# Application Engineering

## *Compression Ratio As It Affects Compressor Reliability*

**BULLETIN NO:** AE17-1268 R1

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# Safety

## Important Safety Information

Those involved in the design, manufacture, and installation of a system, system purchasers, and service personnel may need to be aware of hazards and precautions discussed in this section and throughout this document. OEMs integrating the compressor into a system should ensure that their own employees follow this bulletin and provide any necessary safety information to those involved in manufacturing, installing, purchasing, and servicing the system.

## Responsibilities, Qualifications and Training

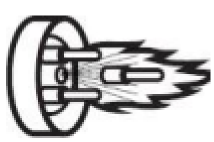
• OEMs are responsible for system design, selection of appropriate components, integration of this component into the system, and testing the system. OEMs must ensure that staff involved in these activities are competent and qualified.

• OEMs are also responsible for ensuring that all product, service, and cautionary labels remain visible or are appropriately added in a conspicuous location on the system to ensure they are clear to any personnel involved in the installation, commissioning, troubleshooting or maintenance of this equipment.

• Only qualified and authorized HVAC or refrigeration personnel are permitted to install, commission, troubleshoot and maintain this equipment. Electrical connections must be made by qualified electrical personnel.

• Observe all applicable standards and codes for installing, servicing, and maintaining electrical and refrigeration equipment.

## Terminal Venting and Other Pressurized System Hazards



If a compressor's electrical terminal pin loses its seal, pressurized oil, refrigerant, and debris may spray out. This is called "terminal venting".

The ejected debris, oil, and refrigerant can injure people or damage property. The oil and refrigerant spray can be ignited by electrical arcing at the terminal or any nearby ignition source, producing flames that may project a significant distance from the compressor. The distance depends on the pressure and the amount of refrigerant and oil mixture in the system. The flames can cause serious or fatal burns and ignite nearby materials.

Each compressor has a terminal cover or molded plug that covers electrical connections. The cover or plug helps to protect against electric shock and the risks of terminal venting. If terminal venting occurs, the cover or plug helps contain the spray of refrigerant and oil and reduces the risk of ignition. If ignition occurs, the plug or cover helps contain the flames. However, neither the terminal cover nor the molded plug can completely eliminate the risk of venting, ignition, or electric shock.

See copeland.com/terminal-venting for more details about terminal venting. Additionally, a compressor's refrigerant lines keep refrigerant and oil under pressure. When removing or recharging refrigerant from this component during service, this can pose a pressurized fluid hazard.

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## Flammable Refrigerant Hazards

If flammable refrigerant is released from a system, an explosive concentration can be present in the air near the system. If there is an ignition source nearby, a release of flammable refrigerant can result in a fire or explosion. While systems using flammable refrigerant are designed to mitigate the risk of ignition if the refrigerant is released, fire and explosion can still occur.

See copeland.com/flammable-refrigerants for more information on flammable refrigerant safety.

## Electrical Hazards

Until a system is de-energized, and capacitors have been discharged, the system presents a risk of electric shock.

## Hot Surface and Fire Hazards

While the system is energized, and for some time after it is deenergized, the compressor may be hot. Touching the compressor before it has cooled can result in severe burns. When brazing system components during service, the flames can cause severe burns and ignite nearby combustible materials.

## Lifting Hazards

Certain system components may be very heavy. Improperly lifting system components or the compressor can result in serious personal injury. Use proper lifting techniques when moving.

## POE Oil Hazards

This equipment contains polyol ester (POE) oils. Certain polymers (e.g., PVC/CPVC and polycarbonate) can be harmed if they come into contact with POE oils. If POE oil contacts bare skin, it may cause an allergic skin reaction.

## Precautions

• Always wear personal protective equipment (gloves, eye protection, etc.).

• Keep a fire extinguisher at the jobsite at all times.

• Keep clear of the compressor when power is applied.

- IMMEDIATELY GET AWAY **if you hear unusual sounds in the compressor. They can indicate that terminal pin ejection may be imminent. This may sound like electrical arcing (sizzling, sputtering or popping). However, terminal venting may still occur even if you do not hear any unusual sounds.**

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• Never reset a breaker or replace a blown fuse without performing appropriate electrical testing

- **A tripped breaker or blown fuse may indicate an electrical fault in the compressor. Energizing a compressor with an electrical fault can cause terminal venting. Perform checks to rule out an electrical fault.**

• Disconnect power and use lock-out/tag-out procedures before servicing.

- Before removing the terminal cover or molded plug, check that ALL electrical power is disconnected from the unit. Make sure that all power legs are open. (Note: The system may have more than one power supply.)

- Discharge capacitors for a minimum of two minutes

- Always use control of hazardous energy (lock-out/tag-out) procedures to ensure that power is not reconnected while the unit is being serviced.

• Allow time for the compressor to cool before servicing.

- Ensure that materials and wiring do not touch high temperature areas of the compressor.

• Keep all non-essential personnel away from the compressor during service.

• For A3 refrigerants (R290) remove refrigerant from both the high and low sides of the compressor. Use a recovery machine and cylinder designed for flammable refrigerants. Do not use standard recovery machines because they contain sources of ignition such as switches, high- and low-pressure controls and relays. Only vent the R290 refrigerant into the atmosphere if the system is in a well-ventilated area.

• Never use a torch to remove the compressor. Only tubing cutters should be used for both A2L and A3 refrigerants.

• Use an appropriate lifting device to install or remove the compressor.

• Never install a system and leave it unattended when it has no charge, a holding charge, or with the service valves closed without electrically locking out the system.

• Always wear appropriate safety glasses and gloves when brazing or unbrazing system components.

• Charge the system with only approved refrigerants and refrigeration oils.

• Keep POE oils away from certain polymers (e.g., PVC/CPVC and polycarbonate) and any other surface or material that might be harmed by POE oils. Proper protective equipment (gloves, eye protection, etc.) must be used when handling POE lubricant. Handle POE oil with care. Refer to the Safety Data Sheet (SDS) for further details.

• Before energizing the system:

1. Securely fasten the protective terminal cover or molded plug to the compressor, and

2. Check that the compressor is properly grounded per the applicable system and compressor requirements.

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## Signal Word Definitions

The signal word explained below are used throughout the document to indicate safety messages.

| | |
|---|---|
| DANGER | **DANGER** indicates a hazardous situation which, if not avoided, will result in death or serious injury. |
| WARNING | **WARNING** indicates a hazardous situation which, if not avoided, could result in death or serious injury. |
| CAUTION | **CAUTION**, used with the safety alert symbol, indicates a hazardous situation which, if not avoided, could result in minor or moderate injury. |

# Introduction

## Compression Ratio as It Affects Compressor Reliability

The compression ratio at which a compressor operates is critical to compressor life. Field failure experience would indicate a growing need for better understanding on the part of the operating and service engineer as to the causes and effects of excessive compression ratios.

Compression ratio is a term describing the compression cycle in a compressor cylinder, and while suction and discharge pressures are used to calculate it, the ratio itself is independent of pressures.

By definition, compression ratio is the ratio of the absolute discharge pressure (psia) to the absolute suction pressure (psia). Absolute pressure is defined as the pressure existing above a perfect vacuum. Therefore, in the air around us, absolute pressure and atmospheric pressure are the same. A pressure gauge is calibrated to read 0 psig when not connected to a pressure producing source, so the absolute pressure of a closed system will always be gauge pressure plus atmospheric pressure. Pressure below 0 psig are actually negative readings on the gauge and are referred to as inches of vacuum. A refrigeration compound gauge is calibrated in the equivalent of inches of mercury for negative readings. Atmospheric pressure at sea level is approximately 14.7 psi, or 29.92 inches of mercury, so two inches of mercury on the gauge are approximately equal to 1 psi.

Atmospheric pressure varies with altitude and weather conditions, but for purposes of this discussion we will consider only conditions at sea level.

To illustrate the calculation of compression ratio, consider two different examples.

Example 1

| | | |
|---|---|---|
| Suction pressure | = 30 psig | = 44.7 psia |
| Discharge pressure | = 433 psig | = 447.7 psia |
| Compression ratio | = 447.7 / 44.7 | = 10 to 1 |

Example 2

| | | |
|---|---|---|
| Suction pressure | = 10 inches of vacuum | = 9.7 psia |
| Discharge pressure | = 83 psig | = 97.7 psia |
| Compression ratio | = 97.7 /9.7 | = 10 to 1 |

It is important to distinguish between excessive pressures and excessive compression ratios because each condition causes totally different wear patterns.

Excessive pressures, either discharge or suction, can create bearing loading beyond the bearing design limits, and eventually will cause connecting rod, crankshaft, and bearing damage.

With excessive compression ratios, the wear occurs at the pin connecting the piston to the connecting rod. As the gas is compressed on the piston discharge stroke, it becomes much more dense than the entering suction gas. Since the gas remaining in the cylinder clearance area does not leave the cylinder on the discharge stroke, it re-expands on the suction stroke. As the compression ratio increases, the difference between the two densities becomes greater, and eventually a point is reached where the residual high-pressure gas actually presses the piston down for most of the down stroke, not only preventing suction gas from entering the cylinder, but more critically keeping the piston pin, starving the pin of lubrication, and creating a wear pattern. Eventually the round pin hole in the connecting rod will be worn egg shaped, and from that point on the play between rod and pin will quickly accelerate additional wear.

Enlarging and strengthening the rod and pin bearing surfaces will increase the compressor's ability to withstand high compression ratios, but the only way to prevent pin damage is to maintain the compressor's operation within allowable limits. Compressors are capable of operating within the limits of their recommended operating parameters without piston pin stress, but operation beyond those limits can cause pin damage.

Field failures of this type can result from operation after losing a condensing fan motor, operating under loss of charge conditions, or more commonly, from operation at excessively low suction pressures. The service engineer who sets the low-pressure control for a lower cut-out point beyond the compressor design limits to obtain a lower

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evaporating temperature may be unknowingly starting a failure pattern. The number of low-pressure controls that are found bottomed out in field investigations indicates this is not an uncommon occurrence.

Changes in suction pressure at low evaporating temperatures have a much greater effect on compression ratio than the same pressure difference at higher pressures, so the field setting of the low-pressure control is obviously the most critical area, as shown in **Table 1**.

It has been a commonly accepted industry rule of thumb that compression ratios above 10 to 1 were the limits of a compressor's capability, but the figures in Table 1 clearly demonstrate that compression ratios of that magnitude are routine in every supermarket and must be exceeded for air-cooled operation of low temperature systems in desert areas.

Both compressor construction and time of exposure are critical factors in determining a compressor's capability to withstand high compression ratios. Lighter duty welded compressors such as the Copelaweld® normally should not be applied beyond compression ratios or 7.5 to 1. The heavier duty Copelametic® models can operate at compression ratios up to 15 to 1 and higher for reasonable periods of time, but for long life, compression ratios of 12 to 1 or less are desirable.

While there has not been any laboratory testing to evaluate the effects of operating in a vacuum with some of the non-standard refrigerants such as R-13, field experience indicates wear patterns of a similar nature may be aggravated at lower compression ratios with R-13 than with R-502, which could mean the solvent qualities of some of the ultra-low temperature refrigerants may be a complicating factor.

In addition to the piston pin wear problem, excessive compression ratios are directly related to excessive discharge temperatures. It is possible that excessive discharge temperatures can be controlled by liquid desuperheating valves or other means, but the basic mechanical wear problem can only be prevented by operating within acceptable limits.

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# *Table*

*Table 1 Effects of Changes in Pressure on Compression Ration with R502*

| Condensing Temperature | PSIG | PSIA | Evaporating Temperature | PSIG | PSIA | Compression Ratio |
|---|---|---|---|---|---|---|
| 110°F | 247.9 | 262.6 | 0°F | 31.08 | 45.78 | 5.7 |
| | | | -10°F | 22.56 | 37.26 | 7.1 |
| | | | -20°F | 15.31 | 30.01 | 8.8 |
| | | | -30°F | 9.20 | 23.90 | 11.10 |
| | | | -40°F | 4.11 | 18.80 | 14.0 |
| | | | -50°F | 0.2” | 14.60 | 18.0 |
| | | | -60°F | 7.15” | 11.18 | 23.5 |
| 100°F | 216.2 | 230.9 | -30°F | 9.2 | 23.90 | 9.7 |
| 110°F | 247.9 | 262.6 | | | | 11.0 |
| 120°F | 282.7 | 297.4 | | | | 12.4 |
| 130°F | 320.8 | 335.5 | | | | 14.0 |

**Revision Tracking R1**

The document format has been updated to the new Copeland format.

All occurrences of "Emerson" have been removed.

A note regarding A3 and R290 venting has been updated.

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