Why Compressors Fail

Causality
eFlex™ Variable Speed Compressors
Lower Operating Cost through 10%-15%
Improvement in Part Load Efficiency
Common Compressor Types

- Reciprocating compressors with hermetic/semihermetic or open type designs
- Rotary compressors
- Scroll compressors
- Screw compressors
- Centrifugal compressors
Rotary
Reciprocating
Rotary

Operation

1. Completion of intake stroke; beginning of compression
2. Compression stroke continued; new intake stroke started
3. Compression continued; 3 new intake stroke continued
4. Compressed vapor discharged to the condenser; new intake stroke continued

High-pressure vapor
Low-pressure vapor
Scroll
What is needed to understand

- The compressor is the heart of the system
- Anything in the system that goes wrong will eventually reflect on the compressor performance.
- 95% of compressor failures are not attributed initially to the compressor itself.
- If a compressor fails and you just replace it you could have another failure.
Types of Failure

- Mechanical, component/system related problems
- Electrical problems
Vapor-Compression Cycle

A: evaporator
B: compressor
C: condenser
D: expansion device

Energy in: absorb heat
Reject heat: condenser

System Components
TXV Operation

- Valve diaphragm
- Spring
- 49°F [94°C]
- 79 psia [0.54 MPa]
- 97 psia [0.67 MPa]
- 79 psia [0.54 MPa]
- 18 psi [0.13 MPa]
- Suction line
- Valve pin
Basic Refrigeration System and subcomponents

- Shutoff valve
- Liquid-line filter drier
- Solenoid valve
- Sight glass
- TXV
- Condenser
- Access port
- Suction line filter
- Evaporator
- Compressor
Categories of Failures

- Incorrect application
- Incorrect design, installation or operation.
- System component failures or application
- Malfunctioning, improperly applied or wrong settings in controls.
- Improper maintenance
- Incorrect diagnosis
- Power not within equipment requirements
- Improper wiring or components.
The Failure

• Most Failures are preventable!
• Replacing compressor often is only a short term solution.

Compressor failures can normally be traced back to:

1. Refrigerant Floodback
2. Contamination
3. Lack of Lubrication
4. System Contamination
5. Electrical Problems
6. Overheating
7. Internal motor temp switch and
   No Compressor overload

7. No failure
The Failure

- Many compressors run thousands of hours without oil changes, new parts, a tuneup or any other form of maintenance.
- Preventative maintenance is the key to compressor longevity.
Preventative maintenance

- Keep Coils Clean
- Replace filters
- Check pressure drops
- Check Design Subcooling/Superheat
- Check system loading
- Check fan controls
- Check safeties
- Check power
- Vibration levels
Mechanical Failure Modes

- **Liquid Slugging at Start Up:** The air coil may store too much refrigerant during the off cycle. In certain conditions liquid refrigerant may be allowed to enter the compressor. Over time this can cause bearing damage.

- **Liquid Refrigerant Migration:** In certain conditions during long off cycles refrigerant may accumulate (Migrate) in the sump of the compressor. When the compressor starts it may attempt to pump some liquid. Furthermore liquid in the sump may cause the oil to become diluted. Over time this can cause bearing damage.

- **Low or No Refrigerant:** Units manufactured between February 2002 and February 2006 may not have loss of charge protection. Therefore, if units manufactured during this period are run in a No/Low refrigerant condition. This can cause the compressor to run hot and the compressor will not pump enough oil to properly lubricate the compressor bearing. Running in this condition can cause bearing damage and or a compressor burn out.

- **Low Oil:** Low oil may be caused by either an excessive amount of liquid refrigerant that washes out the oil in the sump of the compressor, and/or low oil charge. Running in this condition can cause bearing damage.

- **Thermal Overload Failure:** Overloads usually are the last thing to fail on the compressor. In most cases when an overload fails this means that the compressor has a mechanical problem. The only cases where this is not true is in the event that the compressor is attempting to start in a low voltage condition or if the compressor is short cycling and the refrigerant pressures are not equalized.
Liquid returning to compressor

- Liquid coming to compressor
  - Flooded start
  - Flooding
  - Liquid or oil slugging

- Discharge pressures go over 1,000 PSI
FloodBack

- Oversized Metering device
- TXV not operating within design
- Head pressure to high and or low pressure to low
- Low Evaporator air flow
- Refrigerant overcharge
- Oversized system
- Low load
Oversized metering device:

- An oversized metering device can allow more refrigerant to enter the evaporator than the evaporator can vaporize. Therefore, the extra liquid refrigerant will pass down the liquid line and enter the compressor.
TXV superheat set too low

- The superheat must be allowed to change in order for the sensing bulb to make corresponding adjustments to the valve opening while it maintains the set superheat. A low superheat setting can allow the superheat to fall to zero. This condition will cause the valve to close and the superheat will soon rise well above its setting.

- This in turn can cause the valve to reopen wider than necessary and overshoot the superheat setting. This condition is called hunting. On one of the valve's swings to the wide open position, liquid refrigerant can flood the suction line and allow liquid to enter the compressor, a potentially damaging condition.
TXV thermal bulb loose or not thermally tight

- A loose thermostatic sensing bulb will sense warmer air temperature rather than the cooler refrigerant temperature leaving the evaporator. The warmer bulb will move the valve to a position opening larger than normal and allow liquid to flood back to the compressor.

- Not only should the thermal sensing bulb be mechanically and thermally tight on the line, it's always a good idea to insulate the bulb and the line where the bulb is located. Remember, both the sensing bulb and the refrigerant line are round; very little surface area of each actually contact each other. It's amazing that so little bulb-to-line contact actually works without insulation covering them.
Head pressure too high and/or low pressure too low

- The pressures across the metering device affect the amount of refrigerant that will be forced through the metering device. As the high pressure increases or the low pressure decreases more refrigerant will tend to enter the evaporator. A higher-than-normal high-side pressure and/or a lower-than-normal low-side pressure oversizes the metering device. It's similar to having the wrong size metering device installed in the first place.
- It's possible for a liquid floodback condition to occur if the high-side pressure is too high, the low-side pressure is too low or if there's a combination of the two. Airflow restrictions of all kinds on both the evaporator and condenser coils are common causes of higher-than-normal head pressures and lower-than-normal suction pressures. Each of these could cause liquid floodback and the loss of the compressor.
Low evaporator airflow

- Having discussed how low evaporator airflow can effectively increase the operating capacity of the metering device and cause liquid floodback, it's still important to look at how the evaporator air flow can cause liquid floodback for yet another reason.
- The air moving across the evaporator contains the heat that vaporizes the liquid entering the evaporator. In order for all the liquid refrigerant in the evaporator to vaporize completely, there must be enough air bringing enough heat to the evaporator to do so. The lack of air across the evaporator also means less heat is available to vaporize all of the liquid. The remainder of the liquid refrigerant can cause floodback and potentially cause mechanical damage.
Refrigerant overcharge

- An overcharge of refrigerant simply means that more refrigerant exists in the system than the evaporator and condenser were designed to operate with. More refrigerant is in the evaporator than the evaporator has surface area to vaporize. The result is the extra refrigerant flooding back to the compressor.
Causes of electrical failures

- Voltages outside design
- Single phasing
- Voltage imbalance
- Current imbalance
- System contamination
Contamination

- Air
- Moisture
- Chips and Dirt
- Acid
- Burnout residue
Causes of Overheating

- Lack of compressor cooling
- Lack of condenser cooling
- Air in system
- System restrictions
Oil Loss causes

- Low refrigerant velocities
- Short cycling
- Low load, or excessive unloaded state
- Improper system design
- Wrong piping
- Low refrigerant charge
- Plugged accumulator oil return
- Oil heater failure
- Improperly designed or installed traps or piping
Excessive Vibration

- Broken Valves
- Blown gaskets
- Broken rods or Crankshaft
- Oil Trapping
- System Flooding
- TXV problems
- High oil level
- Defective capacity controls
No Overload protection

• When is simply using an internal compressor temperature protector problems will development.
  – Compressor can be off for several hours with a call for cooling enabling the compressor to be flooded with refrigerant.
  – A motor temperature control is simply a last line of defense when everything else fails.
  – Compressor could cycle on motor temperature control leading to compressor failure.
  – You need a compressor overload to protect the compressor from damage.
Reciprocating
Scroll
Scroll Protection

Oil Fill Connection & Gauge Port

Oil Drain Connection
Centrifugal control panel starter
Why Screw Compressors Fail

- The majority of failed screw compressors are attributed to seizures. A seizure is considered any metal-to-metal rub within the compressor that ceases rotor rotation. This type of failure is not surprising when trying to keep the rotating components and their housings separated by dimensions measured in ten thousandths of an inch. Most of these clearances are established by precision machining and press fits, but rotor discharge end clearance must be set and measured by hand. This critical clearance has a narrow range of 0.0006 of an inch. If it is set too large, the compressor runs poorly and potentially seizes; if set too small, the compressor will very likely seize. This particular failure mode is Pueblo’s number one opportunity in improving GP and GP2 screw compressor product reliability.
Requirements Reciprocating Compressors

- Superheat at compressor
  - 15 deg min to 20 deg (at Compressor).
  - @ oil sump running > 20 deg Sump temp - Suction temp
  - @ oil sump off > 20 deg Sump temp - Suction temp
  - Discharge 65 deg.

- Sub cooling
  - Per manufactures design at design conditions.

- Oil pressure
  - Manufactures design

- Discharge temperature (12 inches form Comp)
  - Less than 275 deg. (Valve temps 50-75 deg higher)
  - Greater than 160 deg.
  - Oil break down at 350 deg.
Something new

- VFD on Compressors
- Scroll unloaders
- Multispeed Compressors
- Phase protection
Phase Protection

INT69 DMY® Motor protector
Part-No. 22 A 190
Line AC 50/60Hz 115/120V 230/240V -15...+10% 3VA
Amb. temp. range -30...+70°C
Relay AC 240V, max 2.5A, C300
Phase sensor 3 AC 50/60Hz 120...632V

Phase Sequence Input

L1 L2 L3
Black Blue Brown

L N S1 S2 M1 M2

Module Power 24or115/230vac

Internal Control Contact

Safety Circuit

Thermistor Connection
2 speed scroll compressor

2-Speed Power Circuit
(Two-Pole Operation — 3500 RPM)

(Four-Pole Operation — 1750 RPM)

T1 — Phase A
T2 — Phase B
T3 — Phase C
T4 — Phase A
T5 — Phase B
T6 — Phase C
High Speed Terminal Block
Low Speed Terminal Block
Motoring Winding Thermostat

L1
L2
L3
CL
(Mech. Interlock)

CH
CT
Scroll Compressor with unloading

![Scroll Compressor](image)

![Graph showing unloader modulation (%) vs. demand signal (VDC)]
Scroll Loading

- Loaded
- Unloaded

- Modulation Chamber at High Pressure
- Solenoid Valve Closed
- Modulation Chamber at Low Pressure
- Piston
- Solenoid Valve Open
VFD on Reciprocating Compressors

- Never run VFD less than 30HZ you will lose oil flow and will not cool down compressor adequately
- Torque stays relatively constant form 5-60 HZ
- On 460 volt motors run 30HZ at 230volts
- Can not use other forms of unloading with VFD
- USE 4-20 ma signal not 2-10 VDC controlled off system demand.
- Any power contactors can only be opened after drive is stopped
- Compressor up to speed in 3 seconds or less
VFD on Scroll Compressor

- HZ range 45-75 HZ
- Discus 25 HZ
- Can not use other Capacity control methods IE Copleland digital compressors
- USE 4-20 ma signal not 2-10 VDC controlled off system demand.
- Any power contactors can only be opened after drive is stopped
- Compressor up to speed in 3 seconds or less
Range Examples

![Graph showing voltage vs. frequency for 460V and 230V line voltages.]

<table>
<thead>
<tr>
<th>Model Family</th>
<th>Speed Range</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D, 4D, &amp; 6D</td>
<td>25 - 60 Hz</td>
<td>Contact your Emerson Climate Technologies representative for extended operating ranges.</td>
</tr>
<tr>
<td>Refrigeration Scroll (ZB,ZS,ZF)</td>
<td>45 - 60 Hz</td>
<td></td>
</tr>
<tr>
<td>Air Conditioning Scroll (ZP,ZR)</td>
<td>45 - 70 Hz</td>
<td></td>
</tr>
</tbody>
</table>
VFD setup Example

25 Hz Minimum Frequency (45 Hz for scroll)
60Hz Maximum frequency (70 HZ for air conditioning scroll products)
5 sec Acceleration ramp
10 sec Deceleration ramp
Motor rated current (A)
1750 Motor Rated Speed (3500 for scroll)
460 Motor rated voltage
3kHz Switching frequency
60 Motor rated frequency
Scroll Variable speed compressor

Brushless Permanent Magnet

Proven Copeland Scroll platform enhanced for variable speed

- Optimized Scroll elements for variable speed performance
- Temperature sensing for Scroll and motor temp protection
- BPM motor technology for highest efficiency
- Proven centrifugal oil pump for oil delivery at low speed

Enabled via communicating system control electronics

- System provides percent speed signal to motor control drive
- Motor control drive converts AC line input to power DC BPM motor
- Motor control drive protects compressor and communicates diagnostics to system control
BPM Motor Controller
Variable speed advantage

Up to 60% capacity reduction turndown

Nearly 60% overspeed capability

Up to 13 HSPF (Heating Seasonal Performance Factor), 29% greater efficiency than today's best heat pumps on the market

The ability to constantly maintain a hotter air supply - even during low ambient winter conditions.
Conclusion

- Always find the Root cause of any compressor failure!
- Always conduct required preventative maintenance.
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