



## What Do All Those Things on an AC Motor Nameplate Mean?

### Introduction:

Ever order a motor on power, speed, and enclosure? PO says maybe "5 hp, 1,800 rpm, TEFC." New-motor nameplate says "HP 5, RPM 1748, Enclosure TEFC, Des B, Frame 184T, Amps 7.0, PH 3, HZ 60, Duty Cont, Volts 460, Type P, Amb 40 C, SF 1.15, INS CL F, EFF 82.5, P.F. 80, DE bearing 35BC02JGG30A26, ODE bearing 3OBC02JGG30A26."

Should you reject the motor because it is not rated at 1,800 rpm? What does all that extra information on the nameplate mean? Do you care? The answers are "maybe," "we'll discuss it in a minute," and "you probably should."

To define the basic performance and mounting parameters of a motor, the National Electrical Manufacturers Association (NEMA) defines some basic design and dimensional parameters in NEMA Standard MG 1. These parameters are then coded onto the motor nameplate to give you a basic definition of what you have received. Manufacturers often include additional information to further define some key motor features.

Section MG 1-10.40, "Nameplate Marking for Medium Single-Phase and Polyphase Induction Motors," of the NEMA standard requires that "The following minimum amount of information shall be given on all nameplates of single-phase and polyphase induction motors. For abbreviations, see MG 1-1.80."

- \* Manufacturer's type and frame designation
- \* Horsepower output.
- \* Time rating. (See MG 1-10.36.)
- \* Maximum ambient temperature for which motor is designed. (See Note I of MG 1-12.43.)
- \* Insulation system designation.
- \* RPM at rated load.
- \* Frequency.
- \* Number of phases.
- \* Rated load current.
- \* Voltage.
- \* Code letter for locked rotor kVA. (See MG 1-10.37.)
- \* Design letter for medium motors. (See MG 1-1.16.)
- \* NEMA nominal efficiency when required by MG 1- 12.55
- \* Service factor if other than 1.0.
- \* For motors equipped with thermal protectors, the words "thermally protected" if the motor provides all the protection described in MG 1-12.52. (See MG 1-1.71 and MG 1-1.72.)

- \* For motors rated above 1 hp equipped with over-temperature devices or systems, the words OVER TEMP. PROT.-. A type number as described in MG 1- 12.53 inserted in the blank would identify the protection type.

The information on a motor nameplate can be arranged in categories. By definition, an induction motor converts electrical energy to useful mechanical energy. With rated electrical input the motor will deliver rated output shaft power. There are established standard indicators of how effective the motor does its job, as well as data on the nameplate concerning safety and reliability.

The following information provides a brief definition and some application considerations regarding motor data on the nameplate.

## **Electrical Input**

### **Voltage**

The voltage at which the motor is designed to operate is an important parameter. Standard voltage for motors built to NEMA MG 1 (1987) are defined in MG 1-10.30. One common misapplication is of motors nameplated (rated) at one voltage but applied on a different voltage network using the + 10% voltage tolerance for "successful" operation. Nameplate-defined parameters for the motor such as power factor, efficiency, torque, and current are at rated voltage and frequency. Application at other than nameplate voltage will likely produce different performance.

It is common for manufacturers to nameplate a wide variety of voltages on one motor nameplate. A common example is a motor wound for 230 and 460 V (230/460 V) but operable on 208 V. This 208-230/460 V motor will have degraded performance at 208 V. Another common misconception is to request a motor rated at network voltage; for example, at 480 V. The NEMA standard is 460 V. The voltage rating assumes that there is voltage drop from the network to the motor terminals. Thus, the 460-V motor is appropriate on a 480-V network.

### **Frequency**

Input frequency is usually 50 or 60 Hz. When more than one frequency is nameplated, other parameters that will differ at different input frequencies must be defined on the nameplate. The increasing use of adjustable frequency drives (AFDs) is also making it necessary to nameplate a frequency range, especially for hazardous-duty-listed applications.

### **Phase**

This represents the number of ac power lines supplying the motor. Single and three-phase are the norms.

### **Current**

Rated load current in amps is at nameplate horsepower (HP) with nameplate voltage and frequency. When using current measurement to determine motor load, it is important that correction be made for the operating power factor. Unbalanced phases, undervoltage conditions, or both, cause current to deviate from nameplate AMPS. Review both motor and drive for a matched system regarding current on AFD applications.

### **Code**

A letter code defines the locked rotor kVA on a per-hp basis. Codes are defined in MG 1-10.37.2 by a series of letters from A to V. Generally, the farther the code letter from A, the higher the inrush current per hp. A replacement motor with a "higher" code may require different upstream electrical equipment, such as motor starters.

### **Type**

NEMA MG 1 requires manufacturer's type, but there is no industry standard regarding what this is. Some manufacturers use "Type" to define the motor as single or polyphase, single or

multispeed, or even by type of construction. Type is of little use in defining a motor for replacement purposes unless you also note the specific motor manufacturer.

### **Power factor**

Also given on the nameplate as "P.F." or PF, " power factor is the ratio of the active power (W) to the apparent power (VA) expressed as a percentage. It is numerically equal to the cosine of the angle of lag of the input current with respect to its voltage, multiplied by 100. For an induction motor, power factor also varies with load. The nameplate provides the power factor for the motor at full load.

Active power is the power that does work; apparent power has a reactive component. This reactive component is undesirable - the utility company must supply it, but it does no work. A power factor close to unity (100%) is most desirable. Because there are tradeoffs when designing an induction motor for improved efficiency or other performance parameters, power factor sometimes suffers. It can be improved by adding capacitors.

### **Capacitor correction**

The nameplate may list the maximum power-factor correcting capacitor size. Nameplate notation would be something like "MAX CORR KVAR" followed by a number. The number would indicate capacitor value in kilovars. A value greater than that suggested may result in higher voltages than desired and could cause damage to the motor or other components.

## **Mechanical Output**

### **Horsepower**

Shaft horsepower is a measure of the motor's mechanical output rating, its ability to deliver the torque required for the load at rated speed. It is usually given as "HP" on the nameplate.

In general:  $HP = (\text{Torque}) \times (\text{speed}) / 5,250$  where: Torque is in lb-ft Speed is in rpm

### **Full-load speed**

The speed at which rated full-load torque is delivered at rated power output is full-load speed. It is generally given as "RPM" on the nameplate. This speed is sometimes called "slip" speed or actual rotor speed rather than synchronous speed. Synchronous speed is the speed at which the motor would run if it were fixed to the ac power line frequency; that is, if it turned at the same speed as the rotating magnetic field created by the combination of winding pattern and power line frequency. An induction motor's speed is always less than synchronous speed and it drops off as load increases. For example, for 1800 rpm synchronous speed, an induction motor might have a full-load speed of 1748 rpm.

There have been conflicting opinions and claims regarding the effect of replacing a "standard-efficiency" motor with an "energy-efficient" motor on a centrifugal-type load. Centrifugal pumps and fans impose what is often called a "cubed-exponential load" on the driver. For such a pump or fan, torque varies approximately as the square of speed. Because, by definition, power varies directly with torque and with speed, for a centrifugal-type load, power varies approximately as the cube of speed - a small speed change produces a much larger change in power requirement. For example, a 1% increase in speed would bring a 3% increase in load:  $(1.01)^3 = 1.03$

Some engineers claim that an energy-efficient motor manifests most of its efficiency improvement at a lower slip speed; that is, as an increase - typically about 1% - in output speed. Because the 1% speed gain equates to a 3% horsepower requirement, they reason, the replacement energy-efficient motor may have to be 1 HP-size larger than the standard motor.

The contention does not fully account for the fact that the power reduction from using an energy-efficient motor is greater than the extra power required by the load - hence, there is a net energy savings and the motor will run cooler, potentially extending insulation life.

## **Design**

NEMA MG 1 (1987), Section MG 1-1.16, defines "design," which defines the torque and current characteristics of the motor. Letters are assigned the defined categories. Most motors are Design B, although the standard also defines Designs A, C, and D. Common headings on nameplates include "Des," "NEMA Design," and "Design."

Some motors may not conform to any torque-current characteristics defined in MG 1. The motor manufacturer may assign them a letter that is not a defined industry standard. It is important to check the design letter when replacing a motor in an existing application.

Another note on Design B: Design B constrains the motor designer to limit inrush current to established standards. This insures that the user's motor-starting devices are suitable. A Design A motor has torque characteristics similar to those of the Design B motor, but there is no limit on starting inrush current. This may cause starter sizing problems. You should be aware of this and work with the motor manufacturer to insure successful operation of your motor systems.

## **Performance**

### **NEMA Nom. Efficiency**

Efficiency is defined as output power divided by input power expressed as a percentage:

$$(\text{Output} / \text{Input}) \times 100$$

NEMA nominal efficiency on a nameplate represents an average efficiency of a large population of like motors. The actual efficiency of the motor is guaranteed by the manufacturer to be within a tolerance band of this nominal efficiency. The band varies depending on the manufacturer. However, NEMA has established the maximum variation allowed. The maximum allowed by NEMA standards represents an additional 20% of motor losses from all sources, such as friction and windage losses, iron losses, and stray load losses. Therefore, you should pay attention to guaranteed minimum efficiencies when evaluating motor performance.

### **Service factor**

The service factor (S.F.) is required on a nameplate only if it is higher than 1.0. Industry standard service factor includes 1.15 for open-type motors and 1.0 for totally-enclosed-type motors. However, service factors of 1.25, 1.4, and higher exist.

It is not considered good design practice to use the rating afforded by S.F. continuously; operating characteristics such as efficiency, power factor, and temperature rise will be affected adversely.

### **Duty**

This block on the nameplate defines the length of time during which the motor can carry its nameplate rating safely. Most often, this is continuous ("Cont"). Some applications have only intermittent use and do not need motor full load continuously. Examples are crane, hoist, and valve actuator applications. The duty on such motors is usually expressed in minutes.

## **Safety**

### **Special markings**

Many motor nameplates have special markings to reflect third-party certification or recognition. Some common markings are:

- \* CSA Indicates that the manufacturing system and the motor components meet the standards of, and are continually reviewed by the Canadian Standards Association.
- \* UL Indicates that the manufacturing system and the motor components meet the standards of, and are continually reviewed by, Underwriters Laboratories. Alternatively, these

motors may display "Underwriters Laboratories File #XXX."

Other special markings may be displayed, such as those of agencies wishing to establish an efficiency certification. You should understand if any special third-party certifications are required and where you can find the proof.

A growing area of nameplate marking relates to capabilities of a motor when used on an adjustable speed drive. Many standard motors are applied to ASDs using general rules of thumb, without the motor manufacturer even knowing of the application. However, given the proper information about the ASD and application, a motor manufacturer can design a motor, or properly apply an existing design, and stamp the approved parameters on the nameplate. This stamping is always required on UL-listed explosion-proof motors.

## **Reliability**

### **Insulation class**

Often abbreviated "INSUL CLASS" on nameplates, it is an industry standard classification of the thermal tolerance of the motor winding. Insulation class is a letter designation such as "A," "B," or "F," depending on the winding's ability to survive a given operating temperature for a given life. Insulation classes of a letter deeper into the alphabet perform better. For example, class F insulation has a longer nominal life at a given operating temperature than class A, or for a given life it can survive higher temperatures.

Operating temperature is a result of ambient conditions plus the energy lost in the form of heat (causing the temperature rise) as the motor converts electrical to mechanical energy.

### **Maximum ambient temperature**

The nameplate lists the maximum ambient temperature at which the motor can operate and still be within the tolerance of the insulation class at the maximum temperature rise. It is often called "AMB" on the nameplate and is usually given in degrees C.

### **Altitude**

This indicates the maximum height above sea level at which the motor will remain within its design temperature rise, meeting all other nameplate data. If the motor operates below this altitude, it will run cooler. At higher altitudes, the motor would tend to run hotter because the thinner air cannot remove the heat so effectively, and the motor may have to be derated. Not every nameplate has an altitude rating.

### **Construction**

#### **Enclosure**

This designation, often shown as "ENCL" on a nameplate, classifies the motor as to its degree of protection from its environment, and its method of cooling. In MG 1, NEMA describes many variations. The most common are Open Drip-Proof (ODP) and Totally Enclosed Fan Cooled (TEFC).

- \* ODP An open drip-proof motor allows a free exchange of air from outside the motor to circulate around the winding while being unaffected by drops of liquid or particles that strike or enter the enclosure at any angle from 0 to 15 deg downward from the vertical.
- \* TEFC A totally enclosed fan cooled motor prevents free exchange of air between inside and outside the motor enclosure. It has a fan blowing air over the outside of the enclosure to aid in cooling. A TEFC motor is not considered air or water-tight; it allows outside air containing moisture and other contaminants to enter, but usually not enough to interfere with normal operation. If contamination is a problem in a given application, most manufacturers can provide additional protection such as mill & chemical duty features, special insulations and internal coating, or space heaters for motors subject to extended

shutdown periods and wide temperature swings that could make the motor "breathe" contaminants.

\* Explosion-proof, Dust ignition-proof

These are variations of totally enclosed motors that are for use in Division 1 hazardous atmospheres as defined in Article 500 of the National Electrical Code (NFPA-70). The enclosure designation on the nameplate is typically TEFC (or TENV; that is, Totally Enclosed Non-Ventilated). The only indication that the motor is suitable for the hazardous atmosphere is a UL label indicating the atmosphere in which the motor may be applied, and a temperature code designation. Explosion-proof motors must contain any explosions of the specified atmosphere inside the motor. Moreover, they won't let the surface temperature exceed the limits of the temperature code even at fault conditions such as overload or locked rotor. The dust ignition-proof motor is designed to have the features of an explosion-proof motor as well as to exclude ignitable amounts of dust.

\* Hazardous Location - Division 2

At normal conditions the motor would not be exposed to the flammable atmosphere. National Electrical Code Article 501-8b states that open or non-explosion-proof enclosures without arc-producing devices are allowed. It also says it is important to consider the temperature of internal or external surfaces that may be exposed to the flammable atmosphere.

Some manufacturers offer special TEFC designs and third-party certification such as CSA for the specific Division 2 area classification. The nameplate for some manufacturers will also indicate that the motor is designed accordingly. Manufacturers produce many variations of these enclosures to suit specific applications.

**Frame**

This nameplate block can offer a lot of information if the motor is nearly standard. The frame size sets important mounting dimensions such as foot hole mounting pattern, shaft diameter, and shaft height. NEMA standards do not set some dimensions that can turn out to be important if the motor must fit into a confined space.

These include maximums of overall height and length, and maximum conduit-box extensions. The data in the "Frame" block can be hard to interpret when special shafts or mounting configurations are used.

Some examples of frame designation:

- \* 445T This motor is a modern standard T-Frame motor. Critical mounting dimensions for all manufacturers are as defined in NEMA Standard MG 1.
- \* 445TC This T-Frame motor has a standard NEMA-defined C-face.
- \* 445TD This T-Frame motor has a standard NEMA-defined D-flange.
- \* 445U The dimensions of a U -Frame motor are defined by NEMA standards prior to 1965. The U- Frame is the predecessor to the present T -Frame motor, and typically it has the equivalent horsepower capability of a T Frame motor that is two frame sizes smaller. For example, the T -Frame equivalent of a 445U Frame motor for 100 hp at 1,800 rpm is a 405T motor for the same power and speed.

The first two digits of the frame size divided by 4 defines the height of the shaft centerline from the bottom of the feet. Thus, the shaft height of a 445T motor is  $44 / 4 = 11$  in. The third digit in the frame size determines the distance between the foot holes nearest the shaft and the opposite drive-end foot holes.

Many manufacturers drill multiple foot holes in motor bases to allow mounting in short or longer

frame positions. For example, a 445T motor base may have mounting holes for 444T and 445T motors.

There are some catch-all designations that may follow the standard frame number. For example, 445TZ indicates that all frame dimensions are standard except for the shaft. A Y following the standard frame designation, such as 445TY, indicates special mounting dimensions such as special flanges or frames. If special dimension designations appear, be sure to contact the motor manufacturer for dimensional information for a replacement. For further standard designations refer to NEMA MG 1- 11.01.

### **Bearings**

Though NEMA does not require it, many manufacturers supply nameplate data on bearings, because they are the only true maintenance components in an ac motor. Such information is usually given for both the drive-end bearing and the bearing opposite the drive end.

Nameplate designations vary from one manufacturer to another. For rolling-element bearings, the most common is the "AFBMA Number." That is the number that identifies the bearing by standards of the Anti-Friction Bearing Manufacturers Association.

Some manufacturers use a simplified designation simply indicating the bearing size and type -for example, 6309 for a size 309 ball bearing. This brief information can leave questions like: Is the bearing sealed, shielded, or open? Still, some manufacturers may use special bearings and elect to display their own bearing part numbers on the nameplate. Many special bearings are applied in motors for reasons such as high speed, high temperature, high thrust, or low noise. It pays to understand your motors' bearing requirements.

### **Other data**

A typical nameplate also includes the motor's brand name, and it includes a "Serial No." or other identifying number unique to that motor, that would let the manufacturer trace the motor back through manufacturing. The nameplate also includes the manufacturer's name, and its principal city and state and "Made in U.S.A." if U.S.-made.

The nameplate is a treasury of important information about a motor. If you specify, buy, maintain, or replace motors, you should know how to read them.

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Note: This material is not intended to provide operational instructions. Appropriate manufacturer instruction manuals and precautions should be studied prior to installation, operation, or maintenance of equipment.