Standard Conditions Labeling per Department of Energy Test Procedures for Electric Motors

On December 13th, 2013 the Department of Energy (DOE) published a final rule regarding test procedures for electric motors. This final rule defines the characteristics and test procedures of electric motors being regulated. One main point of interest in this notice is the clarification of testing procedures for motor types previously not covered by DOE regulations. Regulating testing procedures for certain definite and special purpose motors allows the DOE to expand the scope of their electric motor energy efficiency standards. All continuous duty, polyphase alternating current, single speed, squirrel-cage induction motors including, but not limited to, vertical solid and hollow shaft electric motors will be covered by these extended definitions. Since many high thrust derivatives of vertical motors contain bearings incapable of horizontal operation, they were not previously covered under DOE efficiency regulations. The inclusion of defined test procedures allows for new energy efficiency standards to be implemented, and the DOE has a preliminary implementation date of December 19th, 2015 for these new efficiency regulations.

Since previous versions of DOE regulations did not give specific instructions on how efficiency was to be reported on vertical motors, the electric motor industry calculated and reported efficiency in different ways. Currently, in the industry, several test procedures are commonly used. The two most popular are IEEE Std 112-2004 test method B and CSA C390-10 which have very similar test procedures; however, IEEE Std 112-2004 testing methods E and F are used by some manufacturers. In the December 13th ruling, the DOE standardized on IEEE Std 112-2004 test method B and CSA C390-10. These two options are the only acceptable testing procedures listed in the DOE's final rule, and both test methods require data acquisition using a dynamometer to load the electric motor. Most test facilities do not have the ability to dynamometer test a vertical electric motor in its natural configuration, so it has been industry practice to fit these types of motors with test brackets. This arrangement is necessary because these types of electric motors contain thrust bearings which cannot operate without a minimum axial load. The fitted test brackets allow the testing facility to replace the thrust bearing with a "standard bearing" that the DOE has defined as a 6000 series, open, single-row, deep groove, radial ball bearing; furthermore, this type of bearing allows the vertical electric motor to operate in a horizontal configuration. The new DOE regulations state that a standard bearing shall be used if the motor is incapable of operating without damage when oriented horizontally for testing purposes.

Testing vertical electric motors horizontally with a standard bearing and vertically using the actual application's thrust bearing will result in two distinct values for efficiency. The first value represents the efficiency as tested in a "standard" condition. This standard condition is considered to be a motor tested at 25°C ambient and up to 3,300 feet above sea level. The second value represents the full load operating efficiency that the motor will operate at when used in its intended application. The testing facility can determine the full load operating efficiency of a vertical electric motor by performing a vertical no load saturation test and a horizontal no load saturation test. The vertical no load test is run with the actual application's thrust bearing while the horizontal no load test is run with the DOE defined 6000 series standard bearing; the difference between these two tests is considered the actual thrust bearing loss. Equations (1) and (2) demonstrate efficiency calculations using the segregated losses from either horizontal or vertical testing; furthermore, the thrust bearing loss variance of approximately 800 watts between the two equations should be noted.

$$Eff_{NNE} = \frac{Power\ Out}{Power\ Out\ + W_R + W_S + W_L + W_C + W_{FW\ HORZ}} = \frac{186.5\ kW}{186.5\ kW + 8.173\ kW} = 95.8\% \quad \textbf{(1)}$$

$$Eff_{Full\ Load} = \frac{Power\ Out}{Power\ Out\ + W_R + W_S + W_L + W_C + W_{FW\ VERT}} = \frac{186.5\ kW}{186.5\ kW + 8.989\ kW} = 95.4\% \quad \textbf{(2)}$$

Indirect method of loss segregation:

W_R = Rotor Losses
W_S = Stator Losses
W_L = Stray Losses
W_C = Core Losses
$W_{FW\ HORZ}$ = Friction & Windage Losses from Horizontal Test
$W_{FW\ VERT}$ = Friction & Windage Losses from Vertical Test

Having two efficiency values for a single electric motor presents a reporting challenge. Nidec's solution is to provide two different efficiencies to the customer. The NNE calculated using equation (1) will be located on the motor's nameplate as shown in Figure 1.

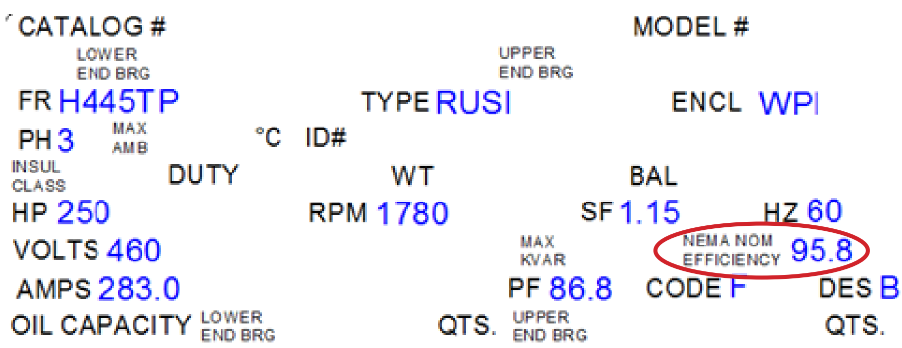

Figure 1: Basic Nameplate

Other parameters located on the electric motor's nameplate, such as power factor and full load current (amps), will be based upon the actual thrust bearing losses ($W_{FW\ VERT}$), standard altitude, and standard ambient conditions. For example, equation (3) uses the NNE value from equation (1) to calculate the electric motor's amps. It is evident that the resulting value does not match the nameplate amps. However, equation (4) uses the full load efficiency from equation (2) which results in a value that agrees with the nameplate. As these examples prove, the NNE value cannot be used to derive the other nameplate parameters.

$$\frac{746 \times HP}{\sqrt{3}\ x\ Volts \times Efficiency \times PF} = \frac{746 \times 250}{1.73 \times 460 \times .958 \times .868} = 281.8\ \text{amps} \quad \textbf{(3)}$$

$$\frac{746 \times HP}{\sqrt{3}\ x\ Volts \times Efficiency \times PF} = \frac{746 \times 250}{1.73 \times 460 \times .954 \times .868} = 283.0\ \text{amps} \quad \textbf{(4)}$$

Submittal data supplied to the customer (Figure 2) will include data calculated for both standard and actual conditions. This data is extremely important and must be thoroughly understood in order to install the electric motor into its intended application.

EFFICIENCY(%)	
S.F.	**95.0**
FULL	**95.4**
3/4	**95.8**
1/2	**95.5**
1/4	**93.0**
POWER FACTOR (%)	
S.F.	**87.2**
FULL	**86.8**
3/4	**84.5**
1/2	**77.9**
1/4	**58.2**
NO LOAD	**4.3**
LOCKED ROTOR	**29.0**
AMPS:	
S.F.	**325.0**
FULL	**283.0**
3/4	**217.0**
1/2	**157.0**
1/4	**108.0**
NO LOAD	**84.3**
LOCKED ROTOR	**1739.7**
NEMA CODE LETTER	**F**
NEMA DESIGN LETTER	**B**
FULL LOAD RPM	**1780**
NEMA NOMINAL EFFICIENCY (%)	**95.8**

Using Actual Application's Thrust Bearings

Shown on Nameplate
(Standard Condition)

Figure 2: Basic Submittal Data

Vertical electric motors are not the only type of electric motor that will have two efficiency values. This type of reporting will be applied to all electric motors that have non-standard conditions on the nameplate, i.e., above 25°C ambient and over 3300 feet above sea level. Since it is essential for all electric motors to have the same nameplate conventions, all Nidec electric motors will be nameplated with a NNE at standard conditions.

The DOE's final rule for electric motor test procedures is their first step toward further energy efficiency regulations. In fact, there are currently proposed DOE regulations requiring all motors defined in the December 19th, 2013 rule to meet NEMA® Premium values starting December 19th, 2015. The proposed rule includes electric motors with the following characteristics:

- Is a single-speed induction motor
- Is rated for continuous duty operation
- Contains a squirrel-cage or cage type rotor
- Operates on 60 hertz polyphase alternating current sinusoidal power
- Is rated 600 volts or less
- Has 2, 4, 6, or 8 pole configuration
- Has a three-digit NEMA frame designation or an enclosed NEMA 56 frame
- Is rated no more than 500 horsepower, but greater than or equal to 1 horsepower
- Meets all of the performance requirements of NEMA motor design types A, B, or C

All electric motors, including vertical solid and hollow shaft electric motors, matching the above listed attributes will be required to meet NEMA Premium® efficiency levels as shown in NEMA MG1 table 12-12 starting December 19th, 2015. The NEMA Premium® efficiency levels will be calculated using IEEE Std 112-2004 test method B or CSA C390-10.

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