

Understanding Induction Motor Nameplate Information

By Ed Cowern, P.E., Baldor Electric Co.

Keeping the language common among manufacturers is critical to making motors interchangeable

The U.S. motor industry has worked on a standardized basis for more than three-quarters of a century. The standardization agency — National Electrical Manufacturers Association (NEMA) — was established in 1926 “... to promote the standardization of electrical apparatus and supplies.” As a result of this group's efforts, you can expect “standard” motors from different manufacturers to meet or exceed minimum performance parameters and, for the most part, be about the same size.

A critical part of making motors interchangeable is ensuring that nameplate information is common among manufacturers. The common language of the motor nameplate enables installation and maintenance personnel to quickly understand and recognize exactly what type of motor they're dealing with during a new installation or replacement procedure.

The NEC states that the motor nameplate must show the following information:

- Rated voltage or voltages
- Rated full-load amps for each voltage level
- Frequency
- Phase
- Rated full-load speed
- Insulation class and rated ambient temperature
- Rated horsepower
- Time rating
- Locked-rotor code letter
- Manufacturer's name and address

In addition to this required information, motor nameplates may also include data like frame size, NEMA design letter, service factor, full-load efficiency, and power factor.

Finally, some nameplates may even include data like bearing identification numbers, certification code, manufacturer serial number, and symbols and logos.

Basic nameplate data. In order to fully understand the details presented on motor nameplates we'll examine each of these items more closely and explain its importance.

Rated voltage — Motors are designed to yield optimal performance when operating at a specific voltage level, or a combination of voltage levels in the case of dual-voltage or tri-voltage motors. This value is known as the nameplate voltage. In recognition of the fact that voltage changes on your power distribution system occur due to changing load conditions within your facility and on the utility supply that feeds your facility, motors are designed with a 10% tolerance for voltage above and below the rated nameplate value. Thus, a motor with a rated nameplate voltage of 460V should be expected to operate successfully between 414V and 506V.

Rated full-load amperage — As the torque load on a motor increases, the amperage required to power the motor also increases. When the full-load torque and horsepower is reached, the corresponding amperage is known as the full-load amperage (FLA). This value is determined by laboratory tests; the value is usually rounded up slightly and recorded as the nameplate value. Rounding up allows for manufacturing variations that can occur and some normal voltage variations that might increase the full-load amps of the motor. The nameplate FLA is used to select the correct wire size, motor starter, and overload protection devices necessary to serve and protect the motor.

Frequency — To operate successfully, the motor frequency must match the power system (supply) frequency. In North America, this frequency is 60 Hz (cycles). In other parts of the world, the frequency may be 50 or 60 Hz.

Phase — This concept is fairly simple in the United States. You either have a single-phase or 3-phase motor.

Rated full-load speed — This is the motor's approximate speed under full-load conditions, when voltage and frequency are at the rated values. A somewhat lower value than the actual laboratory test result figures is usually stamped on the nameplate because this value can change slightly due to factors like manufacturing tolerances, motor temperature, and voltage variations. On standard induction motors, the full-load speed is typically 96% to 99% of the no-load speed.

Insulation class and rated ambient temperature — A critical element in motor life is the maximum temperature that occurs at the hottest spot in the motor. The temperature that occurs at that spot is a combination of motor design (temperature rise) and the ambient (surrounding) temperature. The standard way of indicating these components is by showing the allowable maximum ambient temperature, usually 40°C (104°F), and the class of insulation used in the design of the motor. Available classes are B, F, and H.

Rated horsepower — Horsepower is the measure of how much work a motor can be expected to do. This value is based on the motor's full-load torque and full-load speed ratings and is calculated as follows:

$$\text{Horsepower (hp)} = [\text{Motor Speed} \times \text{Torque (lb-ft)}] \div 5,250$$

The standardized NEMA table of motor horsepower ratings runs from 1 hp to 450 hp. If a load's actual horsepower requirement falls between two standard horsepower ratings, you should generally select the larger size motor for your application.

Time rating — Standard motors are rated for continuous duty (24/7) at their rated load and maximum ambient temperature. Specialized motors can be designed for “short-time” requirements where intermittent duty is all that's needed. These motors can carry a short-time rating from 5 minutes to 60 minutes. The NEMA definition for short-time motors is as follows: “All short-time ratings are based upon corresponding short-time load tests, which shall commence only when the windings and other parts of the motor are within 5°C of the ambient temperature at the time of the test.” By using short-time ratings, it's possible to reduce the size, weight, and cost of the motor required for certain applications. For example, you may choose to install an induction motor with a 15-minute rating to power a pre-operation oil pump used to pre-lube a gas turbine unit because it would be unusual for this type of motor to be operated for more than 15 minutes at a time.

Locked-rotor code letter — When AC motors are started with full voltage applied, they create an inrush current that's usually many times greater than the value of the full-load current. The value of this high current can be important on some installations because it can cause a voltage dip that might affect other equipment. There are two ways to find the value of this current:

- Look it up in the motor performance data sheets as provided by the manufacturer. It will be noted as the locked-rotor current.
- Use the locked-rotor code letter that defines an inrush current a motor requires when starting it.

Manufacturer's name and address — Most manufacturers include their name and address on the motor nameplate.

Optional nameplate data. In addition to the required items noted above, more information is typically included on a motor nameplate.

Frame size — Under the NEMA system, most motor dimensions are standardized and categorized by a frame size number and letter designation. In fractional horsepower motors the frame sizes are two digits and represent the shaft height of the motor from the bottom of the base in sixteenths of an inch. For example, a 56-frame motor would have a shaft height (“D” dimension) of 56/16 of an inch, or 3.5 inches.

On larger 3-digit frame size motors, 143T through 449T, a slightly different system is used where the first two digits represent the shaft height in quarters of an inch. For example, a 326T frame would have a “D” dimension of 32 one-quarter inches, or 8 inches. Although no direct inch measurement relates to it, the third digit of three-digit frame sizes, in this case a 6, is an indication of the motor body's length. The longer the motor body, the longer the distance between mounting bolt holes in the base (i.e. greater “F” dimension). For example, a 145T frame has a larger F dimension than does a 143T frame.

When working with metric motors (IEC type), the concept is the same as noted above with one exception — the shaft height above the base is now noted in millimeters rather than inches. The frame size is the shaft height in millimeters.

NEMA design letter — Certain types of machinery may require motors with specialized performance characteristics. For example, cranes and hoists that have to start with full loads imposed may require motors with operating characteristics much different from what is required for pumps and blowers. Motor performance characteristics can be altered by design changes in lamination, winding, rotor, or any combination of these three items.

Most standard motors for general-purpose applications meet or exceed the values specified for Design B motors in NEMA MG-1, Standard for Motors and Generators. Design A motors are sometimes used on applications that require high breakdown (pull-out) torque, such as injection molding machines. Design C motors are selected for applications that require high starting (locked-rotor) torque, such as inclined conveyors. Design D motors, also called “high slip” motors, are sometimes used to power hoists and cycling loads, such as oil well pump jacks and low-speed punch presses.

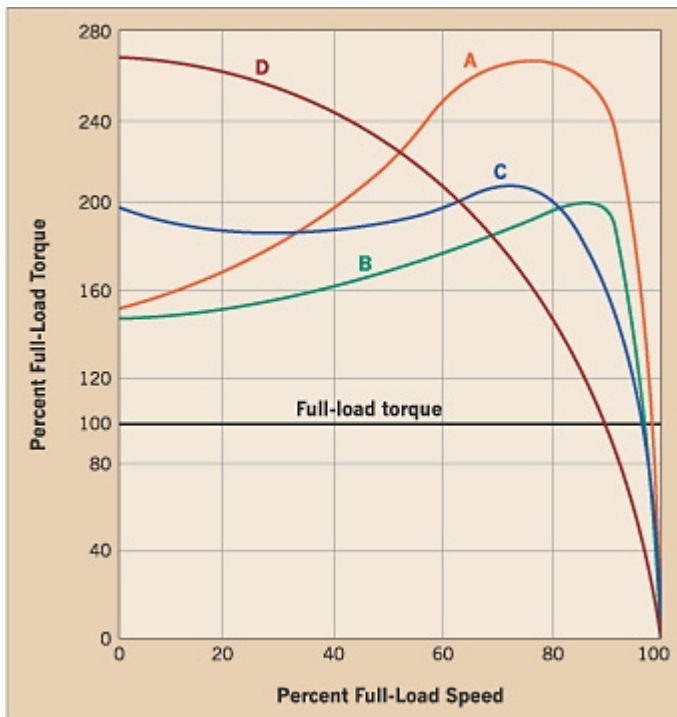


Fig. 1. These graphs show typical torque-speed curves for Design A, B, C, and D motors.

Fig. 1 shows the general shape of torque-speed curves for motors with NEMA Design A, B, C, and D characteristics.

Bear in mind that the curves shown in Fig. 1 and the figure in the sidebar on page 24 are general shapes. In real motors, each motor would have its own distinct values different from the percentages reflected in these figures.

Service factor — Service factor (SF) is an indication of how much overload a motor can withstand when operating normally within the correct voltage tolerances. For example, the standard SF for open drip-proof (ODP) motors is 1.15. This means that a 10-hp motor with a 1.15 SF could provide 11.5 hp when required for short-term use. Some fractional horsepower motors have higher service factors, such as 1.25, 1.35, and even 1.50. In general, it's not a good practice to size motors to operate continuously above rated load in the service factor area. Motors may not provide adequate starting and pull-out torques, and incorrect starter/overload sizing is possible.

Traditionally, totally enclosed fan cooled (TEFC) motors had an SF of 1.0, but most manufacturers now offer TEFC motors with service factors of 1.15, the same as on ODP motors. Most hazardous location motors are made with an SF of 1.0, but some specialized units are available for Class I applications with a service factor of 1.15.

Full-load efficiency — As energy costs have increased, conservation efforts have become more important to commercial and industrial operations. As a result, it's become important to have full-load efficiency information readily available on motor nameplates. The efficiency is given as a percentage and indicates how well the motor converts electrical power into mechanical power. The closer this value is to 100%, the lower the electricity consumption cost is going to be.

Generally, larger motors will be more efficient than smaller motors. Today's premium efficiency 3-phase motors have efficiencies ranging from 86.5% at 1 hp to 95.8% at 300 hp. The efficiency value that appears on the nameplate is the nominal full-load efficiency as determined using a very accurate dynamometer and a procedure described by IEEE Standard 112, Method B. The nominal value is what

the average would be if a substantial number of identical motors were tested and the average of the batch were determined. Some motors might have a higher value and others might be lower, but the average of all units tested is shown as the nominal nameplate value.

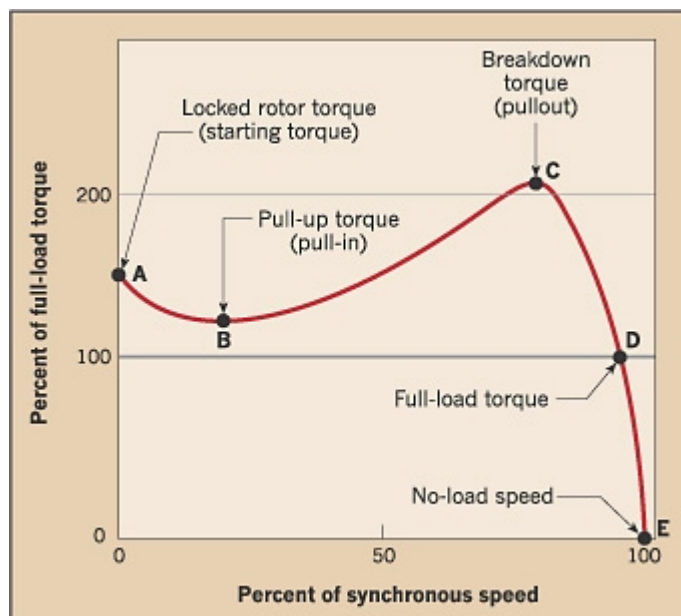
Guaranteed minimum is another efficiency that's sometimes noted on a nameplate. This value is determined from a mathematical relationship that assumes that the worst efficiency of any motor in the batch — used to determine the average (nominal) value — could have losses as much as 20% higher than the average. As a result, each nominal efficiency value would have a corresponding minimum efficiency value. You can view these values in Table 12-8 in NEMA MG-1.

Power factor — Power factor is the ratio of motor load watts divided by volt-amps at the full-load condition. Power factor for a motor changes with its load. Power factor is minimum at no load and increases as additional load is applied to the motor. Power factor usually reaches a peak at or near full load on the motor.

Final spin. Changing motors out becomes a lot easier when you can quickly recognize the key items that describe a motor's size, speed, voltage, physical dimensions, and performance characteristics. All of this information and more is usually available on the motor's nameplate. It's your responsibility to be able to correctly interpret the information on this nameplate, correctly apply it in the field, and verify conformance to NEMA, IEC, or other industry standards.

Editor's Note: This text was written by Ed Cowern when he was a district manager for Baldor Electric Co. in Wallingford, Conn. He has since retired.

Sidebar: The Delicate Relationship of Motor Speed and Torque



This is a typical torque-speed curve for a standard AC induction motor.

It's important to understand some details of motor performance as shown by a typical Torque-Speed curve in the **Figure** to the right. The plot shows what happens in terms of output torque and motor

speed when a motor is started with full voltage applied.

The motor is initially at zero speed and develops locked-rotor torque (Point A). As the motor accelerates, some motor designs produce a slight dip in torque. If they do, the lowest point on this curve is called the pull-in or pull-up torque (Point B). As the speed increases further, the torque generally increases to the highest point on the curve (Point C), which is called the pullout or breakdown torque. Finally, when the motor is loaded to its full-load torque, the motor speed stabilizes (Point D).

If the motor isn't driving anything, its speed goes up to its no-load speed or synchronous speed (Point E). For example, on a four-pole motor operating at 60 Hz, the no-load speed might be 1,799 RPM and synchronous speed would be 1,800 RPM.

Each of these points (A, B, C, and D) has absolute values (usually expressed in pound-feet). However, they're frequently given in terms of a percentage of the full-load torque. For example, a 20-hp, 60-Hz, four-pole motor could have a full-load torque of 59.5 pound-feet and a locked-rotor torque of 116 pound-feet. This is shown as: $(116 \div 59.5) \times 100 = 195\%$

Similarly, the breakdown torque of 199 pound-feet could be shown as: $(199 \div 59.5) \times 100 = 334\%$