Using PI ProcessBook to Monitor Centrifugal Compressor Performance

Presented by Walter R. Fisher, PE
Staff Mechanical Engineer
One of 14 refineries in Valero system; others in Texas, Louisiana, Oklahoma, California, Canada and Wales (UK)

10 Ethanol Plants in US Midwest

Products: Petroleum Fuels
  Gasoline
  Diesel Fuel
  Jet Fuel
Centrifugal/Axial Compressor Population

5 Air Compressors
• One 30,000 hp Main Air Blower
• Four 400 hp Plant/Instrument Air Compressors

3 Hydrogen Compressors
• One 7300 hp
• Two 6000 hp

1 Hydrocarbon Gas Compressor
• One 6000 hp

2 Turbo Expander/Compressors
• Two 400 hp
Centrifugal Compressor Operation is Critical to Plant Function

- Expensive – Unspared: Loss of Machine Means Unit Shutdown
- Limited Stable Operating Range – Surge or Choke
- Subject to Wear and/or Fouling

**Business Challenge**

Insure Maximum Availability of Compressors
Provide Operations Personnel with Easy-to-Understand Information

**Solution**

Monitor Compressor Performance and Condition Using PI System-Linked Excel Spreadsheets

**Results and Benefits**

Provides Graphic Representation of Compressor Operating Point on Curve
Surge and Choke

Surge

Backflow Caused by Decay of Compressor Discharge Pressure at Low Flow Rates

Repeated Surges Shock Load Thrust Bearings and Rapidly Generate Heat in the Gas Path

Overstresses Axial Compressor Blades

Choke

Maximum Flow Limited by Shock Wave Internal to Machine

Particularly Damaging to Axial Machines with Cantilevered Blades
Main Air Blower
30,000 hp
Axial Compressor

- Ingests Atmospheric Air
- Inlet Temperature Varies Widely Over the Year
- Sensitive to Both Surge and Choke
Wet Gas Compressor
6000 hp Turbine

Two Section Compressor
Variable Speed Drive via Steam Turbine
Suction Pressure and Temperature Vary due to Use of Air Coolers
Main Air Blower

Performance Test Data Furnished by Manufacturer – not in Commonly Used Engineering Units

So…Hand-Drawn Curve Generated….
Hand-Drawn Blower Curve

Converted to Commonly Used Units

Curves like this are not very useful to an operator

So……PI System-linked spreadsheets were developed to give the operators and engineers a graphical indication of where the machine is operating:
**Spreadsheet Detail**

Highlighted boxes are data extracted from the PI Server using Current Value functions.

PI System tag descriptor is placed above the data cell.

One value is extracted with a timestamp so printed copies will retain that information.

<table>
<thead>
<tr>
<th>PI Data</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>MAB Inlet Flow</strong></td>
<td>MAB Disch Flow (corr)</td>
<td></td>
</tr>
<tr>
<td>11FI504.pv</td>
<td>11FC018.pv</td>
<td></td>
</tr>
<tr>
<td>190.0 MACFM</td>
<td>129.1 MSCFM</td>
<td></td>
</tr>
<tr>
<td><strong>MAB Inlet Temp</strong></td>
<td>MAB Disch Press</td>
<td></td>
</tr>
<tr>
<td>11TI503.pv</td>
<td>11PI017.pv</td>
<td></td>
</tr>
<tr>
<td>90.0 °F</td>
<td>59.5 psig</td>
<td></td>
</tr>
<tr>
<td><strong>MAB Disch Temp</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11TI506.pv</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date &amp; Time:</td>
<td>13-Aug-13 13:04:26</td>
<td>472.3 °F</td>
</tr>
</tbody>
</table>
Wet Gas Compressor
6000 hp Turbine

Two Section Compressor
Variable Speed Drive via Steam Turbine
Suction Pressure and Temperature Vary due to Use of Air Coolers
Wet Gas Compressor – Variable Speed

Vendor-supplied performance curve for first section.
Wet Gas Compressor – Variable Speed

Curves are plotted for a given set of inlet conditions:

• MW
• Suction Pressure, P1
• Suction Temperature, T1
• Compressibility, Z1
• Polytropic Exponent, n

Guarantee is for One Point

But…..
What if Inlet Conditions Change?

Recalculate Curves

- Polytropic Head

\[ H_p = \frac{1544}{MW} \frac{T_1}{n-1} \left[ \left( \frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right] Z \]

- Inlet Flow

\[ V_i = V_s \frac{P_s}{P_i} \frac{T_i}{T_s} \]

Set up Excel spreadsheet

Import Pressures and Temperatures

Assume MW and other variables are constant
## Wet Gas Compressor

### Operating Points

**12F1061 pv**

<table>
<thead>
<tr>
<th>S1 OP</th>
<th>Speed</th>
<th>Side Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7000</td>
<td></td>
</tr>
<tr>
<td>Inlet Flow</td>
<td>Suct Press</td>
<td>Suct Temp</td>
</tr>
<tr>
<td>12F1061 pv</td>
<td>12F1066 pv</td>
<td>12F1060 pv</td>
</tr>
</tbody>
</table>

**12SI009 pv**

<table>
<thead>
<tr>
<th>SHU Splitter</th>
<th>Cryo I/G</th>
<th>Total Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRC (No Cls)</td>
<td>Stream Gas Flow</td>
<td>MDCH</td>
</tr>
</tbody>
</table>

**Section 1**

- SHU Stab o/g: SHU Splitter o/g
- Cryo I/G: Cryo I/G
- Total Side: Total Side

<table>
<thead>
<tr>
<th>Inlet Flow</th>
<th>Suct Press</th>
<th>Suct Temp</th>
<th>Disch Press</th>
<th>Disch Temp</th>
<th>SHU Stab o/g</th>
<th>SHU Splitter o/g</th>
<th>Cryo I/G</th>
<th>Total Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>12FI016 pv</td>
<td>12PI772 pv</td>
<td>12TI750 pv</td>
<td>12PI774 pv</td>
<td>12TI751 pv</td>
<td>15FI1257 pv</td>
<td>15FI281 pv</td>
<td>12FI016 pv</td>
<td>12PI772 pv</td>
</tr>
</tbody>
</table>

**Section 2**

- SHU Stab o/g: SHU Splitter o/g
- Cryo I/G: Cryo I/G
- Total Side: Total Side

<table>
<thead>
<tr>
<th>Inlet Flow</th>
<th>Suct Press</th>
<th>Suct Temp</th>
<th>Disch Press</th>
<th>Disch Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>12FI016 pv</td>
<td>12PI772 pv</td>
<td>12TI750 pv</td>
<td>12PI774 pv</td>
<td>12TI751 pv</td>
</tr>
</tbody>
</table>

### Compressor Curve - Design

#### Section 1

- MW: 37.69
- Constant: 157704.7
- k: 1.166
- k = 1/k = 0.861
- Z = 0.97
- k/k - 1 = 7.024
- P1 = 30 psig
- T1 = 104.3 F

#### Section 2

- MW: 35.12
- Constant: 139740.8
- k: 1.2
- k = 1/k = 0.833
- Z = 0.946
- k/k - 1 = 6.000
- P1 = 79 psig
- T1 = 120.0 F

### Compressor Curve - Actual

#### Section 1

- MW: 37.66
- Constant: 161886.8
- k: 1.166
- k = 1/k = 0.861
- Z = 0.97
- k/k - 1 = 7.024
- P1 = 32.5 psig
- T1 = 120.0 F

#### Section 2

- MW: 35.12
- Constant: 139740.8
- k: 1.2
- k = 1/k = 0.833
- Z = 0.946
- k/k - 1 = 6.000
- P1 = 79 psig
- T1 = 120.0 F
Wet Gas Compressor

Discharge Pressure - PSIA

Flow - ACFM

Speed - rpm

- P2 79 design
- P2 60 design
- P2 79 actual
- P2 60 actual
- P1 79 design
- P1 60 design
- P1 79 actual
- P1 60 actual
- S1 OP
- S2 OP
- Corr S2 OP
- Speed

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Trending Capability

- PI ProcessBook allows trending of time-based data with simple points and clicks.
- PI ProcessBook screens can be configured to plot sets of data for evaluation.
- Alternative is to develop Excel spreadsheet using PI Sampled Data function to define start and end times.
- Typical plot would start at current time and sample backwards at set intervals to a defined point in the past.
- For repeated trending, set up data in a spreadsheet tab.
- Use Excel’s Move or Copy command to copy the tab to the end of the workbook.
- The new tab will contain data starting from the current date and time.
- Convenient for collecting a set of trends on a daily, weekly or other basis.
Conclusions

- PI System is an excellent tool for capturing process data.
- Current Value and Timed Data functions permit versatile collection of information.
- Excel with the PI DataLink Add-In is a powerful tool for evaluating not only compressors, but any other process data.
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