Chapter – 5  Reciprocating Compressors

The constructions of reciprocating compressor can be classified in accordance with the Cylinder Arrangements such as Horizontal, Vertical, VSA, Radial, V, W and V/W. Most compressors that are with Horizontal, Vertical, VSA or Radial cylinder arrangement are the low speed large cylinder design; the size of these compressors is huge, the compressor operating speed is between 100 RPM to 500 RPM. Those compressors were mostly used in the old days and there are no longer available in the market. The modern reciprocating compressors are designed for high speed operation; the operating speed is from 1,000 RPM to a top speed of 3,600 RPM. Most modern reciprocating compressors are designed for operating speed about 1,000 to 1,800 RPM.

The maintenance and service are very costly for the Horizontal, Vertical or VSA old style reciprocating compressor; most spare parts are not available from stock and it has to be specially made. These old installation can easily be retrofitted by using a new high speed reciprocating or screw compressor.

The general classification for the modern design reciprocating compressors is shown in FIG. 5-1. Open type compressors are usually used for industrial refrigeration application. Therefore, the application information listed in this manual are mostly for the open type reciprocating compressor. The typical construction for the open reciprocating compressor is shown in FIG. 5-2.

Typical capacity ratings are shown in FIG. 5-3 for R-22; FIG. 5-4 is the typical ratings for R-717. Those ratings are for single stage compression for 8, 12 and 16-cylinder compressors respectively.

The general limitations for the reciprocating compressors are as the following:

**General Limitations (Single Stage):**

<table>
<thead>
<tr>
<th>Limitation</th>
<th>Halogens</th>
<th>Ammonia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Compression Ratio:</td>
<td>14</td>
<td>9.5</td>
</tr>
<tr>
<td>Maximum Oil Temperature:</td>
<td>160°F</td>
<td></td>
</tr>
<tr>
<td>Maximum Discharge Temperature:</td>
<td>275°F</td>
<td>360°F</td>
</tr>
<tr>
<td>Maximum Pressure Differential:</td>
<td>275 Psi</td>
<td></td>
</tr>
<tr>
<td>Maximum Condensing Temperature:</td>
<td>135°F</td>
<td>120°F</td>
</tr>
<tr>
<td>Maximum HP for Belt Driven:</td>
<td>125 HP</td>
<td></td>
</tr>
</tbody>
</table>
The actual limitations recommended by the compressor manufacturer are always to be observed.

FIG. 5-1 Reciprocating Compressor Classification
FIG. 5-2. Typical Reciprocating Compressor Construction

(1) Compressor Housing
(2) External Discharge Manifold
(3) Water Cooled Head
(4) Stop Valves
(5) Suction Strainer
(6) Lubrication Line
(7) Valves Plates
(8) Piston
(9) Connecting Rod
(10) Cylinder Sleeves
(11) Crankshaft
(12) Bearing
(13) Shaft Seal
# Refrigerant -22, 1170 RPM, Direct Drive, 60 Hz

## Unit Capacity

<table>
<thead>
<tr>
<th>Saturated Suction Temp.</th>
<th>TONS</th>
<th>BHP</th>
<th>MBH HR</th>
<th>TONS</th>
<th>BHP</th>
<th>MBH HR</th>
<th>TONS</th>
<th>BHP</th>
<th>MBH HR</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td>24.4</td>
<td>66.0</td>
<td>461</td>
<td></td>
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<td></td>
<td></td>
<td>35.4</td>
<td>80.2</td>
<td>629</td>
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<td>826</td>
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<tr>
<td>-10</td>
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<td></td>
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<td>64.9</td>
<td>107.7</td>
<td>1063</td>
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<td></td>
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<tr>
<td>0</td>
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<td>86.5</td>
<td>143.1</td>
<td>1576</td>
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</tr>
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<td>10</td>
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<td></td>
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<td>112.0</td>
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<td></td>
<td></td>
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<td></td>
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<td>143.2</td>
<td>174.9</td>
<td>2178</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td>177.3</td>
<td>178.6</td>
<td>2588</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
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<td></td>
<td>228.5</td>
<td>231.7</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
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<td></td>
<td>328.2</td>
<td>330.4</td>
<td>4365</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
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<td>426.5</td>
<td>5463</td>
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<td>546.3</td>
<td>548.4</td>
<td>6661</td>
<td></td>
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<tr>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td>666.1</td>
<td>668.2</td>
<td>7969</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
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<td></td>
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<td>796.9</td>
<td>799.0</td>
<td>9377</td>
<td></td>
<td></td>
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<td>100</td>
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<td></td>
<td>937.7</td>
<td>939.8</td>
<td>10885</td>
<td></td>
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<tr>
<td>110</td>
<td></td>
<td></td>
<td></td>
<td>1088.5</td>
<td>1090.6</td>
<td>12503</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>1250.3</td>
<td>1252.4</td>
<td>14121</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Operation below 20 F Suction Temperature requires accessory oil cooler.*

For 50 Hz applications (1000 RPM) multiply above TONS by 0.83 and BHP by 0.86.

## FIG. 5-3 Typical Capacity Rating for R-22
**-REFRIGERANT-717, 1170 RPM, DIRECT DRIVE, 60 HZ**

<table>
<thead>
<tr>
<th>Unit Model</th>
<th>TONS</th>
<th>BHP</th>
<th>MBH HN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sat. Disch. Temp. F</td>
<td>-15</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>80</td>
<td>52.2</td>
<td>64.8</td>
<td>587</td>
</tr>
<tr>
<td>90</td>
<td>55.1</td>
<td>77.4</td>
<td>870</td>
</tr>
<tr>
<td>100</td>
<td>62.7</td>
<td>82.7</td>
<td>843</td>
</tr>
<tr>
<td>110</td>
<td>69.8</td>
<td>91.4</td>
<td>1070</td>
</tr>
<tr>
<td>120</td>
<td>77.5</td>
<td>104.2</td>
<td>1316</td>
</tr>
<tr>
<td>56.25</td>
<td>36.4</td>
<td>74.3</td>
<td>625</td>
</tr>
<tr>
<td>60</td>
<td>50.4</td>
<td>85.0</td>
<td>823</td>
</tr>
<tr>
<td>100</td>
<td>67.4</td>
<td>95.5</td>
<td>1051</td>
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<tr>
<td>110</td>
<td>80.9</td>
<td>100.0</td>
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<tr>
<td>120</td>
<td>94.9</td>
<td>107.4</td>
<td>1203</td>
</tr>
<tr>
<td>150</td>
<td>109.5</td>
<td>115.3</td>
<td>1607</td>
</tr>
<tr>
<td>180</td>
<td>137.4</td>
<td>121.1</td>
<td>1957</td>
</tr>
<tr>
<td>200</td>
<td>169.7</td>
<td>128.6</td>
<td>2352</td>
</tr>
</tbody>
</table>

For 50 Hz applications (1000 RPM) multiply above TONS by 0.83 and BHP by 0.86.

**FIG. 5-4 Typical Capacity Rating for R-717**
FIG. 5-5 shows the typical Overall Efficiency and Volumetric Efficiency Curve for Halocarbon refrigerant.
FIG. 5-6 shows a typical oil Cooling and Jacket Cooling for the compressor. Some cases, the water in the oil cooler will not drain completely; therefore, if the installation is located outdoor and exposed to ambient that is below freezing, the oil cooler must be protected against freeze up.

Maximum HP limit for belt drives are to be given by the manufacturer. Usually, maximum driving motor is not to over 125 HP for belt drive application. The horsepower required for belt drive is about 3% higher than the direct drive or correct in accordance with the recommendation of the manufacturer. Maximum operating speed is given by the compressor maker also. Some reciprocating compressor is having maximum speed of 1200 Rpm and some are having 1800 Rpm.

The motor should be sized for pull down application for refrigeration application. Pull down HP power is the average of horsepower of standby suction condition and the design suction condition.

The high speed reciprocating compressors are designed for dry compression and the tolerance of liquid carry over in the suction line is very limited; even some liquid particles in the compressor suction may cause faster wear of the cylinder walls and pistons. Therefore, the refrigeration system design using reciprocating compressor must take proper care that the vapor flow to the compressor suction is superheated; Also, no liquid oil should be allowed to slug back to the compressor suction.

Capacity control for reciprocating compressor is achieved by controlling the suction pressure using a throttling valve at the suction or by hot gas bypass or by cylinder unloading. The suction throttling valve is not used by refrigeration application; Cylinder Unloading method is commonly used by Refrigeration Industries.

Most common sizes of reciprocating compressor are 4, 6, 8, 12 and 16 cylinders. The cylinder unload is controlled by solenoid valve. The capacity steps and percent of part loads are as the following:

<table>
<thead>
<tr>
<th>Number of Compressor Cylinder</th>
<th>Minimum Percent of Full Load Capacity</th>
<th>Capacity Steps</th>
<th>Capacity Steps</th>
<th>Capacity Steps</th>
<th>Capacity Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1% Full Load Capacity</td>
<td>2% Full Load Capacity</td>
<td>3% Full Load Capacity</td>
<td>4% Full Load Capacity</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>100</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>33-1/3</td>
<td>100</td>
<td>66-2/3</td>
<td>33-1/3</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>12</td>
<td>33-1/3</td>
<td>100</td>
<td>66-2/3</td>
<td>50</td>
<td>33-1/3</td>
</tr>
<tr>
<td>16</td>
<td>25</td>
<td>100</td>
<td>75</td>
<td>50</td>
<td>25</td>
</tr>
</tbody>
</table>

FIG. 5-7 shows the oil piping and oil receiver connections for uneven sizes compressor in parallel operation. It is important to note that the oil receiver should be in line with the inlets of the crankcase oil float valves of the both compressors.

FIG. 5-8 shows the oil and piping arrangement for the parallel reciprocating compressors for oil rich liquid return from the system. Also, high pressure refrigerant liquid is used for the oil cooling for the compressor instead of water.
FIG. 5-6 Oil & Jacket Cooling
Reciprocating Compressor

FIG. 5-7 Piping & Oil Connections for Uneven Units
Reciprocating Compressors Parallel Operation
FIG. 5-8  Oil & Piping for Parallel Operation
Refrigerant Cooled Oil Cooling
Reciprocating Compressors
Internally compound reciprocating compressor is a compressor that certain numbers of cylinder are used as the low stage and certain numbers of cylinder are used as the high stage within the same compressor casing; the discharge gas from the low stage cylinders is mixed with intercooling gas then internally discharged to the high stage cylinders. FIG. 5-9 shows the typical internally compound reciprocating compressor.

FIG. 5-10 shows the typical capacity ratings for R-22 internally compound reciprocating compressors; FIG. 5-11 shows a typical factory supplied intercooling arrangement kit for the internally compound reciprocating compressor.

FIG. 5-9  Typical Internally Compound Reciprocating Compressor
Typical Capacity Ratings, R-22:

<table>
<thead>
<tr>
<th>Unit Model</th>
<th>C83</th>
<th>C123</th>
<th>C163</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sat. Disch. Suction Temp. °F</td>
<td>TONS</td>
<td>BHP</td>
<td>TONS</td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-80</td>
<td>4.5</td>
<td>23.0</td>
<td>5.6</td>
</tr>
<tr>
<td>-70</td>
<td>6.5</td>
<td>30.0</td>
<td>8.8</td>
</tr>
<tr>
<td>-60</td>
<td>9.0</td>
<td>36.5</td>
<td>12.4</td>
</tr>
<tr>
<td>-50</td>
<td>12.3</td>
<td>43.0</td>
<td>17.4</td>
</tr>
<tr>
<td>-40</td>
<td>16.5</td>
<td>49.5</td>
<td>23.6</td>
</tr>
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<td>31.2</td>
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<td>-80</td>
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<td>-20</td>
<td>25.0</td>
<td>72.5</td>
<td>37.2</td>
</tr>
</tbody>
</table>

Superheat: 25°F from –20°F to –70°F STP.
For STP lower than –70°F, consult table on page 6.

Subcooling: 10°F above interstage saturation temp.

FIG. 5-10 Typical Capacity Ratings – R22
Internally Compound Reciprocating Compressor
FIG. 5-11 Typical Intercooling Arrangement
Internally Compound Reciprocating Compressor