IHP Losses From Valve/System Loss and How to Determine Which is the Cause

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Outline

- Theoretical Valve Losses
  - Factors that affect Theoretical Valve Losses
- Actual Valve loss
- Losses due to cylinder load conditions
- Losses due to pulsation
Compressor Report

Valve losses

- Horsepower is how we will measure valve and piping losses

<table>
<thead>
<tr>
<th>Cyl End</th>
<th>Stg</th>
<th>Set Clear</th>
<th>Clearance (%)</th>
<th>Calc</th>
<th>Suc</th>
<th>Dis</th>
<th>Pressure Ps (psi)</th>
<th>Temp °F</th>
<th>Comp Ratio</th>
<th>Calc Capacity (MMSCFD)</th>
<th>Ind Power (hp)</th>
<th>Suc Loss (hp)</th>
<th>Dis Loss (hp)</th>
<th>Flow Bal</th>
<th>Dis T Delta (°F)</th>
<th>Rod Load (%)</th>
<th>SVE (%)</th>
<th>DVE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1H</td>
<td>1</td>
<td>17.4</td>
<td>20.6</td>
<td>17.1</td>
<td>24.0</td>
<td></td>
<td>421</td>
<td>112</td>
<td>150</td>
<td>1.25</td>
<td>14.2</td>
<td>10.2</td>
<td>11.0</td>
<td>1.02</td>
<td>2</td>
<td>77.8C</td>
<td>97</td>
<td>82</td>
</tr>
<tr>
<td>1C</td>
<td>1</td>
<td>12.2</td>
<td>23.1</td>
<td>16.6</td>
<td>29.6</td>
<td></td>
<td>422</td>
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<td>150</td>
<td>1.24</td>
<td>13.4</td>
<td>9.1</td>
<td>9.6</td>
<td>1.03</td>
<td>3</td>
<td>64.3T</td>
<td>97</td>
<td>81</td>
</tr>
</tbody>
</table>

Total Indicated Power, (IHP) 343.9 @ 397.3 average RPM
Total BHP, (ghp) 362.0 @ 397.3 average RPM
Auxiliary Power, (bhp) 0.0 @ 397.3 average RPM
Compressor Total Power, (BHP) 362.0 @ 397.3 average RPM

Rated Power, (bhp) 599.0 @ 400.0 RPM
Derated Power, (bhp) 594.9 @ 397.3 Avg RPM
Percent Torque Load, % 60.9
Compressor Efficiency, % 88.4
Compressor Losses
Calculating Horsepower

- It takes WORK to move gas in and out of a cylinder and through a pipe.
- WORK is the area inside the PV curve; the rate of doing work is HP.
Theoretical Horsepower

Theoretical indicated power (IHP).

Horsepower required to compress the gas.
Horsepower Loss

Total loss indicated power (IHP).

Horsepower required to move the gas in and out of the cylinder.
Compressor Valve Theory
Gas Movement Out of Cylinder vs. PV Card

[Graph showing the relationship between pressure and volume during compression and discharge phases of a compressor cycle.]

Suction Line Pressure (Ps)

Cylinder Pressure (Pcyl) is above Pd and decreasing to Pd. Discharge valves close when Pcyl equals Pd (3) at TDC.

Discharge Line Pressure (Pd)
Theoretical Discharge Pressure
How Do We Verify The Software’s Decision?
Verifying Computer Generated Toe Pressures
Normal - Nozzle pressures or panel gauge readings
Effects on Theoretical Toe Pressures
TDC Issue
Effects on Theoretical Toe Pressures
Smoothing
Effects on Theoretical Toe Pressures
Leaking Valves/Rings – Crank End Suction Valve Leak
Effects on Theoretical Toe Pressures
Leaking Valves/Rings – Crank End Suction Valve Leak

1: Comp 1 H Pressure, R=1, LS=1, C=9
3: Comp 1 Dis Nozzle, R=1, LS=1, C=9
5: Comp 1 C 1 D Val Ultra, R=1, LS=1, C=9

2: Comp 1 C Pressure, R=1, LS=1, C=9
4: Comp 1 C 4 S Val Ultra, R=1, LS=1, C=9
Losses Due To Valve Issues
Magnitude Of Losses

- Factors affecting the magnitude of losses are:
  - Valve Design
  - Suction and Discharge Pressure
  - Suction and Discharge Temperature
  - Compressor Speed
  - Gas Composition
  - Suction and Discharge Piping Design
  - Compressor Passage Design
  - Clearance Area
  - Foreign Material in Valve
Where To Sample Data?
Normal Pressure Overlays
Nozzle Pressure – Orange    Cap Pressure - Black
Compressor Valve Loss
Compressor Valve Loss
Losses Due To Clearance Issues
Theoretical vs. Nozzle Pressure – Head-end Pocket Open
Added Clearances on High Speed Compressor
Theoretical vs. Nozzle Pressure – Head-end Pocket Open
Added Clearances on High Speed Compressor
Losses Due To Pulsation Issues
Pulsation Losses

- Pressure waves caused by the suction and discharge events in the compressor ends
- Can cause vibration in piping
- Easier for gas to flow in through the suction than the discharge
- Vibration may be extreme if the pulsation coincides with:
  - the acoustic resonance frequency of the piping
  - the mechanical natural frequency of the piping
- Affects compressor performance
  - when valves open and close
  - volumetric efficiency (capacity)
  - HP consumed moving gas
- Easier for gas to flow in through the suction than the discharge
Pulsation
Nozzle Pressure Trace

Pressure in discharge nozzle

Pressure in suction nozzle

Crank Angle (deg)

Pressure (psig)
Pulsation

Total Head-End Power

Total HE IHP = 514 IHP
Pulsation

Theoretical Head-End Power

Theoretical IHP = 421 IHP
Pulsation
Total Loss From Theoretical

Total Discharge loss = 104 IHP, or 20%

Total Suction loss = -11 IHP, or -3%
Pulsation

Valve and Passage Losses

Discharge valve = 24 IHP or 5%

Suction valve loss = 31 IHP or 6%
Pulsation

Pulsation Losses

Discharge pulsation loss = 80 IHP or 16%

Suction pulsation loss = -42 IHP
# Valve and System Loss Summary

<table>
<thead>
<tr>
<th>Observation</th>
<th>Typical Characteristics</th>
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<tr>
<td>Excessive Valve Loss</td>
<td>- Valve and passage loss calculated from the PV &gt; 10% (rule of thumb).</td>
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<td>- Valve lift or flow area insufficient.</td>
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<td>- Foreign material in plates or valve area.</td>
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<td>- PT and PV curve appears rounded during the suction or discharge phase.</td>
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<td></td>
<td>- Verify with nozzle pressure as close as possible to the valve</td>
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<tr>
<td>Passage or System Loss</td>
<td>- Flow area of nozzle, orifice, bottle, piping or cooler is insufficient.</td>
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<td>- Unwanted bottle/piping pulsation.</td>
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<td></td>
<td>- Clog suction screens.</td>
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<td>- Collapsed bottle baffle.</td>
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<td></td>
<td>- Verify with nozzle pressures throughout the piping system.</td>
</tr>
</tbody>
</table>
Thank you!