CHAPTER 17

SINGLE-PHASE MOTORS

INTRODUCTION

Single-phase AC motors are the most common motors built. Every home, workshop, and vessel has them. Since there is such a wide variety of these motors, it is impossible to describe all of them. This chapter will describe the most common types found on Army watercraft. Figure 17-1 shows the basic schematic diagrams for the single-phase motors.

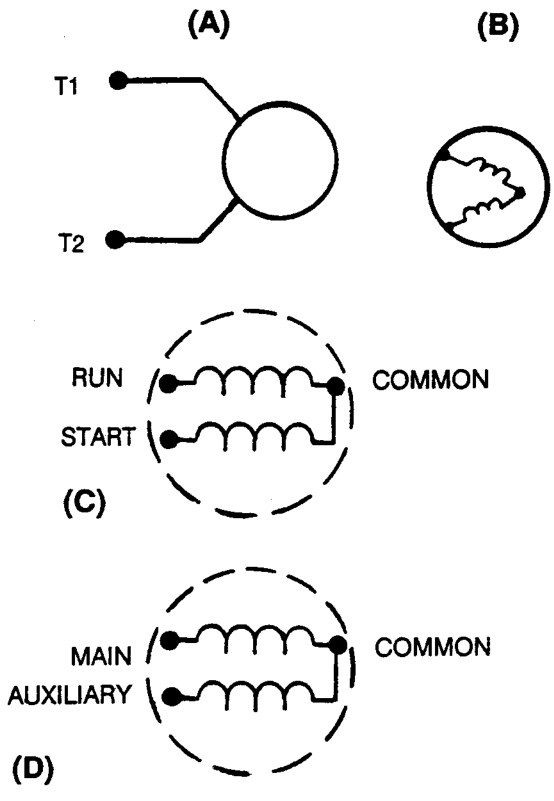

FIGURE 17-1. Single-Phase Motor Symbols.

The basic diagram (view A) shows a circle with two leads labeled T1 and T2. Just as in the three-phase motor diagram, the motor shows the power supply lines as being identified with the T. For most shore facility applications, this is the case. In many cases, the single-phase motors on board a ship will be wired into the lighting distribution panels. The lighting distribution panels are the source for single-phase power supply. The power distribution panels are the source of the three-phase power supply. For this reason, the single-phase motors are commonly connected to L1 and L2, as shown in Figure 17-2.

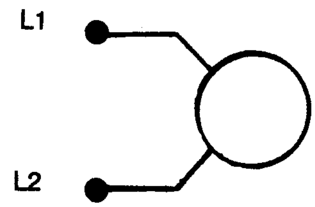

FIGURE 17-2. Single-Phase Motor Labeled L1 and L2.

Figure 17-1 shows four single-phase motor diagrams. Diagram A shows the motor as it will be seen on blueprints and general layouts. It is concerned only with the overall operation of the electrical distribution system. Diagrams B and C show a more involved internal wiring system indicating two inductors and three terminals. These diagrams are necessary to understand the exact nature and function of the single-phase motor. Refrigeration and manufacturer's wiring schematics also use diagrams B and C to ensure a positive troubleshooting application.

Figure 17-3 shows a very basic one-line diagram of the single-phase motor. Refer back to this diagram as the operational requirements of the single-phase motor are discussed.

The single-phase induction motor is much the same in construction as the three-phase motor. Some single-phase induction motors are also called squirrel cage motors because of the rotor's similarity to a circular animal exercise wheel. As discussed in Chapter 16, the squirrel cage comprises the bars and shorting-rings that make up the rotor windings. The squirrel cage is also considered the secondary windings of the motor (Figure 17-4).

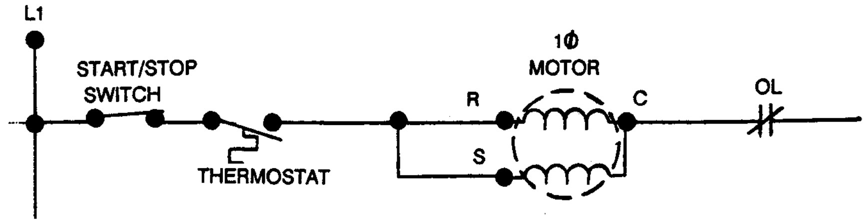

Figure 17-3. Line Diagram of the Single-Phase Motor.

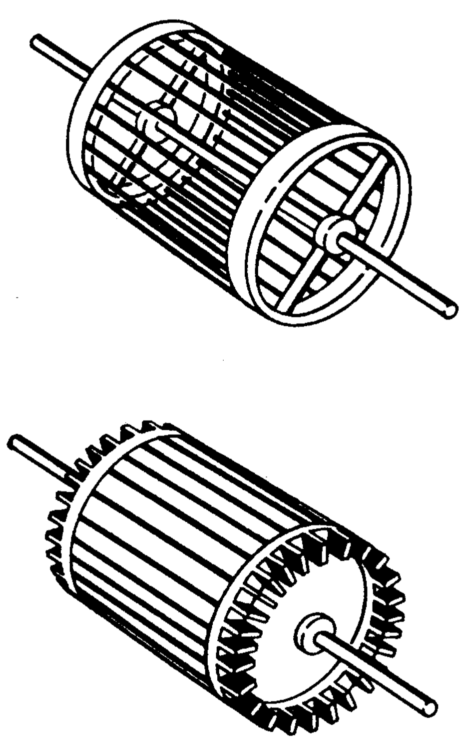

FIGURE 17-4. Squirrel Cage Induction Motor Rotor.

INDUCTION MOTORS

Despite the fact that the three-phase motor has more phases than the single-phase motor, the single-phase motor is a much more complex machine. Several additional components are necessary to operate the single-phase motor.

Single-phase motors have only two power source supply lines connected. The single-phase motor can operate off either the A-B, B-C, C-A, A-N, B-N, or C-N power source phases. The two-wire power supply can provide only a single-phase alternating source (Figure 17-5). The individual single-phase current arriving in the stator winding of the single-phase motor does not have the same "revolving" effect that the three individual phases of the three-phase power supply provides. The magnetic field developed by the single-phase current is created in the stator windings and then is gone. An entire cycle must be completed before current is again available at the single-phase motor stat or. This prevents the development of the revolving field so easily obtained with the three-phase power supply. The problem with the single-phase motor is its inability to develop a revolving field of its own accord. Without a revolving field, torque cannot be developed, and the rotor will never turn. With only one stator winding, the single-phase motor can only produce an oscillating magnetic field.

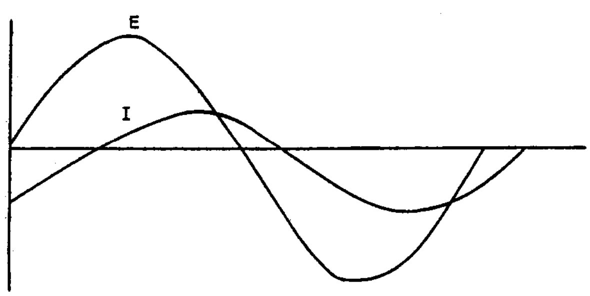

FIGURE 17-5. Single-Phase Voltage and Current Sine Waves.

Figure 17-6 shows a main winding separated into two coils. Each winding is wound in a different direction. The importance of the two different coil winding directions is to emphasize the application of the left-hand rule for coils as expressed in previous chapters. By winding the wire in a different direction, the polarity of the coil face closest to the rotor can be changed. By using one wire wrapped in two different directions, the polarity of every other coil can be changed.

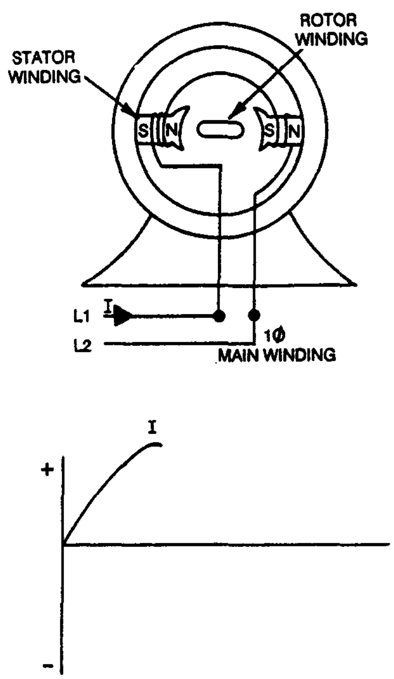

FIGURE 17-6. Current Flow Through Four Main Windings.

When current flows in the main winding, the magnetic field is established throughout the windings (Figure 17-6). Soon the current flow stops and changes direction (Figure 17-7). With this change in current direction comes a change in all the coil polarities.

The magnetic field of the rotor is developed through induction in the same manner as described for the three-phase induction motor rotor. The rotor bars and the shorting rings have an induced EMF created in them, and a current flow develops. This current flow establishes a magnetic field of an opposite polarity of the stator coil directly across from it. Unfortunately, there are no overlapping 120-degree individual stator windings in this single-phase motor.

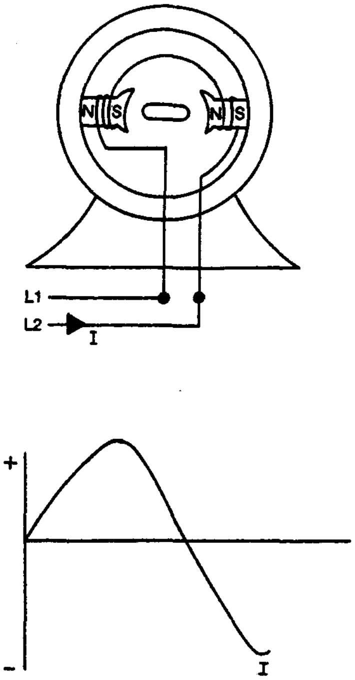

FIGURE 17-7. Current Flow Changes Direction and so Does the Coil Polarity.

Whenever current changes direction and a new magnetic field is established in the stator, the induced rotor magnetic field changes to the opposite polarity of the stator coil directly across from it. All the rotor can do is oscillate. Without some force to twist or turn the rotor, no torque can be developed.

A person examining this motor will hear a distinct hum. This is called an AC hum. It is often heard coming from transformers or single-phase motors that are not turning. If the soldier physically turned the rotor shaft (not recommended) in either direction, the rotor would start to move. The speed would continue to increase until it reached its normal operating speed.

NOTE: Although certain motors, such as fans, can be found to be started physically by turning the rotor shaft, this action is not recommended. Whenever a motor does not start of its own accord, it is because something is wrong. If the motor has an electrical malfunction, it is not wise to touch the electrical components when current is applied.

As long as the rotor's magnetic field is slightly displaced from the magnetic field in the stator, a torque can be developed. Slip will keep the rotor's field slightly behind the stator's field. The difference in speed (relative motion) is necessary to maintain the torque. Relative motion is necessary to induce the EMF into the rotor to maintain the rotor's magnetic field. If the soldier disconnects power and allows the rotor to stop, he again must provide the initial movement to start the rotor. This is not an acceptable condition for a motor.

Without the use of a three-phase alternating current, an artificial phase displacement must be established. If the stator could only develop another current, slightly out of phase from the original current, a revolving field could be assimilated. This is the problem encountered by single-phase induction motors. It is also the area of greatest component failure and maintenance requirements, In fact, the specific names for induction motors represent the means in which the revolving field is developed from a single-phase power source.

There are a multitude of single-phase motor combinations. This text will discuss only five basic designs:

- Split-phase (resistance-start).
- Capacitor-start.
- Permanent-capacitor.
- Two-capacitor.
- Shaded-pole.

Single-Phase Motor Starting

In addition to the run or main winding, all induction single-phase motors are equipped with an auxiliary or start winding in the stator. The auxiliary or start winding overlaps the main or run winding. This provides the revolving field necessary to turn the rotor. The terms are used in sets. The frost group is the run and start set. The second group is the main and auxiliary winding set. Each group has a common terminal connection.

Run and Start Winding Set. The term "run winding" is used to designate a winding that receives current all the time the motor is in operation. It is the outermost winding, located next to the motor housing. The term "run" is used only when the other winding is a start winding.

A start winding is in parallel with the run winding. The start winding receives current only during the initial starting period. Then it becomes disconnected from the power source. The start winding is the set of coils located nearest to the rotor (Figure 17-8).

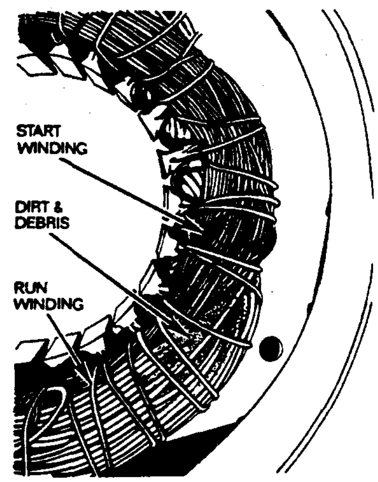

FIGURE 17-8. Two Overlapping Stator Windings in the Single-Phase Motor.

Main and Auxiliary Winding Set. The term "main winding" is used to designate a winding that receives current all the time the motor is operating. The main winding is located next to the motor housing. The term "main" is used only when the other winding is an auxiliary winding.

An auxiliary winding receives current all the time the motor is operating. It is always in parallel with the main winding. The auxiliary coils are located closest to the rotor. By creating a winding with better insulating properties and a motor housing with better heat dissipation qualities, the auxiliary winding can remain in the circuit as long as the main winding. This then increases the motor's running load capabilities.

Common Connection. The auxiliary or start winding is connected to the main or run winding through a connection called the common. The auxiliary or start winding is in parallel with the main or run winding (Figure 17-9). Both the windings in the motor use the same single-phase power source. The common connection between the set of windings is necessary to complete the parallel circuit.

SPLIT-PHASE (RESISTANCE-START) MOTORS

Figure 17-10 is a basic one-line diagram of the split-phase motor. It shows the run and start winding of the stator as well as the centrifugal switch (CS).

The run and start stator windings are connected in parallel. If you apply current to both windings and establish a magnetic field simultaneously, the rotor could do nothing more than oscillate. Unless two or more slightly out of phase currents arrive in different windings, torque cannot be achieved. Every time current changed directions, the magnetic polarities of the stator coils would switch as well. The induced rotor EMF and its resulting magnetic field would also switch. No torque can be produced. Something must be done so that a given magnetic field in one winding can happen at a slightly different time than in the other winding, thus producing a pulling or pushing effect on the established magnetic polarity in the rotor. The would create motion.

Figure 17-11 illustrates the run winding (view A) and the start winding (view B) as separate coils of wire. In view C, the two coils are connected at a common terminal. This is how the two windings are placed in the circuit in parallel.

Figure 17-12 shows how the start and run windings are in parallel with the same voltage source available to each.

Current entering a node must divide between the two windings (Figure 17-13). Magnetism is a property of current. Forcing current to arrive at one winding before it arrives at the other winding would create the phase difference necessary to create a torque.

The split-phase motor takes advantage of an increased resistance in the start winding. This is done by merely making the start winding wire a smaller diameter. Contrary to popular beliefs, the higher resistance in the start winding lets the current develop a magnetic field in the start winding before the run winding.

More current goes into the run winding because there is less resistance in the wire. The greater current in the run winding generates a greater CEMF than can be developed in the start winding. This forces the run current to lag voltage by about 50 degrees.

The smaller current entering the start winding generates less CEMF. Power supply EMF quickly overcomes the start winding CEMF. Start winding current lags voltage by about 20 degrees. This puts the magnetic field in the start winding ahead of the run winding by about 30 degrees (Figure 17-14).

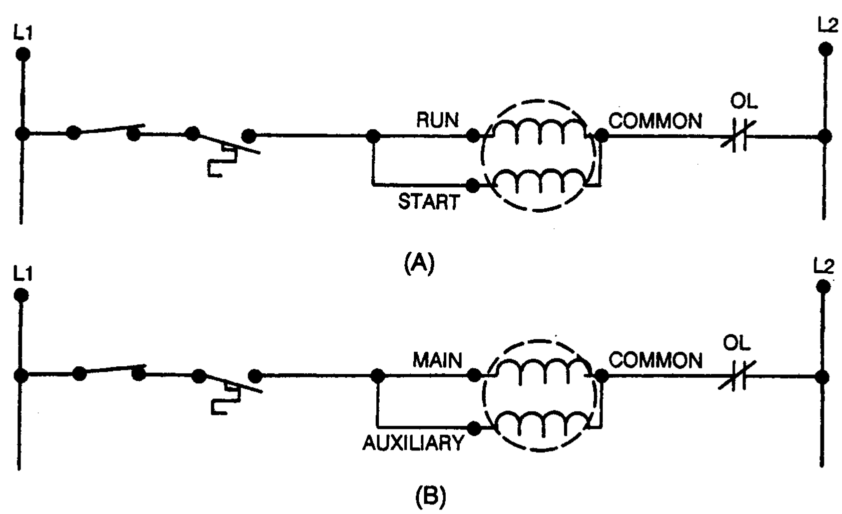

FIGURE 17-9. Single-Phase Motor Terminals.

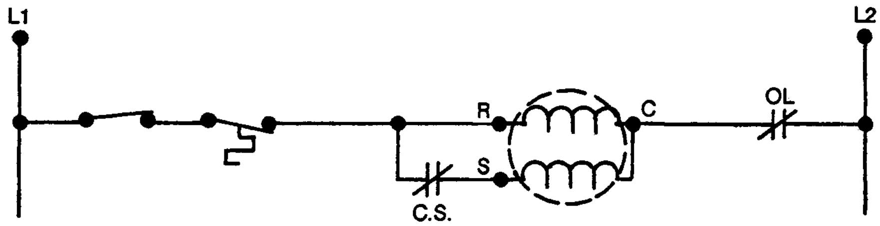

FIGURE 17-10. Simple Line Diagram Of the Single-Phase Motor.

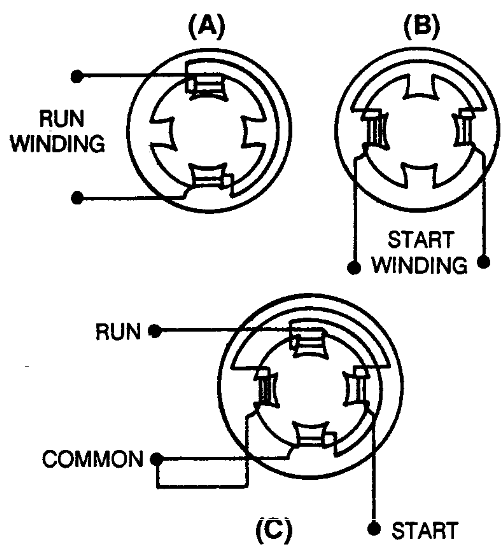

FIGURE 17-11. Run and Start Windings.

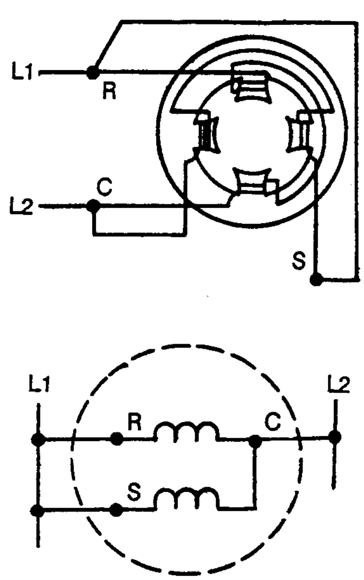

FIGURE 17-12. Run and Start Windings Joined at the Common Terminal.

In Figure 17-15, the start winding current precedes the current arriving in the run winding. The magnetic field develops in the start winding first. A moment later, the start winding current starts to diminish, and its magnetic field decreases. As this happens, the current and the magnetic field in the run winding is increasing.

The induced rotor EMF, resulting current flow, and magnetic polarity remain the same. The magnetic polarities of the rotor winding were first developed under the start winding. Now the increasing magnetic pull of the run winding, which is displaced physically, attracts the rotor. This is the phase displacement necessary for torque. The direction of rotation will always be from the start winding to the adjacent run winding of the same polarity.

At about 75 percent of the rotor rated speed, the centrifugal switch disconnects the start winding from the power supply. Once motion is established, the motor will continue to run efficiently on the run winding alone (Figure 17-16).

Centrifugal Switch

Many single-phase motors are not designed to operate continuously on both windings. At about 75 percent of the rated rotor speed, the centrifugal switch opens its contacts. It only takes a few moments for the motor to obtain this speed. An audible click can be heard when the centrifugal switch opens or closes.

The centrifugal switch operates on the same principle as the diesel governor flyballs. Weights attached to the outside periphery of the switch rotate with the rotor shaft (Figures 17-17 and 17-18). As the rotor shaft speed increases, centrifugal force moves the weights outward. This action physically opens a set of contacts in series with the start winding.

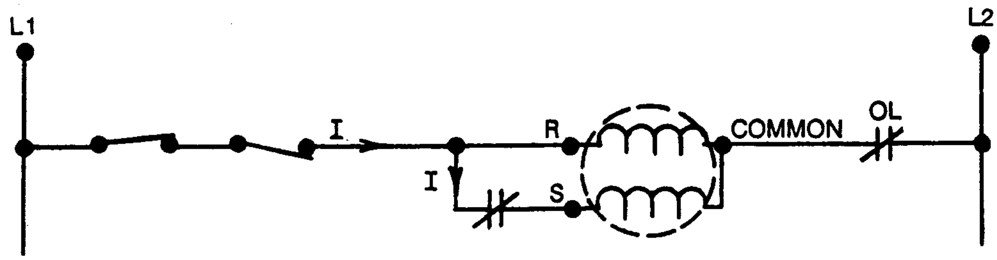

FIGURE 17-13. Current Divides According to Resistance.

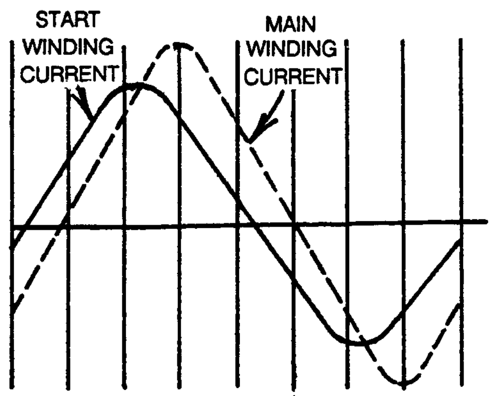

FIGURE 17-14. Start Winding Current Leads Run Winding Current.

Once the start winding is disconnected from the circuit, the momentum of the rotor and the oscillating stator field will continue rotor rotation. If, however, the motor is again stopped, the start winding is reconnected through the normally closed and spring-loaded centrifugal switch. The motor can only develop starting torque with both start and run windings in the circuit.

Reversal of Direction of Rotation

The rotor will always turn from the start winding to the adjacent run winding of the same polarity. Therefore, the relationship between the start and run windings must be changed. To change the relationship and the direction of rotation, the polarity of only

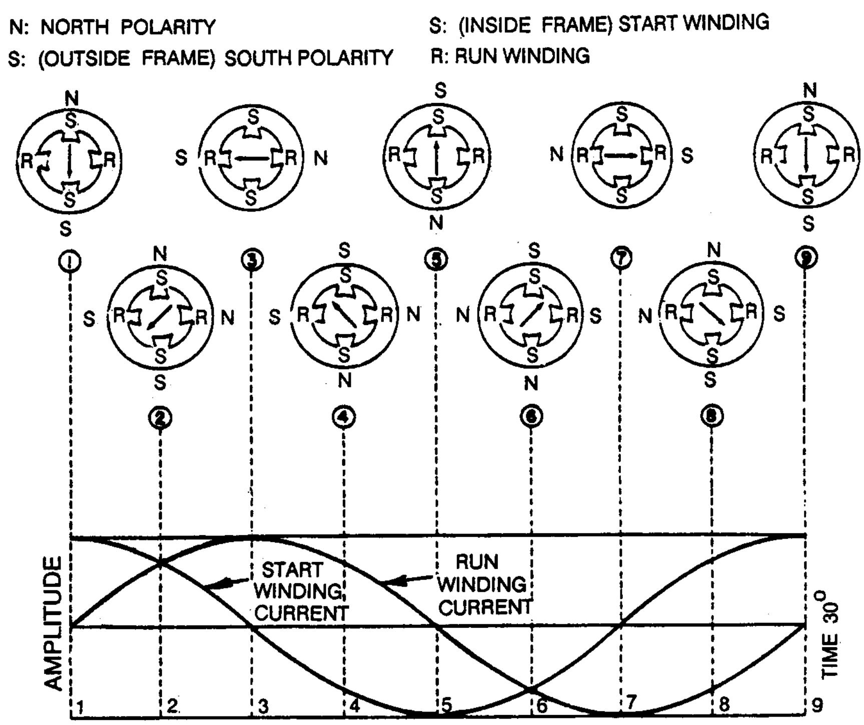

FIGURE 17-15. Start and Run Winding Magnetic Field.

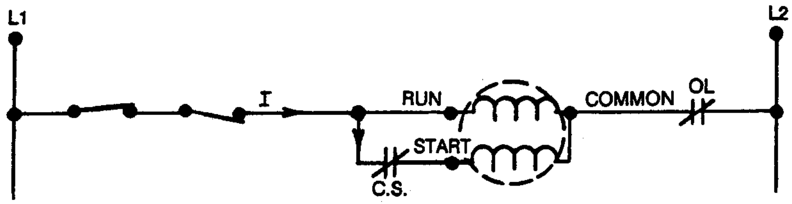

FIGURE 17-16. Centrifugal Switch Opens.

one of the fields must be reversed. In this manner, only one field polarity will change, and the rotor will still move toward the run winding of the same polarity as the start winding. The current entering the run winding or the current entering the start winding must be reversed, but not both. Figure 17-19 shows a schematic of the reversal of the start winding.

If the main power supply lines, L1 and L2, are switched, then the polarity of all the windings will be reversed. This, however, will not change the direction of rotation because the polarity of both the start winding and the run winding reverses. The relationship between the start winding and the run winding has not changed. The rotor will still turn in the direction from the start winding to the run winding of the same polarity (Figure 17-20).

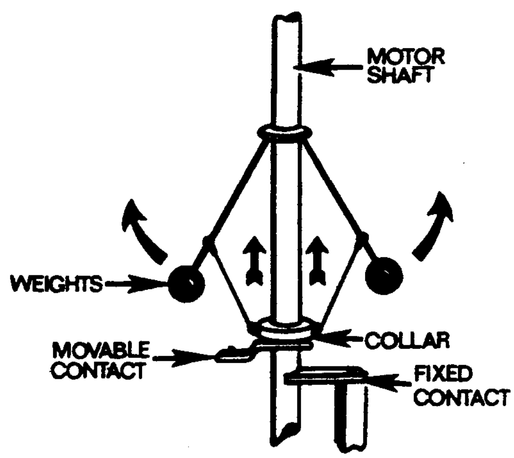

FIGURE 17-17. Centrifugal Switch Operation.

Split-Phase Motor Applications

Split-phase motors are generally limited to the 1/3 horsepower size. They are simple to manufacture and inexpensive. The starting torque is very low and can be used for starting small loads only.

CAPACITOR-START MOTORS

Capacitor-start motors are the most widely used single-phase motors in the marine engineering field. They are found on small refrigeration units and portable pumps. They come in a variety of sizes up to 7.5 horsepower. The characteristic hump on the motor frame houses the capacitor (Figure 17-21).

The capacitor-start motor is derived from the basic design of the split-phase motor. The split-phase motor had a current displacement, between the start and run winding, of 30 degrees with wire resistance alone. To increase this angle and increase motor torque, a capacitor can be added. The product of capacitance can be used to increase the current angles, or in other words, to increase the time between current arrival in the start and current

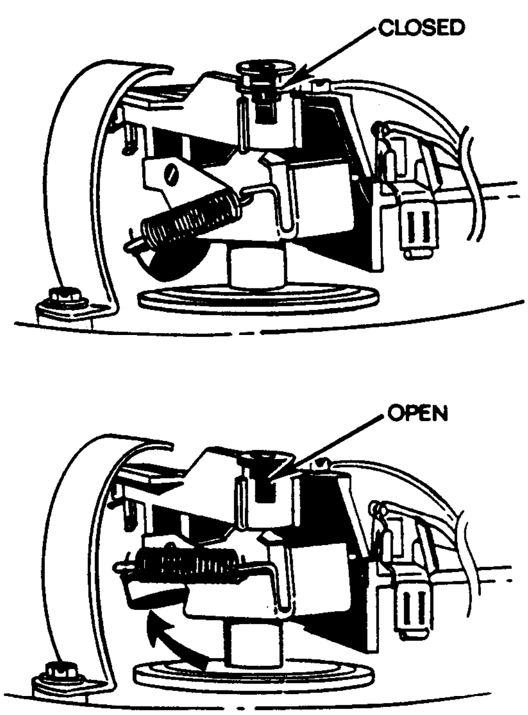

FIGURE 17-18. The Centrifugal Switch.

arrival in the run windings. In capacitance, current leads voltage.

The capacitor, unlike a resistor, does not consume power but stores it so it can be returned to the circuit. The combining of the inductive run (current lagging) winding and the capacitive start (current leading) winding would create a greater current displacement. This would increase the torque.

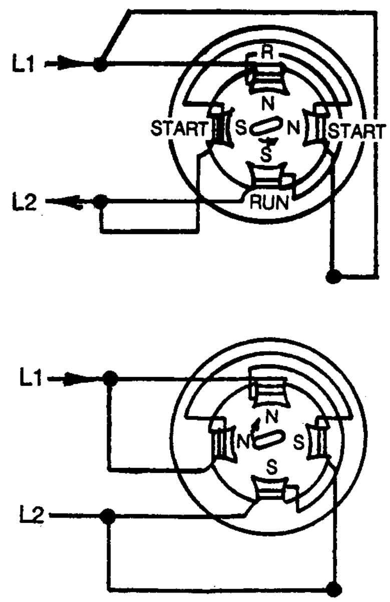

FIGURE 17-19. Reversing the Direction of Current Through the Start Winding.

Capacitor Application

The capacitor is placed in series with the start winding. Figure 17-22 shows a line diagram of its position. Optimum torque can be delivered if the current entering the run and the start winding is displaced by 90 degrees. With this in mind, and knowing an inductive run winding current can lag voltage by 50 degrees, an appropriated capacitor can be selected. A capacitor that can effectively produce a current lead of 40 degrees would give the optimum 90-degree displacement angle (Figure 17-23).

Once the motor has attained 75 percent of its rated speed, the start capacitor and start winding can be eliminated by the centrifugal switch. It is not necessary for this motor to operate on both windings continuously.

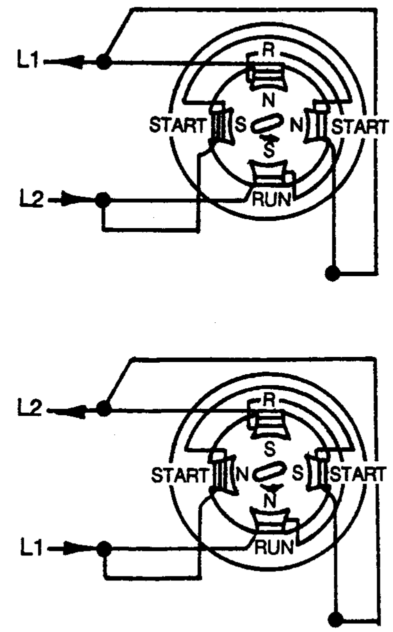

FIGURE 17-20. No Change in the Relationship Between the Start and Run Winding.

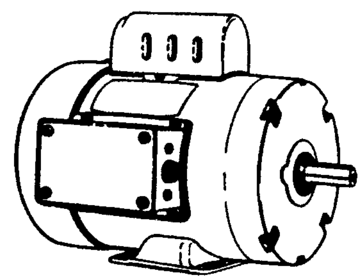

FIGURE 17-21. Capacitor Housing.

PERMANENT-CAPACITOR MOTORS

The capacitor of the capacitor-start motor improves the power factor of the electrical system only on starting. Letting a capacitor remain in the circuit will improve the electrical power factor that was modified initially by the use of a motor. The permanent capacitor is placed in series with one of the windings. The two windings are now called the main and auxiliary (sometimes called the phase) windings. They are constructed exactly alike. Both are left in the circuit during the operation of the motor. A centrifugal switch is no longer needed. Another switch will let the capacitor be connected to either the main or auxiliary winding. The advantage of this is the comparative ease in which the capacitor can be connected to the main or auxiliary winding to reverse direction of rotation. The capacitance forces the current to lead the voltage in the winding it is connected to. This means that the magnetic field is developed in the capacitor winding first.

Certain disadvantages become apparent. The permanent-capacitor motor is very voltage-dependent. How much current delivered to the winding depends on the capacity of the capacitor and the system voltage. Any fluctuation in line voltage affects the speed of the motor. The motor speed may be reduced as low as 50 percent by small fluctuations. Speed changes from no load to full load are extreme. No other induction motor undergoes such severe speed fluctuations.

TWO-CAPACITOR MOTORS

When additional torque is required to start and keep a motor operating, additional capacitors can be added. An excellent example is the refrigeration compressor. A lot of torque is required to start the motor when the compressor it turns may be under refrigerant gas pressure. Also, the compressor may become more heavily loaded during operation, as the refrigeration system requires it. In this case, the high starting torque of the start capacitor motor and an increased phase angle while the motor is running are needed to handle additional torque requirements.

Figure 17-24 shows the two-capacitor motor. It is commonly referred to as the capacitor-start/

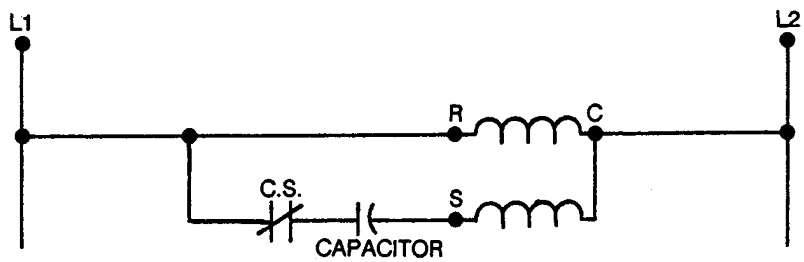

FIGURE 17-22. Capacitor-Start Motor.

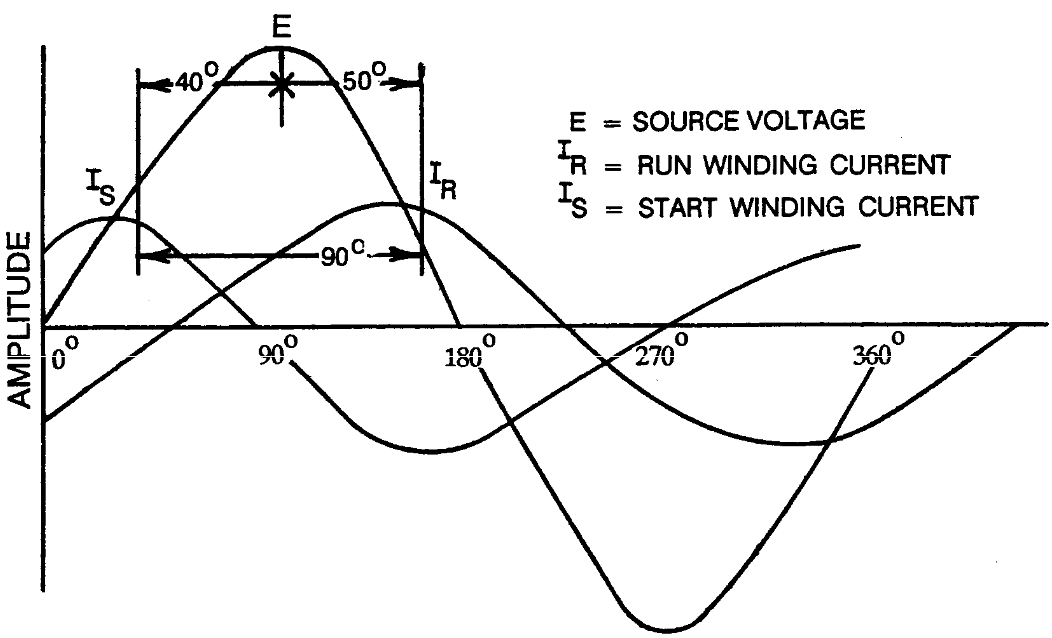

FIGURE 17-23. Capacitor Starting Current and Run Winding Current.

capacitor-run motor. Notice that the start capacitor is in series with the auxiliary winding. The centrifugal switch is used to control the start capacitor in the same manner as it did in the capacitor-start motor. This capacitor is used only to develop enough torque to start the motor turning.

The run capacitor is connected in parallel with the start capacitor. In this manner, both capacitor capacitances add together to increase the total phase angle displacement when the motor is started. Also, the run capacitor is connected in series with the auxiliary winding. With the run capacitor connected in series with the auxiliary winding, the motor always has the auxiliary winding operating, and increased torque is available.

At about 75 percent of the rated motor speed, the centrifugal switch opens and removes the start capacitor from the auxiliary winding. The run capacitor is now the only capacitor in the motor circuit.

CAPACITORS

The capacitor is the heart of most single-phase revolving field motors. If the single-phase motor fails to operate, always check the source voltage first. Then check the fuses or circuit breakers. If these areas are operable, check the capacitor. Visually inspect the capacitor for cracks, leakage, or bumps. If any of these conditions exist, discard the capacitor immediately.

CAUTION

Always discharge a capacitor before testing, removing, or servicing the single-phase motor. This is done by providing a conductive path between the two terminals.

WARNING

Never connect a capacitor to a voltage source greater than the rated voltage of the capacitator. Capacitors will explode violently due to excessive voltage.

Capacitor Operation

A capacitor is not a conductor. Current does not pass through the device as it would a resistor or motor winding (Figure 17-25). Instead, the capacitor must depend on its internal capacity to shift electrons.

FIGURE 17-25. The Capacitor Symbol Does Not Show A Completed Circuit Between the Terminals.

The power supply voltage establishes a magnetic polarity at each plate. Remember, even AC generators establish a freed polarity (or difference in potential) throughout the distribution system. However, the polarity changes 120 times a second. The capacitor plates change polarity from negative potential and positive potential rapidly, depending on the frequency of the generated voltage (Figure 17-26).

Between the two capacitor plates is an insulator called a dielectric. The dielectric can store energy in an electrostatic field, known commonly as static

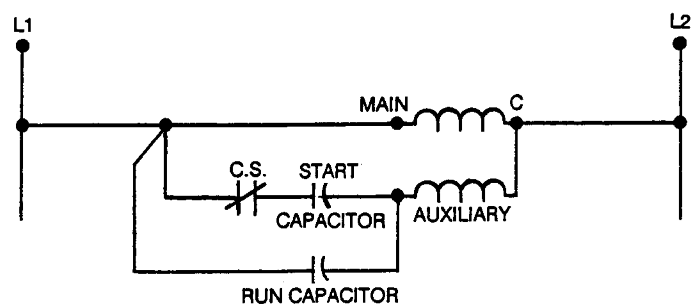

FIGURE 17-24. The Two-Capacitor Motor.

electricity. This is done in the following manner: The electrons in the dielectric of the capacitor are tightly bound in their orbits around the nucleus of their atom. A positive polarity is established in one capacitor plate by virtue of the connection to the positive ion terminal of the generator. A negative polarity is established in the other plate of the capacitor by virtue of the negatively charged electrons from the other generator terminal.

The positive polarity at the capacitor plate pulls the negative electrons in the dielectric. The negative polarity at the other plate pushes the dielectric electrons away. The distorted electron orbit has energy much like that found in a stretched out spring. When the spring is no longer forcibly held in the extended position, it pulls itself back together (Figure 17-27).

The greater the circuit voltage, the greater the difference in potential at the capacitor plates. The stronger the magnetic effects at the capacitor plates, the greater the effect on the electrons in the dielectric.

When the voltage in the AC system is reduced, before changing its direction, the magnetic field decays, and the dielectric electrons are pulled back into their original orbits by their nucleus. This movement of dielectric electrons offsets all the other electrons throughout the capacitor circuit (Figure 17-28). This generates the electron flow (current) that is required to produce the desired magnetic effects in motors. Current flows through the circuit in the opposite direction as would have been originally intended by the generator. Because of this action, current now arrives before the voltage of the next comparable voltage direction.

Capacitor Inspection

The internal condition of a capacitor maybe checked with an ohmmeter (Figure 17-29). Always consult the manufacturer's manuals or appropriate technical manuals for specific information on the capacitor being inspected. Remove the capacitor from the motor and disconnect it. Always short the

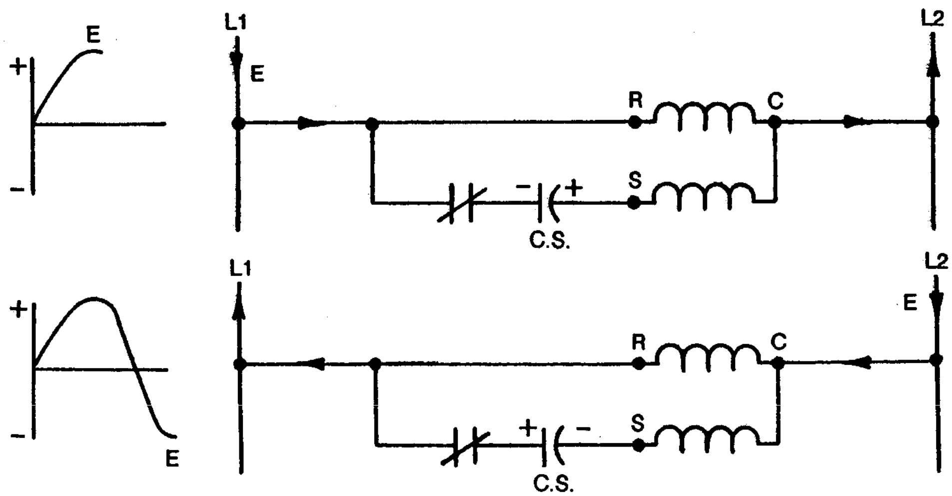

FIGURE 17-26. Polarity from AC at the Capacitor.

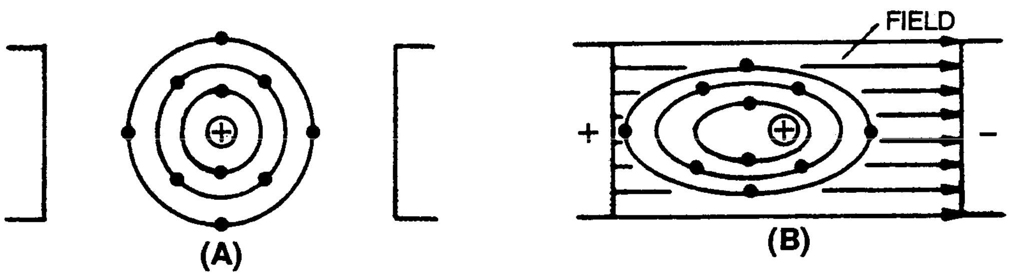

FIGURE 17-27. Electron Orbits With and Without the Presence of an External Electric Field

capacitor terminals before making a test. If a spark occurs when you short the capacitor terminals, this is a good indication that the capacitor is serviceable and maintaining its charge.

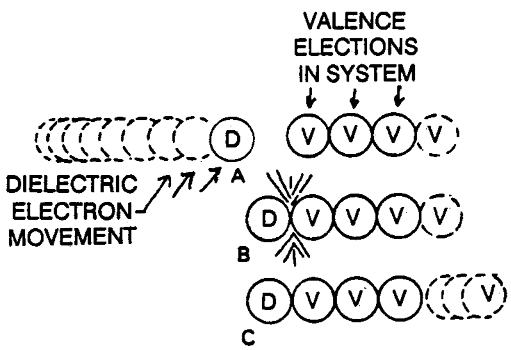

FIGURE 17-28. Displacement of the Circuit Valence Electrons.

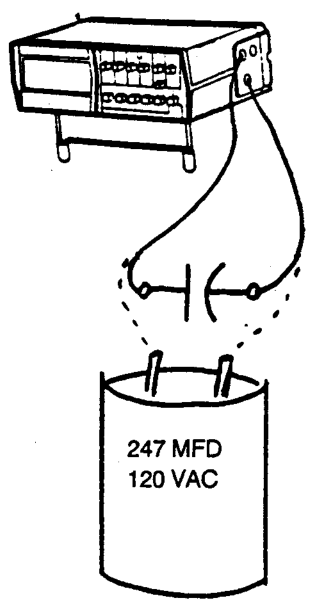

FIGURE 17-29. Testing the Capacitor.

CAUTION

The capacitor starting tool should have an insulated handle. The actual shorting bar should be high-resistance (15k to 20k ohms).

Consult the meter manual to determine the correct range for testing capacitors with the ohmmeter. This is usually a range that provides the highest internal battery voltage from the ohmmeter.

Connect the meter leads to the terminals. Notice the meter display. A good capacitor will indicate charging by an increase in the display's numerical value. This indicates that the capacitor is accepting the difference in potential from the ohmmeter's battery. Once the display stops charging, remove the meter leads and discharge the capacitor (short the terminals).

Reconnect the ohmmeter again, but this time remove one of the meter leads just before the meter display would have indicated the capacitor has stopped charging. Remember the display reading. Wait 30 seconds and reconnect the ohmmeter leads to the same capacitor terminals. The meter's display should start off with the value displayed before removing one ohmmeter lead. If the meter returns to zero, this indicates that the capacitor is unable to hold its charge and must be replaced.

NOTE: Digital meters require some familiarity before this test can be done with a degree of confidence. It may take a moment for the digital meter to display the correct reading upon reconnection. Practice with known good capacitors.

Shorted and Open Capacitors

Capacitors that are shorted or open will not display a charge on the ohmmeter. These meters will show either continuity or infinity.

A shorted capacitor means that the plates of the capacitor have made contact with each other and pass current readily. This will be indicated by a very low and steady resistance reading on the ohmmeter. A shorted capacitor must be replaced.

An open capacitor means that the distance between the plates of the capacitor is too far apart. The magnetic fields are not close enough to properly distort the electrons and their nucleus in the dielectric. The ohmmeter will not show a charging condition. For example, when the terminals of the capacitor have become disconnected from the capacitor plates, there will bean indication of infinite or maximum meter resistance. The capacitor must be replaced.

Types of AC Motor Capacitors

There are two capacitors commonly found on single-phase motors: the start capacitor, which has a plastic housing, and the run capacitor, which has a metal housing.

The start or electrolytic capacitors are encased in plastic and have as much as 20 times the capacitance of the run capacitor. One of the plates consists of an electrolyte of thick chemical paste. The other plate is made of aluminum. The dielectric is an aluminum oxide film formed on the aluminum plate surface. These capacitors cannot be operated continuously.

Run or paper capacitors are generally used for the motor-running circuit in the single-phase motor. These capacitors are encased in metal and made durable for continuous operation. The internal construction is made of two or more layers of paper rolled between two layers of aluminum foil (Figure 17-30).

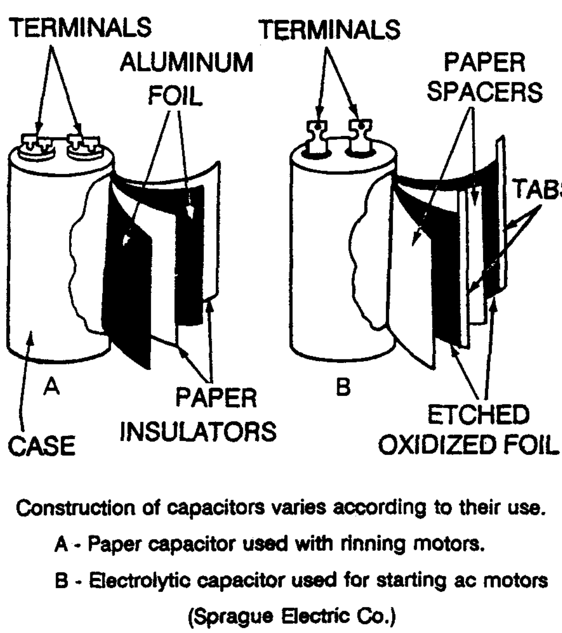

FIGURE 17-30. Capacitor Construction.

AC Capacitors

The start winding of a single-phase motor can be damaged if the run capacitor is shorted to ground. This type of damage can be easily avoided if care is taken when installing replacement capacitors.

Manufacturers mark the capacitor terminal connected to the outermost foil. General Electric uses a red dot. Cornell Dubilier indents a “dash.” Sprague points an arrow to the problem terminal. When the outer foil fails and comes in contact with the capacitor housing, a short to ground completes a circuit which bypasses the normal circuit protection. When this happens, the start winding can be destroyed. To prevent this casualty from developing, connect the marked terminal to the “R” or power supply line. Never connect the marked terminal to the “S” (start) terminal.

DC Capacitors

The discussion on capacitors has been directed toward the AC capacitor. Our field technology, however, spans decades of marine engineering. For this reason, a few cautions are in order for installing DC capacitors.

The DC capacitor is designed differently from the AC capacitor. The DC capacitor must be placed in the DC circuit in one position only. Always connect the positive terminal of the capacitor to the positive conductor in the DC circuit. Connect the negative terminal in a like manner to the negative conductor. Always observe the polarity of the capacitor. The terminals will be marked positive(+) and negative (-). If the capacitor terminals are incorrectly connected in the circuit, the capacitor will be ruined.

WARNING

Never connect the DC capacitor in an AC circuit. If this is done, the DC capacitor can explode.

Capacitor Rating

Capacitors are rated by the amount of current that results from the changing frequency of the generated voltage. Every time voltage changes polarity, current is displaced through the capacitor circuit. This action is a measurement of farads (F). A capacitor has a capacity (to displace electrons) of 1 farad when a current of 1 ampere (6.242 x 10 to the

18th electrons per second) is produced by a rate of change of 1 volt per second.

The farad is an extremely large value for our motor applications. Most common motor capacitor ratings will be found in the microfarad range.

The capacitance of a capacitor is determined by its construction. The area of the capacitor plates as well as the dielectric material and thickness determine the capacity. Always select a capacitor by the capacitance desired (farad rating) and the voltage rating of the system.

Capacitor Characteristics

When two capacitors are connected in series, the magnetic effects that distort the electron's orbit are further apart. Remember that distance determines the influence that can be exerted by a magnetic field. The capacitor is not a conductor so that only the outermost capacitor plates have a magnetic polarity when they are connected in series (Figure 17-31).

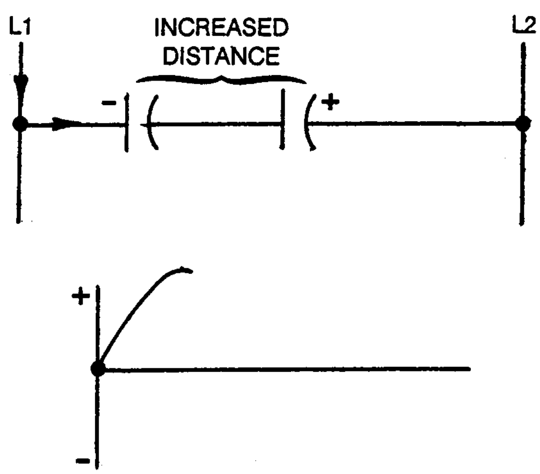

FIGURE 17-31. Capacitors Connected in Series.

The total capacitance of capacitors connected in series can be derived by using the product-over-sum method (as used for determining resistance in a parallel circuit). Notice that the total capacitance is now less than the smallest capacitor.

Capacitors connected in parallel are like adding extra storage batteries in parallel (Figure 17-32). The voltage does not change, but the current, or ability to move electrons, increases. To determine the total capacitance of the circuit, add all the capacitors in parallel.

Voltage is constant in a parallel circuit. This provides an equal positive potential at every capacitor plate connected by a node. A negative potential is also available at the other plates of the other capacitors. In this manner, the magnetic effects available from a difference in potential (voltage) can be most effectively used to displace electrons in the dielectric.

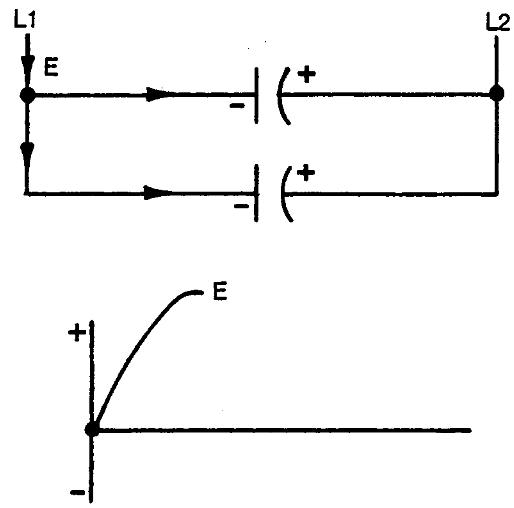

FIGURE 17-32. Capacitors in Parallel.

SHADED-POLE MOTORS

The shaded-pole motor does not use two windings to develop the torque necessary to turn the rotor. Instead, the stator pole piece is divided into two sections. One section has a copper ring encircling the tip (Figure 17-33).

Alternating current enters the stator winding field coil surrounding the stator pole. A magnetic field is readily developed in the stator pole portion without the copper ring.

This expanding magnetic field develops an EMF and resulting magnetic field in the squirrel cage rotor of the opposite polarity of the stator field that induced it. In other words, the stator pole might have been a north polarity, but by virtue of the property of induction, the polarity in the squirrel cage rotor winding directly beneath the stator north polarity would become a rotor pole of south polarity.

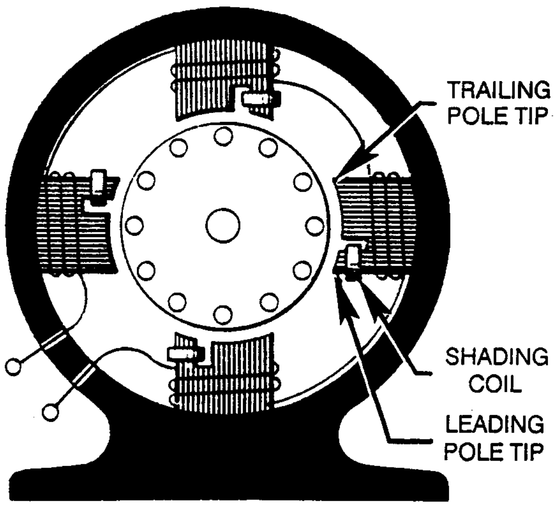

FIGURE 17-33. Shaded-Pole Motor Pole Piece.

While this is happening, the copper ring has impeded the developing magnetic field in the shaded-pole section of the stator pole piece. First, the growing magnetic field expands across the copper ring. The copper ring is short-circuited, like the winding in an induction motor rotor, and an EMF is induced in the ring. An EMF is induced into the copper ring (shaded pole) by the impeded, yet expanding magnetic field. Since the copper ring is short-circuited a current ensues. With this shaded pole current, a magnetic field is established. All of this takes time and inhibits the magnetic field from developing, or decaying, during the same time as the remaining field winding.

By the time the magnetic field finally becomes established in the shaded-pole section of the pole piece, the current flow through the field coil encompassing the entire pole piece has stopped. The shaded-pole section has developed a strong north pole. The unshaded portion weakens rapidly because of the elimination of current in the field coil.

The shaded-pole section retains its magnetic field longer because it takes longer for the field to collapse. The magnetic field developed in the copper ring collapses first. This relative motion of the collapsing field helps induce and sustain an EMF. The resulting current flow and magnetic field are momentarily maintained in the pole piece surrounded by the copper ring.

The property of induction states that induction opposes a change in current. This reluctance to stop current flow maintains the magnetic field longer.

The south polarity developed in the rotor winding directly under the unshaded portion of the pole piece is now attracted to the stronger magnetic field of the shaded-pole section. This is how torque is developed.

Figure 17-34 shows the magnetic field developed in the unshaded portion of the stator pole, the field developed in the shaded stator pole section, and finally the field developed in the copper ring. All these things happen very rapidly, but at different periods in time.

Shaded-pole motors are low cost but are not capable of developing enough torque to turn large equipment. Shaded-pole motors usually range from 1/500 to 1/4 horsepower.

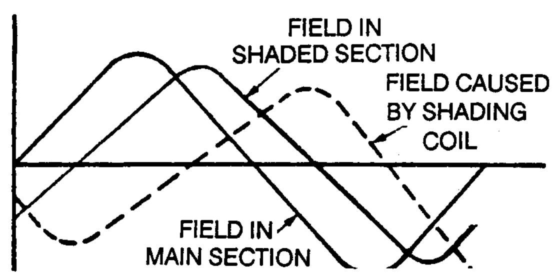

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FIGURE 17-34. The Three Current Sine Waves In the Shaded-Pole Motor.