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**COMPRESSION RATIO AS IT AFFECTS
 COMPRESSOR RELIABILITY**

The compression ration 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.

$$\begin{aligned}\text{Suction pressure} &= 30 \text{ psig} = 44.7 \text{ psia} \\ \text{Discharge pressure} &= 433 \text{ psig} = 447.7 \text{ psia} \\ \text{Compression ratio} &= \frac{447.7}{44.7} = 10 \text{ to } 1\end{aligned}$$

Example 2.

$$\begin{aligned}\text{Suction pressure} &= 10 \text{ inches of vacuum} = \\ &9.7 \text{ psia} \\ \text{Discharge pressure} &= 83 \text{ psig} = 97.7 \text{ psia} \\ \text{Compression ratio} &= \frac{97.7}{9.7} = 10 \text{ to } 1\end{aligned}$$

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 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 affect 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,

Table 1

Effects Of Changes In Pressure On Compression Ratio With R-502

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	11.0
			-40°F	4.11	18.80	14.0
			-50°F	.2"	14.60	18.0
			-60°F	7.15"	11.18	23.5
100°F	216.2	230.9	-30°F	9.20	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

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.

