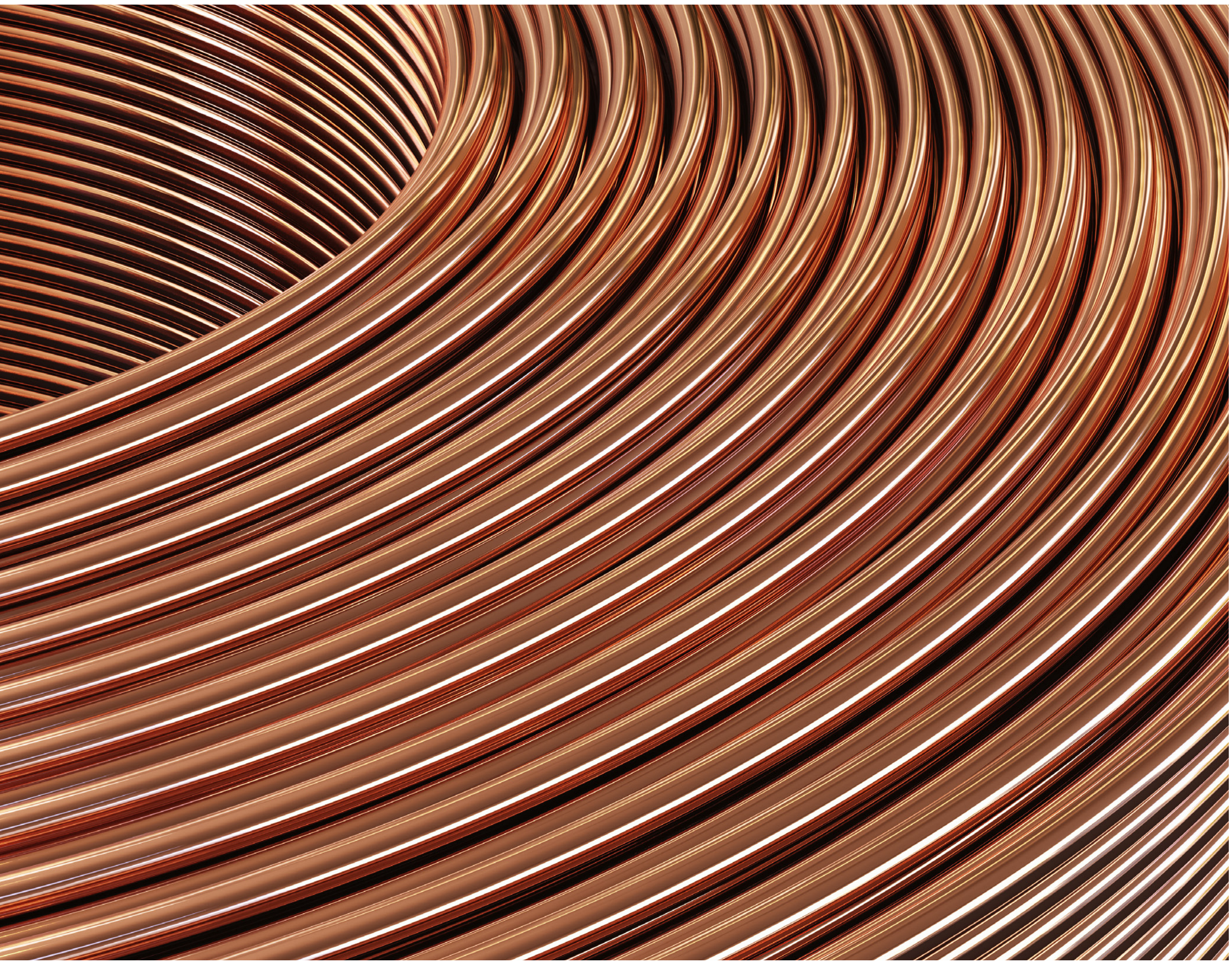
WHITE PAPER

Rule change:
Department of Energy (DOE) requirements



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Introduction

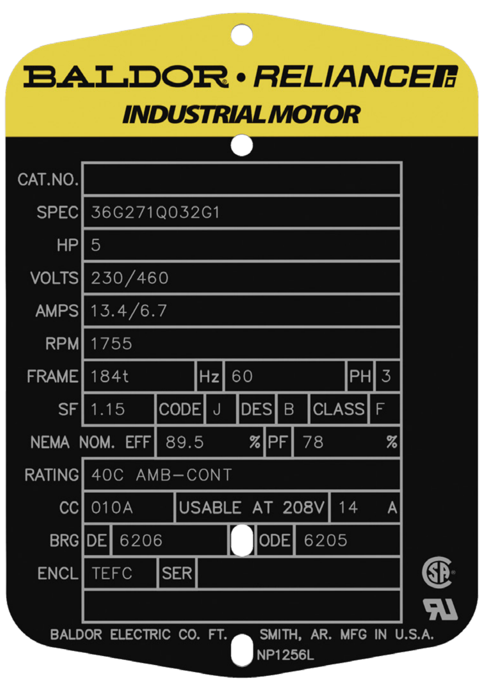
Electric motors are included in the list of covered equipment for which the U.S. Department of Energy (DOE) is authorized to establish and amend energy efficiency and conservation standards and test procedures. The DOE requirements consist of test procedures that manufacturers of included equipment must use to certify that their equipment complies with all applicable energy conservation standards. Test results must reflect energy efficiency, energy use and/or estimated annual operating cost of a given type of equipment during a representative average use cycle and requires that test procedures not be unduly burdensome to conduct. At least once every seven years, the DOE evaluates these test procedures to determine if they continue to provide accurate, reliable results that remain relevant for evolving energy efficiency standards[1].

This paper pertains to the final test rule from the DOE that explains the requirements for motor efficiency at nameplated voltage. The final rule changes will be mandatory for product testing on 60Hz electric motors effective April 17, 2023 (pending extension).

DOE rule change

Description of DOE rule change
In this final rule, the DOE clarifies that its proposal to allow any nameplate voltage to be selected for testing does not mean a manufacturer will have to certify a motor's efficiency at every rated voltage. Instead, the DOE is requiring that a manufacturer will only have to certify the efficiency of the motor at one voltage, but that the DOE could select any nameplate voltage for enforcement testing. The DOE considers “Usable At” voltages that appear on the nameplate as a nameplate voltage, and thus could be selected for testing.

In the DOE's view, any voltage at which the manufacturer declares an electric motor may be installed and operated by making a representation on its nameplate, the electric motor must meet the standards when measured by the DOE test procedure. However, the DOE notes that if a “Usable At” voltage is included in marketing materials but is not printed on the nameplate, then that voltage would not be selected for testing as it would be for reference only.

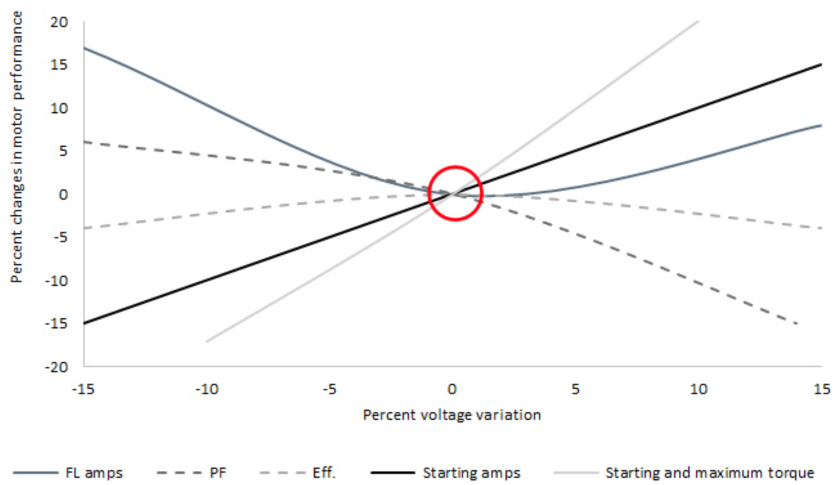


Understanding nameplate rated voltage and efficiency
The nameplate on an electric motor is where one finds the necessary information when specifying a motor for an application. NEMA MG 1 – 2021[2] in section 12.44.1 states that alternating-current motors shall operate successfully under running conditions at rated load with a variation in the voltage up to ±10 percent of rated voltage with rated frequency for induction motors. For example, a 230 VAC motor can operate down to 207 VAC or up to 253 VAC. This allows a motor to operate in locations that may have an inconsistent voltage supply or could be susceptible to a voltage drop or voltage spike. The motor will run smoothly through a voltage change but would not be as efficient during this time.

Nameplated performance information, such as RPM, efficiency, power factor (PF), locked rotor (kVA) code and design letter, are valid at nameplated voltage and frequency. As the voltage and frequency deviate from rated values, the efficiency, PF and RPM will change. The design letter and kVA code will deviate as well, but to a much lesser extent.

Impact on induction motor manufacturers

This change will require a motor to meet the DOE required efficiency at any voltage listed on the nameplate if produced after April 17, 2023 (pending extension). This will impact motor nameplates that state “Usable At” and give the amps if the motor is running at the given voltage. A motor can successfully operate continuously with a voltage deviation of ±10 percent of the rated voltage; however, the performance of the motor will not necessarily be in accordance with the standards established for operation at rated voltage and frequency.



Operating below or above rated voltage has consequences to motor life

There are a few other operating conditions that will not be optimal and must be considered if one expects a motor to operate at a higher or lower than rated voltage for an extended period[3].

NOTE: a one percent voltage unbalance may result in a 6-10 percent current unbalance.

Low Voltage

- Higher than normal current
- Higher than normal motor temperature

High Voltage

- Higher than normal inrush current
- Lower than normal power factor

The torque produced by a squirrel cage induction motor is directly proportional to the line voltage times the rotor bar current. When the line voltage differs from the nameplate voltage, the rotor bar current must change to maintain the same torque. If the line voltage increases, the rotor bar current will decrease by the same percentage and the power factor will decrease. If the line voltage decreases, the rotor bar current must increase for the motor to maintain the same amount of torque. The rotor bar current is proportional to the slip of the motor, so for the rotor bar current to increase, the motor must slip more. This will result in a hotter rotor, which also heats the winding, and will result in an increased winding temperature. Totally enclosed, fan-cooled (TEFC) and open motors are self-cooled. As the slip increases, the rotor speed decreases, which in turn results in less air moving across the motor for cooling. Combined, these two phenomena will result in a hotter winding temperature and less efficiency[4].

200V rated motors

This rule does not affect motors which are 208V or 208-230/460V on the nameplate voltage line. These motors were required to meet NEMA 12-12 for the Integral HP Motor Rule of 2016. Additionally, all 200V catalog specs already meet NEMA 12-12 efficiency. If an application is expected to see reduced voltage, there is an opportunity to move to a 200V motor and improve system efficiency.

Consider a farm that has a grain silo in the middle of a field. When the motor on the grain silo is unloaded, the voltage will be slightly lower than equipment located closer to the source of power. When loaded, the voltage on that motor will decrease. Per the National Electrical Code (NEC), the wire should be sized sufficiently large enough so that reasonable efficiency of equipment operation can be provided, and the total maximum voltage drop should not exceed 5 percent. However, nameplate nominal voltage is not the same as the utility nominal voltage. For example, a motor nameplated 230V will be used with a utility nominal voltage of 240V. The utility has a service voltage of ±5 percent and a utilization voltage of +6 percent/-13 percent, where utilization voltage takes into account the voltage drop specified by the NEC.

The motor is designed to operate on ±10 percent nameplate rated voltage. These voltages are specified such that the utility utilization voltage, or the voltage at the terminals of the motor when loaded, should always be within the ±10 percent voltage on the nameplate. In the case of the grain silo, if the nominal service voltage is 240V, the minimum utilization voltage is 208.9V. The minimum voltage for a 230V motor is 207V. As required by NEMA, the 230V motor will successfully operate on a 240V service voltage.

It is important to understand that the performance of that motor or system is not optimized for that reduced voltage and the performance will not necessarily be in accordance with the standards established for operation at rated voltage and frequency. As the voltage is decreased, the torque of the motor is reduced by the square of the ratio of the voltages. As an example, a Design B motor that produces 285 percent locked rotor torque at 230V will only produce 233 percent locked rotor torque at 208V. Using a 200V motor when 208V operation is desired would optimize efficiency, lower temperature of the winding, and will meet nameplated NEMA design and efficiency.

Electric motor literature

Motor manufacturers are still allowed to state “Usable At” voltage and related current information in their literature for reference only. These voltages will not be subject to testing if it is not on the motor nameplate. This would include material such as product data packets, websites, product catalogs, training presentations, service manuals, etc.

After April 17, 2023 (pending extension):

- Motor manufacturers must remove “Usable at” voltages from the nameplate if the motor does not meet regulated efficiency at that voltage.
- Motor manufacturers are still allowed to put “Usable At” voltage and related current information in their literature for reference only.
- Users can continue using 230/460V motors as before since these designs are not required to change and refer to data sheets for information at operation at other voltages.
- A 208-230/460V rated motor is required to meet efficiency of entire voltage range ±10 percent voltage variation which will require more material than a standard 230/460V motor.
- Users should consider 200V motors if 208V supply is needed in order to optimize efficiency, lower temperature of the winding, and meet nameplated NEMA design and efficiency.

References

1 10 CFR Parts 429 and 431 [EERE–2020–BT–TP–0011] RIN 1904–AE62, Energy Conservation Program: Test Procedure for Electric Motors, October 19, 2022, U.S. Department of Energy

2 ANSI/NEMA MG 1-2021 Motors and Generators Standard, ANSI approval date: June 6, 2022, National Electrical Manufacturers Association

3 CST821-01 Rev 14, Fundamentals of Motors, revised August 7, 2021 ABB Inc.

4 NEMA MG 2-2014 Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators, February 24, 2014, National Electrical Manufacturers Association

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