43rd Turbomachinery
30th Pump SYMPOSIA
GEORGE R. BROWN CONVENTION CENTER
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# CASE STUDY:

## Solution for PD Pump Suction Piping System Pulsation/Vibration Problem

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# Author’s Biography

- **<u>Eugene "Buddy" Broerman</u>** 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

- **<u>Ray Durke</u>** 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 | Pump Operating Conditions |
|---|---|
| 2 pumps (plunger)<br>Separate piping systems | Suction Pressure:<br>30-40 psig (2.1-2.8 barg) |
| 3 plungers per pump | Discharge Pressure:<br>1000-1250 psig (69-86 barg) |
| 3.375” bore (8.57 cm) | Temperature:<br>210-230°F (99-110°C) |
| 5” stroke (12.7 cm) | |
| 166 rpm | |

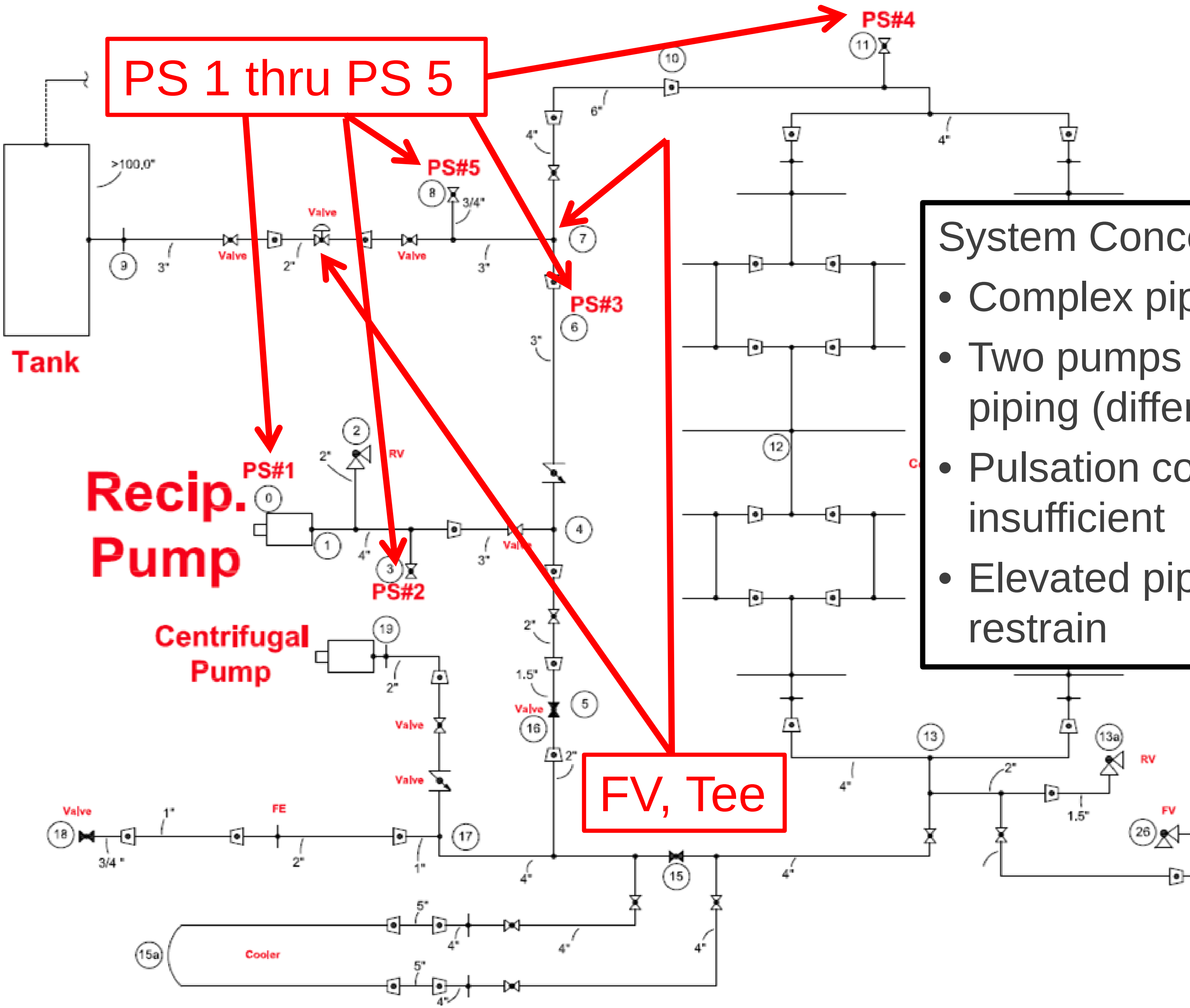
# Problems

- High suction piping vibration causing:
  - Pipe insulation deterioration
  - Pipe restraint damage
  - Shortened pump valve life
  - High noise
- Gas-liquid pulsation dampeners 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

# Summary of Field Measured Pulsation & Estimated Forces

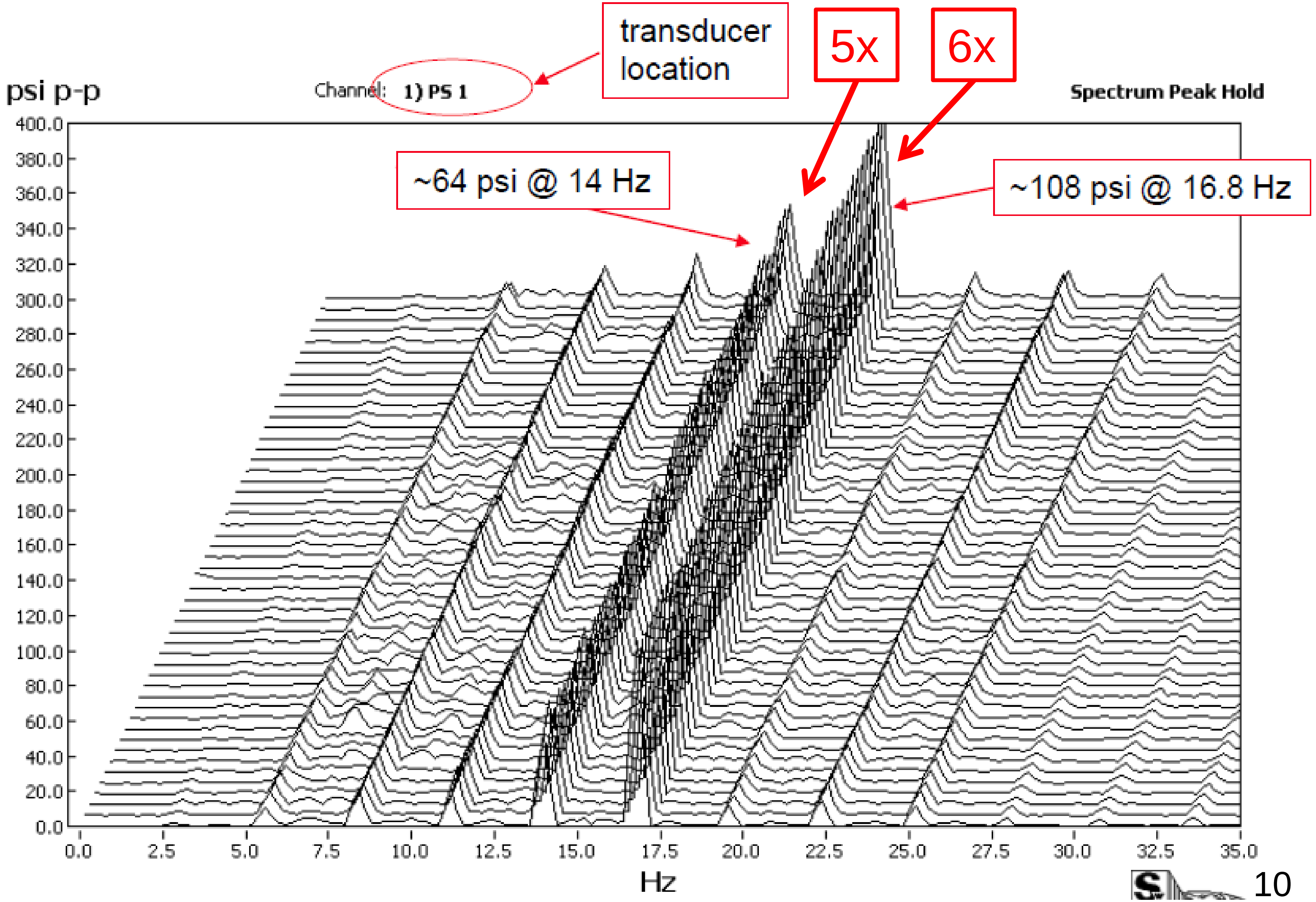
| Test Point | Overall Amplitudes | | Pulsation (psi p-p) at Discrete Frequencies | | | |
|---|---|---|---|---|---|---|
| | Pulsation psi pk-pk | Shaking Force $lb_f$ p-p | 3x | 5x | 6x | ~10x |
| PS 1 | 110 | 1749 | 22 | 64 | 108 | -- |
| PS 2 | 143 | 1820 | 19 | 60 | 96 | -- |
| PS 3 | --------------- No signal -------------- | | | | | |
| PS 4 | 45 | 573 | 15 | -- | 95 | -- |
| PS 5 | 80 | 591 | 11 | -- | 17 | 24 / 25 |

Indicates potential of failed valves

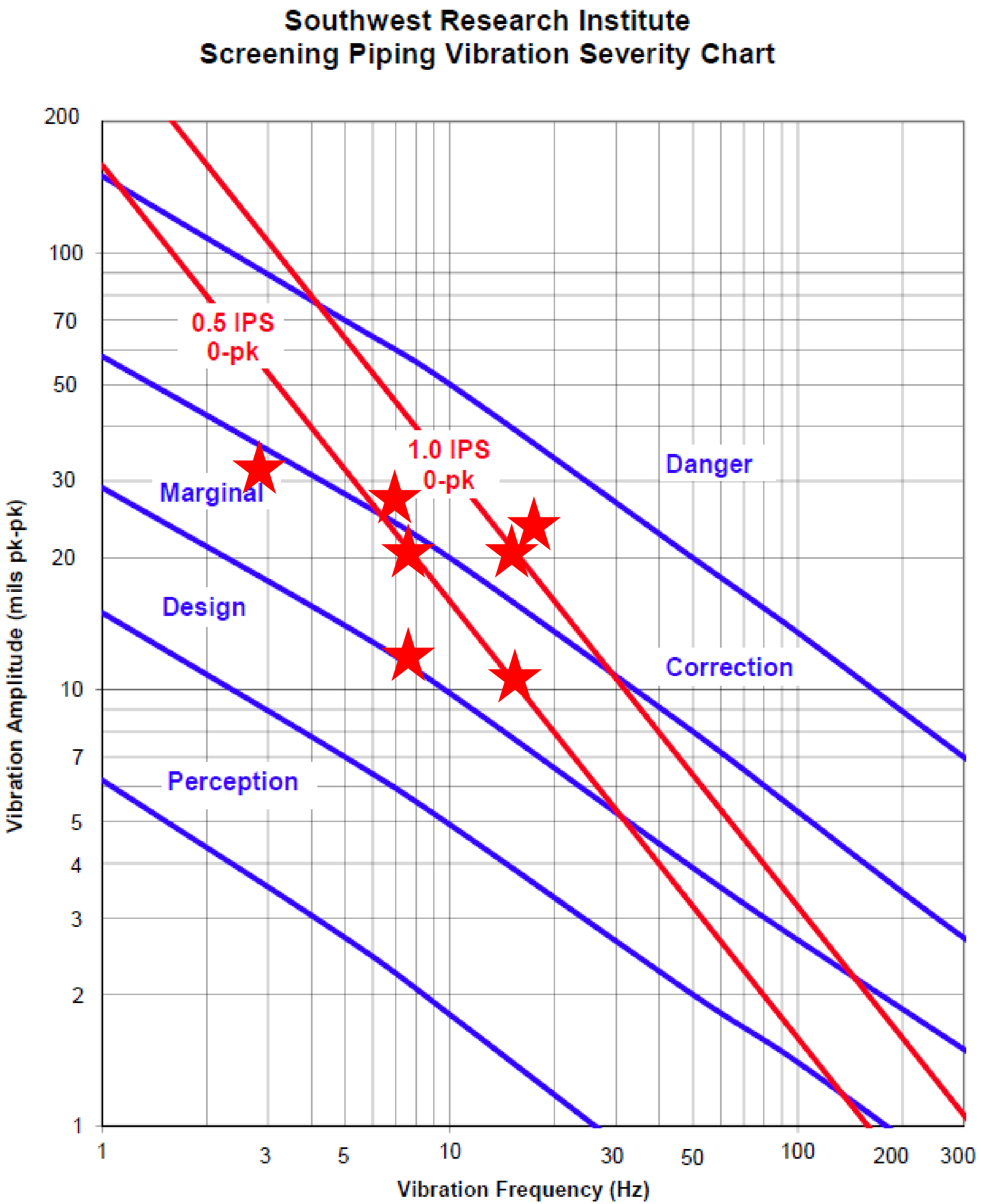
# Summary of Field Measured Vibration

| Test Point | Overall Amplitude | Vibration (mils p-p) at Discrete Frequencies | | | | |
|---|---|---|---|---|---|---|
| | Vibration mils p-p | 1x | 3x | 5x | 6x | 7 Hz |
| FV E-W | 45 | 11 | 4 | 10 | 3 | -- |
| Tee E-W | 65 | -- | 20 | 20 | 13 | 26 |
| Tee N-S | 65 | 31 | 11 | 9 | 22 | -- |

# Field Pulsation Data at Pump



# Field Vibrations on SwRI Vibration Guideline Chart

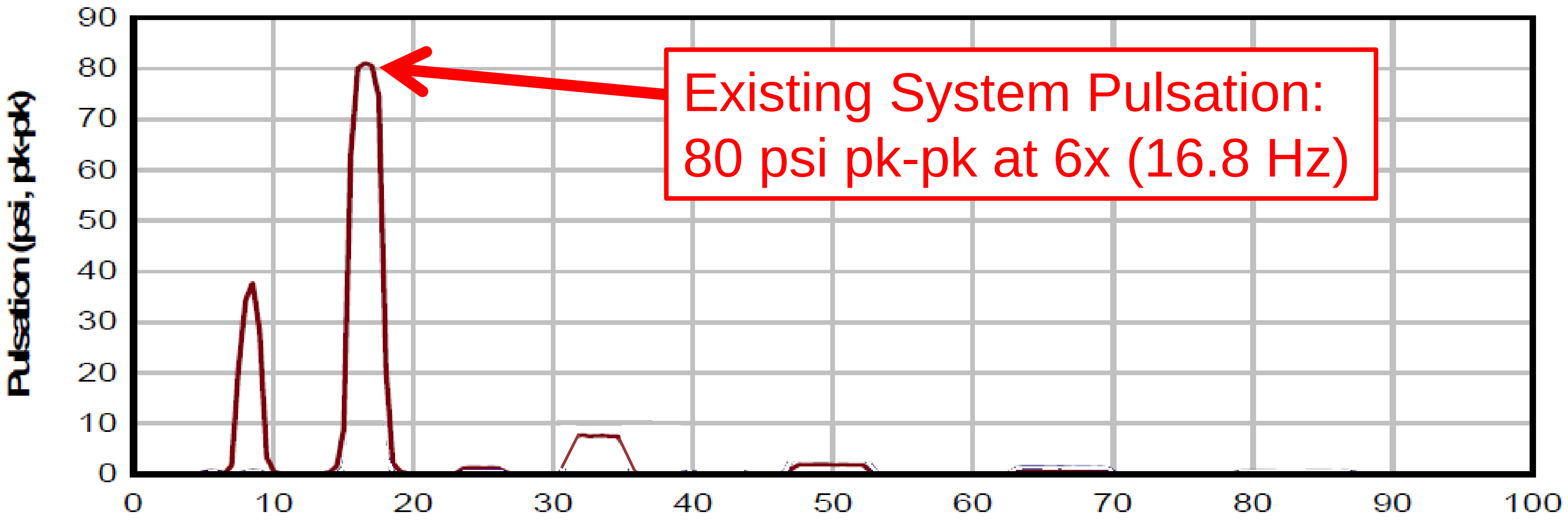



Field measured vibrations in "Marginal" and "Correction" regions

# Pulsation Model Results

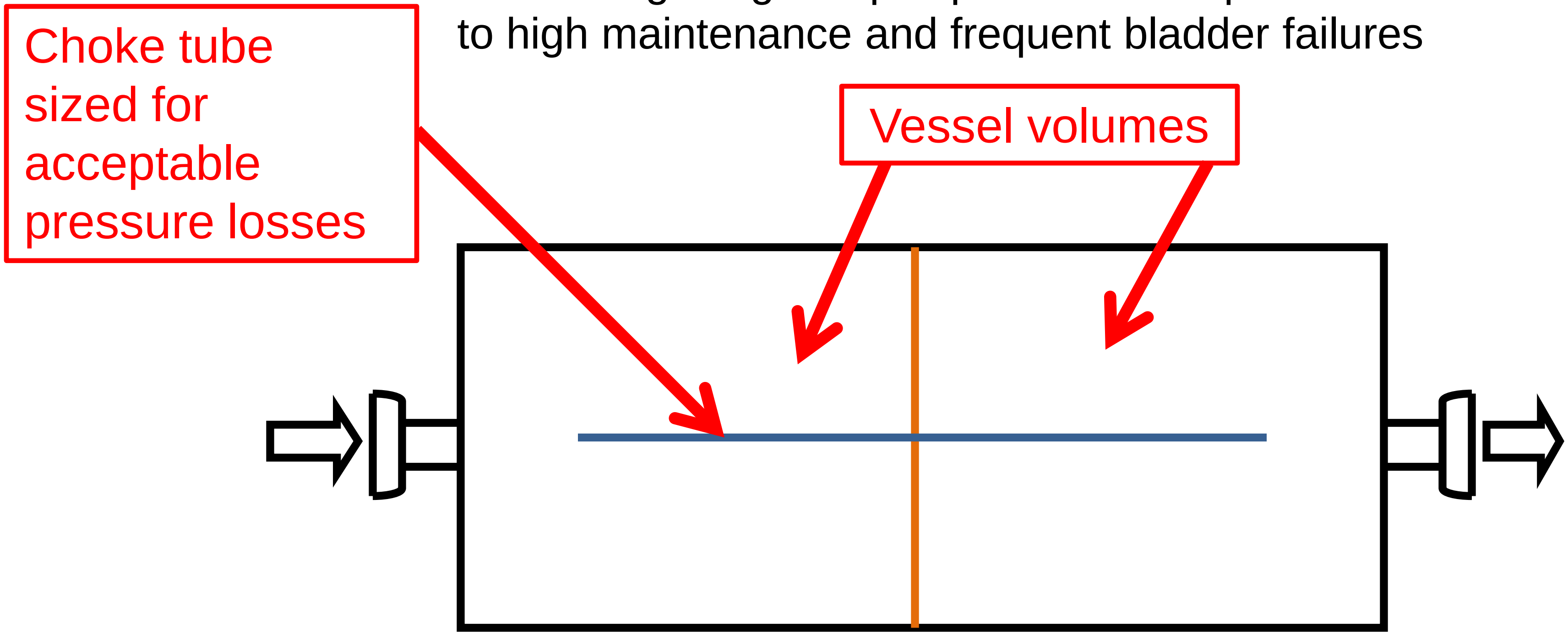
Highest pulsation amplitudes predicted at 6x running speed:

- at pump manifold: 80 psi pk-pk
- in upstream piping: ~ 11 to 80 psi pk-pk



# All-liquid Acoustic Filter

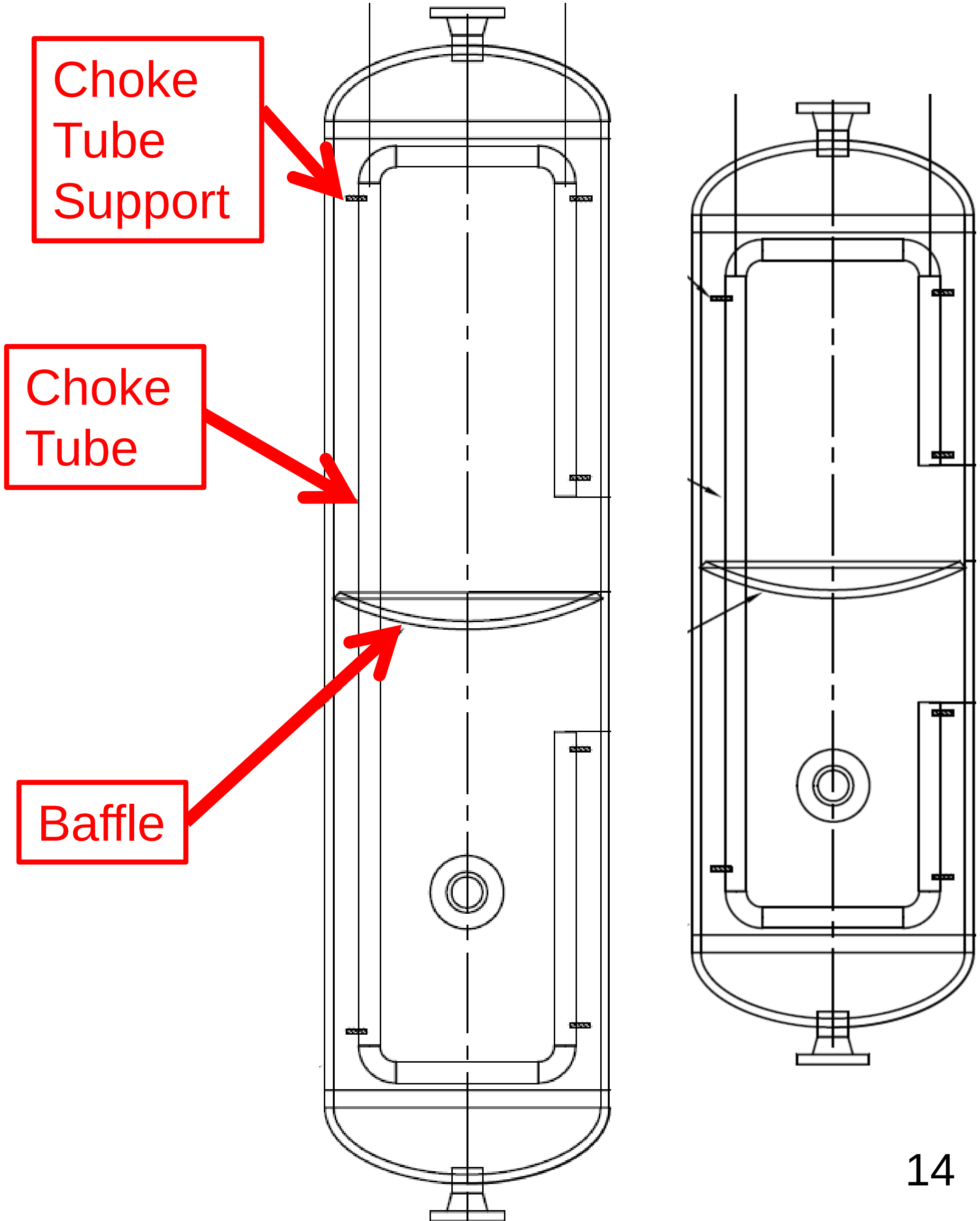
Note: Original gas-liquid pulsation dampeners removed due to high maintenance and frequent bladder failures




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

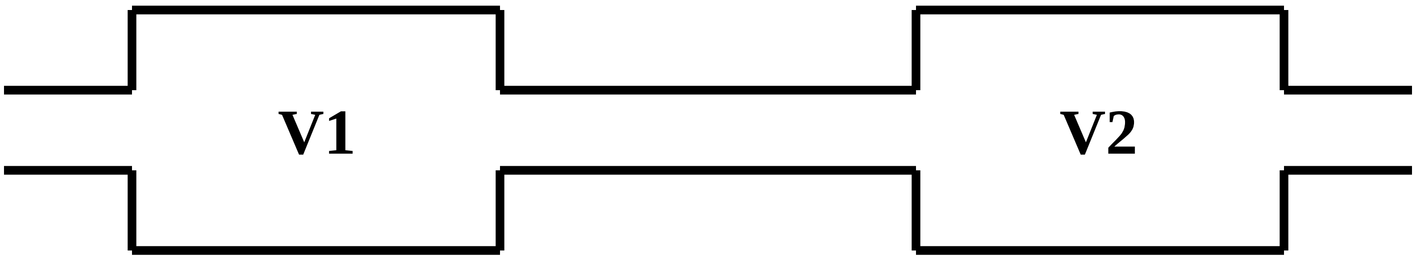


# Equation – Acoustic Filter

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

$f_H$ = 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 ($ft^3$)

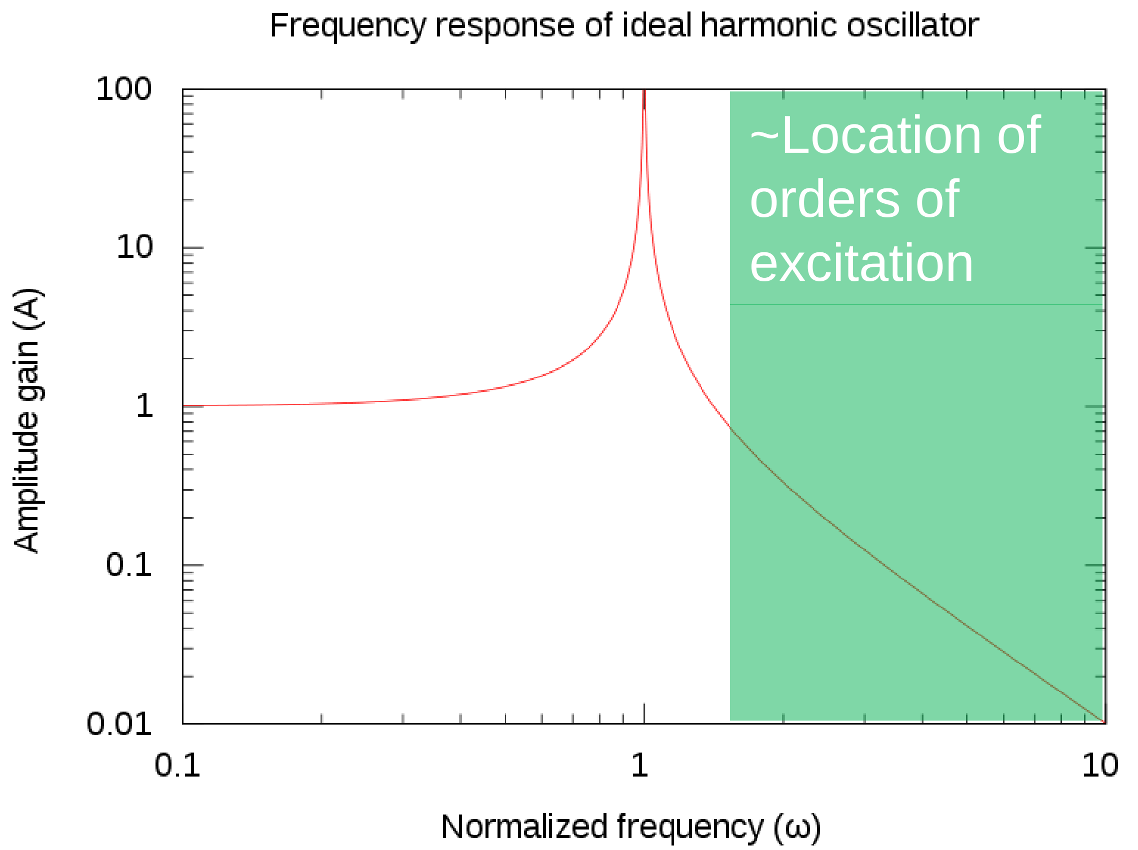
- Green = Geometry
- Red = Operating conditions property

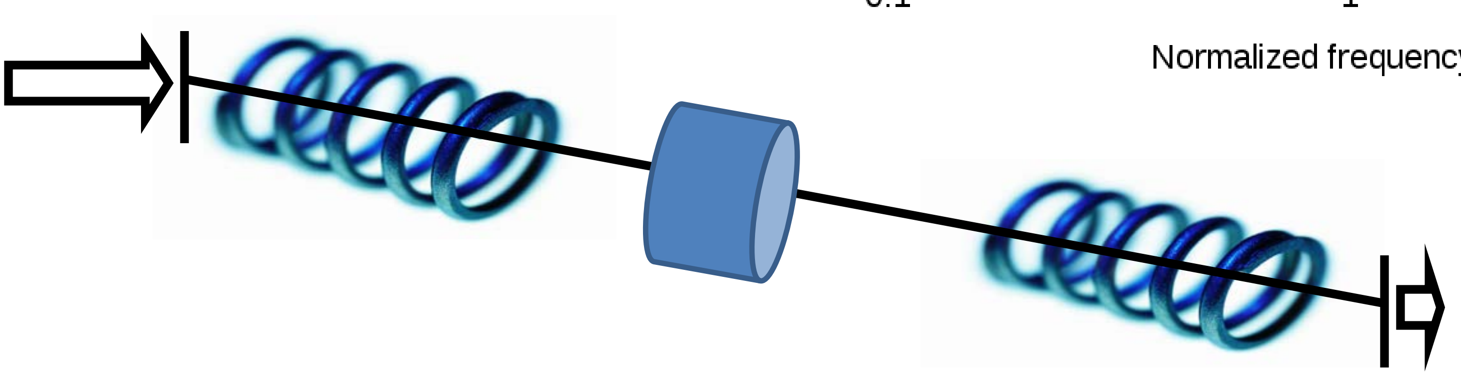


# General Concept of an Acoustic Filter

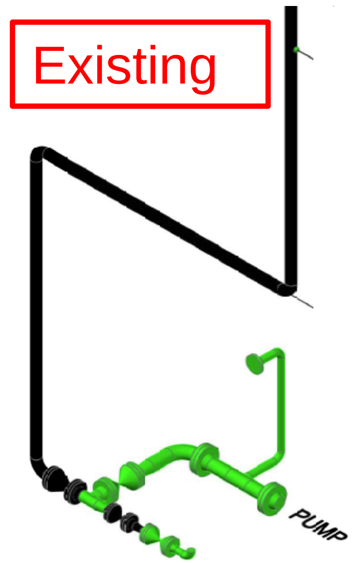
Analogous to low-pass electrical filter or **mechanical spring-mass system**

- Volume = Spring
- Choke tube = Mass



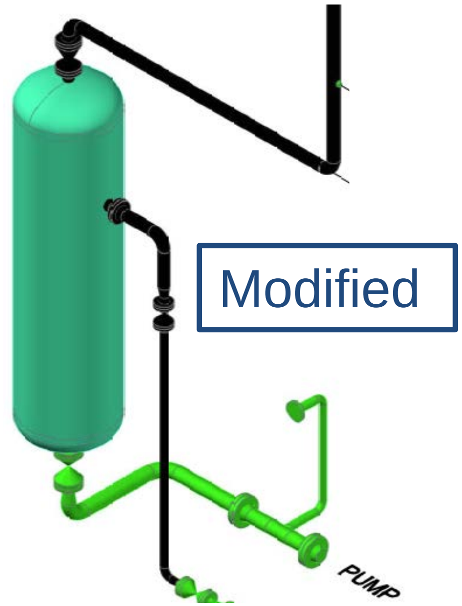



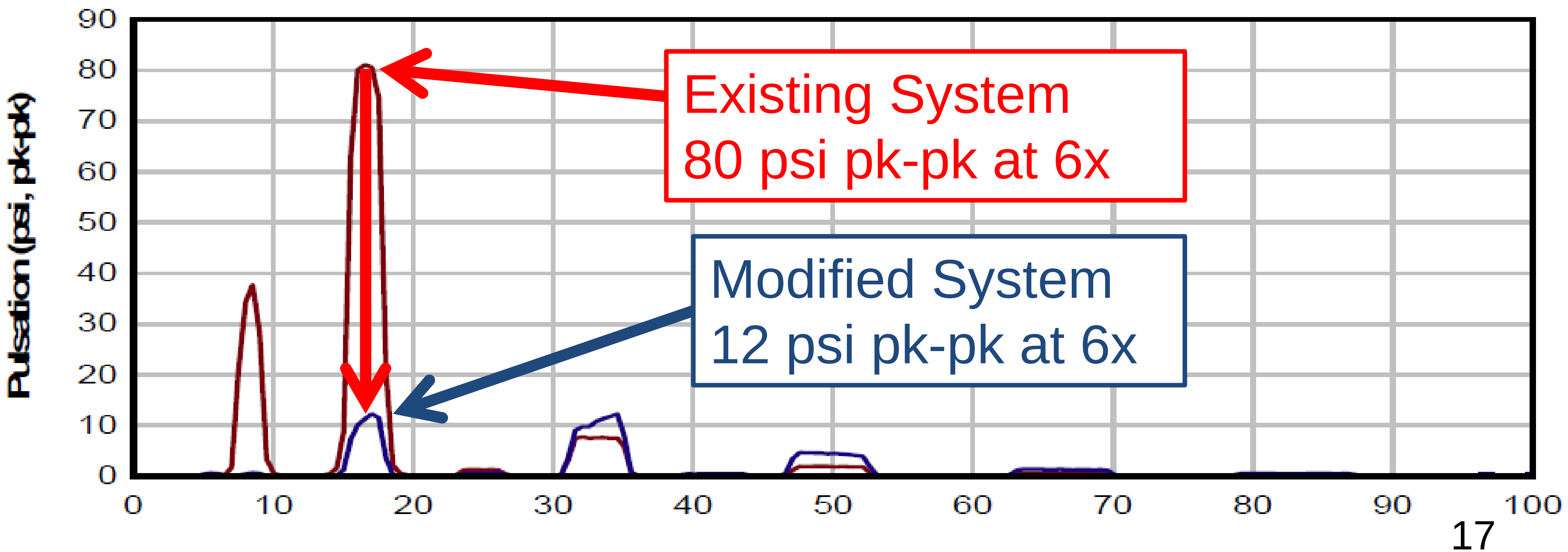
# Pulsation Model Results – Modified System




Maximum amplitude pulsations reduced with filter:

- Pump manifold: **12** psi pk-pk
- in upstream piping: **0.1-12** psi pk-pk



# Vibrations with Filter Installed

| Test Point | __Before__ 3x (mils pk-pk) | __After__ 3x (mils pk-pk) |
|---|---|---|
| FV | 79 | 0.73 |
| Pump Suction | 34 | 0.37 |
| Pump Discharge | 33 | 1.25 |

- 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.