Case – 19 Centrifugal Gas Compression Calculation

Case Background:

See Case-18 Gas Analysis for calculating gas properties for mixture gas.

Practically all hydrocarbon gases are usable for as refrigerant in refrigeration system. Gas compression calculation is for compressor selection which is used for gas other than halocarbon refrigerants. The compressor can also be used for the application such as mixed hydrocarbon gas compression or transmission.

The case is to demonstrate how to handle the application which is involved with gas compression.

If the Gas compression is for gas pumping for special gases such as Hydrogen, Oxygen, HCl, H₂S, Cl₂, Helium and etc, these requires special compressor and are not in the scope of this case cogitation. A standard hydrocarbon compressor only can accept small amount of special gas mixed with main hydrocarbon gas flow.

The purpose of this case is only to provide an understanding to the basic knowledge of some requirements to the approach of gas compression application. It shall be always ask the compressor manufacturer to make compressor selection or to confirm any validity and feasibility of gas compression application.

The operating conditions for gas compressor selection are not the same as for refrigeration application. The conditions which are required for gas compressor selection are:

- Inlet Pressure at suction of the compressor.
- Inlet temperature at the suction of the compressor.
- Compressor discharge pressure requirement.
- Gas flow rate. (Flow rate shall be weight flow or SCFM)
- Gas composition in mole percent or weight percent.

The necessary charts and curves are shown in the Related Technical Data and Engineering Information for the Case.
Related Technical Data and Engineering Information for the Case:

Table 19-1  Compressor Impeller Diameter-Inches and (Dia.)²

<table>
<thead>
<tr>
<th>CASING SIZE</th>
<th>DIA.</th>
<th>(DIA.)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>26B</td>
<td>12.2</td>
<td>149</td>
</tr>
<tr>
<td>26A</td>
<td>14.8</td>
<td>219</td>
</tr>
<tr>
<td>38B</td>
<td>18.0</td>
<td>324</td>
</tr>
<tr>
<td>38A</td>
<td>21.9</td>
<td>480</td>
</tr>
<tr>
<td>55B</td>
<td>26.7</td>
<td>713</td>
</tr>
<tr>
<td>55A</td>
<td>31.5</td>
<td>993</td>
</tr>
</tbody>
</table>

Table 19-2  Maximum Allowable HP Per 1,000 RPM

<table>
<thead>
<tr>
<th>CASING SIZE</th>
<th>SHAFT OR COUPLING</th>
<th>EACH IMPELLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>.26</td>
<td>356</td>
<td>91</td>
</tr>
<tr>
<td>38</td>
<td>1,360</td>
<td>295</td>
</tr>
<tr>
<td>55</td>
<td>2,650</td>
<td>877</td>
</tr>
</tbody>
</table>

Table 19-3  Maximum Allowable Compressor Speed and CFM Flow

<table>
<thead>
<tr>
<th>CASING SIZE</th>
<th>MAXIMUM RPM</th>
<th>MAXIMUM CFM*</th>
</tr>
</thead>
<tbody>
<tr>
<td>26B</td>
<td>15,950</td>
<td>3,690</td>
</tr>
<tr>
<td>26A</td>
<td>13,150</td>
<td>5,450</td>
</tr>
<tr>
<td>38B</td>
<td>10,800</td>
<td>8,050</td>
</tr>
<tr>
<td>38A</td>
<td>8,900</td>
<td>11,900</td>
</tr>
<tr>
<td>55B</td>
<td>7,300</td>
<td>17,700</td>
</tr>
<tr>
<td>55A</td>
<td>6,180</td>
<td>24,600</td>
</tr>
</tbody>
</table>

*Note: Maximum CFM may be less than shown depending on head requirements and mol. wt. of gas being pumped.
Table 19-4 Approximate Compressor First Critical Speed - RPM

<table>
<thead>
<tr>
<th>Comp. Model</th>
<th>Impeller Material</th>
<th></th>
<th>Impeller Material</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Aluminum</td>
<td>All Steel</td>
<td></td>
<td>All Aluminum</td>
</tr>
<tr>
<td>226B</td>
<td>61,200</td>
<td>48,700</td>
<td>526B</td>
<td>14,400</td>
</tr>
<tr>
<td>226A</td>
<td>55,700</td>
<td>41,500</td>
<td>526A</td>
<td>13,100</td>
</tr>
<tr>
<td>238B</td>
<td>41,000</td>
<td>32,700</td>
<td>538B</td>
<td>9,700</td>
</tr>
<tr>
<td>238A</td>
<td>37,300</td>
<td>27,800</td>
<td>538A</td>
<td>8,800</td>
</tr>
<tr>
<td>255B</td>
<td>28,100</td>
<td>22,400</td>
<td>555B</td>
<td>6,600</td>
</tr>
<tr>
<td>255A</td>
<td>25,600</td>
<td>19,100</td>
<td>555A</td>
<td>6,000</td>
</tr>
<tr>
<td>326B</td>
<td>31,900</td>
<td>25,400</td>
<td>626B</td>
<td>11,100</td>
</tr>
<tr>
<td>326A</td>
<td>29,200</td>
<td>21,500</td>
<td>626A</td>
<td>10,000</td>
</tr>
<tr>
<td>338B</td>
<td>21,400</td>
<td>17,000</td>
<td>638B</td>
<td>7,400</td>
</tr>
<tr>
<td>338A</td>
<td>19,600</td>
<td>14,500</td>
<td>638A</td>
<td>6,700</td>
</tr>
<tr>
<td>355B</td>
<td>14,700</td>
<td>11,700</td>
<td>655B</td>
<td>5,100</td>
</tr>
<tr>
<td>355A</td>
<td>13,400</td>
<td>10,000</td>
<td>655A</td>
<td>4,600</td>
</tr>
<tr>
<td>426B</td>
<td>20,300</td>
<td>16,100</td>
<td>726B</td>
<td>8,900</td>
</tr>
<tr>
<td>426A</td>
<td>18,400</td>
<td>13,600</td>
<td>726A</td>
<td>8,000</td>
</tr>
<tr>
<td>438B</td>
<td>13,600</td>
<td>10,800</td>
<td>738B</td>
<td>6,000</td>
</tr>
<tr>
<td>438A</td>
<td>12,300</td>
<td>9,200</td>
<td>738A</td>
<td>5,400</td>
</tr>
<tr>
<td>455B</td>
<td>9,300</td>
<td>7,400</td>
<td>755B</td>
<td>4,100</td>
</tr>
<tr>
<td>455A</td>
<td>8,400</td>
<td>6,300</td>
<td>755A</td>
<td>3,700</td>
</tr>
</tbody>
</table>

Note: The first number refers to number of stages. The operating compressor speed of the compressor shall not exceed 80% of the first critical speed.

Table 19-5 Maximum Temperature Limitation for Impellers

<table>
<thead>
<tr>
<th>Aluminum</th>
<th>Stainless Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPS</td>
<td>°F</td>
</tr>
<tr>
<td>850</td>
<td>300</td>
</tr>
<tr>
<td>800</td>
<td>317</td>
</tr>
<tr>
<td>750</td>
<td>334</td>
</tr>
<tr>
<td>700</td>
<td>351</td>
</tr>
<tr>
<td>650</td>
<td>368</td>
</tr>
<tr>
<td>600</td>
<td>384</td>
</tr>
<tr>
<td>550</td>
<td>400</td>
</tr>
<tr>
<td>&lt; Less</td>
<td></td>
</tr>
</tbody>
</table>
Figure 19-1 Compressibility Z Factor
Figure 19-2  Compression Head Factor - Ba
Figure 19-3  Compressibility Y Factor
Figure 19-4  Temperature X Factor
Figure 19-5  Compression Head Correction Factor $\varnothing$
Table 19-6 Compressor Efficiency Multiplier

<table>
<thead>
<tr>
<th>COMPRESSOR SIZE</th>
<th>MULT.</th>
<th>STAGES</th>
<th>MACH NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>UP TO</td>
</tr>
<tr>
<td>26&quot;</td>
<td>1.00</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>38&quot;</td>
<td>1.01</td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>55&quot;</td>
<td>1.02</td>
<td>3</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 19-7 Polytropic Head Coefficient

<table>
<thead>
<tr>
<th>CAF FACTOR</th>
<th>UP TO 0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1.0</th>
<th>1.1</th>
<th>1.2</th>
<th>1.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.17</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.50</td>
<td>0.49</td>
</tr>
<tr>
<td>0.18</td>
<td>0.50</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.50</td>
<td>0.49</td>
</tr>
<tr>
<td>0.19</td>
<td>0.49</td>
<td>0.50</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.50</td>
<td>0.49</td>
</tr>
<tr>
<td>0.20</td>
<td>0.48</td>
<td>0.49</td>
<td>0.50</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>0.21</td>
<td>0.46</td>
<td>0.48</td>
<td>0.49</td>
<td>0.50</td>
<td>0.51</td>
<td>0.51</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>0.22</td>
<td></td>
<td>0.48</td>
<td>0.49</td>
<td>0.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 19-6  Compressor Polytropic Capacity Factor

Note: Compressor efficiency and part load performance can be improved by changing the impeller profile design. Ask the compressor manufacturer for a better energy consumption selection for energy conservation application.
Figure 19-2 Friction HP for Multistage Centrifugal Compressor
Cogitation

This case is a compressor selection illustration for natural gas pumping application.

Outline operating conditions for the compressor:

- Gas Flow: 15 MMSCFD
- Inlet pressure: 40 Psia
- Inlet temperature: 80°F
- Outlet pressure: 96 Psia

Gas compositions:

- Methane: 89% Mole
- Ethane: 4%
- Propane: 5%
- Carbon Dioxide: 2%

Properties of the mixture gas:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>C1</td>
<td>16.0</td>
<td>89%</td>
<td>14.24</td>
<td>668</td>
<td>343</td>
<td>8.54</td>
<td>595</td>
<td>305</td>
<td>7.600</td>
</tr>
<tr>
<td>Ethane</td>
<td>C2</td>
<td>30.1</td>
<td>4%</td>
<td>1.20</td>
<td>708</td>
<td>550</td>
<td>12.60</td>
<td>28</td>
<td>22</td>
<td>0.504</td>
</tr>
<tr>
<td>Propane</td>
<td>C3</td>
<td>44.1</td>
<td>5%</td>
<td>2.21</td>
<td>616</td>
<td>666</td>
<td>17.6</td>
<td>31</td>
<td>33</td>
<td>0.880</td>
</tr>
<tr>
<td>Carb.Dioxide</td>
<td>CO2</td>
<td>44.0</td>
<td>2%</td>
<td>0.88</td>
<td>1071</td>
<td>548</td>
<td>8.89</td>
<td>21</td>
<td>11</td>
<td>0.178</td>
</tr>
<tr>
<td>Mixture Gas</td>
<td>100%</td>
<td>18.53</td>
<td></td>
<td>675</td>
<td>371</td>
<td>9.162</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Therefore, the properties of the gas mixture:

- MW = 18.53
- Critical Pressure = 675 Psia
- Critical Temperature = 371°F
- MWcp = 9.162

Gas Constant of the Gas Mixture:

\[
R = \frac{1545}{18.53} = 83.5
\]

Gas Constant for the Gas Mixture  
\[R = 83.5\]
Calculate the Gas Flow:

Mixture Gas Flow   15 MMSFD

\[\text{15,000,000 SFD} \]

\[\frac{15,000,000}{24 \times 60} = 10,416.7 \text{ SCFM}\]

Calculate the Weight Flow of the Gas at Standard Conditions:

Standard Condition is usually at 14.7 Psia and 60°F (520°R)

Gas Mixture \(P_c = 675\) Psia  
Gas Mixture \(T_c = 371\)°R

\[P_R = \frac{14.7}{675} = 0.0218\]

\[T_R = \frac{520}{371} = 1.4\]

\[Z = 0.997 \text{ at Standard Conditions}\]

(Obtain from Figure 19-1 at \(P_R = 0.0218\) and \(T_R = 1.4\))

\[V_g = \frac{R \times (\deg F + 460) \times Z}{144 \times P}\]

\[V_g = \frac{83.5 \times (60 + 460) \times 0.997}{144 \times 14.7} = 20.4 \text{ Cu.Ft/#}\]

Weight Flow = \[\frac{\text{SCFM}}{V_g}\]

\[\frac{10,416.7}{20.4} = 510.6 \text{ Lbs/Min}\]
**Suction and Discharge Pressure Drops:**

Assume Compressor Suction Inlet PD = 0.5 Psi  
Assume Compressor Discharge Outlet PD = 4.0 Psi

**Actual Compressor Suction and Discharge Pressure:**

Actual Compressor Suction Pressure = 40 – 0.5 = 39.5 Psia  
Actual Compressor Discharge Pressure = 96 + 4.0 = 100 Psia

**Compressor Actual Suction Conditions:**

- Compressor Suction pressure = 39.5 Psia  
- Suction temperature = 80°F  
- Gas Mixture Pc = 675 Psia  
- Gas Mixture Tc = 371°F

\[
P_R = \frac{39.5}{675} = 0.0585
\]

\[
T_R = \frac{(460 + 80)}{371} = \frac{540}{371} = 1.45
\]

Z factor at actual suction conditions:

\[Z = 0.993 \quad \text{(From Figure 19-1 at } P_R = 0.0585 \text{ and } T_R = 1.45)\]

Gas Specific Volume at Suction Conditions:

\[
V_g = \frac{R \times (°F + 460) \times Z}{144 \times P}
\]

\[
= \frac{83.5 \times (80 + 460) \times 0.993}{144 \times 39.5} = 7.87 \text{ Cu.Ft/#}
\]

Suction Actual CFM = 510.6 x 7.87

\[= 4,019.30 \text{ ACFM}\]
Compressor Selection Calculation:

**k factor of the gas at suction conditions:**

\[ k = \frac{C_p}{C_v} = \frac{MW_{cp}}{MW_{cp} - 1.99 \times Z} \]

\[ = \frac{9.162}{9.162 - 1.99 \times 0.993} = \frac{9.162}{7.1859} \]

\[ = 1.275 \quad \text{Use} \quad k = 1.28 \]

**Adiabatic Head:**

\[ H_{ad} = 83.5 \times (80 + 460) \times 0.993 \times \frac{1.28 - 1}{1.28 - 1} \times \left( \frac{100}{39.5} \right)^{\frac{1.28 - 1}{1.28} - 1} \]

\[ = 46,116 \text{ Ft.} \]

**Check & Compare Head using B_a factor from Figure 19-2:**

Let \( B_a = \frac{k}{k - 1} \times \left( \frac{P_2}{P_1} \right)^{\frac{k - 1}{k} - 1} \)

\[ = \frac{1.28}{1.28 - 1} \times \left( \frac{100}{39.5} \right)^{\frac{1.28 - 1}{1.28} - 1} \]

\[ = 1.03 \quad (B_a \text{ Calculated}) \]

\[ CR = \frac{P_2}{P_1} = \frac{100}{39.5} = 2.532 \]
At \( CR = 2.532 \) and \( k = 1.28 \)

\[ B_a = 1.035 \quad \text{(From Figure 19-2)} \]

\[ H_{ad} = R \times T \times Z \times B_a \]

\[ = 83.5 \times (80 + 460) \times 0.993 \times 1.035 \]

\[ = 46,341 \text{ Ft.} \]

\textbf{y factor}

\[ y = 1.005 \quad \text{(From Figure 19-3 at} \; P_R = 0.0585 \; \text{and} \; T_R = 1.45) \]

Acoustic Velocity at suction conditions:

\[ V_a = \sqrt{\frac{k \times g \times R \times (460 + ^\circ F) \times Z}{y}} \]

\[ V_a = \sqrt{\frac{1.28 \times 32.2 \times 83.5 \times (460 + 80) \times 0.993}{1.005}} = 1356 \text{ Ft/Sec} \]

\textbf{Trial No. 1, Assume} \( \text{Eff}_p = 68\% \)

Head Factor \([\phi]\) for Polytropic Function

Temperature Factor \([X]\)

\[ X = 0.225 \quad \text{(From Figure 19-4 at} \; k = 1.28 \; \text{CR} = 2.532) \]

\[ \phi = 1.0515 \quad \text{(From Figure 19-5 at} \; \text{Eff}_p = 68\% \; \text{X} = 0.225) \]

\textbf{Polytropic Head:}

\[ H_p = H_{ad} \times \phi \]

\[ = 46,341 \times 1.0515 \]

\[ = 48,728 \text{ Ft.} \]
Maximum tip speed for the impeller is 900 fps. Assume \( \mu_p = 0.5 \)

Estimate 4-stage

\[
T_s = \sqrt{\frac{32.2 \times Hp}{N \times \mu_p}}
\]

\[
= \sqrt{\frac{32.2 \times 48728}{4 \times 0.5}} = 885.7 \text{ fps}
\]

Too close to the 900 fps limit, change to 5 stages

\[
T_s = \sqrt{\frac{32.2 \times 48728}{5 \times 0.5}} = 784.4 \text{ fps}
\]

**Assume using 26A compressor casing:**

Capacity Factor = \( \frac{Q}{ND^3} = \frac{7.54 \text{ x CFM}}{T_s \times D^2} \)

ACFM = 4,019.3

\( T_s = 784.4 \) fps

\( D = 14.8" \)

\( D^2 = 219 \)

Capacity Factor = \( \frac{7.54 \times 4019.3}{784.4 \times 219} = 0.1763 \)

\( \eta_p = 78.5\% \)

(From Efficiency Figure 19-6 at CR = 2.532, Q/ND^3 = 0.1763)

The Trial #1 is no good, the original \( \eta_p \) assumed was 68\%
Trial No. 2, Assume \( \text{Eff}_p = 78.5\% \)

\[
X = 0.225 \quad \text{(From Figure 19-4 at } k = 1.28 \text{ CR = 2.532)}
\]

\[
\phi = 1.0285 \quad \text{(From Figure 19-5 at } \text{Eff}_p = 78.5\% \text{ X = 0.225)}
\]

\[
Hp = H_{ad} \times \phi
\]

\[
= 46,341 \times 1.0285
\]

\[
= 47,662 \text{ Ft.}
\]

Assume \( \mu_p = 0.50 \)

Estimate compressor is with 5-stage

\[
T_s = \sqrt{\frac{32.2 \times Hp}{N \times \mu_p}}
\]

\[
= \sqrt{\frac{32.2 \times 47,662}{5 \times 0.5}} = 783.5 \text{ fps}
\]

Assume using 26A compressor casing:

Capacity Factor = \( \frac{Q/ND^3}{T_s x D^2} \)

\[
\text{ACFM} = 4,019.3
\]

\[
T_s = 783.5 \text{ fps}
\]

\[
D = 14.8''
\]

\[
D^2 = 219
\]

Capacity Factor = \( \frac{7.54 \times 4019.3}{783.5 \times 219} = 0.1766 \)

\[
\text{Eff}_p = \eta_p = 78.5\%
\]

(Obtain from Efficiency Figure 19-6 at CR = 2.532 and Q/ND\(^3\) = 0.1766)
The Trial #2 is good, the original $\text{Eff}_p$ assumed was 78.5% 

\[
M_0 = \frac{T_s}{V_a} = \frac{783.5}{1355} = 0.578 \quad \text{OK it is below 1.3 limit}
\]

Re-check $\mu_p$ factor. (See Table 19-7)

The $\mu_p$ should be 0.503 at $M_0 = 0.578$ and $Q/ND^3 = 0.1766$ instead of assumed 0.5

**FINAL CORRECTION:**

Let $\mu_p = 0.503$

5-stage Rotor Assembly  
26A size casing  
M526A Compressor

\[
T_s = \sqrt{\frac{32.2 \times \text{Hp}}{N \times \mu_p}} = \sqrt{\frac{32.2 \times 47,662}{5 \times 0.503}} = 781.2 \text{ fps}
\]

Capacity Factor $= \frac{Q/ND^3}{T_s \times D^2} = \frac{7.54 \times \text{CFM}}{781.2 \times 219} = 0.177$

ACFM $= 4,019.3$  
$T_s$ $= 781.2$ fps  
$D$ $= 14.8”$  
$D^2$ $= 219$  

Capacity Factor $= \frac{Q/ND^3}{T_s \times D^2} = \frac{7.54 \times 4019.3}{781.2 \times 219} = 0.177$
From Efficiency Figure 19-6 at CR = 2.532 \quad \frac{Q}{ND^3} = 0.177

Efficiency correction factors:  
- Casing correction = 1.0 for 5-stage, \( M_o < 1.10 \)
- Mach No. correction = 1.0 (See Table 19-6)

Corrected \( \text{Eff}_p \) = 78.5\% x 1.0 x 1.0  
= 78.5\%

Gas HP Calculation:

\[
\text{GHP} = \frac{W \times H_p}{33000 \times \text{Eff}_p} = \frac{510.6 \times 47,662}{33000 \times 0.785} = 939.4 \text{ HP}
\]

Compressor Speed Calculation:

\[
\text{Rpm} = \frac{229 \times T_s}{D} = \frac{229 \times 781.2}{14.8} = 12,087 \text{ RPM}
\]

Compressor Friction HP:

FHP = 33 HP (From Figure 19-2 at 12,087 RPM for 26” compressor)

Compressor Shaft HP:

\[
\text{SHP} = \text{GHP} + \text{FHP} = 939.4 + 33 = 1,005.4
\]

Add Safety Factor 3\%

\[
\text{SHP} = 1,005.4 \times 1.03 = 1,035.6
\]

Say compressor power consumption **SHP = 1,036 BHP**
Compressor Coupling Size 1-1/4” from information given by maker.

**Driving HP with the external gear loss:**

\[ = 1,036 \times 1.03 = 1,067 \text{ BHP} \]

**Check Compressor Suction Pressure Drop:**

M426A suction connection is 10” given by the maker.

\[ \text{CFM} = \frac{\text{FPS}}{60 \times \text{FT}^2} \]

\[ \text{CFM} = 4,019.3 \]

\[ \text{FTP}^2 = 0.548 \]

\[ = 122.24 \]

\[ (\text{FPS})^2 \times k \]

\[ \text{FVH} = \frac{64.4}{k} = 348.05 \]

\[ \text{FVH} \]

\[ \text{PD Psi} = \frac{144 \times V_g}{V_g} = 0.307 \text{ Psi} \]

Suction Inlet PD = 0.307 Psi < 0.5 Psi assumed, Ok.

(Need to reduce the PD if the power consumption is tight)

**Compressor Discharge Temperature:**

\[ t_{\text{out}} = \text{Discharge temp.} = t_1 + \frac{(460 + t_1) \times X \times \phi}{\eta_p} \]

\[ \phi = 1.0285 \]

\[ X = 0.225 \]

\[ \eta_p = 0.785 \]

\[ (460 + 80) \times 0.225 \times 1.0285 \]

\[ t_{\text{out}} = 80 + \frac{(460 + 80) \times 0.225 \times 1.0285}{0.785} = 80 + 159.2 = 239.2^\circ \text{F} \ (\text{Ok}) \]
**Temperature Rise with Inlet Guide Vane Closed:**

\[ T_{\text{disch}} = 80 + 159.2 \times 1.3 = 286.96^\circ F \text{ with inlet guide vane closed (Ok)} \]

**Impeller Material:**

\[ T_{\text{disch}} = 287^\circ F \text{ when inlet guide vane closed.} \]

Max. Temperature limit is 323°F when \( T_s = 781.2 \text{ fps} \), all aluminum impeller Ok.

(See Table 19-5)

**Check Compressor Discharge Outlet Pressure Drop:**

Discharge pressure = 100 Psia
Discharge temperature = 239.2°F

\[
\frac{P_R}{675} = 0.148
\]

\[
\frac{(460 + 239.2)}{371} = 1.885
\]

Z factor at discharge: 0.995 (From Figure 19-1)

\[
V_g = \frac{83.5 \times (460 + 239.2) \times 0.995}{144 \times 100} = 4.034
\]

\[
\Delta P = \frac{W^2 \times V_g}{C} + 0.25
\]

\[
W = \text{Compressor discharge flow, Lbs/Min} = 510.6
\]

\[
V_g = \text{Specific volume of the gas, Ft}^3/\text{Lb} = 4.034
\]

\[
C = 309,000 \text{ for M526A}
\]

\[
\Delta P = \frac{(510.6)^2 \times 4.034}{309,000} + 0.25 = 3.62 \text{ Psi}
\]
ΔP = 3.62 Psi

Discharge PD = 3.62 Psi < 4.0 Psi assumed. Ok.

**Check Critical Speed:**

The first critical speed of all Aluminum wheel of M526A compressor is 13,100 RPM (See Table 19-4); the compressor speed is 12,087 RPM. The critical speed is above the operation speed, it is within the 20% range. Therefore, critical speed correction is needed by the manufacturer by changing the rotor assembly design.

**Check Last Wheel Capacity Factor Q/ND³:**

Calculate the last wheel inlet pressure = Pₓ

Overall Bₐ = 1.035

On equal head theory, each impeller carries Bₐ = 0.207

Bₐ at the 5th wheel inlet is 0.207 x 4 = 0.828

From Bₐ Chart, CR = 2.13 at k = 1.28 and Bₐ = 0.828

Pₓ = 39.5 x 2.13 = 84.14 Psia

Calculate the last wheel inlet temperature = tₓ

From X Chart, X = 0.178 at CR = 2.13 and k = 1.28

\[
tₓ = \text{Discharge temp.} = t₁ + \frac{(460 + t₁) \times X \times \phi}{\eta_p}
\]

\[
\phi = 1.0285
\]

\[
X = 0.178
\]

\[
\eta_p = 0.785
\]

\[
tₓ = 80 + \frac{(460 + 80) \times 0.178 \times 1.0285}{0.785}
\]

= 206°F

5th wheel inlet pressure = 84.14 Psia
5th wheel inlet temperature = 206°F
\[
P_R = \frac{84.14}{675} = 0.1247
\]
\[
T_R = \frac{460 + 206}{371} = 1.795
\]

Z factor at discharge: 0.996

\[
V_g = \frac{83.5 \times (460 + 206) \times 0.996}{144 \times 84.18} = 4.569
\]

5th wheel flow = 510.6 \times 4.569 = 2,333 CFM

\[
T_s = 781.2 \text{ ft/sec.}
\]

\[
Q/ND^3 = \frac{7.54 \times 2,333}{781.2 \times 219} = 0.103
\]

Last wheel Q/ND^3 = 0.103 > Minimum 0.02 Limit, Ok

**Check Driving Coupling:**

SHP = 1,036 BHP

Compressor Speed = 12,087 RPM

Maximum HP limit 93.4 HP per 1000 RPM (As advised by the maker)

\[
\text{Maximum coupling HP} = 93.4 \times \frac{12,087}{1,000} = 1,128 \text{ HP} \quad \text{Ok.}
\]

**Check Impeller Fasten:**

Each impeller carries \[
\frac{1,036}{5} = 207.2 \text{ HP}
\]

Maximum impeller fasten limit = \[
120 \times \frac{12,087}{1,000} = 1,450 \text{ HP} \quad \text{Ok.}
\]
**Oil Cooling:**

FHP = 33 HP

\[
\text{Oil cooler} = \text{FHP} + F \times (T_{\text{disch.}} - 275)
\]

\[
T_{\text{Disch.}} = 287{}^\circ F
\]

\[
F = 0.08 \text{ for } 25'' \text{ casing compressor}
\]

\[
\text{Oil Cooling} = 33 + 0.08 \times (287 - 275) = 33.96 \text{ HP}
\]

Therefore, Oil cooling = 34 FHP

**External Gear:**

The compressor speed is 12,087 RPM and a 2-pole motor speed is 3,540 RPM for 60 Hz power supply; or 2,950 RPM for 50 Hz power supply. An external gear is required to step up the motor input speed to compressor operating speed.

**Conclusion:**

Compressor Selected: M26A with 5 stages  
Compressor Casing: Cast Iron  
DWP, Casing: 300 Psig Standard  
Shaft HP: 1,036 BHP  
Compressor Speed: 12,087 rpm  
Compressor Coupling: 1-1/4”φ  
Oil Cooler: 34 HP  
Driving HP: 1,067 BHP with estimated gear loss of 3%.

**Important Notes:**

(A) The compressor selection shown above is just for preliminary study and information only. The final and official selection must be either made or confirmed by the compressor manufacturer.

(B) Different impeller design results in different compressor efficiency and different partial load characteristics, check with the compressor manufacturer for details.