45TH TURBOMACHINERY & 32ND PUMP SYMPOSIA
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GEORGE R. BROWN CONVENTION CENTER

Thermal Load Effect on Vibration on a Reactor Feed Water Pump (FWP)

By:

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Maki M. Onari:

- Mechanical Solutions, Inc. – Manager of Turbomachinery Testing Sr. Principal Engineer: responsible for all MSI Turbomachinery Testing
- B.S.M.E., Zulia University, Venezuela
- Rotating Equipment Engineer, PDVSA: responsible for the predictive maintenance of one of the largest petrochemical complexes in Latin America
- Co-Author Pump Vibration Chapter, McGraw-Hill Pump Handbook
- Member of ASME and the ISO TC108/S2 Standards Committee for Machinery Vibration
- Presented tutorials, case studies, and lectured at the Texas A&M Symposia since 2007 as lead instructor on vibration short courses.

General Information

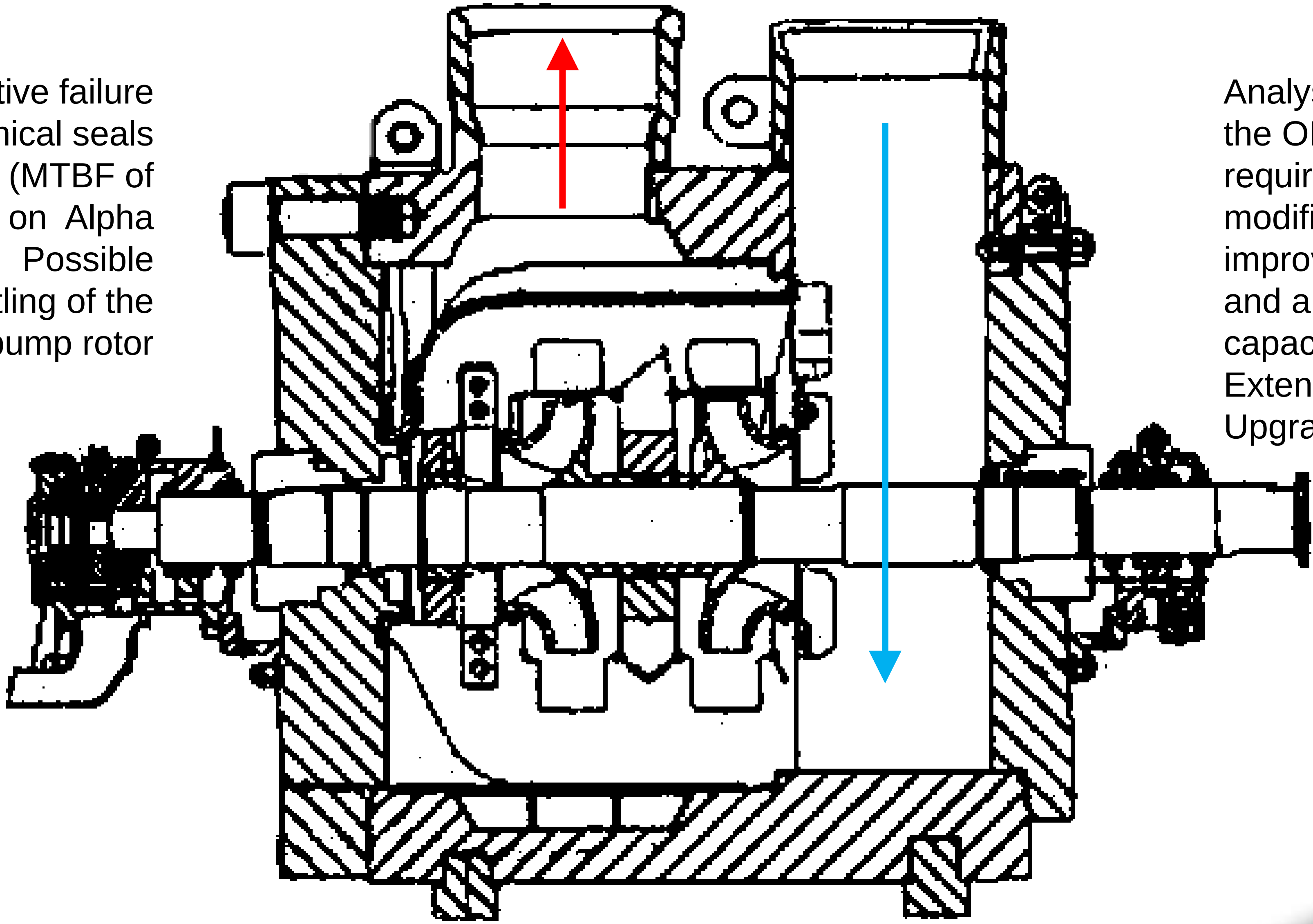
Constellation Energy – Exelon Corp.

Nine Mile Point Nuclear Station (NMPNS) Unit 2 – 1150 MW (Oswego, NY)

Application:	Reactor Feed Water Pump (FWP)
Type:	20x20x22 – 2 Stage (barrel type radial split)
Capacity:	8,000 gpm (min flow) to 22,870 gpm (max flow) Normal operation steady slightly above BEP
Suction Press.:	550 psig
Discharge Press.:	1,200 psig
Speed:	3,339 rpm (55.7 Hz)
Temperature:	382 ºF
Normal Load:	10,500 to 11,500 BHP
Driver:	Induction Motor (16,500 HP @ 1785 rpm (29.8 Hz)
Gearbox:	Speed Increaser (Gear ratio 1:1.87)

Background

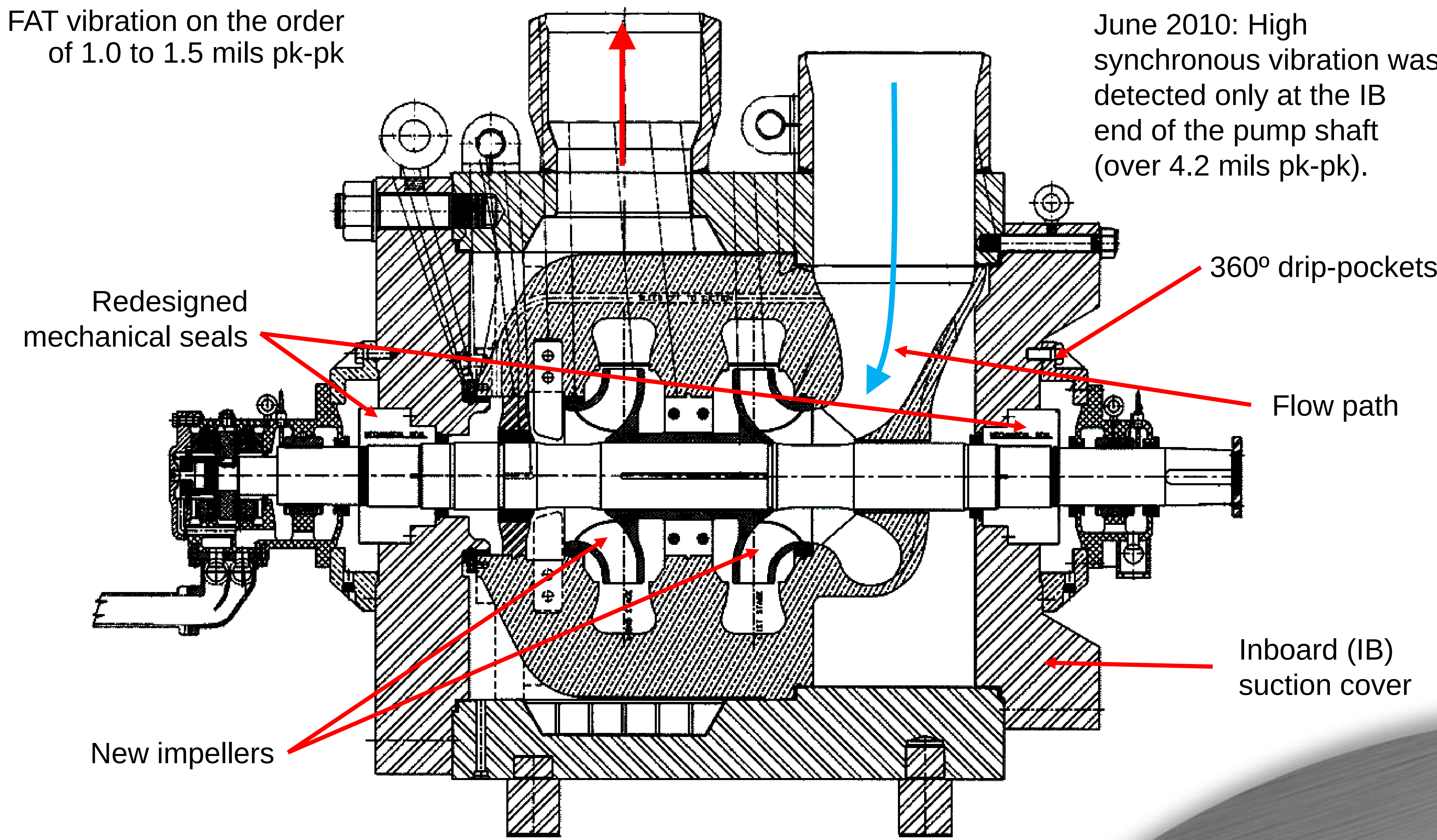
Repetitive failure mechanical seals since 1987 (MTBF of 6 months on Alpha FWP). Possible axial shuttling of the pump rotor



Former Design Cross Section
20x20x22 – 2 Stage

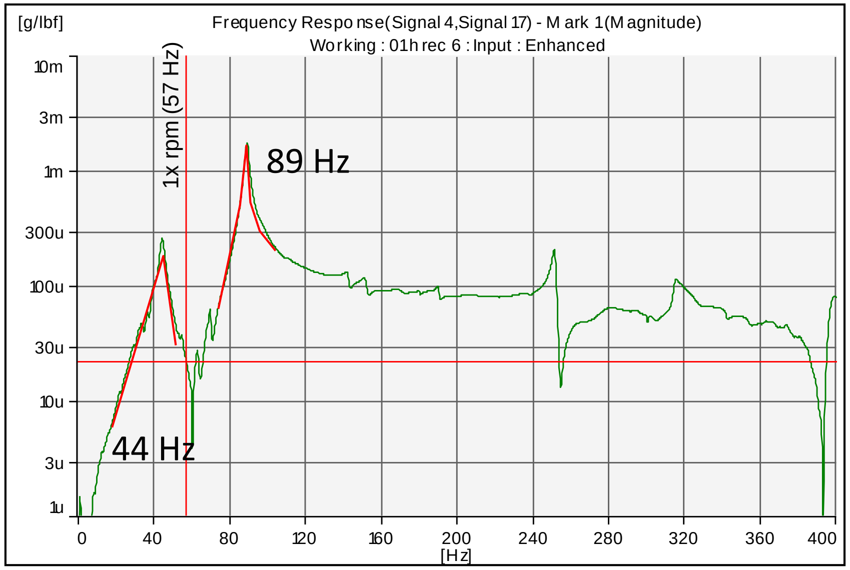
Analysis performed by the OEM, the pumps required a series of modifications to improve seal reliability and also increase plant capacity by 15% Extended Power Upgrade (EPU)

Background

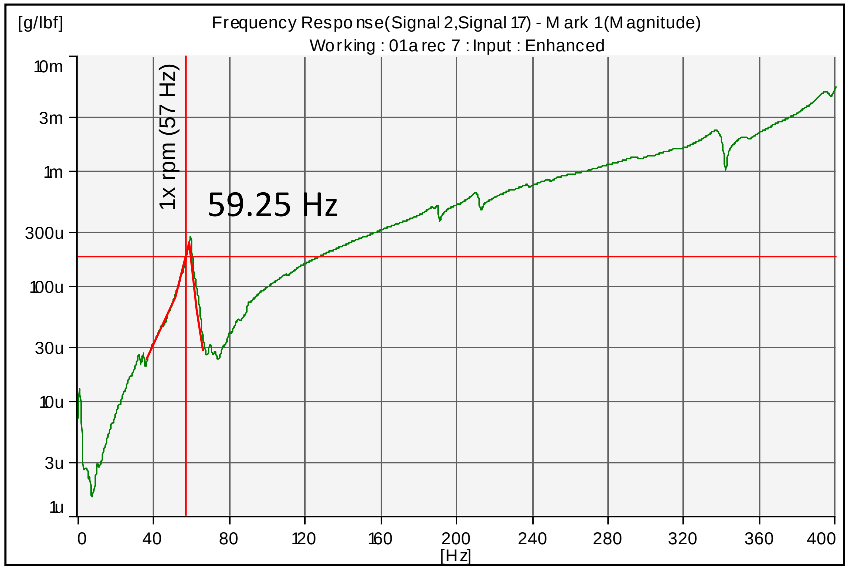


Modified in Spring 2010

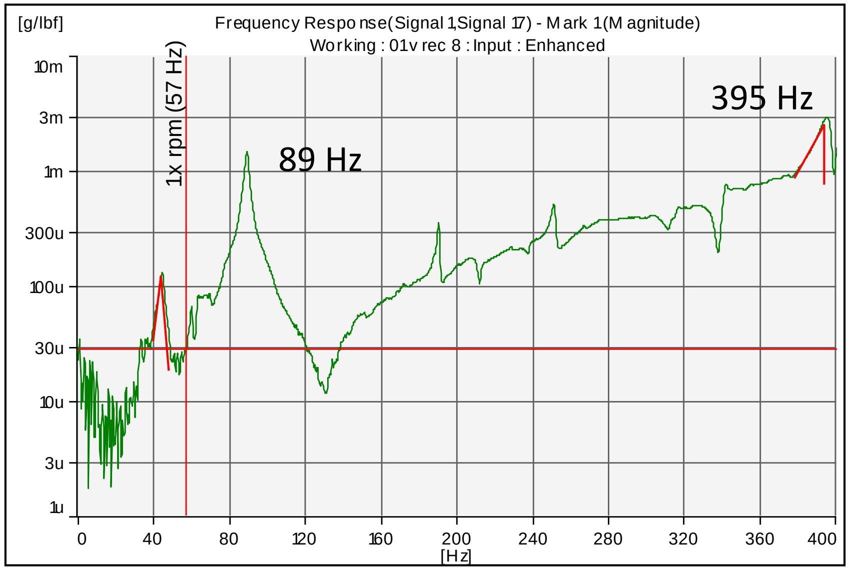
Initial Testing June 2010
2FWS-P1A Pump Typical FRF Plots



Horizontal Direction

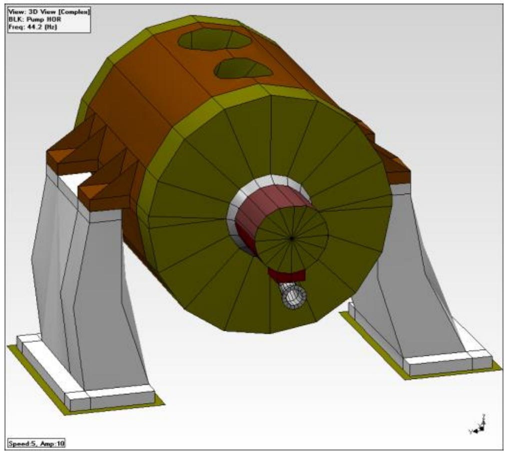


Axial Direction

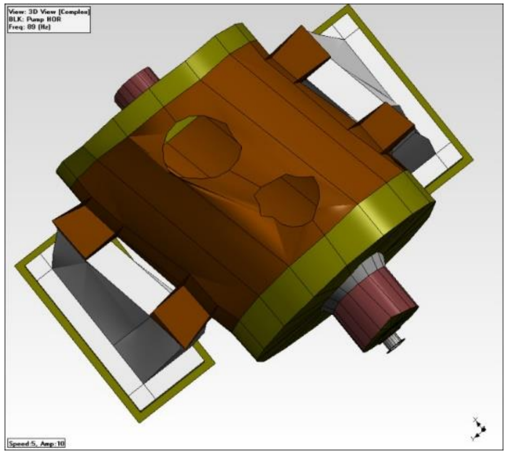


Vertical Direction

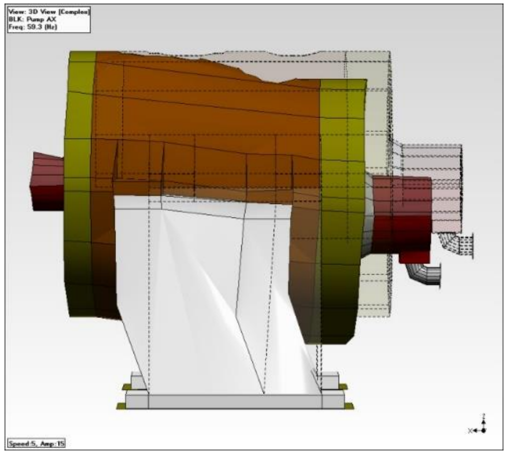
2FWS-P1A Pump Main Mode Shapes



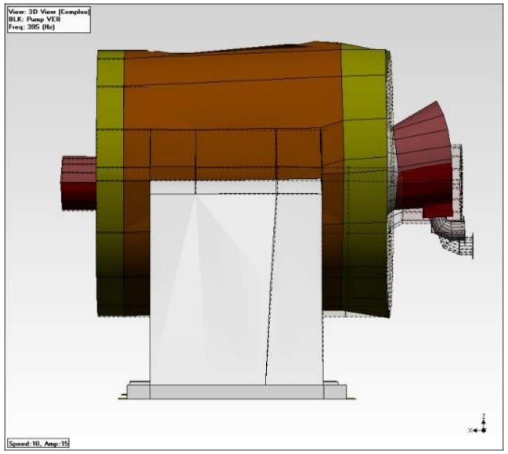
Lateral Rocking Mode @ 44 Hz



Twist Mode @ 89 Hz

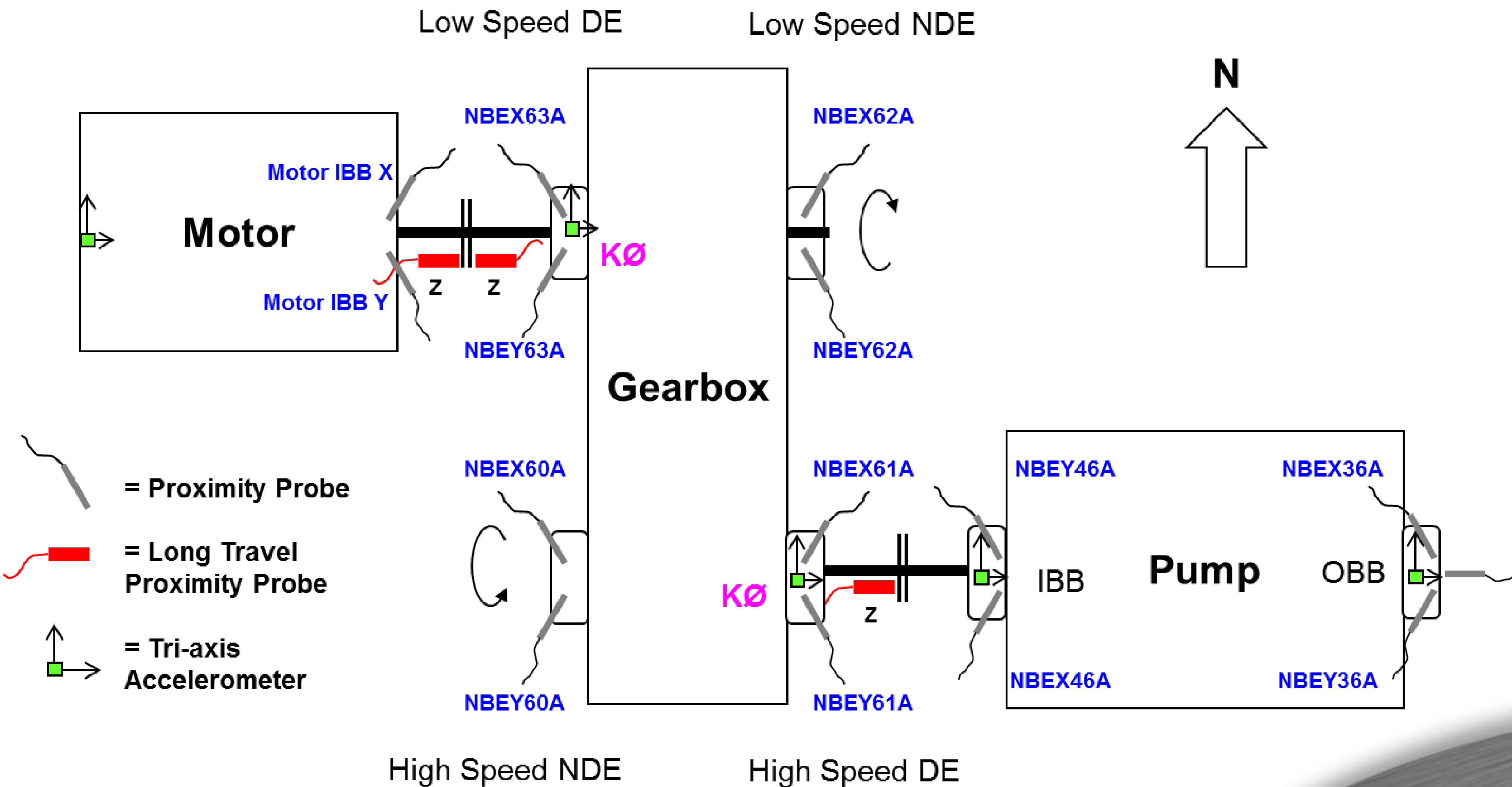


Axial Rocking Mode @ 59.3 Hz

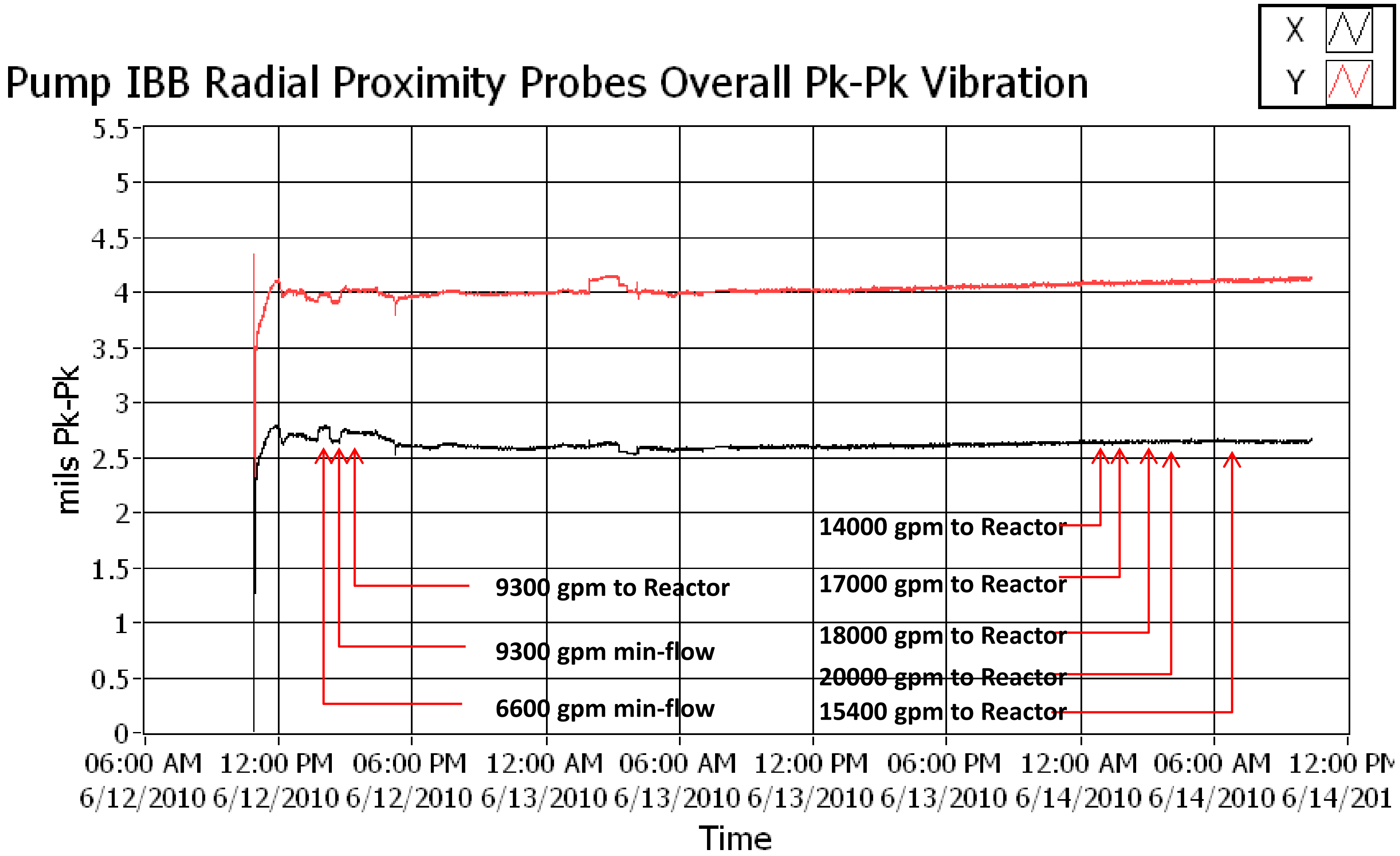


OBB Vertical Mode @ 395 Hz

Continuous Monitoring (CM) Testing

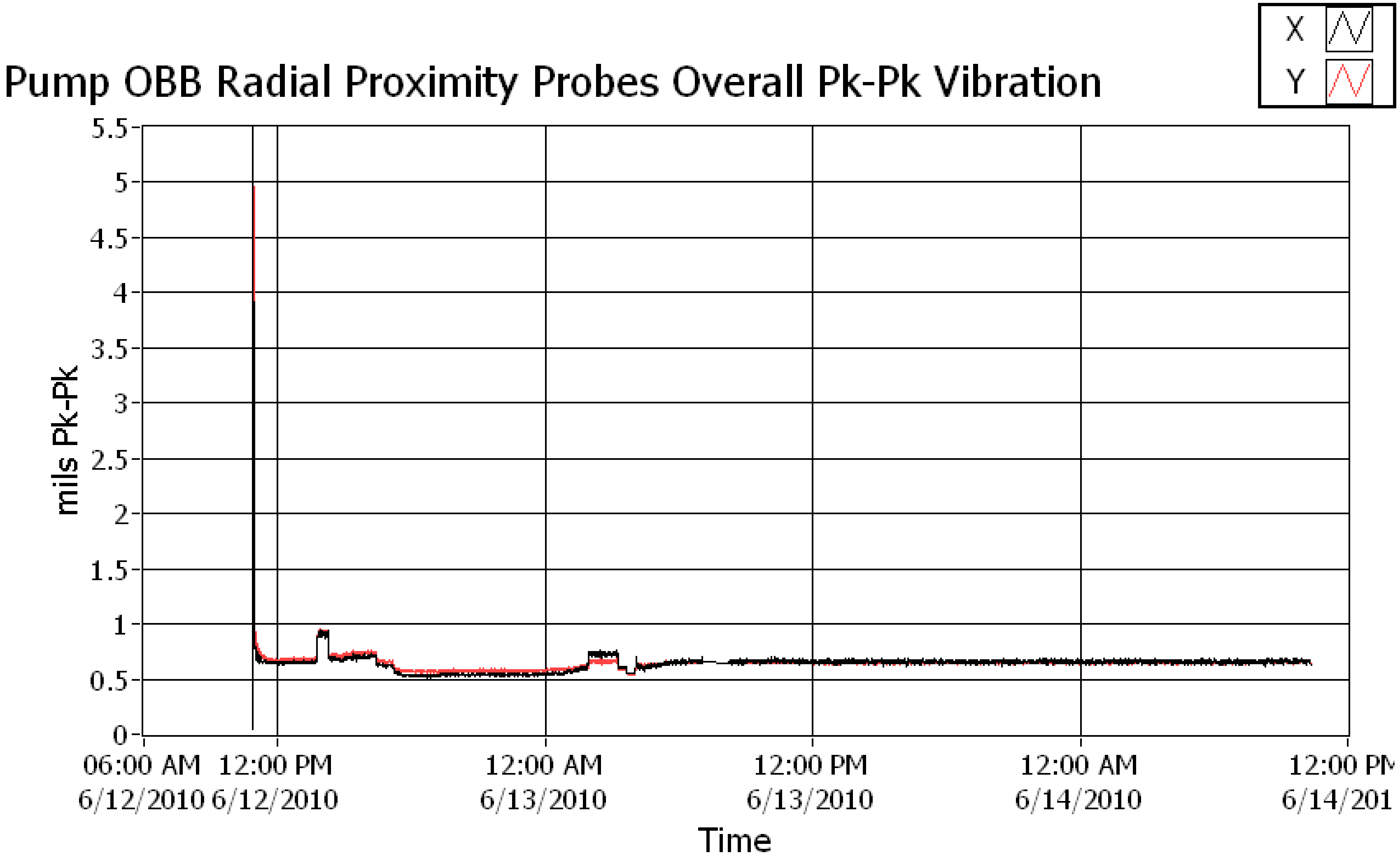


Pump Shaft Vibration



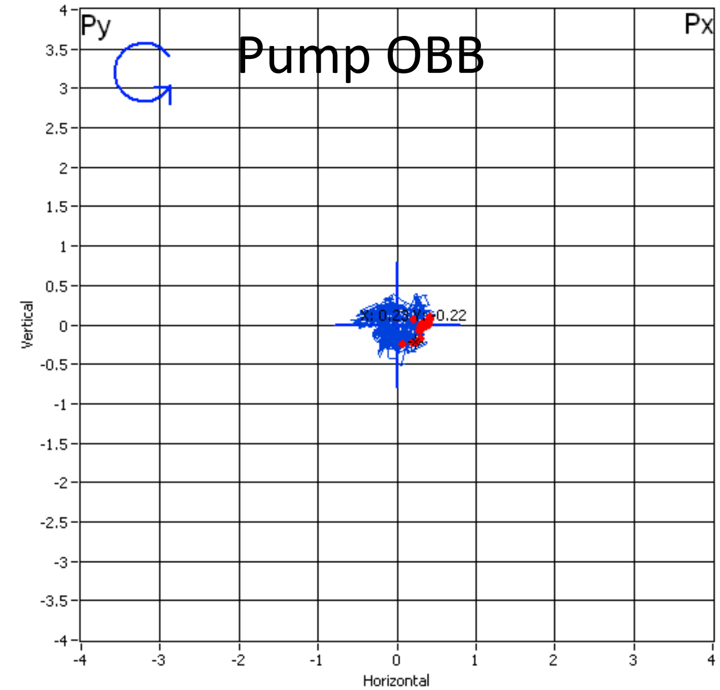
Shaft vibration mostly at 1x rpm
Bearing housing vibration was acceptable

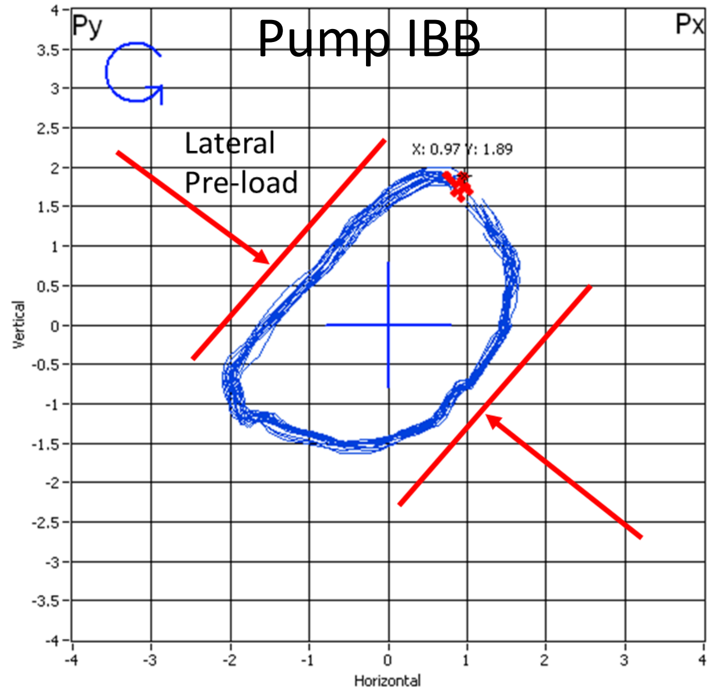
Pump Shaft Vibration

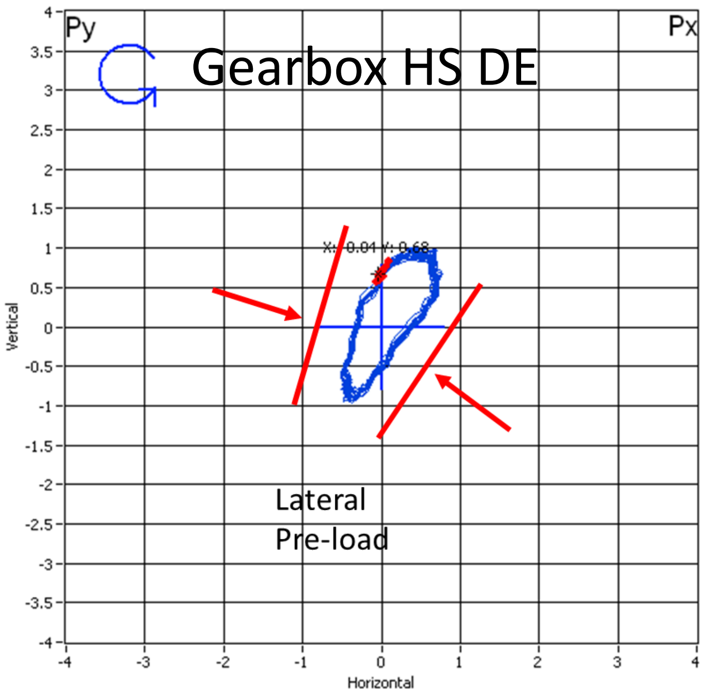


Shaft vibration mostly at 1x rpm
Bearing housing vibration was acceptable

Orbit Plots 20,000 GPM @ 3:56, 6-13-2010

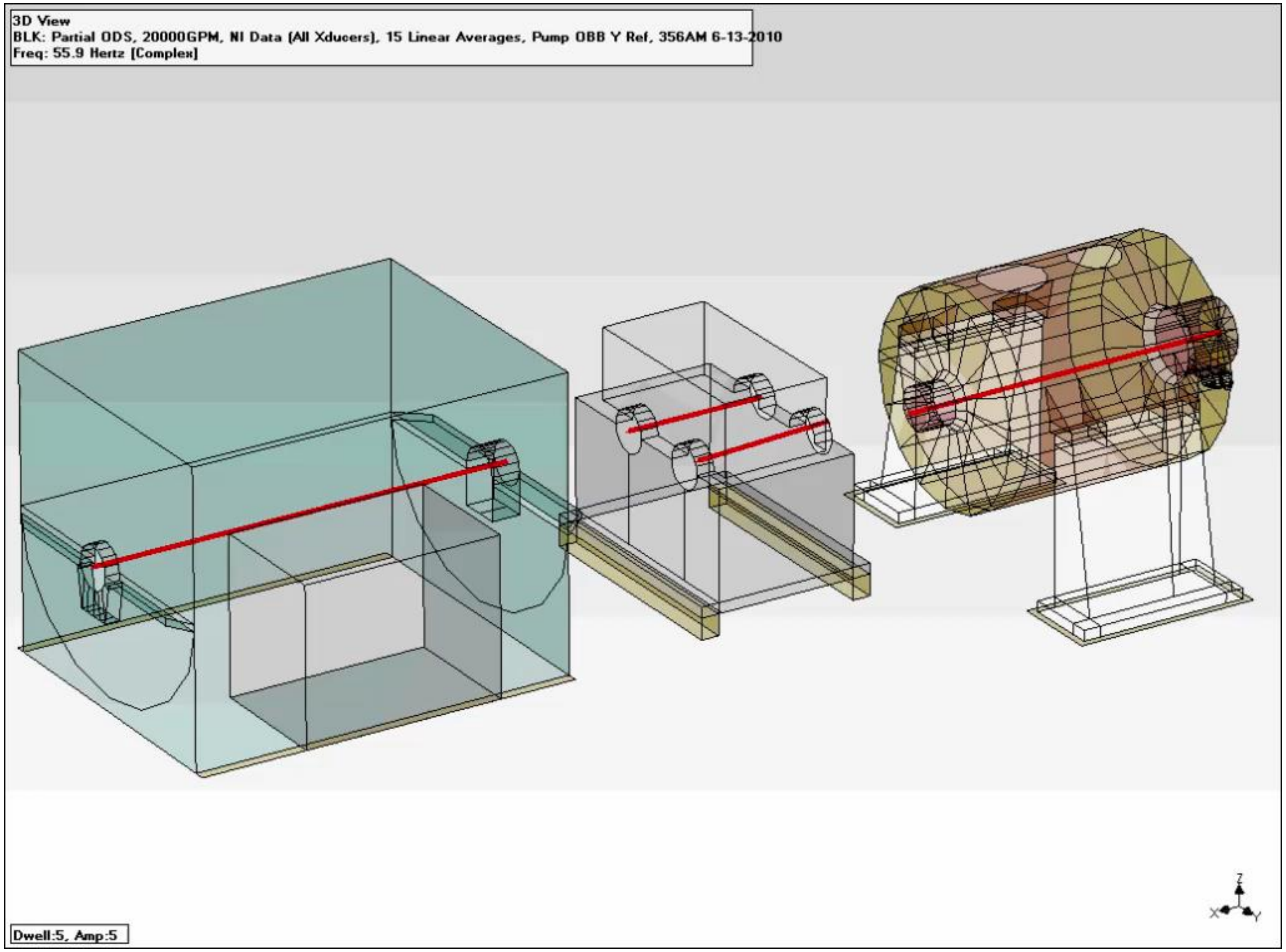






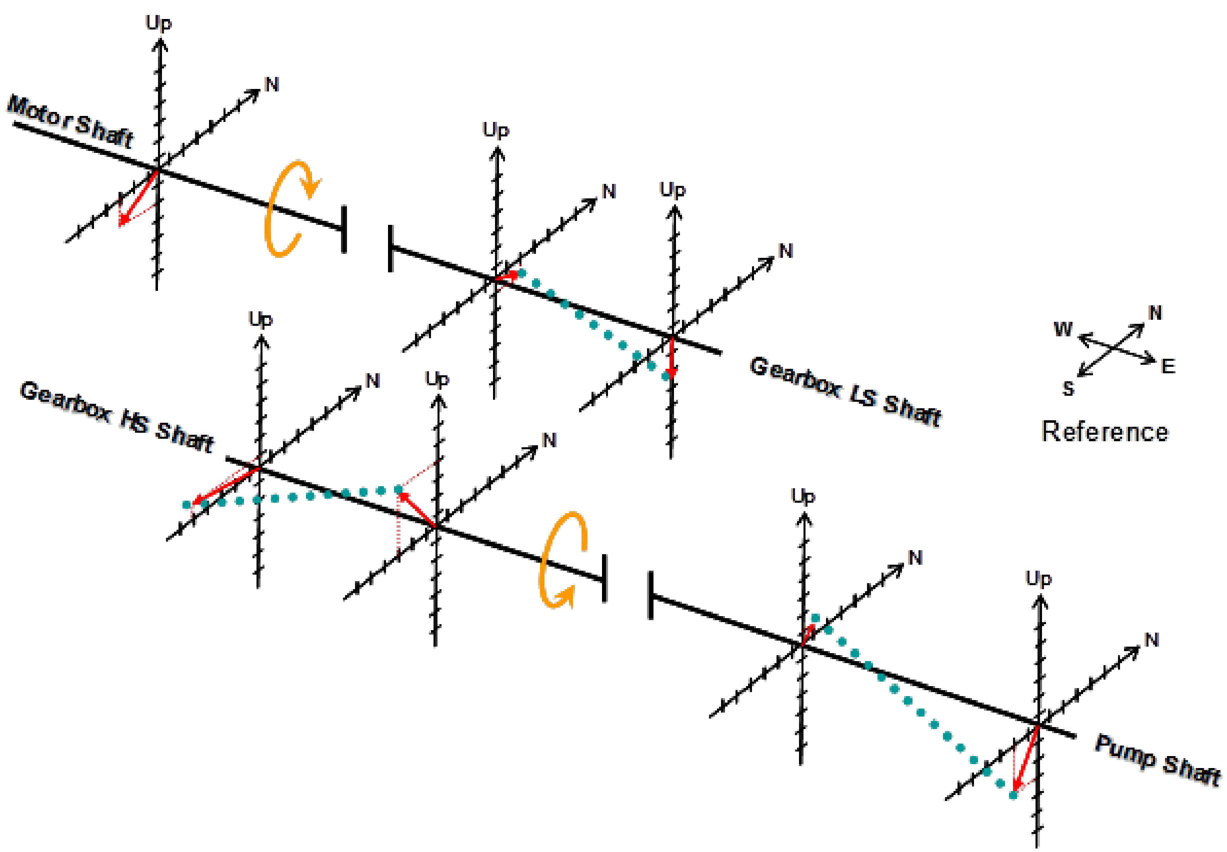
* View from pump end unless otherwise stated

ODS Animation at 1x rpm

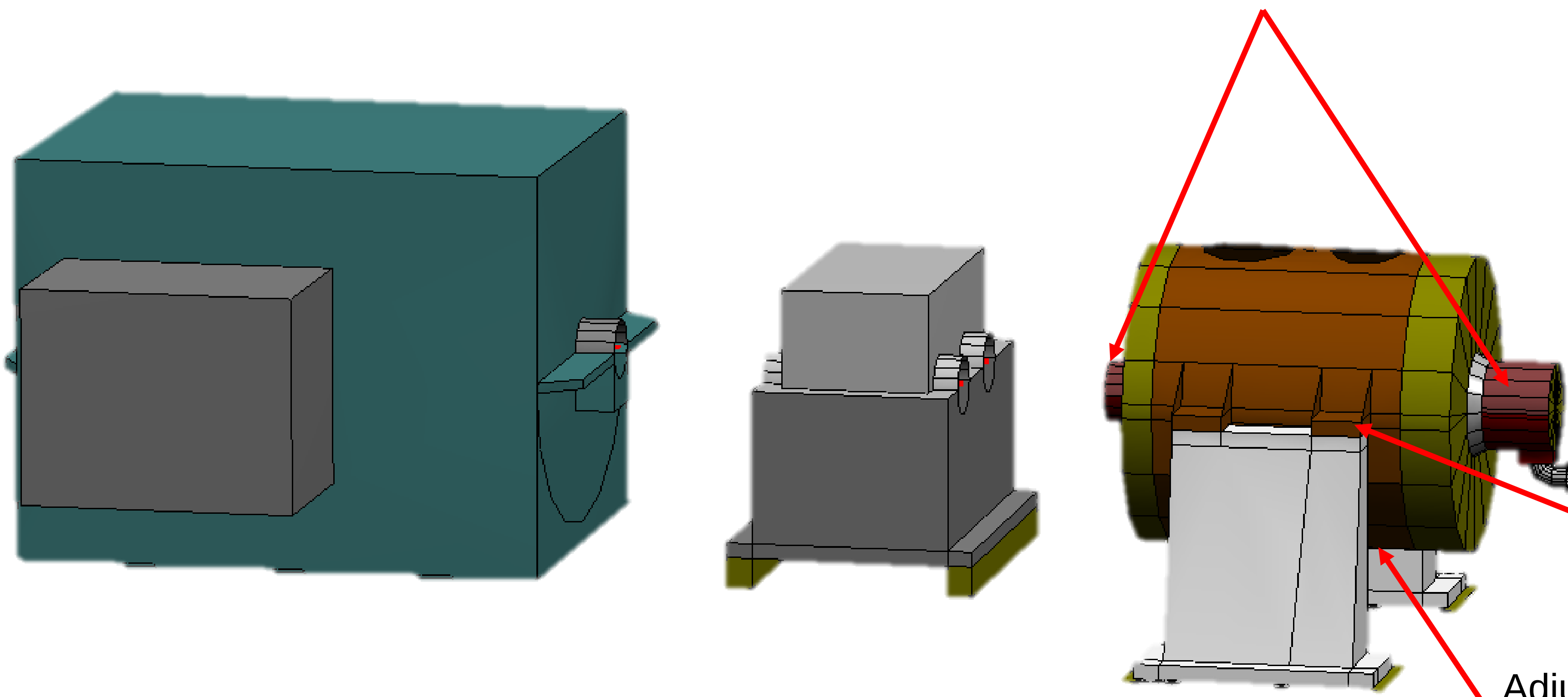


Possible Causes…

- Misalignment: Severe offset misalignment between the HS gearbox pinion shaft and the pump. Modify the cold alignment.
- Coupling Imbalance: Eccentricity of the coupling spacer from the coupling mounting center line.
- Thermal growth between the pump shaft and the HS gearbox pinion.
- Verify the radial position of the coupling spacer for potential eccentricity that could lead to imbalance forces.

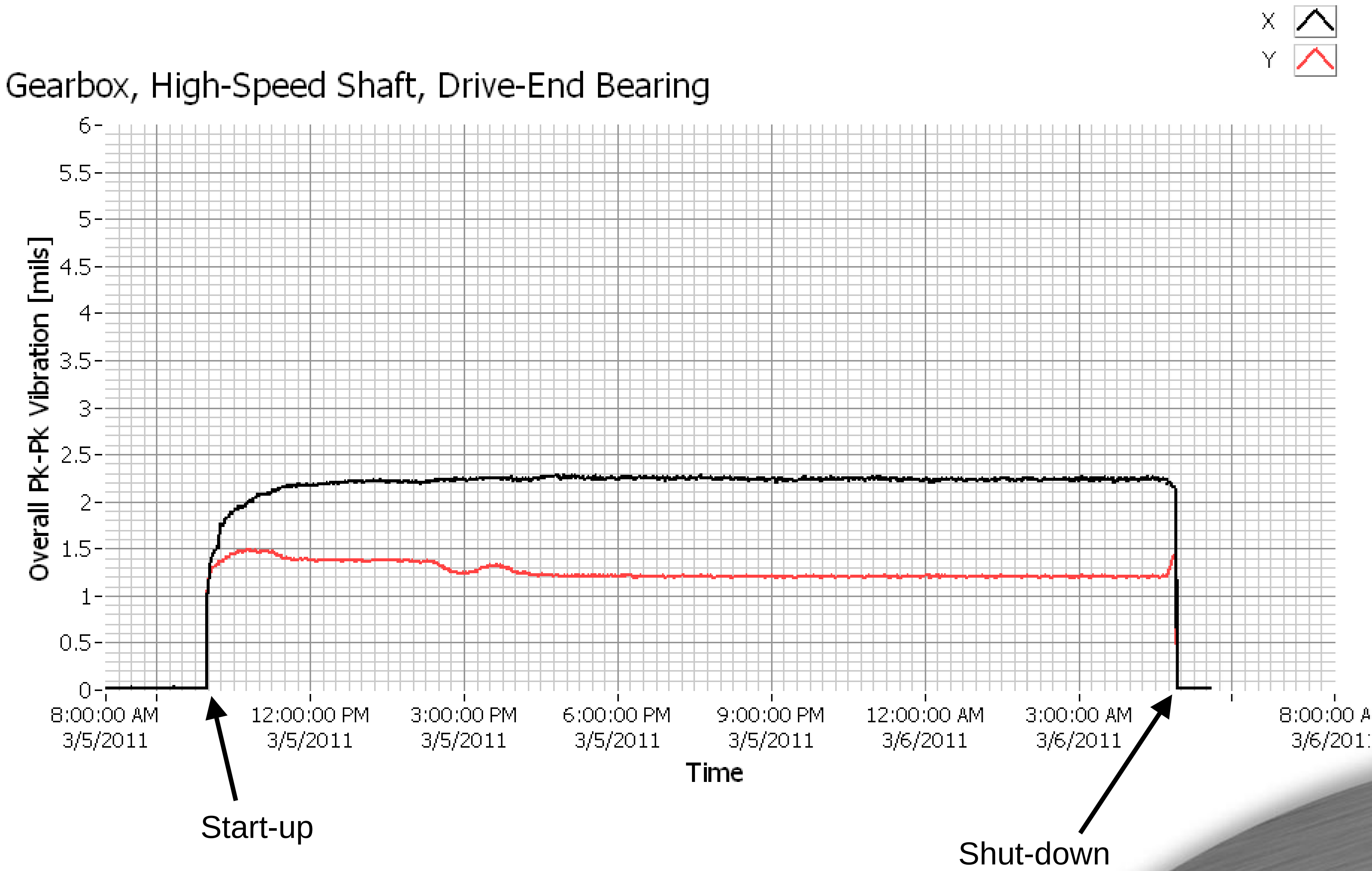


March 2011 Vibration Data
Alpha FWP Testing – Root Cause Detection

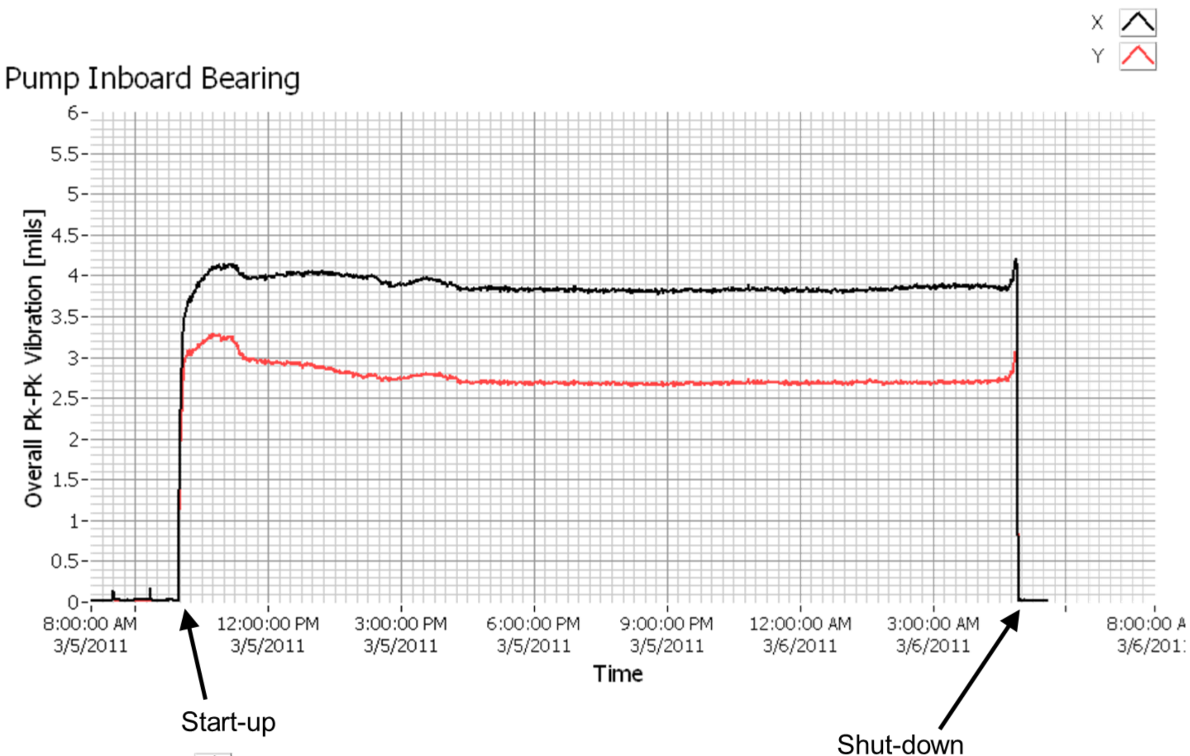


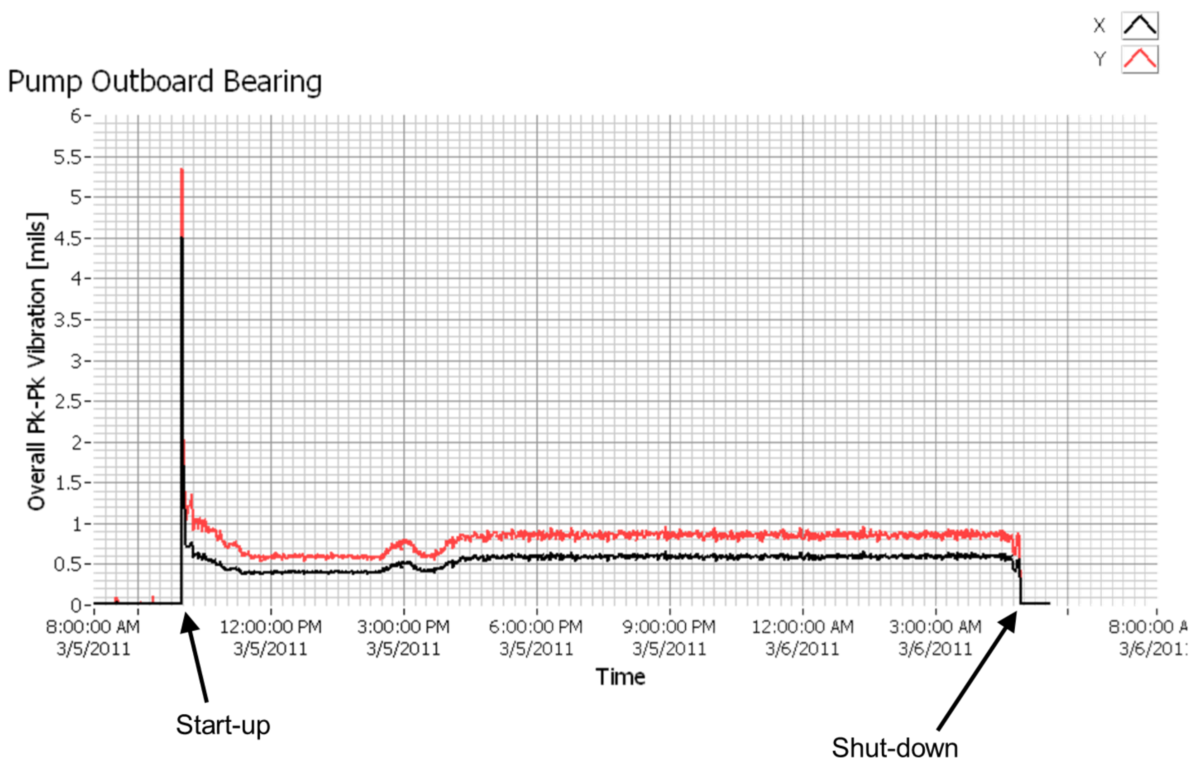
- Installed temporary thermocouples at the IB and OB faces of the pump casing to measure transient temperature field
- Installed temporary laser instrumentation to measure thermal growth of the pump casing in the axial and horizontal directions
- Modified the warm-up procedure to alleviate rubbing during high thermal gradients within the pump (reduced seal cooling water flow rate from 10 to 5 GPM).

GB HS DE - Shaft Vibration



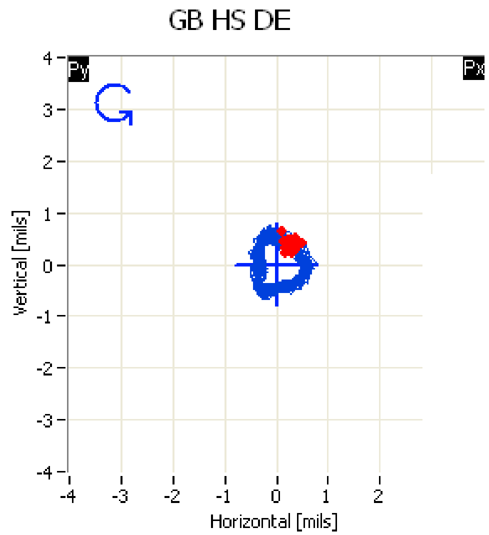
Pump - Shaft Vibration

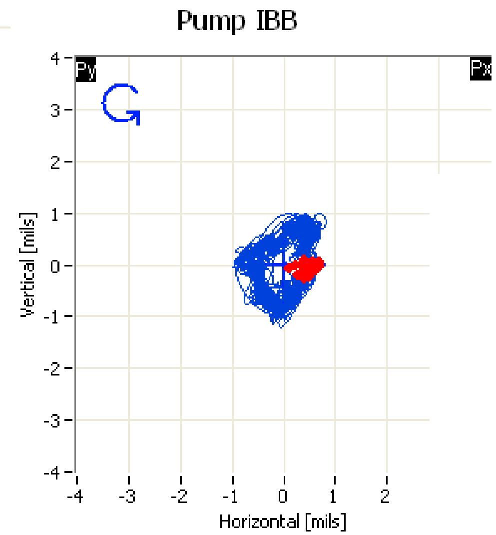


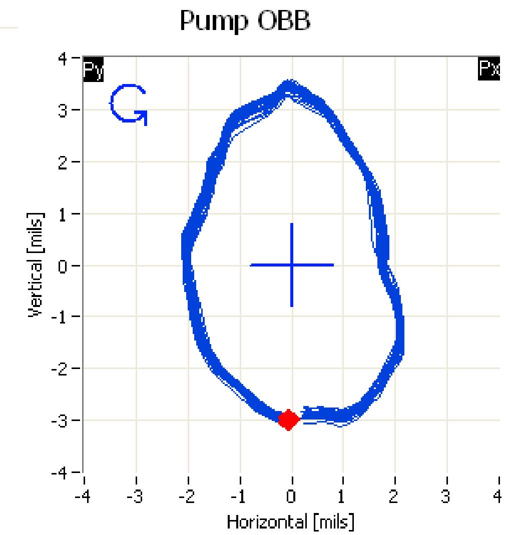


Shaft Orbits

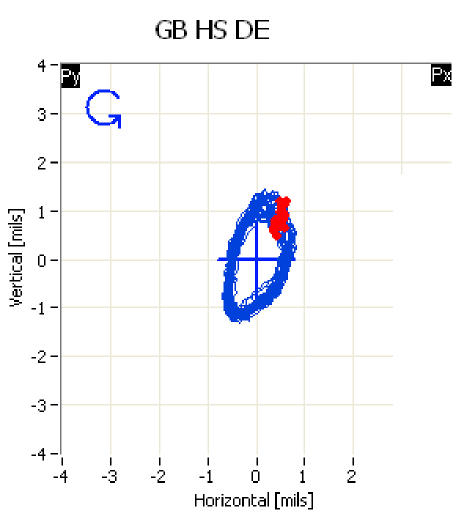
09:59:23 AM
03/05/2011

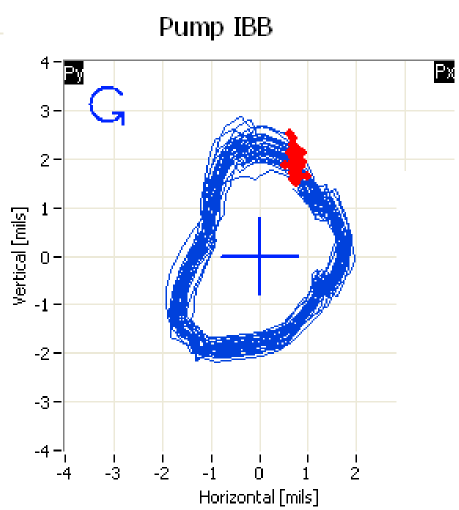


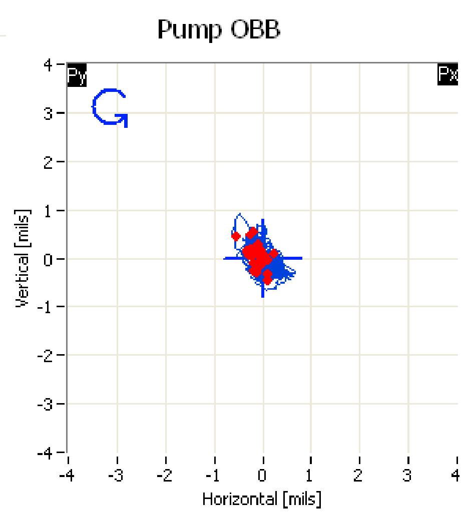




11:00:23 AM
03/05/2011







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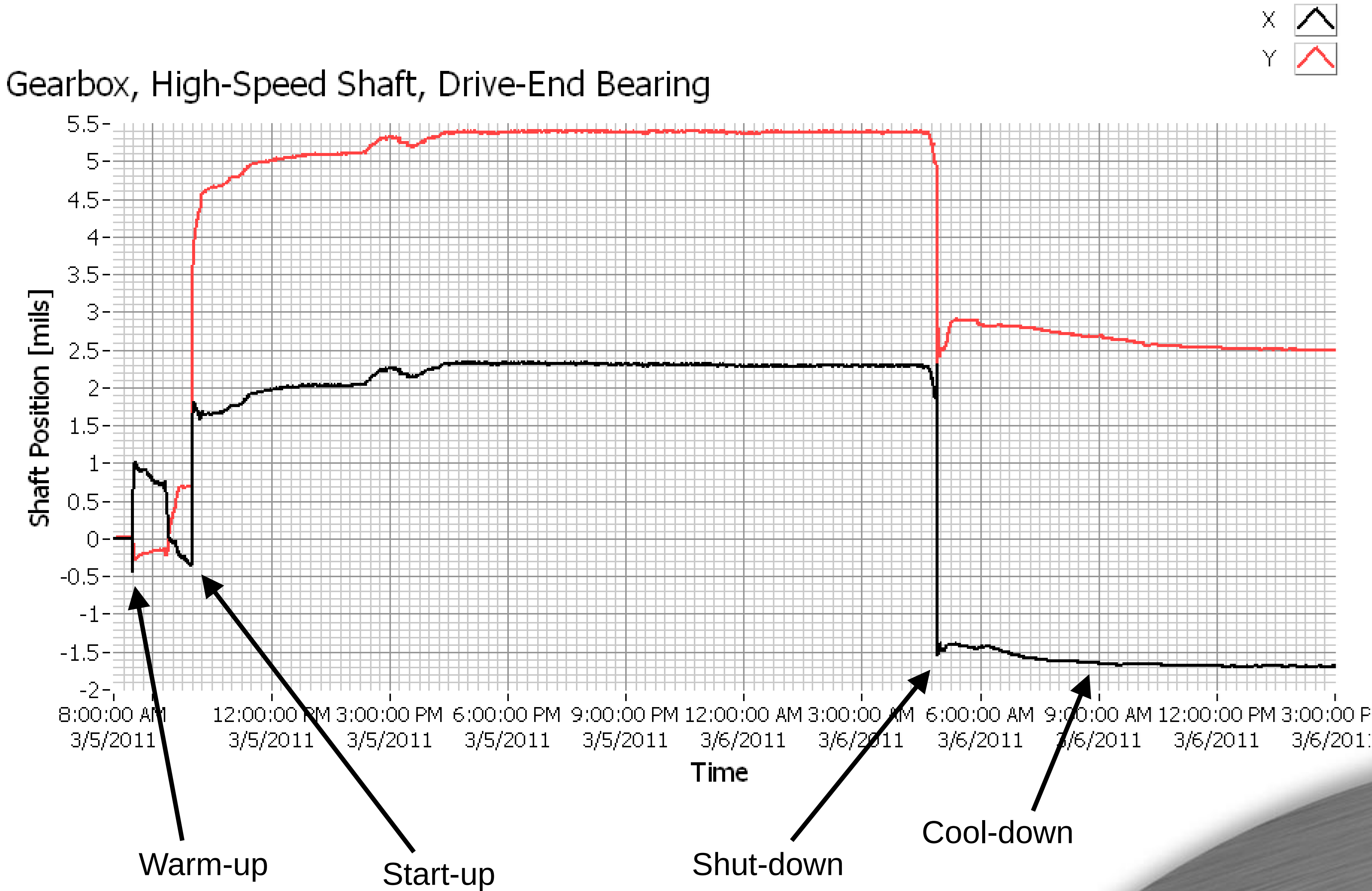
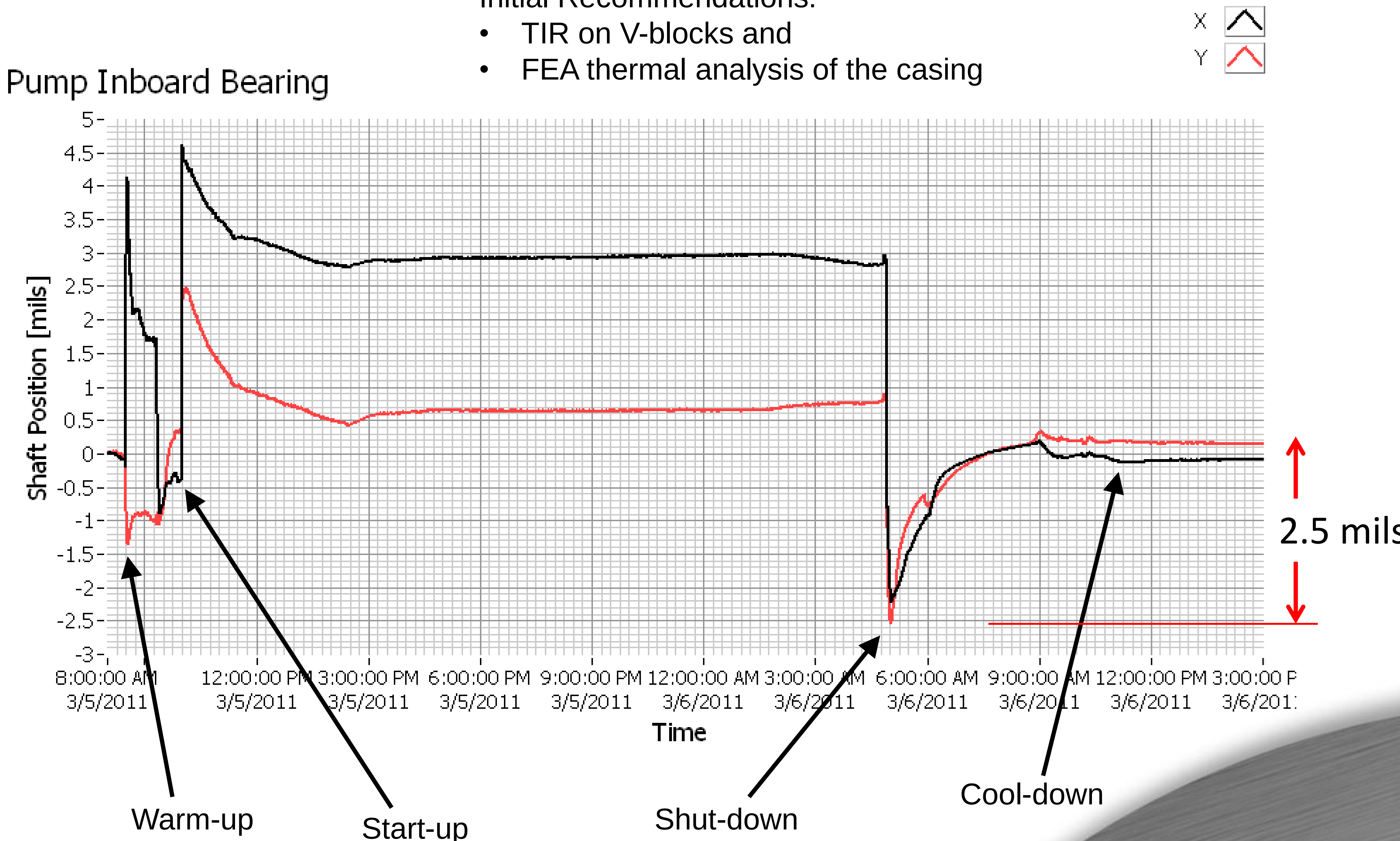
View from East (pump OBB)

GB HS DE - Shaft Movement

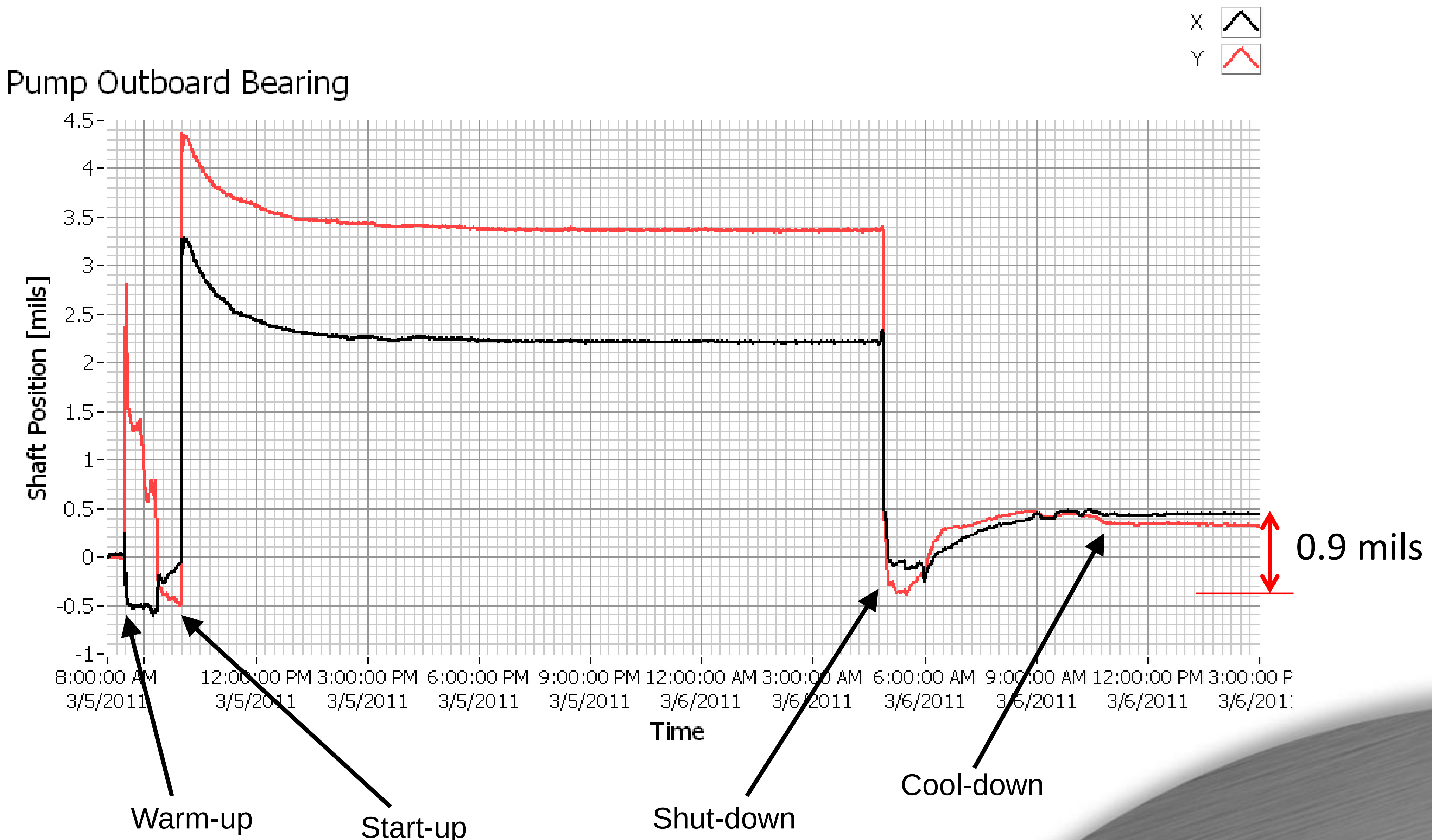


Pump IBB - Shaft Movement

Initial Recommendations:
- TIR on V-blocks and
- FEA thermal analysis of the casing

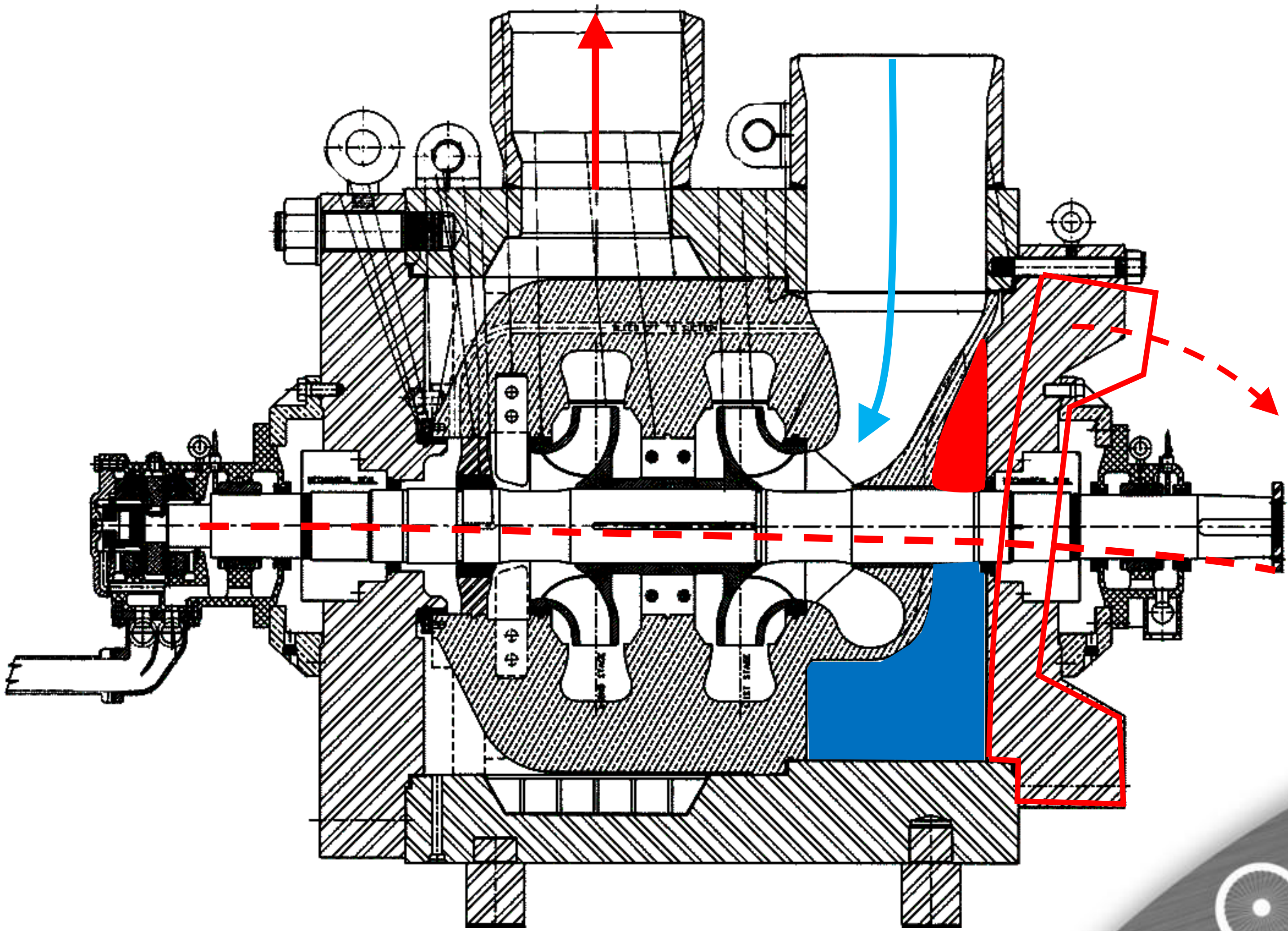


Pump OBB - Shaft Movement



Root Cause

1st stage flow path did not allow uniform thermal expansion of the pump casing at the IB end cover. Former seal injection design allowed accumulation of condensate seal water at the bottom of the pump casing with lower temperature than the reactor feed water. This was causing distortion of the inboard cover plate and therefore internal misalignment at the IBB.



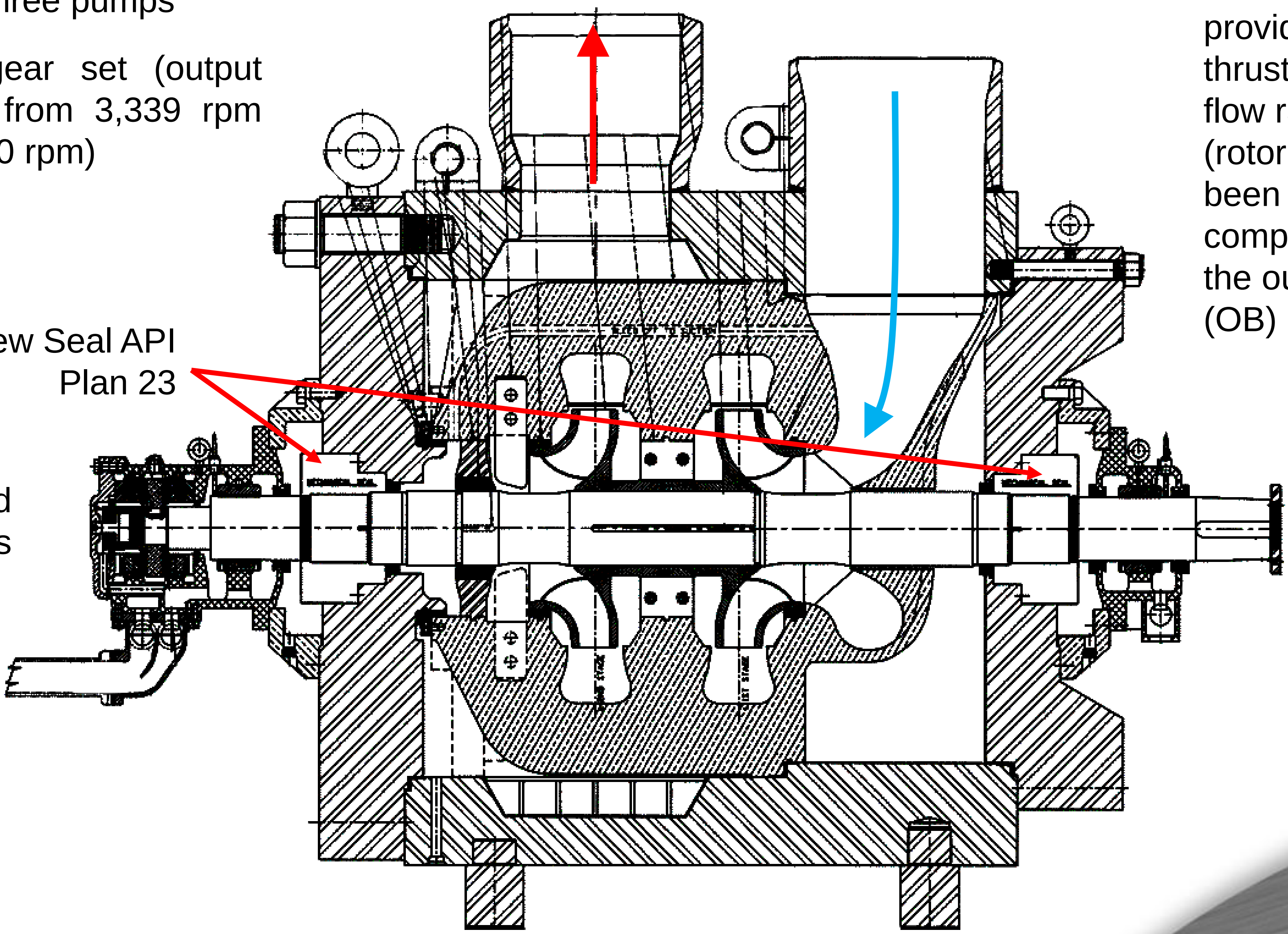
June 2012 Vibration Data FWP A/B/C Follow-Up Testing

- New rotating elements on all three pumps
- New gear set (output speed from 3,339 rpm to 3,400 rpm)

Balance drum re-dimensioned to provide unidirectional thrust load at any flow rate.
(rotor at times had been under compression towards the outboard (OB) end)

New Seal API Plan 23

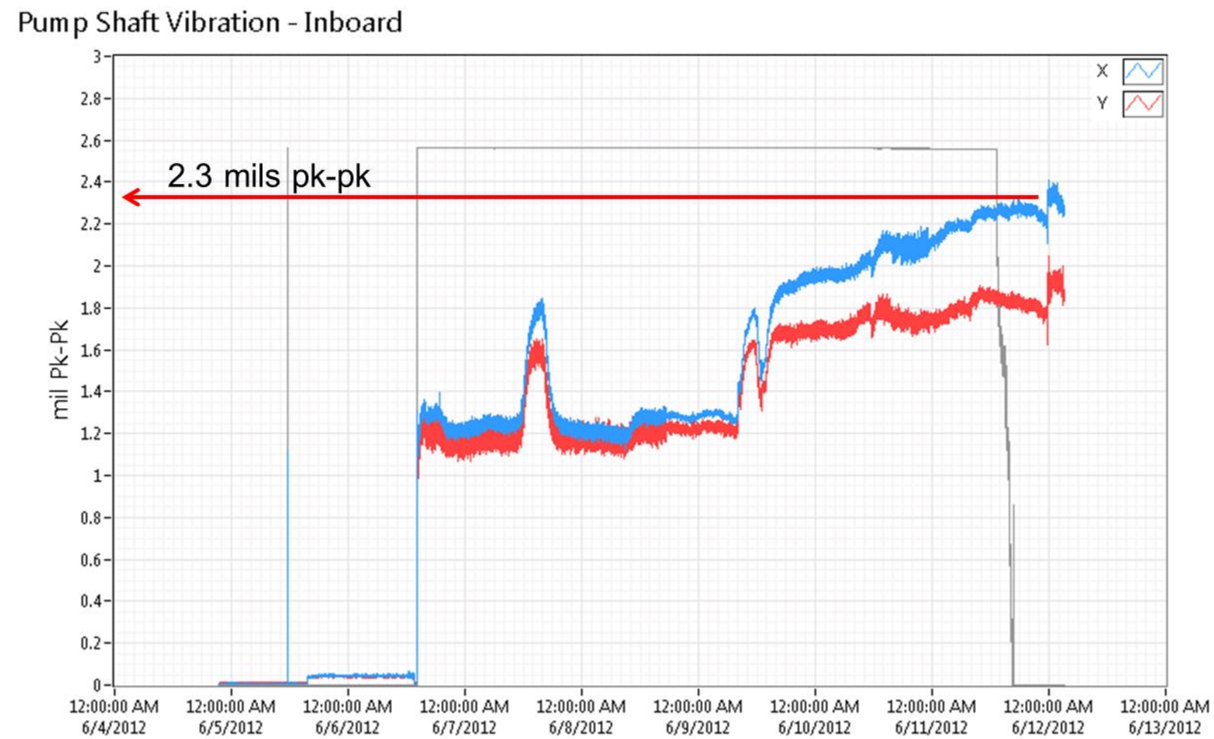
Tri-land bearings

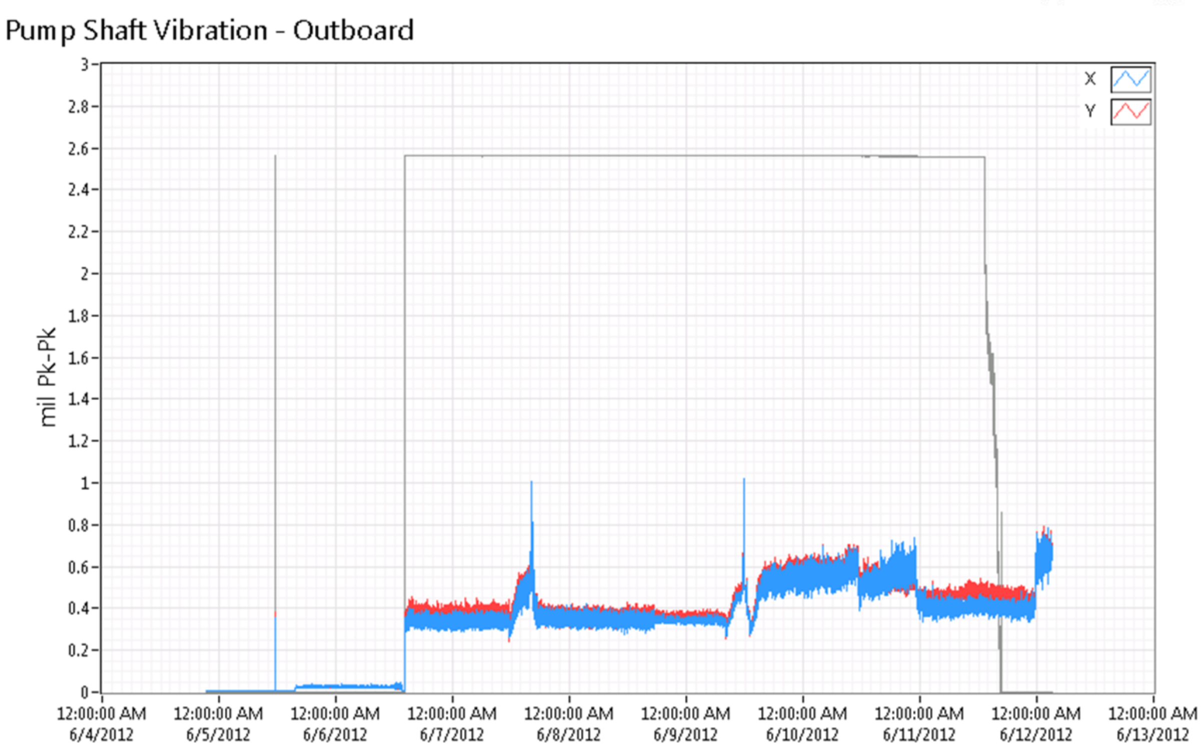


Plant EPU Project

2FWS-P1A/B/C Modified by June 2012

2FWS-P1A Pump Shaft Vibration





Final Conclusions

1. Modifications implemented on these pumps during the outage (i.e. seal injection API plan 23) eliminated the thermal distortion effect that was causing deformation of the inboard end cover of the pump.
2. Previous seal injection design allowed accumulation of condensate seal water at the bottom of the pump casing with lower temperature than the reactor feed water. This was causing distortion of the inboard cover plate and therefore internal misalignment at the IBB.
3. The shaft vibration at the IBB used to be approximately 4.5 mils pk-pk, while the vibration at the OBB was approximately 1.0 mil pk-pk. Vibration data gathered after the outage indicated significant improvement at the IBB (2x reduction).
4. Radial proximity probe GAP voltage readings were not changing over time during the warm-up or cool-down processes, versus such changes that had been identified in previous tests.

Final Recommendations

1. Pre-installation FEA analysis (structural and thermal) would have been able to reduce risk by spotting problems before they occur (PREVENTION).

2. ODS / EMA / Continuous Monitoring Tests coupled with appropriate analysis is a powerful troubleshooting tool to identify and visually understand the most difficult vibration problems in turbomachinery and pumping systems.