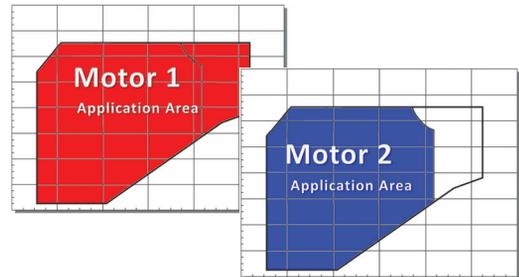




THE COMPRESSOR OPERATING ENVELOPE



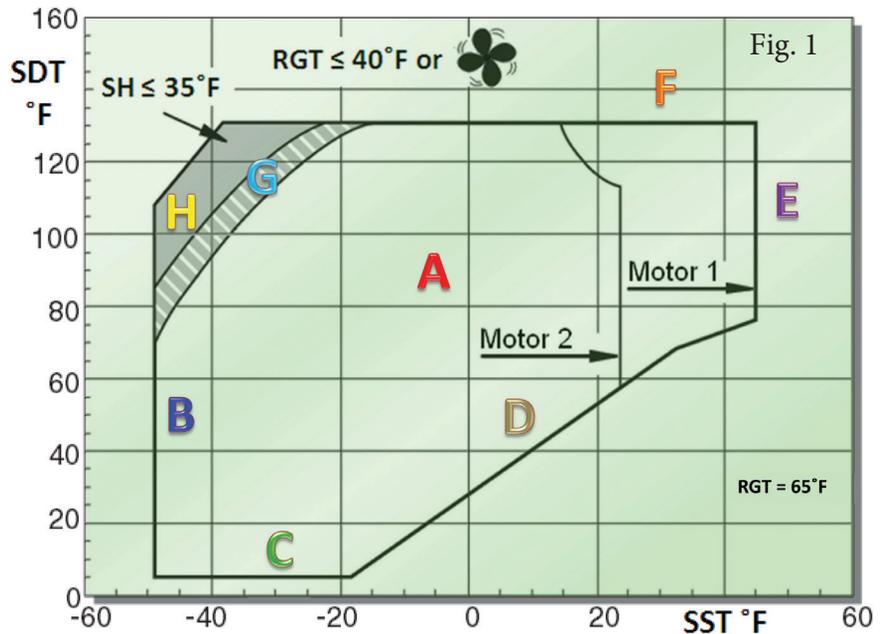
All refrigerant compressors are designed for specific refrigerants and a range of operating conditions. Manufacturers of refrigeration, comfort cooling and heat pump compressors generally publish an operating envelope in the form of a graphic that shows the sandbox of conditions that the compressor is permitted to operate within. Operation outside the envelope will, of course, result in the eventual failure of the compressor.

In Figure 1, a letter indicates each limiting area of a theoretical operating envelope, which we will use to discuss each of the limits, looking at the factors that establish these limits, along with the consequences of operating outside the limits of a reciprocating compressor.

In addition to the limitations discussed here, there are other limits that may need to be considered. For example, if the compressor will



be used in conjunction with cylinder unloading or a variable speed drive, the manufacturer will usually impose additional limits. Additional limits can generally be found in the manufacturer's software and performance data sheets.



AREA A – ACCEPTABLE OPERATING CONDITIONS

Conditions that fall inside the boundaries of the operating envelope (Area A) are considered to represent acceptable operating conditions. However, many operating envelopes actually refer to one compressor displacement that may be available with one, two, or even three different motor versions. The motor used will, of course, depend on the application. It is important to know which motor version the compressor uses.

In our example, this particular compressor displacement is available with two motors. Motor 1 shows the operating limits represented by Area A in Figure 1 for the high-power motor and Motor 2 illustrates the same for the low-power motor.

AREA B – MINIMUM SATURATED SUCTION TEMPERATURE (SST)

The left-most boundary for the envelope represents the minimum SST. There are a few factors that are used to establish this limit. At minimum SSTs, the density of the refrigerant is low and the mass flow rate is low. These two conditions reduce the availability of motor cooling present in hermetic and semi-hermetic compressors.

On another note, it is not desirable to operate compressors that have refrigerant-cooled motors in a vacuum as this will likely result in motor failure. Operation in a vacuum will also permit the entrance of air into the system if a leak takes place. The entrance of air also permits the entrance of moisture, oxygen, nitrogen and other contaminants present in the surrounding air. The entrance of these contaminants can lead to a host of other problems.

AREA C

AREA C – MINIMUM SATURATED DISCHARGE TEMPERATURE (SDT)

Low condensing temperatures contribute to lower discharge temperatures and may even permit condensation in the cylinder heads of a compressor. This can result in damaged reed valves. An SDT that is too low may also prevent the discharge valves from seating properly reducing the efficiency of the compressor.

AREA D

AREA D – LOW COMPRESSION RATIO

Area D represents conditions that result in high refrigerant flow rate and low compression ratio. The upper-right-most section of this sloping line represents the lowest compression ratio and highest mass flow rate. When compression ratios are too low, the improper sealing of reed valves will reduce the efficiency of the compressor.

Due to the high mass flow rate, the compressor suction and discharge reed valves are under a great deal of stress. Therefore, operation at compression ratios below the minimum is likely to result in valve damage or breakage.

As refrigerant is compressed, its enthalpy increases due to the heat of compression. As a result, the refrigerant will always leave the compressor with some degree of superheat; even if the refrigerant enters the compressor as a saturated vapour (zero superheat).

At these low condensing temperatures, discharge superheat tends to be lower. It is important to ensure that this superheat is not less than the manufacturer's minimum requirement, especially at these lower SDTs, since excessive refrigerant solution in the oil is likely to occur. Possible consequences of this are reduced lubrication due to a low oil viscosity, excessive oil foaming and higher oil carry-over rate.

AREA E

AREA E – MAXIMUM SATURATED SUCTION TEMPERATURE (SST)

This is the upper limit for the SST. This limit is established by the maximum allowable forces on the running gear of the compressor due to high suction pressure. The running gear includes the bearings, crankshaft, connecting rods, etc.

A film of oil must be present between moving parts at all times. At higher loads, this film becomes thinner as it is "squeezed" out of the clearance. This results in a condition known as boundary lubrication. In extreme cases, this can even lead to metal to metal contact.

AREA F

AREA F – MAXIMUM SATURATED DISCHARGE TEMPERATURE (SDT)

Area F is the upper limit for the SDT. This is established, in part, by the maximum load on the compressor's running gear during high SSTs. This limit also depends on the maximum design pressure capabilities of the compressor housing.

When selecting compressors near this limit, the effects of pull-down become even more important. In some cases it is necessary to limit the suction pressure during start-up and pull-down so that these limits are not exceeded. For example, pressure-limiting metering devices or crankcase pressure regulating can serve this purpose.

The highest motor load will be present at the upper-right-hand corner of the operating envelope. It is never advisable to operate a compressor too close to this limit. Not only is the motor at its maximum load, but an unbalanced compressor supply voltage will place further stress on the motor.

For example, a voltage deviation of one per cent can result in an increase of current that is in excess of five per cent. Also, the motor winding temperature will increase exponentially with the percentage of voltage deviation.



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AREAS G & H – HIGH COMPRESSION RATIO

This area is established by the maximum compression ratio and upper thermal limits of the compressor. At conditions beyond this barrier, motor cooling is compromised, discharge temperatures are high and lubrication issues arise. The high discharge temperature occurs because the suction densities are very low and the heat of compression is at a maximum.

This area may reveal additional limits depending on whether or not other measures are implemented in order to reduce the temperature. The envelope shown here includes two shaded areas. In this case, shaded area G identifies the need to keep the return gas temperature (RGT) or suction superheat below a certain value; or apply auxiliary cooling, such as a head cooling fan, that will impinge air on the outer surface of the compressor body to help remove heat.

Shaded area H in this case indicates the need for both a limited RGT (or superheat) along with a form of auxiliary cooling such as a head cooling fan.