Tech to Tech—April 07
Compressors Part 2

“Make daily deposits to your box of knowledge, soon it will have many reference cards” *Randal S. Ripley*

Compression Ratio:

Compression Ratio is the difference between the low and high sides of the compression cycle. It is calculated by the following formula:

$$\text{Compression ratio} = \frac{\text{Absolute discharge pressure}}{\text{Absolute suction pressure}}$$

Once the technician determines the compression ration, he can determine the *volumetric efficiency* of the cooling system and how efficiently it is operating.

When your gauges read 0 psig (pounds per square inch gauge), the *atmospheric pressure* at sea level is exerting a force of approximately 15 psi (pounds per square inch) on the gauge, so the gauges are calibrated to read zero at atmospheric pressure.

To calculated true or *Absolute pressure* at 0 psig the technician must add 14.696 (rounded up to 15 psi) to the gauge reading.

- Absolute discharge pressure = gauge reading + 15 psi
- Absolute suction pressure = gauge reading + 15 psi

A compression ratio of 8 to 1 is expressed as 8:1, this means the discharge pressure is 8 times the suction pressure.

Discharge and Suction Stroke:

Reciprocating compressors must have a clearance space between the piston and valve port at top dead center of the compression stroke. If this space wasn’t there a collision of the two parts would take place on each up stroke of the piston.

This clearance pocket traps a certain amount of refrigerant vapor that is at the discharge pressure, after the discharge valve closes. This left over vapor becomes compressed to the discharge pressure. When the downward stroke of the piston starts this vapor must be re-expanded to below the suction pressure before the intake valve can open and take in more suction gas.

However the piston has already completed part of its suction stroke by the time this vapor pressure is lower than the suction pressure. The cylinder is partially filled with the expanded clearance vapors before new gas is allowed in, taking space that would be occupied by the suction gas coming from the evaporator through the suction line.

This creates a situation where the total volume of the pistons cylinder is not being utilized by taking in new refrigerant vapor and is said to have a *volumetric efficiency*.

Volumetric Efficiency:

Volumetric efficiency is defined as a ratio of the actual volume of the refrigerant gas pumped by the compressor to the volume displaced by the compressor piston(s).

Volumetric efficiency is expressed as a percentage from 0 to 100, depending on the system. The higher the volumetric efficiency the more new refrigerant vapor is being introduced to the cylinder and circulated with each revolution of the crankshaft, resulting in the system operating at a higher capacity and efficiency.

System pressures play a major role on what a systems volumetric efficiency will be. The farther apart the system pressures are the lower the volumetric efficiency will be. This is because of the re-expansion of the discharge gases before the suction valve opens.

In summary the lower the compression ratio, the higher the volumetric efficiency and this equals lower energy usage.

Compressor or Condenser Installation:

- Regardless of what brand of equipment you install, a **filter drier** should be installed if the equipment doesn't have one factory installed. All Goodman units come with factory installed filter driers.

Goodman's compressor failure rate is lower than the industry average and they directly attribute this to the factory installed filter drier. Filter driers should not have more than a 2 degree temperature differential between the inlet and outlet. If higher you have the beginnings of a restricted drier.

I will not go into installation. That is a topic for another article. **For all questions about installation please refer to the Installation & Operating manual that comes with each unit.**

Compressors are affected by a multitude of other problems that could be happening in the system that cause it to stop working and are one of the most misdiagnosed components in this industry. Even though mechanical failure is not uncommon, many manufacturers say 1/3 of all returned compressors have no defect.

The hermetic compressor is not repairable and is replaced when found to have a defect, what caused the premature failure of the compressor often is repairable. Accurate diagnosis is the key.

In the air conditioning world, **you**, the start up or service technician are the compressor's doctor. Not only must you be able to understand the basic checks of the compressor, you must be able to detect & accurately diagnose the symptoms, determine what caused the problem, how to fix it and whether replacing the compressor is necessary.

Poor installation procedures are the cause of many compressor problems. When installed improperly, premature failure is going to be the result.

If you install another compressor without verifying what caused the failure, what do you think is going to happen again? Isn't that the definition of insanity, doing the same thing and expecting different results?

It is hard to know what is going on inside of a compressor because we can't see inside. But there are test that can be taken to let us know what is happening in there.

After replacing a compressor but before start up:

- Look for poor piping practices, resulting in oil not coming back to the compressor, such as necessary traps and line set sizing (refer to I & O manual)

- Does the unit require a crankcase heater and/or pump-down capability
- Does the unit have proper voltage to the line side of the contactor
- Is the unit wired correctly

Start up checks:

- Suction and discharge pressures
- Amount of superheat at the condensing unit
- Amount of sub-cooling
- Suction gas temperature
- Discharge gas temperature
- Amperage and applied voltage
- Verify CFM (airflow) of the system
- Temperature split across the coil--difference between return & supply temperature

Some typical causes and/or indicators of future compressor failure:

- Liquid returning to the compressor
- High suction gas temperature or superheat
- Subcooling—abnormally high or low
- High discharge temperature
- Non-condensables
- Incorrectly applied voltage
- Improper pipe sizing and/or trapping

Let’s address each of these:

Liquid returning to the compressor:

Signs to look for: low suction pressure, low superheat reading, frosted suction line, low condensing pressure due to unit running when outside temperature is low (computer room or other space with heat generating equipment).

In sufficient airflow across the evaporator coil, is the blower running, check temperature drop across the coil (should be 18-22), verify actual airflow across coil (by static pressure method, temperature rise method, duct traverse method)

- Also see migration, flooding & slugging in part 1

High suction gas temperature or high superheat:

Compressor windings and other moving parts are cooled by suction gas**.** The resulting elevated discharge temperature can cause the insulation on the windings to break down causing eventual compressor burnout and/or cause the oil to breakdown and loose its lubrication qualities.

Sub-cooling:

High sub-cooling can be a sign of an overcharge that can cause a cold or frosted suction line and refrigerant return to the compressor or a restriction in the liquid line or metering device which will cause high superheat on the other side of the system.

Food for thought: if you have a fixed orifice metering device and have abnormally low suction and high side pressures with high superheat this could be a sign of two different things, a liquid restriction with a correct charge or an undercharge or loss of refrigerant due to a leak.

The only difference in these two problems is their sub-cooling. The restriction will have high sub-cooling and the under charge or leak will have low sub-cooling.

<u>High discharge temperature</u>: You can tape or use a Velcro strap to attach a beaded thermistor or use my personal favorite "the pipe clamp temperature probe", to measure discharge temperature about 6" for the outlet of the compressor.

Discharge temperatures above 300 degrees will slowly breakdown the oils lubricating abilities and the performance of the compressor.

Plugged condensers are probably the number 1 problem that creates high discharge pressures.

The condenser coil is larger than the evaporator coil because it has the task of rejecting the heat load of the evaporator coil, superheat, and the heat of compression (which includes the heat generated by the motor windings and other moving parts). Therefore, it is extremely important that airflow through the condenser not be impeded by a partial blockage of the coil.

Hot and/or humid temperatures, insufficient refrigerant charge, non-condensables, high superheat from the evaporator, restricted suction line filters and low suction pressure, can also be the cause of high condensing temperatures and pressures. These conditions cause high compression ratios, the compressor to work harder and hotter internal hermetic motor windings that can result in premature failure of the compressor.

<u>Non-condensables:</u>

Non-condensable gases such as water vapor, nitrogen and air enter a residential/light commercial air conditioning system in one of two ways:

1. They are left behind from an improper evacuation & charging at the factory, improper evacuation after installation or from the service technician's refrigerant gauge hoses.
2. The suction side of the system has a leak and enough refrigerant has been lost to cause the compressor to draw a vacuum, pulling air into the system and the service technician then adding refrigerant without repairing and evacuating the system.

The non-condensable vapors will pass through the compressor because the compressor is basically a vapor pump and settle in the top rungs of the condenser tubing. These non-condensables take up valuable condenser surface area and will cause high head pressure.
The sub-cooled liquid at the bottom of the condenser forms a seal that prevents vapor from escaping.

The high head pressure causes a higher temperature differential between the liquid temperature in the condenser and the ambient air entering the condenser, resulting in more sub-cooling.

When using a thermostatic expansion valve, non-condensables and an overcharged system have similar symptoms.

Symptoms of non-condensables include:

- High head pressures
- Low sub-cooling
- High Compression ratios
- High discharge pressures

<u>Improper Voltage:</u>

Neither, too little or too much voltage is good for a compressor. Compressor are usually designed to run within + or – 10% of the rated voltage. Verify voltage and take corrective action if necessary.

Improper Pipe Sizing or Trapping:
See sections on line sets and trapping in part 1

RLA:
Many technicians mistakenly call this *Running Load Amps* instead of its proper terminology *Rated Load Amps*.

In order to provide a uniform basis for nameplate values in accordance with the Underwriters Laboratory, Copeland establishes a "*Rated Load Amp*" value for each compressor. This is arbitrarily on the basis of 71% of the maximum continuous current allowed by the motor protection system. This will allow the compressor motor to draw 140% of the "Rated Load Amp" value prior to the protector tripping.

A compressor by itself cannot have a set running load amperage because the compressor amp draw varies greatly depending on the load.

LRA:
Locked rotor current is defined as the current drawn by a motor which is locked from motion. This occurs very briefly during start up. The current to load the winding, overcome inertia, and create the starting torque is enormous; approximately 6 to 7 times the Rated Load Amps (RLA).

The current drawn by a 7.5 hp motor during start for just a split second approaches 160 amps. The contacts must handle this heavy current and heat and open and close rapidly so that minimum arcing will occur. The contacts must be able to dissipate any heat build up rapidly so that rapid cycling will not cause overheated and welded contacts.

Internal Overload Protection:
Since the motor is a large percentage of the cost of the compressor, most compressors use an internal overload protector mounted inside the compressor enclosure so that it is in direct contact with the motor. An internal protector responds quickly to any heating condition which could degrade the insulation and cause a motor failure.

This protector is either strapped to the winding or held in a specially designed clip on the motor winding. The internal protector adds protection from loss of charge and low loads. Both result in low mass flow and a lack of motor cooling.

It also protects against locked rotor and frequent maximum load conditions that overheat the windings and cause winding insulation to degrade and ultimately the compressor windings to burnout.

In welded compressors particularly, the motor is entirely dependent on suction gas for cooling so this is a highly desirable type of protection.

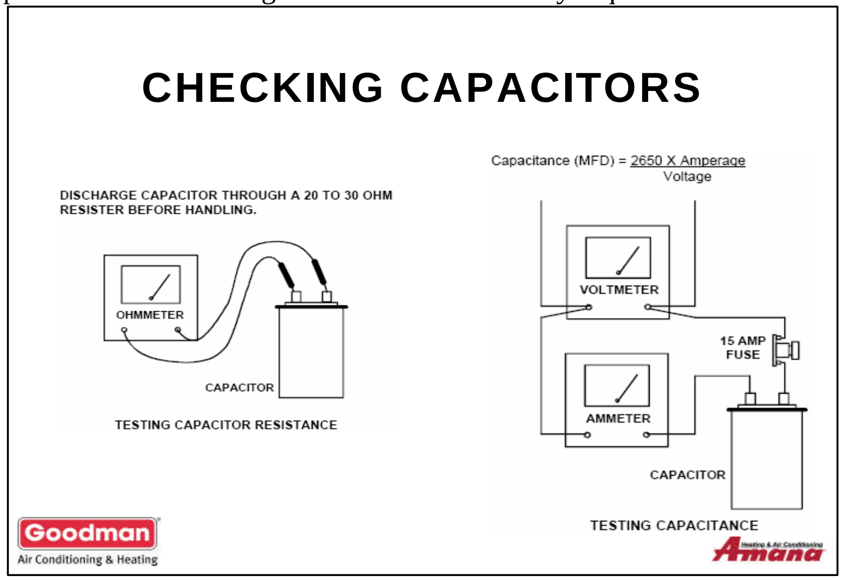
Hard Start Kit:
Every technician should have at least one of these devices on his truck. They can solve many compressor start problems on single phase compressors and are great for freeing up a locked rotor.

This device is basically a start capacitor with a switching device built in (typically a potential relay) with two wires that are connect across the run and start winding by connecting the two wires to the common and herm terminals of the capacitor in the condensing unit.

This device provides a big kick to the compressor to help it get started and then the potential relay opens at a specified voltage above the line voltage, removing the start capacitor from the circuit and the motor continues to run.

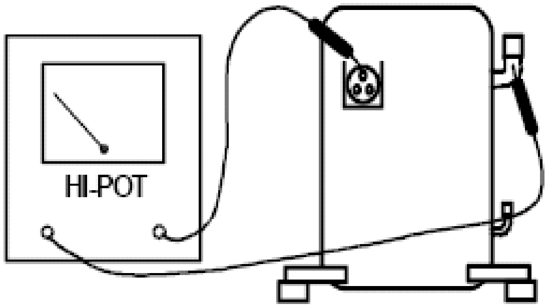
Some Manufacturers recommend only using factory approved hard start kits.

Run Capacitors:
A run capacitor is designed to stay in the circuit all the time and packaged in a metal can. Since run capacitors are in the circuit at all times and connected in series with the start winding, they are subject to line voltage plus the induced voltage. A 250 volt motor may require a 320 to 450 volt capacitor. Always use the next highest voltage rating if there is any doubt. MFD rating must always be the same as the original. Follow the manufacturer's specification.

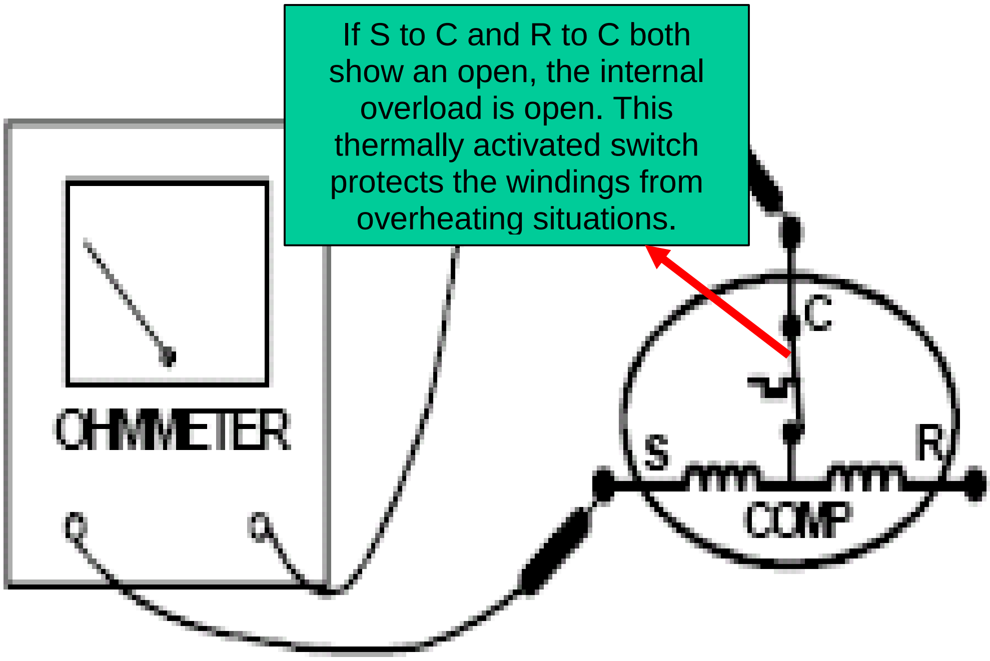


It should be noted that if the run capacitor has polarity, the terminal that is marked should always be wired to the 'R' terminal of the motor. This keeps a grounded capacitor from burning out the start winding. The new style capacitor is made from a material which will burn itself free of a grounded condition.

When checking the windings to ground set your meter to its most sensitive ohms reading scale. There should be no continuity between any of the windings and ground.



COMPRESSOR GROUND TEST



TESTING COMPRESSOR WINDINGS

If the thermal overload is open the compressor will have to be cooled down and then checked again. It can take hours for the heat deep in the winding to dissipate and I have seen it take an overnight.

Signs of bad Compressor valves:

Damaged or broken suction and/or discharge valves on reciprocating or scroll flanks on scroll compressors cause inefficiency and reduce the compressors ability to pump refrigerant vapor. Some signs of compressor inefficiency are:

- Unit runs continuously with very little cooling
- Low head pressure
- High suction pressure
- For broken valves add compressor will be noisy

Some compressors manufacturers recommend you check the valves or flanks by:

1. Attaching gauges to both the high and low side
2. Start the system and run a cooling performance test. If the test shows **ALL** the following symptoms and the charge is correct, the compressor is faulty-replace the compressor.
    - **Below** normal high side pressure
    - **Above** normal low side pressure
    - **Low** temperature difference across coil
    - **Low** amp draw at compressor

There is also a pump down test that can be used but **YOU** should always refer to the manufacturer's service manual or technical support to see what test are recommended.

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<u>WINDING VALUES</u>
<u>C to R …… The lowest amount of Ohms</u>
<u>C to S ……. The next highest reading of Ohms</u>
<u>R to S ……. The highest reading of Ohms</u>
<u>C to R ……. 1 Ohm</u>
<u>C to S ……. 4 Ohms</u>
<u>R to S ……. 5 Ohms</u>

If C to R + C to S = R to S, in a single phase compressor the windings are good.

Causes of Mechanical Compressor Failures:
- Refrigerant Flood back
- Flooded Starts
- Slugging
- Compressor Overheating
- Loss of Oil

Causes of Low Load Conditions:
- Blocked Airflow
- Dirty Evaporator coils
- Frosted Evaporator Coils
- Broken Evaporator Fan Blade
- Burned Out Evaporator fan

Causes of Overheating:
- High Compression Ratios
- High Return Gas Temperature
- Lack of External Cooling

High Compression Ratios Result From:
- Low Suction Pressure
- High Discharge Pressure
- Combination of Both

Causes of Low Suction Pressure:
- Loss of Refrigerant Charge
- TEV Adjusted Wrong
- Plugged Drier or TEV Strainer
- Suction Line Pressure Drop

Causes of High Condensing Pressure:
- Blocked Condenser
- Dirty Condenser
- Undersized Discharge
- Re-circulation of Condenser Air
- Inoperative Condenser Fan
- Overcharge
- Air in System
- Undersized System

Key Facts about Oil Temperatures:
- Oil Vaporizes at 310-320 Degrees—Causing Ring and Cylinder Wear
- Breaks Down at 350 Degrees—Creates Contaminates and Accelerated Wear

Causes of Loss of Oil Failures:
- Poor Piping
- Improper Traps
- Inadequate Defrost (Heat Pumps)
- Loss of Charge
- Short Cycling
- Low Loads