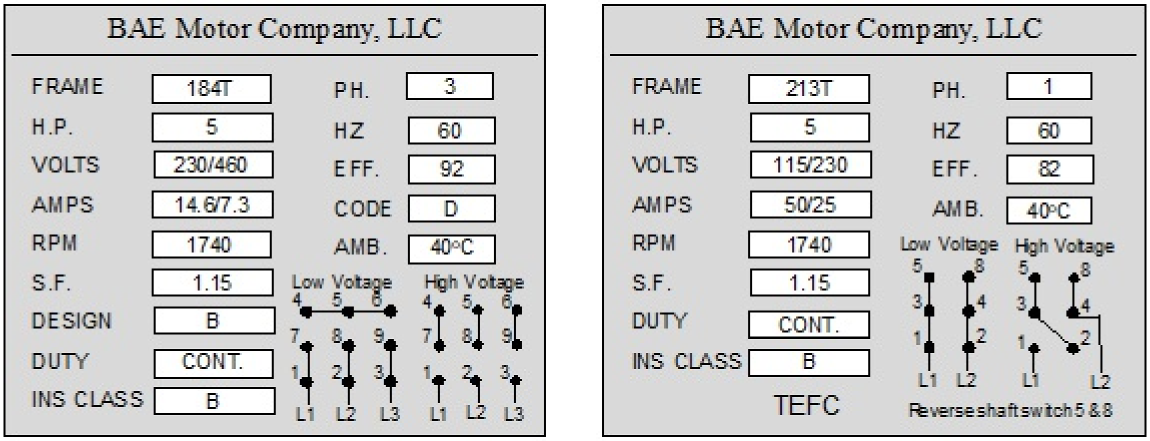
Electrical Tech Note — 103

Agricultural Engineering Department
Michigan State University

Understanding Electric Motor Nameplates[1]

Understanding the information provided on an electric motor nameplate and how to use the information is important. It may be necessary to replace an electric motor in the future, and nameplate information in needed to make sure the replacement motor is acceptable for the application. Nameplate information is provided in manufacturers catalogs, and selecting the right motor for an application requires an understanding of that information. The following discussion explains information found on a typical motor nameplate, and how that information can be used. Figure 1 shows a typical 3-phase and single-phase motor nameplate. Some motor nameplates provide additional information.



BAE Motor Company, LLC

FRAME	184T	PH.	3
H.P.	5	HZ	60
VOLTS	230/460	EFF.	92
AMPS	14.6/7.3	CODE	D
RPM	1740	AMB.	40°C
S.F.	1.15		
DESIGN	B		
DUTY	CONT.		
INS CLASS	B		

BAE Motor Company, LLC

FRAME	213T	PH.	1
H.P.	5	HZ	60
VOLTS	115/230	EFF.	82
AMPS	50/25	AMB.	40°C
RPM	1740		
S.F.	1.15		
DUTY	CONT.		
INS CLASS	B		

TEFC

Figure 1 *Nameplate of a typical dual-voltage, 3-phase, squirrel cage motor.*

FRAME: The frame number is necessary to know when replacing a motor, or ordering a motor for an application. The frame number will specify the mounting dimensions for the motor, shaft diameter, and shaft height. If the frame numbers of two different motors are identical, the mounting dimensions and shaft diameter will be the same even if the motors are made by different manufacturers. An industry trade organization, NEMA, National Electrical Manufacturers Association, sets and maintains electrical industry manufacturing specifications such as motor frame numbers. A manufacturer may add letters to the frame number to specify options available from that manufacturer. There are specific numbers and letters which have the same meaning regardless of which manufacturer builds the motor. There are motors built for specific purposes that have unique frame numbers. This discussion deals with general purpose motors.

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The frame number specifies dimensions of a general purpose motor frame. Figure 2 is a view of the underside of an electric motor. The letters are NEMA standard letters and the actual dimensions for general purpose motors are shown in Table 1. The diameter of the bolt hole of the motor mounting bracket is letter **H**. The diameter is 1/32 of an in. larger than the bolt used for mounting. For example in Table 1, the bolt hole for a motor frame 143T is 13/32 in. The proper bolt for mounting this motor is 12/32 in. or ⅜ in. The dimension **F** is not very useful by itself, therefore, usually the dimension is given as **2F**. The dimension **2F** is the distance from the center of one bolt hole to the center of the other bolt hole measured parallel to the shaft. The dimension **E** is the distance from the center of the bolt hole to the center line of the shaft. If the distance from the center of one bolt hole to the center of the other measured perpendicular to the shaft is desired, then that distance is two times **E** or **2E**.

The dimension **BA** is the distance from the center of the bolt hole nearest the shaft end of the motor to the point where the shaft is exposed. This distance is used in combination with the exposed shaft length **V** to determine if the motor gear or pulley will line up with the machine gear or pulley. The actual shaft diameter may be listed as shaft diameter, or it may be given as the dimension **U**. In Table 1, there is a column labeled shaft diameter.

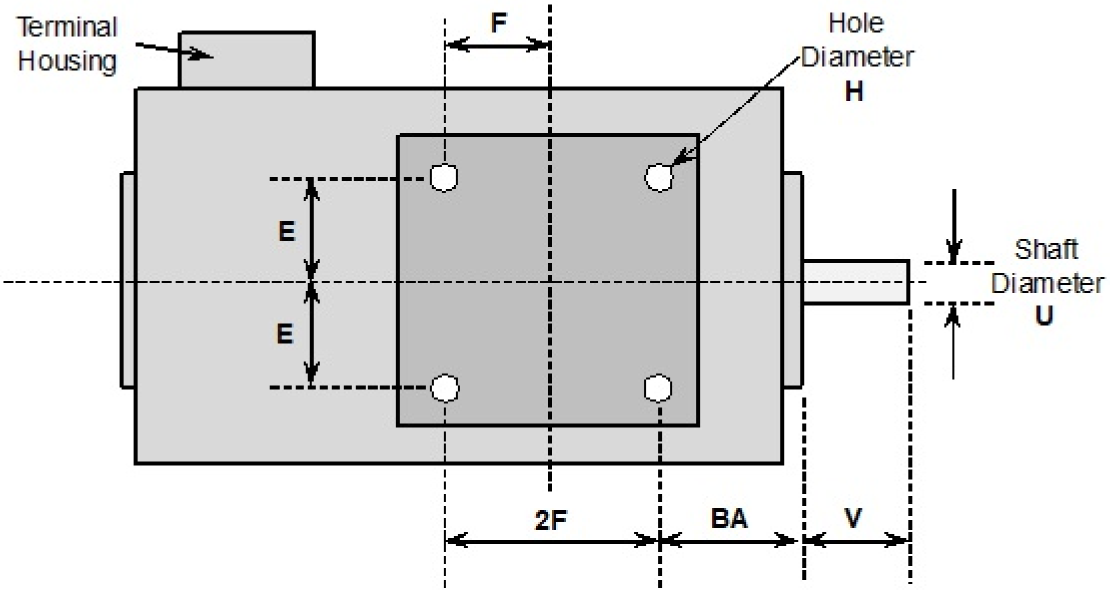

Figure 2 *This is a bottom view of an electric motor showing the mounting bracket and standard letters used to specify dimensions.*

If the frame number is followed by the letter **C**, the motor is face mounted. That means that the bolt holes are on the shaft end of the motor. Motors which are mounted as shown in Figure 2 usually have only a frame number or a frame number followed by the letter **T** or the letter **U**. These are often referred to as T-frame motors and U-frame motors. There are some differences in dimensions even though the numbers are the same as shown in Table 1. A U-frame is heavier and more massive than a T-frame of the same number.

Figure 3 shows a side view of an electric motor. Some of the dimensions shown in Figure 2 are also shown in Figure 3. Dimension **D** is the distance from the bottom of the mounting bracket to the center of the shaft. If an electric motor is to be directly coupled to a machine shaft, this dimension is very important.

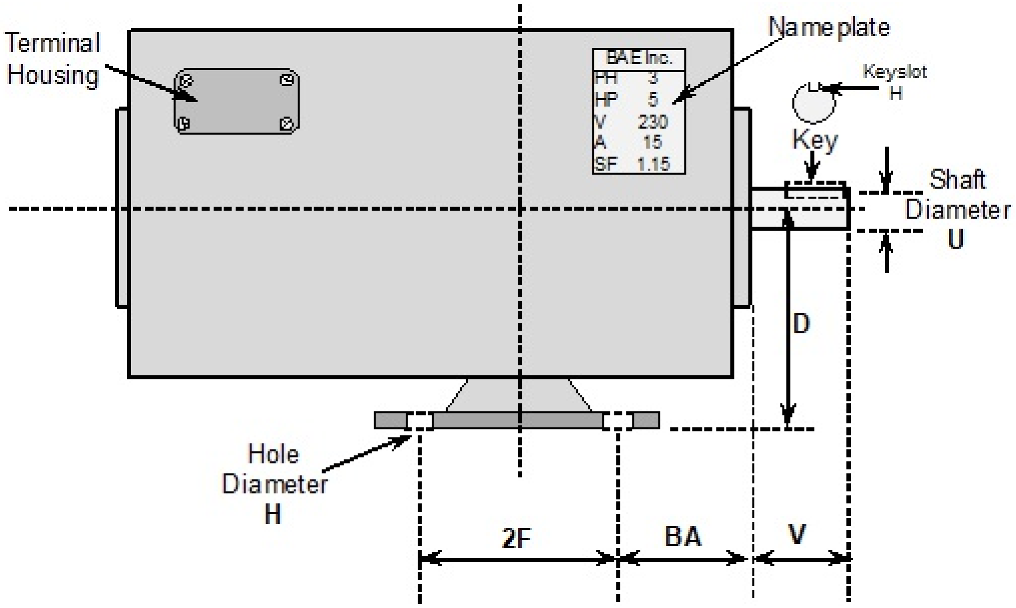

Figure 3 *Side view of an electric motor showing the standard mounting dimension letters.*

Table 1 Motor frame numbers and mounting dimensions for electric motors.

Frame No.	Shaft Dia.	Key	BA	D	E	2F	H Slot	V
All dimensions in inches								
42	⅜	3/64 × 3/64	2-1/16	2⅝	1¾	1-11/16	9/32 slot	1⅛
48	½	3/64 × 3/64	2½	3	2⅛	2¾	11/32 slot	1½
56	⅝	3/16 × 3/16	2¾	3½	2-7/16	3	11/32 slot	1⅞
143T	⅞	3/16 × 3/16	2¼	3½	2¾	4	13/32	2¼
145T	⅞	3/16 × 3/16	2¼	3½	2¾	5	13/32	2¼
182	⅞	3/16 × 3/16	2¾	4½	3¾	4½	13/32	2
182T	1⅛	1/4 × 1/4	2¾	4½	3¾	4½	13/32	2½
184	⅞	3/16 × 3/16	2¾	4½	3¾	5½	13/32	2
184T	1⅛	1/4 × 1/4	2¾	4½	3¾	5½	13/32	2½
213	1⅛	1/4 × 1/4	3½	5¼	4¼	5½	13/32	2¾
213T	1⅜	5/16 × 5/16	3½	5¼	4¼	5½	13/32	3⅛
215	1⅛	1/4 × 1/4	3½	5¼	4¼	7	13/32	2¾
215T	1⅜	5/16 × 5/16	3½	5¼	4¼	7	13/32	3⅛
254U	1⅜	5/16 × 5/16	3½	6¼	5	8¼	17/32	3½
254T	1⅝	3/8 × 3/8	4¼	6¼	5	8¼	17/32	3¾
256U	1⅜	5/16 × 5/16	4¼	6¼	5	10	17/32	3½
256T	1⅝	3/8 × 3/8	4¼	6¼	5	10	17/32	3¾
284U	1⅝	3/8 × 3/8	4¾	7	5½	9½	17/32	4⅝
284T	1⅞	1/2 × 1/2	4¾	7	5½	9½	17/32	4⅜
286U	1⅝	3/8 × 3/8	4¾	7	5½	11	17/32	4⅝
286T	1⅞	1/2 × 1/2	4¾	7	5½	11	17/32	4⅜
324U	1⅞	1/2 × 1/2	5¼	8	6¼	10½	21/32	5⅜
324T	2⅛	1/2 × 1/2	5¼	8	6¼	10½	21/32	5

A key is used to prevent a gear or pulley from turning on the motor shaft. The size of the key slot is determined by the frame number. This is illustrated in Figures 3 and 4. The key dimension may be given as shown in Table 1. Some manufacturers actually specify the size of the keyway or slot in the motor shaft. The first dimension will be the width of the keyway which is the dimension of the key needed. For example, the keyway dimension may be shown as 3/16 × 3/32. This means that the key way is 3/16 in. wide which requires a key that is 3/16 in. square. The second number 3/32 is simply the depth of the keyway in the motor shaft. The keyway maximum length may also be given. Usually length is not important because a key is cut to the desired length. The most important number is the width of the keyway (the first number) or simply the key dimension.

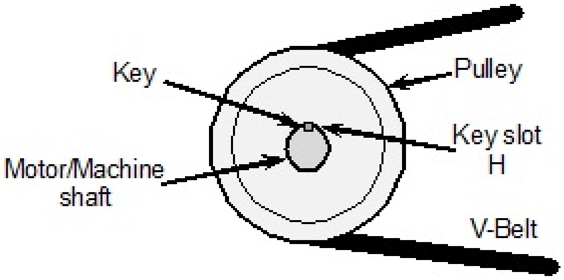

Figure 4 *A square cross-section key cut to length is usually used to prevent a gear or pulley from turning on the motor shaft.*

HORSEPOWER or KW: Internationally motor power ratings are given in kW, but in the U.S. most motors are rated in horsepower. To convert a kW rating to horsepower divide kW by 0.746. To convert horsepower to kW multiply horsepower by 0.746. It is important to match the horsepower when replacing an electric motor, but there is more to replacing a motor than simply matching the horsepower. A motor should be replaced with one of the same type. This may require the help of a person experienced in working with motors. For example, a single-phase capacitor-start induction-run motor should be replaced with the same type. A split-phase single-phase motor may have the same horsepower, frame size, and similar features, but it has a much lower starting torque than a capacitor-start motor. Information used by an expert to match motors is the design letter, service factor, code letter, and insulation class. These will be discussed later. Electric motors should be matched to the load as close as possible. Electric motors are designed for maximum efficiency when operating at or near rated horsepower. Efficiency usually drops rapidly when an electric motor operates well under the rated horsepower on the nameplate.

VOLTS: Electric motors must be matched to the voltage of the circuit. Some motors are only single voltage. If that is the case, then only one voltage will be shown on the nameplate. Many general use motors are dual voltage. They can be connected to operate at two or more voltages. Connecting a single-phase dual voltage motor for operation at different voltages is discussed later. The motor with the nameplate shown in Figure 1 is a dual voltage motor. The slash (/) is very important. It separates the two different voltages. A typical single-phase dual voltage motor would operate at 115 volts or at 230 volts. Commercial buildings often have single-phase power available at 115 volts and at 208 volts. If the nameplate only lists 240 it should not be operated at 208 volts. At 208 volts the motor will draw more current to produce the same power than if operated at 240 volts. Some nameplates show 208-230/460 which means the motor can be operated at 208 volts or at 240 volts.

Electric motors are rated for operation at such voltages as 115 and 230. These are considered nominal voltages for motors. Usually the circuit will have a voltage greater than 115 volts or greater than 230 volts. Actual circuit voltages may be as high as 125 and 250. Having a circuit voltage a little higher than the motor voltage is usually not a problem. There are some motor and circuit voltage combinations which should be avoided. A motor nameplate with 200, 208, or 200-208 volts should not be operated on a 240 volts circuit unless specifically stated by the manufacturer. Many motor nameplates have 230 volts or 115/230 volts. These motors should not be connected to a 208 volt circuit. When the voltage is lowered, the motor draws more current at full load than shown on the nameplate. This may cause a motor burnout.

AMPS: The amperes shown on the motor nameplate are the full-load amperes drawn by the motor at the voltages given. First consider a motor with a nameplate marked 115/230 volts and 6.2/3.1 amps. The nameplate is saying that when the motor is operating at 115 volts and at full-load, the motor will draw 6.2 amperes. If the motor is rewired to operate at 230 volts, it will have a full-load current of 3.1 amperes.

It takes both volts and amperes to get horsepower form a motor. If the volts are doubled from 115 to 230, it will take only half as much current at 230 volts as at 115 volts. This is why it is usually recommended that motors be operated at the highest voltage for which the motor is rated. If the motor draws less current by being operated at 230 volts rather than 115 volts, the supply wire will not need to be as large. Also, there will be less voltage drop on the line. Motors in particular can be damaged if they are operated with an excessive amount of voltage drop. If the previous motor draws 6.2 amperes to deliver the rated horsepower of the motor at 115 volts, it will have to draw even more current to deliver the same horsepower if the power reaching the motor is only 100 volts. If the motor overload protectors are properly sized, the motor will shut down due to a current overload before the current overheats the motor. If the motor is not properly protected from overload, it will be damaged due to excessive heat. Refer to the 3-phase motor with the nameplate shown in Figure 1. That motor draws 14.6 amperes at 230 volts. If the same motor was operated from a 480 volt 3-phase supply the motor would only draw 7.3 amperes.

The manufacturer marks on the nameplate the full-load current of the motor which is used when determining the size of overload sensing elements for the motor circuit. *The National Electrical Code*® contains a *Table 430.250* that given the values of motor full-load current for a 3-phase motor that is required to be used to size components in the circuit other than the running overcurrent protection. In the case of a single-phase motor, the full-load current is given in *Table 430.248*.

RPM: Typical motors for general use are induction motors. Induction motors have a variation in full-load operating speed depending upon how they are designed. Machines and equipment usually are not required to operate at an exact speed. It usually does not matter if one motor has an RPM which is slightly different from another motor. For an induction motor, the RPM will change as the load on the motor changes. If the load on a motor increases, the RPM will decrease. If the load gets too heavy, the motor will stall. As the load on an induction motor is decreased, the RPM will increase, but there is a maximum limit.

An induction motor is designed to operate at a specific RPM depending upon the frequency of the power supplying the motor. An induction motor connected to a 60 Hz supply may operate at 3450 RPM. Some motor manufacturers show 3600 RPM in their catalog, but the motor usually operates at less than 3600 RPM. This is a two-pole motor. A two-pole motor has one magnetic field but two poles, a North and a South. A four-pole motor has two magnetic fields which make four poles and a shaft rotation of approximately 1750 RPM. A six-pole motor operates at approximately 1140 RPM. Number of motor poles versus RPM are summarized in Table 2.

It is necessary when replacing an electric motor to make sure the RPM of the replacement motor is approximately the same as the RPM of the original motor. It usually does not matter if one motor operates at 1750 RPM and the other operates at 1740 RPM. If an exact shaft rotation is required for a specific application, a synchronous motor will be required.

Table 2 Induction motor approximate RPM available.

Magnetic Poles in the motor	Magnetic Field r.p.m.	Approximate Full-Load r.p.m.
2	3600	3450
4	1800	1725
6	1200	1140
8	900	825

HERTZ: The designation **Hz** on the motor nameplate refers to the frequency of the electrical power supplying the motor. In the United States, electrical power is produced and distributed at 60 cycles per second which is given the units of hertz. Hertz stands for cycles per second. Some power systems in the world operate at 50 hertz. When replacing a motor, make sure the motor is rated to operate at 60 hertz. A motor designed for 50 hertz when powered by a 60 hertz supply will develop less torque and will draw less than full-load current. The motor will have a shaft RPM that is 15 to 20% higher than stated on the nameplate.

PHASE: The designation **PH** on the nameplate indicates whether the motor is single-phase (1) or 3-phase (3). A single-phase circuit can be obtained from a 3-phase power system. If the voltages match, then a single-phase motor can be operated from the 3-phase system. A 3-phase motor can be operated directly from a single-phase electrical system by using a device called a phase converter to produce the third phase. Generally a 3-phase motor operated with a variable frequency drive can be connected to either a single-phase supply or a 3-phase supply but in general the motor must be 3-phase.

DESIGN: The designation **DESIGN** means the torque verses rpm characteristics of the motor. The design letter designates the relationship between the torque developed by the motor at any RPM from locked-rotor (zero RPM) to full-speed. Typical 3-phase motor design letters are B, C, and D. The most common 3-phase induction motor in use is the design B. A typical design B motor has a locked rotor torque which is approximately 150% of the full-load torque. As load is increased for an operating motor, the shaft and rotor will slow down and the torque will increase to match the requirement of the load. A typical design B motor is capable of developing about 200% of full-load torque before it will stall. This is called the break-down torque. For a design B motor, the locked-rotor torque will generally be less than the break-down torque. Torque and RPM values are controlled by the manufacturer and for some design B motors the locked-rotor torque may be higher than the break-down torque.

A design C motor is one where the locked-rotor torque is higher than the break-down torque. Locked -rotor or starting torque is more than 200% of full-load torque for a design C motor. When operating near full-load a design C motor has a greater variation in RPM with load variation than does a design B motor. A design C motor would then be considered to have greater rotor slip than a design B motor. The design D motor has the highest starting torque (locked-rotor torque) at approximately 300% of full-load torque. It does not have a break-down torque or a stalling torque. The motor simply slows down as more load is applied and the torque increases to match the load. This type of motor is particularly well suited to loads that may have periodic high torque demands. This is a high slip motor and RPM will vary considerably from light load to maximum load.

Locked-rotor currents are compared in *Table 430.251(A)* of the *National Electrical Code.* A motor controller is required to be capable of interrupting the circuit under locked-rotor conditions. Premium efficiency and very high efficiency motors tend to draw a higher locked-rotor current than standard efficiency motors. As a general guide assume a standard efficiency motor will draw five times full-load current when starting or under locked-rotor conditions. In the case of premium efficiency motors and very high efficiency motors starting and locked-rotor current can be as high as eight time full-load current.

The design letter on the motor nameplate is used to select the rating of the short-circuit and ground-fault protection for the circuit. This is the circuit breaker or fuse that is at the source of the circuit. The rules for sizing these fuses or circuit breaker are found in *Section 430.52* of the *National Electrical Code*.

Single-phase motors have design letters that are different than for 3-phase motors. Single-phase motors often have a starting winding that is disconnected when the motor approaches operating RPM. The shape of the torque - RPM curves is different than those in Figure 5. Important considerations when selecting a single-phase motor are locked-rotor torque, break-down torque, and full-load torque. Single-phase motors are generally described based upon the type of starting. For example, a common single-phase motor is a capacitor start-induction run motor. This type has moderate starting torque. On the other hand, a split-phase start, induction run motor has low starting torque. For high starting torque applications a dual value capacitor single-phase motor is required.

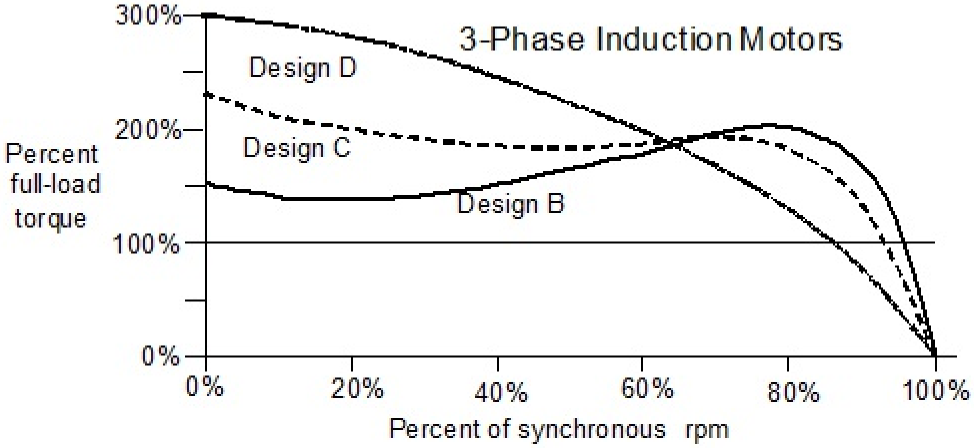

Figure 5 *Torque verses RPM curves are compared for the three common designs of 3-phase motors with equal horsepower ratings.*

INSULATION CLASS: The motor nameplates of Figure 1 show the words **INS CLASS**. This refers to the thin insulation on the wires of the stator windings. The insulation is simply a coating on the windings which is very thin. The insulation must be thin in order to get many wires into the small slots cut into the steel stator of the motor. The insulation class refers to the maximum temperature which the insulation can withstand before it begins to break down. If the insulation breaks down the motor will fail. Overloading the motor will cause the current to increase through the windings and the increased current causes heat which raises the winding temperature. The windings must always operate below the break-down temperature of the winding insulation.

Most general purpose motors have an insulation class of **A**, **B**, or **F**. Class A insulation has the lowest break-down temperature which is approximately 105°C. Class B insulation has a higher break-down temperature which is approximately 130°C. This is one case when **B** is better than **A**. Class A and B insulation are common for single-phase motors. Class F insulation is common for 3-phase motors. The break-down temperature for class F insulation is approximately 155°C. In situations where an electric motor is exposed to a high ambient temperature, a motor can be equipped with class **H** insulation which has an approximate breakdown temperature of 180°C.

SERVICE FACTOR: The service factor, S. F. on the nameplates of Figure 1, is an indication of the overload capacity of the motor. The service factor of the motor with the nameplate in Figure 1 is 1.15. This means that the motor can operate at a 15% overload without damaging the motor. Motors with high service factors are recommended for farm and many industrial applications where the load on the motor may increase. A service factor of at least 1.15 or larger is recommended for farm applications. If a motor has a service factor of 1.0 the motor has no overload capacity. If the motor is overloaded for a period of time the motor will probably overheat and it's operating life will be shortened.

The service factor and the nameplate full-load current are used to determine the rating of the motor overload sensing element. The rules for sizing the overload sensing elements for a motor are found in *Section 430.32* of the *National Electrical Code*. Manufacturers of motor controllers provide overload sensing elements that protect a motor from overloads. The nameplate full-load current is used to select the manufacturer part number for the overload sensing element needed for a specific motor. A detailed explanation of how to size the components of an electric motor branch circuit are described in the text *Interpreting the National Electrical Code*. (see references at the end)

CODE: The code letter can be used to estimate motor starting inrush current or locked rotor current if a motor stalls. These conditions are called locked rotor. Locked rotor current values can be found in *Table 430-251* of the *National Electrical Code*, but these values are only generalized estimates. Using the Code letter provides a better estimate of a particular motor's locked rotor current. Locked rotor current drawn by the motor must be considered by an electrician when installing a motor circuit. Code letters start at **A** and go to **V**. The further down the alphabet higher the value of kVA per horsepower which means the higher the motor starting current. The 3-phase motor of Figure 1 has a code letter of D which has a value of as low as 4.0 kVA/hp to as high as 4.5 kVA/hp. This means the locked-rotor current of the motor is in the range of 83 to 94 amperes. According to *Table 430.251(B)* the value for a 5 horsepower motor at 240 volts is 92. But assume this is a high efficiency motor and the Code letter is the letter E. This means the locked rotor current falls in the range of 94 to 104 amperes. Code letter is not required to be provided on a motor nameplate so if this information is needed it may be necessary to refer to specific manufacturers information for the particular model of motor.

The code letter may be a clue as to why the fusees blow or the circuit breaker trips when a replacement motor tries to start the load. If the replacement motor has a higher code letter than the original motor it will draw a higher starting current, thus possibly causing the fuses to blow or circuit breaker to trip.

EFFICIENCY: The full-load efficiency is being marked on the nameplate of many motors. Efficiency is the percentage of power drawn by an electric motor that is supplied to the shaft as mechanical power. Since 1997 manufacturers have been required to build motors meeting minimum efficiency standards. Many motors are built to a high efficiency standard and are listed on the nameplate as ***Premium Efficiency*** motors. Efficiency marked on the nameplate of motors is at full-load under all the conditions listed on the nameplate. If a motor is powering a load which requires much less horsepower than the motor is rated to deliver, the efficiency will be much lower. A motor which is too large for the load is usually operating with a very low efficiency. It is important for motors to be matched to the load. Since many motors are powering highly variable loads, variable frequency drives are being used in many cases to control the speed and power output of motors so they are always operating at their peak efficiency.

POWER FACTOR: The letters P.F when marked on the nameplate of some motors means the power factor which is an indication of the amount of current the motor must draw to power the load. For example comparing two electric motors of the same voltage and horsepower rating, the one with the higher power factor will draw less current provided their operating efficiency is the same. Assume a 10 horsepower, 3-phase, 240 volt motor with an efficiency of 80% one with a power factor of 0.95 and the other with a power factor of 0.80. The motor with the 0.95 power factor will have a full-load current of 21 amperes where the other will have a full-load current of 25 amperes. Since the motor with the high power factor draws less current, voltage drop on the circuit wires for long circuit runs will be less. For the example the voltage drop difference is 15%. A motor with a low power factor will usually draw more current for the same horsepower than a motor with a high power factor.

AMBIENT TEMPERATURE: The motor nameplate of Figure 1 has a temperature marked as 40°C AMB. This means the motor is designed to operate with a ambient or surrounding temperature of not more than 40 degrees on the Celsius scale (104°F). The information on the nameplate is for the motor tested at full load for an extended period of time in an area where the temperature is at 40ºC. If the motor will operate in an area where the temperature frequently exceeds 104°F, then the motor may overheat if operated at full load as marked on the nameplate. If a motor burns-out frequently, find out if it frequently operates in an area where the temperature is very high or the ventilation around the motor is inadequate. If this is the case, then one solution may be to oversize the motor for the load. Another solution may be to choose a motor with class “F” or “H” insulation which has a high break-down temperature.

DUTY: The motor nameplate in Figure 1 has a space marked DUTY. The marking ***continuou***s means the motor can be operated continuously. The motor is designed to operate for long periods of time. If the motor is not continuous duty the duty cycle will be marked on the nameplate. For example, an intermittent duty motor may be marked to operate only 12 minutes per hour. For some applications a continuous duty motor is operated at an overload condition for short intervals of time. An example is a passenger elevator. The motor is only working during lifting of the load so much of the time it’s load is small or even zero.

ENCLOSURES: The type of motor enclosure is extremely important when it comes to certain applications. Dust, dirt and combustible materials that may be present in an location must be considered when selecting a motor.

An open motor is one that has ventilation openings that will permit the passage of air over and around the windings of the motor. Fan blades on the rotor force air over the windings. Open motors may be drip-proof or splash proof. The *Open Drip-Proof* (ODP) enclosure, allows air passage through the motor but the openings are arraigned so falling liquids such as rain will not enter through the openings. Open motors are not recommended for use in building where excessive dust is present, such as an agricultural building.

Totally enclosed motors should be installed in areas where dust may settle on the motor. Air is not drawn into the motor for cooling. Totally enclosed motors may be cooled by a fan, *Totally Enclosed Fan-Cooled* (TEFC) or by natural convection, *Totally Enclosed Non-Ventilated*. (TENV). The totally enclosed fan-cooled motor is similar to the non-ventilated motor except an external fan mounted on the end opposite the shaft blows air over the exterior housing of the motor. While these motors are enclosed, they are not air tight. Gasses and vapors can enter through the seals of a totally enclosed motor housing, but dust and other foreign materials cannot enter the enclosure. In areas where combustible gases or dusts are present dust ignition proof or explosion proof motors are required.

CONNECTING AND REVERSING SINGLE-PHASE MOTORS

Single-phase electric motors are frequently made to operate at two voltages. This type is called a dual voltage motor. This is done so that a motor can be used for a wide variety of applications. Figure 6 is a diagram of the windings inside of a dual voltage single-phase capacitor-start motor. The dual voltage single-phase motor has two main running windings. In Figure 6, lead wires 1 and 2 supply one running winding, and lead wires 3 and 4 supply the other running winding. In addition to the running winding, there is a starting winding in most single-phase induction motors. The electric motor diagramed in Figure 6 has a centrifugal switch in the starting winding which opens when the rotor is turning at more than about three-quarters of full speed. Therefore, the starting winding is only used when the motor is first turned on. Assume the motor nameplate shows two voltages, 115 and 230 (115/230). The motor is rated to operate at either 115 volts, or at 230 volts. The circuit voltage may be as high as 125 or 250 volts. This is acceptable, as the 115 and 230 are only nominal voltages. The lower of the two voltages marked on the motor nameplate gives the maximum voltage at which each winding is permitted to operate. Each of the windings of the motor shown in Figure 6 should not receive more than 125 volts. If the winding receives a higher voltage, it will probably be damaged.

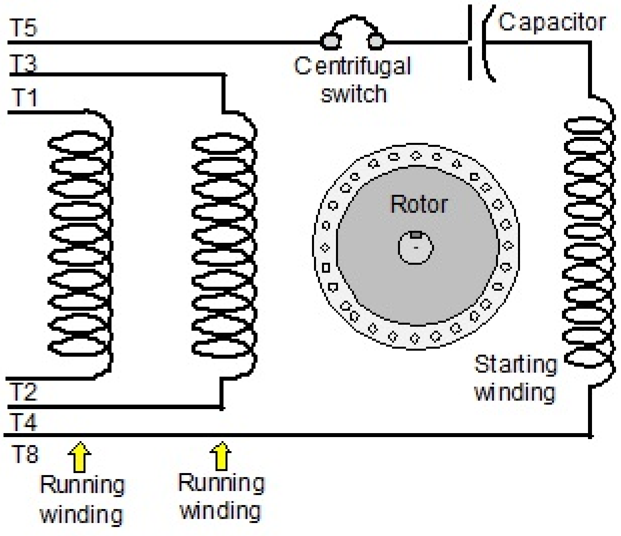

Figure 6 *A dual voltage single-phase electric motor usually has two running windings and one starting winding.*

Low Voltage Motor Connections

The single-phase dual voltage motor of Figure 6 will be connected to a 120 volt circuit. Each winding of the motor is designed to operate at 120 volts, therefore, all windings are simply connected in parallel so that each receives 120 volts. Figure 7 shows how the internal windings are connected to the 120 volt circuit. A diagram is either marked on the motor nameplate or on the motor which shows which wires are to be connected together. The windings on most motors will be identified with numbers. Some older motors may have the windings identified by color. Try to visualize that all of the windings are connected in parallel when a dual voltage single-phase motor is connected for operation at 120 volts. Most of the time the motor shaft will turn in the clockwise direction when the motor is connected for operation as shown on the nameplate, but not always. In this case assume that the shaft turns in the clockwise direction.

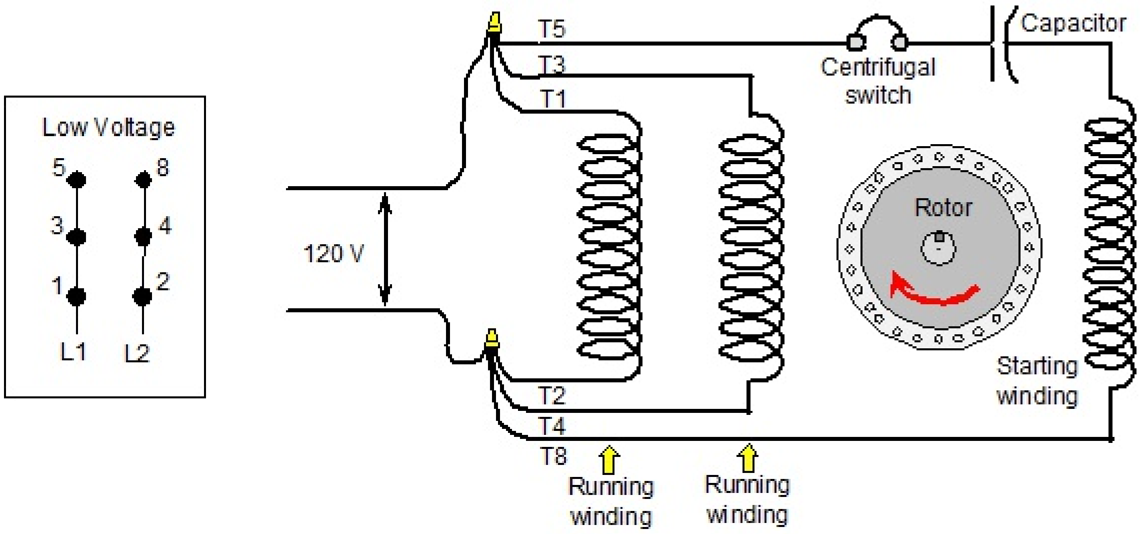

Figure 7 *The windings of a single-phase dual voltage electric motor are connected in parallel when the motor is operated from a 120 volt circuit.*

Reversing Shaft Rotation for the 120 Volt Connection

The starting winding of a single-phase electric motor determines the direction of rotation of the shaft. In order to make the rotor and shaft turn in the opposite direction, it is necessary on most single-phase motors to reverse the leads of the starting winding. Note in Figure 8 the leads of the running windings are connected the same as in Figure 7. However, the leads of the starting winding have been reversed. Note that the arrow of Figure 8 indicates that the rotor and shaft are turning in the counter clockwise direction.

Usually the connection diagram will show how to connect the motor, and then give instructions to reverse two specific wires to reverse the direction of rotation of the shaft. If the instruction is to reverse leads 5 and 8 to reverse the rotation of the shaft, then it is obvious from what we know about single-phase electric motors that leads 5 and 8 are for the starting winding.

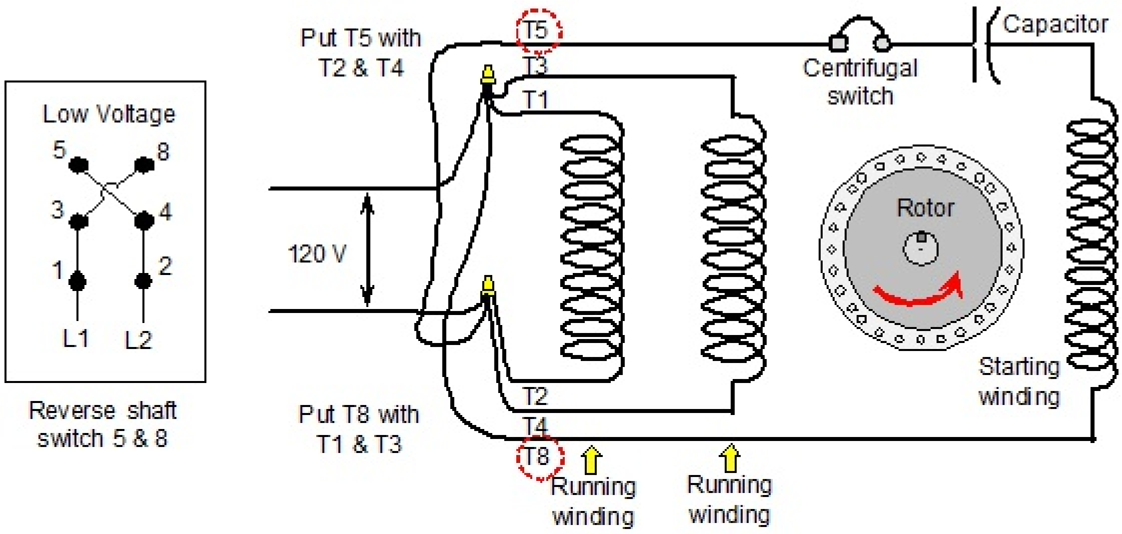

Figure 8 *Reversing the leads of the starting winding reverses the direction of shaft rotation of a single-phase dual voltage capacitor-start electric motor.*

High Voltage Motor Connections

The dual voltage single-phase motor has windings which are not permitted to be operated at more than about 120 volts. If the supply circuit is operated at 240 volts, then the motor cannot be connected as shown in Figure 7 or Figure 8 or the windings will receive 240 volts instead of 120 volts.

If the motor running windings are connected in series as shown in Figure 9, half of the supply voltage will be across one running winding and the other half will be across the other running winding. The voltage across each winding (120 V) will add up to the supply circuit voltage (240 V). The starting winding is connected in parallel with one of the running windings. In this case it is assumed that the rotor and shaft will turn in the clockwise direction. Like for the 120 volt circuit, the starting winding is disconnected by the centrifugal switch when the rotor approaches full speed.

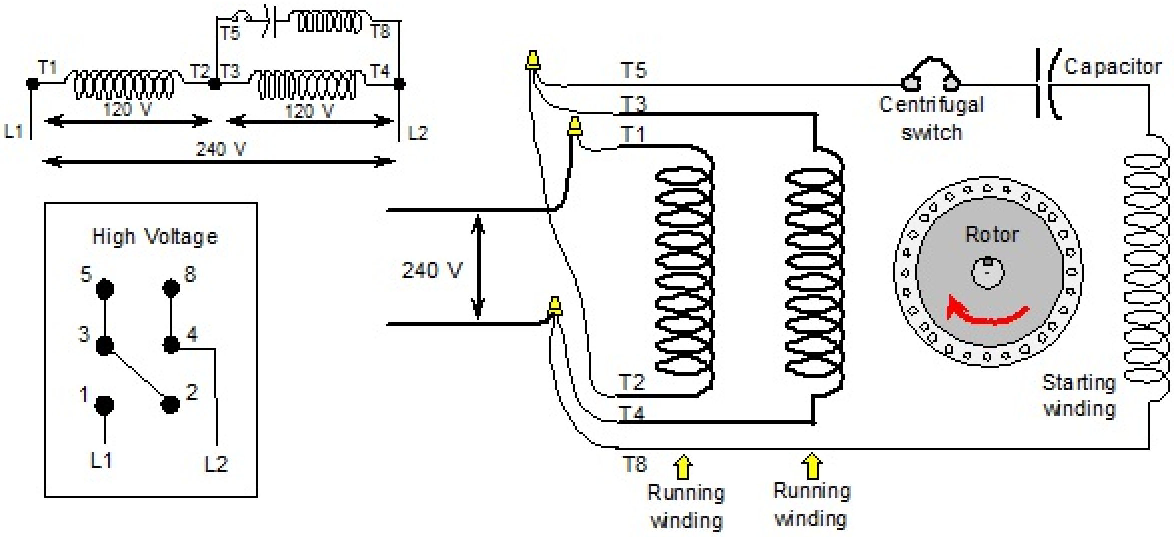

Figure 9 *The running windings of a dual voltage single-phase electric motor are connected in series when the motor is operated from a 240 volt circuit.*

Reversing Shaft Rotation for the 240 Volt Connection

Rotor and shaft rotation are reversed when the leads of the starting winding are reversed. Figure 10 shows how the leads of the starting winding are reversed in relation to the running windings. The starting winding is still connected in parallel with just one of the running windings. Study the diagrams of Figure 10 and note that each winding only receives 120 volts even though the supply circuit is 240 volts. During starting one of the running windings is connected in parallel with the starting winding. Since these two windings are connected in parallel their combined impedance will be slightly less than the impedance of the other running winding. The result is that the voltage across the single running winding will likely be higher than 120 volts and the voltage across the parallel running winding and starting winding will be most likely lower than 120 volts. Once the starting winding is disconnected from the circuit the impedance of the two running windings will be nearly the same so each winding will have half the 240 volt supply. Notice in Figure 10 the leads of the starting winding are reversed.

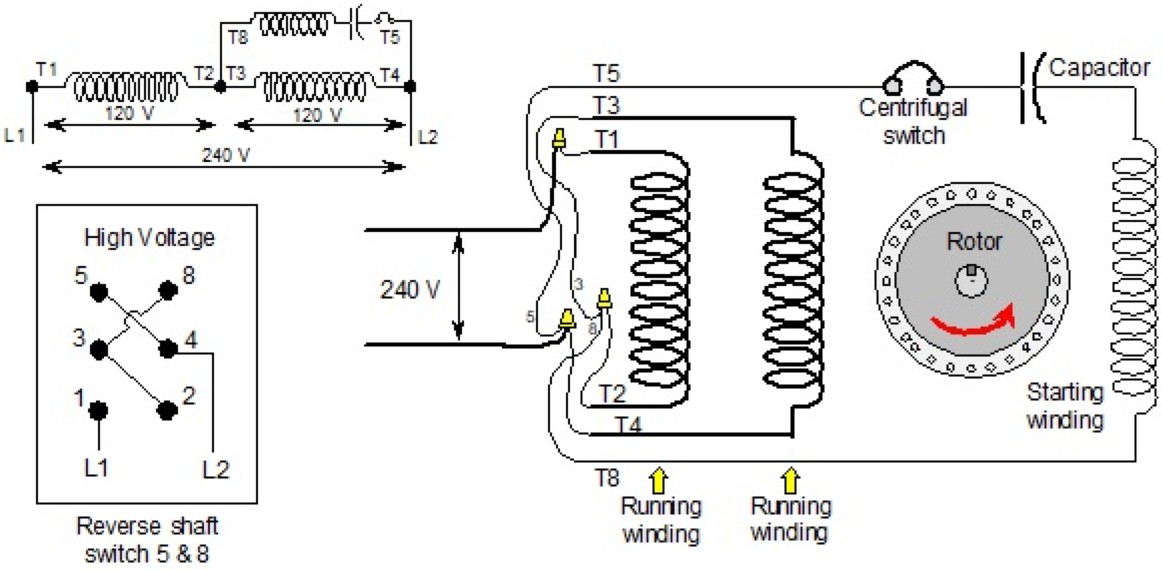

__Figure 10__ The leads of the starting winding are reversed to reverse the rotor and shaft rotation when the motor is connected for operation from a 240 volt circuit.

Reversing Shaft Rotation for 3-Phase Motors

A 3-phase induction motor requires three wires from a 3-phase electrical system. The wires are identified by the letters A, B, and C. Usually all three wires are ungrounded (hot), but on some electrical systems one of the wires is grounded to the earth. In all cases, a safety equipment grounding conductor is also run to the frame of the motor.

A 3-phase electric motor will have three windings in the outside or stator part of the motor. These windings can be connected end to end to form a delta shape, or one end of each winding can be connected together to form what is called a wye. The wye connection, as shown in Figure 11 is a common way of connecting the windings of a 3-phase motor. These motors can also be dual voltage. The nameplate in Figure 1 is of a dual voltage 3-phase motor with wye connected windings. Each branch of the wye will have two windings. For high voltage the windings in each branch are connected in series. For low voltage the windings in each branch are connected in parallel. As shown in Figure 11 dual voltage 3-have motors have 9 leads.

The direction of rotation of the shaft of a 3-phase motor is easy to reverse. All that needs to be done is to switch any two of the supply wires to the motor (example: switching lead wires A and B will reverse the motor). This can be done at any point in the motor circuit. The wires can be reversed at the disconnect switch, at the circuit breaker, or at the controller. It can also be done at the motor, but often the motor is not easily accessible and it is an easier task to perform at the controller or disconnect switch. In general it is not easy or practical to reverse single-phase motor shaft rotation without bringing the motor shaft to zero rpm.

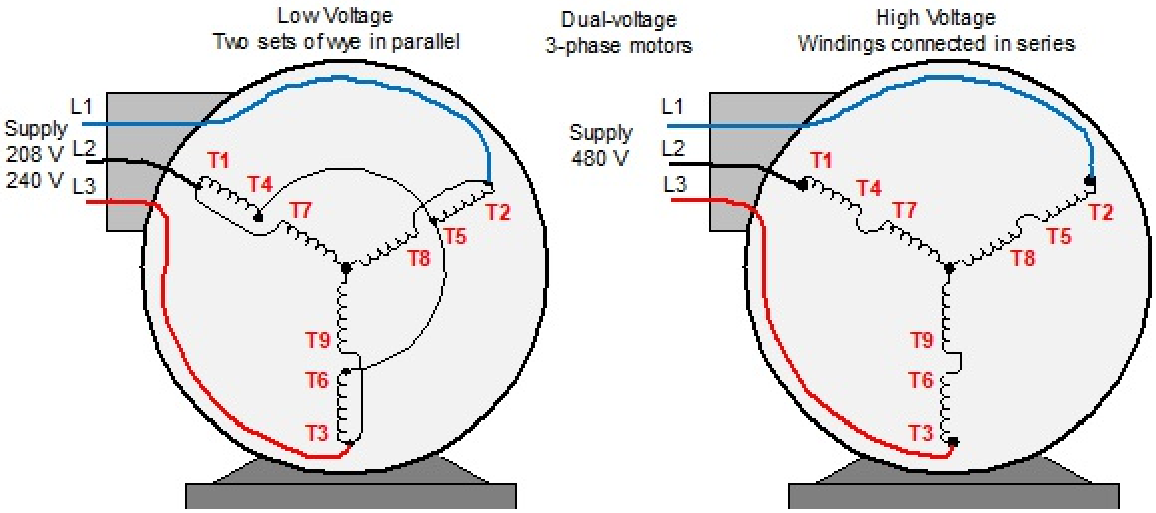

Figure 11 *A 3-phase dual-voltage induction motor frequently has the stator windings connected to form a wye with the windings of each phase connected in parallel for low voltage operation and connected in series for high voltage operation.*

Belt Drive Pulley Diameter:

The relationship between drive pulley and load pulley is that the rpm of the motor times the diameter of the motor pulley is equal to the rpm of the load pulley times the diameter of the load pulley. This is illustrated in Figure 12.

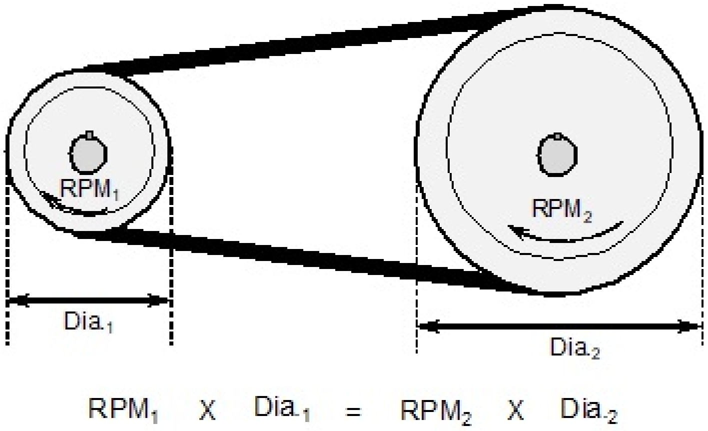

Figure 12. To determine the diameter of the load pulley, divide the product of the motor rpm and motor pulley diameter by the desired load rpm.

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