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Wiring for Electric Motors

by Ross King

Characteristics of electric motors: As the load increases on a gasoline motor, it slows down and finally stalls. Therefore, the horsepower rating of a gasoline motor must be as high as the highest load the motor will experience. An electric motor, on the other hand, responds to an increase in load in a different way. It consumes more current (amps) and produces more torque. That's why a lawn mower which needs a four horsepower gasoline motor to mow thick grass may need only a one horsepower electric motor: the lower rated electric motor is capable of producing four horsepower for short time, probably long enough to get through the rough spots. But if the overload lasts too long, the motor gets so hot that its components are damaged. A switch which recognizes a small overload of a long period of time- in other words, a motor starter- protects the motor.

An electric motor pulls a large current when it starts. This means that the circuit supplying the motor must have wires large enough and fuses with a rating high enough to provide that starting current. A motor with an FLA (full load amps) rating of five amps may pull 20 amps for the one second or so that it takes to come up to full speed. Those 20 amp fuses protect the building from fire in case a wire shorts out, for instance, but they do not protect the motor from long lasting overloads. Therefore, the motor needs heaters rated at five amps and fuses rated at 20 amps.

The load rating of an electric motor: The horsepower rating and the full load amperage of a motor are determined by the designer of the motor as the current which the motor can pull continuously without causing the motor to get hot enough to damage itself. The motor is capable of producing more horsepower than shown on the nameplate, but if it does so continuously, it will oveheat and fail. We determine the load on a motor in the field by reading its current consumption with an amp meter. If the motor is pulling more amperage than the FLA stamped on the nameplate, we look for causes of overload.

Some of the ways to overload a motor: Friction... when the bearings run out of grease or oil. Blower overload...if the motor operates a centrifugal blower such as an organ blower, the load increases as the quantity of air moved increases. A centrifugal blower consumes the least amount of electricity- the smallest number of amps- when the outlet or inlet is closed. It consumes the most amperage when it is pumping the highest quantity of air. If there is a massive leak or an open pipe fitting, the motor is likely to oveheat. One lead of the three phase current goes dead ("single phasing, loss-of-leg")...This happens when there is a fault in the power line, usually before the line reaches the building. The motor overheats because current continues to flow through the other two legs and thus through one of the motor coils. Heaters in the motor starter are supposed to detect the overheating, but they often do not work properly. The best insurance is to have an up to date solid state sensor inside the motor starter which disconnects all three legs when it detects a lack of current in one leg.

Circuit protection: Motors need two kinds of circuit protection. The first is a fast acting fuse or circuit breaker with a fairly high amperage rating, say 20 amps, to protect against some sudden severe malfunction, such as one wire coming loose and touching another. The second is a slow acting thermal device of fairly low amperage rating, say four amps, to protect against motor overload. Selecting a fuse or circuit breaker...The fuse is sized according to the wire from the breaker to the motor. The wire is sized according to the current consumption of the motor. Some older buildings were wired with 14 guage wire. 12 guage wire is the minimum allowed by code in modern commercial buildings. It will handle motors up to about three horsepower.

Wire Guage	Maximum fuse
#14	15 amp
#12	20 amp
#10	30 amp

If a fuse of greater amperage is used, there is the danger that the wire can get hot enough to cause a fire.

How a motor starter works: Even though everyone calls it a "motor starter", it is really a "remote control motor thermal protective device". Turning on the remote switch- the switch on the console in the case of an organ- energizes a magnet in the motor starter which causes contacts to "make", sending current to the motor. The motor current passes through the heaters located near temperature-sensitive switches. If the motor is overloaded, it pulls too much current, causing the heaters to warm. If the overload lasts long enough, one of the temperature sensitive switches gets warm and opens, which breaks the circuit energizing the holding coil. This allows the main contacts to open, turning off the motor. A motor is considered overloaded if it pulls more amps than the FLA on the motor nameplate.

Selecting a heater for the motor starter: Look on the motor for the FLA rating (Full Load Amps). Look inside the motor starter cover for a chart comparing the motor FLA with heater identification numbers. Do not choose heaters with a higher rating. If the electrician wants to put in a heater with a higher rating to prevent nuisance tripping of the motor starter, rest assured that we will run the motor long enough before the organ goes into use to find out if the rating is too low. As far as using fuses in the place of a motor starter, most fuses contain a single element composed of a simple lead link which melts quickly when there is a significant overload. Dual element fuses have the same sort of lead link, but they also contain a temperature sensing element which causes the fuse to open when there is a small overload over a long period of time. Dual element fuses are satisfactory for motor protection.

Wire size at different voltages: Wattage, which is the measurement of power, is the product of volts times amps. If a device can be wired to operate on two different voltages, delivering the same power at either voltage, the amperage consumed is greater at the lesser voltage. Greater amperage requires larger wire. Therefore, the lower the voltage, the larger the wire needed. A motor connected at 115 volts needs wire twice as large as it would if it was connected at 220 volts.

The importance of grounding: A motor will operate satisfactorily if only the hot wires are connected, but it is not safe. The ground wire- the fourth wire (green) in a three phase circuit, the third wire (white or green) in a two phase circuit- would be connected to the motor frame so that a fuse will not blow if a hot wire comes loose inside the motor and touches the frame. If the frame is not grounded, and a hot wire touches the frame, anyone touching the motor is likely to recieve a dangerous, potentially fatal, shock.

Three phase versus single phase 220 volt motors: A motor built for three phase operation is more trouble free than one built for single phase, as it starts easily. A motor built for single phase requires a separate coil (winding) to enable it to start, and that start winding requires an internal switch which disconnects the start winding after the motor reaches a certain speed. A single phase motor often requires, in addition, a starting capacitor. Capacitors deteriorate with age. Note that reversing any two of the three hot wires leading into a three phase motor reverses the direction of rotation of the motor. To reverse a single phase motor, one has to change wiring connections inside the motor.

Reading a sample motor nameplate:

HP 1.5 1.5 horsepower

Phase 3 Requires three phase current, not single phase

Volts 208-220/440 The fact that the voltage shown on the nameplate is stamped with a slash (/) means that this is a dual voltage motor. The wires can be connected one way for low voltage, whether 208 or 220, or they can be connected another way for high voltage, 440 volts in this case. See the motor nameplate for the wiring diagram.

Amps 4.4-4.2/2.1 4.4 amps is the full load rating at 208 volts, 4.2 amps at 220 volts, and 2.1 amps at 440 volts. Use this information when choosing heaters for the motor starter.

Hz 60/50 The motor can be operated on alternating current which has a frequency of 60 cycles per second (Hz) or 50 Hz.

RPM 3450/2850 If used on 60Hz current, the motor turns at 3,450 revolutions per minute (RPM), and 2,850 RPM when used with 50Hz current.

FR 56c This is the type of motor frame.

Encl TEFC The motor enclosure totally enclosed, fan cooled.

Duty CONT The motor can be run continuously at the rated amperage as opposed to intermittently.

NEMA Design B National Electric Motor Association design B

Protocol and Liabilities: Any circuits involving more than 24 volts must be installed and connected by a locally licensed electrician, and the work must be performed in accordance with the National Electrical Code and any local building codes. If we as organbuilders do work which should be done by a licensed electrician, we are liable for any damages which may occur, and we are violating the law. We also may be jeopardizing the client's insurance.