CASE STUDY:
Solution for PD Pump Suction Piping System Pulsation/Vibration Problem

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Author’s Biography

• **Eugene "Buddy" Broerman** is a Senior Research Engineer with Southwest Research Institute (SwRI). He has nearly 13 years of experience with pulsation/vibration related problems. He holds a bachelor’s degree in mechanical engineering from Texas A&M University – Kingsville. Contact him at: EBroerman@swri.org

• **Ray Durke** is a Senior Research Engineer with Southwest Research Institute (SwRI). He has 35 years experience in plant dynamics, primarily in diagnosing and correcting machinery vibration and pulsation-related problems. He holds a BSME from Texas A&M University and an MBA from UTSA. Contact him at: rdurke@swri.org
Agenda

• Introduce System & Problem

• Steps taken to Solve Problem

• Summary & Lessons Learned
# Pump Description Details

## Pumps Details

- 2 pumps (plunger)
  - Separate piping systems
- 3 plungers per pump
- 3.375” bore (8.57 cm)
- 5” stroke (12.7 cm)
- 166 rpm

## Pump Operating Conditions

- **Suction Pressure:**
  - 30-40 psig (2.1-2.8 barg)
- **Discharge Pressure:**
  - 1000-1250 psig (69-86 barg)
- **Temperature:**
  - 210-230°F (99-110°C)
Problems

• High suction piping vibration causing:
  – Pipe insulation deterioration
  – Pipe restraint damage
  – Shortened pump valve life
  – High noise

• Gas-liquid pulsation dampereners installed years prior to field investigation – removed due to high maintenance and frequent bladder failures

• Issues above raised safety & reliability concerns
Steps Taken to Solve Problem

• Field investigation for problem characterization and diagnostics – vibration & pulsation data measured

• Pulsation analysis conducted to develop potential solutions

• Maintenance-free, all-liquid acoustic filter bottle recommended
Piping Layout

System Concerns:
- Complex piping system
- Two pumps with similar piping (different services)
- Pulsation control insufficient
- Elevated pipe difficult to restrain
<table>
<thead>
<tr>
<th>Test Point</th>
<th>Overall Amplitudes</th>
<th>Pulsation (psi p-p) at Discrete Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pulsation psi pk-pk</td>
<td>Shaking Force lb_f p-p</td>
</tr>
<tr>
<td>PS 1</td>
<td>110</td>
<td>1749</td>
</tr>
<tr>
<td>PS 2</td>
<td>143</td>
<td>1820</td>
</tr>
<tr>
<td>PS 3</td>
<td></td>
<td>No signal</td>
</tr>
<tr>
<td>PS 4</td>
<td>45</td>
<td>573</td>
</tr>
<tr>
<td>PS 5</td>
<td>80</td>
<td>591</td>
</tr>
</tbody>
</table>

Indicates potential of failed valves
## Summary of Field Measured Vibration

<table>
<thead>
<tr>
<th>Test Point</th>
<th>Overall Amplitude</th>
<th>Vibration (mils p-p) at Discrete Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vibration mils p-p</td>
<td>1x</td>
</tr>
<tr>
<td>FV E-W</td>
<td>45</td>
<td>11</td>
</tr>
<tr>
<td>Tee E-W</td>
<td>65</td>
<td>--</td>
</tr>
<tr>
<td>Tee N-S</td>
<td>65</td>
<td>31</td>
</tr>
</tbody>
</table>
Field Pulsation Data at Pump

- Transducer location
- 5x
- 6x
- ~64 psi @ 14 Hz
- ~108 psi @ 16.8 Hz
Field Vibrations on SwRI
Vibration Guideline Chart

Field measured vibrations in “Marginal” and “Correction” regions
Pulsation Model Results

Highest pulsation amplitudes predicted at 6x running speed:
- at pump manifold: 80 psi pk-pk
- in upstream piping: ~ 11 to 80 psi pk-pk

Existing System Pulsation:
80 psi pk-pk at 6x (16.8 Hz)
All-liquid Acoustic Filter

Choke tube sized for acceptable pressure losses

Note: Original gas-liquid pulsation dampeners removed due to high maintenance and frequent bladder failures

Vessel volumes

Filter sized to attenuate pulsations at plunger frequency (3x running speed) and at higher harmonics
Acoustic Filter Details

- **Recommended bottle**
  - ~9-feet seam-to-seam
  - ~30” diameter
- **Choke Tube**
  - Nearly 20-feet long
- **Different size filter for each pump due to different services**
Equation – Acoustic Filter

\[ f_H = \frac{c}{2\pi} \left( \frac{\mu}{V_1} + \frac{\mu}{V_2} \right)^{\frac{1}{2}} \]
\[ \mu = \frac{A}{L} \]

- \( f_H \) = Helmholtz frequency (Hz)
- \( A \) = Cross-sectional area of choke (ft\(^2\))
- \( L \) = Acoustic length of choke (ft)
- \( c \) = Velocity of sound (ft/sec)
- \( V_1 \) = Volume of cylinder bottle or chamber (ft\(^3\))
- \( V_2 \) = Volume of filter bottle or chamber (ft\(^3\))

- Green = Geometry
- Red = Operating conditions property
General Concept of an Acoustic Filter

Analogous to low-pass electrical filter or mechanical spring-mass system

- Volume = Spring
- Choke tube = Mass
Pulsation Model Results – Modified System

Maximum amplitude pulsations reduced with filter:
- Pump manifold: 12 psi pk-pk
- in upstream piping: 0.1-12 psi pk-pk

Existing System
80 psi pk-pk at 6x

Modified System
12 psi pk-pk at 6x
Vibrations with Filter Installed

<table>
<thead>
<tr>
<th>Test Point</th>
<th>Before 3x (mils pk-pk)</th>
<th>After 3x (mils pk-pk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FV</td>
<td>79</td>
<td>0.73</td>
</tr>
<tr>
<td>Pump Suction</td>
<td>34</td>
<td>0.37</td>
</tr>
<tr>
<td>Pump Discharge</td>
<td>33</td>
<td>1.25</td>
</tr>
</tbody>
</table>

- Data measured by operating company
- Highest vibration with filter = 1.8 mils pk-pk at 9x on disch. pipe

The following is a quote from the client:

“operators saying they have to walk up and touch the motor to make sure it’s running… whereas they could hear the pump from the road, before the change.”
Summary and Lessons Learned

• Pump System Problem
  – High amplitude piping vibrations
  – Insulation and restraint damage
  – Gas-liquid dampener bladder failures

• Steps taken to Solve Problem
  – Field investigation for problem evaluation – vibration & pulsation measurements
  – Pulsation analysis

• Summary & Lessons Learned
  – All-liquid acoustic filter can significantly reduce system pulsation and vibration amplitudes
Questions/Comments?

Please ask. If you have a question, someone else in the room probably has a question also.