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Investigation & Resolution on Oxination Feed Pump Pulsation Related fatigue failures

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Presenter/Author bios

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Agenda

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Abstract Synopsis

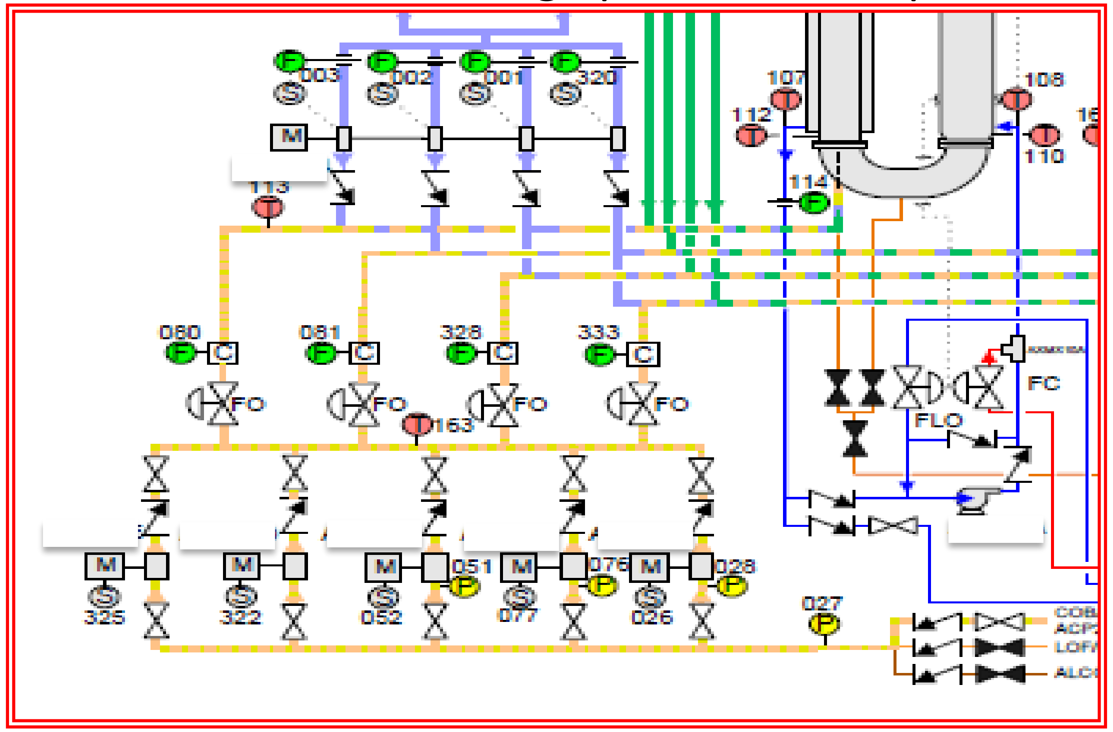
This case study presents the detailed analysis on the high pressure Triplex reciprocating pump .
Issues were observed during the operation and subsequent detailed pulsation analysis was carried out to understand the root cause of the piping and pump valve failures.

A more detailed pulsation analysis of the cylinder nozzles of the discharge resonators showed that standing wave type resonance with the same frequency as measured during actual operation was present, leading to large pulsation-induced forces. The problem was resolved by implementing recommendations of the study: installation of orifice plates at the inlets of the discharge dampeners.
Piping designs and its structural J-hanger supports were reviewed and modified to countermeasure the influence on hydraulic pulsation forces and mechanical vibrations, leading to acceptable cyclic stresses.

Problem Definition

Three positive displacement pumps were installed in one of our plant. Each pump is sized for 13 tph at 290 bar-g, driven by a VFD operated 200 kW LV motor. During the plant and pump design phase pulsation study based on API 674 Approach 2 was performed, to ensure a safe and reliable system for the long term without pulsation and vibration problems.

Two additional pumps were installed subsequently to meet increased process demand. By Design all 5 Pumps are operated in parallel. After a few operating hours very high vibrations were observed on the cylinder nozzles, between pump cylinder and discharge pulsation dampener, resulting in a fatigue failure of butt welds of these nozzles. This failure only occurred on the new installed pumps. The differences between the initially and new installed pumps were the layout and length of the cylinder nozzles of the discharge pulsation damper.



Case For Action

- High vibration amplitudes on cylinder nozzles in parallel mode of operation
- Excessive stresses on the butt welds of the resonator nozzles and pipe weld joints leading to fatigue failures and loss of process containment
- Impact and fatigue loading on the cone valve seats leading to premature failures
- Pump MTBF and on stream availability factor significantly impacted
- Increased maintenance down time and repair cost affecting pump TCPI(Total cost per pump install)

Equipment Details

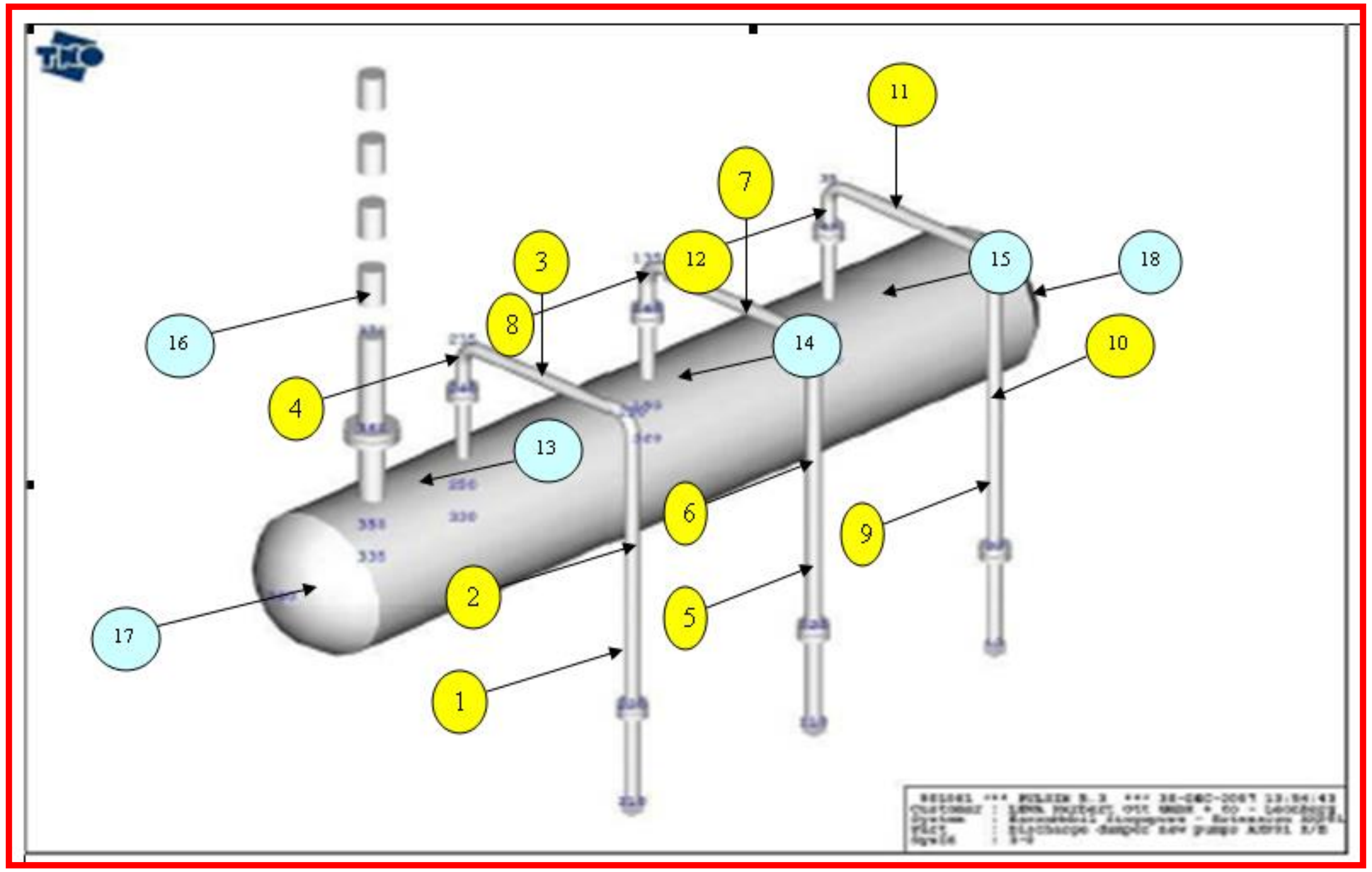
#	Equipment details	New pumps	Existing old pumps
1	Pump manufacturer	LEWA GmBH	LEWA GmBH
2	Pump Model	G3R	G3R
3	Flow : m^3/Hr	14.0	14.0
4	Suction Pressure : bar-g	1.81	1.81
5	Discharge Pressure : bar-g	292.92	292.92
6	Liquid density : g/cm^3	0.7	0.7
7	Pumping temperature : ^{O}C	45	45
8	Driver Power : KW	200	200
9	Driver speed : RPM - VSD	990	750

Maintenance Statistics & KPI Snapshot

KPI Details	Before Improvement	After Improvement	% Improvement
Pump MTBF : Mean Time between failure - months	8	12	50%
Piping and resonator nozzle failures	6	0	100 %
Loss of process containment caused by vibration	4	0	100%
Downtime attributed by leaks: Days	26	3	88.5%

Field Investigation Analysis & Data Mining

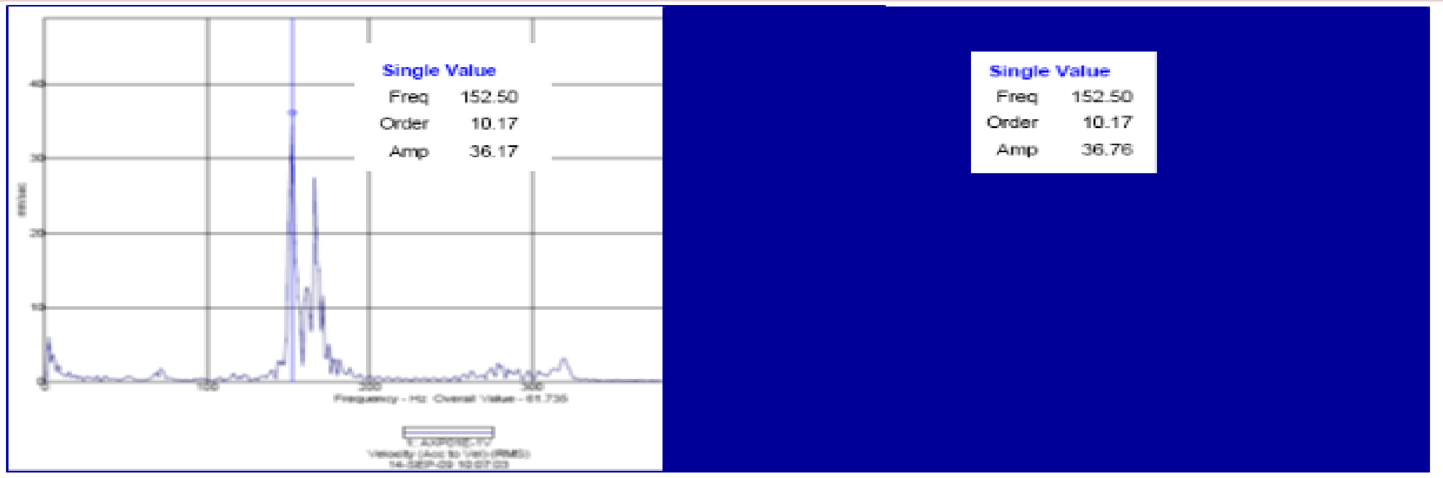
- Vibration measurements were taken on both new pumps with the same operating conditions
- Vibration data was collected by means of vibration spectrum analyzer and a magnetically mounted accelerometer.
- Operating conditions at time of vibration data collection:
  - Pump speed : 150 rpm
  - Suction pressure : 5.15 bar-g
  - Discharge pressure : 284 bar-g
  - Flow (total feed) : 37.1 tons/hr
  - Suction dampener pressure : 5.25 bar-g



Locations of vibration measurements

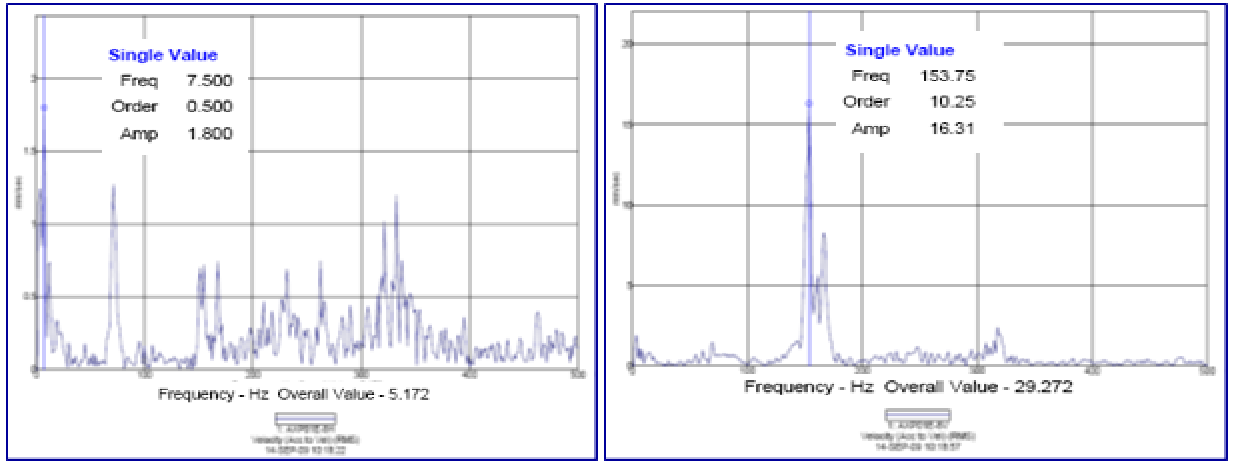
Field Investigation Analysis & Data Mining

Vibration Spectrum Data Analysis and Inference



Vibration spectrum of AXP01E (Head #1 at J-bend - Vertical

- Multiples of harmonics and raised noise floor in spectrum at J-bend piping was evident
- Peaks of 152.5 Hz and 175 Hz likely to be associated with acoustic and mechanic resonant frequencies
- These are not 1X,2X or 3X dominant spikes associated with rotary component deficiencies



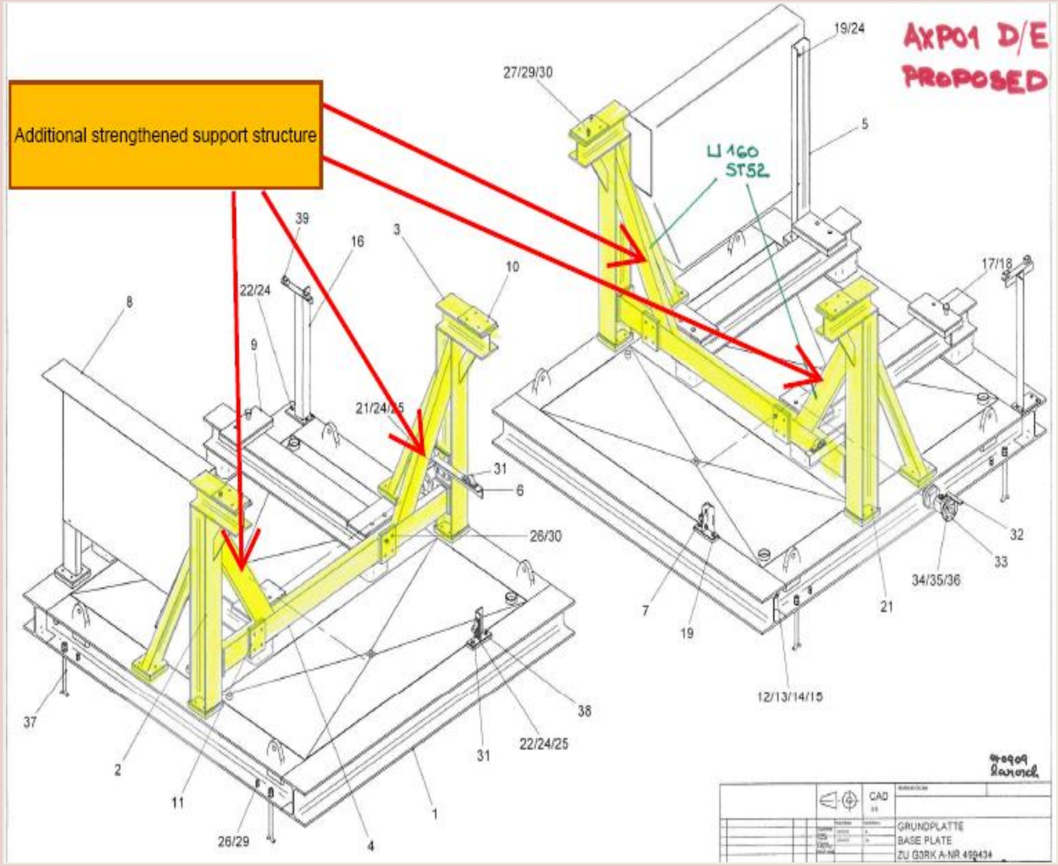
Vibration spectrum at pos 8. (Head #2 at J-bend – Horizontal &Vertical)

- Higher vibration response of J-bend frequency at 153.75 Hz (suspected this harmonic contains more energy) in vertical direction as compared to horizontal direction which is deemed acceptable
- Acceptable overall vibration velocity level: 19 mm/s r.m.s

Technical Feasibility & Evaluation

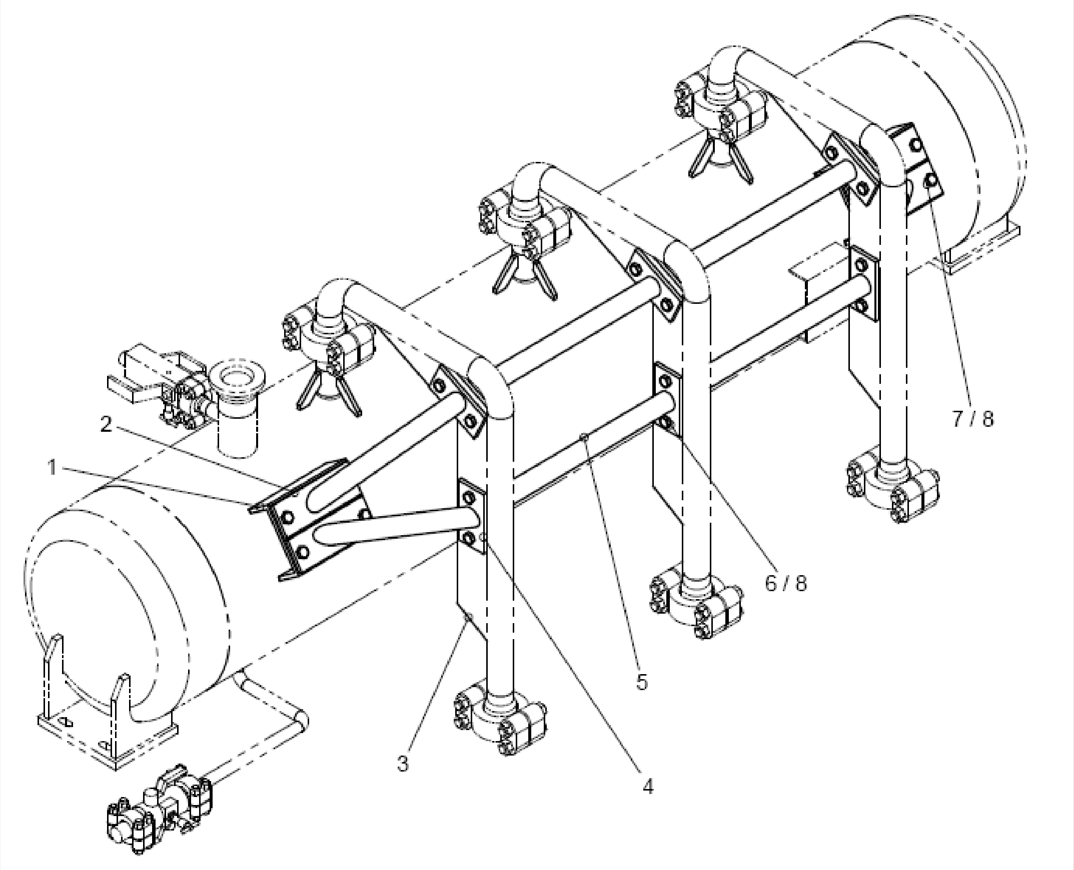
- Evaluated the J-bend piping design by analyzing the natural frequencies, hydraulic pulsations and mechanical response.
- Technical proposal and Solution :
  - Bracing / supports modification at J-bend piping to lower the stress levels.
  - Stiffening of the resonator support structure will increase the resonant frequencies and reduce the possibility of an excitation at low harmonics.
- By stiffening the J-bend piping and resonator supports, the natural frequency will increase since operating deflection will be decreased (ie: moving the natural frequency away from resonance).
- Overall vibration levels were reduced typically from 15% to 75% in vertical direction. However the highest vibration amplitudes were observed at the J-bend piping, primarily in the horizontal direction This may be due to a shift of the natural frequency to a higher range (100 – 200 Hz) and therefore the dominant vibration is anticipated to be higher
- Pulsation analysis conducted on the J-bends only inferred that standing waves in the J-bends are responsible for the high vibration amplitudes.
- Outcome of this technical evaluation called for orifice installation on the discharge resonator take off section to dampen and mitigate the effects of standing wave issue.

Technical Proposal Back up

Base Frame Support Re-enforcement	
	
Stiffening of the resonator support structure will increase the resonant frequencies and reduce the possibility of an excitation at low harmonics	

Technical Proposal Back up

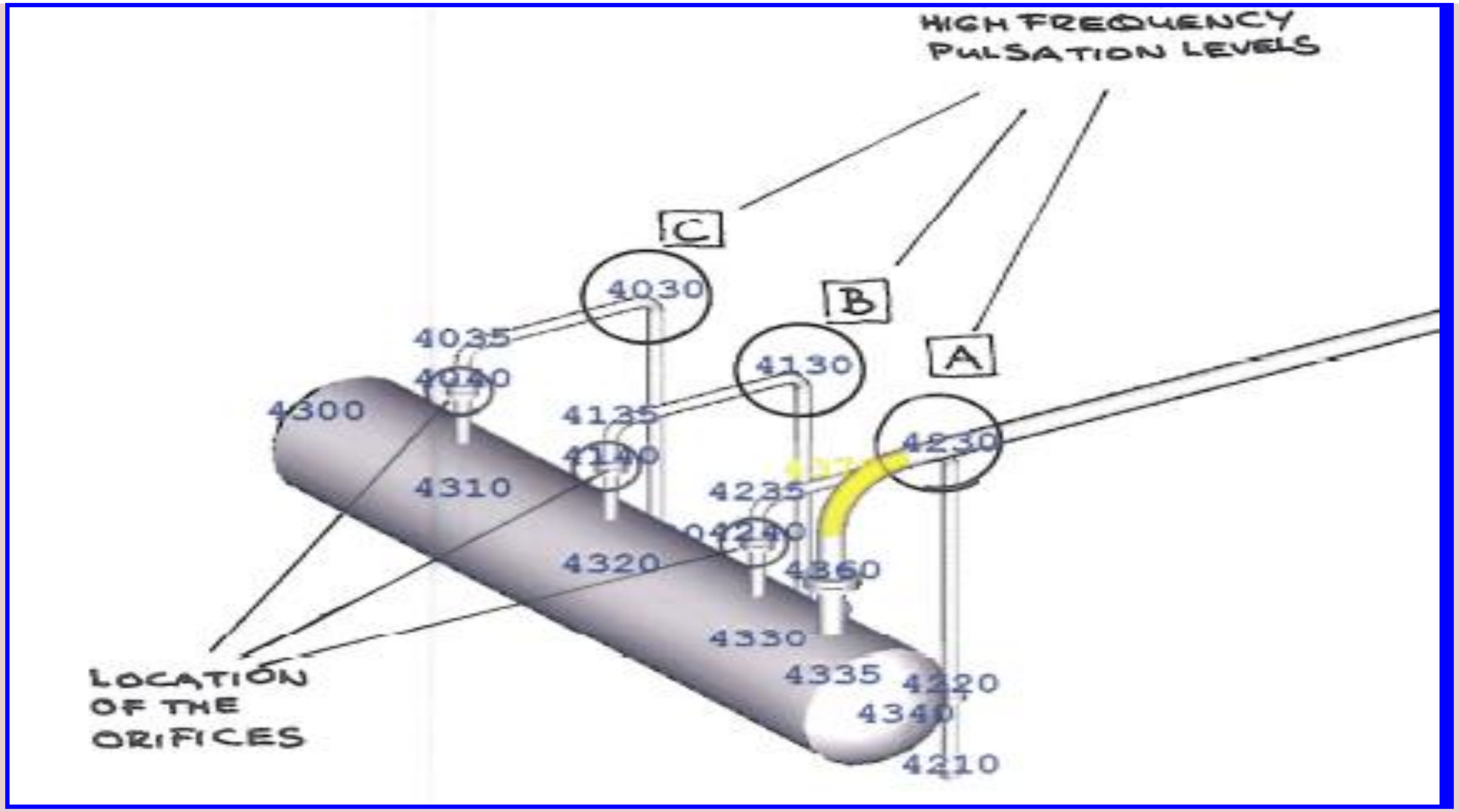
J-bend Brazing Stiffener Addition



- Bracing / supports modification at J-bend piping to lower the stress levels.
- Stiffening the J-bend piping, the natural frequency will increase and consequently the operating deflection will be decreased leading to lower cyclic stresses

Technical Proposal Back up

Orifice Sizing & Installation : Standing Waves Attenuation



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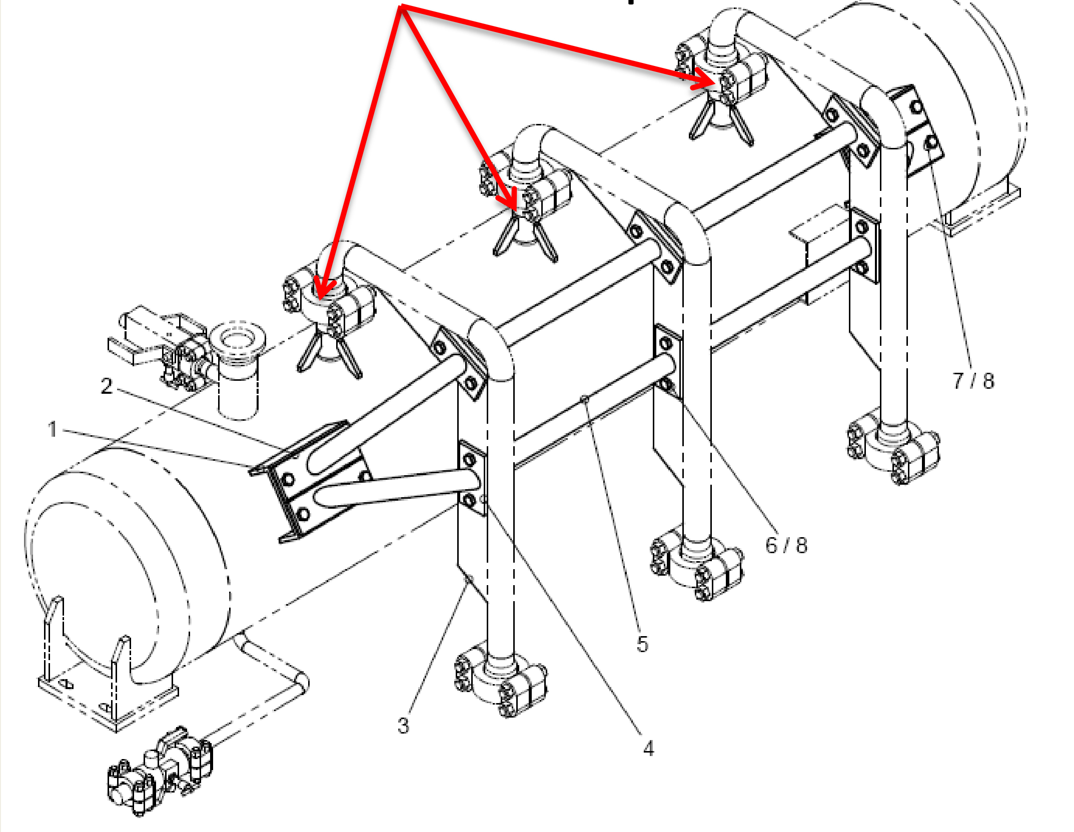
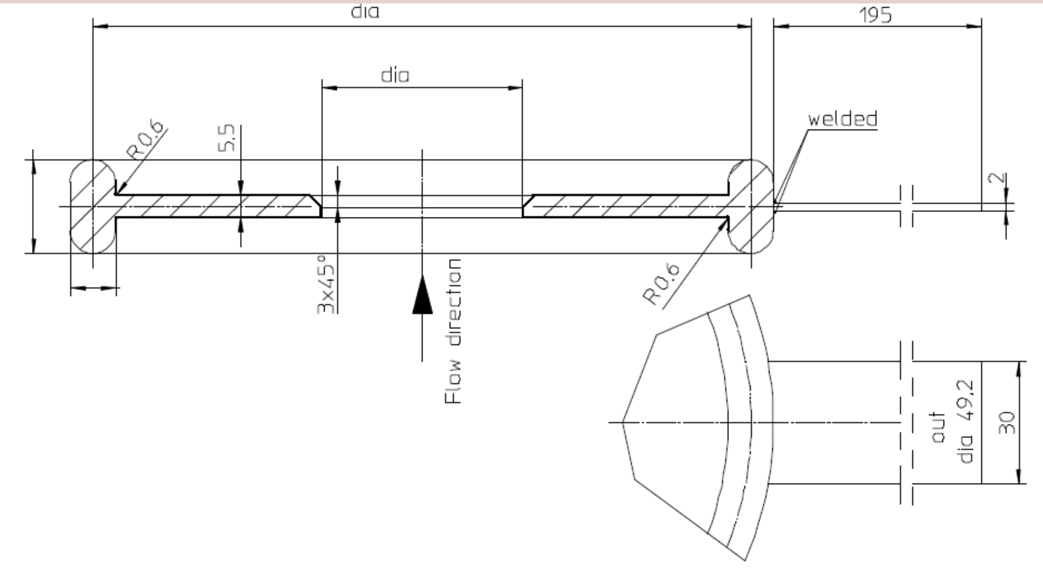
Technical Proposal Back up

Location and type of orifice plates

Location of orifice plates





- Location of orifice plates: outlet of resonator
- Orifice plate design: RTJ-type sealing elements

Results Accomplished

Field Test Evaluation : Five pump Parallel mode operation

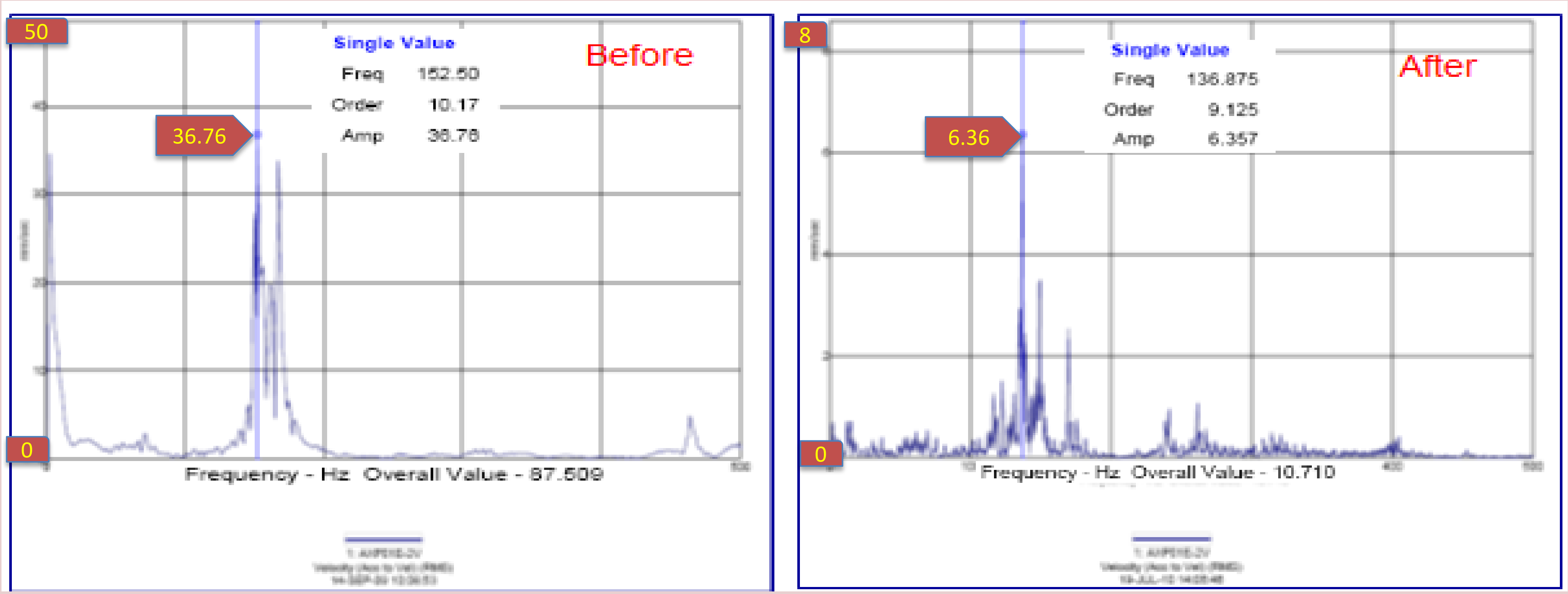
- Vibration measurements were recorded on both pumps, with same operating conditions when running all five pumps were operated on parallel mode
- Operating conditions at time of vibration data collection:
  - Pump load : 70% with all five pumps running
  - Pump load : 100% for two pumps; the remaining 3 pumps run at 65% load.
  - Suction pressure : 5.21 bar-g - 5.11bar-g
  - Discharge pressure : 278 bar-g - 281 bar-g
  - Flow (total feed) : 38.5 tn/hr - 39.6 tn/hr
  - Suction dampener pressure : 6.0 bar-g
- After installation of the orifices, the pulsation levels and overall vibration levels were reduced significantly in all directions.
- Vibration results of newly added two pumps are deemed acceptable with five pump operation.
- Vibration response of J-bend piping was reduced significantly by 95% from 87.5 mm/s r.m.s. to 10.7mm/s r.m.s. in vertical direction after the modification with the installation of Orifice
- Vibration response of J-bend piping in horizontal direction was also significantly reduced from 30.8 mm/s r.m.s. to 10 mm/s r.m.s. after the modification

Conclusion and Learning Opportunities

- Pulsation and mechanical response studies to include evaluation on various permutation and combinations of parallel mode operations during engineering phase
- Careful attention to be given on the consequences of standing waves
- Adequate stiffening and re-enforcement to be considered for dampener cylinder nozzle and take off piping from the pump
- Wave form models to be analyzed during FAT & SAT using CMS (Oscillographic based condition monitoring system)

Results Accomplished

Vibration spectrum at pos 2 (Head #1 at J-bend - Vertical).



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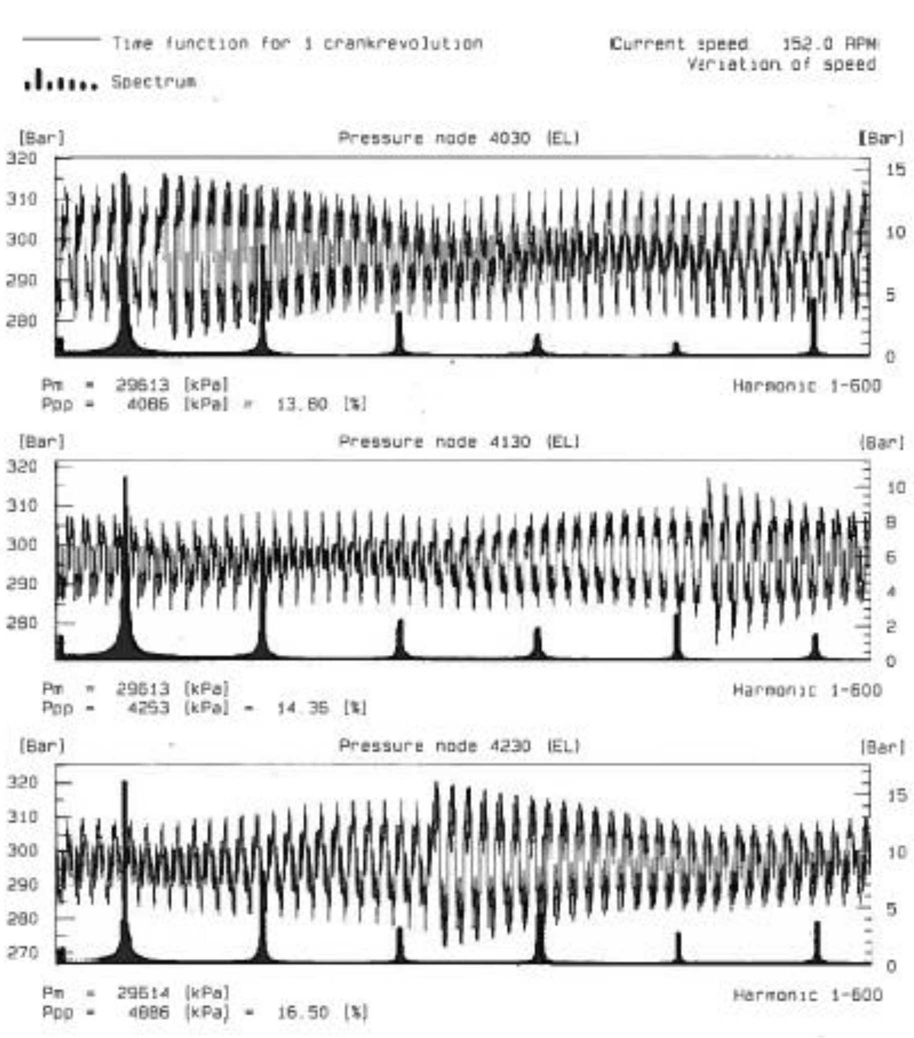
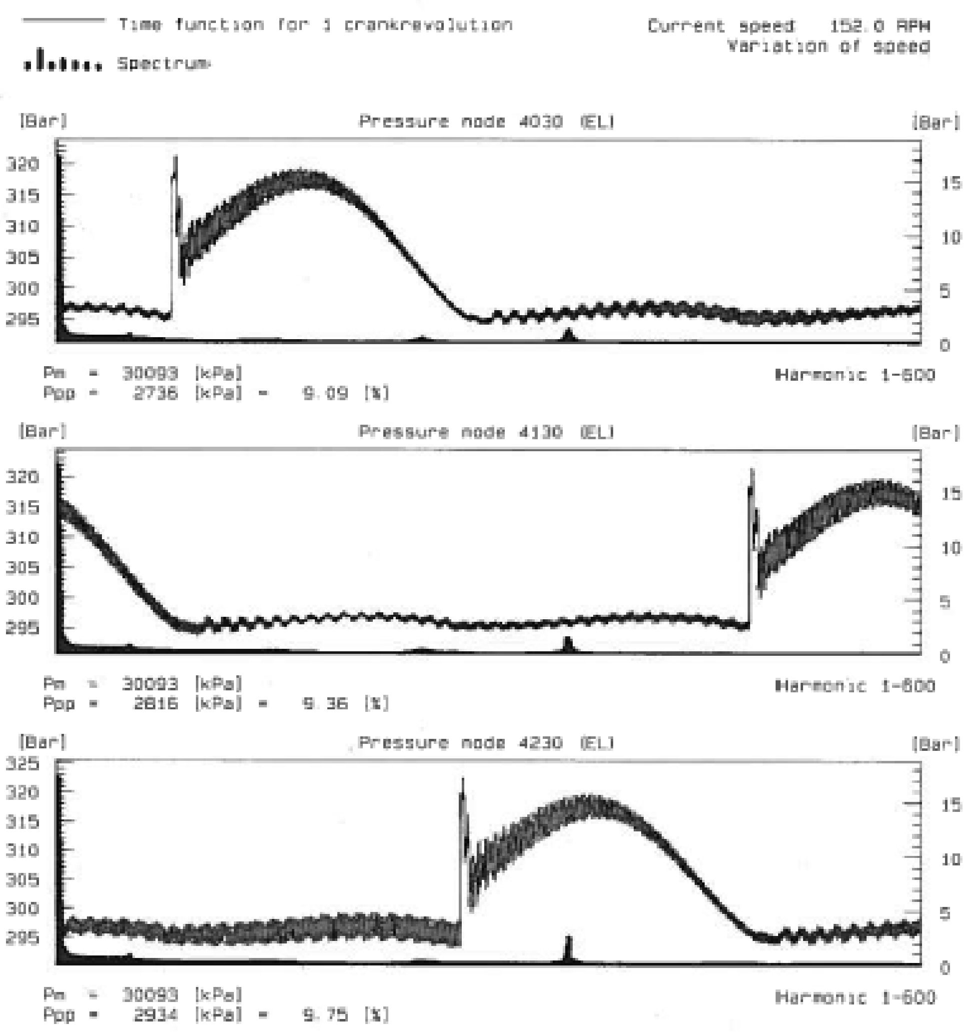
Results Accomplished





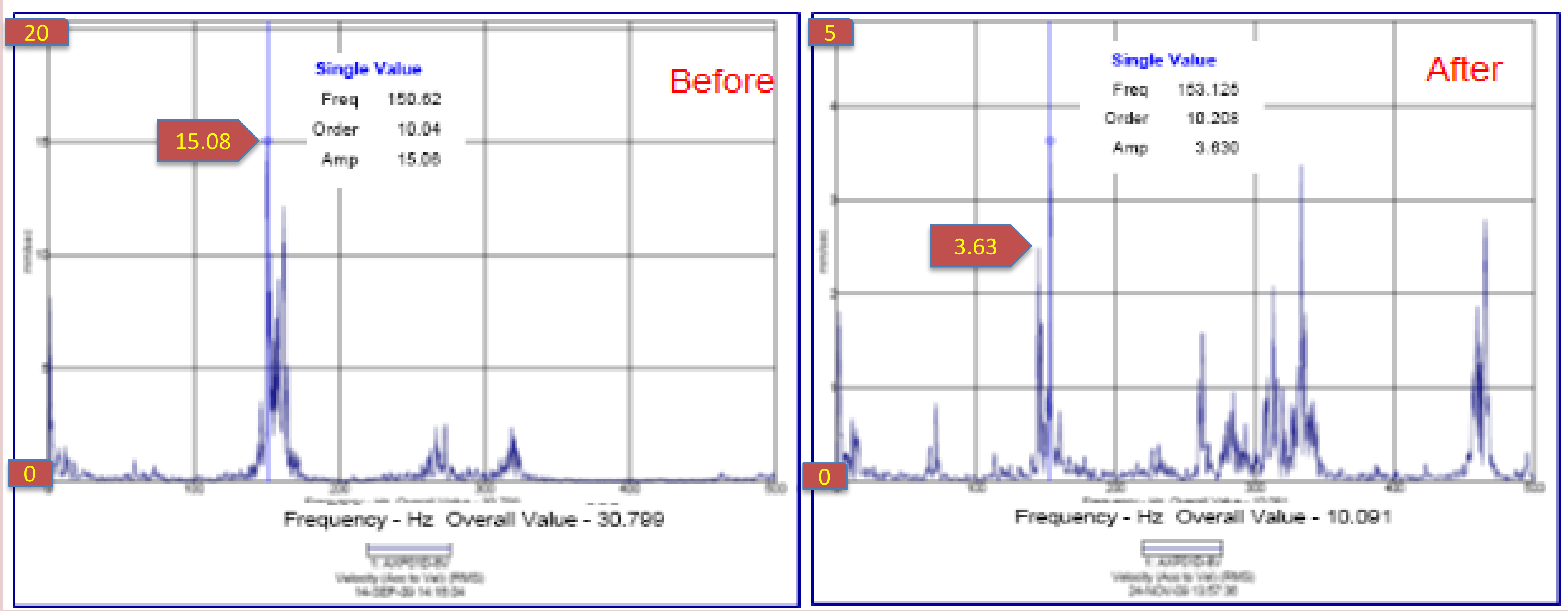
Pulsation level at bends before installation of the orifice plates

Pulsation level at bends after installation of the orifice plates

Conclusion: pulsation levels were reduced significantly after the installation of the orifice plate

Results Accomplished

Vibration spectrum at pos 2 (Head #1 at J-bend - Horizontal)



Vibration response of J-bend piping in horizontal direction was also significantly reduced from 30.8 mm/s r.m.s. to 10 mm/s r.m.s. after the modification

Results Accomplished

Vibration Snapshot Data

Before modification

ID	Units	Date	Last Value	Previous Value	Percent Change	Alarm Status
Machine: AXP01D Desc:						
AXP01D-1H	mm/sec	24-NOV-09	33.21	9.389	253.8	A2
AXP01D-1V	mm/sec	24-NOV-09	14.12	62.7	-77.5	A2
AXP01D-2H	mm/sec	24-NOV-09	39.49	28.27	39.7	
AXP01D-2V	mm/sec	24-NOV-09	45.06	85.54	-47.3	
AXP01D-3H	mm/sec	24-NOV-09	18.8	18.24	3.1	
AXP01D-3V	mm/sec	24-NOV-09	18.29	23.93	-23.6	
AXP01D-4H	mm/sec	24-NOV-09	31.22	18.09	72.6	A2
AXP01D-4V	mm/sec	24-NOV-09	10.43	34.61	-69.9	
AXP01D-5H	mm/sec	24-NOV-09	26.77	15.02	78.2	
AXP01D-5V	mm/sec	24-NOV-09	17.47	45.27	-61.4	A2
AXP01D-6H	mm/sec	24-NOV-09	30.91	23.82	29.8	A2
AXP01D-7H	mm/sec	24-NOV-09	10.69	42.2	-74.7	
AXP01D-7V	mm/sec	24-NOV-09	28.48	59.14	-51.8	
AXP01D-8H	mm/sec	24-NOV-09	20.04	13.28	50.9	
AXP01D-8V	mm/sec	24-NOV-09	10.09	30.8	-67.2	A2
AXP01D-9H	mm/sec	24-NOV-09	32.24	13.68	135.6	A2
AXP01D-9V	mm/sec	24-NOV-09	25.46	30.56	-16.7	A2
AXP01D-10H	mm/sec	24-NOV-09	43.02	20.58	109.1	
AXP01D-10V	mm/sec	24-NOV-09	52.43	59.6	-12.0	A2
AXP01D-11H	mm/sec	24-NOV-09	10.29	20.05	-48.7	
AXP01D-11V	mm/sec	24-NOV-09	29.05	30	-3.2	
AXP01D-12H	mm/sec	24-NOV-09	24.04	18.77	28.1	
AXP01D-12V	mm/sec	24-NOV-09	13.54	25.76	-47.4	A2
AXP01D-13	mm/sec	24-NOV-09	6.181	1.987	211.1	
AXP01D-14	mm/sec	24-NOV-09	4.373	2.996	46.0	A2
AXP01D-15	mm/sec	24-NOV-09	5.203	3.421	52.1	A2
AXP01D-16	mm/sec	24-NOV-09	14.69	10.6	38.6	A2
AXP01D-17	mm/sec	24-NOV-09	3.505	3.156	11.1	
AXP01D-18	mm/sec	24-NOV-09	4.549	2.381	91.0	
AXP01D-6V	mm/sec	24-NOV-09	44.28	76.13	-41.8	A2

After modification

ID	Units	Date	Last Value
Machine: AXP01E Desc: Discharge Spools to Resanator			
AXP01E-1H	mm/sec	19-JUL-10	5.046
AXP01E-1V	mm/sec	19-JUL-10	12.06
AXP01E-2H	mm/sec	19-JUL-10	6.428
AXP01E-2V	mm/sec	19-JUL-10	10.71
AXP01E-3H	mm/sec	19-JUL-10	3.645
AXP01E-3V	mm/sec	19-JUL-10	4.605
AXP01E-4H	mm/sec	19-JUL-10	3.515
AXP01E-4V	mm/sec	19-JUL-10	5.927
AXP01E-5H	mm/sec	19-JUL-10	5.378
AXP01E-5V	mm/sec	19-JUL-10	7.622
AXP01E-6H	mm/sec	19-JUL-10	6.06
AXP01E-6V	mm/sec	19-JUL-10	6.514
AXP01E-7H	mm/sec	19-JUL-10	3.731
AXP01E-7V	mm/sec	19-JUL-10	3.424
AXP01E-8H	mm/sec	19-JUL-10	2.982
AXP01E-8V	mm/sec	19-JUL-10	4.666
AXP01E-9H	mm/sec	19-JUL-10	4.484
AXP01E-9V	mm/sec	19-JUL-10	10.69
AXP01E-10H	mm/sec	19-JUL-10	5.711
AXP01E-10V	mm/sec	19-JUL-10	9.798
AXP01E-11H	mm/sec	19-JUL-10	4.416
AXP01E-11V	mm/sec	19-JUL-10	4.684
AXP01E-12H	mm/sec	19-JUL-10	3.509
AXP01E-12V	mm/sec	19-JUL-10	6.446
AXP01E-13	mm/sec	19-JUL-10	1.487
AXP01E-14	mm/sec	19-JUL-10	1.271
AXP01E-15	mm/sec	19-JUL-10	1.311
AXP01E-16	mm/sec	19-JUL-10	2.563
AXP01E-17	mm/sec	19-JUL-10	1.403
AXP01E-18	mm/sec	19-JUL-10	1.452

- Significant reduction in piping vibration levels by 95% (87.5 to 7 mm/sec r.m.s.)
- Overall vibration levels were reduced significantly in all directions after orifice installation
- Vibration results on newly added two pumps are deemed acceptable even with five pumps in parallel mode operation

CMS Oscillographic Wave forms