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Compressor Motor Failures

Compressor motor failure can be caused by a variety of electrical or mechanical conditions. Here is a review of the common causes of motor failure, how you can diagnose them, and prevent costly replacements.

Voltage Unbalance

The most probable cause of current unbalance on any induction motor is voltage unbalance. Current unbalance rises sharply with a small voltage unbalance. Therefore, in any current unbalance problem, suspect source voltage unbalance. The max allowable voltage unbalance from winding to winding is 2%. The effect of voltage unbalance on current unbalance for any type of three-phase induction motor is shown below. The band indicates the spread that is likely to be encountered. For a given voltage unbalance, the current unbalance will increase as load decreases.

To check voltage unbalance, take the voltage readings between phases at the disconnect or the compressor contactor load side while the compressor is operating. The most accurate way to measure what is occurring at the compressor is to read the voltage at the compressor terminals. For example, if: L1 to L2 is 220V, L2 to L3 = 231 V., and L3 to L1 = 235 V. the average is 220 + 231 + 235 divided by 3 or 229V. Average.

Next, figure the unbalance for each phase by getting the difference between the voltage reading and the average: L1 to L2 = 229 – 221 = 8V. L2 to L3 =231 –229 = 2 V. L3 to L1 =235 – 229 = 6 V.
Five volts is the maximum unbalance. Use it in the formula: % unbalance is the maximum unbalance divided by the average voltage times 100.
% Unbalance + 8 divided by 229 X 100 =3.49%
This voltage unbalance is greater than 2% and therefore is not acceptable. The customer should be advised. Having said that, most power companies will say that is well within their tolerance. Not all problems in this area are easily resolved.

Current Unbalance

Voltage unbalance will cause a current unbalance, but a current unbalance does not mean that a voltage unbalance necessarily exists. Take a three-phase situation, where there is a loose terminal connection on one leg or where there is a buildup of carbon or dirt on one set of contacts of the contactor. Using L1 as our problem leg would cause a higher resistance on that leg than on L2 and L3. As we know, the current will follow the path of least resistance and cause the current to increase in the other legs. Higher current causes more heat to be generated in the windings. Lately, some problems have been brought to light involving the use of inverters on the same distribution lines as other loads. That, plus capacitor and inductance unbalance of modern lighting systems, can unbalance the three phase lines feeding the motors. Percent of current unbalance is calculated like voltage unbalance.

Single Phasing

Single Phasing, where one leg of a three-phase system is lost will react much the same as the conditions just described, but the motor failure may be more rapid. When a three phase motor single phases, one phase is unaffected but the other generally show signs of overheating. The pattern of failure shows up below:
One phase is bright, shiny and clearly unaffected. This was the open phase. The other two phases are burned. Many times the visual effects are not as dramatic as shown here, but are evidenced in broken end ties and slight discoloration. In single phasing if the compressor is operating and one phase of a three phase motor supply opens, the motor may continue to run. The other two phases will attempt to pick up the load that the lost phase was carrying. The current draw of the remaining two phases will increase to about one to two times normal. If the compressor is loaded, it will push the current draw of the motor beyond the must trip current of the overload protection. Under light load conditions, the current may not reach the trip current of the overload and will remain running. The windings will run hot and depending on the type of motor protection, will trip. Once the motor stops, it generally cannot restart, tripping on the overload protectors again and again, which normally leads to motor failure.

Supply Voltage

Overheating can also occur if the supply voltage is too high or too low, and outside the maximum minimum limits set by the manufacturer. For a compressor with single rating of 230 volts, the operating limits are within + or – 10% of the 230 (207 to 253 v.). On a dual rated voltage or spread voltage unit such as a 208/230 volt three phase system, the operating parameters are within 10% below the 208 and 10% above the 230-name plate voltage (187 to 253v.). And on a motor rated for 200/230 the lower voltage allowable is a full 180v. Keep in mind some single phase 208/230 rated motors will be rated for only 5% below the nameplate of 208 or 197V. The use of a single rated 208-volt single-phase motor will give better reliability.

In a single-phase motor another cause for overheating is faulty or improper start components as well as the run capacitor, if applied. It could be the start of run capacitor, or any of the contactor relay devices used in conjunction with the start winding components. Without the proper voltage and microfarad rating, the compressor will not operate within the design tolerance or might fail to start. If it fails to start, it could cause a locked rotor situation, which brings on overheating of the windings and rapid failure. Pay careful attention to the run capacitor, if applied. Existing designs of run capacitors tend to become weak and out of specs. Check them during a service call.

Short Cycling

Finally, one of the causes of overheating often overlooked as a cause of compressor failure is rapid cycling. The start stop cycling of controls and safety devices can result in shorted motor windings like the one listed below. Each time the motor starts, the current draws locked rotor amps. It takes a few minutes of running to get rid of the heat caused by locked rotor current. Frequent cycling causes a buildup of heat because the heat from the previous start has not been removed. In addition, wires and end turn coils in the motor can also rub together due to induced wire vibration that occurs during rapid current and temperature changes that happen every time the motor starts. In the case of many starts, wire rubbing may eventually result in the erosion of the insulation, causing a short. In summary electrical problems are usually caused by electric supply unbalance or rapid compressor on off cycling. All four typical electrical problems shown below can lead to overheating and eventual burnout. In addition, rapid cycling can cause failure of the motor windings due to constant flexing of insulated turns and connections.

Motor Failure Caused by Mechanical Problems

More common among motor failures are the ones that result from a mechanical problem within the compressor. When these occur, the resulting motor failure is quite often thought to be a "motor burn" when it is actually not the motor's fault. Analysis of the failed compressor is the only way to determine the true cause of the problem.

Refrigerant Flood Back

One of the most common types of mechanical causes of motor failure is flood back. Liquid refrigerant returns down the suction line into the compressor. The compressor is a vapor pump, and the entering liquid will eventually cause damage. The liquid refrigerant returns to the suction cooled type motor compressor at the bottom of the compartment or barrel and make it's way under the motor, where it will chill the motor. The remaining liquid will travel with the oil into the crankcase where it may boil off a little more until the oil is chilled. Now begins the problem. Surviving liquid will be on the bottom of the oil refrigerant mixture. The oil pump pickup is at the bottom of the sump, and it will conduct the liquid rich oil into the pump and then into the first bearing. Liquid refrigerant will flash off, displacing the oil, and result in a shortage of lubricant for the remaining bearing surfaces farther down the drive train such as those shown below. The progressive shortage of oil will worsen as you travel to the bearings farthest away from the oil supply, the motor end bearings. In a semi hermetic compressor, as those bearings wear, the stator air gap is lost and the rotor will finally drop to a point where it will touch and rub on the stator with a resulting spot burn. An internal inspection of the failed compressor will reveal the true cause of the motor failure. The welded compressor has a vertical shaft: while running, the rotor remains somewhat centered. When the compressor stops, the worn bearings and lost air gap allow the rotor to become magnetically locked against the stator. Since we cannot inspect the internals of the welded compressor very easily, we must logically assume that if a welded compressor draws locked rotor amps at start, it is most probably the result of liquid flood back. The problem remains one of the most serious and all too common in the industry. Less common but still a frequent occurrence is the damage done to the motor windings from pieces of metallic debris.

Slugging

The motor windings are quite close to the suction areas of the cylinders. Parts or small pieces from broken suction valves or even discharge valves like those shown below and backers or casting particles broken during a liquid slug will make their way back to the giant magnet called a motor. Those little pieces then act as a worm and bore into the winding or bridge the gap of poles and air gap, resulting in a spot burn Again, the true cause cannot be determined without an internal inspection.

Overheating

Less often, the possible motor failure may stem from a compressor operating at high discharge temperatures. When the discharge temperature is high enough to destroy the lubricants ability to keep the metal rings and pistons apart, minute cast iron particles from the cylinder walls and rings become suspended in the oil. That oil will eventually find its way to the motor where the magnetic action can build a gap between the poles of the stator iron or become imbedded in windings causing a spot burn.