1956

Good Electric Motor Care for Advanced 4-H Electrification Club Members and Leaders: Extension Circular 7-81-2

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GOOD ELECTRIC MOTOR CARE

For Advanced 4-H Electrification

Club Members and Leaders

EXTENSION SERVICE
UNIVERSITY OF NEBRASKA COLLEGE OF AGRICULTURE
AND U. S. DEPARTMENT OF AGRICULTURE
COOPERATING
W. V. LAMBERT, DIRECTOR
A Note To 4-H Club Leaders And Members

You are enrolling in one of the 4-H activities that has been set up for members who have taken first year electrification. During the year you will be expected to do the following:

1. Become acquainted with the working principles of an electric motor.
2. Learn how to properly install, use, and care for an electric motor.
3. Make an electric motor or some article that can be powered by an electric motor.
4. Make at least one improvement in the use of an electric motor that is used in your home or farm. Some suggestions are as follows:
   a. Make sure a motor is being properly used.
   b. Make sure that proper pulleys and pulley ratios are being used.
   c. Make sure that proper V-belts are being used.
   d. Replace worn V-belts or pulleys.
   e. Make sure that V-belts are being used properly (includes installing of belts).
   f. Clean a dirty motor.
   g. Make sure that an electric motor is properly wired and protected.

The purpose of this manual is to help you with the electric motor project by providing the basic information about electric motors. The manual will not answer all your questions. For further information you are referred to your electrical dealer, power supplier, and County Extension Agent. They will have material, bulletins, and information that can be used to supplement what has not been discussed in this manual.

It is hoped that you and your friends will enjoy this project, and that you and your friends will enroll in other electrical projects during the coming year.
PROBLEM ONE

Fundamentals Of The Electric Motor

The electric motor is a very useful machine and can be used for many farm and home jobs. In this problem, you will review what you learned about electric motors during your First Year Electrification Project, and you will study some of the basic principles of how an electric motor works.

Experiments With Magnets

In a way, an electric motor is a spinning magnet. The earth itself is a huge magnet. We know it has magnetism because it causes a compass needle -- also, a magnet -- to swing around. Ordinary horseshoe and bar magnets affect a compass needle this same way. To further understand how a magnet works, and thus how an electric motor works, it is suggested that you try the following experiments. To do them you will need two dry cells, two permanent magnets, a steel knitting needle or a large sewing needle, two iron nails, some iron filings, a small compass, and some copper wire.

Experiment One: Place a permanent magnet under a card or sheet of paper and sprinkle iron filings over the paper. Then tap the card gently and note how the filings arrange themselves. This demonstrates the power of a magnet.

Experiment Two: With two magnets see what happens when you place the north poles of the two magnets near each other. Also, notice what happens when you put the two south poles near each other, and when a north pole is placed near a south pole. This action is shown in Figure 1. This experiment shows you that like poles repel and unlike poles attract.

Fig. 1. Like Poles Repel.
Unlike Poles Attract.

Experiment Three: Lay a steel needle on the table and stroke it with one end of a permanent magnet as shown in Figure 2. Stroke only in one direction. Lift the magnet high on the return stroke. After a few strokes, the needle will become magnetized. This same feat will be demonstrated in a later experiment by the use of a nail and an electric current.

Experiment Four: Hang a magnetized needle from a stand made of wood as shown in Figure 3. Use a thread stirrup to keep the needle horizontal. See if the needle will be attracted or repelled by the permanent magnet. Try both poles of the magnet.
Experiment Five: For this experiment you will need a small compass, a dry cell, and a piece of copper wire. The compass needle always points to the north. Before making contact with the battery, place the wire parallel to the needle as shown in Figure 4. Touch the end of the wire to the battery. The needle will then set itself crosswise to the wire. This experiment shows the relation between electricity and magnetism -- the basis for all electrical machinery.

Experiment Six: In Experiment Five you saw that a wire carrying a current has a magnetic field around it. Now, if you take the wire and form a coil around a nail, as in Figure 5, you can make what is called an electromagnet. Touch the ends of the wire to the terminals of a dry cell. The nail will now pick up objects made of iron or steel. To increase the strength of the magnet use more turns of wire or two or more batteries in a series.

![Fig. 4. Magnetic Field About a Wire.](image)

![Fig. 5. Electromagnet.](image)

Note: Iron and steel can be magnetized by other magnets or electric currents. Steel will retain its magnetism for a short period, but iron will not retain magnetism. For this reason high grade steel is used to make permanent magnets; and iron is used in motors and electromagnets where we wish to change the poles or the entire force of magnitude.

Working Principals Of An Electric Motor

By knowing how to apply the laws of magnetism, which you can observe by applying the experiments in this problem, you can make an electric motor work. An electric motor consists of two or more magnets (electro-magnets). One magnet usually stands still and is called the field. The rotating magnet or magnets is called the armature. In the DC motor, which you made in your First Year Electrification Project, the magnetism was made to change by the commutator and brushes. Most AC motors change magnetism by the current itself, which reverses the direction of electric current flow 120 times a second.
THINGS TO DO

1. Try the suggested experiments with magnets and magnetism. 'The list of things needed is given in the opening paragraph "Experiments With Magnets."

2. Practice winding electromagnets. The strength of the magnet depends upon the number of turns of wire and the number of cells connected in series.

3. Make magnets of various strengths and see how many nails they can lift.

4. Review the working principles of an electric motor. One way of doing this is to have the club members review their first year motor pamphlet, E.C. 7-45-2 "How to Make a Toy Electric Motor." Members might be asked to bring their toy motors to the club meeting and work with them.

PROBLEM TWO
Types Of Electric Motors And Their Uses

Before selecting an electric motor, you should know (1) the electric service available and (2) the conditions under which the motor is to be oper-

Fig. 7. Types of electric motors commonly used on farms: above (left to right) split-phase, capacitor; below, repulsion-start.
ated. The service on most Nebraska farms is 120-240 volt, 3 wire, single-phase, 60 cycle, alternating current. Because of this fact, the electric motor project is devoted entirely to motors commonly used in such situations.

In Problem One, you learned that alternating current motors run because of the direction of the flow of electric current; as the electrical current changes direction of flow the magnetic poles change positions. However, when the alternating current, single-phase electric motor is inactive, the poles of the electromagnets locate so that they change together. Thus, the motor does not run. To start an alternating current, single-phase motor, the armature must be started. When the armature beings to turn, its magnetic relationship with the field's magnetic poles is changed. The magnetic forces are then useful in making the armature rotate.

Since it is inconvenient for you to start motors by hand, the armature is started by the use of additional electrical wiring or coils in the motor. These additional wirings are arranged to carry the electric current through the armature and the field at different time intervals or positions than are the main or running windings. Thus, the armature is started by changing its magnetic pole relationship. The way a single-phase motor is started determines the type of single-phase alternating current motor.

The types of electric motors commonly used in single-phase, 120-240 volt farm system are (1) split-phase, (2) capacitor, and (3) repulsion-start induction. You may also use universal motors for some appliances. Starting torques, starting current, and overload capacity vary to some extent in each type of motor. These characteristics are explained below:

Starting Current refers to the current which an electric motor draws at the time of starting or when coming up to full speed. Motors require more current when starting than while running.

Starting Torque (starting ability) is a term used to designate the turning or rotating ability of a motor while starting and coming up to speed. Starting torque varies with the type of motor; some being able to deliver four or five times more torque while starting than others.

Overload Capacity refers to the ability of an electric motor to develop more than its rated horsepower. An electric motor is capable of developing more than its rated horsepower, but in so doing carries a large overload for a very short time. Even though a very small overload can be carried, no motor can be continuously overloaded without "burning out."

**Split-Phase Motor**

The split-phase motor is probably the simplest for use on single-phase alternating current. It is usually available in sizes of 1/3 horsepower and smaller. The starting device of a split-phase motor is an additional coil or wiring in the field. The wiring is placed in such a position that it causes a magnetic pull on the armature. When the motor almost reaches its full speed, a centrifical switch disconnects this winding.

A split-phase motor has a low starting torque and a high starting current. It is not suitable for use on loads that are hard to start. Full power is not developed until the motor reaches full speed. This motor can be used on any machine that is easy to start, or one where the load is thrown on after the motor has reached full speed. The common applications for this motor are washing machines, tool grinders, bench saws, and similar articles. The direction of rotation can be reversed by interchanging motor connections as specified by the manufacturer.
Capacitor Motor

The capacitor motor has a condenser or capacitor with the starting winding as explained in the split-phase motor. The capacitors increase the magnetic pull of the starting winding. This enables it to start loads one and one-half to two times heavier than will the split-phase motor of the same horsepower rating. The starting current of the capacitor motor is about half that of the split-phase. Efficiency of the capacitor is higher than that of the split-phase. Common sizes are up to 3/4 horsepower, but larger sizes can be obtained. By interchanging motor connections as specified by the manufacturer, the direction of rotation can be reversed. This motor can easily be identified by the container, either on topside, or underneath the motor which houses the condenser.

There are two different types of capacitor motors: capacitor-start and capacitor start-capacitor run. The difference is in the number of capacitors used. The capacitor start-capacitor run uses two capacitors; one which remains in the circuit while running and the other which shuts off when the motor almost reaches full speed. The capacitor-start has only one capacitor which shuts off when the motor nears full speed. The capacitor start-capacitor run motor is larger.

Repulsion-Start Induction Motor

There are two factors that make the repulsion-start induction motors different than other types of motors. One is the "brush-riding" and the other is the "brush-lifting." The brush-riding types lift the brushes from the commutator while the brush-lifting do not. The brush-lifting type of motor saves wear on the brushes, except where frequent starts are made. Repulsion-start induction motors use additional windings in the armature, and use a commutator and brushes for starting. The effect of such a combination is that this motor starts similarly to a direct current motor.

The repulsion-start induction motor has the lowest starting current and highest starting torque of all single-phase motors. It will start almost any load that it can continuously carry. It is commonly used on cream separators, milking machines, feed grinders, and ensilage cutters.
Most of these motors are so designed that by changing the motor connections as specified by the manufacturer, it is possible to operate them on either 120 or 240 volt current. The direction of rotation can be reversed by changing the position of the brush-holding yoke. Repulsion-start induction motors are available for loads up to 10 horsepower.

**Universal Motor**

This type of motor will operate on either direct or single-phase alternating current. This motor uses commutator and brushes which remain in the circuit while the motor runs. The speed of the motor may be varied over a wide range by changing the voltage or load. While idling, the motor may attain a speed of 15,000 rpm. But when loaded it may slow down to 550 rpm. This characteristic makes the motor unsuitable for most jobs. Universal motors are commonly used on such machines as vacuum cleaners, electric drills, and fans where the load is constant; and on sewing machines and food mixers where speed control is essential. The universal motor is usually made in small sizes and is often a permanent part of the machine that it operates.

**Power Consumed By A Motor**

It has been figured that 746 watts is equal to 1 horsepower. However, some of the power is lost in the process of converting the electrical power into useful work. Thus, the amount of power your motor consumes will depend (1) its efficiency and (2) upon the power delivered. If used to carry one-half to a full load, most large motors are more efficient than small motors. Below a half load, the motors efficiency drops. Most electric motors have an efficiency of 75 to 90 per cent. The name plate on your electric motor will state the current consumption in amperes. By multiplying the amperes times the voltage, you can determine the volt-amperes consumed at full load.

![Fig. 10. The name plate of an electric motor. All of the information about rating and electrical needs of the motor is on this plate.](image)

You may have noted that in the case of electric motors, volts times amperes equals volt-amperes consumed and not watts consumed as in the case of heating and lighting. This is because your electric motor causes more amperes to flow than the meter actually registers. The term used to identify this characteristic is known as power factor. Thus, volts times amperes times the power factor equals watts consumed.

You may have a need to know how to determine the number of watts (or kilowatts) a motor is drawing. Following is a useful method of checking the consumption of various appliances:

1. Look at the small metal information plate on the meter and note the letter "Kh." Following will be a number. This number is called the meter constant and represents the watt-hours consumed per disk revolution. (The disk is a thin piece of aluminum that revolves horizontally and is usually below the dials or numbers on the meter.)

2. Turn off all lights and electrical devices.

3. See that the disk in your electric meter is not running.
4. Turn on the motor or other device to be tested for wattage consumption.

5. Count the number of revolutions that the disk makes during a minute period.

6. Now use the following formula:
   \[ K_n \times \text{revolutions per minute} \times 60 = \text{watts consumed}. \]
   For example, let us suppose the \( K_n \) or meter constant is 3 and the disk makes 10 revolutions during the minute period. Then multiply 3 times 10 times 60. The answer is 1800 watts consumed.

THINGS TO DO

1. Bring different kinds of motors (split-phase motor, capacitor motor, repulsion-start induction motor, and universal motor) to the club meeting and have those present identify them and their uses. Such motors may already be in use at the home where the meeting is being held.

2. Take a motor apart, and study the parts.

3. Figure the amount of power that is consumed by at least one electric motor. The method of figuring power consumption is explained in "Power consumed by a motor."

4. Practice reversing the direction of motor rotation. This can be done by interchanging the motor connections of a split-phase and a capacitor motor, or by changing the position of the brush-holding yolk of the repulsion-start induction motor. Be sure to follow the manufacturer's directions.

### TABLE I: SINGLE-PHASE MOTOR SELECTION GUIDE

<table>
<thead>
<tr>
<th>Motor Type</th>
<th>Cost</th>
<th>Starting Ability (torque)</th>
<th>Starting Current</th>
<th>Common Uses</th>
<th>Sizes Commonly Available (Horsepower)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Split-phase</td>
<td>Low</td>
<td>Fair</td>
<td>High</td>
<td>Washing machines, Power saws-small</td>
<td>1/20 to 1/3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ventilating fans, Emery wheels</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fanning mills, Sheep shearers</td>
<td></td>
</tr>
<tr>
<td>Capacitor-start</td>
<td>Medium</td>
<td>Good</td>
<td>Medium</td>
<td>Refrigerators, Concrete mixers</td>
<td>1/20 to 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Crop dryers</td>
<td></td>
</tr>
<tr>
<td>Capacitor start-capacitor run</td>
<td>High</td>
<td>Very good</td>
<td>Medium-low</td>
<td>Grain elevators, Feed grinders</td>
<td>3-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Milking machines</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Water systems</td>
<td></td>
</tr>
<tr>
<td>Repulsion-start induction</td>
<td>High</td>
<td>Excellent</td>
<td>Low</td>
<td>Cream separators, Feed grinders</td>
<td>1/4 to 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Crop dryers</td>
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<td>Milking machines</td>
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<td></td>
<td></td>
<td></td>
<td>Grain elevators</td>
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<td></td>
<td></td>
<td>Hay hoists</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Water systems (automatic pressure)</td>
<td></td>
</tr>
</tbody>
</table>
PROBLEM THREE
Motor Speeds And Drives

Motor Speed

Most electric motors used on farms operate at about 1800 rpm. The actual full-load speed of these motors varies from 1725 to 1760 rpm. Low voltage and motor overload tend to cause further reduction in speed.

Some motors are also made to operate at speeds of about 900, 1200, and 3600 rpm. Whenever possible, use an 1800 rpm motor.

If you need low speeds, obtain a 1800 rpm gear motor or a 1800 rpm variable belt drive motor. These motors are comparatively high in first cost; but the cost is offset by high operating efficiency, dependability, and compactness. Speeds as slow as 15 rpm are obtainable. The variable belt drive units have adjustable speed drives.

Note: Split-phase, capacitor, and repulsion-start induction motors are not designed for speed control by rheostats or other similar devices. Universal motors, however, lend themselves readily to such speed control.

Motor Drives

In order to get power from electric motors, you need a drive mechanism that connects the motor to the machine you wish to operate. There are two types of drives in general use. One is the direct-connected drive and the other is the belt drive. Both are practical.

The direct-connected drive is not commonly used on the farm, because it requires that the motor speed and the machine speed be the same. With machines such as vacuum cleaners, fans, and centrifugal pumps, the mechanism is mounted directly to the motor shafts. Machines that have bearings and shafts must have a flexible shaft, or coupling, between the motor shaft and the machine shaft.

The most practical and popular drive is the V-belt and pulley. V-belts are easily installed and speed ratios are easily obtained. Also, they absorb shock and vibration and the belts do not slip off the pulleys.

Selection Of V-Belts And Pulleys

To obtain the greatest efficiency and satisfaction from electric motors that use V-belts, properly select and use the belt or belts and the pulley(s). V-belts and pulleys are made in various sizes; and the pulley groove width should always match the belt width. Figure 11 shows three of the standard belt widths and shapes and corresponding pulleys.

V-belt and V-pulley sizes most commonly used by farmers are: (a) Fractional-horse-power belt (FHP) and pulley used with fractional-horse-power motors equipped with pulleys that are 2 1/2 inches or less in diameter. (b) A-section belt and pulley used for most farm jobs requiring 3/4 to 5 hp. Motor-pulley size should be 3 inches or more in diameter. (c) B-Section belt and pulley used on 3-hp motors and larger, if motor pulley is 5 1/2 inches in diameter or larger.
Selection of V-belts: The selection of V-belts will depend upon two factors: (1) the diameter of the motor pulley, and (2) the size of the motor. By referring these two factors to Table II, you can quickly determine the proper V-belt(s).

To figure the proper length of a V-belt for an already mounted motor, measure the distance with a piece of string as shown in Figure 12. If the motor does not have to be mounted in a certain place, the following procedure will give you the length of belt needed for efficient operation.

Length of V-belt needed is:

\[ \text{Total length equals} \]

- \( 4 \times \text{diameter of largest pulley} \)
- \( 1.6 \times \text{diameter of motor pulley} \)
- \( 1.6 \times \text{diameter of equipment pulley} \)

For example, let us find the belt length for a 3-inch motor pulley and an 8-inch equipment pulley.

\[
\begin{align*}
4 \times 8" &= 32.0 \\
1.6 \times 3" &= 4.8 \\
1.6 \times 8" &= 12.8 \\
\text{Length} &= 49.6 \text{ inches}
\end{align*}
\]

As soon as you know the proper length, buy the standard length belt that comes closest.

Selection of Pulleys: Farm machines do not necessarily operate at the speed that the electric motor runs. For example a hammer mill may require a speed of 3000 rpm; a tool grinder, 2000 rpm; a burr mill 800 to 1000 rpm; a hay hoist, 300 rpm; a concrete mixer, 150 rpm; and an ice cream freezer or barrel churn, 70 rpm. In order to change the motor speed to the required machine speed, you will need to use different size pulleys on the two shafts. A simple way of figuring the proper sizes of a pulley is to use the following formula:

\[
\text{Motor speed times motor pulley diameter} = \text{Machine speed times machine pulley diameter.}
\]

To help you better understand this formula let us suppose that the information on the name plate of your electric motor says the motor speed is 1725 rpm, and that the motor has a 3-inch pulley. If you wish to operate a burr mill at 800 rpm, the formula would be as follows:
Motor speed $\times$ motor pulley diameter = Machine speed $\times$ machine pulley diameter

\[
\frac{1725 \times 3}{800} = \text{Machine pulley diameter, which is 6.5}
\]

It is not always possible to obtain the correct speed with one set of pulleys. A speed jack can then be used. You will then need to apply the pulley formula twice; between motor and speed jack, and between speed jack and machine.

Note: There is a minimum pulley size that you should use with each type of belt. This is because (1) small pulleys require a sharper bend than large pulleys, (2) heavy belts cannot bend as easily as light belts, and (3) a belt on a small pulley has a small area contact and the result is increased slippage and belt wear. Under normal conditions a 2 1/4-inch pulley is the smallest size recommended for use with farm electric motors. Generally it is best to use the largest pulley possible on the motor to obtain the correct machine speed. However, belt speeds should not be greater than 4000 feet per minute. In other words, the maximum size pulley recommended for use on a 1750 rpm motor would be 8 1/2 inches in diameter.

**V-flat Drive:** In some instances you will find it desirable to have a small pulley driving a large pulley. A V-flat drive is recommended for such use; because V-pulleys in the larger sizes are expensive and hard to obtain. The V-flat drive consists of a V-pulley on the motor and a flat pulley on the machine. A standard V-belt is used that fits the V-pulley on the motor. This arrangement is particularly good if you are (1) running a machine that needs a pulley larger than 12 inches in diameter and (2) are operating at 600 rpm or less.

It is recommended that the distance from the center of your motor pulley to the center of the machine pulley not be greater than the diameter of the machine pulley. By mounting your motor this close to the machine you will have very little belt slippage, because the belt(s) have a large area of contact on the flat pulley.

In selecting the number and size of belts, follow the same procedure as outlined under "Selection of V-belts."

**Tips on Correct V-belt Installation:**

1. Clean the pulleys - wipe out all oil, dirt, and grease from the grooves.
2. Check pulley grooves - worn or bent pulleys wear out belt(s) fast.
3. Release the take-up adjustment before installing the belt. DO NOT "roll" a belt on a pulley.
4. Check pulley alignment. You may do this by placing a straight-edge against the two pulleys.
5. Get the right belt tension. A good rule is to allow a depression of 1/2 inch to 3/4 inch for every foot of belt between the pulley shafts.
6. Always use "matched" belts in multiple drives. When you replace one, replace all belts.
7. Re-check the pulley alignment and belt tension periodically.
8. Never use a belt so worn that it rides the bottom of the groove.
9. Be sure the belt matches the pulley.
10. Keep the center distances of the two shafts as close together as practical.
11. Try to have the bottom section of the belt do the pulling.
12. For V-flat drives distance between the two shafts should be about the same as the diameter of the large pulley.

**Fig. 16. Get the right tension.**

### TABLE II: NUMBER AND TYPE OF V-BELTS RECOMMENDED FOR 1750-RPM MOTORS

<table>
<thead>
<tr>
<th>Diam. of Motor Pulley in Inches</th>
<th>Size of Motor in Horsepower</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/2 or smaller</td>
</tr>
<tr>
<td>2</td>
<td>FHP*</td>
</tr>
<tr>
<td>2 1/2</td>
<td>FHP*</td>
</tr>
<tr>
<td>3</td>
<td>1-A</td>
</tr>
<tr>
<td>3 1/2</td>
<td>1-A</td>
</tr>
</tbody>
</table>

*FHP -- (Fractional horsepower) a belt designed for small pulleys and small motors. Most commonly available in 3/8-inch width but also available in 1/2- and 5/8-inch widths.

** The same number of type A belts could be used instead of type B.

### THINGS TO DO

1. Determine the proper V-belt and pulley size for an electric motor and machine that is to be used for a specific purpose.
2. Have someone set up several electric motors and power driven machines in advance. Then have those present judge which motor is set up for the most efficient work. When planning and judging be sure to consider the following:
   a. Location of pulleys. (If possible avoid vertical belt drives.)
   b. Type and conditions of belt and pulleys. -- Do you have the proper belts and pulleys and are they in good condition?
   c. Machine speeds -- Are the motor and the machine set up to give the proper machine speed?
   d. Installation of V-belt -- Is the belt properly installed?
3. Have a demonstration on the proper way to install a V-belt.
Motor Enclosures

To protect the windings and other parts, your motor must be enclosed or covered. The enclosure must also allow for enough ventilation to prevent overheating. Motor enclosures are classified according to the protection they give the windings. They are commonly referred to as open, drip-proof, splash-proof, totally-enclosed, totally-enclosed fan-cooled, and explosion-proof.

The open type of enclosure costs the least. An open motor is self-ventilated and so constructed that the housing offers little resistance to airflow and little protection from dust, water, insects, and mice. Open motors are sometimes installed under conditions that are not favorable. Thus, the motor's life is shortened. A little more money spent for a better enclosed motor will result in longer life, more dependable service, and in the long run, a cheaper motor.

Drip-proof motors are so constructed that falling drops of liquid or falling solids, such as dirt, do not enter the enclosure. The ventilating opening is protected by screen or perforated covers. This motor can be used for outdoor installations.

Splash-proof enclosures give additional protection over that offered by drip-proof motors. The enclosure is designed so that splashing liquids do not enter the ventilating openings.

A totally-enclosed motor has a housing that prevents the exchange of air between the inside and outside of the motor case. It can be used outdoors in moist, dusty, dirty, or corrosive conditions. Such conditions may be found in grain elevators and feed mills. The higher purchasing cost is usually more than justified by longer motor life and trouble-free operation.

The totally-enclosed fan-cooled motor has a double housing with a fan blowing air between the two housings. It is suitable for use under the same conditions as the totally enclosed motor. Due to fan-cooling, it can be made smaller in size for use where space is limited.

An explosion-proof motor is totally-enclosed and is built to withstand explosions of vapor gas that take place within it. This enclosure is designed to prevent the ignition of gas, vapor, or dust in the air around it.

Motor Mountings

The mounting for an electric motor is determined by the motor's base or frame. There are various types of bases, of which the most common are the rigid mounting and the resilient mounting. There are other types of mountings where the motor is a permanent part of the machine, such as a pump.

The rigid mounting consists of a heavy pressed steel or cast base that is a part of the motor's frame. This base has four holes that are sometimes slotted for bolting down the motor. For ceiling mounting, the end brackets should be rotated on sleeve bearing motors to keep the oil reservoir in the proper position.
The resilient mounting has a bracket that extends up and around the motor bearing housing. A rubber ring is inserted between the housing and the mounting. These rubber rings prevent transmission of mechanical and torsional vibrations. This mounting is recommended for use where quietness is important. It is commonly used on furnace blowers and on some washing machines.

Motor Bearings

Two main types of bearings are available for electric motors. They are sleeve bearings and ball bearings, with variations in each. Motors with sleeve bearings must always be mounted so that the shaft of the motor is horizontal. Ball bearing motors can usually be mounted in any position; but before mounting in a vertical position check with the manufacturer. Some ball bearings will not withstand end thrust. Either type of bearing should operate almost indefinitely, if proper care is maintained.

Ball-bearing housings are often filled with grease and permanently sealed; thus, the job of greasing is eliminated. Such bearings require no lubrication until the grease gets dirty or hardens. Then the bearings should be removed, cleaned, and all old grease should be replaced with fresh grease. When to clean and grease depends upon hours of use. Most farm motors should be repacked every three or five years.

Other types of ball bearings have grease fittings, or a plug that can be removed so that a grease fitting can be installed. There will also be a plug on the bottom or side of the bearing called a pressure relief plug. Before applying grease to such motors, be sure the pressure relief plug is removed and that the hole is free of hardened grease. Then apply grease until fresh grease appears at the relief hole. Before replacing the plug, run the motor for a few minutes to allow excess grease to escape from the bearings.

Sleeve bearings are generally wool-packed and require small applications of light grade oil at regular intervals. Care must be taken that only small applications of oil are made. Excessive amounts of oil will saturate the winding insulation and cause motor trouble. Always follow oiling instructions that are given with the motor.

Bearings are one of the first things to check, if your motor hums and fails to start. An easy way of checking the sleeve type bearing is to drain the oil and turn the motor upside down. If the motor starts in this position it is a good indication that the bearings are worn.
THINGS TO DO

1. Bring as many different types of enclosures and mountings as possible to the meeting and identify them; or tour a farm with a number of electric motors and observe the enclosures and mountings used. Your electric supply dealer may have a variety of motors with different types of enclosures and mountings.

2. Have a demonstration on how to grease electric motors.

3. Have someone give a report on the kinds of oils and greases that should be used in electric motors.

PROBLEM FIVE
Motor Controls

Controls are sometimes called the "brains" of motor driven equipment. They are used to start and stop the motor, and include both switches and overload protective devices. Some controls are manually operated and others are automatic.

Switches

Motor switches may be of the manual type or the magnetic type. Manual switches are operated by means of a lever or push button; and should always be located near the motor.

If a magnetic switch is used, it should also be installed near the motor; but the actual switch control can be at a distant point. Magnetic motor starters are recommended for one horsepower motors and larger; and are essential for all but fractional horsepower motors when automatic remote control devices are used.

Protective Controls

A motor should never be installed without suitable overload protection. If such protection is not provided, your motor may overheat and "burn out." Motors can be protected from overheating by fustats or fusetrons, thermal reset devices, and magnetic devices. Often the protective device is a part of the motor switch, or is built into the motor. Fuses can not be used as a protective device.

Fustats and fusetrons are inexpensive and easily installed. They must be replaced when "blown," and are practical when overloads are rarely expected to occur. They should match the motor current rating and should be installed near the motor.

Thermal overload protection devices, usually located in the starting switch, are based on the heating effect of current flow. Excessive heating causes an alloy to melt; or a bi-metal bar, helix, or disk to change shape or position. When such a change happens the starting mechanism is tripped and the motor circuit is opened. Some types are manually reset; others reset automatically when cooled to near normal temperature. The heating element in most controls is interchangeable for use on various types of motors. Always make certain that the heating element fits the ampere rating of the motor. In the lid or box you can find a chart giving sizes and identification number of letter for various ampere ratings of motors.
In magnetic overload protection devices, excessive current produces a magnetic field that is strong enough to move a mechanical switch. This switch can open or close the circuit. These devices have the same advantages and disadvantages as the thermal units.

**Automatic Control Switches**

There are times when an automatic control switch is desirable. The use of an automatic control switch is limited only by your ability, skill, and imagination. Most automatic control devices depend upon heat, water level, time, humidity, or pressure for their operation.

Thermostats. Most thermostats operate by unequal expansion of two metal strips with an increase of temperature, or by the increase in pressure of a liquid or gas contained in the closed element. They are of two general types. One type is closed and used for heating. The other type is open and used for cooling.

Pressure switches are operated by air, gas, steam, or water pressure. Most of these switches have springs for adjustment. Most water systems are set to shut the motor off when the pressure rises to 40 pounds and to start the pump when the pressure drops to 20 pounds. Usually, it is possible to change either the stopping or starting pressure or both by a simple adjustment.

Float switches are used to control a motor and pump, to keep an open tank filled with water or to operate a sump pump. Figure 18 shows such a unit.

A humidistat controls an electrically operated unit used to maintain a certain humidity. There are two types, the open and the closed. Humidistats are used in places such as greenhouses and incubators to control electric fans, an electrically operated water spray valve, or an electric motor-driven pump.

Time switches are useful to keep electrical devices operating a certain number of hours each day and at a certain time each day. Examples of their use are time controls in the poultry house, and time controls on an electric hot water heater.

**THINGS TO DO**

1. Study, observe, and discuss the different kinds of switches in your community.
2. Discuss progress made with the articles that are being made, and the improvements that are being made in this project. The group might have them displayed at the next club meeting.
3. Plan a tour at which time the group can observe different types of electric motors, and how they are used and installed.
4. Secure a thermal overload switch or inspect one that is installed. Check the installed heater element and see if it matches the motor according to the motor's name plate and the chart in the element's box.
PROBLEM SIX

Wire

For efficient operation, it is just as important to select the correct size of wire between the motor and meter, as it is to choose the right type of motor. Excessive "voltage drop" or a loss in voltage occurs, if too small wire is used. If your motor is operated at a voltage lower than that shown on the name-plate, reduced motor efficiency and overheating are likely to occur.

Because motors need more power to start than to run, be sure to allow for extra motor load when the wire is being selected and installed. Table III is a guide to the size of wire that will be required, if you allow for a starting torque of 110 per cent of the normal motor load.

Reference to the table on motor wiring shows that the larger the motor or the greater the distance between the motor and meter, the larger the size of wire. For example, a one horsepower motor operated 100 feet from the source of power on a 120-volt service line requires a number 10 A.W.G. (American Wire Gage), copper wire; but at 400 feet a number 4 is required. The table also shows that the same motor operating at 120-volts requires a number 6 wire at 300 feet; while if it were on a 240-volt line at the same distance, only a number 12 wire is needed.

When you run wires underground or outdoors, be sure to consider the strength of the wire. A number 10 wire is the minimum size recommended for outdoor spans up to 50 feet. Greater spans require at least a number 8 or larger. Underground wire should not be smaller than a number 12.

Each motor installation, also, has various short lengths of wire. These short runs of wire start at the motor and run to the control box and connect with the main wiring system. These wires should be flexible and need only be large enough to carry the current. Voltage drop is not considered on these wires as their length is very short.

Note: Adequate size wire will not give you the highest efficiency and satisfaction, unless your transformer is of sufficient size to carry your load. Whenever you plan to make a large change in load demands, consult the power company.

Extension Cords

Do not use extension cords on any motor except on portable equipment such as drills and mixers. When an extension cord is used, it should have proper wire size according to its length and the current consumption of the motor. Extension cords for motors should never have wire smaller than number 14.

Grounding

Motor frames should always be grounded to protect the operator from possible shock. This is best done by running a third wire from the motor frame directly back to the grounded neutral bus bar in the service entrance panel. If the panel has been correctly wired, a 3-wire outlet will be available to permit the use of this third wire. This is an important and necessary safety measure for both 120- and 240-volt connections.

Fig. 21. A three prong plug and outlet.
TABLE III: WIRE SIZES FOR USE BETWEEN MOTOR AND METER

<table>
<thead>
<tr>
<th>Motor Horsepower</th>
<th>120 Volts</th>
<th>240 Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>1/4</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>1/2</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>3/4</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

Based on a maximum of 3 per cent voltage drop and 110 per cent motor load.

Fuses, Fusetrons, Fustats, and Breakers

The fuse panel found in the building's service entrance panel is for the protection of the wire within the building. Also, ordinary fuses will not always allow a motor to start. For example, a one-fourth horsepower motor may require 30 amperes while starting. If your motor is on a circuit fused at 20 amperes, the fuse will probably "blow" when the motor starts. The size of the fuse should not be increased, because the wire would then be in danger. Use a special type of time-delay fuse. These time-delay fuses are called fusetrons or fustats. They are so constructed that a momentary overload will not open the circuit. Only a "short" or an extended overload will cause a fusetron or fustat to "blow."

The breaker type of circuit protection, also, has the features of fusetrons and fustats. The breaker can be re-set, but the fusetron or fustat must be replaced.

THINGS TO DO

1. Figure the proper wire sizes to be used for different size motors at different distances from the meter. Members might check the motor wiring on a farm or in a home.

2. Check the grounding of electric motors and learn the proper way to make a ground.

3. Bring fuses, fusetrons, and fustats to the meeting and have the members identify them.

4. Finish the motor project. If not completed, you may plan more meetings.

Note: For more complete information about wiring (wire, grounds and grounding, and fuses and breakers) you are referred to the advanced electrification project manual on good wiring, E. C. 7-61-2 "Good Wiring."
Making An Electric Motor Portable

A 1/4 or 1/3 horsepower motor can be used for many jobs about the farm if it is made to be portable (Figure 22). A simple mounting must be provided at each place the motor is to be used. For making a portable motor the following materials are required:

1/4 or 1/3 horsepower motor
10 feet of number 16 rubber covered extension cord,
one 5 inch diameter 4-step pulley
four stove bolts and washers
two pieces of number 10 rubber covered wire about 18 inches long

To make the motor portable do the following:

1. Twist the two pieces of rubber covered wire together. Make a hook on each end of each wire and fasten under the bolts on the top of the motor frame.
2. Bolt the pipe to the motor base.
3. Attach 4-step pulley to motor shaft. This type pulley makes it possible to turn equipment at various speeds without changing pulleys.
4. Mount the motor by placing one of the pipes attached to the base between two 2 inch x 2 inch wood strips fastened at a distance far enough away from the equipment to be driven so that the weight of the motor will keep the belt tight. The motor must always be mounted so that the top of the belt will travel away from it.
Electricity is one of your best friends. However, it can cause many accidents unless used carefully. Always apply the following safety rules when using electrical appliances and motors:

1. Know what you are doing before you attempt to do any electrical work. You can not guess and be safe!

2. Provide adequate service to your appliance and motor. This includes wire of sufficient size, proper installation of motor and appliances, overload protection, correct fuses, and approved type switches.

3. Equip all electric motors with a three-wire cord and all portable motors with a three-pronged plug. The outlet should be the type that will take such a plug; the service should be grounded at the service panel.

4. Stop the machine that is driven by the motor before tinkering with it.

5. Disconnect the motor before adjusting or working on it.

6. Place guards over all belts, chains and shaft drives.

7. Keep the motor clean.

8. Do not locate motors in small confined spaces.

9. Do not overload an electric motor.

10. Do not use extension cords.

11. Do not run a universal motor when it is removed from its appliance.

12. Inspect, frequently, all of the wiring system and electrical appliances.

To make electricity a friend and helper, do not mistreat it. Learn as much about it as you can.