

Informative Application Guidelines, with respect to *Motors & Drives* to keep you better INFORMED.

APPLICATION GUIDELINE #05

(Temperature Rise – Insulation)

.....Brought to you by your Motor & Drive Specialists

Temperature Kills Motors

Application Guideline #4 indicated common causes of motor failures, and it was determined that temperature kills motors. Ideally, a motor should have a relatively high insulation temperature rating, and a relatively low operating temperature for both the insulation system and bearing system. This provides for thermal margin in the event of motor overload, severe starting duty, safety margin for adjustable speed drive applications and for many other reasons indicated in 'Application Guideline #4'. (A well-accepted rule of thumb is that for every 10°C, that the motor temperature exceeds its rated insulation temperature, the insulation life is reduced by half, likewise for every 10°C cooler, the insulation life is doubled.)

Temperature Rise - Today's 'HOT' AC Motors

During the reign of the Class "A" insulated U-frame motors, it was common practice to determine whether a motor was running all right by simply placing your hand on it. If the motor was "too hot to touch", it was overheating. With the advent of T-frame motors and the high temperature insulation that made them possible, this old "rule of thumb" is no longer valid. Surface (Skin) temperatures usually run 20 to 30°C lower than the temperature at the windings. Subtracting 30C from a 'Class F' insulated motor whose total allowable running temperature is 155°C, results in a skin temperature of 125°C (257F), therefore if your T-frame motor is "too hot to touch", it does not necessarily mean that its operating improperly. Today's motors are designed to run hotter than our human hands can tolerate.

NEMA specifies letter designations for motor insulation temperature ratings. These insulation temperature ratings are denoted as Class: A=105°C, B=130°C, F=155°C, and H=180°C. Further, NEMA specifies allowable **temperature rises** for motors at full load (and at service factor, if applicable). These allowable temperature rises are based upon a reference ambient temperature of 40°C, and are determined by the "**resistance method**", in which the resistance of the windings is measured with a bridge after the motor has achieved thermal equilibrium under load. The resistance of the winding is a function of temperature of the winding. ***NEMA allowable temperature rises (at full load) for a 1.0 S.F. motor are A=60°C, B=80°C, F=105°C, and H=125°C. NEMA allowable temperature rises (at service factor) for a 1.15 S.F. motor are A=70°C, B=90°C, and F=115°C.***

Adding the NEMA allowable temperature rise of 105°C (for a Class F insulated, 1.0 S.F. motor), to the reference ambient temperature of 40°C, results in a total operating temperature for the motor of (105+40)=145°C. The 10°C temperature differential between the Class F insulation maximum temperature rating (155°C) and the allowable maximum temperature (145°C) provides an allowance for the "hotspot" temperature of the interior of the winding, which is difficult to measure directly. The overall winding resistance is the sum of the resistance of the cooler end turns, and the warmer (hot spot) windings embedded in the stator slots.

NEMA Motor Insulation Temperature Ratings		Temperature Rises			
		1.0SF Motors			1.15SF Motors
Class	Temp.	Ambient	Hotspots	Rise@1.0	Rise@1.15
A	105	+40	+5	60	70
B	130	+40	+10	80	90
F	155	+40	+10	105	115
H	180	+40	+15	125	not defined

Although NEMA does not specify **temperature rises** by letter designation, it has become common practice in industry to refer to the allowable temperature rise for a given class of insulation, as a temperature rise letter classification. For example, an 80°C rise is often referred to as a 'Class B' temperature rise, since 80°C is the maximum allowable temperature rise (by resistance) for a 1.0 S.F. motor insulated with Class B insulation based on a 40°C ambient. Thus, a motor with Class F insulation and an 80°C rise is commonly referred to as an 'F/B' motor.

Many improvements have been made in motor insulation in the past couple of decades, such that a Class F (or better) insulation system is common for motor winding insulation. With conservative motor design, a 'Class B' temperature rise is quite achievable. For a 1.15 S.F. motor wound with Class F insulation, a Class B temperature rise at full load translates to a thermal margin of $155 - (40 + 90) = 25^\circ\text{C}$. This means insulation life will be approximately 5 to 6 times that which would be expected with a motor operating at its rated insulation temperature (i.e. for every 10°C lower temperature, the insulation life is doubled).

Insulation Life - Thermal Deterioration

Above a certain threshold temperature, the insulation ages at an ever increasing rate which approximately doubles for every 10°C increase in temperature. By definition, class F insulation will lose ½ its mechanical strength after being subjected to 20,000 hours at its rated temperature. This does not mean that the insulation will fail at this point, it just means that it is substantially weakened.

- 20,000 hours (2.5 years) at 155°C
- 10,000 hours (1.25 years) at 165°C, or likewise, 40,000 hours (5 years) at 145°C
- 5,000 hours (<1 year) at 175°C, or likewise, 80,000 hours (10 years) at 135°C
- etc.

Obviously, motors don't run continuously at one temperature since loads and ambient temperatures vary. Once thermal deterioration has occurred, it is non-reversible. Reducing the temperature can however, stop further deterioration.

– **Tip** – If RTD's are fitted in a motor, the temperature should be trended. If the temperature goes up, this is a clear indication that the ambient has increased, the load has increased or it is time to clean the motor. A simple way to implement a trigger to perform cleaning is to monitor the temperature of a motor shortly after installation when it is running at its peak-operating load, ideally during the hottest ambient condition. (Note – if the ambient temperature is not at its highest level when initially monitoring the RTD reading, increase the alarm point by the amount of expected ambient increase.) Set the alarm point of the RTD monitor 5-10°C hotter than the maximum expected operating temperature. If the RTD alarms in the future, either the load has changed or it is time to schedule cleaning of the motor.

– **Tip** – There is a 10°C difference between temperature measurements by Resistance versus by Embedded Detectors (resistance elements, or Thermocouples). For example, a Class F temperature rise of 105°C **by Resistance**, is 115°C **by Embedded Detector**.