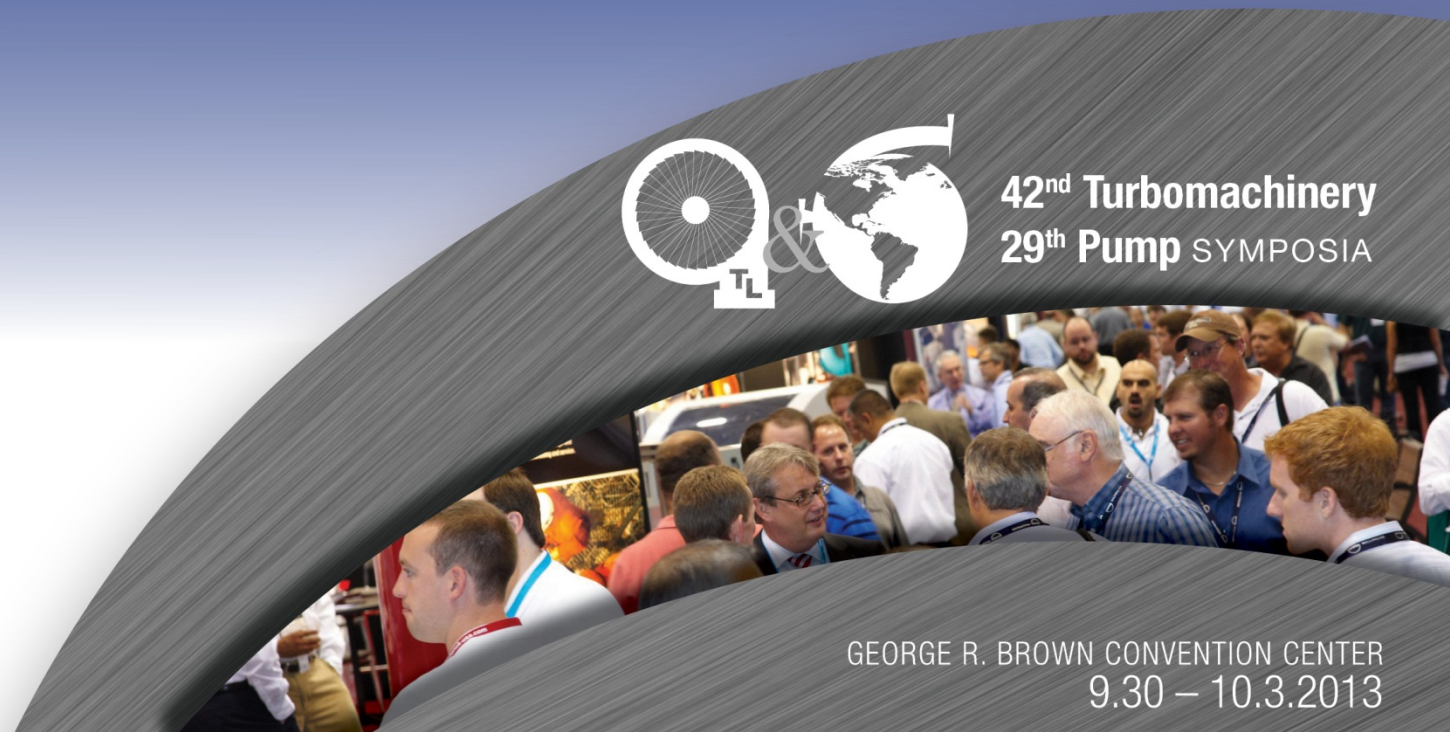
WORLD-CLASS OUTSTANDING INTERNATIONAL

PROGRAM | EXHIBITION | NETWORKING

ELEVATED PRESSURE PULSATION WITH A METHANOL INJECTION RECIPROCATING PUMP SYSTEM



Kelm Engineering, LLC

"Turning theory into practical solutions"

Texas A&M Engineering TEES Turbomachinery Laboratory

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Methanol Injection Reciprocating Pump Pulsation Problem

- Offshore Floating Production Storage and Offloading (FPSO) high pressure methanol system
- Four quintuplex recip pumps in parallel
- During commissioning, failure of Pressure Safety Valve (PSV) components were observed
- Likely issue was pressure pulsation

Discharge pressure of 323 bar_g

Relief valve (PSV) set pressure of 339 bar_g

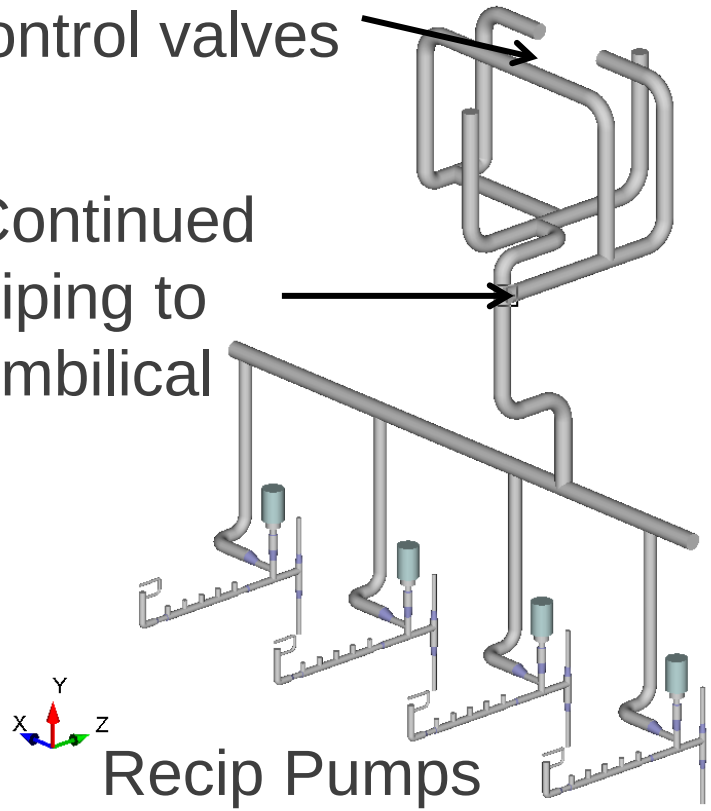
Fixed Pump Speed: 446 RPM

Flow Rate: 80 GPM per pump

Piping System Layout

Spillback pressure control valves

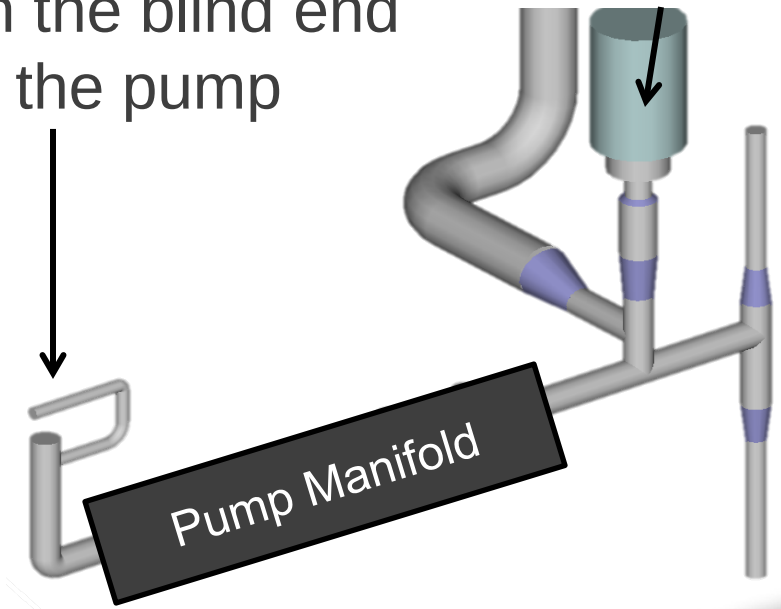
Continued piping to umbilical



Recip Pumps

PSV installed on the blind end of the pump

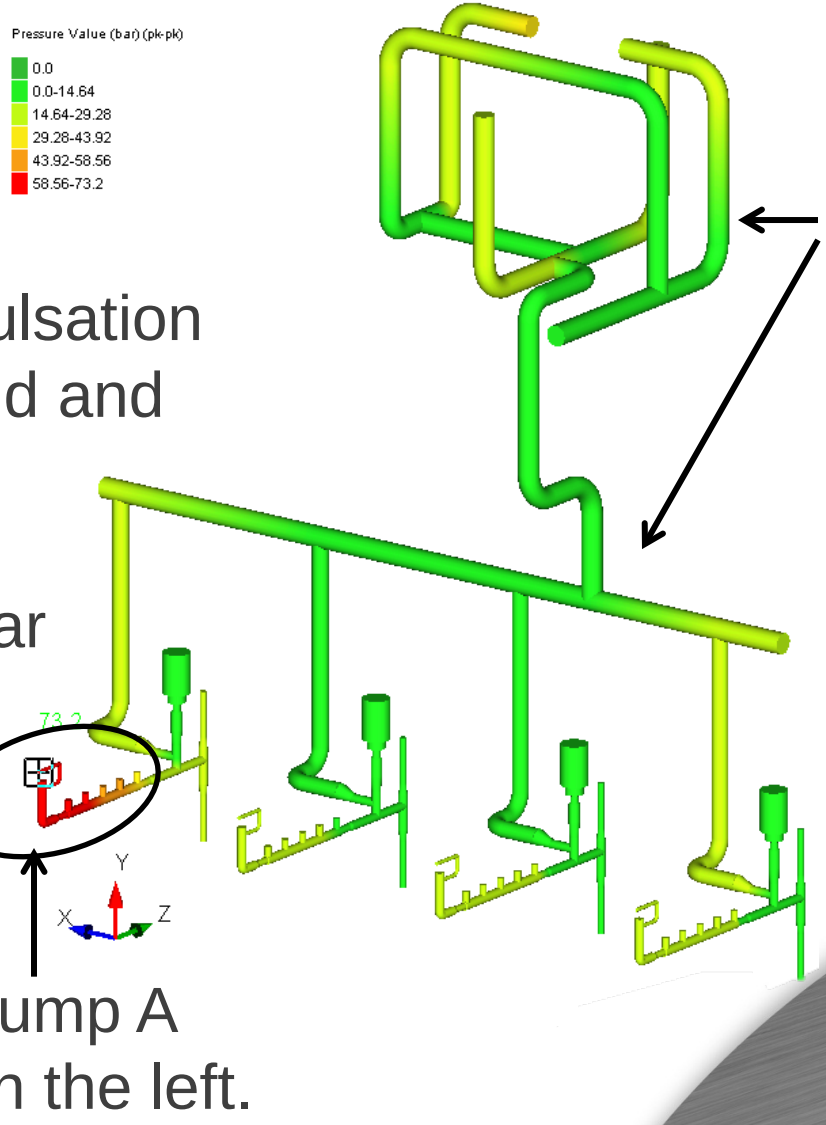
2 liter gas charged dampener



An acoustic study was done to review the pressure pulsation at the PSV body.

Acoustic Study Results

Pressure pulsation due to pump A in operation



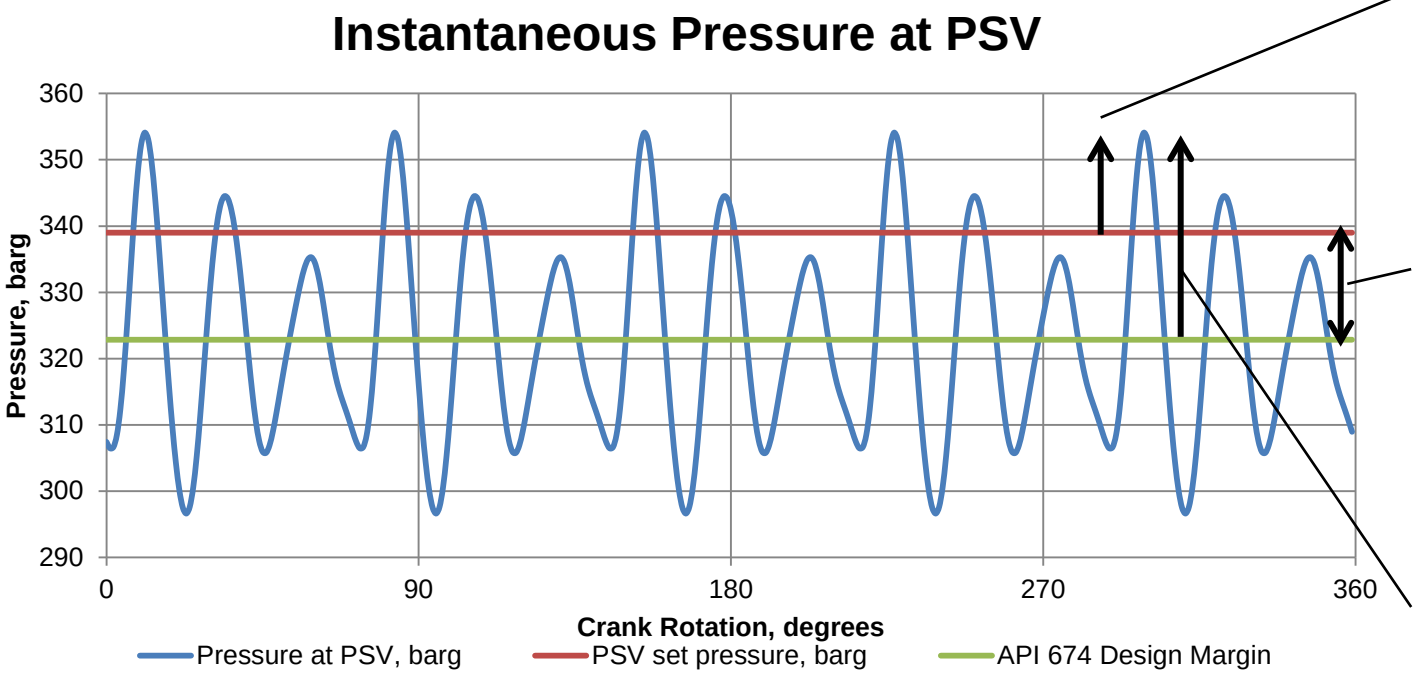
5-30 bar pk-pk pulsation in the piping, which is +/- 2.5-15 bar

Highest pressure pulsation in the pump manifold and at the PSV.

Maximum of 73.2 bar peak-peak which is +/- 36.6 bar.

Pump A on the left.

Review of Acoustic Study Results



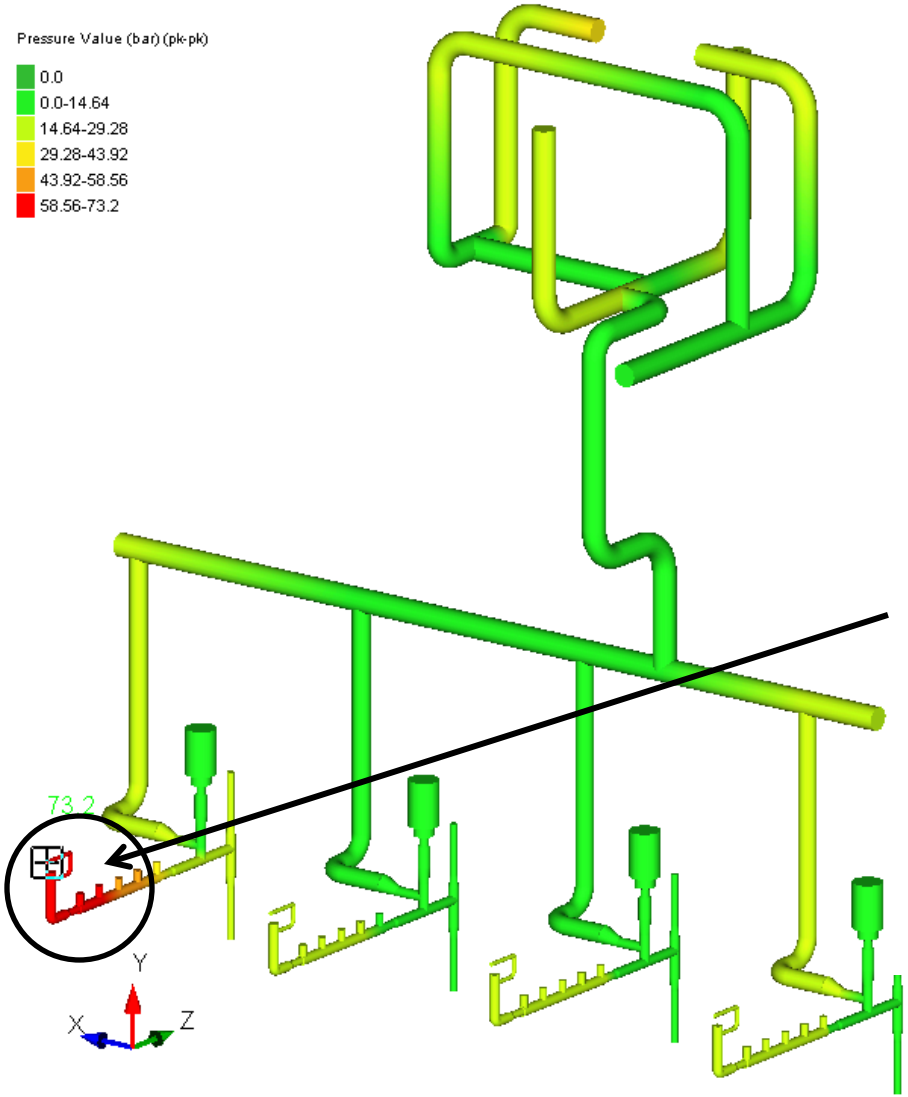
Exceeds PSV set pressure by 16 bar

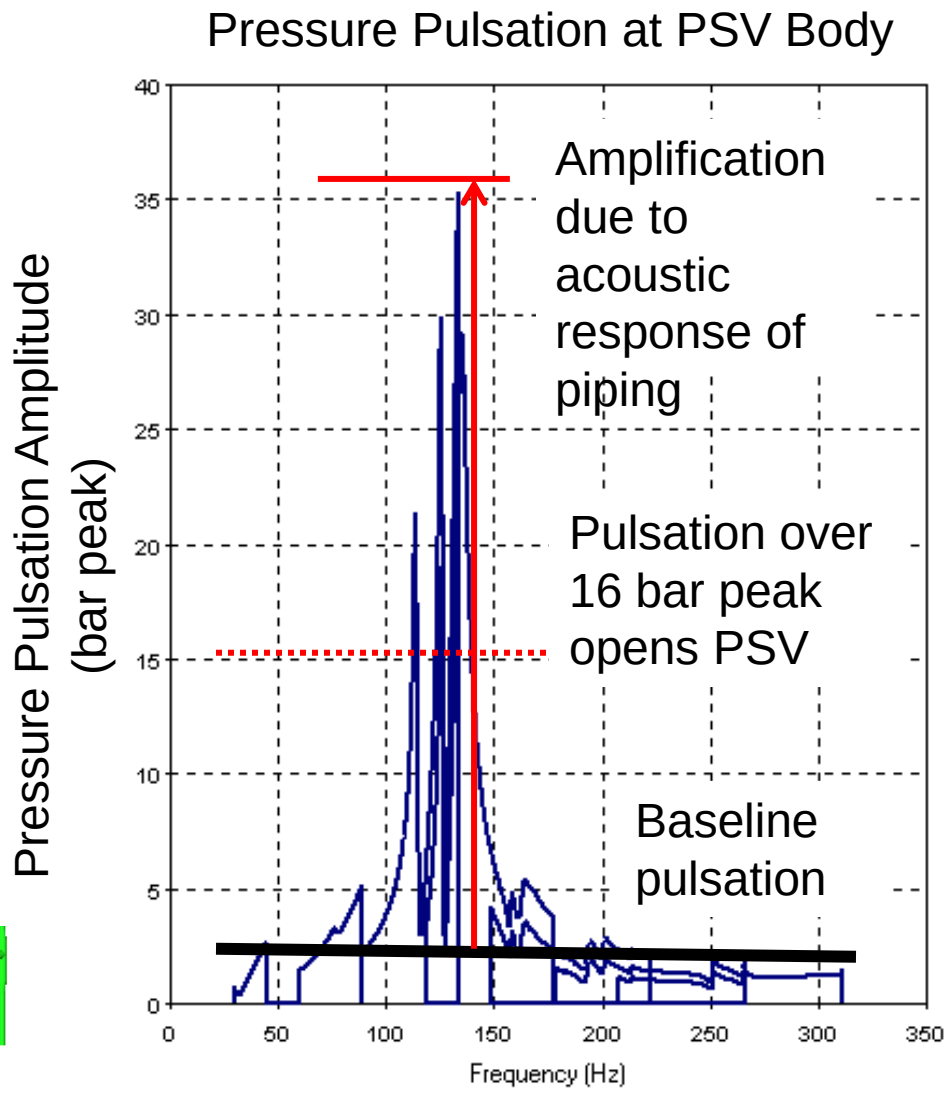
PSV set 5% above line pressure with 16 bar margin

Exceeds API 674 design margin by 31 bar

API 674 3rd Ed C.1.7 specifies a 5% design margin between the maximum instantaneous pressure, including pulsation, and the PSV set pressure

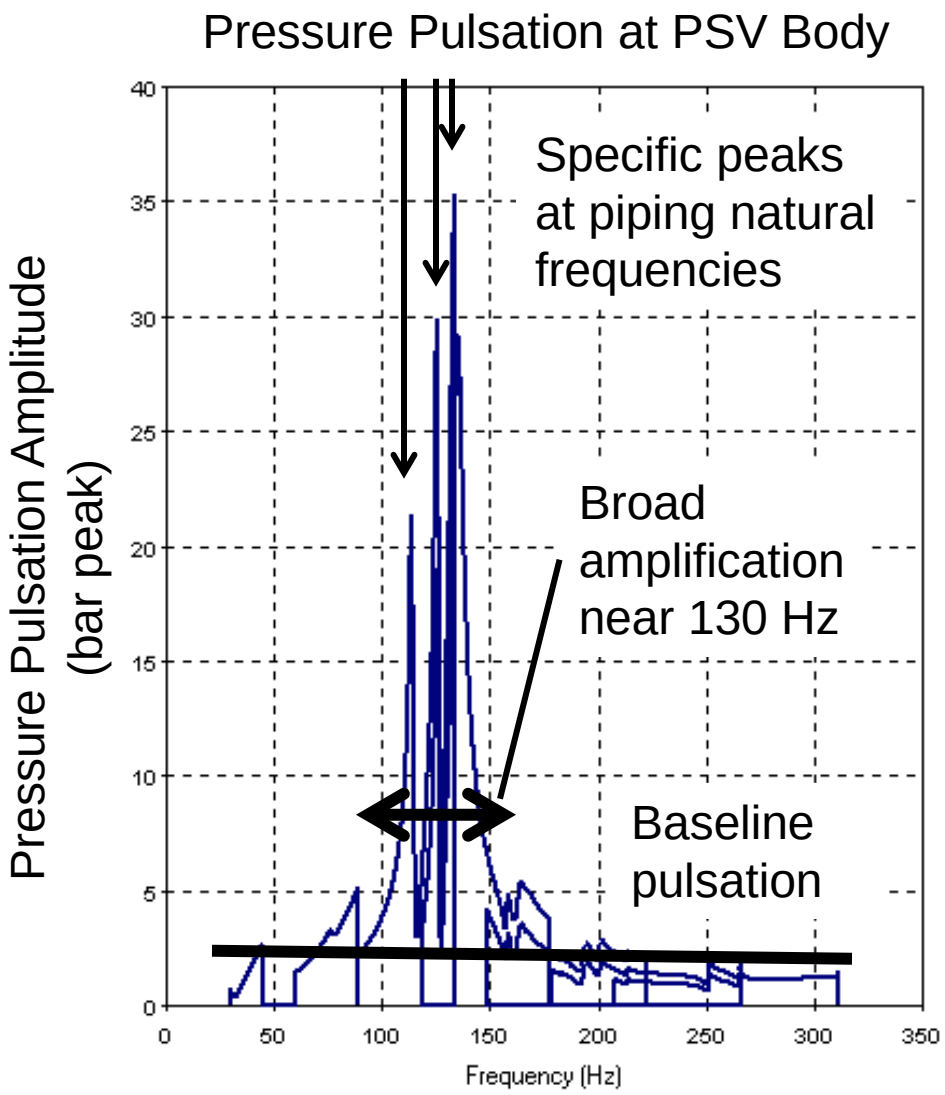
Acoustic Study Results





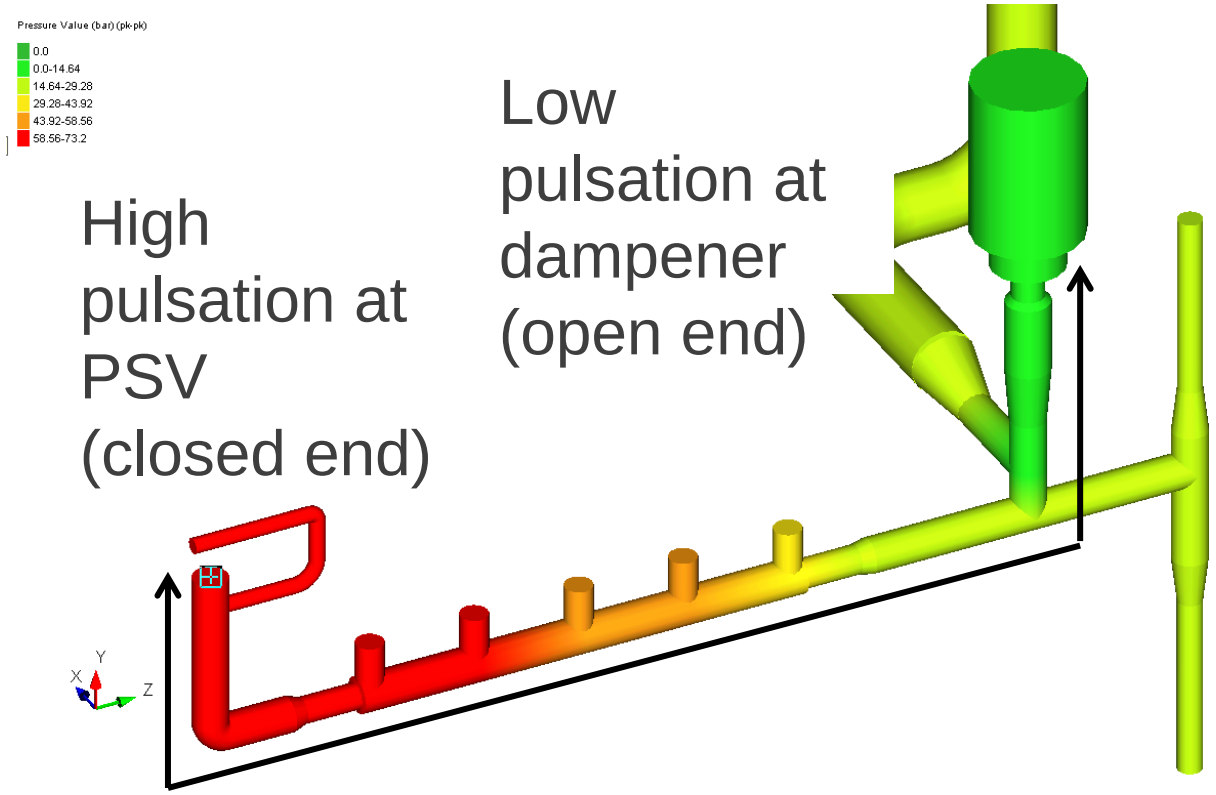
Acoustic Study Results

- Acoustic resonance results in amplified pulsation.
- Resonance occurs when a pump excitation frequency is near an acoustic natural frequency.
- There is broad amplification centered near 130 Hz due to manifold ¼ wave acoustic response.
- There are specific peaks at piping natural frequencies between 110-140 Hz.



Manifold ¼ Wave Acoustic Response

A pump manifold ¼ wave acoustic response is common for all pumps with a **closed end** on one side (PSV, blind flange, …) and an **open end** on the opposite side (gas or liquid dampener).



Manifold ¼ Wave Acoustic Response

- ¼ wave acoustic natural frequency is a classic acoustic response with a **closed end** on one side and an **open end** on the other side.
- Wavelength, $\lambda = 4 * L_a$ L_a is acoustic length
  $\lambda = 31.6$ ft L_a is 7.9 ft
- Frequency, $f = c / \lambda$ c is speed of sound
  $f = 130$ Hz c is 4108 ft/s
- This equation works fairly well when there is a clearly defined **closed** and **open end**.
- But for complex piping, acoustic modeling must be done to accurately calculate acoustic natural frequencies.

Manifold ¼ Wave Acoustic Response

- For this application, the manifold ¼ wave frequency exists at 130 Hz due to the length of pipe from the PSV to the gas dampener.
- Due to the high pump speed (446 RPM), this frequency is near the 3rd and 4th pump harmonic(n=3,4)

$$f_{excitation} = RPM \times 5 / 60 * n$$

$$f_{3rd} = 111.5 \text{ Hz}$$

$$f_{4th} = 148.7 \text{ Hz}$$

Possible Solutions

- Improve margin between line pressure and PSV set pressure
  - Increase PSV set pressure
  - Decrease line pressure
- Reduce pressure pulsation
  - Add an orifice near pump discharge
  - Add a gas charged dampener near PSV
  - Add liquid flow through style dampener to reduce high frequency pulsation

Solutions: Improve PSV Margin

- Increase PSV set pressure
  - This was not possible because the PSV set pressure was selected due to the pipe pressure rating.
- Decrease line pressure
  - Lowering the line pressure by 36 bar would satisfy the API 674 3rd Ed C.1.7 recommended margin
  - However, the process requires a certain pressure

Solutions: Reduce Pressure Pulsation

- Add an orifice plate downstream of dampener
  - Pressure drop provides acoustic damping that reduces amplification due to acoustic resonance
- Add a gas charged dampener near the PSV
  - Changes the acoustic response near the PSV
- Add a liquid volume
  - Liquid volume reduces high frequency pulsation.

Implemented Solution/Results

Two changes were made to reduce the pressure pulsation and improve the margin

- A small gas charged dampener was installed on the PSV sense line to reduce the pressure pulsation measured by the PSV.
- The pump discharge set pressure was reduced to 302 barg.

These modifications have resulted in improved PSV life.

Lessons Learned

- For a reciprocating pump, a PSV must be set with a sufficient margin above line pressure.
- API 674 recommends a 5% margin including pressure pulsation.
- Due to the manifold ¼ wave response, pressure pulsation on the back side of a pump can be much higher than in the piping system.
- If a PSV is used on the back side of a pump, be sure to consider pulsation when choosing the PSV set pressure.