Why Compressors FAIL

Understanding common issues found in the system itself can save the oft-misdiagnosed heart of the system.

BY DENNY MARTIN

Images courtesy of Embraco North America Inc.

The compressor is the heart of the refrigeration system. It is the component that does the most work and consumes the most energy in a system. Because of this, today's manufacturers have achieved significant improvements in the efficiency of reciprocating compressors. The compressor's role is to pump refrigerant through the circuit and cause a pressure difference between the high and low side of the system. This pressure difference is needed to cause the refrigerant to change states in the condenser and the evaporator. Also needed is a load on the evaporator and condenser in the form of warm air from the refrigerated space and outside ambient air to help the refrigerant properly evaporate (in the evaporator) and absorb the heat from the refrigerated space. The compressor then compresses this saturated refrigerant vapor further increasing its temperature and pressure and delivers it to the condenser where it is condensed into a liquid, releasing the heat to the ambient air passed across the coil.

Modern refrigeration compressors are designed with a high level of quality but, like any other product, can still suffer defects from time to time. Still, the main cause for the highest number of returns from the field is misdiagnosis. More than 50% of the compressors returned for warranty have no defect. Before replacing a compressor, it is necessary to perform a complete analysis of the entire system to determine if the compressor needs to be changed or not. Often, the fault lies somewhere in the cooling system and not in the compressor itself. These faults may have overheated the compressor and caused the overload to trip. If the overload is internal common to the run and start windings will show open. The compressor may need time to cool off to reset the overload and sometimes this cool off period can be lengthy. Sometimes, a little water carefully poured over the shell can speed up the cool off process.

There are a few simple tests of the compressor motor that are easy to perform and may prevent changing a compressor that is still good:

1. Winding resistance measurement: The first test is to find out how many Ohms of resistance we have through the run winding and the start winding. To do this, first identify the pins using the manufacturer's spec sheet. Then use a digital multimeter to test the resistance from the common to the run pin and the common to the start pin. Then compare this to the values listed on the spec sheet. The reading should be ±8% of the values listed. These values are measured at 77°F (25°C), so a very hot or cold compressor could possibly show slightly higher or lower than 8%. We are looking for open windings or winding-to-winding shorts and this test will identify those with readings that are out of specification.

2. Winding insulation test: The second test is done with a megohmmeter. This meter uses high voltage to test the winding insulation under load and looks for weaknesses or "breaks" in the insulation where current can pass from the windings to the compressor's housing. This test can also be used to log deterioration of the insulation during routine maintenance and possibly prevent a compressor motor burnout. Generally, these meters use different colored LEDs (green, yellow and red) to indicate the condition of the insulation.

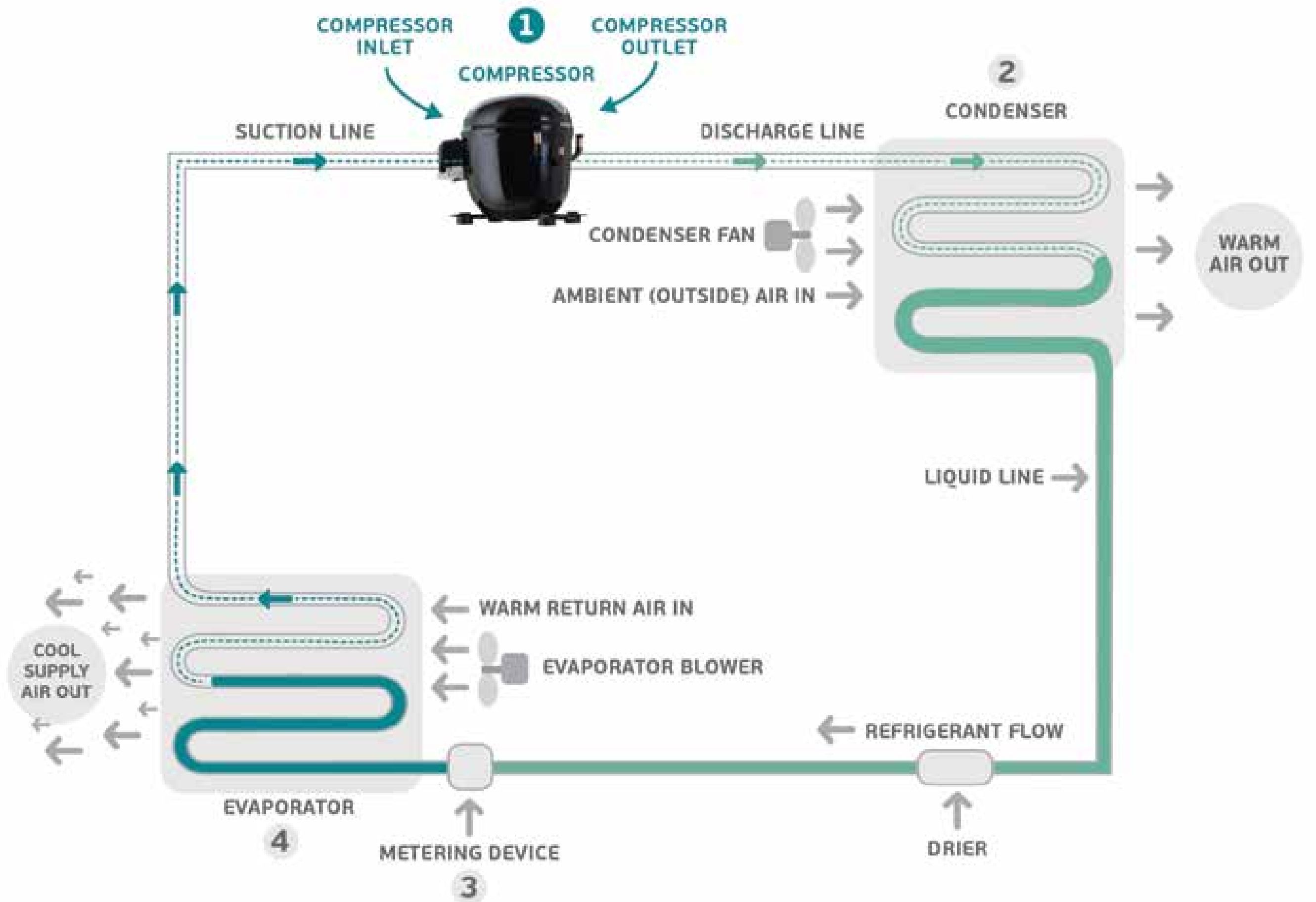
Contaminants

Contaminants cause a very high number of compressor failures in a refrigeration system, and the three main ones are moisture, dirt and debris, and noncondensable gases.

Moisture—Moisture is one of the main contaminants in a system and almost always present in some quantity because modern refrigeration oils and refrigerants are hygroscopic, meaning they have a tendency to absorb moisture out of the ambient air. Many refrigeration service procedures must be followed to assure excess moisture does not find its way in the system and the moisture that is in the system is properly removed.

Compressors should not be left open to the atmosphere whenever possible, and if you must do this, a maximum of 15 minutes should be observed. The compressor tube plugs should only be pulled right before connecting tubing for brazing. Service hoses should always be purged of air before charging a system.

A quality vacuum pump must be used to put a deep vacuum on a refrigeration system, and the oil should be changed before every system evacuation. These pumps will lower the pressure in the system to the point where water is boiled and turned into vapor. The pump can now easily remove this water vapor. Vacuum level is measured in microns, so an electronic micron gauge should be used to verify a vacuum level of 500 microns or less to assure water is vaporized and



This is a basic diagram showing the four components found in almost every refrigeration system. The compressors role in the system is to provide a pressure difference between the high and low side of the system to properly condense and evaporate the refrigerant. This pressure difference is needed to cause the refrigerant to change states in the condenser and evaporator. Heat is pumped from inside the space to the outside by absorbing it in the evaporator and pumping it via the refrigerant to the condenser where it is released through condensation. The refrigerant should fully evaporate in the evaporator leaving only superheated gas returning to the compressor. A compressor is a vapor pump only and should not be subjected to liquid refrigerant at any time.

effectively removed. This procedure will typically remove almost all moisture in a system but a properly sized filter-drier is a must to be sure any residual water is caught and retained by the drier. A new drier should be installed every time the system is opened for service.

When water enters a system it can mix with the oil and make organic solids and mild acids. Water will mix with refrigerant and create stronger hydrochloric acid. Winding insulation and metals are attacked by these acids, causing contaminants to travel throughout the system. Copper particles can be deposited on overheated bearings and journals causing copper plating, which will cause the bearings to quickly fail. If these contaminants are not properly removed, a subsequent compressor failure can result within a few hours.

Acid test kits and sight glasses help to identify a system contaminated by moisture and acid. Once acid is identified in a system a flushing solvent should be used for the tubing and coils. Liquid- and suction-line filters should be installed and pressure drops should be monitored after startup and the driers changed if pressure drop exceeds 2–3 psi across the driers. Driers with inlet and outlet service taps are useful here. These driers should be changed until the system is clean and it is recommended to remove the suction-line drier after the clean-up is complete. Excessive pressure drop in the suction line can cause compression ratios to rise and capacity to drop.

Dirt/debris—Another reason for system contamination is the accumulation of dirt that can come from field working environments, dirty pipes and components. It is good practice to cap the ends of stored AC/R tubing. When cutting and deburring tubing, technicians must be careful not to introduce any shavings or dirt into the tubing. These particles will travel through the system and lodge in small metering device orifices or could end up damaging compressor windings or bearings.

Non-condensables—Air, nitrogen, hydrogen or any foreign gas in a system that does not condense under pressures seen inside the refrigeration system are called "non-condensables." These gases become trapped in the high side of the system because they will not condense and occupy space in the condenser effectively, reducing the surface area of the coil. The system becomes inefficient from elevated temperatures and pressures, which will also cause the compressor to overheat. Systems suspected of non-condensables will need refrigerant reclaimed, a deep vacuum and a recharge with new refrigerant.

Additional suspects

"*Liquid slugging*" is the term used when liquid refrigerant is allowed to reach the compressor's valves. It can sometimes be heard as a violent vibration of the equipment or compressor. A compressor is a positive-displacement vapor pump so what it takes into the cylinder it will try to compress. Liquids will not compress and extreme cylinder pressures sometimes exceeding 3,000 psi will result. These pressures are capable of breaking connecting rods, pistons and reed valves, and sometimes rupturing the cylinder head gasket. If a compressor is equipped with a sight glass, sometimes foaming can be observed, which indicates liquid refrigerant is reaching the compressor.

A common cause of liquid slugging is charging a system with too much refrigerant. When this occurs, the evaporator's capacity is exceeded and refrigerant travels in liquid form through the suction line to the compressor. A lack of low-side air flow from a dirty evaporator coil, failing fan motor or undersized ductwork will cause refrigerant to pass through the evaporator in liquid form to a certain degree depending on the problem. As mentioned previously, the evaporator needs a heat load and refrigerant correctly metered to it in order to vaporize the refrigerant efficiently and assure no liquid returns to the compressor. Finally, a metering device such as a TXV that is stuck open could allow unrestricted refrigerant flow and cause evaporator flooding and compressor slugging.

In the off cycle, refrigerant wants to move toward the lowest temperature and pressure part of the system, which can be the compressor outside. This is called "*refrigerant migration*." The refrigerant will mix with the lower vapor pressure oil, and if enough migration occurs it will cause a flooded start. The refrigerant will boil rapidly out of the oil on startup and can take some or most of the oil out of the crankcase. This oil may take several minutes of system runtime to return to the compressor causing rapid bearing and pump wear.

To prevent refrigerant migration, crankcase heaters are used. A common type is the self-regulating PTCR, which varies its resistance according to the compressors oil temperature, so it only consumes energy when needed. These are usually the white, round units that fit in a well located in the crankcase. Another common one is the belly-band type that is fully on or off. Some manufacturers use run capacitance off-cycle heating. On single-phase compressors only one power leg is broken, leaving one hot leg to the run cap inducing a trickle charge through the start winding. This effectively turns the winding into a resistance heater and warms the compressor oil just enough to prevent migration. This is often seen in use on residential heat-pump applications.

Overheating of the compressor is another culprit of failure, which happens when it is forced to operate under loads and conditions it was not designed for. When the system is unable to reject heat, compression ratios and discharge temperatures elevate. Bearings can become hot enough to cook oil out, allowing metal-to-metal contact and cause extreme wear. Oil will start to break down at temperatures above 200°F and lose its ability to cool, lubricate and prevent corrosion.

This degraded oil will turn to sludge and clog orifices in the system, mainly the small metering-device passages. Clogged metering devices will cause even more stress on the compressor trying to pump against high discharge pressures. Overloads will eventually trip, but oil quality can be compromised in the process. Deposits from degraded oil will end up on hot valves and cylinder heads. This could lead to poor reed-valve sealing, decreased efficiency and capacity, broken valves and increased cylinder temperatures. Overheating of a refrigeration compressor is a destructive cycle that will lead to compressor failure if left unchecked.

Summary of Common **Compressor Problems**

If the compressor starts but the overload trips:

- A refrigerant overcharge can cause high startup and running amps.
- High or low voltage can cause the motor to over work with every start. Voltage should be tested when the compressor is starting and verified to be within the correct range of the manufacturer specs.
- Bad start components are a common source of startup problems. Generic relay kits can be used for temporary operation while waiting for factory components to be shipped.
- A high starting torque compressor should be used on systems with TXVs or when pressures are not sufficiently equalized during the off cycle.
- Compressors damaged during transport can experience mechanical problems. One that is dropped in shipment can cause the removal of the air gap between the stator and rotor in the motor, leading to a DOA compressor or high startup and running amps.

If the system has high energy consumption:

- Excess refrigerant causes the compressor to draw more energy while trying to pump the excess charge.
- Always be sure to verify that the correct replacement compressor was used. A compressor with too little capacity will cause long runtimes and reduced service life, and too much capacity will cause short cycling and inefficiency with every cycle.
- Excess oil mixes with the refrigerant, reducing system efficiency and increasing energy consumption.
- A mechanical defect can cause high startup and running amps.
- An electrical defect can cause high startup and running amps, as well increase energy consumption. Always check winding resistance.
- A faulty thermostat can cause long runtimes, look for signs of overcooling.
- Leaving doors open for long periods, overloading with hot product, or using the unit in applications it was not designed for also can increase energy consumption.

There are many reasons a compressor could overheat but a clogged condenser coil from poor maintenance is common, as are failed condenser fan motors. Sometimes it can be as simple as equipment location where condensers are located too close together and compete for air or units are stuffed into tight areas with poor air flow. Compressor motor windings are cooled by suction gas, so an undercharged or leaking system can lead to overheating as well. Any system suspected of overheating must have suction and discharge pressures analyzed and verified to be in the proper range. Superheat should be checked in systems equipped with fixed orifices and subcooling checked in TXV systems to verify correct refrigerant charge.

Electrical/oil issues

While it may not seem important to change electrical components when replacing a compressor, it is actually a must considering the lengthy service life of a properly installed compressor. A sticking relay can burn out the start winding in a very short time. Start windings are only meant to be energized during startup. Capacitors can wear and lose their microfarad rating. This can cause undue stress on the compressor with every start, leading to high startup amps and overheating.

One of the most common relays found on fractional-horsepower compressors is the current relay. This relay can be checked, after turning off and locking out the power supply, by checking for continuity through the coil terminals easily identified by the heavy copper wire connected to them; an infinity reading indicates an open coil and would require a new relay. Then, hold the relay in its mounted position and check the power or pin terminals. The current relay is normally open so there should be no continuity. Then turning the relay upside down should close its contacts and indicate the contacts are actuating properly. Correct overloads and capacitors should be verified by the manufacturer's spec sheet when servicing a compressor.

Excess oil in a system is sometimes overlooked when replacing a compressor. This oil could become trapped in the system from refrigerant migration and cause a flooded start. If the compressor fails before this oil returns the oil will remain in the system and cause inefficiencies by taking up space where the refrigerant would normally be. This oil could return in a large slug upon startup of the replacement compressor and cause bearing or valve damage.

It is good practice to pour the old oil into a container and compare it to the amount listed on the manufacturer's spec sheet. An amount less than 3% may indicate the need for a solvent flush for the tubing and coils followed by a dry nitrogen purge. Oftentimes, this oil is contaminated and removing it will insure good service life of a replacement compressor.

Denny Martin is the Aftermarket Distribution Technical Support Specialist/Product Line Manager for Embraco North America (a supplier of hermetic compressors for refrigeration systems) in Duluth, GA. In addition to supplying technical support to HVACR contractors and wholesale customers, he is responsible for product management of the aftermarket product line. Martin has 20 years' experience in the HVACR field. For more information, email denny.martin@embraco.com or visit www.embraco.com.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