

Pump ED 101

AC Motors Part 5 - AC Motor Life

Joe Evans, Ph.D

<http://www.pumped101.com>

One of the major impacts on motor life is common sense - - or maybe the lack there of! It always amazes me how many ODP motors are used in agricultural irrigation applications where there is no pump house or even a simple cover over the motor. Rain and excess heat due to direct sunlight greatly reduce their expected life. And, don't get me started on the piping arrangements found in some of these systems! Another example that I saw often in Hawaii was the use of steel motor enclosures near the windward coastline. They were cheaper than cast iron or aluminum but the high salt concentration in the air limited their life span to two or three years. Often they were replaced several times before the customer could be convinced to spend a little more up front. Obviously, proper selection and application which includes the enclosure, coatings, bearings, load and timely maintenance will have a major impact on useful life. That said, the induction motor component with the largest impact on motor life is the winding insulation and the largest contributor to shortened insulation life is heat.

Temperature - Ambient & Rise

Over 40 percent of all motors failures are due to overheating. The maximum allowable operating temperature of a motor depends upon the insulation class used in the windings. Classes A, B, F and H have maximum centigrade temperatures of 105°, 130°, 155° and 180° respectively. These temperature ratings are the maximum temperature that can be tolerated in order for the insulation to provide an average life of 20,000 hours. Class A is pretty much history and B is usually limited to certain fractional HP motors. Most industrial motors, including EISA compliant models, are built with Class F or H.

The actual operating temperature of a motor is a combination of the ambient temperature (the temperature of the air surrounding the motor) and the internal temperature rise caused by the load. Most industrial motors have an ambient rating of 40° C (104° F). In the case of Class F insulation the rise temperature (including hot spot allowance) would be limited to 115° (155 - 40). The difference

between the actual ambient temperature and the class rating is the allowable temperature rise. As a rule of thumb, insulation life will double for each 10 degrees of unused allowable temperature. Unfortunately the opposite is also true. For each 10 degrees over the allowable temperature, insulation life will be reduced by one half.

Temperature rise is measured by the resistance method and utilizes the equation below.

$$\text{Rise (}^{\circ}\text{C)} = ((R_h - R_c) / R_c) \times (234.5 + T_a)$$

Where: R_h is the hot winding resistance in ohms
 R_c is the cold winding resistance in ohms
 T_a is the ambient temperature

R_c is measured before the motor is started and R_h is measured after several hours of operation. If T_a increases due to the increased temperature of the motor, the increase should be subtracted from the calculated rise temperature. The sum of the actual rise and ambient temperatures is the actual operating temperature. Please note that motor surface temperature is not an indication of the actual operating temperature.

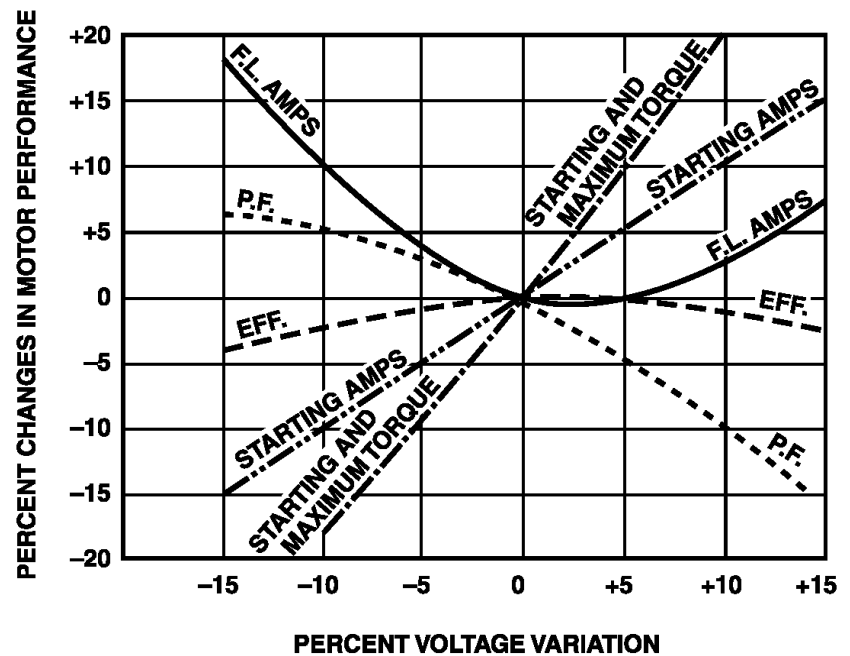
Another factor that can affect operating temperature is elevation. At elevations above 3300 feet the temperature rise increases by approximately 1 percent for each 330 foot rise in elevation. There are times, however, when increasing temperature can be a good thing. Motors that are installed in damp or humid environments can experience shortened insulation life due to condensation on the windings during extended periods of non operation. Heaters can be installed or a low "trickle" voltage can be applied to the windings to keep the temperature above the condensation point.

Temperature - Voltage Variation

NEMA T-Frame motors are designed to tolerate a plus or minus 10 percent variation in its nameplate voltage. Notice that I said tolerate and toleration does not mean that there will not be some negative consequences. Figure 1 shows the effects of low and high voltage on the performance of a typical T-Frame motor. It can be used to illustrate the general effects but it is not completely accurate

because these characteristics can vary substantially depending upon the winding design of a particular motor. The graph shows substantial changes in most of the characteristics over the voltage range. The one that contributes to motor temperature rise is full load amps (FLA). If you remove power factor from the equation, power in watts is roughly equivalent to the

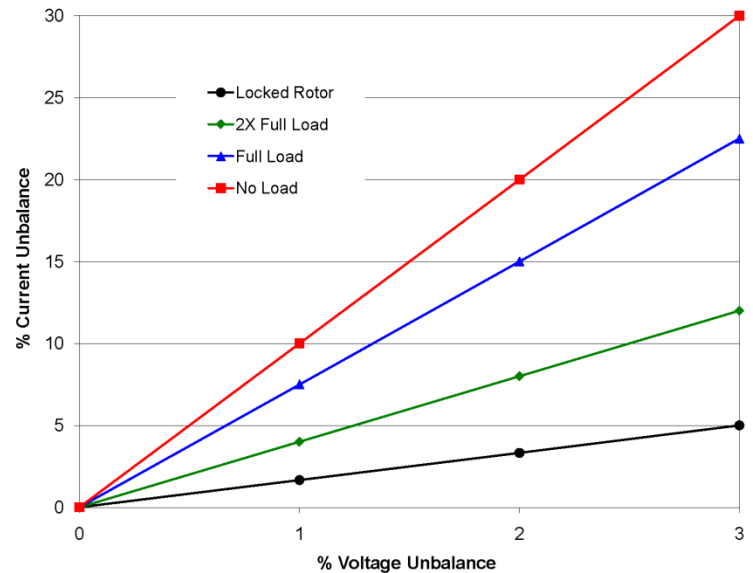
product of volts and amps. When voltage drops, a motor draws more amperage thus keeping power in watts constant. This is usually not a problem if the motor is not fully loaded and amps do not exceed the nameplate FLA. If, however, the motor is fully loaded a 5 to 10 percent voltage drop will cause amps to exceed FLA and maybe even service factor amps. This is especially problematic if a motor is operated at a consistently low voltage as the higher current draw will increase the operating temperature. Now you would think that the exact opposite would occur at an increased voltage - - amps should drop. But, higher than nameplate voltages can cause magnetic saturation in the stator and result in a much larger increase in current than shown in the graph. Even lightly loaded motors are prone to high amp draw at higher voltages and the net result is an increase in operating temperature. It is always best to keep the source voltage as close as possible to the nameplate voltage.



Temperature - Current unbalance

Unbalanced phase current is one of the largest contributors to reduced winding insulation life. Although the motor can be the culprit, unbalanced phase voltages and voltage distortion due to harmonics are the more typical causes. Unbalanced phase voltages can be due to poor distribution by the utility or uneven single phase loading on a three phase system. A small voltage unbalance of just 2 percent can result in a current unbalance of 14 to 16 percent. This will result in an increase in temperature in the winding with the highest current load. The percentage increase in temperature due to voltage unbalance is $2 \times (\% \text{ Voltage Unbalance})^2$. So, for a

relatively small unbalance of 2 percent winding temperature will increase by 8 percent. Current unbalance due to harmonics will not affect the phase voltages as measured by a volt meter so the resulting current unbalance must be measured with an amp meter. Figure 2 shows the effect of voltage unbalance on current unbalance at various motor loads.



Current unbalance in motors that are operating at less than full load is usually not a problem as long as none of the legs exceed the nameplate amperage. For more information on diagnosing the sources of current unbalance and how to fix them, see my July 2008 P&S column.

Although Class F and H insulation allow a temperature rise of 25 to 50 degrees more than Class B, we are using a portion of that increase to build higher horsepower motors on a smaller frame size. Therefore we still have to pay attention to the factors that affect motor operating temperature if we want to achieve maximum winding life.

When Ed Cowern was with Baldor Motors, he wrote a 115 page white paper called the "Cowern Papers". It is, by far, the best and most comprehensive AC motor reference I have seen. It is also written in a simple and understandable "Pump Ed 101" manner. Unfortunately it is not on the Baldor site but you will find it on the "Electricity, Motors & Controls" page at www.PumpEd101.com.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pumps & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.pumped101.com. If there are topics that you would like to see discussed in future columns, drop him an email.