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***SINGLE-PHASE MOTORS***

***Lesson One***

***Introduction to  
Single-Phase Motors***



***TPC Training Systems***

20701

**Lesson**

# **Introduction to Single-Phase Motors**

**TOPICS**

Parts of a Single-Phase Motor  
 Definitions  
 NEMA Motor Standards  
 Motor Enclosures  
 Nameplate Data  
 Induction Motors  
 Single-Phase Stator Field

Single-Phase Rotor Field  
 Split-Phase Starting  
 Number of Poles  
 Electrical Degrees  
 Synchronous Speed  
 Starting Switches  
 Standard and Special Split-Phase Motors

**OBJECTIVES**

After studying this lesson, you should be able to...

- List the parts of a rotor.
- List the data given on a typical motor nameplate.
- Explain how an induction motor works.
- Demonstrate how to calculate the number of electrical degrees in one complete rotation of a motor.
- Explain how a centrifugal switch works.

**KEY TECHNICAL TERMS**

**Rotor** 1.01 the rotating part of a motor or generator  
**Stator** 1.01 the stationary part of a motor or generator  
**Service factor** 1.07 the allowable overload of a general-purpose motor  
**Slip speed** 1.07 the difference between a motor's synchronous speed and its operating speed

**Phase splitting** 1.39 the production of a rotating magnetic field by using two stator windings with a different impedance to create a difference in phase  
**Synchronous speed** 1.51 the speed of the rotating magnetic field in an induction motor

Single-phase fractional horsepower ac motors are widely used in the plant. Uses include driving fans, pumps, clocks, and many types of power tools. Single-phase motors are divided into various classifications, some or all of which you may find in your plant.

This lesson introduces you to many terms associated with single-phase ac motors. Do not let the number of definitions confuse you. Many will be used in the other lessons in this course, and you will become familiar with them.

This lesson explains the fundamentals of single-phase motors. This information covers stator and rotor fields, split-phase starting, magnetic poles, electrical degrees, synchronous speed, starting switches, and standard and special split-phase motors.

### Parts of a Single-Phase Motor

1.01 The single-phase fractional-horsepower ac motor is used in many industrial applications. It drives fans, pumps, clocks, and power tools. Every single-phase motor has a rotating part, called the *rotor*, and a stationary part, called the *stator*. End plates bolted to the stator frame support the bearings for the rotor shaft. Figure 1-1 shows the parts of a single-phase motor.

1.02 The rotor consists of three elements—the *core*, the *squirrel cage*, and the *shaft*. The core is made of sheet-steel laminations to keep the eddy currents to a minimum. The assembled core is pressed onto the shaft. A squirrel-cage, made of heavy bars of copper or aluminum, is embedded in slots cut in the

core. The bars are connected to each other by a ring of copper or aluminum around each end of the core. The rings provide electrical continuity by short-circuiting all the bars at the ends.

1.03 The name “squirrel cage” comes from the appearance of the rotor winding. Separated from the rotor core, the bars and connecting rings make a structure that looks like the exercise wheel in a cage for squirrels. This structure is shown in Fig. 1-2, on the following page.

1.04 The stator core is made of sheet-steel laminations pressed into a frame made of steel or cast iron. The core has slots that are partially closed. Coils of copper wire fit into the slots. These coils make up the stator winding.

**Fig. 1-1. Parts of a single-phase ac motor**

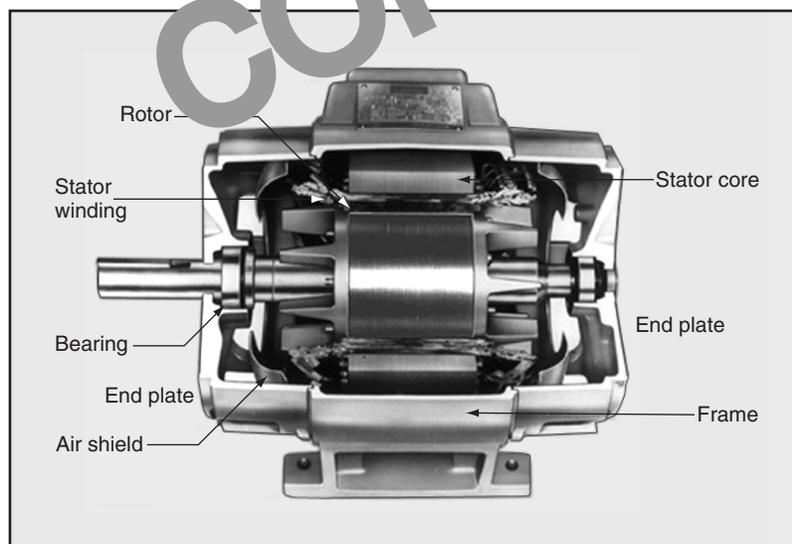


Fig. 1-2. Squirrel cage



1.05 The end plates (also called *end shields*, *end bells*, or *end housings*) are bolted to the stator frame. The end-plate bearings support the rotor and keep it centered within the stator.

### Definitions

1.06 In order to understand the information in this course you must learn the meanings of certain motor descriptions. The following descriptions define various classifications of motors.

- **General-purpose motor.** Any open-enclosure motor having a continuous 40°C rating and designed, listed, and offered in standard ratings, with standard operating characteristics and mechanical construction, for use under ordinary service conditions without restriction to a specific application or kind of application.
- **Definite-purpose motor.** Any motor designed, listed, and offered in standard ratings, with standard operating characteristics or mechanical construction, for use under service conditions other than ordinary conditions or for use in a specific kind of application.
- **Special-purpose motor.** A motor with special operating characteristics or special mechanical construction (or both), designed for a specific application.
- **Split-phase motor.** A single-phase induction motor with an auxiliary winding displaced in magnetic position from the main winding and connected in parallel with the main winding.

- **Capacitor-start motor.** A single-phase induction motor with a main winding arranged for direct connection to the power source and an auxiliary winding connected in series with a capacitor. The auxiliary winding with the capacitor is in the circuit only during starting.
- **Capacitor-run motor.** A single-phase induction motor similar to the capacitor-start motor. However, in this motor the capacitor remains in the circuit for both starting and running.
- **Shaded-pole motor.** A single-phase induction motor having one or more short-circuited auxiliary windings. The windings are displaced in magnetic position from the main winding to provide the rotation of the magnetic field.

1.07 In addition to understanding the definitions of various kinds of motors, you need to know how several terms are defined. The following terms are used in describing the operating characteristics of motors.

- **Locked-rotor torque.** The minimum torque developed by a motor with its rotor locked in all possible angular positions, when the motor receives its rated potential difference at the rated frequency.
- **Breakdown torque.** The maximum torque a motor can produce at its rated potential difference and frequency, without an abrupt decrease in speed.
- **Full-load torque.** The torque produced by a motor when it delivers its rated power at its full-load speed.
- **Pull-up torque.** The minimum torque developed by the motor as it accelerates from rest to full speed.
- **Service factor.** The allowable overload of a general-purpose motor. It is expressed as a number equal to the ratio of the permissible operating power to the rated power.
- **Slip speed.** The difference between a motor's synchronous speed and its operating speed.

- **Locked-rotor current.** The steady current in the motor when the rotor is locked in position and the rated potential difference and frequency are applied.

**NEMA Motor Standards**

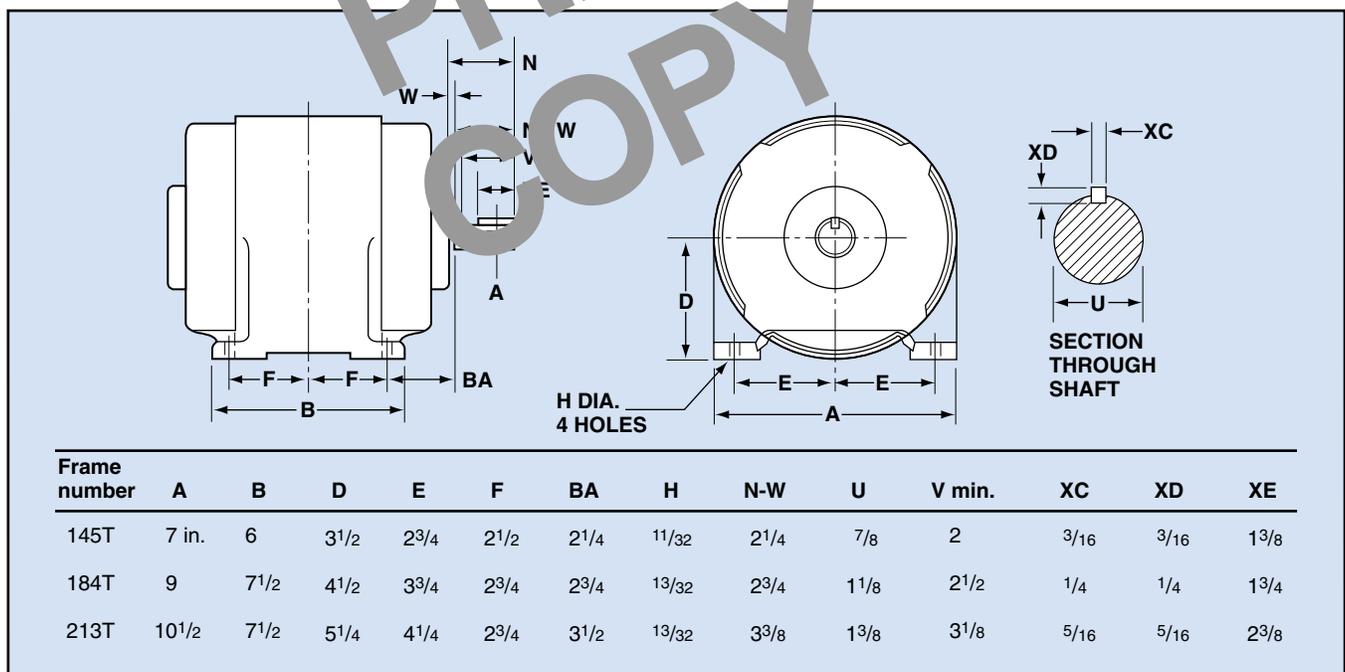
1.08 Many motors are manufactured according to standards set by the National Electrical Manufacturers Association (NEMA). A standard motor made by one manufacturer can be replaced by the same standard motor made by another manufacturer. The motor ratings, operating characteristics, and mechanical construction and dimensions are identical for all motors manufactured according to NEMA standards.

1.09 Standard motors are identified by a *frame number*. For example, all motors identified by the frame number 145T have the same physical dimensions. Figure 1-3 is a drawing of a motor with lettered dimensions. The table below the drawing lists the dimensions for foot-mounted ac motors. The dimensions for three frame numbers are listed as examples.

1.10 The drawing and table in Fig. 1-3 identify the following dimensions by letter. Three examples are listed with all dimensions specified.

- A = maximum width of base
- B = maximum length of base
- D = height of shaft center above lower bottom of base
- E = radial distance of center of mounting hole from centerline of shaft
- F = axial distance of center of mounting hole from center of frame
- BA = axial distance of center of mounting hole from front surface of collar
- H = diameter of holes in mounting base
- N = overall length of exposed shaft
- W = thickness of shaft collar
- N-W = overall length of exposed shaft, minus thickness of collar
- U = diameter of shaft

**Fig. 1-3. NEMA motor dimensions**



**Table 1-1. NEMA standard voltages**

System voltage	Motor voltage	
	Single phase	Polyphase
120	115	115
120/208Y	115	200
240	230	230
480	—	460
600	—	575

V = maximum width for mounting a pulley or sprocket

XC = width of keyway

XD = depth of keyway

XE = length of keyway

1.11 Table 1-1 is a list of the NEMA standard designations of potential difference for ac motors and supply systems. AC motors are designed to operate at  $\pm 10\%$  of their rated potential difference, and  $\pm 5\%$  of their rated frequency.

- A motor rated at a potential difference of 115 V is designed to operate at a minimum of 103.5 V and a maximum of 126.5 V.
- A motor rated at a frequency of 60 Hz is designed to operate at a minimum of 57 Hz and a maximum of 63 Hz.

1.12 There is nothing you can do to affect the frequency of the incoming ac power. Public utility companies control the frequency very accurately.

**Motor Enclosures**

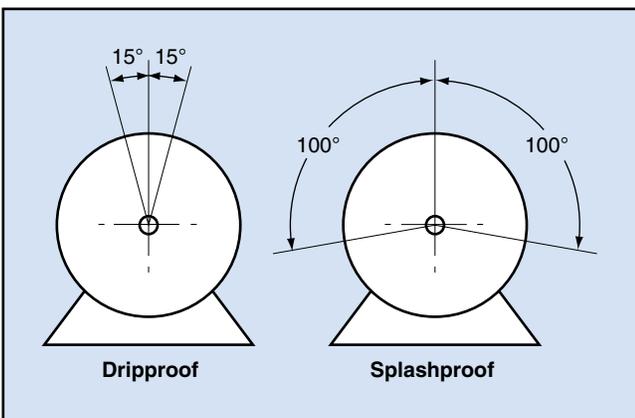
1.13 There are two general classifications of motor enclosures—the open motor and the totally enclosed motor.

1.14 **Open motors.** These motors have openings to allow air to pass through and cool the windings. The openings are usually located in the end plates.

1.15 Open motors are further classified into the following categories:

- *Dripproof motors* are designed to prevent solid particles and drops of liquid from entering the motor at any angle up to  $15^\circ$  from the vertical, as shown at the left in Fig. 1-4.
- *Splashproof motors* prevent solid particles and drops of liquid from entering the motor at any angle up to  $100^\circ$  from the vertical, as shown at the right in Fig. 1-4.
- *Semiguarded or guarded motors* have openings that are covered with a screen or grill to prevent accidental contact with rotating parts.
- *Dripproof, fully guarded motors* are a combination of a dripproof motor and a guarded motor.
- *Open, externally ventilated motors* are cooled by outside air coming from an external fan or from a metal duct.
- *Open, pipe-ventilated motors* are cooled by air that enters the motor through piping.
- *Weather-protected motors* have ventilating openings designed to minimize the entrance of rain, snow, and dust.

**Fig. 1-4. Motor enclosures**



1.16 **Totally enclosed motors.** These motors are enclosed tightly enough to prevent air from entering the enclosure. However, the motors are not sealed tightly enough to be considered “airtight.” There are several classifications of these motors.

- *Totally enclosed, nonventilated motors* are cooled by the surrounding air.
- *Totally enclosed, fan-cooled motors* have a fan mounted on one end of the motor shaft to cool the motor by forcing air over it when it is running.
- *Explosionproof motors* are used in locations where flammable vapors exist.
- *Dust ignitionproof motors* are used in grain elevators and other areas where dust exists and must not be ignited.
- *Waterproof motors* can operate even when submerged in water.
- *Totally enclosed, pipe-ventilated motors* are cooled by air forced through a pipe.
- *Totally enclosed, water-cooled motors* have a special jacket surrounding them. Water circulates through the jacket to remove heat.

**Nameplate Data**

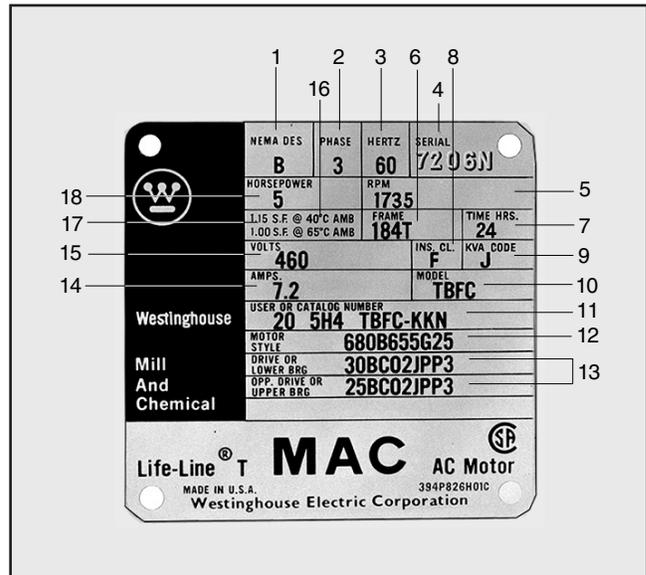
1.17 All performance information for a motor is based on the motor being supplied by power at the potential difference and frequency stated on the nameplate. A motor rating consists of the power output, speed, potential difference, and current specified by the manufacturer.

1.18 A typical motor nameplate is shown in Fig. 1-5. It includes the following information, labeled by numbers in the figure.

1. *NEMA designation* indicates the torque and current characteristics. The most common designations are A, B, C, and D.

NEMA letter	Starting torque	Starting current	Breakdown torque	Slip at full load
A	Normal	Normal	High	Low
B	Normal	Low	High	Low
C	High	Low	Normal	Low
D	Very high	Low	— — —	High

**Fig. 1-5. Motor nameplate**



2. *Phase* indicates the kind of power the motor is designed for. Some motors operate on single-phase ac power, others on three-phase ac power, and still others on dc power.
3. *Hertz* indicates the frequency of the ac power required to run the motor properly. This frequency is almost always 60 Hz in the United States and Canada. You may sometimes see motors rated for 50 Hz for use in other countries of the world.
4. *Serial* is the manufacturer's code number that identifies the motor. It may indicate a general kind of motor sold to many customers, it may indicate a specific kind of motor built for one customer only, or it may indicate only the date the motor was manufactured.
5. *RPM* is the speed of the motor at its rated power, when running on its rated potential difference and frequency. The speed is measured in revolutions per minute (rpm). Small motors generally run at one of four speeds, depending on how many poles they have—3450 rpm (two pole), 1735 rpm (four pole), 1140 rpm (six pole), and 825 rpm (eight pole).
6. *Frame size* is defined by NEMA. The most common frame sizes for small motors are 42,

48, and 56. Medium motor frame sizes are 143T through 149T.

- 7. *Time hours* indicates how long the motor may be operated at one time without overheating. For most motors, the rating is continuous. That is, the motor can run continuously without overheating.
- 8. *Insulation class* indicates the class of insulation used in the motor. The classes are defined by NEMA according to the maximum temperatures the insulation can withstand.

Class	Maximum temperature	
A.....	105°C	221°F
B.....	130	266
F.....	155	311
H.....	180	356

- 9. *KVA code* is a letter indicating the locked-rotor power input (measured in kilowatts) per horsepower of rated output. This letter is based on a NEMA code. For example, the letter M indicates a locked-rotor power of 10.0 to 11.2 kW per horsepower.
- 10. *Model* is a NEMA letter code. The first letter indicates the type of motor (T is the NEMA frame designation). The second letter indicates the kind of enclosure (FC indicates a totally enclosed fan-cooled motor).

- 11. *User or catalog number* is used by the manufacturer or user to identify the motor.
- 12. *Motor style number* is the manufacturer's specification code. It identifies a set of drawings and electrical specifications necessary to manufacture the motor.
- 13. *Bearings* are identified by number. Any bearing supply house can identify and supply a replacement bearing from this number.
- 14. *Amps* indicates the normal current drawn at the motor's rated load, potential difference, and frequency.
- 15. *Volts* indicates the potential difference of the power supply for the motor.
- 16. *Ambient temperature* is the temperature in the immediate location of the motor. The standard is 40°C (104°F).
- 17. *Service factor* indicates how much the motor may be overloaded when operating at its rated potential difference and frequency.
- 18. *Horsepower* is the amount of power the motor can produce at its rated speed.

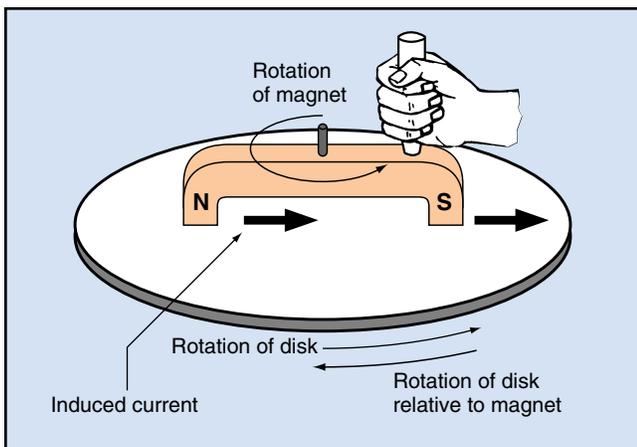
**Induction Motors**

1.19 The basic idea of an induction motor is shown in Fig. 1-6. A disk of aluminum or other non-magnetic metal is mounted on an axis of rotation. A magnet is also mounted so that it can rotate on the same axis without touching the disk.

1.20 When the magnet rotates near the disk, it induces an electric current in the disk, just as it would induce a current in a wire. You can think of the disk as a wire having an infinite width—a wire that never passes out of the region near the magnet.

1.21 You can figure out the direction of the induced current by using the left-hand rule for generators. In applying the rule, you must pay close attention to the *relative* motion between the magnet and the disk.

**Fig. 1-6. Principle of the induction motor**



- The magnet and the disk both rotate in the same direction relative to stationary objects outside the motor.
- The magnet rotates faster than the disk. Therefore, the disk rotates *backward relative to the magnet*.

1.22 The current induced in the disk passes through the magnetic field of the magnet. Therefore, the magnetic field exerts a force on the disk. This force causes the disk to rotate, just as it causes the armature to rotate in a motor that receives electric current from an outside source.

1.23 The disk can never attain the speed of the magnet. If it did, there would be no relative motion between them. Without this relative motion no current would be induced in the disk, and no force would keep the disk rotating. The speed of the relative motion is called *slip speed*.

**The Programmed Exercises on the following page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.**

PREVIEW  
COPY

## 12 Programmed Exercises

<p>1-1. What is the name for the rotating part of a motor? For the stationary part?</p>	<p>1-1. ROTOR; STATOR Ref: 1.01</p>
<p>1-2. The end plate bearings support the _____ and keep it centered within the _____.</p>	<p>1-2. ROTOR; STATOR Ref: 1.05</p>
<p>1-3. Slip speed is the difference between a motor's _____ speed and its _____ speed.</p>	<p>1-3. SYNCHRONOUS; OPERATING Ref: 1.07</p>
<p>1-4. Can a standard motor made by one manufacturer be replaced by the same standard motor made by another manufacturer?</p>	<p>1-4. YES Ref: 1.08</p>
<p>1-5. AC motors are designed to operate at <math>\pm</math> _____% of their rated potential difference and <math>\pm</math> _____% of their rated frequency.</p>	<p>1-5. 10; 5 Ref: 1.11</p>
<p>1-6. What cools the windings in an open motor?</p>	<p>1-6. AIR Ref: 1.14</p>
<p>1-7. How long can most motors run without overheating?</p>	<p>1-7. CONTINUOUSLY Ref: 1.18</p>
<p>1-8. Which rotates faster in an induction motor, the magnet or the disk?</p>	<p>1-8. MAGNET Ref: 1.21</p>

### Single-Phase Stator Field

1.24 A symmetrically wound single-phase induction motor cannot start by itself. However, once it is started by something else it will continue running.

1.25 Starting the motor requires a second winding, called the *start winding*. The winding that keeps the motor running after it starts is called the *run winding*. The start winding has higher resistance than the run winding. Single-phase motors are classified according to the starting method used. These methods are called the *split-phase*, *repulsion start*, and *shaded-pole* methods.

1.26 When a single-phase potential difference is applied across the stator winding of a single-phase induction motor, it produces an alternating current in the winding. The current produces a magnetic field, as shown in Fig. 1-7.

- During one half-cycle of the incoming ac power, the magnetic field has one direction. In Fig. 1-7, this direction is upward through the rotor.
- During the next half-cycle of the incoming ac power, the stator current is in the opposite direction. Therefore, the magnetic field is in the opposite direction.

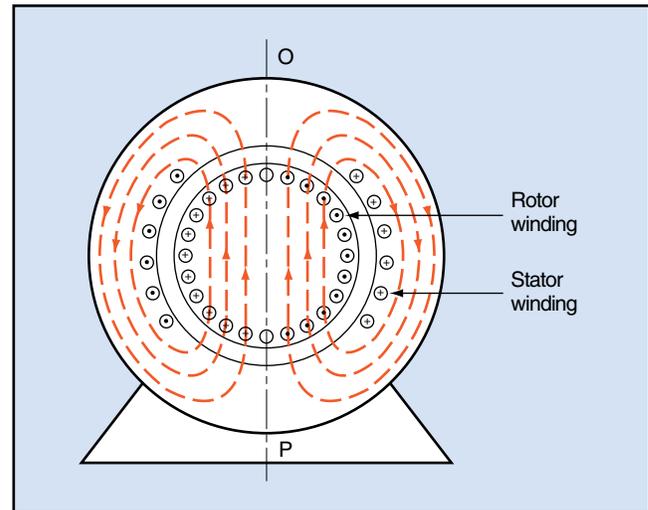
1.27 The stator field strength varies and its direction reverses at the same rate as the alternating current. However, its direction is always parallel to line OP in Fig. 1-7.

1.28 An induction motor is similar to a transformer. In a transformer, the alternating current in the primary winding produces an alternating magnetic field. This magnetic field induces an alternating potential difference across the secondary winding.

1.29 In an induction motor, the stator is like the primary winding of a transformer, and the rotor is like the secondary winding. A potential difference is induced in the rotor winding by the stator's magnetic field.

1.30 When the rotor is stationary, the effect on one side of the rotor is balanced by an equal effect on the other side. Therefore the rotor remains stationary. But

Fig. 1-7. Magnetic field of stator



once the rotor is rotating, cross-magnetization occurs which unbalances the forces on the rotor and enables it to develop torque.

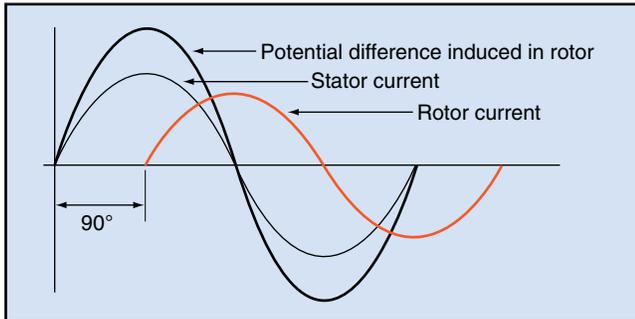
### Single-Phase Rotor Field

1.31 When the rotor of a single-phase induction motor starts to turn, its conductors cut through the magnetic field produced by the stator. Potential differences are therefore induced in the conductors of the rotor. These potential differences are in phase with the stator current. This phase relationship is shown by the graphs in Fig. 1-8, on the following page.

1.32 The induced potential difference causes current to flow in the rotor circuit. The impedance of the rotor circuit is *inductive*. The current in an inductive circuit always *lags* the potential difference by about  $90^\circ$ . Therefore, the rotor current lags the induced potential difference, as shown in Fig. 1-8.

1.33 The rotor current produces a maximum magnetic field nearly one-fourth of a cycle ( $90^\circ$ ) later than maximum induced potential difference. Therefore the magnetic field of the rotor is at right angles to the stator field. The field is therefore called a *cross field*.

1.34 The cross field acts at right angles to the stator field and lags the stator field by  $90^\circ$ . The rotor field and the stator field combine to form a resultant field that rotates at the synchronous speed.

**Fig. 1-8. Induction motor phase relationships**

1.35 The cross field is produced by generator action. It is present only when the rotor is turning. The strength of the cross field is proportional to the rotor speed.

1.36 At synchronous speed, the cross field is nearly equal in strength to the stator field. However, an induction motor runs at a speed less than synchronous speed. The slower rotor speed causes the cross field to be weaker than the stator field at operating speed.

1.37 The rotating field pulsates in a single-phase induction motor. Therefore, the torque developed by the motor also pulsates. Single-phase motors are mounted on rubber or on spring mounts to reduce the noise they produce.

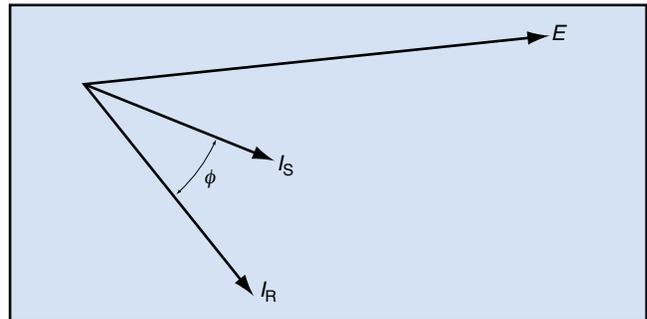
### Split-Phase Starting

1.38 If two identical windings are connected in parallel to a single-phase source, their combined magnetic field will alternate in direction, but it will not rotate. The two windings act like a single winding.

1.39 But if the two windings have different impedances, then their currents will differ in phase. The currents can be made to differ by as much as  $90^\circ$ , producing a rotating field. This is the idea behind *phase splitting*.

1.40 If two identical windings are connected in parallel to an ac source, the currents in the windings lag the potential difference by the same number of electrical degrees. As a result, the two currents are in phase with each other.

1.41 If a resistor is connected in series with one winding, the current in that winding will lag the potential difference by less. The current in the second winding is not affected by the resistance added to the

**Fig. 1-9. Phase relationships in split-phase motor**

first. Therefore, the two currents become different in phase. This is one method of phase splitting.

1.42 Instead of adding an external resistor, one winding is made of wire with a smaller diameter. The smaller wire has a higher resistance and lower inductive reactance than the other winding. The high-resistance winding is called the *start winding* or *auxiliary winding*. The low-resistance winding is called the *run winding* or *main winding*.

1.43 The vector diagram in Fig. 1-9 shows the phase relationship of the applied potential difference  $E$ , the current in the run winding  $I_R$ , and the current in the start winding  $I_S$  at the instant the motor is started.

1.44 The phase angle  $\phi$  between the two currents is small—about  $30^\circ$ . This phase difference is sufficient to provide a rotating magnetic field. The currents in the two windings are not equal in magnitude. Therefore the rotating field is not uniform. It produces only a small starting torque.

1.45 A single-phase induction motor develops torque once it has been started. The start winding is then no longer needed to keep the motor running. It is disconnected from the line when the motor reaches 70 to 80% of its synchronous speed. A centrifugally operated switch disconnects the start winding at a predetermined speed.

### Number of Poles

1.46 All motor stators have magnetic poles that you can identify and count. They always occur in north-south pairs, so the number of poles is always an even number. The dc motor stator, shown at the right in Fig. 1-10, has two permanent-magnet poles.

1.47 The stator windings in an ac induction motor are arranged to produce the effect of individual poles. The ac stator shown at the left in Fig. 1-10 is wound to produce four magnetic poles at any given instant in the ac cycle. It is a four-pole stator, even though it has many more pole pieces. As the current alternates in the individual windings, the position of each magnetic pole shifts from one pole piece to the next, creating a rotating magnetic field.

### Electrical Degrees

1.48 Electrical degrees measure time if you know the frequency of alternation. In a motor or generator, a conductor must move past both a north and a south magnetic pole to complete one cycle. The angle of rotation to accomplish this cycle depends on the number of poles in the motor.

- In a two-pole motor, the conductor must make one complete revolution, passing through an angle of 360°.
- In a four-pole motor, the conductor moves only half a revolution, an angle of 180°, to complete 360 electrical degrees.

1.49 The time required to complete one cycle is constant for a given frequency, regardless of the number of poles in the motor. You can measure the

time in fractions of a second, but it is usually easier to divide the time for one cycle into 360 electrical degrees.

1.50 You can use the following equation to calculate the number of electrical degrees in one complete rotation of the motor:

$$\text{Electrical degrees in one rotation} = 360^\circ \times \text{number of pairs of poles.}$$

### Synchronous Speed

1.51 The speed of the rotating magnetic field of an induction motor is known as the *synchronous speed*. You can calculate the synchronous speed if you know the frequency of the power source and the number of poles in the motor. The following equation describes the calculation:

$$\text{Sync rpm} = \frac{120 \times f}{p}$$

where  $f$  = frequency in Hz

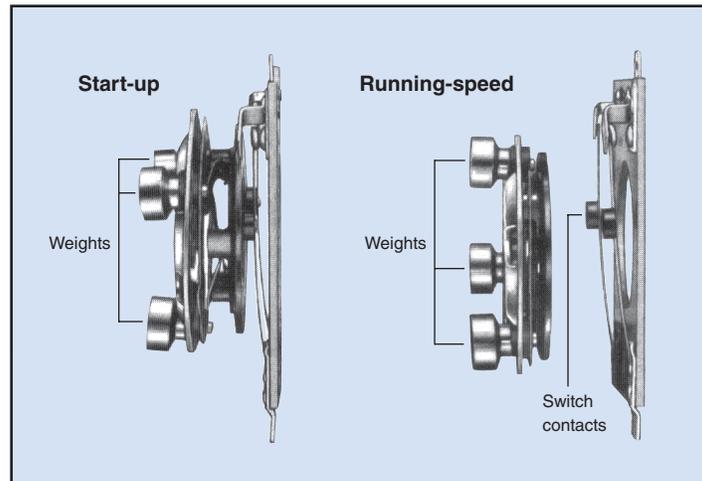
$p$  = number of poles.

1.52 For example, suppose that you need to calculate the synchronous speed of a six-pole motor running on an ac source that has a frequency of 60 Hz.

Fig. 1-10. Stators



Fig. 1-11. Centrifugal switch



$$\begin{aligned}\text{Sync rpm} &= \frac{120 \times f}{p} \\ &= \frac{120 \times 60}{6} \\ &= 1200 \text{ rpm}\end{aligned}$$

### Starting Switches

1.53 The start winding of a single-phase induction motor is disconnected from the motor circuit by a switch. It may be a centrifugal switch, a magnetic relay, or a thermal relay. The centrifugal switch is the most common device.

1.54 A centrifugal switch has two basic parts. One part remains stationary. The other part, called the *actuator*, rotates. Both parts are shown in Fig. 1-11.

1.55 The actuator is mounted on the rotor shaft. It is insulated from the shaft. The actuator consists of weights and contacts. As the motor comes up to its rated speed, the weights fly outward.

1.56 The motion of the weights opens the contacts and disconnects the start winding from the motor circuit. The switch contacts open quickly. They must not hesitate, or arcing will occur. Arcing causes burning and pitting of the contacts.

1.57 The motor continues to run on the main winding alone until you shut the motor off. When the rotor speed decreases, the weights on the actuator move

inward and close the contacts for the start winding. Thus, the start winding is ready to start the motor when the main switch is turned on again.

### Standard and Special Split-Phase Motors

1.58 Two kinds of split-phase motors are available:

- The *standard split-phase motor* has moderate starting torque. It is usually rated at a 40°C temperature rise.
- The *special-purpose split-phase motor* has a higher starting torque. It is rated at a 50°C temperature rise.

The construction of both kinds of motors is basically the same. The main difference is in their electrical performance.

1.59 The standard split-phase motor is used for applications requiring frequent but easy starting and long operating periods. The motor is used for driving fans, furnace blowers, oil burners, and unit heaters.

1.60 The special-purpose split-phase motor is used for driving equipment that is hard to start, but that is started infrequently. These motors are ideal for use in washing machines, dishwashers, and condensate pumps.

1.61 Where high starting torque is not required, the standard split-phase motor is generally preferred. It has a higher service factor and a lower operating cost.

**PREVIEW  
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## 18 Programmed Exercises

<p>1-9. Can a symmetrically wound single-phase induction motor start by itself?</p>	<p>1-9. NO Ref: 1.24</p>
<p>1-10. In an induction motor, a potential difference is induced in the _____ by the _____ of the stator.</p>	<p>1-10. ROTOR; MAGNETIC FIELD Ref: 1.29</p>
<p>1-11. Single-phase induction motors are noisy, because the rotating magnetic field _____.</p>	<p>1-11. PULSATES Ref: 1.37</p>
<p>1-12. If two identical windings are connected to a single-phase source, will their combined magnetic field rotate?</p>	<p>1-12. NO Ref: 1.38</p>
<p>1-13. In a motor or generator, how far must a conductor move in order to complete one cycle?</p>	<p>1-13. PAST TWO POLES Ref: 1.48</p>
<p>1-14. To calculate the synchronous speed of an induction motor, you need to know the _____ of the power supply and the _____ in the motor.</p>	<p>1-14. FREQUENCY; NUMBER OF POLES Ref: 1.51</p>
<p>1-15. What devices may be used for disconnecting the start winding in a single-phase induction motor?</p>	<p>1-15. CENTRIFUGAL SWITCH, MAGNETIC RELAY, THERMAL RELAY Ref: 1.53</p>
<p>1-16. A standard split-phase motor is used for applications that require _____ starting and _____ operating periods.</p>	<p>1-16. FREQUENT; LONG Ref: 1.59</p>

Answer the following questions by marking an "X" in the box next to the best answer.

- 1-1. Which of the following is not part of a rotor?
- a. Core
  - b. End plates
  - c. Shaft
  - d. Squirrel cage
- 1-2. Which kind of motor has one or more short-circuited auxiliary windings that are displaced from the main winding?
- a. Capacitor-start motor
  - b. General-purpose motor
  - c. Shaded-pole motor
  - d. Special-purpose motor
- 1-3. The maximum torque a motor can produce without an abrupt decrease in speed is called its \_\_\_\_\_ torque.
- a. breakdown
  - b. full-load
  - c. locked-rotor
  - d. pull-up
- 1-4. The service factor of a motor is defined as the \_\_\_\_\_
- a. allowable overload
  - b. difference between synchronous and operating speeds
  - c. kind of power the motor uses
  - d. length of time it can operate continuously
- 1-5. According to Fig. 1-3, all standard motors with frame number 184T have a maximum base width of \_\_\_\_\_ in.
- a. 7
  - b. 9
  - c.  $10\frac{1}{2}$
  - d.  $11\frac{3}{8}$
- 1-6. All the following are open motors, except the \_\_\_\_\_ motor.
- a. dripproof
  - b. splashproof
  - c. waterproof
  - d. weather-protected
- 1-7. What is the NEMA designation for a motor having normal starting torque, normal starting current, high breakdown torque, and low slip?
- a. A
  - b. B
  - c. C
  - d. D
- 1-8. If two identical windings are connected in parallel to an ac source, the currents in the windings will both \_\_\_\_\_ the potential difference.
- a. be in phase with
  - b. cancel
  - c. lag
  - d. lead
- 1-9. In order to complete one ac cycle, a conductor must move \_\_\_\_\_
- a. past a north magnetic pole
  - b. past a south magnetic pole
  - c. past two magnetic poles
  - d. through  $360^\circ$
- 1-10. What is the synchronous speed of a six-pole motor running on power at 50 Hz?
- a. 1000 rpm
  - b. 1200 rpm
  - c. 6000 rpm
  - d. 7200 rpm

## SUMMARY

Fans, pumps, clocks, and power tools are examples of devices that have single-phase fractional-horsepower motors. Every single-phase motor has a rotor and a stator. The rotor consists of the core, the squirrel cage, and the shaft.

The types of single-phase motors you may work with in the plant include general-purpose, definite-purpose, special-purpose, split-phase, capacitor-start, capacitor-run, and shaded-pole motors. Motor enclosures are classified as either open or totally enclosed.

Most motors are manufactured according to standards set by the National Electrical Manufacturers Association (NEMA). Standard motors are identified by a frame number—145T, for example. Any

motor with this particular number can be replaced by another motor with the same frame number.

The motor nameplate is an important source of information. It includes such data as the motor's style number, frame size, phase, horsepower, torque and current characteristics, service factor, standard ambient temperature, potential difference of the power supply for the motor, and the class of insulation used.

Although the pole pieces in an ac induction motor are not readily identifiable, the stator windings are arranged to produce the effect of individual poles. In a motor or generator, a conductor must move past both a north and a south magnetic pole to accomplish one complete cycle, which is 360°.

### Answers to Self-Check Quiz

- |      |    |                               |       |    |                                    |
|------|----|-------------------------------|-------|----|------------------------------------|
| 1-1. | b. | End plates. Ref: 1.02         | 1-6.  | c. | Waterproof. Ref: 1.15              |
| 1-2. | c. | Shaded-pole motor. Ref: 1.06  | 1-7.  | a. | A. Ref: 1.18                       |
| 1-3. | a. | Breakdown. Ref: 1.07          | 1-8.  | c. | Lag. Ref: 1.40                     |
| 1-4. | a. | Allowable overload. Ref: 1.07 | 1-9.  | c. | Past two magnetic poles. Ref: 1.48 |
| 1-5. | b. | 9. Ref: 1.10, Fig. 1-3        | 1-10. | a. | 1000 rpm. Ref: 1.51                |

### Contributions from the following sources are appreciated:

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|--------------|--|
| Figure 1-1.  | Westinghouse Electric Corp.            |
| Figure 1-2.  | Bodine Electric Co.                    |
| Figure 1-5.  | Westinghouse Electric Corp.            |
| Figure 1-10. | A.O. Smith Electrical Products Company |
| Figure 1-11. | Torq Corporation                       |