELECTRIC MOTOR, (3) HOW CAN I IDENTIFY AND SELECT THE PROPER TYPE AND SIZE OF ELECTRIC MOTORS, (4) HOW SHOULD I INSTALL THE MOTOR PROPERLY, (5) WHAT CARE SHOULD I GIVE AN ELECTRIC MOTOR, (6) HOW CAN I DETERMINE WHAT IS WRONG WHEN A MOTOR WILL NOT OPERATE, AND (7) WHAT ARE THE IMPORTANT PRINCIPLES OF ELECTRIC MOTORS. DEMONSTRATIONS AND SHOP EXERCISES ARE SUGGESTED. ILLUSTRATIONS ARE INCLUDED. DESIGNED FOR BOTH HIGH SCHOOL AND POST-HIGH SCHOOL USE, THE MATERIAL IS APPROPRIATE FOR THOSE STUDENTS WHO HAVE AVERAGE ABILITY, AGRICULTURAL INTEREST, AND AN OCCUPATIONAL OBJECTIVE. THIS DOCUMENT IS AVAILABLE FOR 45 CENTS FROM VOCATIONAL AGRICULTURE SERVICE, 434 MUMFORD HALL, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS 61801. (JM)

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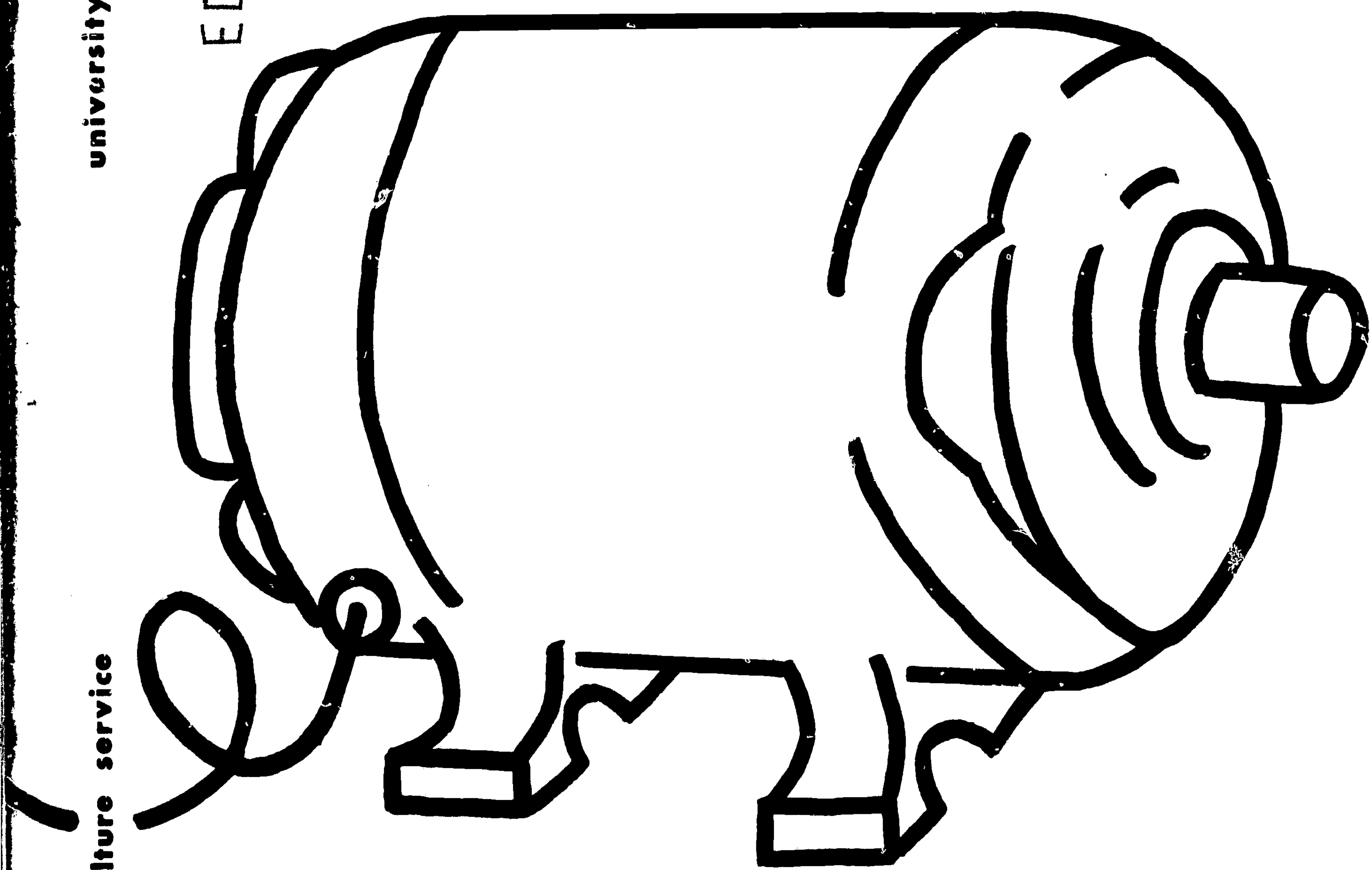

ELECTRIC MOTORS FOR FARM USE

vocational agriculture service

ELECTRIC MOTORS FOR FARM USE

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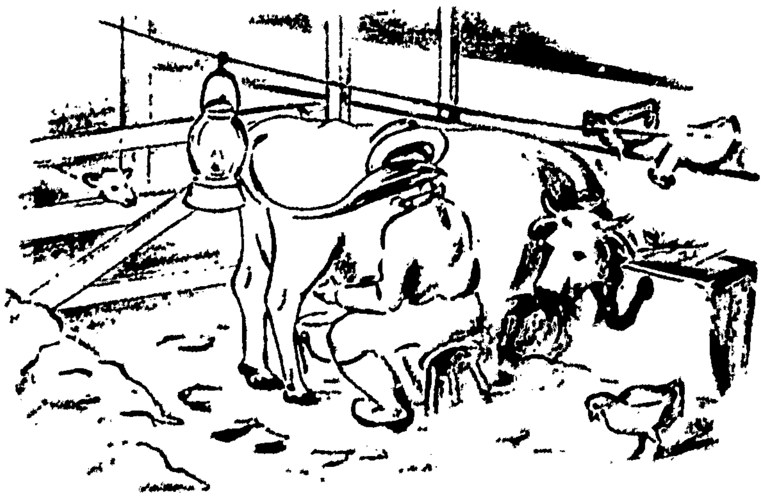
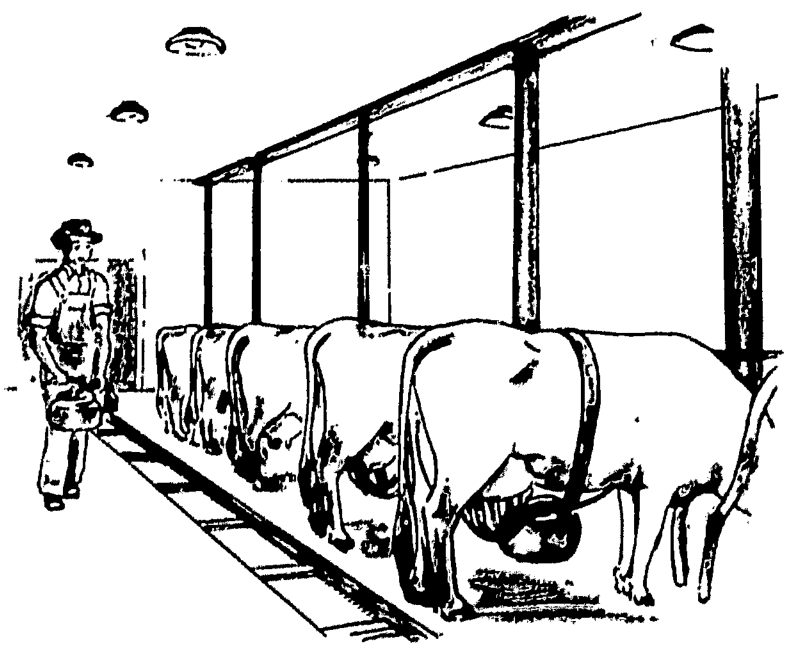
Vocational Agriculture Service

ELECTRIC MOTORS FOR FARM USE

1. *What Are the Advantages of Electric Motors?*
2. *What Factors Should I Consider in Selecting an Electric Motor?*
3. *How Can I Identify and Select the Proper Type and Size of Electric Motors?*
4. *How Should I Install the Motor Properly?*
5. *What Care Should I Give an Electric Motor?*
6. *How Can I Determine What Is Wrong When a Motor Will Not Operate?*
7. *What Are the Important Principles of Electric Motors?*
8. *Suggested Demonstrations and Shop Exercises*





Rural electrification has made possible great changes in farming and in farm living during the past generation. A type of energy has been brought to the farm which can furnish light, heat, and power more effectively and efficiently than we once dreamed possible.

The number and variety of farm chores which electric motors can perform has grown steadily. Motors truly provide the "push" behind "push-button farming". A vast number of our time- and labor-saving devices would not be possible without the electric motor, the most efficient source of mechanical energy on the farm.

Electric motors provide power in one of the safest forms known. Nevertheless, power in any form presents the possibility of a hazard, and suitable precautions must be observed in installation and use. Safety from moving parts will depend on the guarding described in this publication and such special precautions as may be needed for the particular machine each motor drives. To provide electrical safety, the National Electrical Code should be carefully followed in making each installation, and all parts of the electrical system should be maintained in good condition.

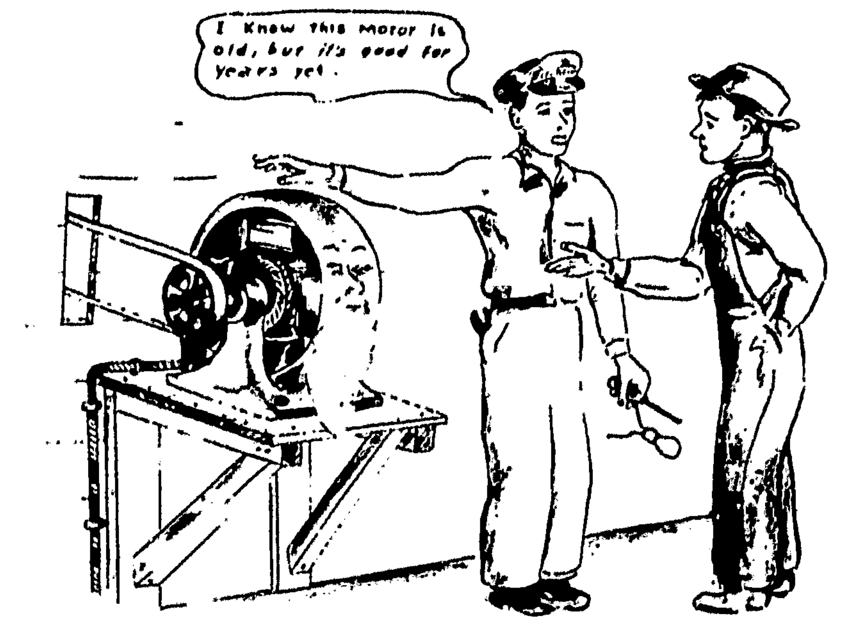
1. WHAT ARE THE ADVANTAGES OF ELECTRIC MOTORS?

Electric motors have many advantages when we compare them with any other kind of farm power. Electric motors are low in first cost, cheap to operate, long in life, highly efficient, simple to operate, quiet in operation, capable of starting a reasonable load, capable of withstanding temporary overloading, capable of being automatically and remotely controlled, compact, and safe.

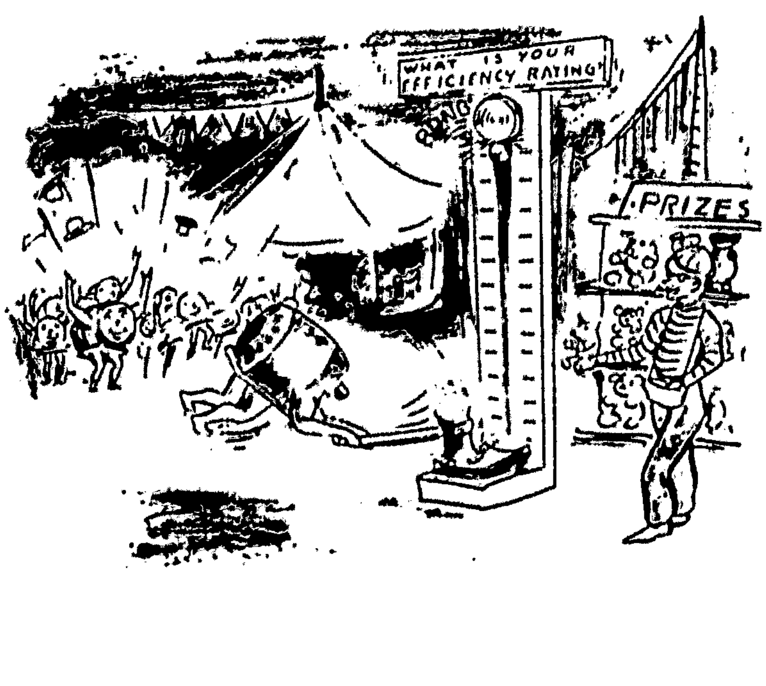
Low in first cost. The initial cost of an electric motor is relatively low, considering the power it will develop. Electric motors are quite simple in construction, have few moving parts, and are manufactured by mass-production methods.

Cheap to operate. Electricity is measured in kilowatt-hours, just as corn is measured in bushels. A kilowatt is equal to 1,000 watts. In terms of mechanical energy, 746 watts equal one horsepower, although for practical purposes, taking account of friction and other losses, it requires about 1,000 watts or 1 kilowatt (electrical power input) to produce one horsepower (mechanical power output.) One kilowatt of power supplied for one hour continuously equals the energy unit of one kilowatt-hour. This kilowatt-hour of electricity, at a cost of 2 or 3 cents, will do as much or more work than can be performed by a man in an eight-hour day. One kilowatt-hour, if properly used, will, among other chores, milk 20 cows, separate 2,000 pounds of milk, ventilate a 25-cow dairy barn for one-half day, pump 400 pails of water, grind 100 to 500 pounds of grain, hoist 2 tons of hay, shell 20 bushels of corn, shear 60 sheep, mix two cubic yards of concrete, or paint 700 square feet of surface with a pressure sprayer.

Long in life. Electric motors are noted for length of life. If given reasonable care, a good motor will last 20 to 30 years, or even longer. Many motors have been in operation for this long a time with no expense for repair and no maintenance cost other than for occasional lubrication.

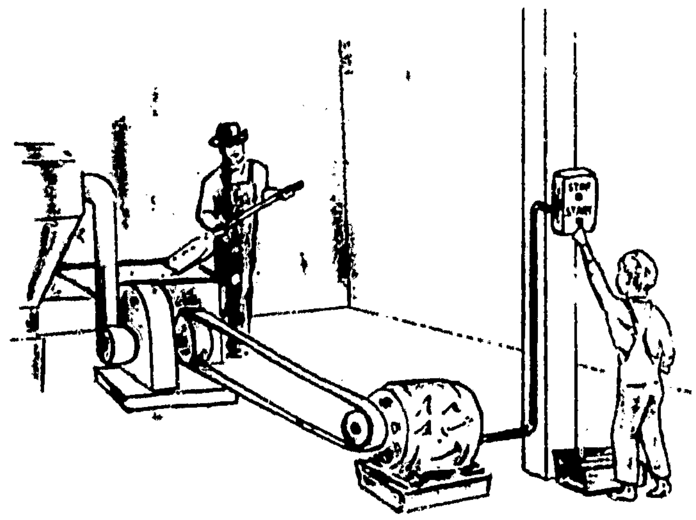


Highly efficient. The electric motor is the most efficient source of power available to the

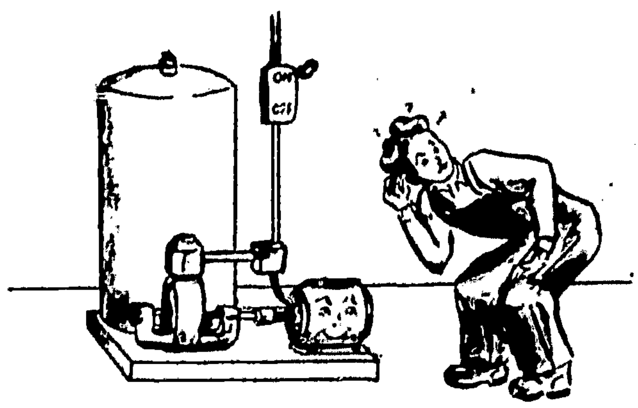


farmer today. Its efficiency will vary from 65 to 85 percent, depending on the type of motor and the conditions under which it operates.

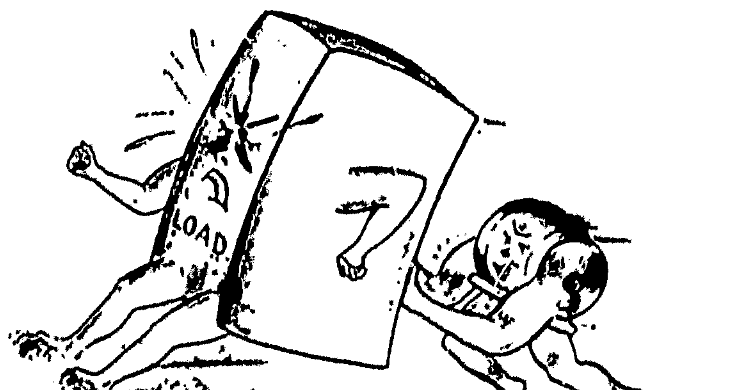
Simple to operate. Electric motors can be started and stopped with the push of a button or the flick of a switch. They start equally well in hot or cold weather, and the electrical connections can generally be made so that the motor will rotate in either a clockwise or counter-clockwise direction.



Quiet in operation. Electric motors operate smoothly, quietly, and with very little vibration.

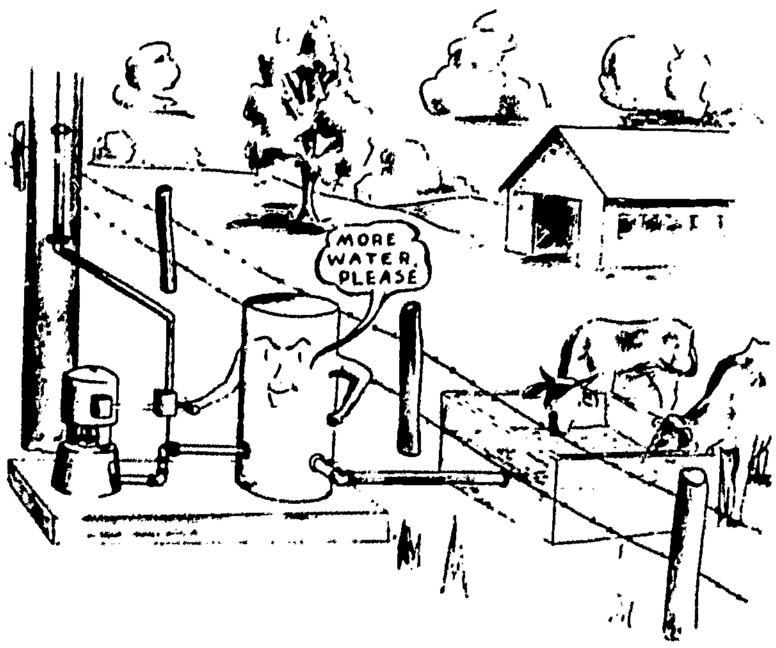


Capable of starting a reasonable load. The ability of electric motors of various types to start under full load eliminates the necessity for a clutch or low gears for starting loads.

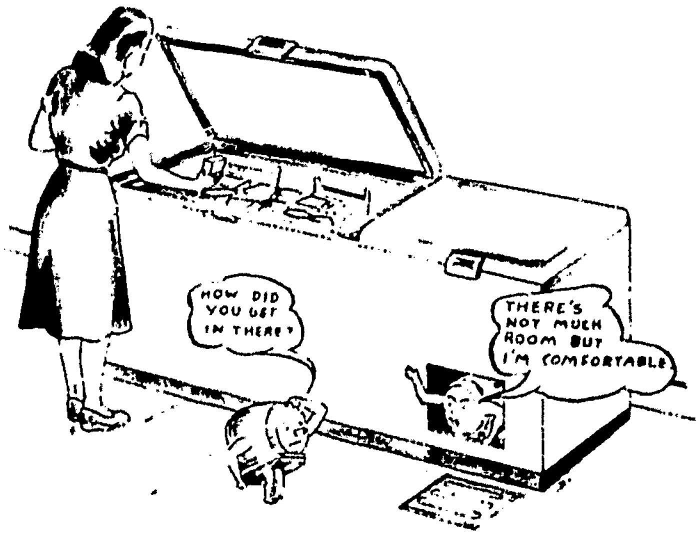


Capable of withstanding temporary overloading. The ability of electric motors to carry momentary loads up to one and one-half times their rated capacity gives them flexibility and adaptability. Of course, an electric motor should not be continuously overloaded.

Capable of being automatically and remotely controlled. This is an important advantage which has made possible the development of mechanical refrigeration and automatic water, heating, and ventilating systems on the farm. Remote controls add a great deal to the convenience and often to the safety of electric-motor applications.



Compact. The electric motor has considerably less weight and bulk than other types of power units. It is often very small compared to the machine it drives.

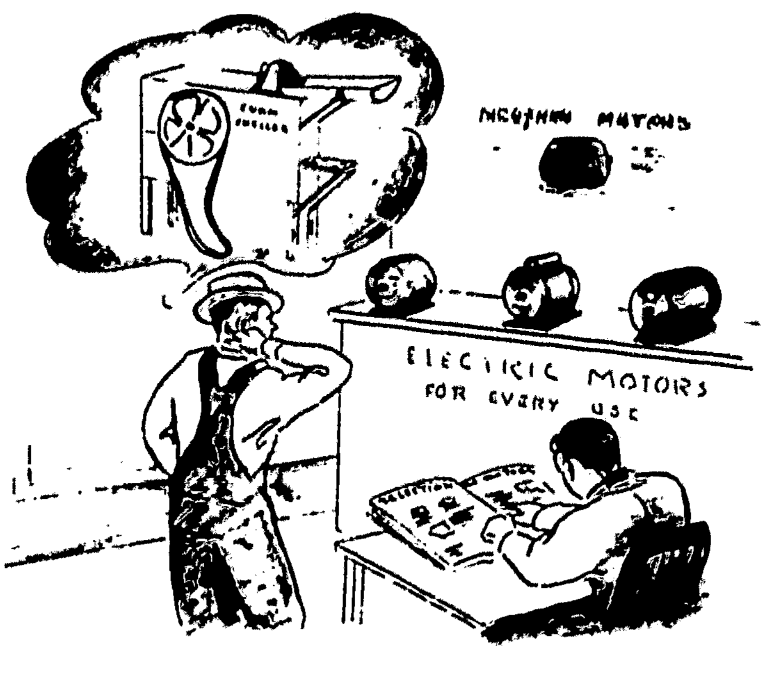


Safe. Motor designs, in general, prevent contact with live wires and electrical parts. They do not operate at high temperatures. Thus electric motors provide the farmer with one of the safest forms of power available.

2. WHAT FACTORS SHOULD I CONSIDER IN SELECTING AN ELECTRIC MOTOR?

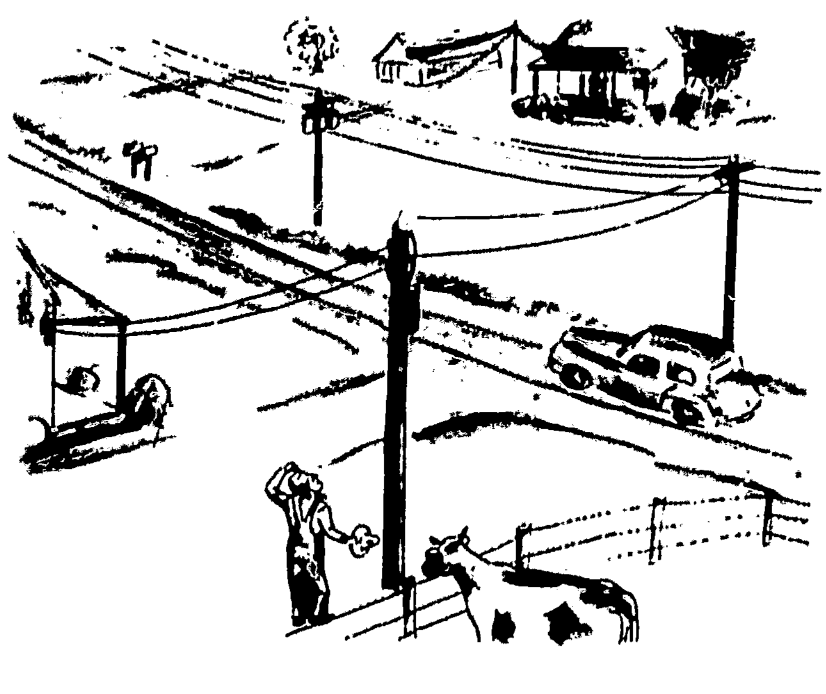
When we buy a milk cooler, an air compressor, or any similar electric motor-driven farm appliance, we need only know what type of electric power is available. Beyond this the equipment manufacturer determines what size and type of motor to use and equips the appliance accordingly.

However, there are frequent occasions when you may wish to buy a separate motor for operating a piece of equipment formerly driven by hand or by some other power unit. There are also times when a motor must be replaced in an emergency and no exact duplicate is available. In situations like these you should be able to intelligently choose the proper type and size of motor to use.



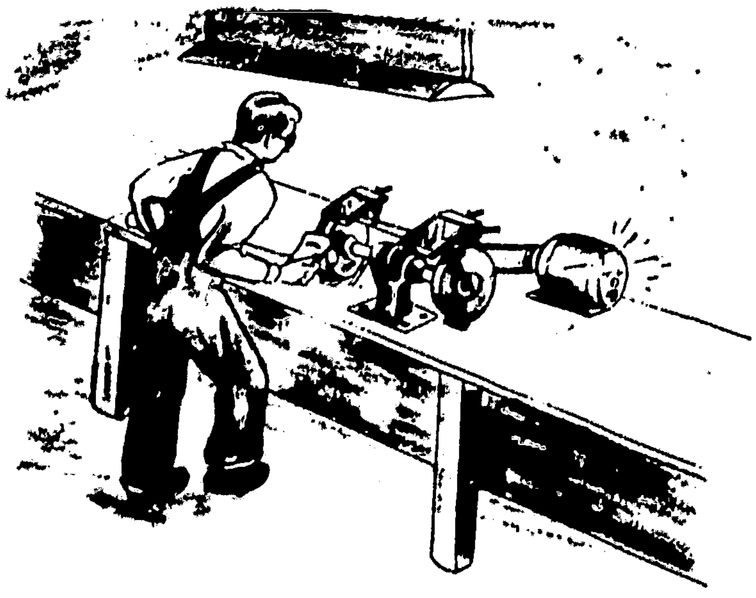
The selection of motors for farm use should take into consideration the type of electric power available, type and size of load, and conditions under which the motor operates.

Type of electric power available. Electricity may be direct current (d.c.) or alternating (a.c.). It may be one of several voltages. If alternating current, it may be single phase or three phase, and one of several frequencies. In almost every case today, however, electric power on the farm is



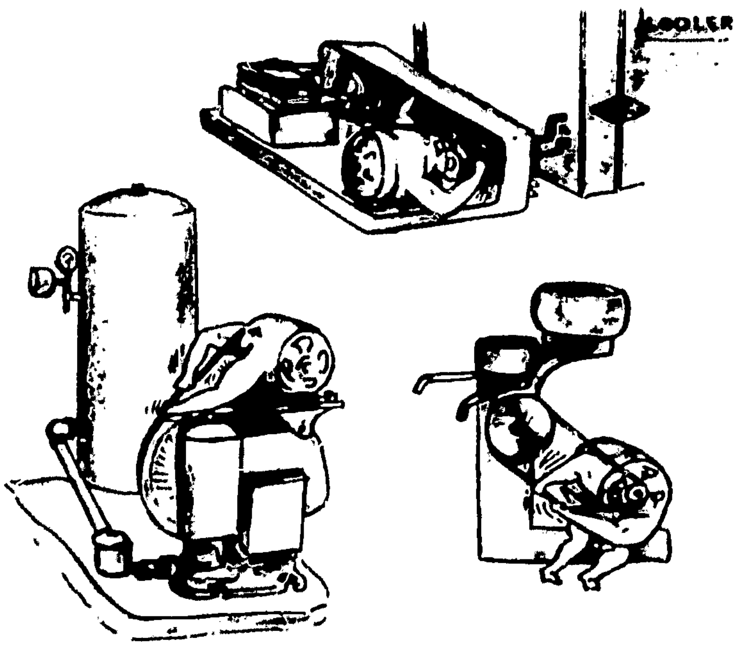
single phase, 60-cycle-alternating current, available at 120 and 240 volts. The voltage ratings of single-phase motors are 115 and 230 volts and are slightly lower than the line voltages of 120 and 240 volts. The reason that the rated voltage of the motor is lower than the line voltage is to allow for the voltage drop which takes place between the meter and the motor or other electrical applications. The voltage ratings of motors are used throughout the remainder of this publication.

Type and size of load. Farm-motor loads vary widely, particularly with respect to power needed for starting. Some are particularly easy for an electric motor to start, or are of a nature that very little load is applied until the machine is up to its full running speed. For example, if we are sharpening an axe on a power-driven grinding wheel, we start the motor and allow the grinder to reach operating speed before we start grinding. This means that the motor is only required to start a small load compared to what it must carry when we bear down sharply with the axe. Likewise a machine like a small fan offers very little resistance at the start.



Other machines like piston-type water pumps, milking machines, refrigerators, and cream separators require much more effort to start than to keep them running. It is logical to choose a different type of motor for these devices.

There are other differences in load requirements which have an important bearing on the choice of motors. Automatic water pumps and refrigerators require frequent starting and stopping. Gasoline tank pumps run only occasionally and for short periods while milking machines and feed grinders may run steadily for long periods of time. Elevators and wood saws may be subjected frequently to momentary overloads.



Operating conditions. Farm motors operate in all kinds of surrounding conditions. Dust and dirt, excessive moisture, flammable liquids, explosive gases, exposure to mice and other rodents, and other unfavorable factors often make the choice of proper type of motor enclosure an important one for safety and protection of the motor.

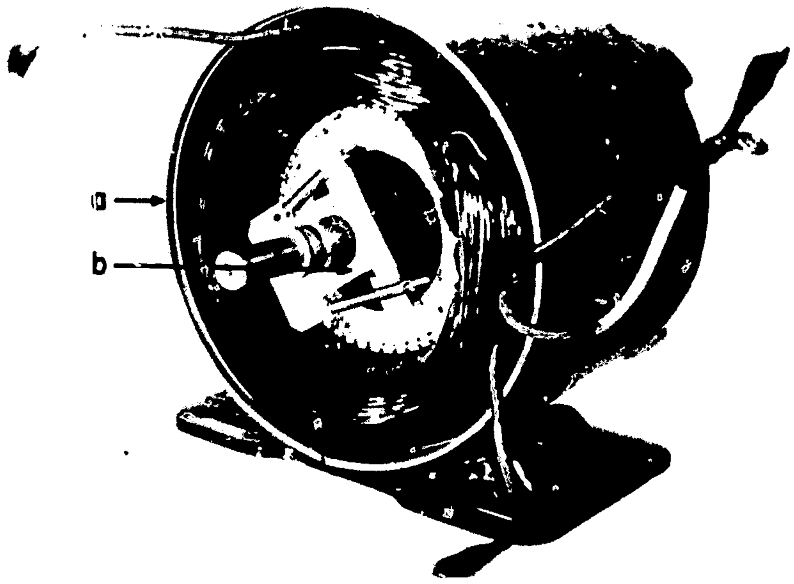
3. HOW CAN I IDENTIFY AND SELECT THE PROPER TYPE AND SIZE OF ELECTRIC MOTORS?

Parts of a motor

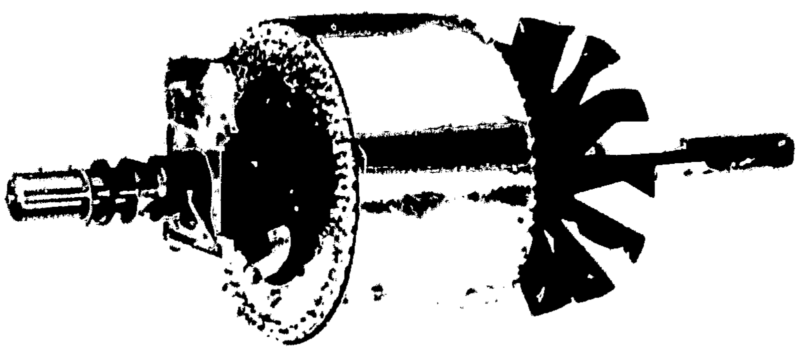
In learning to identify and select the proper type of motor, you should first become familiar with the parts of a typical motor. All motors consist essentially of a rotating part called the rotor which revolves freely within a stationary part called the stator (Fig. 1).

Rotor. The rotor consists of a slotted core, made up of thin sections of a special soft steel, carefully balanced on a central shaft. This shaft has a ground bearing surface at each end of the core and extends beyond the bearing surface at one or both ends to provide for pulleys or other means of attachment to the device it drives. Rotors may be of the squirrel-cage type (Fig. 2a) or of the wound-rotor type (Fig. 2b).

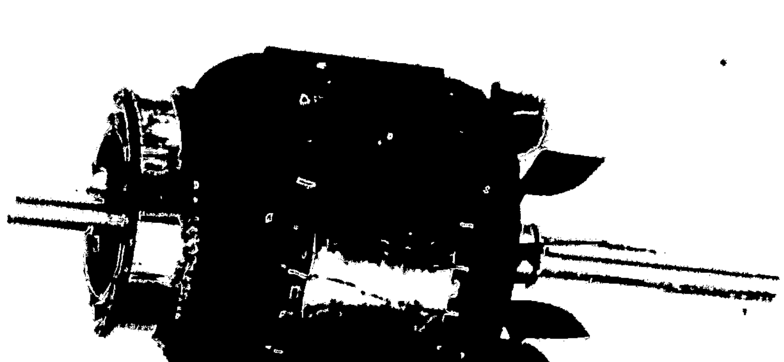
The squirrel-cage rotor got its name from the fact that it resembles the cage sometimes used to



A typical motor consists of a stator (a), and a rotor (b). (Fig. 1)



a

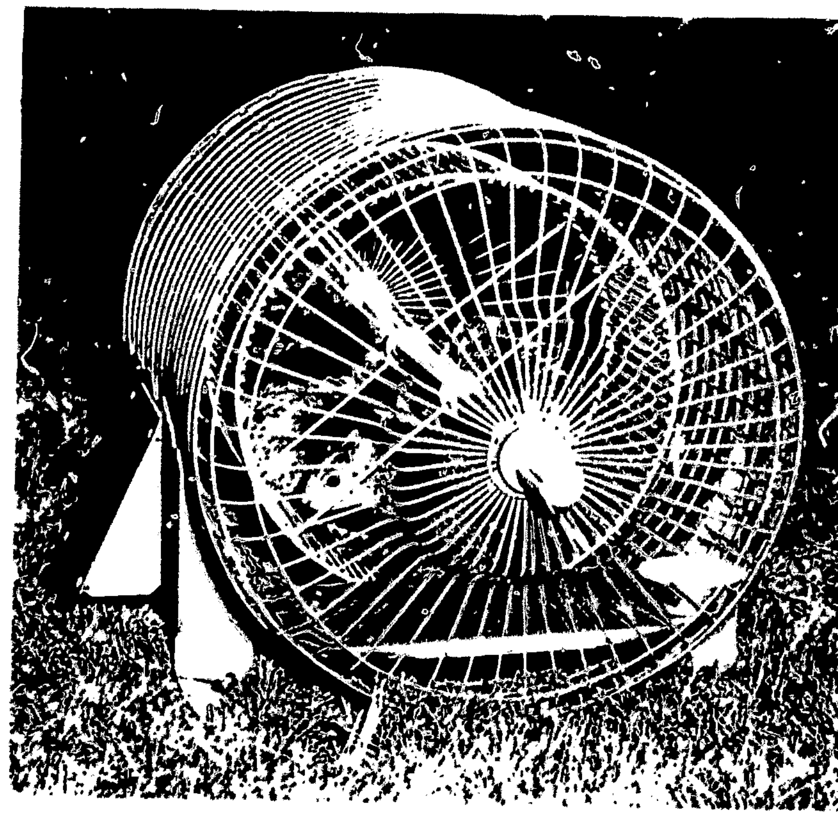


b

The rotor may be of the squirrel-cage type (a), or wound-rotor type (b). (Fig. 2)

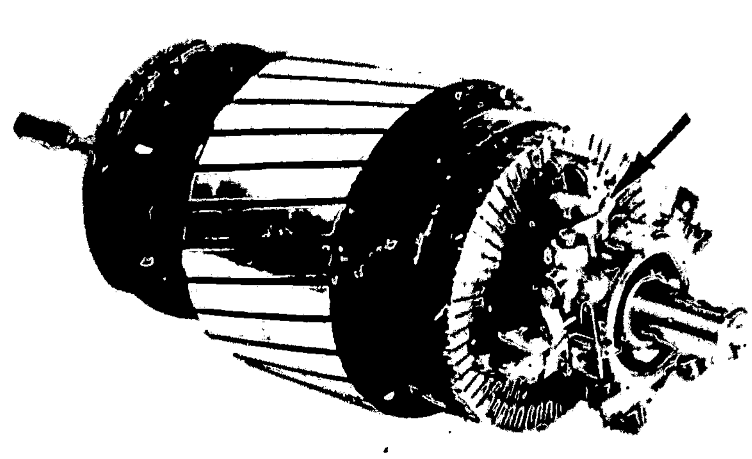
exercise pet squirrels (Fig. 3). The slots of the rotor contain bare copper, brass, or aluminum bars which are short-circuited together at each end by the end rings. Most squirrel-cage rotors also have some type of cooling fan and, in addition, those for single-phase motors have a centrifugal device for operating the starting-switch mechanism.

The single-phase wound rotor, such as that found in a repulsion-start induction motor, has coils of insulated copper wire wound in the rotor slots. It also has a commutator made up of copper segments which are insulated from the rotor shaft



Note the similarity of the actual squirrel cage to the squirrel-cage rotor. (Fig. 3)

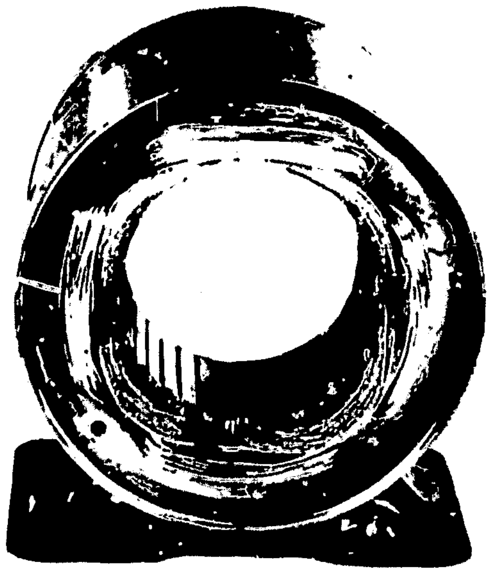
and from each other with mica or a similar substance. The ends of the rotor coils are soldered to individual commutator segments. When the motor brushes contact these segments, they complete the circuit, thus permitting currents to flow through all of the coils in the rotor in the proper sequence for starting purposes. These motors have a cooling fan and a centrifugal device for short-circuiting all the commutator segments when the rotor comes up to speed. The wound rotor in Fig. 4 also has a brush ring and a device for lifting the brushes away from the commutator at the same time the segments are short-circuited.



Some wound rotors are of the brush-lifting type. (Fig. 4)

Stator. The electrical part of the stator consists of a slotted core also made of special laminated steel. Insulated copper wire is wound in the slots in such a way as to form one or more pairs of definite magnetic poles (Fig. 5).

For the so-called constant-speed motors, which



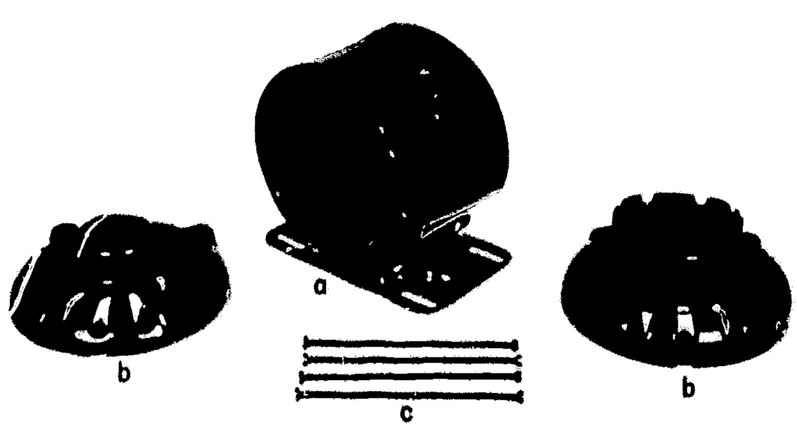
The stator has coils of insulated wire wound to form magnetic poles. (Fig. 5)

includes most of the types used on the farm, the speed at which the motor runs is determined by the frequency of the power supply and the number of poles. With ordinary 60-cycle current, full-load running speed of a 2-pole motor is about 3450 r.p.m.; a 4-pole motor, 1725 r.p.m.; and a 6-pole motor, 1140 r.p.m.

In addition to the rotor and stator, the motor has a **frame, end shields,** and **through bolts** or **cap screws** (Fig. 6). The frame supports the entire motor and provides for mounting. The end shields house the bearings and usually one of the end shields contains the starting switch or the brushes and the terminal box where the attachment is made to the line. The through bolts or cap screws hold the motor together.

Types of motors

There are three popular types of single-phase, alternating-current motors to choose from for

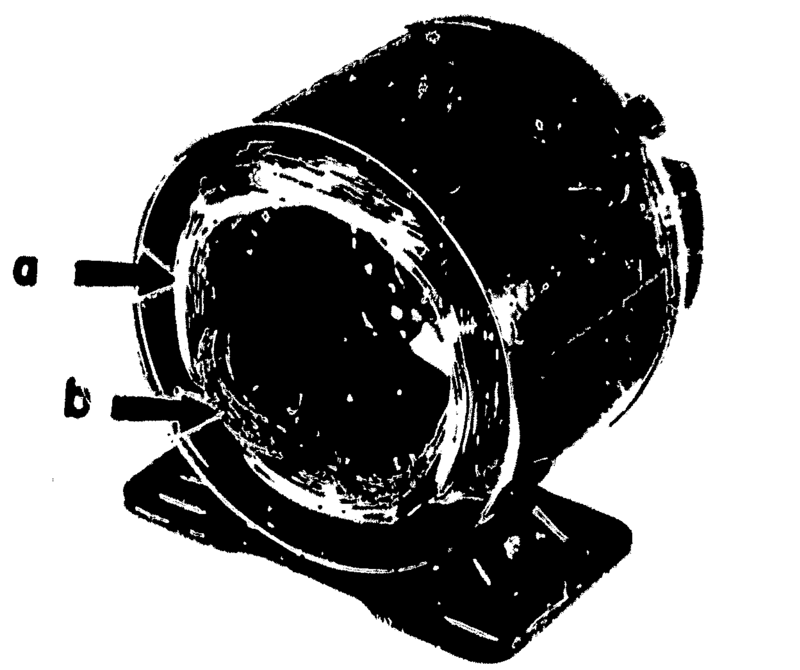


In addition to its electrical parts, a motor has a frame (a), end shields (b), and through bolts (c). (Fig. 6)

farm and home applications. They are the split-phase, capacitor, and repulsion-start induction. Two more types will be discussed briefly. They are the universal and the three-phase induction type.

The main difference between the first three types is in the way they start and come up to running speed. For motors of the same horsepower rating, there is no practical difference between these types in the amount of work they will do, nor in the current they will require in doing it, after they have come up to operating speed.

Split-phase. The typical split-phase motor consists of a squirrel-cage rotor and a stator in which are found two different sets of windings (Fig. 7). One is called the main or running winding, and the other the auxiliary or starting winding. In general, the running winding consists of a greater number of turns of larger diameter wire than the starting winding and is usually wound in the stator slots first. The motor shown in Fig. 7 has four distinct poles. The starting and running windings have the same number of poles. The poles of the starting winding are spaced halfway between those of the running winding.



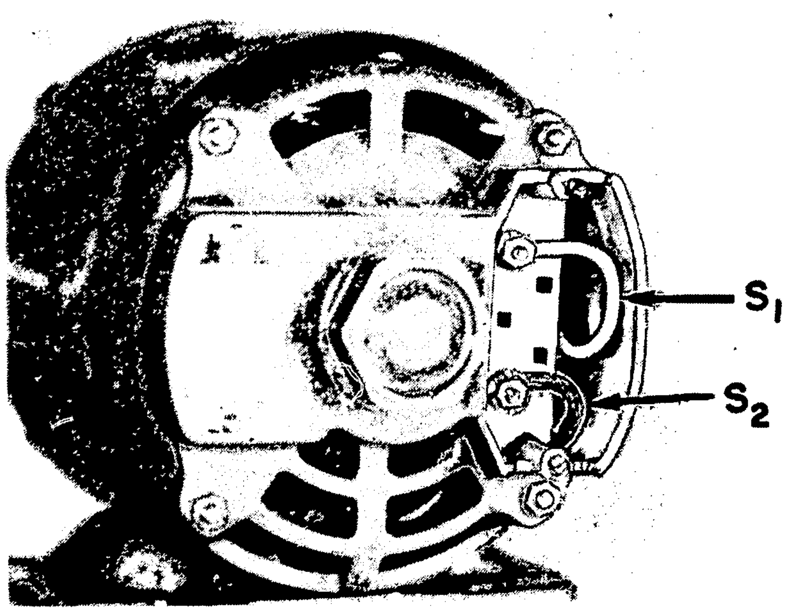
The split-phase stator has a running winding (a), and a starting winding (b). (Fig. 7)

At starting, the starting switch in the motor is closed and the current flows through both windings. The rotor commences to turn and when it reaches about three-fourths full speed a centrifugal device opens the starting switch. This disconnects the starting winding from the circuit and the motor continues to operate on the running winding only. When the motor stops, the starting switch again closes so that both windings in the circuit will be ready for starting. This process is more completely explained in Section 7.

The split-phase motor is the simplest in construction and, consequently, the least expensive to buy. However, it has a relatively low starting torque, or ability to start a load, and requires a high starting current. This limits its use to loads that are easy to start, and, because of the large starting current required, split-phase motors are rarely made in sizes larger than 1/3 horsepower.

Split-phase motors are usually made for only one voltage, either 120 or 240, and cannot be readily changed from one to the other.

Direction of rotation is determined by the direction the current flows through the starting winding with relation to the direction it flows through the running winding. Switching starting-winding leads S_1 and S_2 or the running winding leads (Fig. 8) will cause the motor to start and run in the opposite direction.

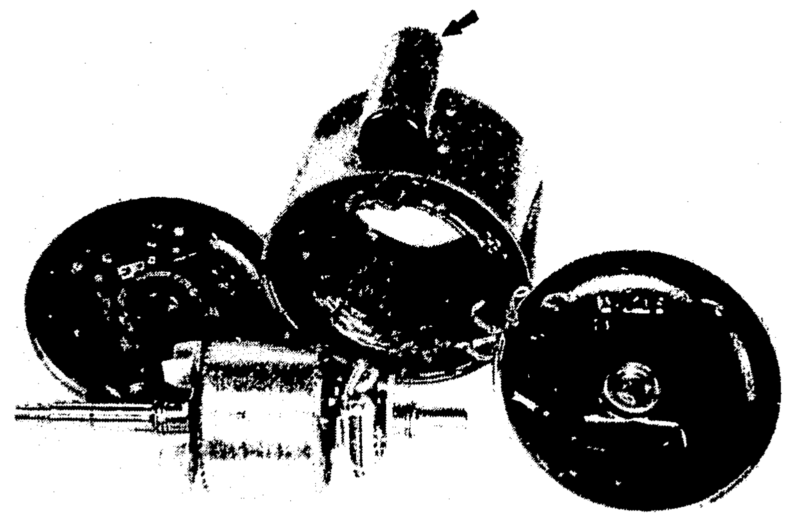


The split-phase motor is reversed by switching the starting winding leads. (Fig. 8)

Direction of rotation of a motor is described as clockwise (c.w.) or counterclockwise (c.c.w.) when viewing the motor facing the end opposite the shaft extension. This is also usually the end where the motor lead connections are made. You should look at this end when describing the direction of rotation for a double-shaft motor.

Capacitor. Two of the widely used types of capacitor motors are: capacitor-start; and capacitor-start, capacitor-run (two-value capacitor).

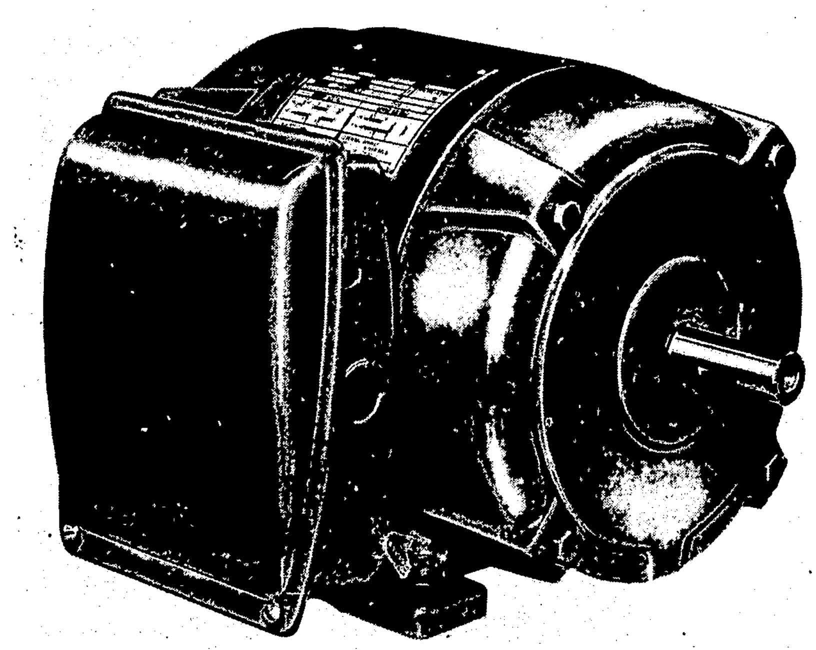
The capacitor-start motor and the split-phase motor are similar in that both have squirrel-cage rotors and two separate windings in the stator, a starting and running winding. The capacitor-start motor has in addition a capacitor (condenser) placed in series with the starting winding. The smaller sizes of capacitor-start motors can usually be identified by the tube-shaped container on top of the motor which holds the capacitor (Fig. 9). Some motors, however, have the capacitor mounted inside one of the end shields, or in the motor base.



The capacitor-start motor has a capacitor or condenser, often mounted on top the motor. (Fig. 9)

A capacitor-start motor is, in reality, a greatly improved split-phase type. The improvements in the starting circuit, made possible by the addition of the capacitor, give this type of motor a greater starting and accelerating torque for the same starting current, usually at least twice as great as a split-phase motor of the same horsepower rating. Because of greater starting torque, capacitor-start motors are widely used for such appliances as water pumps, and air compressors which start and stop frequently and have relatively high starting torque requirements. Recent developments in capacitors make these motors practical in sizes up to 5 or 7½ horsepower, or even larger.

Frequently in the larger horsepower ratings a capacitor-start, capacitor-run motor is used (Fig. 10). The capacitor-start, capacitor-run motor is



The capacitor-start, capacitor-run motor is often used in sizes from 2 to 10 h.p. (Fig. 10)

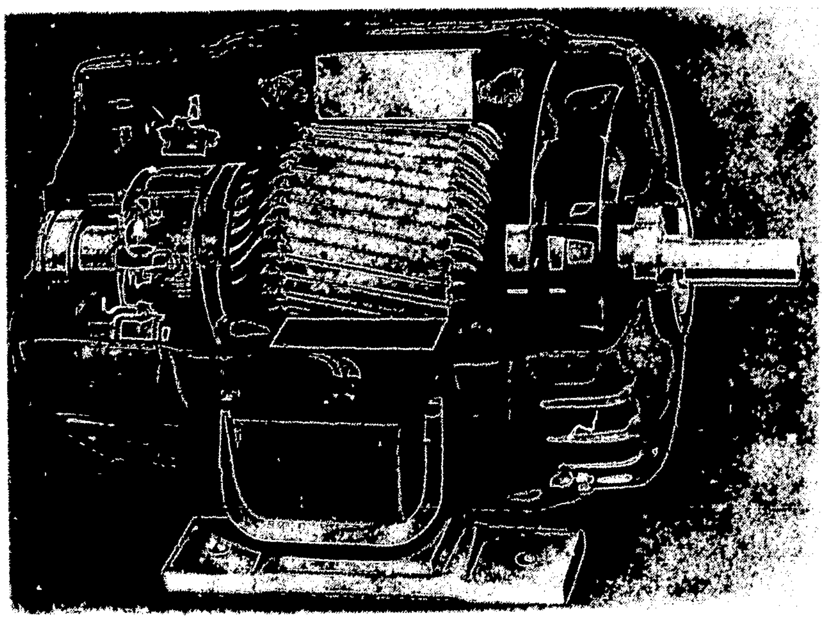
similar in external appearance to the capacitor-start motor. It has a starting winding and a running winding in the stator with a capacitor connected in series with the starting winding, and a squirrel cage rotor. However, the capacitor-start, capacitor-run motor differs from the capacitor-start motor in that the motor starting switch does not remove the starting winding from the circuit but serves only to disconnect the starting capacitor when the motor comes up to speed.

Capacitor motors smaller than ½ horsepower are usually wound for 120 volts while many rated ½ horsepower and larger can be connected to either 120 or 240 volts by changing the lead wires. If this is possible, it will be indicated by both voltages being shown on the nameplate. However, it is to your interest to use the 240-volt conection when 240 volt service is available. The direction of rotation is reversed in the same way as the split-phase motor.

If in doubt as to whether the motor is a capacitor-start or a capacitor-start, capacitor-run motor the information is generally supplied on the motor nameplate or instruction tag.

Repulsion-start induction. The repulsion-start induction motor is quite different from the two types previously described. It has only one winding in the stator which acts as a running winding. It has a wound rotor instead of the squirrel-cage type and therefore has a commutator and brushes (Fig. 11).

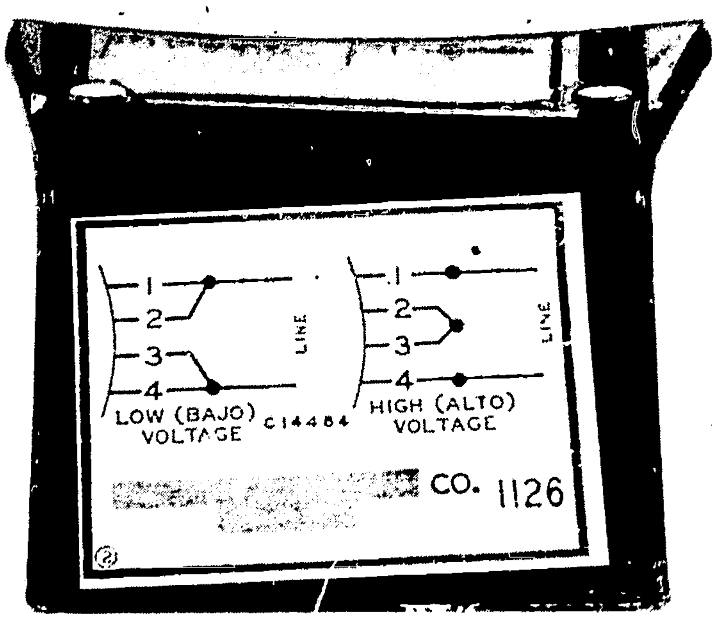
There is no direct connection between the line current and the brushes or rotor windings. The brushes merely serve to complete the circuit in certain rotor coils. This creates strong magnetic forces within the rotor which react with those of the stator causing the motor to start. When it approaches full running speed, a centrifugal device within the rotor short-circuits all the commutator bars together so that the rotor operates at full speed like the squirrel-cage type.



The repulsion-start induction motor has a wound rotor and only a running winding in the stator. (Fig. 11)

Both capacitor and repulsion-start induction motors are designed to have the same high-starting torque. For this reason they can be used interchangeably in farm applications under normal voltage conditions. Because of having greater starting torque per ampere of current, the repulsion-start induction motor is less likely to aggravate a low-voltage condition or be troubled by voltage drop. Both types of motors are ruggedly built and give good service on the farm for steady or intermittent use.

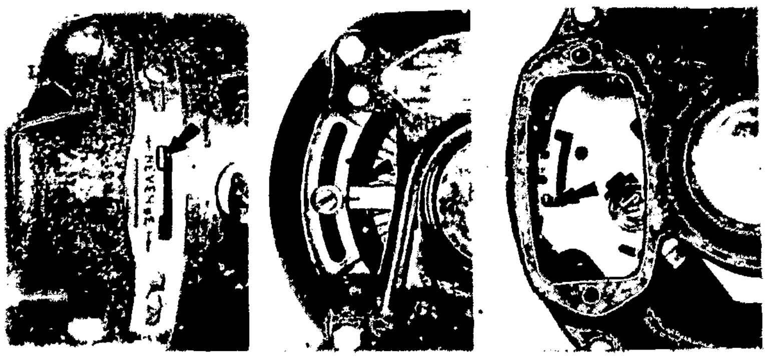
Most repulsion-start induction motors, even in the fractional horsepower sizes, can be operated on either 120- or 240-volt current. The stator winding is usually divided into halves and four leads are brought into the terminal box. These two halves are connected in parallel for 120-volt and, in series, for 240-volt operation (Fig. 12).



Directions for connecting to low or high voltage are usually found on the motor. (Fig. 12)

Direction of rotation is determined by the position of the brushes with respect to the centers of the stator coils. Therefore, reversing is accomplished by shifting the brushes to a different position. Some motors have a brush-shifting lever which extends outside the motor (Fig. 13a). With others it may be necessary to remove a plate on the end shield, and move an internal brush shifting device (Fig. 13b and c).

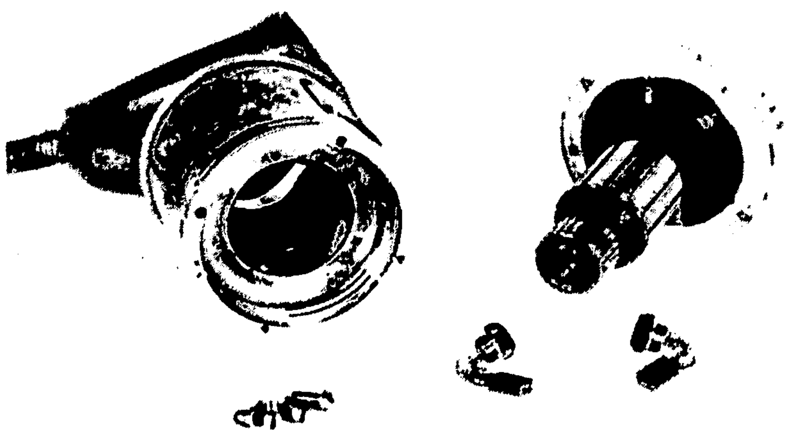
Universal motors. The universal motor gets its name from the fact that it will operate on either direct or alternating current of the correct voltage. It has a wound rotor and brushes somewhat



a b c

To reverse a repulsion-start induction motor shift the brush position by moving an external lever (a) or by removing a cover and operating an internal shifting device (b or c). (Fig. 13)

like the repulsion-start induction motor (Fig. 14). It is different, however, in several important respects. The universal motor is not an induction motor. Line current flows through the brushes to the rotor as well as to the stator in such a way that the two windings are in series with each other. Both are in the circuit constantly during operation.



The universal motor also has a wound rotor and brushes. (Fig. 14)

Universal motors do not operate at constant speed like induction motors. They operate like a gas engine with the throttle wide open; that is, they run as fast as their load will permit. For this reason, universal motors are usually permanently and directly connected to some device or appliance.

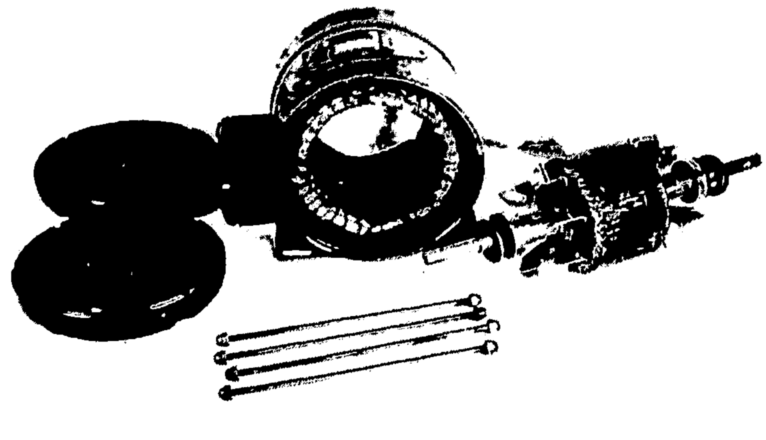
Universal motors have high starting torques and high starting currents. They are widely used on portable electric tools and on household appliances such as vacuum sweepers, food mixers, and sewing machines.

Three-phase motors. Up to the present time, the availability of three-phase power on the farm has been limited. This is because the costs involved in supplying such service have not been justified by the amount of power the average farmer was prepared to use. Three-phase electricity consists of three distinct currents which require three or more primary (high-line) wires, two or three transformers at the farm, and three or more secondary wires to the motor. The utilization voltage may be either 240 or 208 volts.

Three-phase motors are very simple in construction and hence relatively low in first cost. They have three phase windings in the stator and usually have a squirrel-cage type rotor (Fig. 15).

The three-phase current produces what amounts to a rotating magnetic field in the stator in which the rotor will start and run without any special starting device. Squirrel-cage three-phase motors are notably free from trouble, having no brushes, starting switch, or short-circuiting device.

Direction of rotation of a three-phase motor is determined by the way the three line wires are connected to the motor. Interchanging the connections of any two line leads will cause the motor to rotate in the opposite direction, so reversing is a very simple process. Three-phase motors cannot be used on a single phase line.

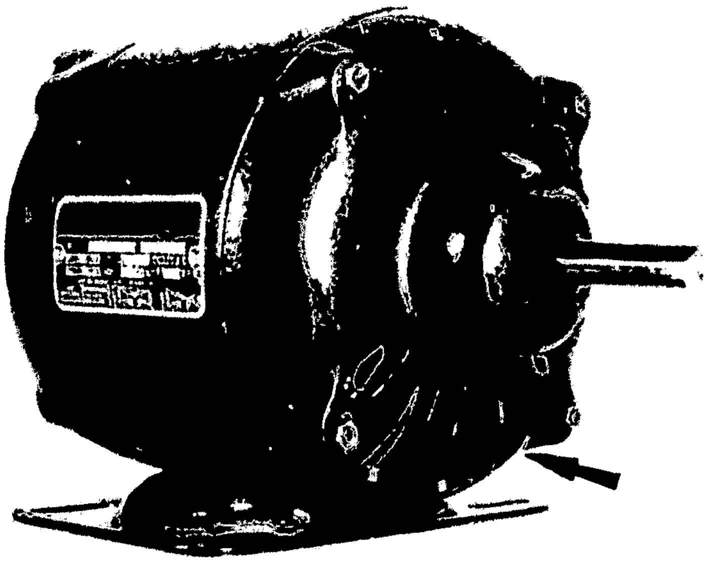


A three-phase motor has a winding made up of three parts in the stator, a squirrel cage rotor, and needs no starting mechanism. (Fig. 15)

Types of enclosures (motor cases)

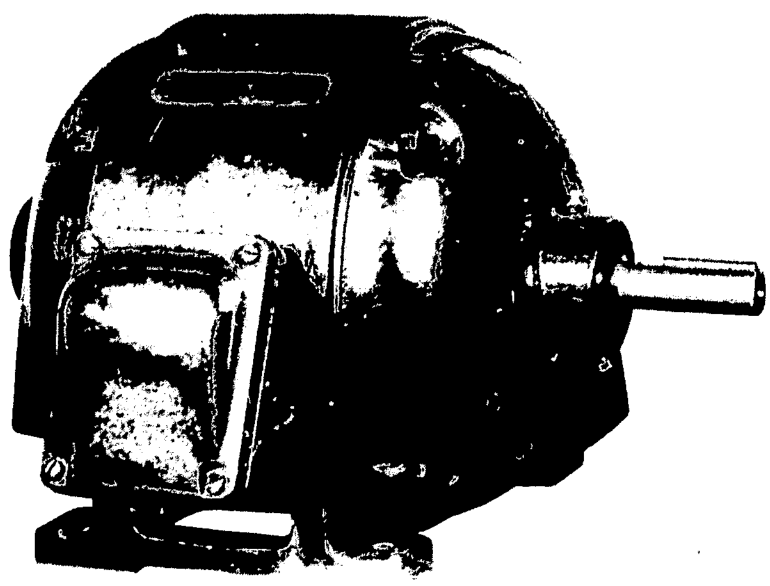
Up to this point we have considered selecting the motor only with regard to basic type. Motors should also be chosen according to type of frame protection or enclosure. The four main types of enclosures are: open, splash-proof, totally-enclosed, and explosion-proof.

Open. Open motors are designed for use indoors where the motor is kept dry and the atmosphere is normally clean. Openings for ventilation are usually of drip-proof design to prevent objects or liquids from falling into the vital parts of the motor (Fig. 16).



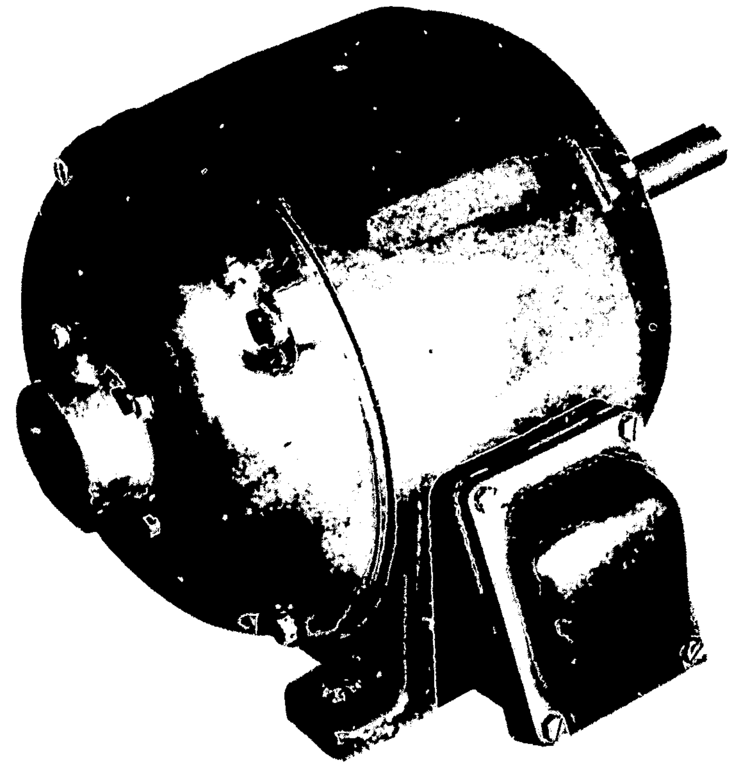
Open motors have openings in the end shields to permit ventilaiton. (Fig. 16)

Splash-proof. Splash-proof motors may be used indoors or sometimes outdoors in mild climates. This construction will protect the vital parts of the motor even where it is necessary to wash down the equipment with a hose. Splash-proof construction (Fig. 17) is seldom used for motors ¾ horsepower and smaller.



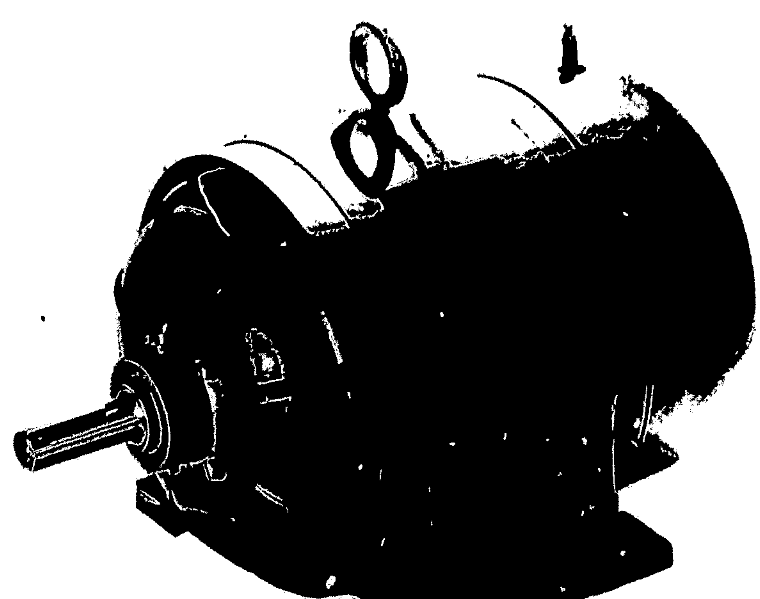
Splash-proof motors may be used around splashing liquids. (Fig. 17)

Totally-enclosed. This construction is designed to protect the motor from dirt and grit in the atmosphere as well as from moisture. Totally-enclosed motors are recommended for farm use in extremely dirty conditions (Fig. 18). Since these motors do not have ventilating openings, an internal and an external frame is sometimes provided with a fan to carry the heat away from the surface of the frame.



Totally-enclosed motors have no ventilating openings to allow dust or dirt to enter. (Fig. 18)

Explosion-proof. Essentially, there are two types of explosion-proof motors. Both are totally enclosed. One is designed to withstand an explosion of gas or vapor inside it without igniting the gas or vapor surrounding the motor. This type is widely used around gasoline and similar vapors (Fig 19). The other is a dust explosion-proof motor which is designed and built so as not to cause ignition or explosion of a hazardous dust concentration on or around the motor. This type is used in such places as flour mills, feed mills, or grain elevators or where grain, flour, or starch dusts may be present in hazardous quantities.



Explosion-proof motors are used where flammable gases or combustible dusts are present. (Fig. 19)

Types of bearings

Type of bearings may be another factor to consider in selecting a motor. In some sizes and types of motors, there may be a choice between sleeve bearings and ball bearings.

Sleeve bearings. Sleeve bearings are usually steel-backed, and babbitt-lined, although some are made of bronze or a similar alloy. Sleeve-bearing motors are usually oil-lubricated and are generally designed for operation only in a horizontal position.

Ball bearings. Ball bearings are widely used on motors. Motors equipped with ball bearings may be operated in a vertical position. Some ball-bearing motors are designed for relubrication at infrequent intervals, while others are provided with prelubricated sealed bearings without provision for relubrication.

Determining the size motor to use

Determining the size of motor to use for a given load is a frequent problem. The ability of the electric motor to withstand momentary overloads was mentioned under the advantages of motors. It is a serious mistake, however, to subject any motor to long and continuous overloading for its useful life will be shortened. It is also probably true that many farm motors are too large for their loads, resulting in low efficiency and increased operating cost. The equipment manufacturer determines the proper size motor to use with a given device by application of engineering principles and extensive testing. The farmer can secure valuable advice and help from his power supplier or his motor dealer.

In some cases it is fairly simple to calculate the theoretical horsepower required, as, for example, when the job to be done consists of lifting something like hay, grain, or water. One horsepower is equal to 33,000 foot-pounds of work done in one minute, 550 foot-pounds done in one second, or the equivalent. A foot-pound of work is done when a weight of one pound is lifted one foot, two pounds one-half foot, or one-half pound two feet.

Suppose, for example, it is desired to hoist a quantity of baled hay weighing about 600 pounds at a rate of two feet per second. How many horsepower would be required?

$$\text{600 lb. x 2 ft. per sec.} = \text{1,200 ft.lb. per sec.}$$

$$\frac{1{,}200}{550} = \text{2.18 h.p.}$$

This calculation does not, however, take account of friction. To allow for friction, the extra force required to pull the bales away from the load, and a reasonable margin of reserve power, the next common larger size, or in this case a 3 horsepower motor should probably be used.

What size motor should be used on a pump that is to raise water 50 feet and deliver it at a rate of 10 gallons per minute?

$$\text{Wt. of water} = \text{8 lb. per gal.}$$

$$\text{10 gal.} = \text{80 lb.}$$

$$\text{80 lb. x 50 ft.} = \text{4,000 ft. lb.}$$

$$\frac{4{,}000}{33{,}000} = \text{.12 or about } 1/8 \text{ h.p.}$$

From these calculations we would probably use a 1/4 horsepower motor. This would take care of pumping into an open tank, but suppose we wish to pump the water into a pressure tank with the same lift and at the same rate. What size motor would be required?

At sea level, 15 pounds of water pressure per square inch is equal to about 34 feet of lift. If we assume the water is to be pumped to a pressure of 45 pounds per square inch, it would be equal to lifting water:

$$\frac{45}{15} \times 34 = \text{102 ft.}$$

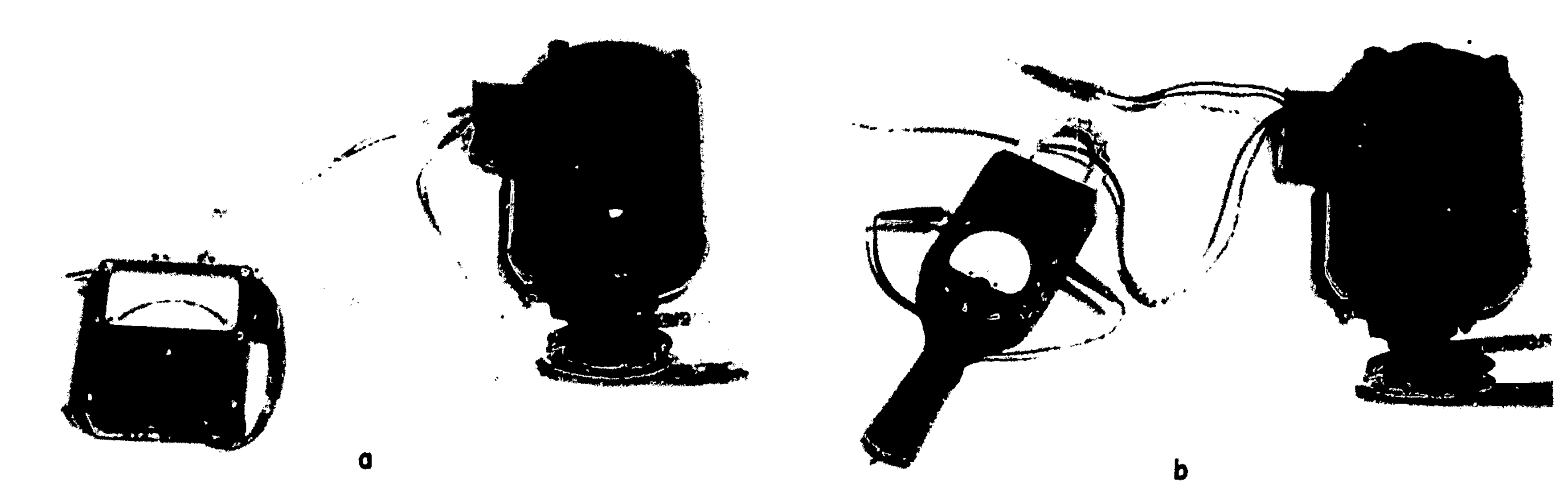
$$\text{Total lift} = 102 + 50 \text{ or 152 ft.}$$

$$\text{80 lb. x 152 ft.} = \text{12,160 ft. lb.}$$

$$\frac{12{,}160}{33{,}000} = \text{.37 or about } 1/3 \text{ h.p.}$$

This again is the theoretical requirement and it would be well to use at least a 1/2 horsepower motor.

One way to determine whether a motor is being overloaded is to measure the current it consumes in doing its job. This can be done by placing an a.c. ammeter of proper capacity in series with the circuit as in Fig. 20 when the motor is operating the load in question and comparing the ammeter reading with the nameplate rating. Line voltage should also be checked to see that it does not vary more than about 10 percent from the rated voltage of the motor.



An overloaded motor may be detected by measuring the current it uses with a regular a.c. ammeter (a), or a special "clip on" ammeter (b). (Fig. 20)

4. HOW SHOULD I INSTALL THE MOTOR PROPERLY?

Installing a motor properly involves problems of connecting to the load, mounting the motor, determining proper wire size, protecting and controlling the motor, and providing for safety. The installation should conform to provisions set forth in the National Electrical Code.

Connecting to the load

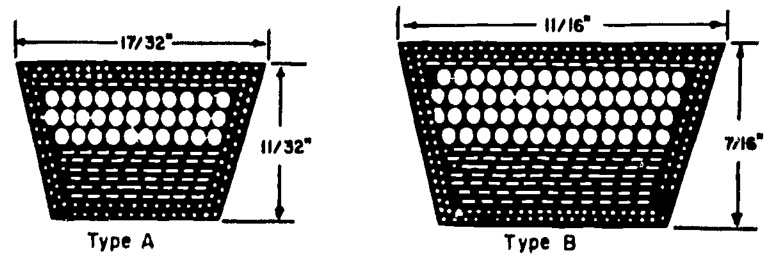
Belts and pulleys. In years past flat belts were widely used for connecting engines and motors to their driven loads. Today, V-belts have largely replaced flat belts for such uses. Some advantages of the V-belt drive over the flat belt are:

a. V-belts permit a lighter, more compact assembly. V-pulleys are narrower and will operate satisfactorily at close centers without using idlers or belt tighteners.

b. The wedging action of V-belts provides a good grip between belt and pulley so that less belt tension is necessary to prevent slippage. This reduces bearing wear and increases belt life.

c. V-belts are easier to install and stay on better. Precise alignment needed by other drives and provision for centering the belt on the pulley are not required.

Standard V-belts are available in a variety of lengths and cross-sectional sizes. The cross-section sizes are designated by the letters A, B, C, D, and E. Types A and B will cover most of the applications found on the farm for electric-motor drives from the fractional sizes up to and including 7½ horsepower. Type B belts should not be used for pulleys smaller than 5½ inches in diameter. Fig. 21 gives the cross-section dimensions of Types A and B belts.



Most V-belts used with electric motors on the farm are Type A or Type B. (Fig. 21)

The number and type of V-belts to use for a given drive depends chiefly on the size of the motor pulley and the speed and horsepower of the motor. Table 1 can be followed as a guide.

TABLE 1.—NUMBER AND TYPE OF V-BELTS RECOMMENDED FOR 1750 R.P.M. MOTORS

Diameter of motor pulley	Size of motor, horsepower							
in.	½	¾	1	1½	2	3	5	7½
2	1-A	2-A	......	......	......	......	......	......
2½	1-A	1-A	......	......	......	......	......	......
3	1-A	1-A	1-A	2-A	2-A	3-A	5-A	8-A
3½	1-A	1-A	1-A	2-A	2-A	3-A	4-A	7-A
4	1-A	1-A	1-A	1-A	2-A	2-A	3-A	5-A
4½	1-A	1-A	1-A	1-A	1-A	2-A	3-A	5-A
5	1-A	1-A	1-A	1-A	1-A	2-A	3-A	4-A
5½	1-A	1-A	1-A	1-A	1-A	1-B	2-B	3-B
6	1-A	1-A	1-A	1-A	1-A	1-B	2-B	2-B
7	1-A	1-A	1-A	1-A	1-A	1-B	2-B*	2-B
8	1-A	1-A	1-A	1-A	1-A	1-B*	1-B	2-B

......Pulleys less than 3 inches in diameter should not be used for motors 1 h.p. and larger.

*Type A could be used instead of Type B.

Belt length can be determined with sufficient accuracy for most installations by measuring around the pulleys with a tape or string while the motor is mounted in place. Measurement should be taken at the point of pitch diameter on the pulleys. Pitch diameter is ⅜ inch less than the outside diameter if the pulley is made for and used with a type A belt, and ½ inch less if type

B. In planning the desirable distance to place the motor from the driven machine, use the following rule. Distance between shaft centers should not be more than three times the sum of the pulley diameters, nor less than the diameter of the larger pulley.

Most V-belt drives are of the type known as V-V drive. This type uses a grooved pulley on both the motor and the driven machine (Fig. 22a).

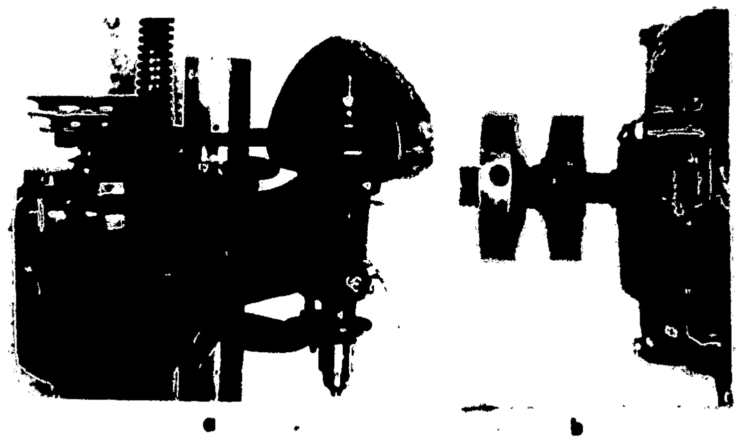
Occasionally a drive known as V-flat is used in which the motor has a V-pulley but the driven machine has a flat pulley, although a V-belt is used (Fig. 22b). This type of drive is quite satisfactory when the flat pulley is large so that the area of contact supplies enough friction to prevent slippage.

V-belt drives may be the V-V type (a), or V-flat type (b). (Fig. 22)

Sometimes the driving and driven pulleys cannot be arranged in parallel and must be placed at right angles to each other. This type of drive is known as a quarter-turn drive and is satisfactory if the speed ratio between pulleys is not greater than 2½ to 1 and the distance between centers is about 6 to 6½ times the diameter of the larger pulley.

On some machines a variable-speed drive is desirable. This may be accomplished in two ways. Multiple-step pulleys may be used on the motor, on the driven machine, or both (Fig. 23a). If used on both, the same belt can be used for all speeds without changing the motor position. Pulleys can also be used that have the space between the groove walls adjustable. This allows the V-belt to ride higher or lower in the groove which in effect changes the pitch diameter of the pulley (Fig. 23b).

Pulley combination. In selecting the proper pulley combination, it is necessary to know the speed (r.p.m.) of the motor and the speed (r.p.m.) required for the driven device. The speed of the motor may be obtained from the nameplate. In determining proper pulley sizes, the following



Different speeds may be obtained by using multiple-step pulleys (a), or adjustable-groove pulleys (b). (Fig. 23)

equation can be used:

Diameter of motor pulley x r.p.m. of motor = Diameter of driven pulley x r.p.m. of driven machine

For example, what size pulley should be used on a corn sheller to drive it at 210 r.p.m. using a motor operating at 1750 r.p.m. with a 3-inch diameter pulley?

$3 \times 1750 = P \times 210$

$5250 = 210\,P$

$25 = P$, or a 25 inch pulley is required

For quick calculations, the outside diameter may be used to figure pulley sizes. Where accurate determinations are required, the pitch diameter of the V-pulleys should be used as described previously.

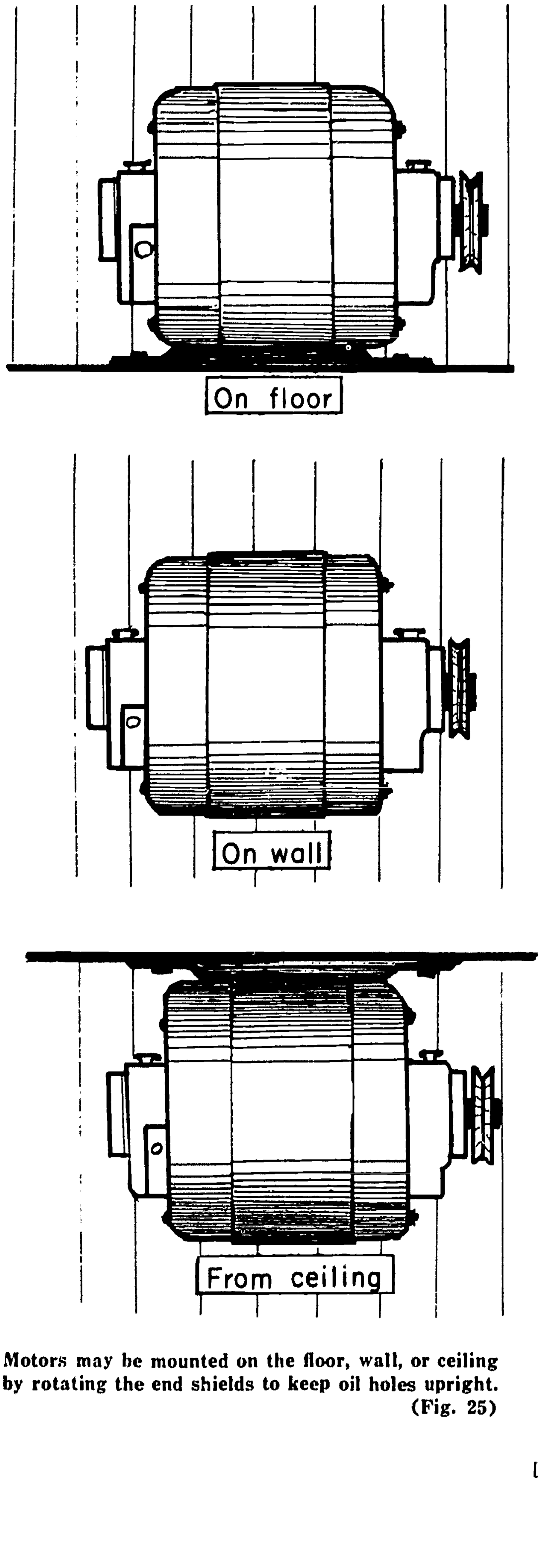
Direct drive. When both the driven machine and the motor have similar operating speeds and mounting conditions are satisfactory, it may be desirable to make a direct, end-to-end shaft coupling between the motor and the load (Fig. 24). Direct connections are often used in driving rotary pumps, blowers, fans, and numerous other machines. Direct drive requires very careful alignment and the use of a coupling device that is at least partly flexible. If properly mounted, direct-

Many devices are connected to motors by direct drive. (Fig. 24)

driven machines result in a minimum of wear on motor and shaft bearings.

Mounting the motor

Sleeve-bearing motors, unless specially designed, should never be used in any position other than horizontal, that is, with the shaft level. However, most motors can be mounted on the floor, on a side wall, or on the ceiling, by rotating the end shields to keep the oil holes and reservoirs in an upright position (Fig. 25). Ball-bearing motors can usually be mounted in any position, including vertical.

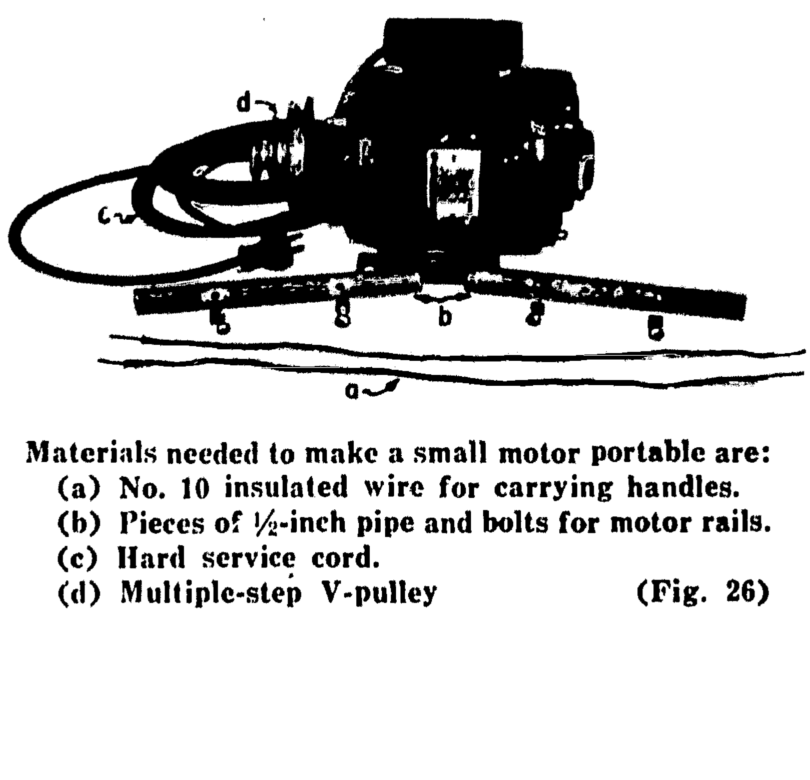


Motors may be mounted on the floor, wall, or ceiling by rotating the end shields to keep oil holes upright. (Fig. 25)

Motors should be mounted with some provision for tightening and loosening the belt. Only a reasonable tension is necessary with a V-belt drive. When in operation, the tight side of the belt should form a straight line from pulley to pulley while there should be a slight sag in the slack side. Running belts tighter than necessary to prevent slippage causes extra wear on the belts and motor bearings. Belts should never be forced over pulleys. More belts are broken from this cause than from actual failure in service. It pays to loosen the motor mounting so that belts can be slipped on easily. Care should be taken not to draw a motor down tight on an irregular surface which will tend to place a strain on it and throw the bearings out of line.

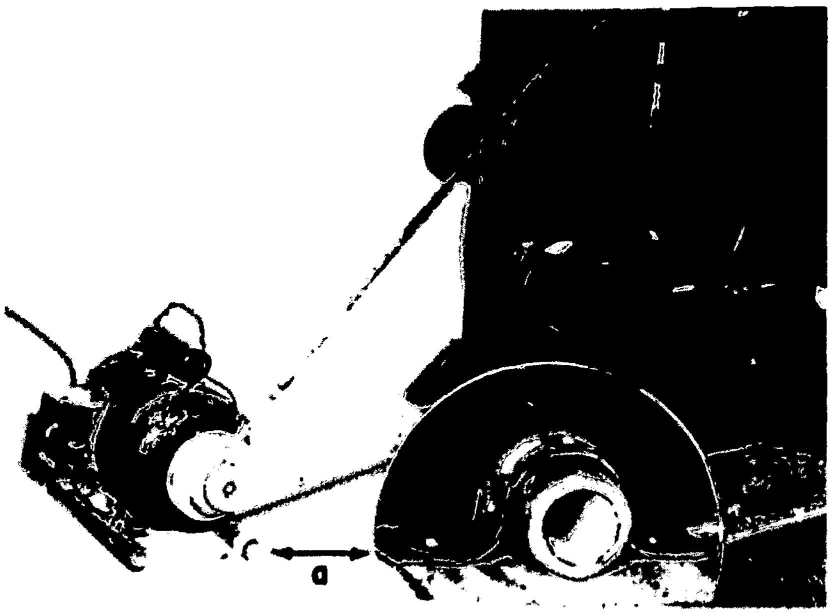
In place of a fixed, permanent mounting, some farm-motor jobs are of a nature that makes the use of portable motors practical. Machines that are used only seasonally or at infrequent intervals can be operated with a portable motor, resulting in a considerable saving in investment.

A portable 1/4 to 1/2 horsepower motor is relatively inexpensive and can be used almost anywhere without special wiring as it can be plugged into a regular 120 -volt outlet. Equipment needed to make a small motor portable is shown in Fig. 26. No. 10 insulated wire can be twisted together to make a carrying handle. Short pieces of pipe may be used to make the motor rails and the motor is equipped with a hard service cord of ample size and a multiple-step V-pulley.



Materials needed to make a small motor portable are:
(a) No. 10 insulated wire for carrying handles.
(b) Pieces of 1/2-inch pipe and bolts for motor rails.
(c) Hard service cord.
(d) Multiple-step V-pulley (Fig. 26)

Fig. 27 shows how a small portable motor may be attached to its load, using the weight of the motor to provide proper belt tension.



The portable motor may be held in position with pipe straps (a). (Fig. 27)

Determining proper wire size

Using a circuit conductor (wire) that is too small is a serious mistake often made in connecting farm motors. When the circuit conductors (wires) are too small, the voltage at the motor terminals is lower than that for which the motor was designed. Since the power produced by a motor is a result of both voltage and current, a voltage drop causes an increase in the current required. This higher current causes an increase in the heating effect of the motor. Since the increase in heating effect is not in direct proportion to the increase in current, but according to its square, doubling the current increases the heating effect four times. This explains why low voltage causes a motor to overheat and often burn out.

Table 2 shows the minimum size of wire to use in connecting motors according to size and distance from the center of distribution on the farm.

Protecting and controlling the motor

A proper electric-motor installation includes means for controlling (starting and stopping) it as well as provision for protecting the motor, the wiring, and other equipment from damage due to overloads or short circuits. Rules for the safe use of control and protective devices are contained in the National Electrical Code, which is the safety standard commonly followed throughout the United States. The following diagram (Fig. 28) is a simplified version of one appearing in the Code and applies to circuits for farm motors not larger than 7½ horsepower.

The four units, designated a, b, c, and d are necessary in all properly installed motor circuits. Each will be discussed separately, although in actual practice, two or more are often combined.

Motor branch-circuit overcurrent protection (Fig. 28a)

Fuses or circuit breakers are installed to protect the entire motor branch-circuit against excessive current due to short-circuits or grounds. This branch circuit includes the motor, the control apparatus, and the wires supplying power to the motor. The maximum limits for these fuses or circuit breakers as prescribed in the Code are about 250 to 300 percent of the full-load current of the motor. This high a rating is permitted because motors draw considerably more than their rated current during the starting period. The amount of current required and the length of time needed for the motor to reach full speed depend on the type of motor and the character of the particular load to which it is connected.

TABLE 2.—WIRE SIZES FOR INDIVIDUAL SINGLE-PHASE MOTORS

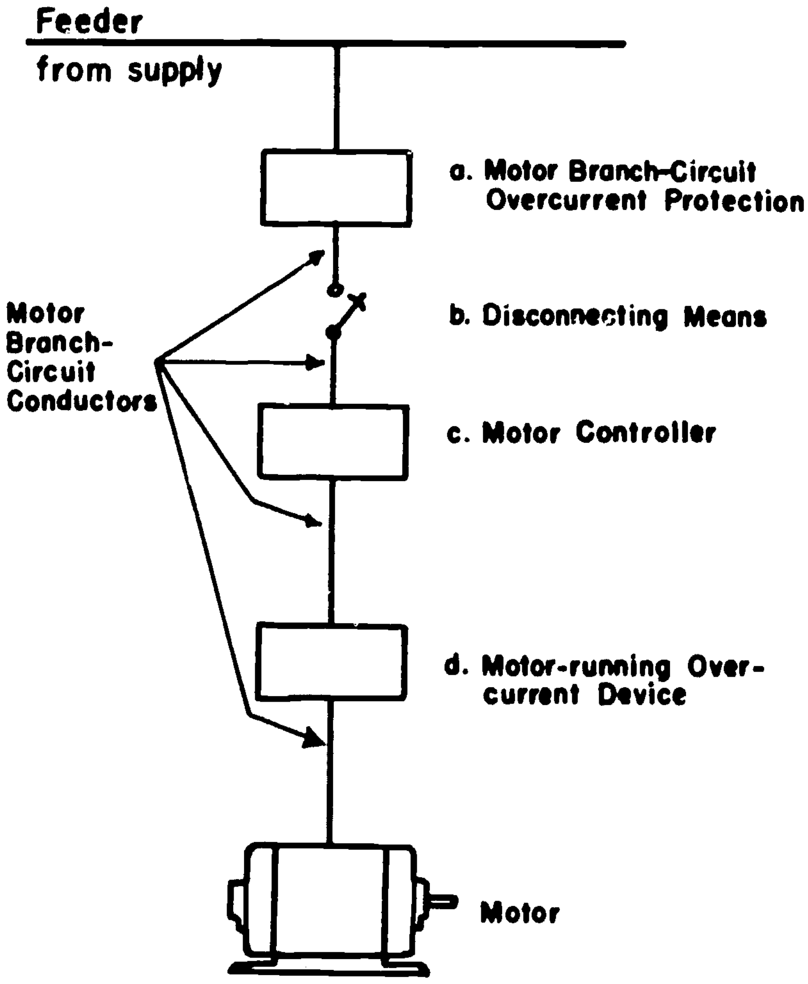
Based on 2 Percent Voltage Drop on Full-Load Current

Motor Horsepower	Volts	Approximate Full-Load Current, Amperes	Length of Run in Feet (One Way) 50	75	100	150	200	250	300	350	400	500	600	700
1/6	115	4.4	14	14	12	12	10	8	8	8	6	6	6	4
1/4	115	5.8	14	12	12	10	8	8	6	6	6	4	4	4
1/3	115	7.2	14	12	10	10	8	6	6	6	4	4	4	2
1/2	115	9.8	12	10	10	8	6	6	4	4	4	2	2	2
3/4	115	13.8	10	10	8	6	4	4	4	2	2	2	1	0
1	115	16.0	10	8	8	6	4	4	2	2	2	1	0	00
1/4	230	2.9	14	14	14	14	14	14	12	12	12	10	10	10
1/3	230	3.6	14	14	14	14	14	12	12	12	10	10	10	8
1/2	230	4.9	14	14	14	14	12	12	10	10	10	8	8	8
3/4	230	6.9	14	14	14	12	10	10	10	8	8	8	6	6
1	230	8.0	14	14	14	12	10	10	8	8	8	6	6	4
1½	230	10.0	14	14	12	10	10	8	8	6	6	6	4	4
2	230	12.0	14	12	12	10	8	8	6	6	6	4	4	4
3	230	17.0	10	10	10	8	8	6	6	4	4	4	2	2
5	230	28.0	10*	10*	8	6	4	4	4	2	2	1	1	0
7½	230	40.0	10**	8*	6	4	4	2	2	1	1	0	00	000
10	230	50.0	6*	6*	6*	4	2	2	1	1	0	00	000	000

* For wires in cable or conduit, use next size larger.

** For wires in cable or conduit, use two sizes larger.

NOTE: For exterior wiring, overhead conductors shall not be smaller than No. 10 for spans up to 50 feet in length, and not smaller than No. 8 for longer spans. (National Electrical Code, Art. 730-6)



A properly installed motor requires the above units to control and protect it. **(Fig. 28)**

Disconnecting means (Fig. 28b)

To permit motors to be serviced safely, there must be provision for disconnecting the motor and controller from the power supply. According to the Code, this disconnecting means must open all ungrounded wires, be readily accessible, and plainly indicate whether it is "on" or "off." Unless in sight of and within 50 feet of the controller, the disconnecting means must be made so it can be locked in the "off" position.

The Code requires motors rated over two horsepower to have, for disconnecting purposes, either a switch of correct horsepower rating made specifically for motor-circuit use or a circuit breaker of proper rating. For two-horsepower or smaller motors, the switch need not be rated in horsepower. providing its ampere rating is at least twice the full-load current of the motor. For portable motors the attachment plug may serve as the disconnecting means. For stationary motors 1/8 horsepower or less, the branch-circuit protective device may serve as means for disconnecting.

Motor controller (Fig. 28c)

To make the motor perform the desired task at the right time, some form of controller must be provided. This means a device which will start and stop it, and perhaps control its speed and direction of rotation.

Common forms of controllers are manual and magnetic. Manual controllers have a handle for hand operation. The magnetic type operates by an electromagnet which is generally controlled by a push button at the controller or at some convenient remote location. For example, in a corn crib it is often desirable to mount the motor at the top of the elevator and place the remote-control button down in the driveway where grain is unloaded. Frequently it is desirable when the building is wired, to make the entrance into the cupola. This requires only a few feet of heavy wiring inside the building since the wire down to the control button does not carry the motor load and can normally be as small as No. 14.

The push button may be replaced by an automatic device such as a thermostat, a pressure-actuated switch, or a tank-float switch. Some of these automatic devices are large enough to operate a small motor directly and when so used are in themselves "controllers."

The Code requires controllers to be marked with the voltage and current or horsepower rating so that they can be selected accordingly. An approved controller of proper horsepower rating shall be used except as permitted in the following cases: (1) for a stationary motor rated two horsepower or less, a general-use switch having an ampere rating of at least twice the full-load rating of the motor may be used; (2) for a portable motor of 1/3 horsepower or less, the controller may be an attachment plug; or (3) a circuit breaker, rated in amperes only may be used in the branch circuit as a controller.

It is required for safety that the controller or a manually-operable switch which will prevent the starting of the motor be in sight of and within 50 feet of the motor unless the controller or disconnecting means can be locked in the "off" position.

Motor-running overcurrent device (Fig. 28d)

Since a motor draws less current running than starting, a "motor-running overcurrent device," sensitive to currents in excess of the normal running current of the motor, is necessary to prevent damage to the motor and the motor circuit, if the motor becomes overloaded while running. Motor overloads may be caused by using a motor that is too small for the machine it drives, lack of lubrication, too tight a belt, or a number of other abnormal conditions.

There are several different types of motor-running overcurrent devices which are recognized by the Code. Continuous-duty motors* of more than one horsepower may be controlled by a separate or integral (built-in) overcurrent device. A separate device shall be rated or set at not more than 125 percent of the motor full-load current rating for a motor marked to have a temperature rise not over 40°C, and at not more than 115 percent for all other types of motors. If this limit does not correspond with a standard rating, the next larger standard size may generally be used. An integral protective device shall be of the rating approved for a specific motor, which will be marked to indicate this fact.

Motors of one horsepower or less may be protected the same as larger motors. However, if the motor is manually operated and within sight of the operator, it may be considered protected by the motor branch-circuit overcurrent protection (Fig. 28a) under most conditions.

An automatically-started motor, rated one horsepower or less, may be installed without specific running overcurrent protection if it is part of an approved assembly equipped with other safety controls, such as the safety combustion controls of a domestic oil burner. If the assembly contains such protective equipment, it is indicated on the nameplate.

Motor-running overcurrent devices other than fuses are required to have a rating of at least 115 percent of the full-load current rating of the motor.

Combination devices

Under the preceding four headings, a brief description of the application of the four elements (shown as a, b, c, and d in the diagram) has been given. They are always required for the control and protection of motors. As has already been mentioned, however, some or all of these functions are frequently combined.

One such combination is for the disconnecting means and the controller to be in the same enclosure. The motor branch-circuit protective device and the motor running overcurrent protective device may also be contained in the same enclosure. To go a step farther, a switch or circuit breaker may serve as both controller and disconnecting means if it meets the requirements for both types of use. Similarly, the motor branch-circuit overcurrent protection and motor running overcurrent protection may be combined in a single overcurrent device if its rating or setting provides the specified running overcurrent protection. A portable motor of 1/3 horsepower or less may have a single attachment plug and receptacle to serve as both a disconnecting means and controller.

Providing for safety

Motor installations should be made as safe from mechanical and electrical hazards as possible. Guards should cover moving parts such as pulleys and belts, as is recommended with any machine. Mention has been made of the importance of the type of motor enclosure used around flammable or explosive materials.

Motors are electrically safe when they are installed in accordance with the Code. Particular attention should be given to the Code provisions on grounding. Many farm motors operate in wet locations that would be rated as hazardous from the standpoint of electric shock. Proper grounding not only removes the danger of fatal shock, should motor insulation fail and the frame become charged, but prevents a more common accident—that of a person jumping or falling into a moving machine as a result of a light shock.

* Any motor is considered to be for continuous duty unless the nature of the apparatus it drives is such that the motor cannot operate continuously with load under any condition of use.

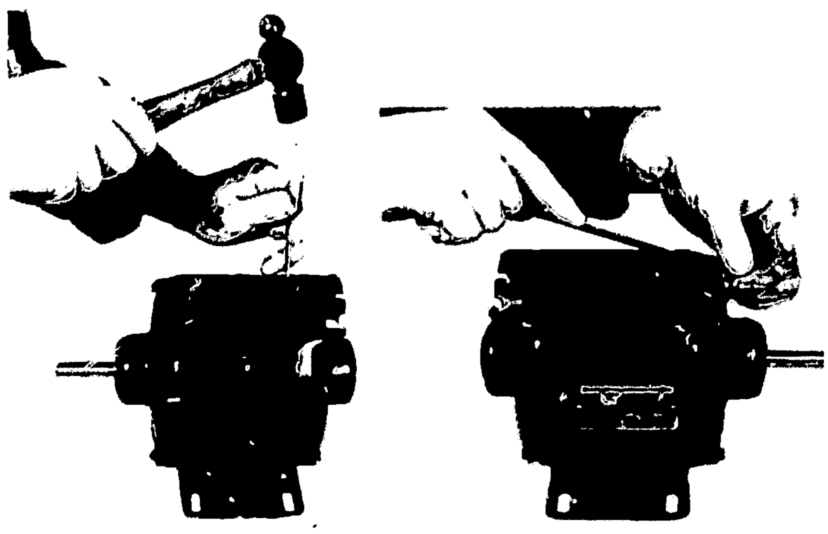
5. WHAT CARE SHOULD I GIVE AN ELECTRIC MOTOR?

The electric motor will give years of trouble-free service with a very minimum of care and maintenance. Normal care consists of cleaning, lubricating, storing, and caring for brushes and commutator (of motors so equipped).

Cleaning

Cleanliness is an important factor in the life and operation of an electric motor. A majority of general-purpose motors have openings in them for ventilation and these allow dirt and foreign matter to enter the motor. Under most conditions a motor will operate for a long period of time without requiring a thorough cleaning. However, in some places dirt may accumulate in the motor to such an extent that difficulties will occur. In most cases, general-purpose single-phase motors have either a starting switch or brushes which operate only while the motor is starting. Dirt or corrosion on these parts may make the motor fail to start, or may cause overheating. Even if the motor does operate, excessive dirt will cause moving parts to wear rapidly. A periodic inspection should be made to determine if the motor requires cleaning.

If it becomes necessary to disassemble and thoroughly clean an electric motor, the outside should be wiped off first to remove all dirt and grease. Considerable damage may be done by improper disassembling of the motor. Extreme care should be taken if this is required. Before taking the motor apart mark the exact position of the end shields on the motor frame with a sharp center punch or file (Fig. 29). This will permit reassembling the motor just as it was for true bearing alignment.



Mark position of end shields with a sharp center punch or file before disassembling. (Fig. 29)

Next, remove the nuts and through bolts or cap screws which hold the end shields in place and carefully remove the rotor with its end shield. If the motor has brushes, it is often advisable to remove them first to avoid breaking them when removing the rotor. The end shield opposite the shaft extension usually has the motor lead wires attached to it and one must be careful to avoid tearing them loose from the motor windings. Special pains must be taken if the motor has ball bearings as bearings and races are often difficult to remove.

If available, use compressed air at low pressure or a vacuum cleaner to remove dust and loose dirt from inside the motor. A soft brush may also be used to clean out loose dirt. To remove grease and oil, apply safe cleaning solvent with a small paint brush and wipe clean with a cloth. Avoid using excessive amounts of cleaning fluid directly on the windings as the insulation may be damaged.

If the motor has sleeve bearings, be sure to remove the yarn or oil wick and wash out the oil well. It is advisable to replace the yarn or oil wick if new is available. Some types of ball-bearing motors are so constructed that the bearings can be cleaned and relubricated while the motor is apart. If the motor has sealed ball bearings, do not allow any of the cleaning fluid to enter the bearings.

After all parts of the motor have been thoroughly cleaned, place them on a clean surface and wipe dry with a clean cloth. If much cleaning fluid has been used, it is well to use an electric heater, a heat lamp, or a large light bulb to further dry out the windings.

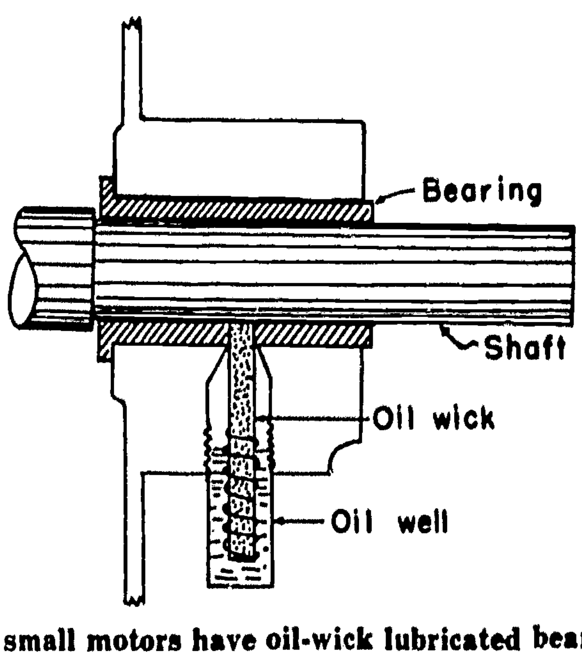
When clean and dry, reassemble the motor carefully. Be sure that the motor leads are pulled out of the way of the rotor fan or other moving parts which might catch and tear them loose when the motor starts. Tighten the through bolts or cap screws gradually and evenly, being sure that the end shields fit tightly all the way around and that the motor shaft finally turns freely.

Lubricating

Proper lubrication is a very important step in electric-motor maintenance. It means the use of the right lubricant, in the right amount, and at the right time intervals. Overlubrication is just as serious as underlubrication. The correct amount of lubricant will remain in the bearings to reduce friction heat and wear. Excess oil or grease will spread to other parts of the motor, cause the motor to plug with dirt, and eventually cause the insulation to break down. Manufacturers' directions should be followed closely in lubricating motors.

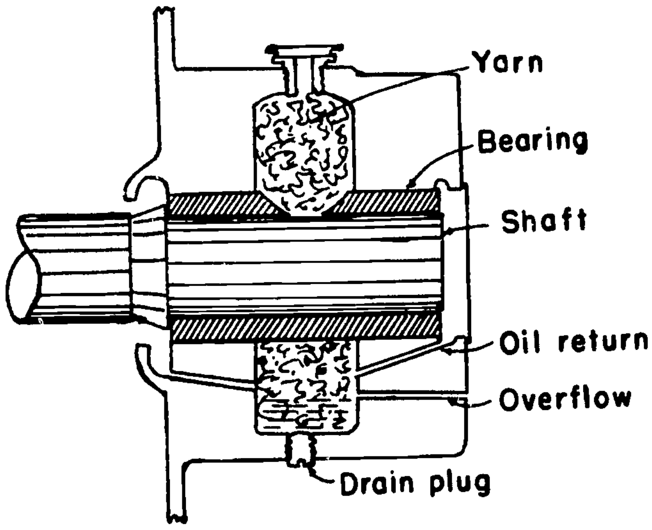
For sleeve-bearing motors in general, use a good grade of SAE 10 or 20 oil. Lighter or heavier oil may be used if temperatures are extremely low or high. There is a wide variation in the oil storage capacity of motors, as found in the three common types of oiling systems used with sleeve-bearing motors.

One type uses an oil well below the bearing with a wick to carry the oil up to the shaft (Fig. 30). Twice a year, or so, the oil well should be unscrewed, the old oil cleaned out and the well refilled about two-thirds full with new oil.



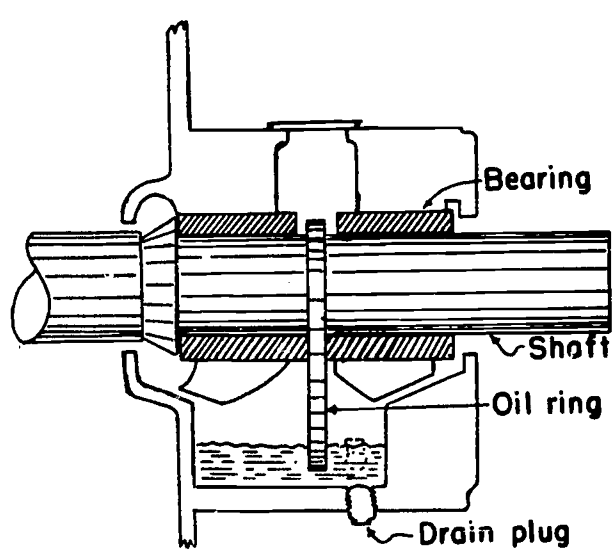
Some small motors have oil-wick lubricated bearings. (Fig. 30)

Another system uses a yarn-packed bearing to which a few drops of oil should be added every few months. If there is a drain plug at the bottom, accumulated oil can be drained off occasionally (Fig. 31).



Many small motors have yarn-packed bearings. (Fig. 31)

A third type has a ring-oiled bearing. Oil is carried from an oil reservoir below the bearing onto the shaft by a loose ring that turns as the motor runs (Fig. 32). With this type it is necessary to keep the oil level up to the filler hole by checking periodically. Every two or three years it is well to drain off the old oil, flush out the reservoir, and add new oil.



Larger sleeve-bearing motors often have ring-oiled bearings. (Fig. 32)

Lubrication is far less critical with the ball-bearing than the sleeve-bearing motor. Ball bearings carry the load by direct contact while sleeve bearings carry the load on an oil film. A ball bearing could be operated dry if it were not for dirt, corrosion, friction heat, and other adverse factors. However, since such conditions are always present, lubrication is necessary.

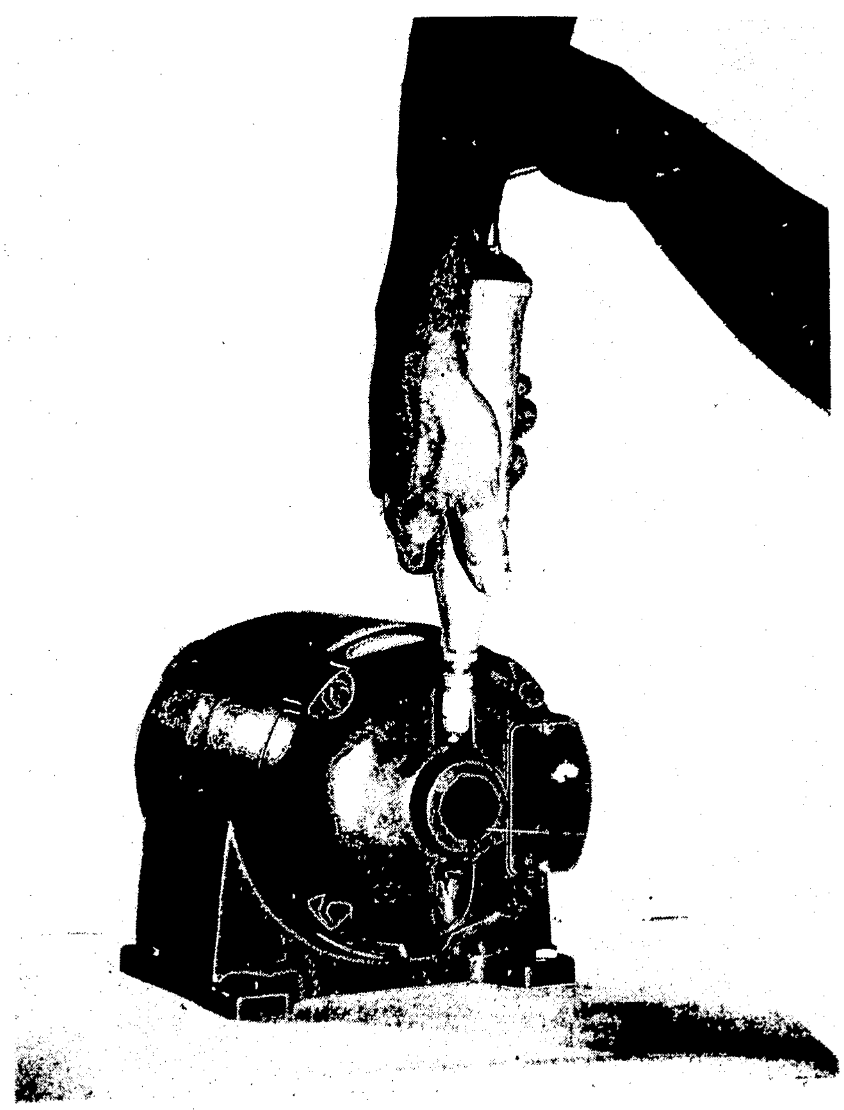
The type of ball bearing which is prelubricated and sealed by the manufacturer should not be disturbed. The other type of ball bearing can be relubricated, either by disassembling the motor, or through lubrication openings. Disassembled bearings should be wiped clean of old grease with a soft cloth and repacked half to two-thirds full of the type of electric-motor ball-bearing grease recommended by the motor manufacturer.

If the bearing has lubrication openings, remove both the filler and drain plugs. If the old grease is hard, run the motor to warm it up and add light oil until the grease softens and runs out. Stop the motor and add new grease until the remainder of the old has been forced out or the new grease starts to appear at the drain opening (Fig. 33). Then operate the motor again with both holes open and let the motor force out excess grease. Finally, before the plugs are replaced, remove an additional quantity of grease with a rod or wire to allow for expansion when the motor is operating.

Storing

Electric motors should be stored in a dry place and kept free from dirt. The following steps are recommended for preparing a motor for storage:

a. Wipe the outside of the motor with a cloth to remove dirt and grease.



Some ball-bearing motors are relubricated with a grease gun containing special ball-bearing grease. (Fig. 33)

b. Check bearings for lubrication and add fresh oil or grease if required.

c. Cover the shaft extension with a coating of grease to prevent rusting.

d. Wrap the motor with heavy paper to keep dust and dirt from accumulating in it.

Caring for commutator and brushes

Proper care of commutator and brushes is important to obtain satisfactory service and long life from commutator-type motors. Sluggish starting and excess sparking at the brushes suggests that trouble is developing in these parts.

Badly worn brushes should be replaced with new ones. It is important to secure the proper brushes from the manufacturer or motor-service man who can secure them if he has all the information given on the motor nameplate. New brushes should be fitted to the contour of the commutator, if it is of the axial type. This can be done by wrapping fine sandpaper around the commutator and placing the new brush in its holder. Then by holding the brush against the commutator with one hand and turning the rotor back and forth with the other, the brush can be ground to the proper contour. Examining the brushes after the motor has been run for a time will tell if the fitting has been properly done, as a well-seated brush will appear shiny all over the contact surface.

Sometimes brushes will fail to make positive contact with the commutator because of sticking due to a gummy accumulation of oil and dirt in the holders, or because of weak or broken springs. The obvious remedy for these conditions is cleaning or replacing the springs.

A dirty or worn commutator will also cause trouble. With some types of motors, it is possible to clean the commutator without taking the motor apart, using a clean, lint-free cloth or fine sandpaper. Emery cloth should never be used since emery dust is a conductor of electricity and may cause short circuits. If the commutator is rough, pitted, or worn, the motor should be taken to a motor repairman who can resurface the commutator and undercut the mica insulation between the commutator bars with special equipment for the purpose.

6. HOW CAN I DETERMINE WHAT IS WRONG WHEN A MOTOR WILL NOT OPERATE?

Trouble shooting, or diagnosing motor trouble, is the first step toward getting the machine back into operation. The most successful trouble shooters are those who look for and eliminate the simplest difficulties first. Sudden failure of a motor to operate may be due to failure of power supply, excessive load, frozen or worn motor bearings, operation of built-in thermal protection, failure of motor-starting mechanism, or failure of motor windings.

Failure of power supply. This is the first thing to check. Use a test lamp or voltmeter to make sure that proper voltage is available right up to the motor terminals. Be sure to check motor control and protective devices.

Excessive load. Check for excessive load conditions in the driven device by removing the belt (if belt driven) and attempting to turn the device by hand. If the driven machine is at fault, the motor will run normally with the belt off.

Frozen or worn motor bearings. If the motor will not run idle, shut off the current and try turning the shaft by hand. If it does not turn freely, the trouble may be a dry or worn bearing. Lubrication may remedy a dry bearing but it is often necessary to take the motor apart to free a bearing that has stuck. If the motor shaft has any noticeable up and down play, bearings may be worn to the extent that the rotor is dragging, particularly when belt tension is applied. Do not confuse this with end play, a slight amount of which is necessary and desirable. The remedy for worn bearings is replacement, a job for the motor serviceman.

Operation of built-in thermal protection. Motors having this protection usually carry a statement so indicating on the nameplate or elsewhere on the motor. If the motor has a reset button, press this to see if it starts. If it is of the automatic reset type, wait until the motor cools, and then turn it on to see if it will run. Like a blown fuse, a tripped thermal protector usually indicates trouble somewhere.

Failure of motor-starting mechanism. A motor with this type of trouble will hum when it is turned on and, if the rotor is given a spin by hand, will usually run normally. If the motor is a split-phase or capacitor-start type, the starting circuit is usually open at some place. It may be failure of the starting switch to make contact due to one of a number of causes. The contacts may be dirty, burned, or pitted. A wire may be burned in two somewhere. The centrifugal device may have failed to close the switch, perhaps due to too much end play in the rotor shaft. With a capacitor-start motor, the capacitor may be burned out.

Failure of motor windings. A burned-out winding, will usually result in a characteristic odor coming from the motor. Charred insulation can often be seen through the openings in an open-type motor. An exception to this is when a single strand of wire quickly burns in two. This occurs most often in the starting winding, in which case the motor shows the characteristics described under "failure of motor-starting mechanism."

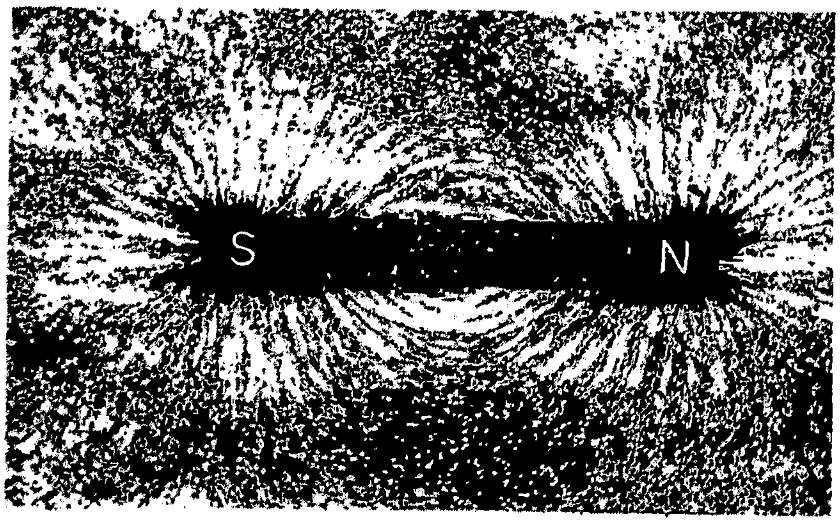
It is well in discussing motor troubles to point out the hazards of "tinkering." The operator of electric motors should realize that they are delicate mechanisms and that he should not go beyond the limits of his knowledge, skill, and experience in attempting to service and repair them.

7. WHAT ARE THE IMPORTANT PRINCIPLES OF ELECTRIC MOTORS?

It may be of interest to take a brief look at some of the fundamental principles of electricity and magnetism which are involved in the operation of electric motors. We shall consider what makes an induction motor run, and the methods used in starting the split-phase, capacitor, and repulsion-start induction motors.

What makes an induction motor run?

To help understand how an induction motor runs, let us first consider a few of the principles of electricity and magnetism as they apply to motors. Permanent magnets made of steel or alloys, such as alnico, will retain their magnetism for a long period of time. A typical magnet has a north (N) pole and a south (S) pole, and an invisible field of magnetic force with lines proceeding from the N pole to the S. This magnetic field is often demonstrated by placing the magnet under a piece of paper or glass and sprinkling iron filings over the top. Upon tapping the paper or glass, the filings are attracted by the lines of magnetic force and form a definite pattern (Fig. 34).



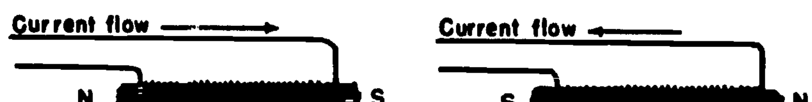
The magnetic field may be demonstrated with iron filings sprinkled on a piece of glass over a permanent magnet. (Fig. 34)

If we touch one end of the magnet to a soft-iron nail, the nail assumes all the properties of a magnet. It has a magnetic field of its own and will attract iron filings. It is interesting to note that the nail does not have to actually touch the magnet to assume these magnetic qualities. It becomes magnetized when it is placed **within the magnetic field** of the permanent magnet. We thus magnetize the nail by **induction** rather than by direct contact.

Any wire that has an electric current flowing through it is surrounded by a magnetic field, though under ordinary circumstances this field is weak and unimportant. If we wind a coil of insulater wire around a soft-iron core as in Fig. 35 and pass a current through the coil, we produce a magnet called an electromagnet. It may be considerably stronger than the permanent magnet described above. The strength of an electromagnet is determined chiefly by the number of turns of wire in the coil and the amount of current flowing through it.

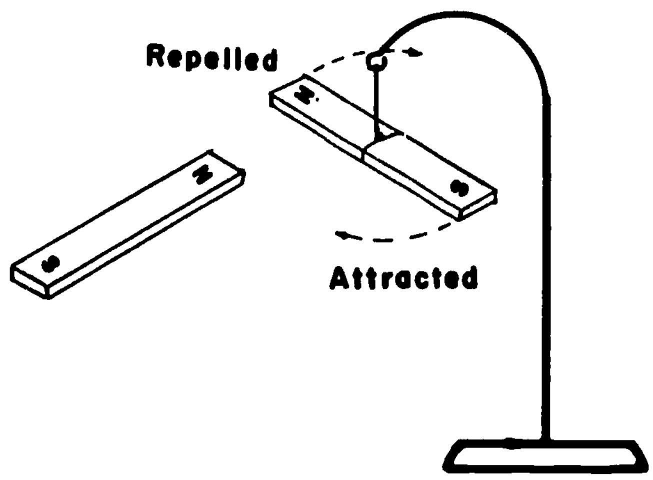
An electromagnet is formed by passing a current through a coil of insulated wire surrounding a soft-iron core. (Fig. 35)

There are two other important ways in which an electromagnet differs from a permanent magnet: (1) It is only a temporary magnet, that is, it has magnetism only while current is flowing through the coil, and (2) the poles of the electromagnet change when the direction of current flow in the coil is reversed (Fig. 36).



Reversing the direction of current flow in the electromagnet coil reverses its magnetic polarity. (Fig. 36)

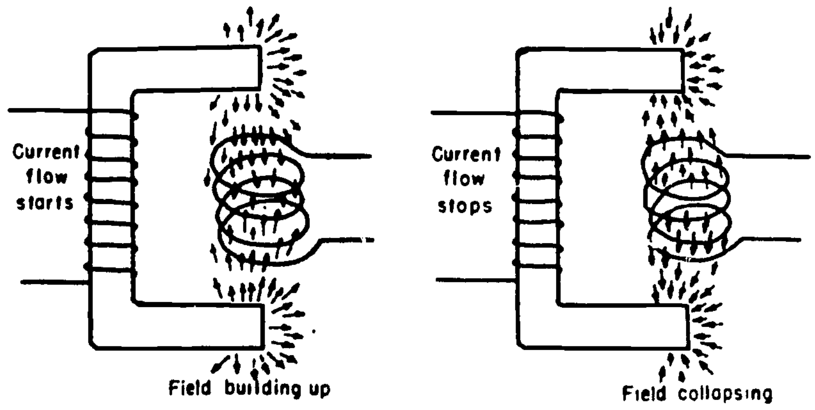
If we experiment with two magnets, we soon observe another fundamental law of magnetism—that unlike magnetic poles attract and like poles repel each other. If we suspend a bar magnet with a string so that it is free to turn and bring another magnet up to it, we get the reaction shown in Fig. 37.



Like magnetic poles repel each other; unlike poles attract. (Fig. 37)

If a copper wire, or other conductor forming a closed circuit is moved through the magnetic field of either a permanent magnet or an electromagnet in such a way that the wire cuts across lines of magnetic force, an electric current will be caused to flow in the wire. This is a basic principle used in the magneto and generator. The amount of current produced in this way is chiefly determined by the strength of the magnetic field, the number of turns of wire, and the speed at which the wire cuts the lines of force. This process may also be reversed. Instead of the coil of wire moving through the magnetic field, the lines of force may be caused to move through a stationary coil of wire, and a flow of electric current will result as before.

Let us imagine a coil of wire placed between the poles of a U-shaped magnet as in Fig. 38. When the current commences to flow through the electro-

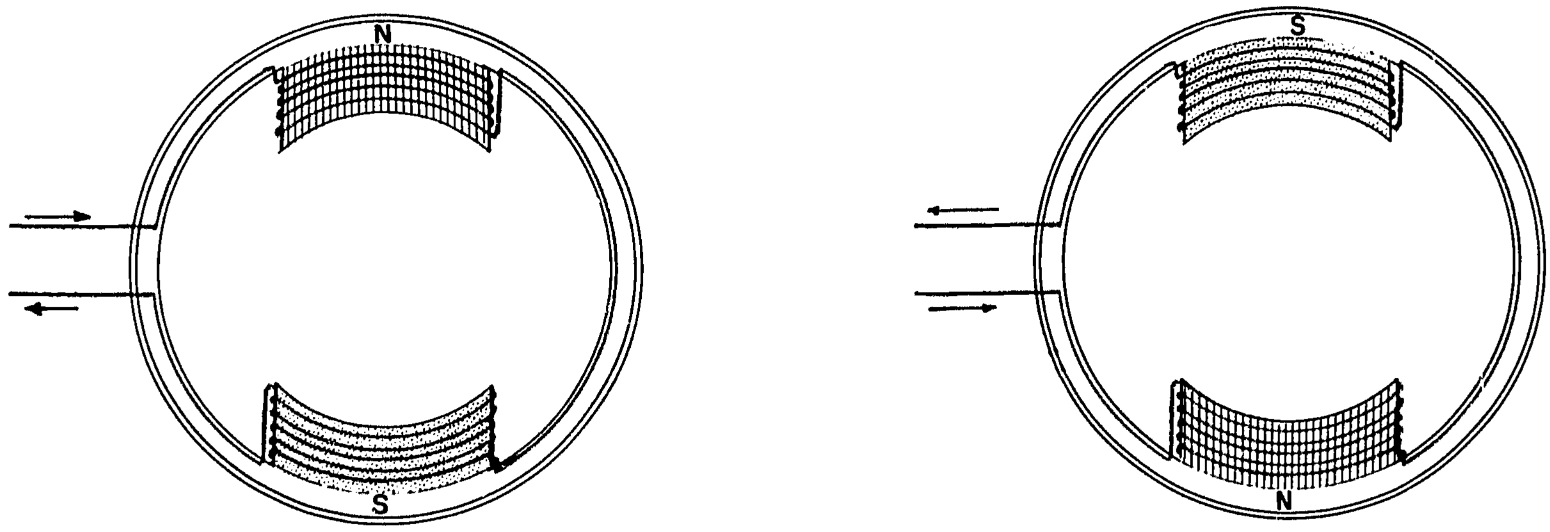


Lines of magnetic force cut through the coil of wire when the current flow starts and stops in the electromagnet coil. (Fig. 38)

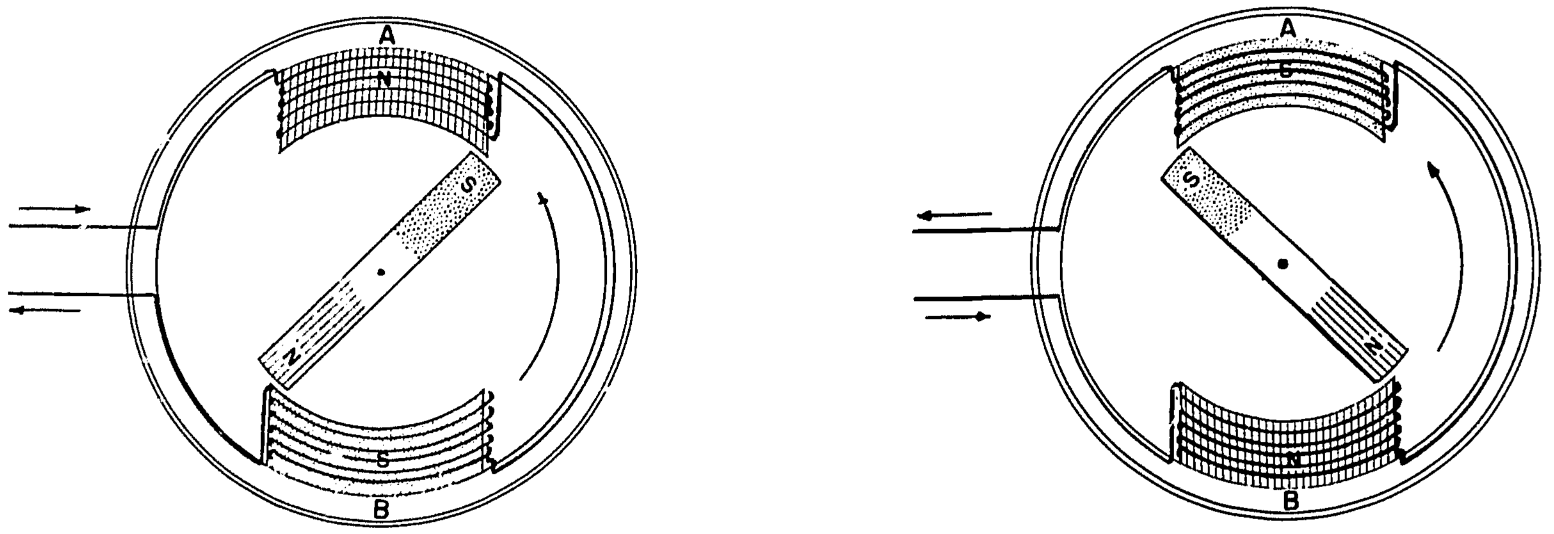
magnet winding, a magnetic field is produced, that is, lines of magnetic force move into position, cutting across the coils of wire. When the current flow stops, the magnetic field disappears or collapses and the lines of force again cut across the coil. No current flows in the coil except at the very instant that lines of force are cutting the coil, or when the current starts and stops flowing through the electromagnet.

If the ordinary 60-cycle, alternating current is connected to the electromagnet winding, the magnetic field will build up and collapse once every alternation or 120 times per second. As a result a similar 60-cycle, induced alternating current will flow in the coil of wire placed in this magnetic field. We call this process **induction** because, again, there is no direct contact between the two coils of wire.

As explained previously, the typical induction motor consists of a stationary part called a stator and a rotating part called a rotor (see pages 4-6). The stator has a slotted core made up of thin sections of soft iron or steel. Insulated copper wire is wound in these slots to form an electromagnet with two or more poles. We will consider, for simplicity, a stator with two poles as illustrated in Fig. 39. If we connect a 60-cycle alternating cur-



Each time the current alternates, the magnetic poles of the stator change. (Fig. 39)



A permanent magnet would rotate in this alternating field if started. (Fig. 40)

rent to the two leads from this winding, the stator becomes an electromagnet whose magnetic poles will reverse every time the current alternates, or 120 times per second.

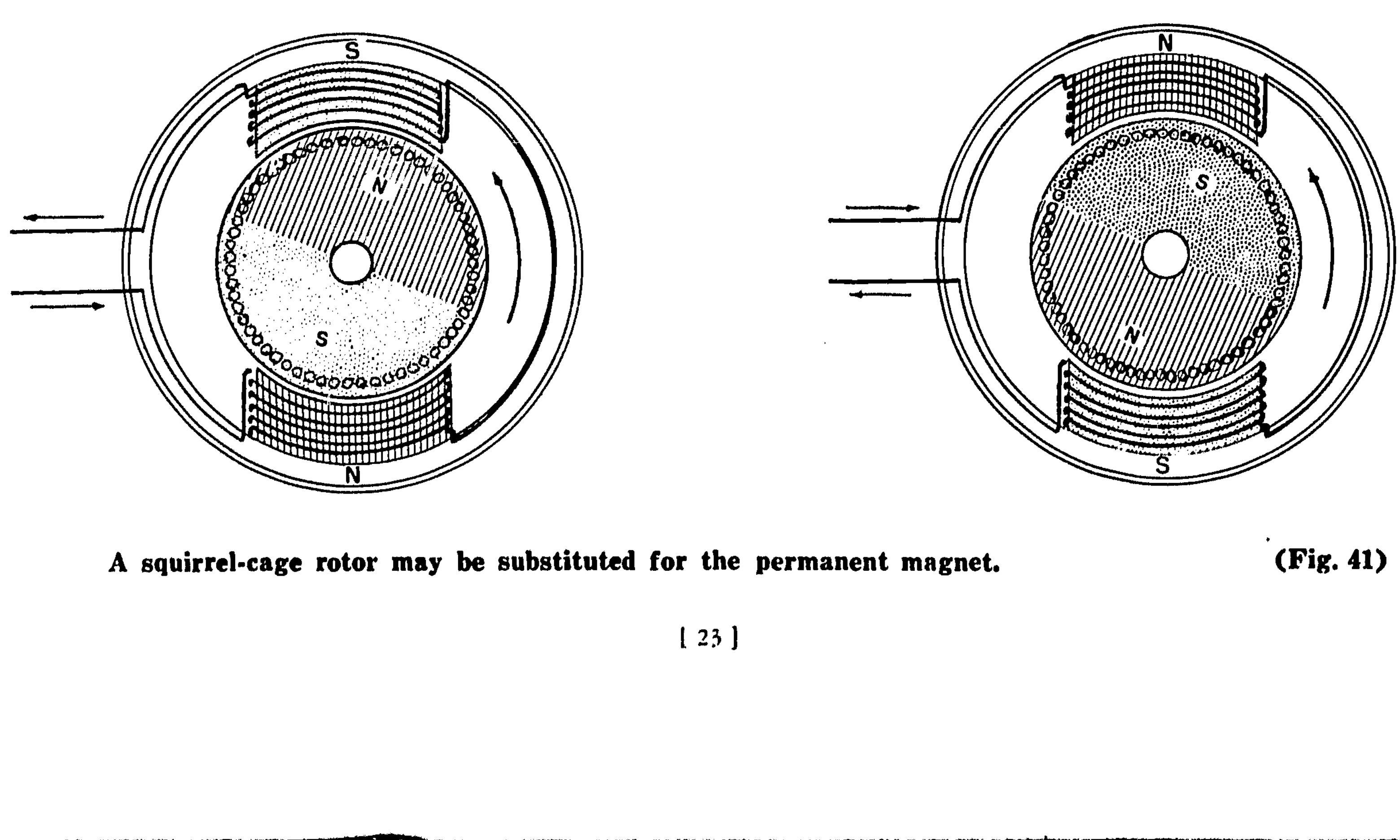
If we mount a permanent bar magnet on a pivot in the center of this magnetic field (Fig. 40.) and give it a spin as we turn on the 60-cycle alternating current to the stator winding, the bar magnet or rotor, will continue to run because of the attraction and repulsion of the alternating poles of the stator.

At the instant that pole A is a north pole and B is a south, the S pole of the rotor will be attracted by A and repelled by B. Likewise the N pole will be attracted by B and repelled by A. However, before the rotor can come to rest in line with poles A and B, the current alternates and the stator poles reverse. Momentum will carry the rotor past center and then A will attract N and repel S while B will attract S and repel N. Thus the rotor continues to rotate and would theoretically adjust itself to a speed of 60 revolutions per second or 3600 revolutions per minute. This is known as **synchronous speed.**

Now we shall substitute a more practical type of rotor for the bar magnet, using a squirrel-cage type rotor **(Fig. 41)**. It has a slotted core made up of thin sections of the same soft iron or steel as found in the stator core. In its slots are bars of bare copper or some similar good conductor which are short-circuited together at each end of the rotor.

If we give this type of rotor a spin and turn on the current to the stator coils, currents are induced into the copper bars of the rotor as they cut the lines of magnetic force. These currents and the magnetic poles which they create in the rotor react with the magnetic field of the stator to make the motor keep on turning.

The actual running speed of this motor would be somewhat less than the synchronous speed of 3600 r.p.m. because the current is induced into the rotor only when its copper bars cut the lines of force in the field of the stator. This occurs only when the rotor turns somewhat slower than the speed of the alternations. This difference in speed is known as **slip.** The greater the slip the more the lines of force that are cut; and the stronger the induced current in the rotor becomes. This causes the rotor to pick up speed but the faster it turns the fewer the lines of force that are cut and the weaker the current and magnetism in the

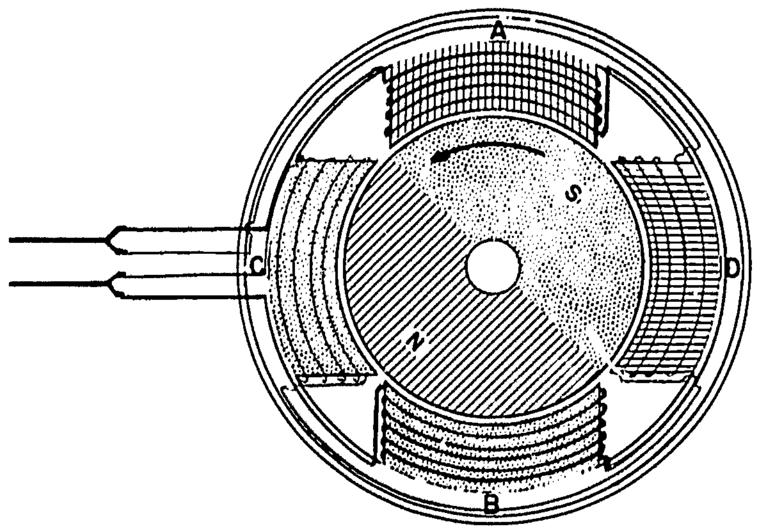


A squirrel-cage rotor may be substituted for the permanent magnet. (Fig. 41) rotor becomes. It then slows down slightly. Thus the actual running speed becomes a balance between these two tendencies and will usually run 4 to 5 percent below synchronous speed, or about 3450 r.p.m.

So far we have been giving the motor a spin to start it. This is because we are dealing with a single current, called a single-phase current, which does not produce a natural **starting torque** (twist) in an induction motor. The magnetic action in the stator is a back-and-forth attraction and repulsion, or push and pull, which will keep a motor running but will not start it. It is like swinging a weight attached to a string around in a circle. After you get it started a simple back-and-forth motion of the hand will keep it whirling, but no amount of back-and-forth motion will start it swinging in a circle. Starting requires a circular moving force.

Split-phase motor

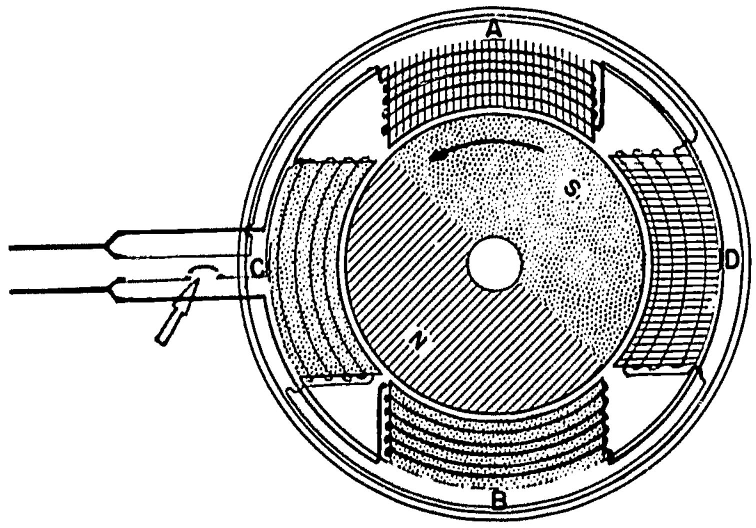
There are several ways to make a single-phase motor self starting. One is to use the split-phase starting principle. To do this another winding is added to the stator. It is made of smaller size wire and fewer turns than the running winding (Fig. 42). A and B represent the poles of the main winding or running winding and C and D are



A special winding is added to make use of the split-phase principle in starting the motor. (Fig. 42)

the poles of the auxiliary or starting winding. These two windings are connected in parallel to the line so that the current enters both windings at the same time. However, because of the difference in size of wire and number of turns, the current and magnetic effect reaches a peak in the starting winding slightly before its peak in the main winding. Although both D and A will be north magnetic poles, the rotor is attracted toward D first, and then, an instant later, toward A, just as though two different currents or phases were present in the motor. For starting purposes, these two windings split the single-phase current into two phases—hence the name "split-phase motor."

One more feature is needed to improve our split-phase motor. Although the starting winding is necessary to make the motor self starting, we have previously seen that it is not needed to keep the motor running. In fact, the starting winding would hinder the running of the motor. Thus, a cut-out switch is added in the starting-winding circuit (Fig. 43). In an actual motor this switch is usually operated by a centrifugal device which is designed to cut out the starting winding when the motor reaches about 75 percent of full running speed. It closes the starting switch again when the motor stops to prepare it for the next start.



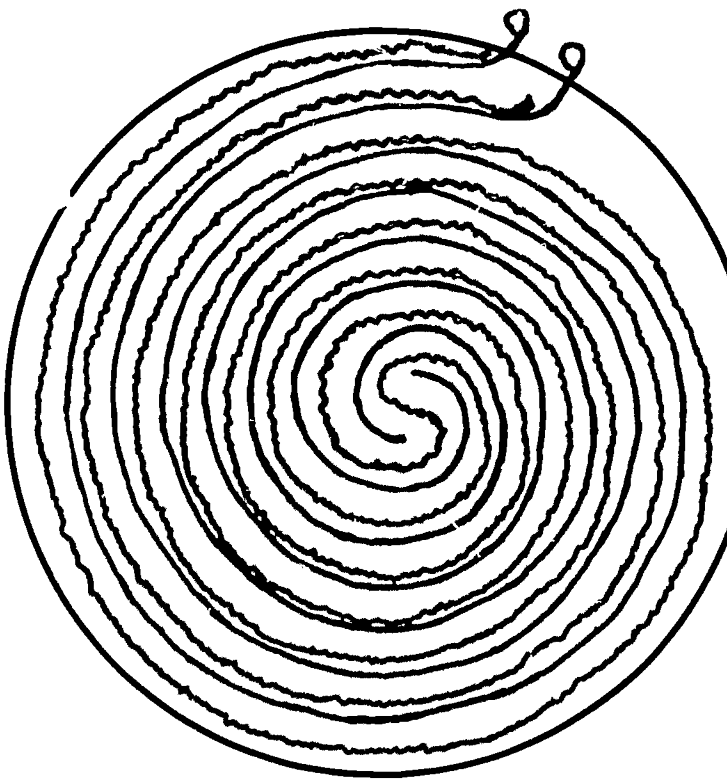
A centrifugal switch cuts out the starting winding when the motor reaches the proper speed. (Fig. 43)

Capacitor-start motor

The capacitor-start motor is an improvement over the split-phase motor described above. The first difference noted is that it has a capacitor (condenser) in series with the starting winding.

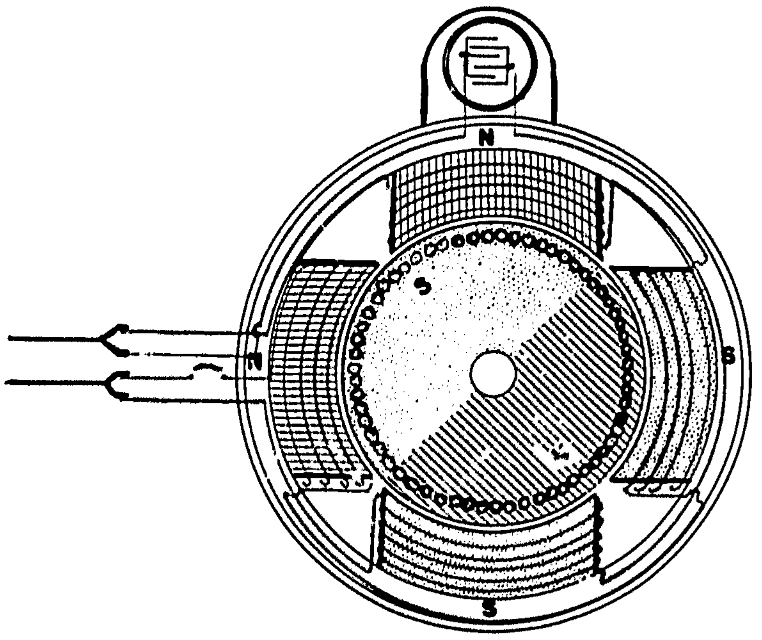
The common type of motor capacitor consists of two sheets of aluminum foil separated by a layer of paper or gauze which is impregnated with a liquid such as ethylene glycol. The two sheets of aluminum foil separated by the insulating layer are rolled up and encased in a metal tube. Each terminal is connected to one of the sheets of aluminum foil (Fig. 44).

A capacitor acts as a reservoir in which an electrical charge can be stored and discharged back again into the circuit. The capacitor does several things to improve the starting performance of the motor, compared to the simple split-phase type. It has the effect of "splitting" the single-phase current wider by creating a greater time interval between the peak of current and magnetism in the starting winding as compared to the running winding. It also permits the use of more copper in the starting winding and other important differences in basic design. These things result in a much greater starting torque and a



A capacitor consists of two conducting surfaces separated by a nonconductor. (Fig. 44)

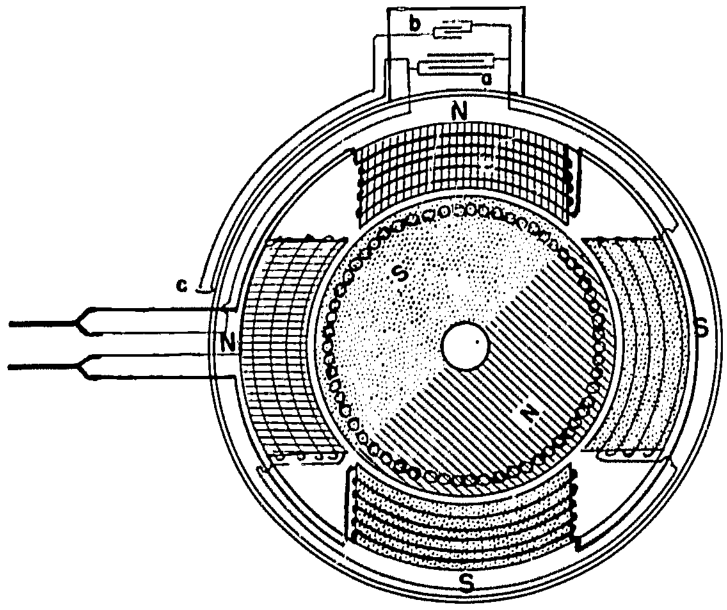
lower starting-current requirement. Fig. 45 shows how the capacitor is connected in the circuit of a typical capacitor-start motor.



In a capacitor-start motor the capacitor is connected in series with the starting winding. (Fig. 45)

Capacitor-start, capacitor-run motor

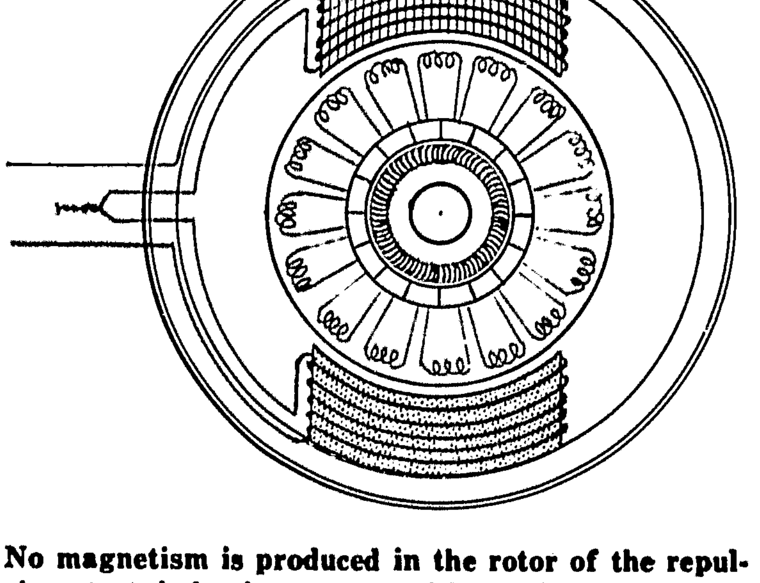
The capacitor-start, capacitor-run motor has a running capacitor which remains in series with the starting winding when the motor is running. The starting winding then becomes an auxiliary running winding. To accomplish this, the centrifugal switch disconnects only the starting capacitor leaving the running capacitor and the starting winding continuously energized during running. Fig. 46 shows the circuit for this type of motor. In capacitor motors rated at approximately 3 horsepower and larger the motor performance at running as well as during starting may be improved by employing such a circuit.



The capacitor-start, capacitor-run motor has a running capacitor (a) permanently connected in series with the starting winding. The starting capacitor (b) is disconnected by the centrifugal switch (c) when the motor comes up to speed. (Fig. 46)

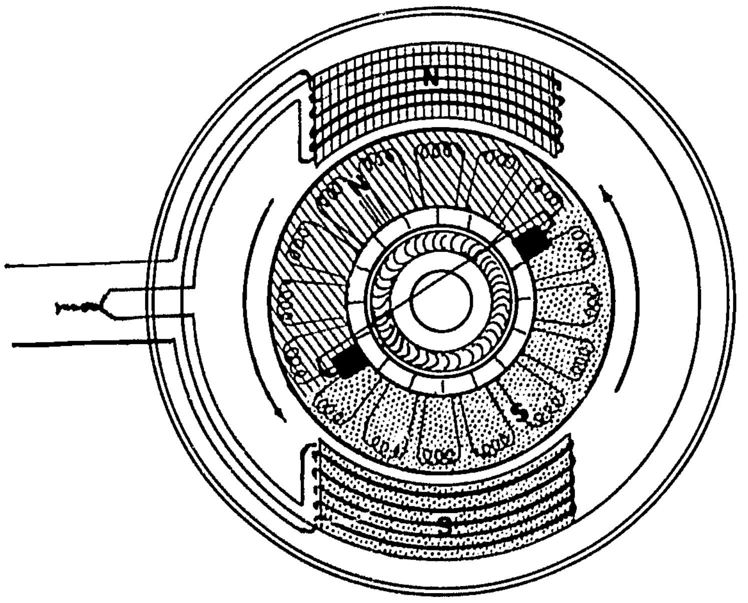
Repulsion-start induction motor

The repulsion-start induction motor is considerably different in appearance from the split-phase and capacitor-start types, although the differences are only employed in starting the motor. It has a single running winding in the stator which is in the circuit at all times when the motor is starting and running. It has a wound rotor with commutator and brushes. We shall first consider a two-pole repulsion-start induction motor as shown in Fig. 47. If we remove the brushes and introduce an alternating current into the stator winding, no current will flow in the rotor because all of the rotor coils are open circuits. The ends of these coils are attached to the commutator bars but the bars are insulated from each other. Consequently no magnetic forces are created in the rotor and



No magnetism is produced in the rotor of the repulsion-start induction motor without the brushes. (Fig. 47) the motor will neither start nor run.

If we add a pair of brushes which are connected together and place them in the proper position, they will complete the circuit in a particular rotor coil. Current will now flow in that coil by induction and magnetic poles will be formed in the rotor core (Fig. 48). The N pole of the rotor will be repelled by the N pole of the stator and attracted toward the S pole, causing the rotor to turn in the direction shown by the arrow. As the rotor turns, the brushes stay in their relative position, completing the circuit in the next rotor

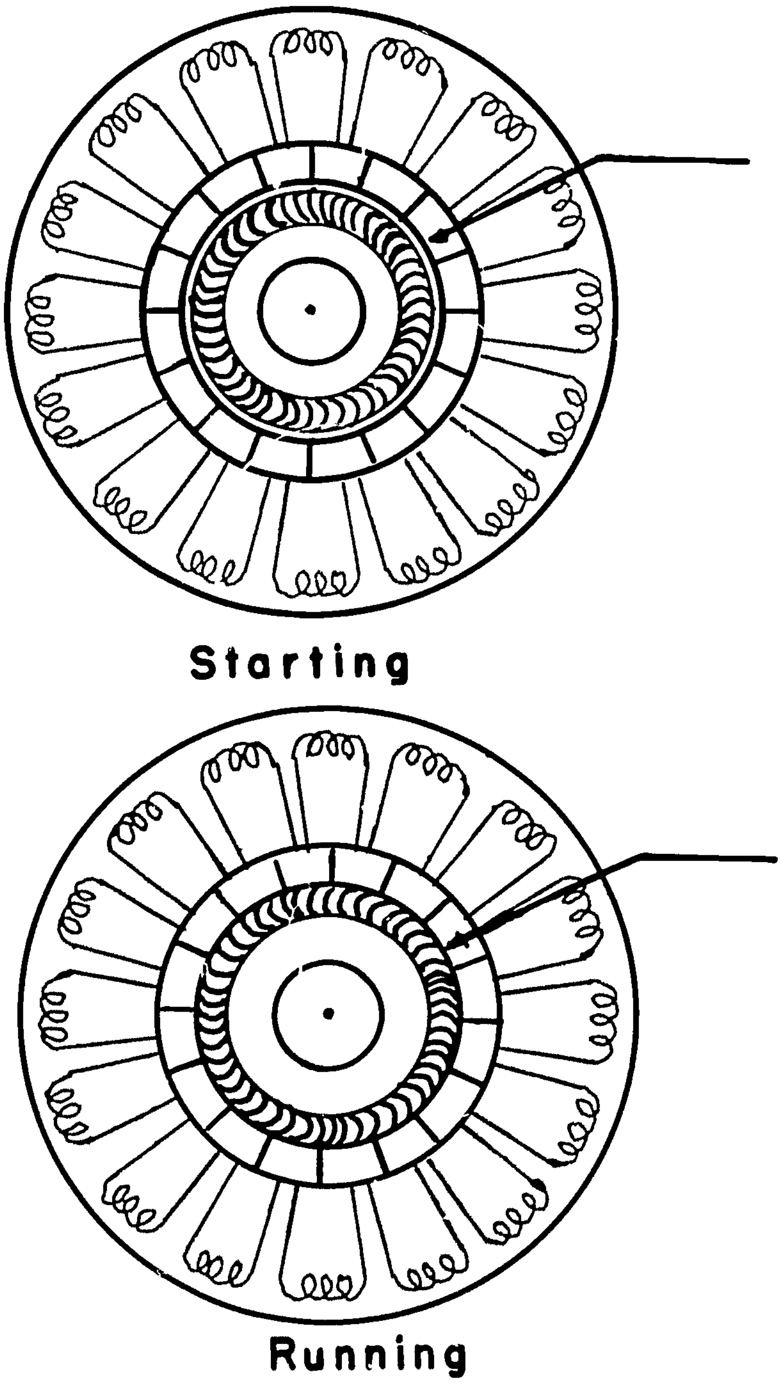


Brushes complete the circuit in certain rotor coils to produce magnetic poles. (Fig. 48)

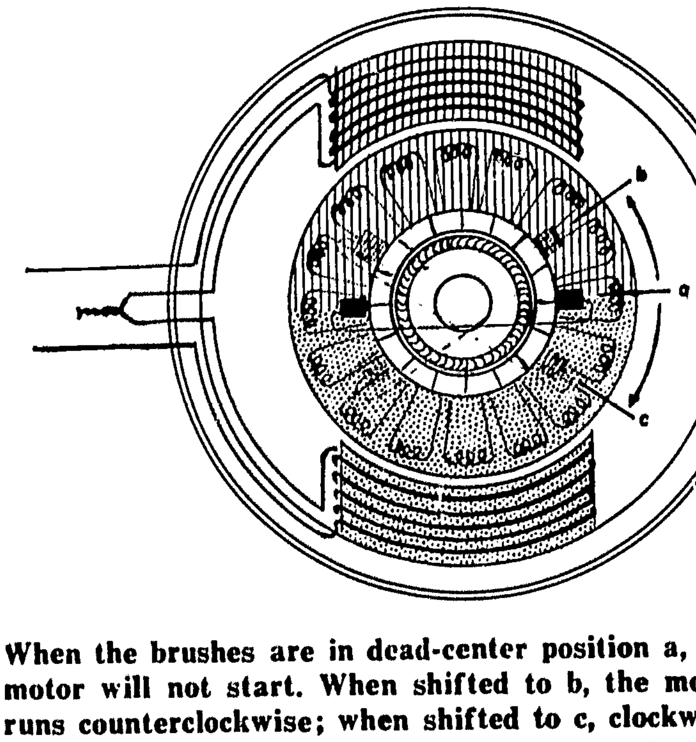
coil, and so on, causing the rotation to continue and the motor to gain speed rapidly.

At about 75 percent of full running speed the commutator bars are all short-circuited together by some type of centrifugal short-circuiting device (Fig. 49). It then assumes the properties of a squirrel-cage rotor and runs as an induction motor in a way similar to the split-phase and capacitor-start motors. At running speed, the brushes no longer function and may or may not continue to rest against the commutator.

The direction of rotation is determined by the brush position when the motor starts. If the brushes are shifted to position a in Fig. 50 so that the magnetic poles of the rotor are directly in line with the corresponding poles of the stator, the motor will not start at all. A slight shift either way from this dead-center position will cause the motor to rotate in that direction (b or c, Fig. 50). However, there is a certain fixed point for the brushes at which the motor will develop its maximum starting torque in either direction. These points are usually indicated by a mark on the brush ring (Fig. 13b).



The short-circuiting device operates to short all commutator bars together when the motor reaches proper speed. (Fig. 49)



When the brushes are in dead-center position a, the motor will not start. When shifted to b, the motor runs counterclockwise; when shifted to c, clockwise. (Fig. 50)

The speed at which an induction motor runs on 60-cycle alternating current is determined by the number of poles in the main or running winding. For simplicity we have dealt thus far with two-pole motors which run at about 3450 r.p.m. at full load. This is one revolution for each cycle of the current, (3600 r.p.m.) less 4 to 5 percent slip. A four-pole motor makes one-half a revolution per cycle, or about 1725 r.p.m. at full load. A six-pole motor makes one-third revolution per cycle, or about 1140 r.p.m. at full load, and so on.

8. SUGGESTED DEMONSTRATIONS AND SHOP EXERCISES

To carry on the following demonstrations and shop exercises, certain items of equipment are needed:

- cardboard or glass
- permanent magnets
- iron filings
- bell wire
- iron rod
- carpet tacks
- compass
- d.c. laboratory demonstration motor
- 6-volt test lamp
- 120-volt test lamp
- growler
- d.c. ammeter test set with self-contained battery
- a.c. test set with voltmeter and ammeter
- split-phase motor, capacitor-start motor, and repulsion-start induction motor of the same horsepower rating
- Torque test stand with pulley, belt, and scale

DEMONSTRATIONS

1. *Show the magnetic field of a magnet*

Place a cardboard or glass over a permanent magnet and sprinkle iron filings over the surface. Gently tap the cardboard or glass and note the pattern taken by the filings (see Fig. 36).

2. *Show the effect of one magnetic pole upon another*

Suspend a bar magnet with a string and hold the N pole of another magnet near its N pole. Note results. Hold the S pole near the N pole of the suspended magnet and note results (see Fig. 39).

3. *Demonstrate how an electromagnet functions*

Wrap several turns of the bell wire around the iron rod and connect the ends to the d.c. test set. Show that:

a. The electromagnet has the same properties as a permanent magnet.

b. It is a temporary magnet. It picks up tacks or bits of iron. Break connection to battery and show that magnetism is lost.

c. Using a given length of wire, the strength of the electromagnet can be increased by using more turns of wire on the electromagnet. Count the number of tacks it will pick up. Increase the number of turns and count tacks again.

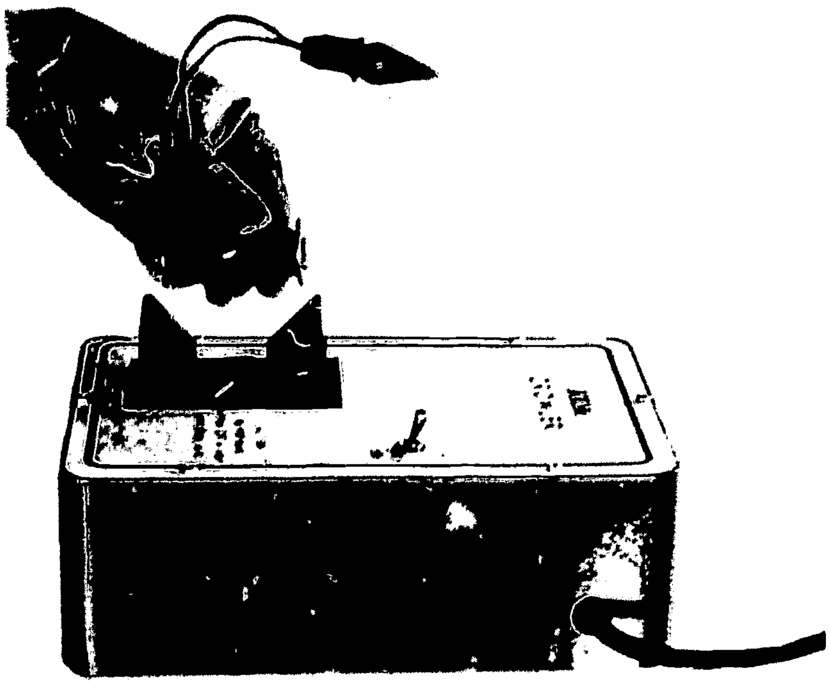
d. The electromagnet can be made to change polarity. Connect to the test set and test polarity of the electromagnet with a compass. Reverse the battery connections and test for polarity. Note results.

4. *Demonstrate action of d.c. laboratory motor*

a. Connect the motor to the d.c. test set and show how it runs.

b. Show that the commutator changes polarity of the rotor. Remove the permanent magnets from the demonstration motor. Connect the motor to the test set and determine the magnetic polarity of the rotor by testing with the compass. Slowly turn the rotor by hand and note change in polarity. Show how the commutator causes this change.

c. Show how the demonstration motor can be reversed. Connect the motor to the test set using electromagnets as the stator, wiring the rotor and stator in parallel. To do this, bring both stator and rotor leads to the battery connections. Note direction of rotation. Reverse the stator lead connections and note



results. Reverse the rotor lead connections and note results.

5. Show how an alternating current flows by induction

Attach the growler to a 120-volt circuit. Connect the 6-volt test lamp to the ends of the windings of the electromagnet used in the previous demonstration. Slowly lower the electromagnet into the magnetic field of the growler (Fig. 51). Note results.

Current flow by induction can be demonstrated with a growler, an electromagnet, and a small bulb. (Fig. 51)

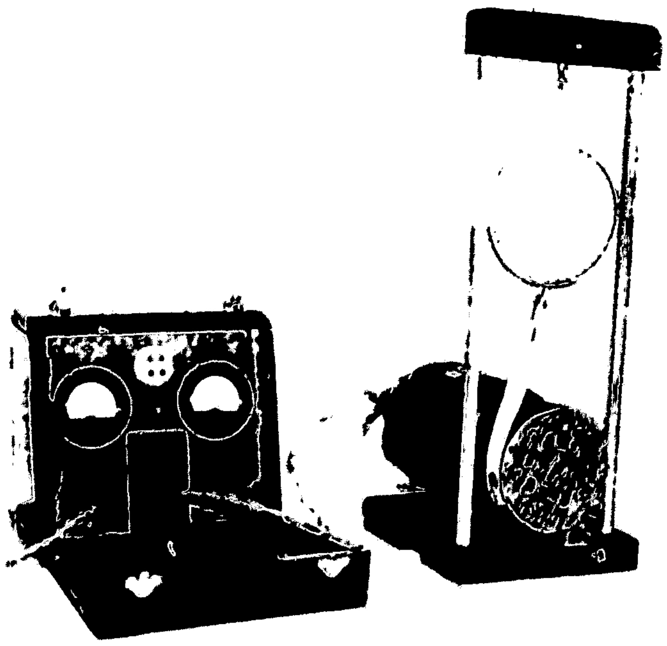
SHOP EXERCISES

1. Interpret motor nameplate information

Study the information given on the nameplates of the three motors. Interpret the meaning of such terms as: h.p., r.p.m., cycle, phase, volts, amperes, hours, type, and degrees C. rise.

2. Study variation in starting torque and current characteristics of split-phase capacitor-start, and repulsion-start induction motors.

Set up the equipment for testing as shown in Fig. 52 and run no-load and locked-rotor tests on each motor.



a b

This equipment is used for making torque and current tests.
(a) a.c. test set containing voltmeter and ammeter.
(b) Torque test stand and scale. (Fig. 52)

No-load tests should be made before the large wooden pulley is put on the motor shaft. It will be necessary to start the motor several times in order to get accurate or average readings of voltage and current as the motor starts and when running at full speed.

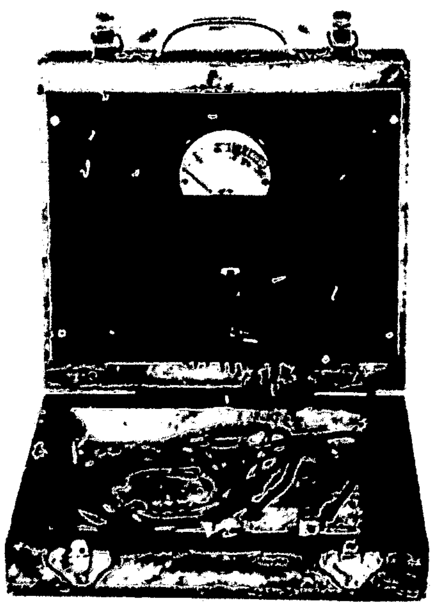
For the locked-rotor test, put on the wooden pulley, tighten the set screw, and connect the fabric strap to the scale. Turn on the motor for just an instant and take the meter readings and the scale reading. It may be necessary to do this several times but avoid leaving the current on for more than a moment at a time to avoid blowing fuses or damaging motor windings.

Record the results of your tests as follows:

	SPLIT-PHASE	CAPACITOR-START	REPULSION-START
NO-LOAD TEST			
Line volts, starting			
Line volts, running			
Current (Amps.), starting			
Current (Amps.), running			
LOCKED-ROTOR TEST			
Scale reading, lb.			
Line volts			
Current in amps.			

3. *Wire the terminal board of a split-phase motor*

a. Test and identify starting and running winding leads. Using the d.c. ammeter test set (Fig. 53), test and identify the starting and running winding leads. Since the starting winding usually has more resistance, it will show as the lower ampere reading.



The d.c. ammeter test set with self-contained battery is useful in testing and identifying motor leads and circuits. (Fig. 53)

b. Locate the starting-switch terminals. Determine whether the starting switch is permanently attached to two of the bolts on the terminal board. The starting-switch terminals will show as a high reading on the ammeter, approximately the same as a dead short made by touching the two test clamps together.

c. Wire up the terminal board and run the motor. It will be well to diagram the hook-up from the results of your testing before trying the motor. The running winding must be connected across the line with starting switch in series with starting winding. It is well to make a preliminary check with the d.c. test set on the terminals to which you intend connecting the 120-volt line. If it shows a low ampere reading, it is safe to go ahead. A high reading shows an error has been made which would blow a fuse or trip a circuit-breaker in the line. When ready to connect the motor to the line, the "hot" (ungrounded) wire should go to the terminal to which the running winding and the starting switch are connected.

d. Reverse the direction of rotation. The motor can be reversed by switching either the starting winding leads or the running winding leads.

4. *Wire the terminal board of a capacitor-start motor*

a. Test and identify motor leads. If a small motor has six leads, it usually indicates a thermal overload protector is built in the motor. Its pair of leads will test on the ammeter as nearly a dead short. The running winding leads will show a low ampere reading as with the split-phase motor. The starting-winding leads will show no reading because of the capacitor which will not pass a direct current. This means that the starting-winding leads can only be found by a process of elmination, or if positive identification is desired, test first with d.c. and then with the 120-volt test lamp in series with the a.c. line. The test lamp will light but no reading will show on the d.c. ammeter. This is a positive identification of the starting-winding circuit. Test the terminal bolts to see if the starting switch is permanently attached to two of them.

b. Wire up the terminal board and run the motor. Diagram your hook-up so that the thermal protector is wired in series with the "hot" line leading to both windings and that the starting switch and capacitor are in series with the starting winding.

c. Reverse the direction of rotation. This motor is also reversed by switching either the starting or running winding leads.

5. *Wire the terminal board of the repulsion-start induction motor and reverse it*

a. Test and identify the two halves of the stator winding. Use the d.c. test set. The two leads representing one half of the winding will give a low reading. The other pair should give the same reading.

b. Wire motor for 120 volts. Connect the two halves in parallel with the line and try the motor on 120 volts. If it does not run properly, diagram what is wrong and correct it.

c. Wire motor for 240 volts. Connect the two halves in series for 240 volts. Make the motor connection and try it first with a 120-volt line. If your connection is wrong, no damage will be done to the motor. If your connection is correct, the motor will start but will pick up speed slowly since it is getting only half voltage. When it reaches full speed it will run quietly and normally. After you get it to run properly, change the line connection to 240 volts. Diagram and explain the possible errors you might make in the series connection for 240 volts.

d. **Reverse the direction of rotation.** Repulsion-start induction motors are reversed by shifting the brush position on the commutator (see Fig. 13). Locate the mechanism for doing this. It may be necessary to take off an inspection plate, loosen a set-screw, and shift the brush ring, or the motor may have an external reversing lever.

QUESTIONS

Some may be interested in determining the answers to the following questions by experimenting with motors:

1. Will a split-phase (or capacitor-start) motor run on the running winding alone, if started by hand? In either direction?
2. Will it run on the starting winding alone?
3. Will it run if the starting switch is wired in series with the running winding instead of the starting winding?
4. What will happen if the starting switch is wired in series with both the starting and running windings?
5. Will a repulsion-start induction motor run on half the stator winding?
6. If the reversing lever of a repulsion-start induction motor is shifted while it is running full speed, will it immediately reverse itself?

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