49TH TURBOMACHINERY & 36TH PUMP SYMPOSIA
SEPTEMBER 14-17, 2020 | HOUSTON, TX | GEORGE R. BROWN CONVENTION CENTER
TEXAS A&M UNIVERSITY
TEES TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

Detection of Misalignment from Vibration Data

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Presenter/Author Bios

Dr. John Yu joined Bently Rotor Dynamics Research Corporation in 1998, followed by General Electric - Bently Nevada in 2002. He has performed not only rotor dynamic research but also machinery vibration diagnostics for customers worldwide, and is now Technical Leader of Machinery Diagnostic Services at Bently Nevada. He has over 50 technical papers in peer-reviewed journals and conference proceedings. He holds a PhD in Mechanical Engineering from the University of Alberta and is an ASME Fellow. He currently serves as an Advisory Committee member to the Asia Turbomachinery & Pump Symposium.

Dr. Nicolas Peton joined GE in 2006 in the Machinery Diagnostic Services group. Previously he worked for two manufacturers (Alstom Steam turbine and Cryostar expander/compressor) where he was in charge of on-site of the startup activities worldwide. He also worked as an operation and maintenance engineer in the chemical industry (PPG industry, USA) and as Free Lance for startup activities worldwide. He has been also a mechanical/acoustical research engineer in research institutes (Technion, Haifa and TU Berlin). He is currently Global Director for the Machinery Diagnostic Services. Nicolas is also a member of the Texas A&M International Pump Symposium Advisory Committee. He has a Diplome d’ingénieur and a PhD from the Université de Technologie de Compiègne, France.

Abstract

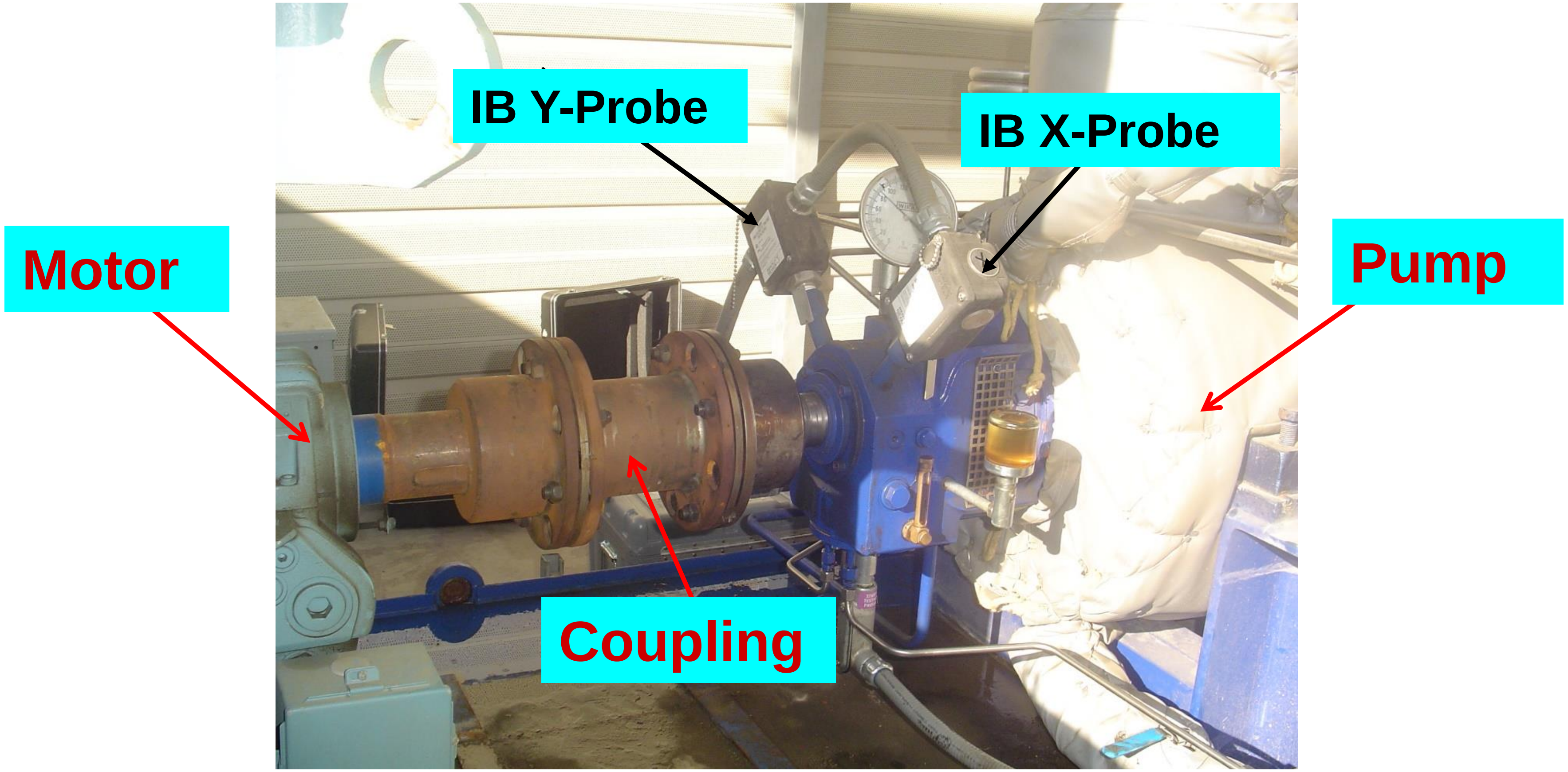
On a boiler feed pump driven by a motor running close to 3600 rpm, a horizontal misalignment issue was suspected by examining orbit plots besides shaft centerline plots. The follow-up inspection did uncover large parallel misalignment of 0.012 inch along the horizontal direction between the pump and the motor. The root-cause of changes in alignment indicates piping strain as evidenced by loose bolts between the pump and the foundation. The unit was then re-aligned to below 0.001 inch in parallel alignment, followed by correct re-assembly of the coupling. Shaft vibration was successfully reduced to below 2 mil pp and with a normal orbit orientation.

Outline

1. Introduction
2. Problem Statement
3. Data Review
4. Observations and Diagnostics
5. Conclusions and Recommendations
6. Inspections and Findings
7. Resolution and Final Vibration Results
8. Lessons Learned

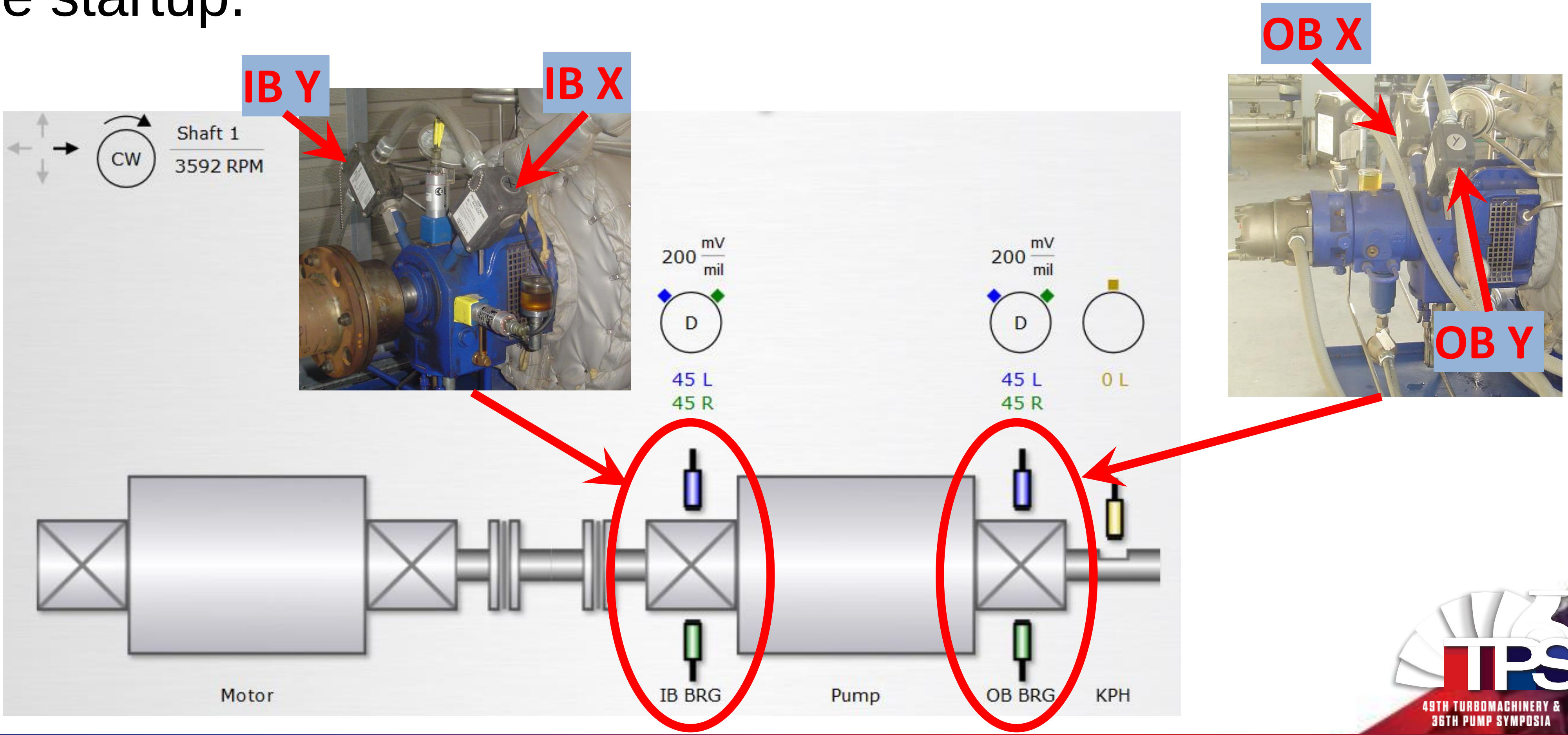
1. Introduction

- A Boiler Feed Pump driven by an induction motor with speed close to 3600 rpm.
- Shaft monitored by proximity probes near each bearing. Data collection performed to support its startup.



2. Problem Statement

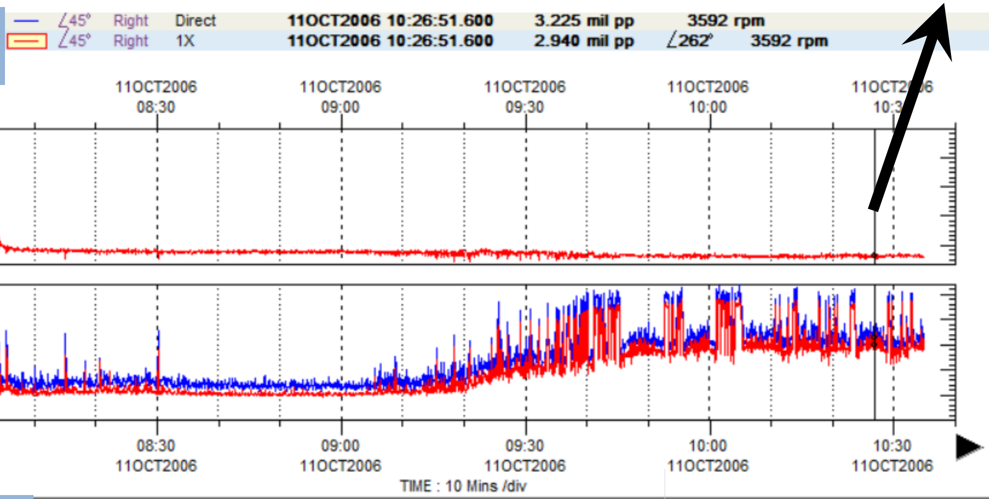
- After startup, shaft vibration gradually increased from 1 mil pp to over 3 mil pp at the pump inboard (IB) bearing.
- Root-cause to be determined as soon as possible to avoid any delay in main turbine startup.



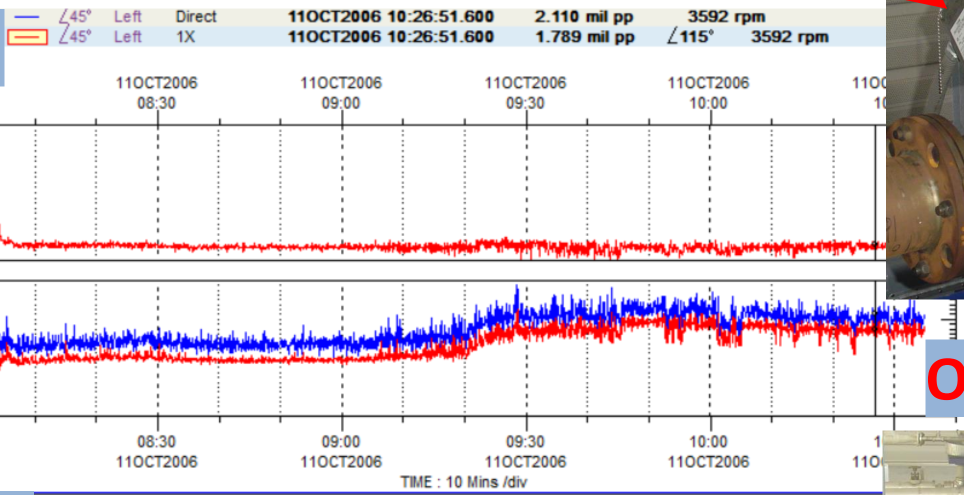
3.1 Data Review – Direct and 1X trend plots

Direct	3.225 mil pp		3592 rpm
1X	2.940 mil pp	262°	

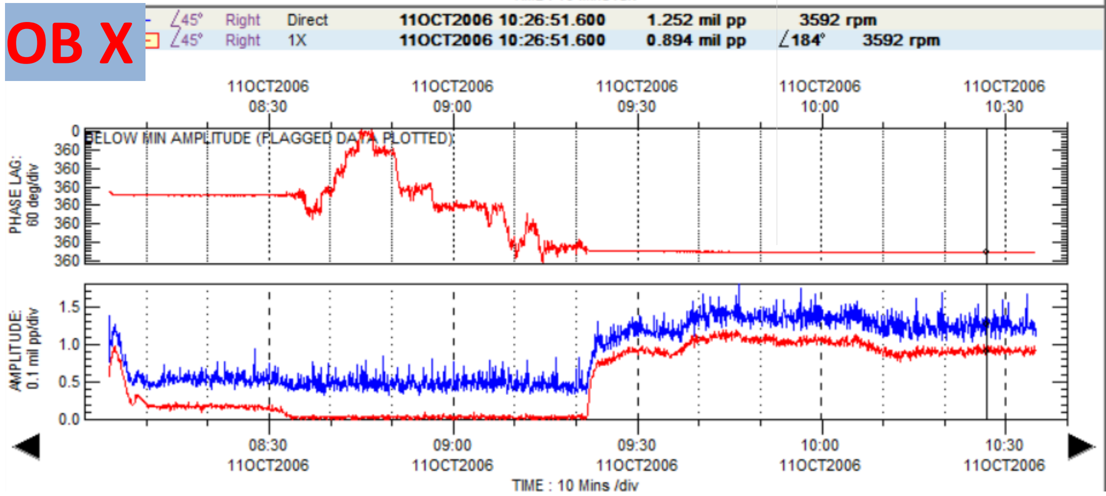
IB X



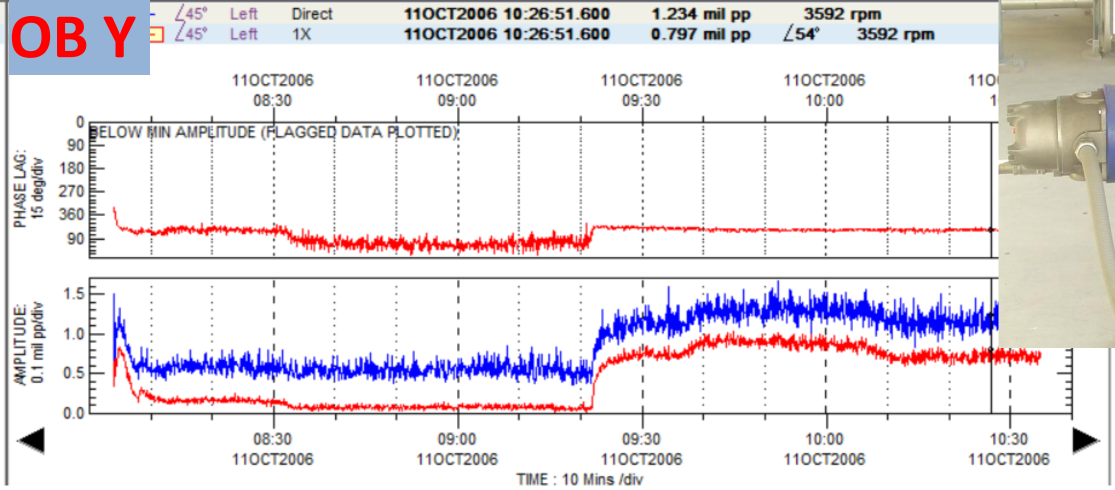
IB Y



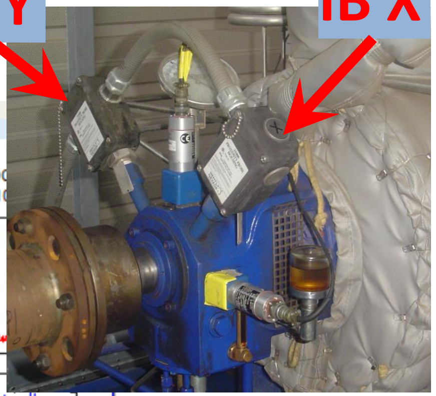
OB X



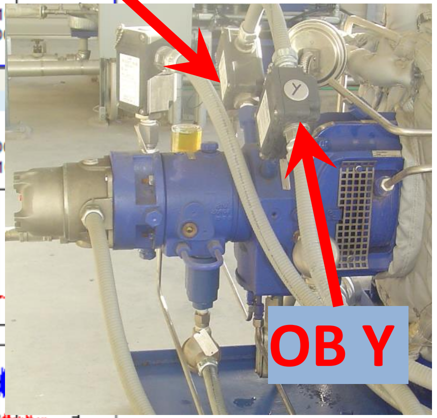
OB Y



IB Y IB X

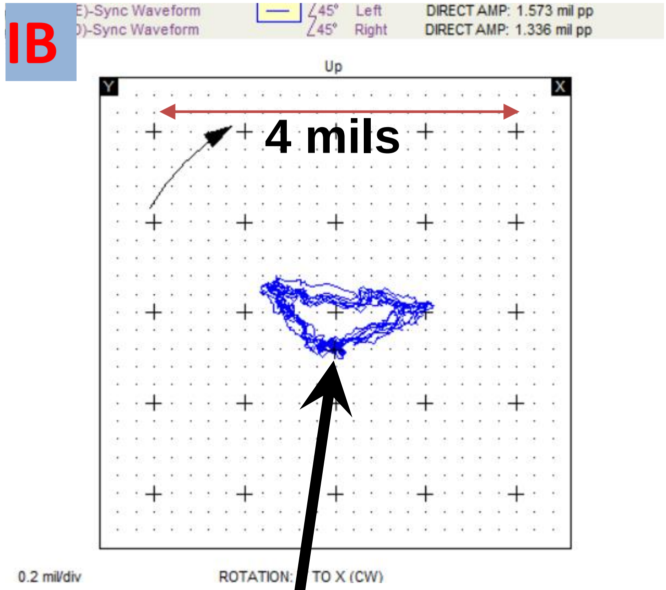


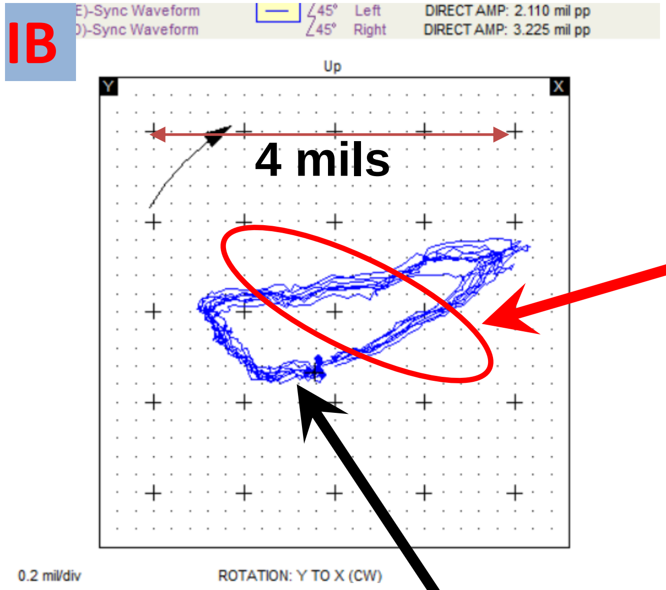
OB X



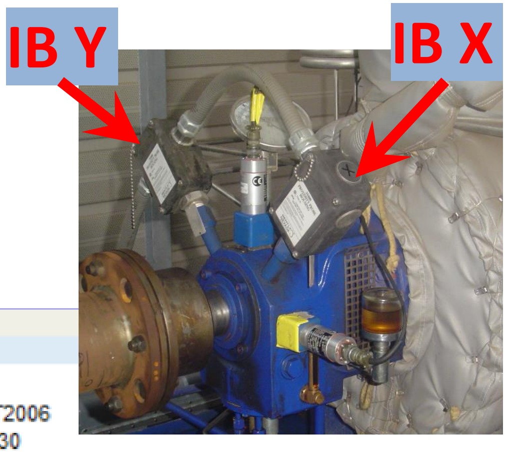
OB Y

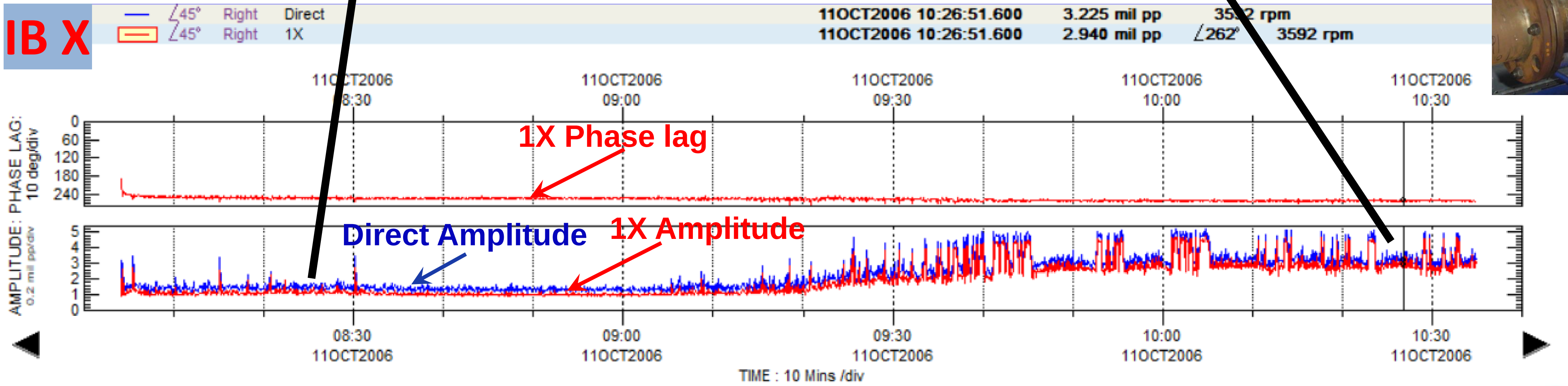
3.2 Data Review –Changes in orbits



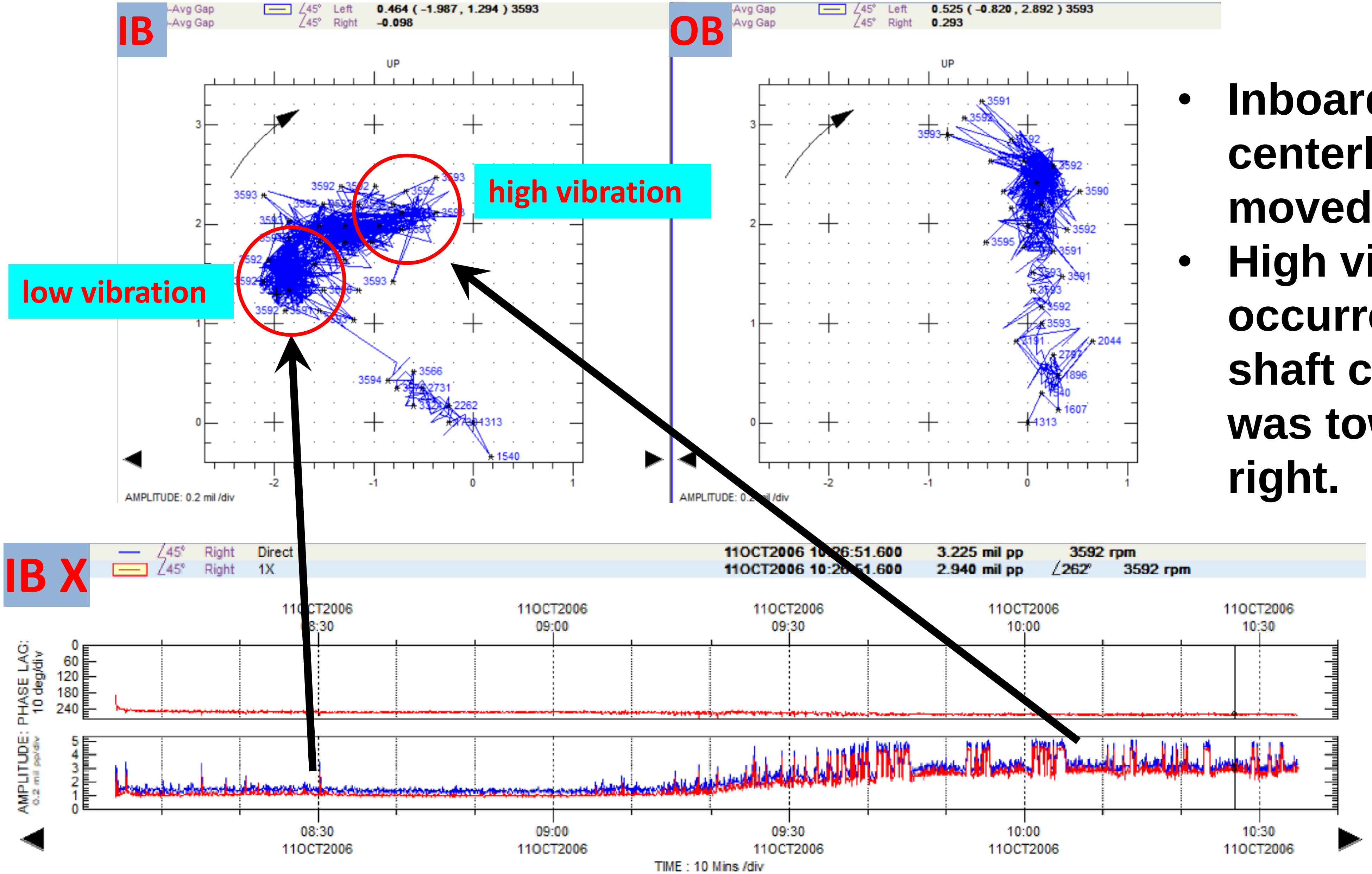


Normal orbit orientation for CW shaft rotation





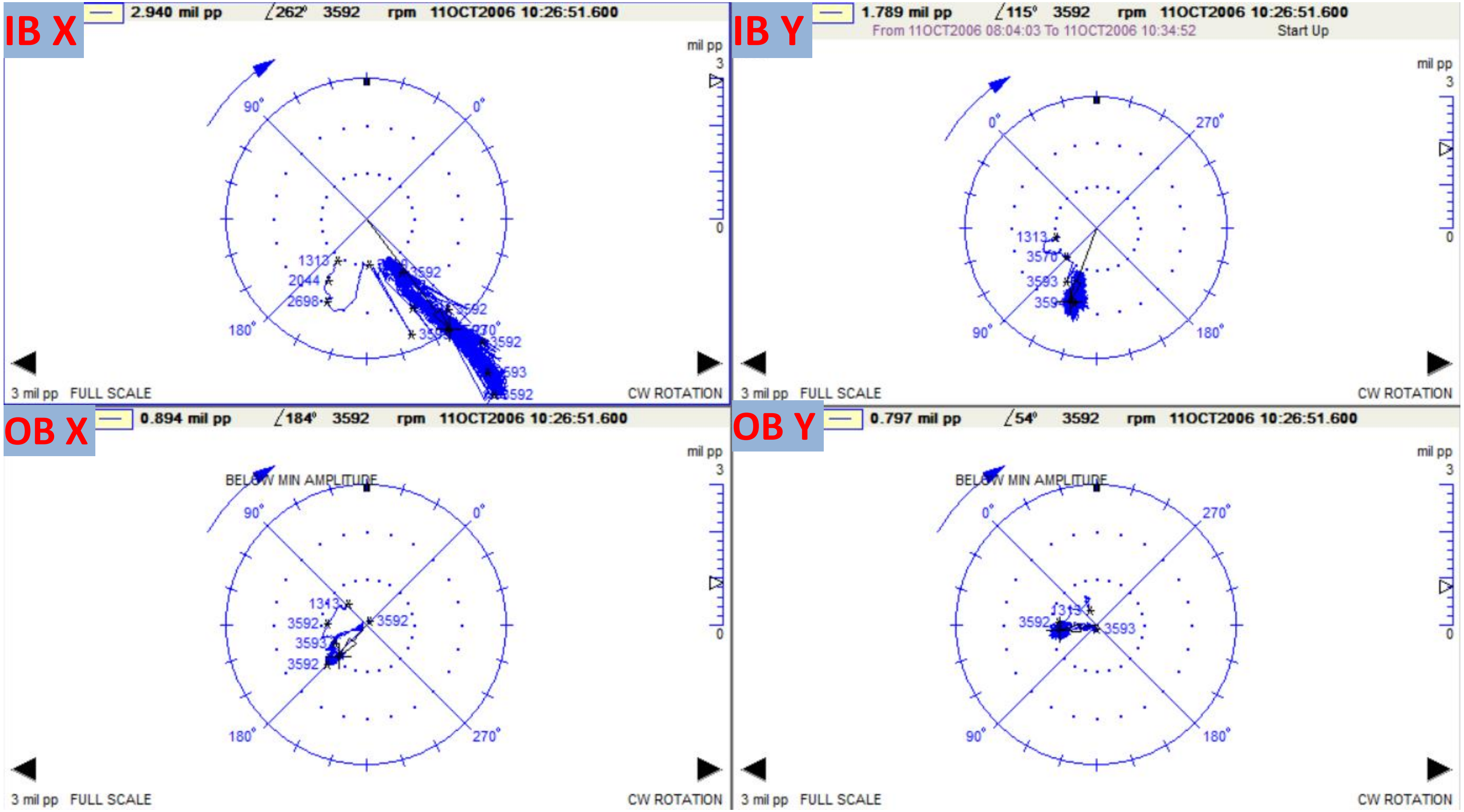
3.3 Data Review – Shaft centerline plots

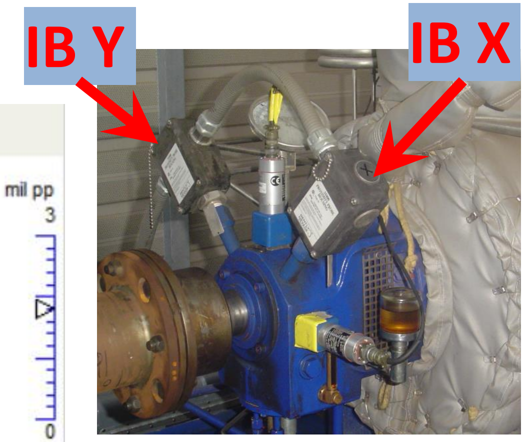


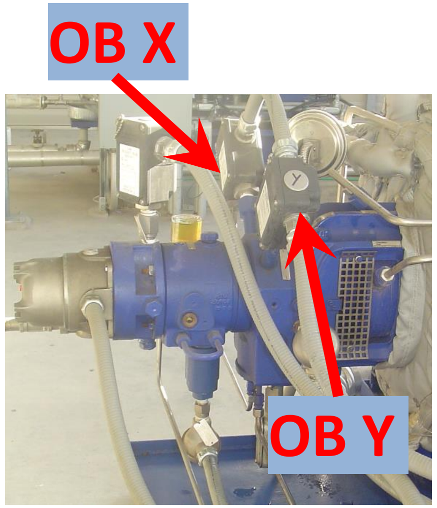
- **Inboard shaft centerline position moved horizontally.**
- **High vibration occurred when shaft centerline was towards the right.**

3.4 Data Review – Polar plots from prox. probe

Changes in 1X vibration vector. Is it a rub?

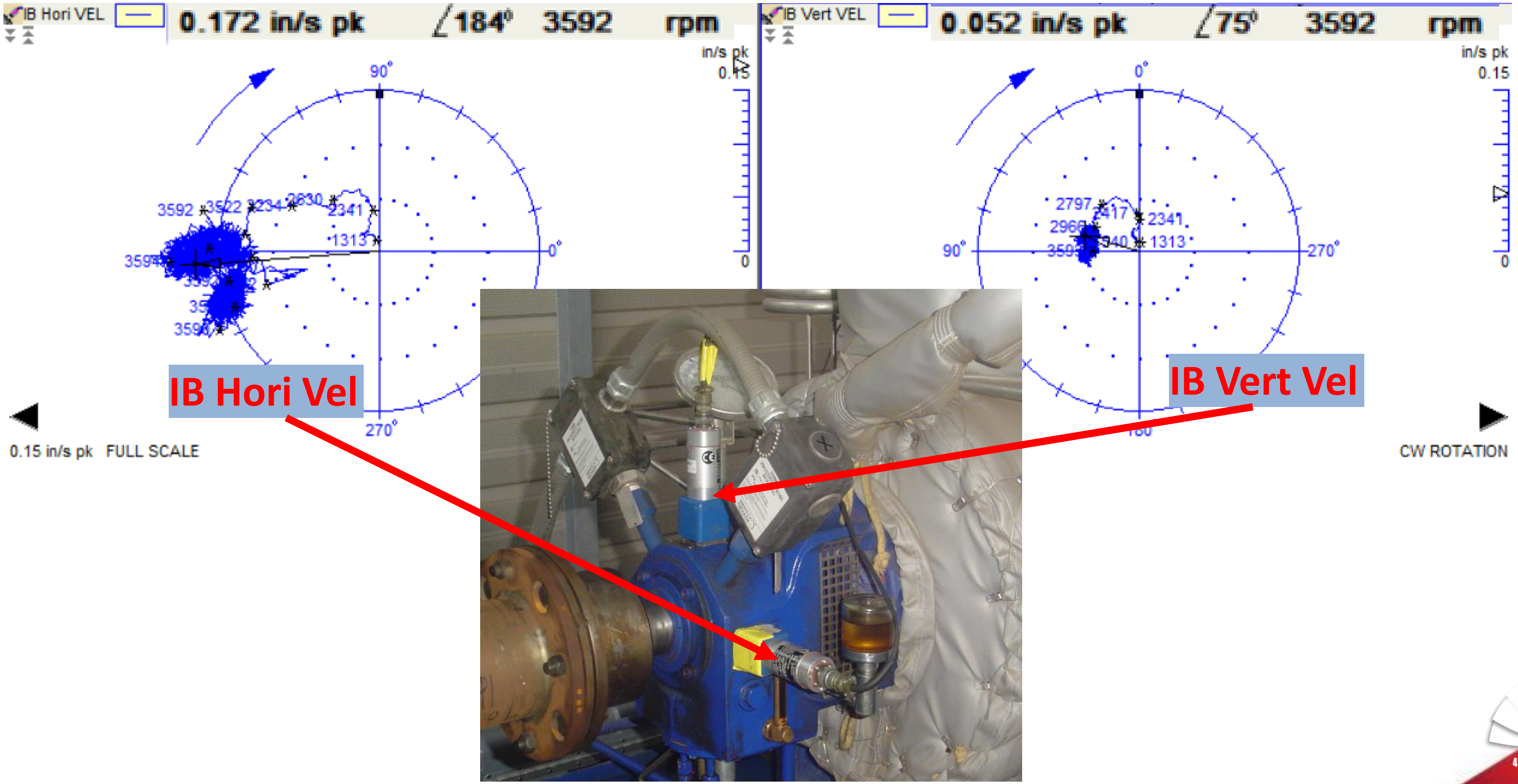






3.5 Data Review – Polar plots from seismics

Changes in 1X vibration vector. Is it a rub?



4.1 Observations and Diagnostics

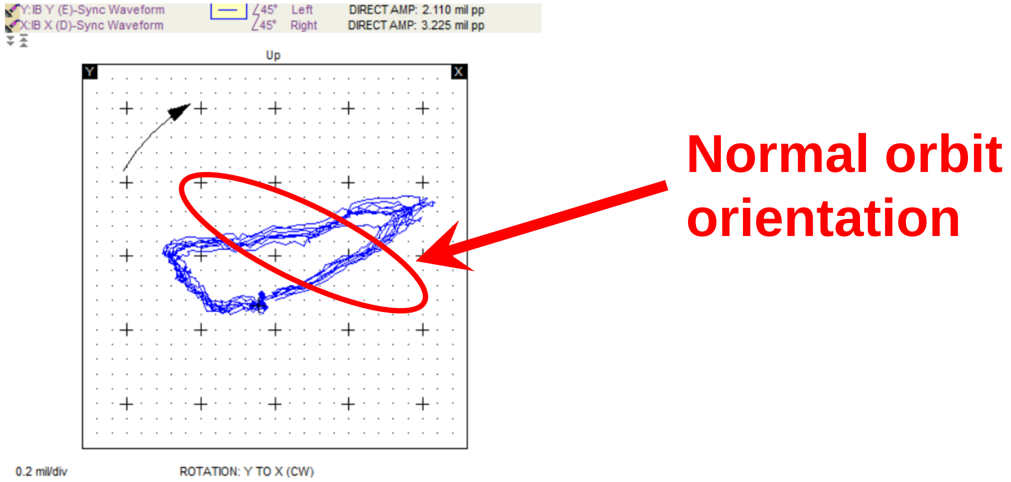
Root-cause of vibration excursion:

- **1X component ? – Yes**
  - 1X dominant with variation at proximity probes as well as casing-mounted transducer in the horizontal direction.
- **Rub? – No**
  - 1X amplitude increased but the 1X vector not behaving as a rub pattern in polar plots at constant speed
  - Distorted orbits resulting from runout only

4.2 Observations and Diagnostics

Root-cause of vibration excursion (Cont.):

- **Misalignment?** – **Yes, likely in the horizontal direction**
  - ➢ Changes in shaft centerline position, mainly in the horizontal direction
  - ➢ Vibration level dependent on shaft centerline position
  - ➢ Abnormal orbit orientation(amplitude higher at 45 Right probe than at 45 Left probe for clockwise shaft rotation)



5. Conclusions and Recommendations

Conclusions:

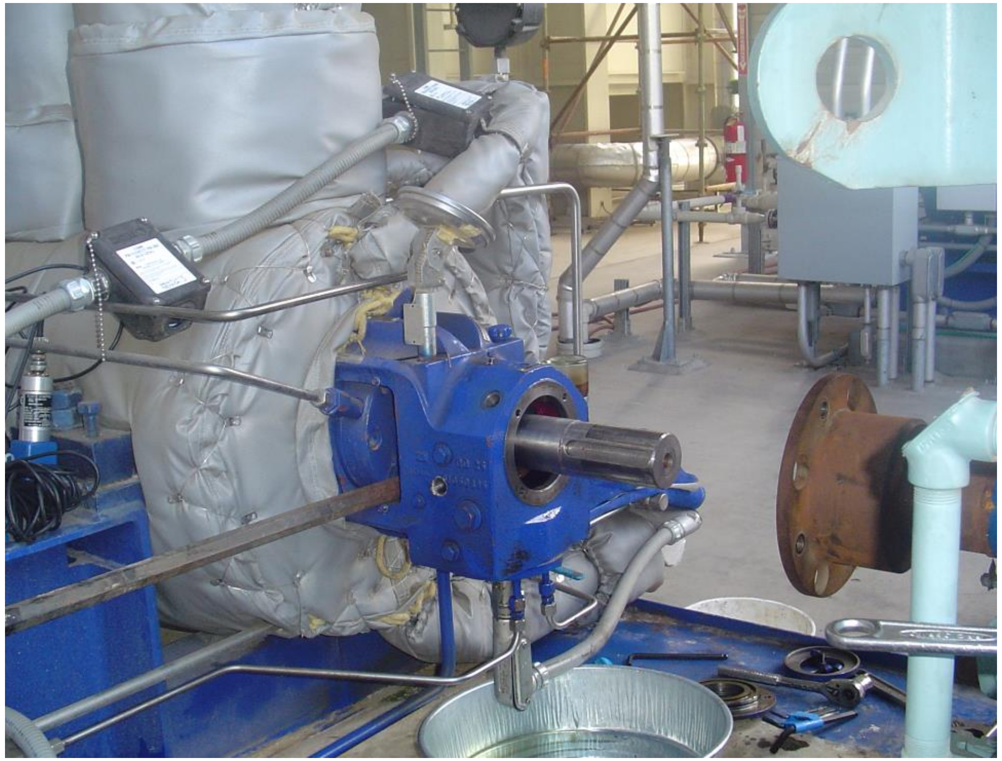
- Misalignment, especially in the horizontal direction, appeared to be the main cause for rotor high vibration.
- As indicated in shaft centerline and orbit plots, pump case appeared to move towards the left (viewed from motor to pump). The inboard journal could have touched the bearing wall in the lower right area.

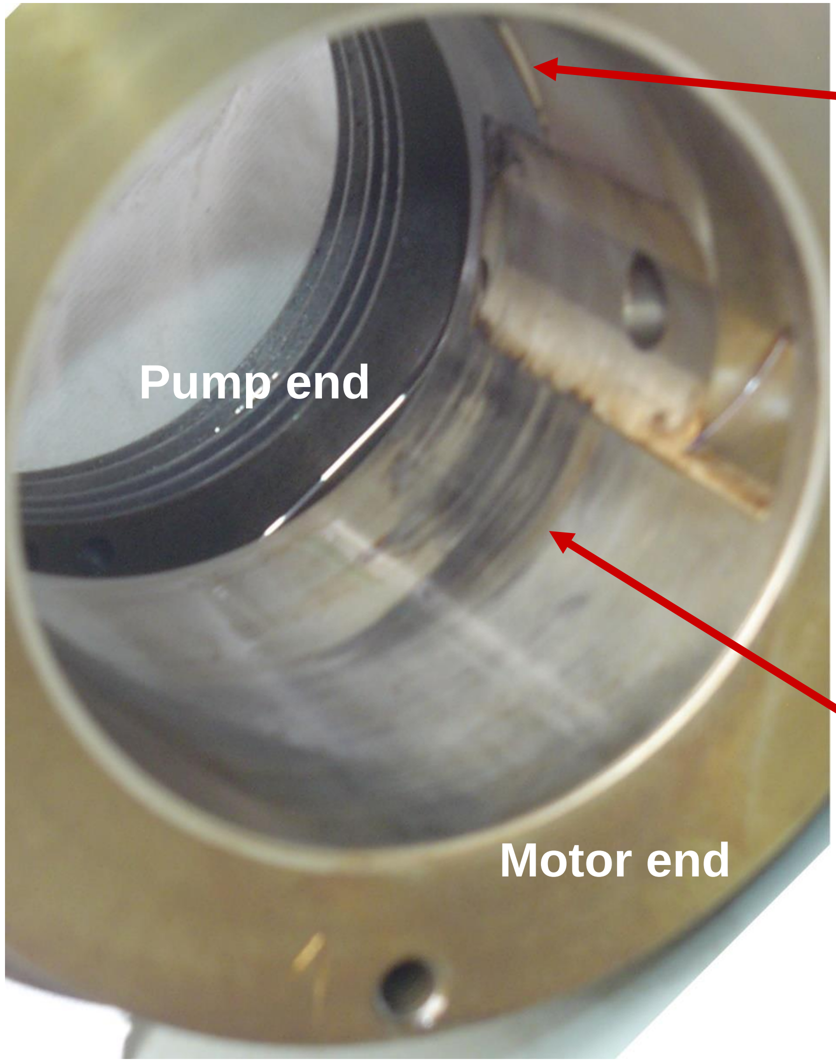
Recommendations:

- Inspect the bearing condition and change it if found worn.
- Check alignment conditions and correct them if found significantly off.

6.1 Inspections and Findings

Inspection of IB bearing





6.2 Inspections and Findings

Alignment Check and Correction

- **Large parallel misalignment (offset of 0.012 inch or 305 μm) was found in horizontal plane between the pump and the motor, as shown below:**

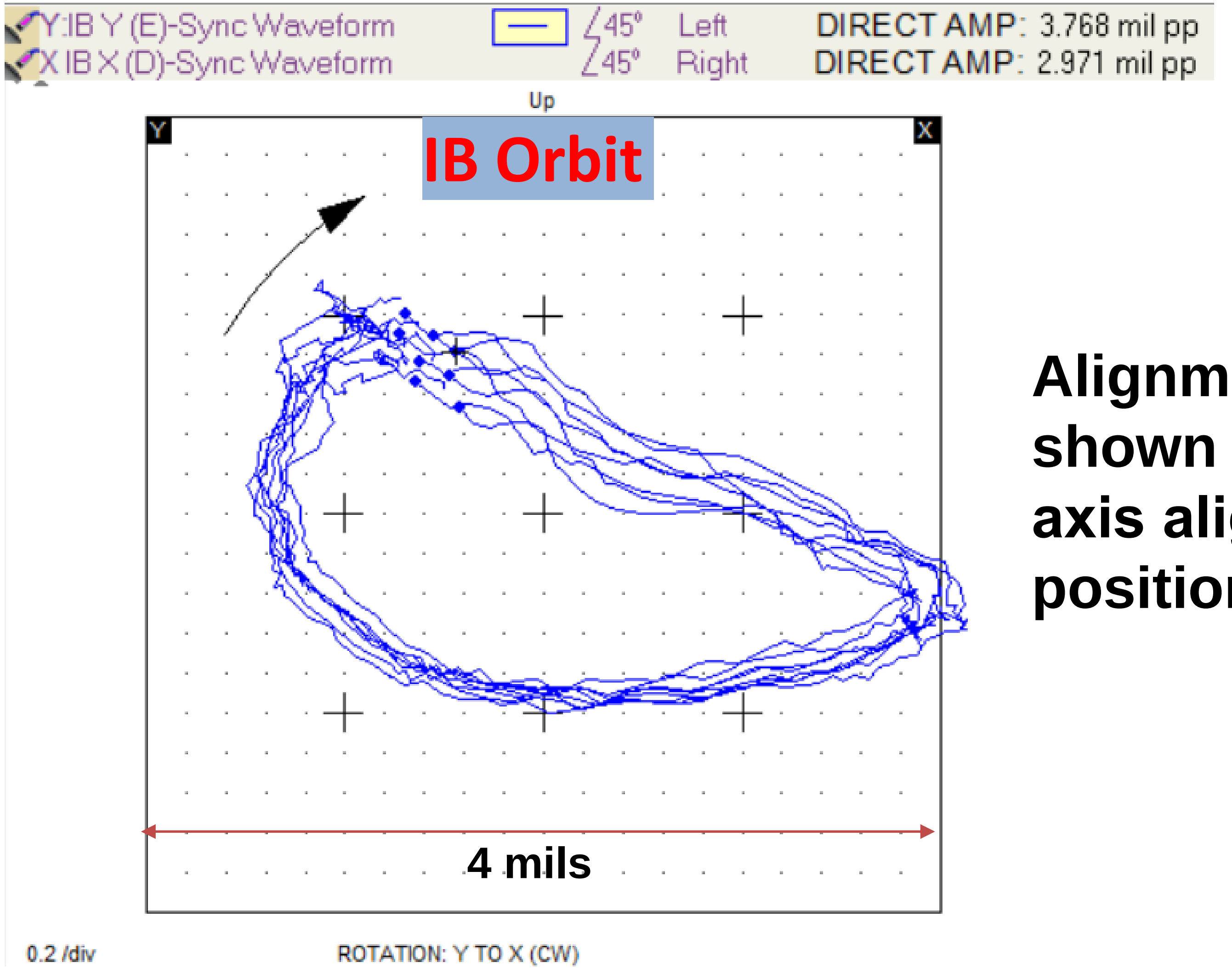
Horizontal Plane

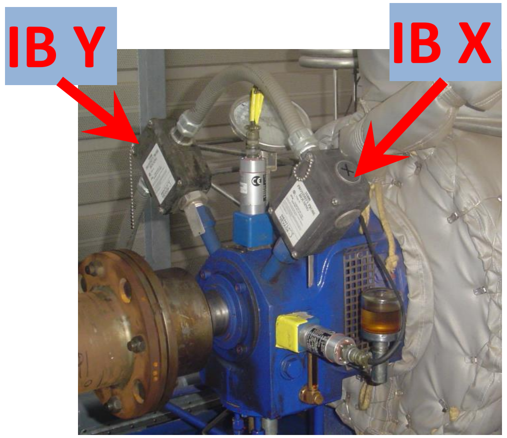
- **Motor was then pulled to the left (viewed from motor to pump). The horizontal plane was corrected as:**

Horizontal Plane

7.1 Resolution and Final Vibration Results

After Re-alignment

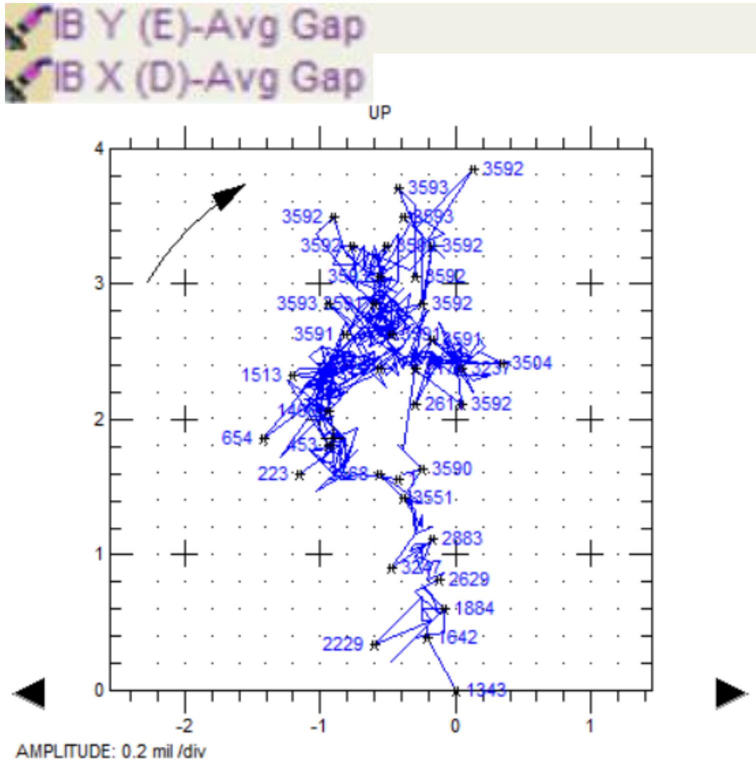


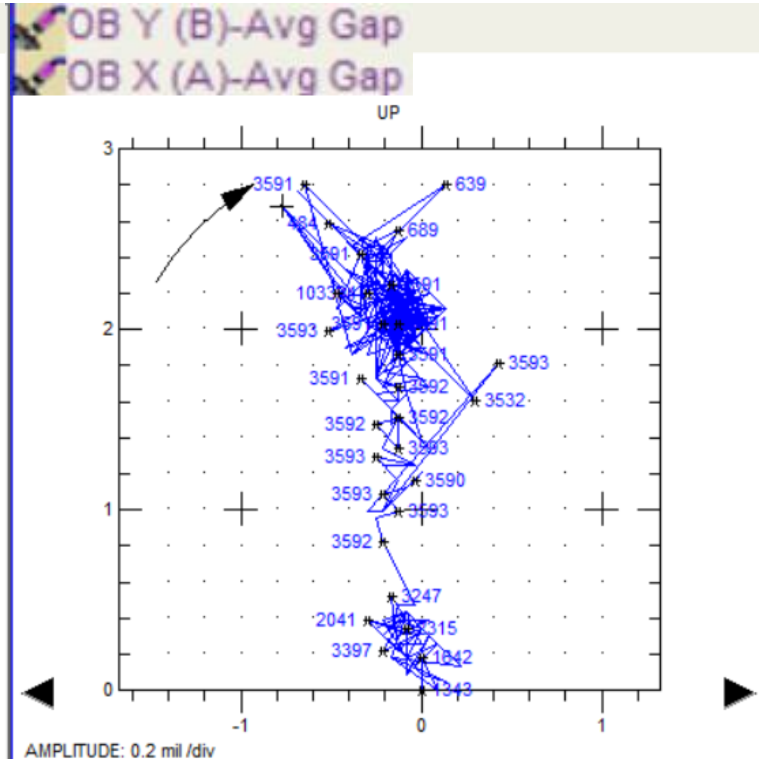


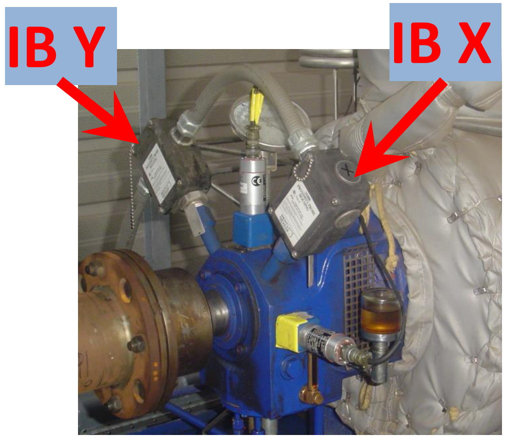
Alignment issue resolved as shown by orbit orientation (major axis aligned to 10 o'clock position) after re-alignment.

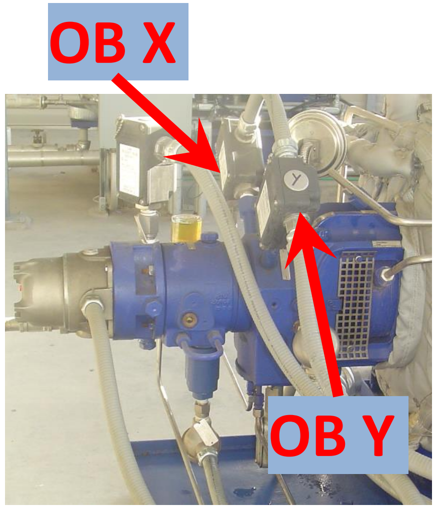
7.2 Resolution and Final Vibration Results

Shaft Centerline Plots After Re-alignment





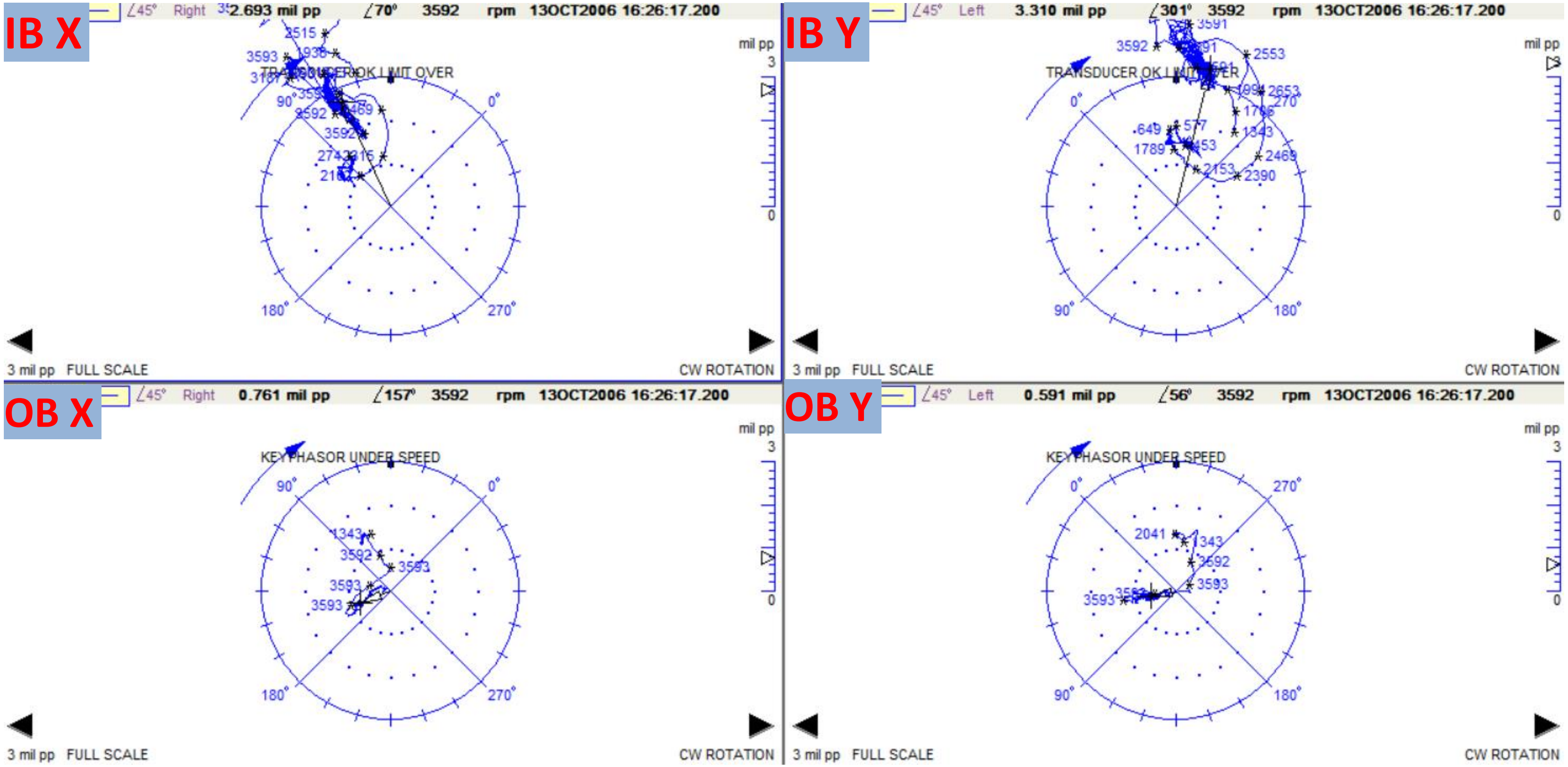


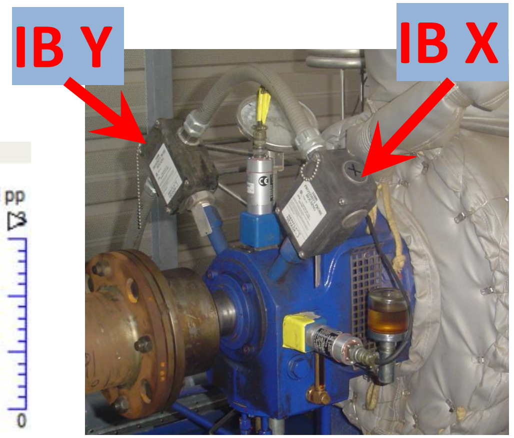


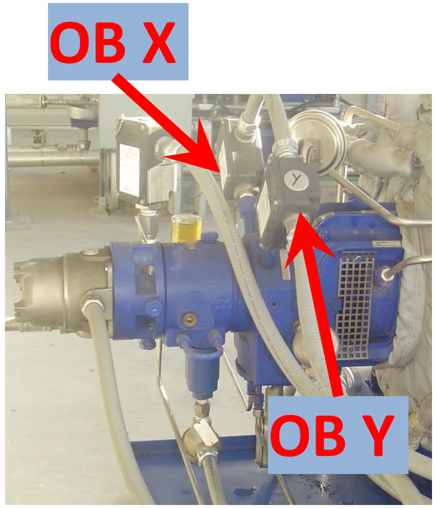
The horizontal misalignment issue resolved as shown by shaft centerline plots after re-alignment.

7.3 Resolution and Final Vibration Results

Note that 1X vectors at IB proximity probes became almost 180-degrees-out-of phase

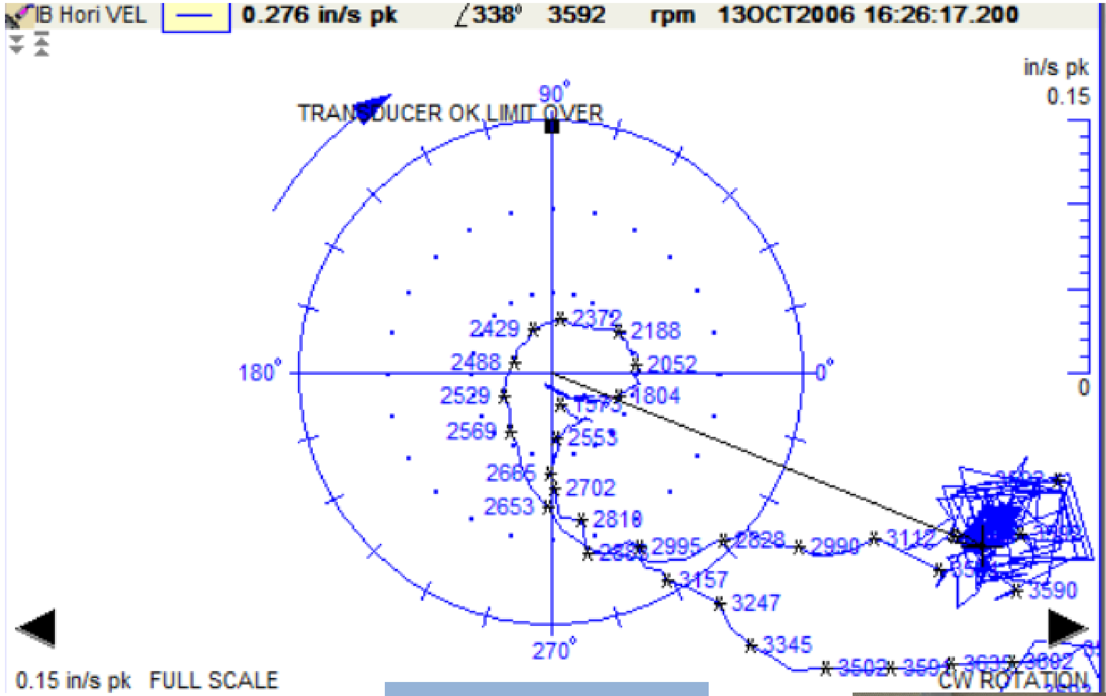


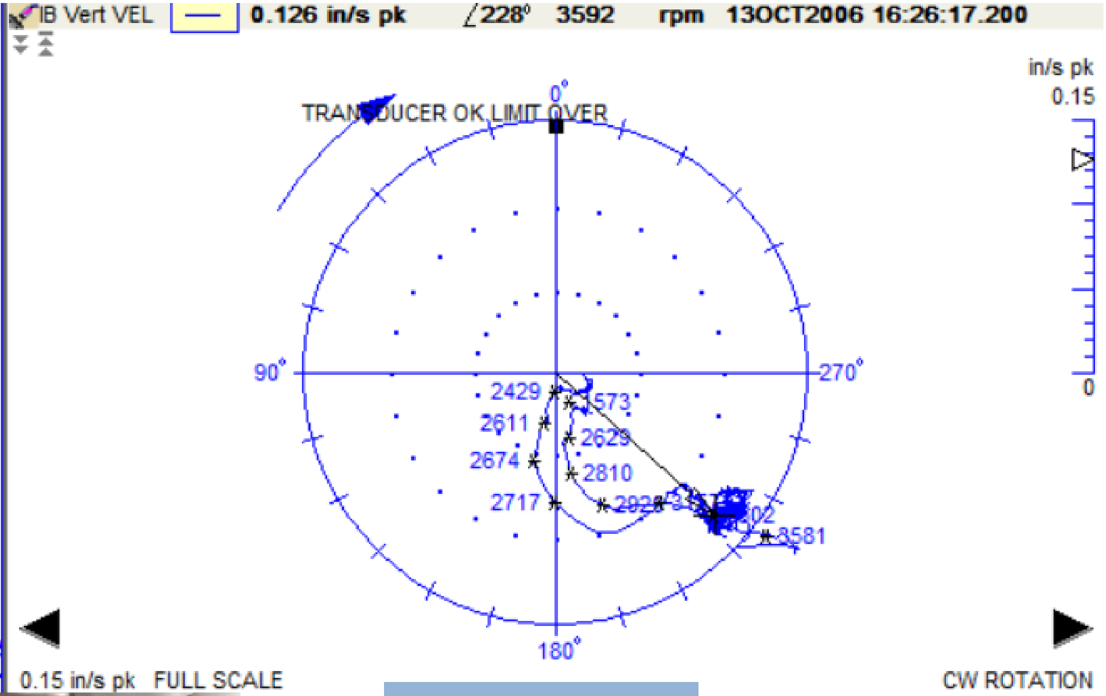




7.4 Resolution and Final Vibration Results

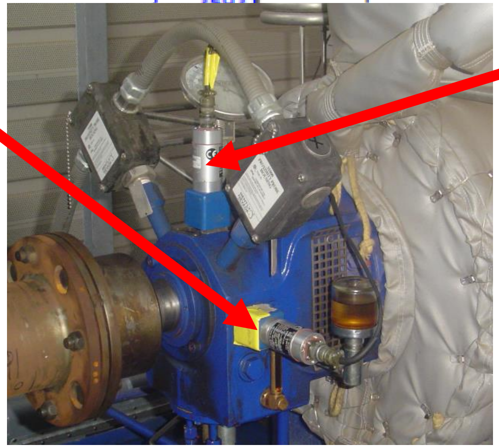
Note that 1X vectors measured by IB casing-mounted transducers became almost 180-degrees-out-of phase as well.





IB Hori Vel

IB Vert Vel



7.5 Resolution and Final Vibration Results

Vibration level was still higher than normal. Wrong coupling spool or bolt installation was suspected.

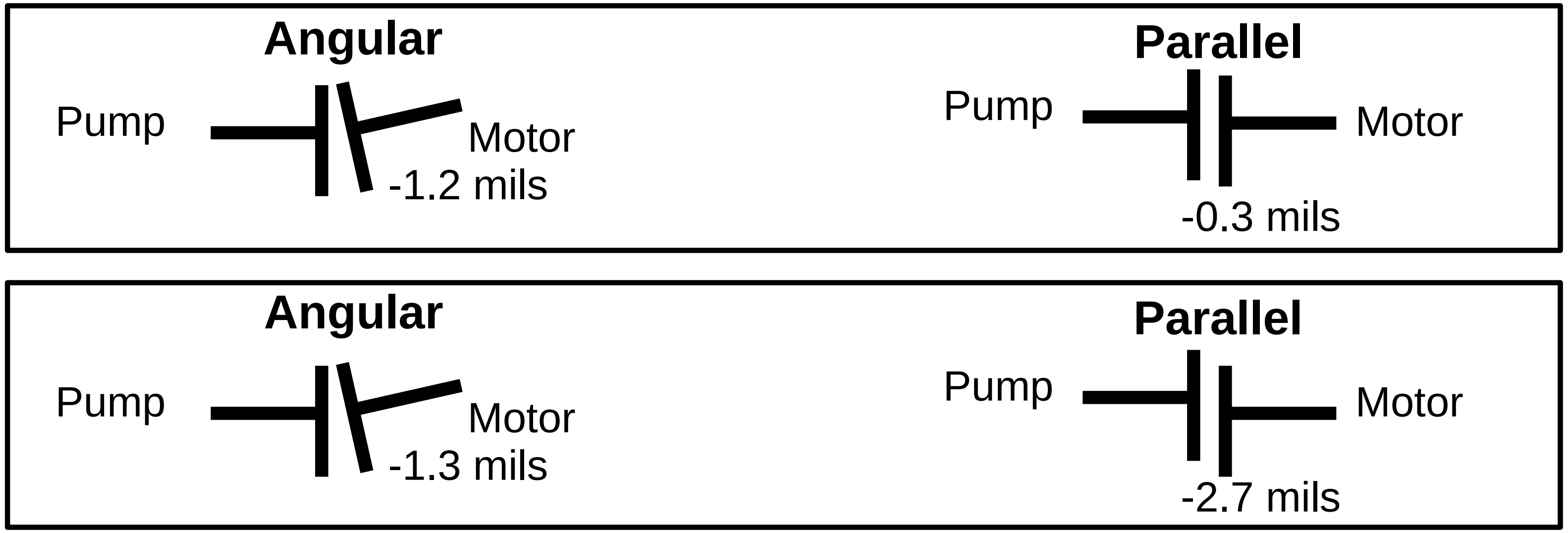
7.6 Resolution and Final Vibration Results

Actions: Re-assembly of Coupling & Checking of Foundation

- **Mismatch of flanges and spool found, which caused high mass unbalance. The coupling re-assembled. Alignment verified as below:**

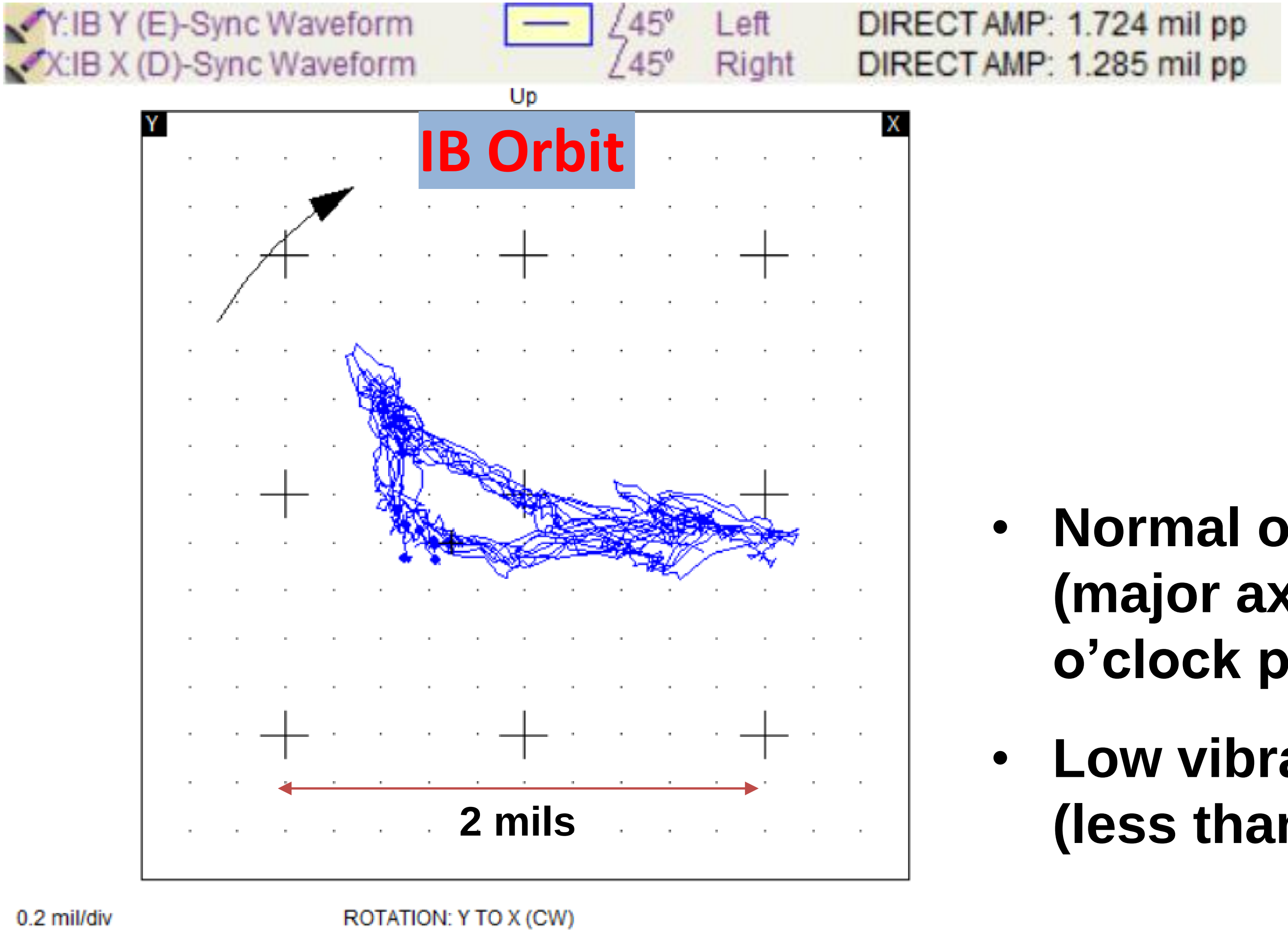
Horizontal Plane

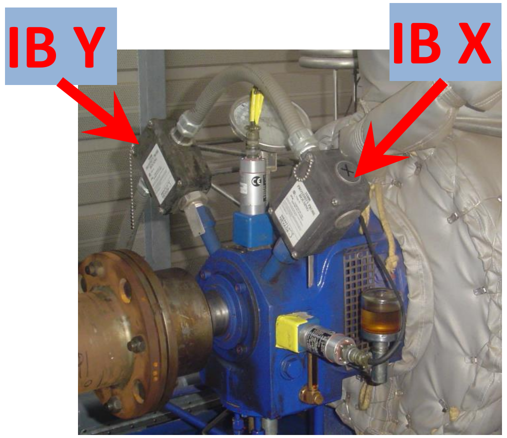
Vertical Plane



- **Bolts connecting the pump to the foundation found to be loose. All four bolts re-tightened.**

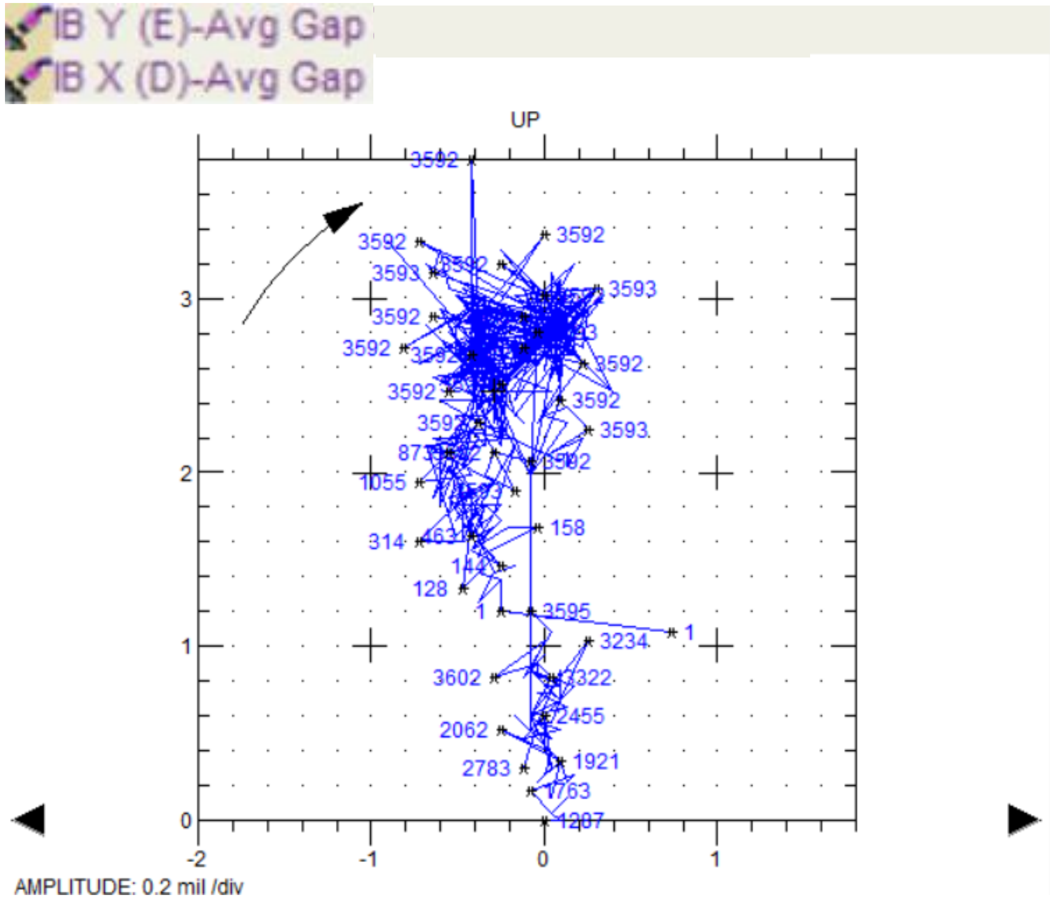
7.6 Resolution and Final Vibration Results

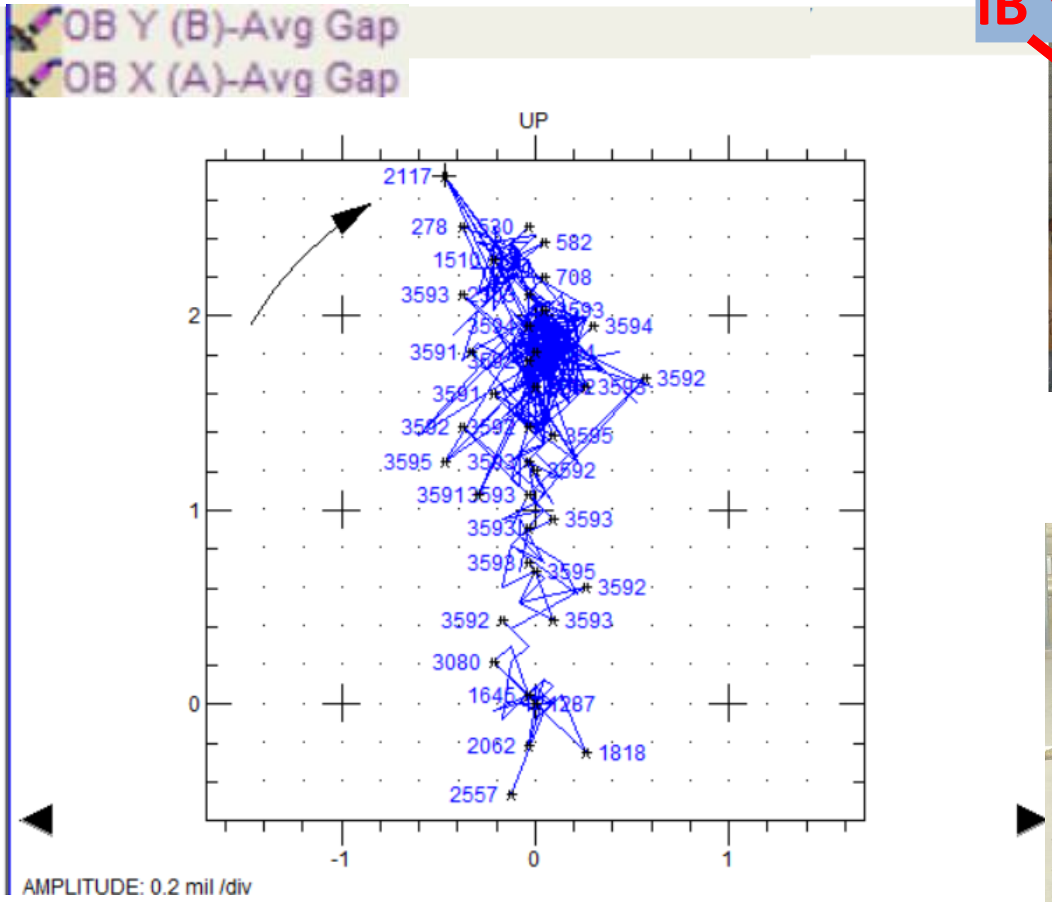


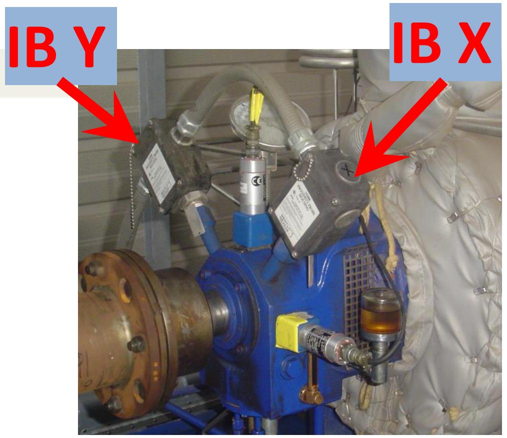


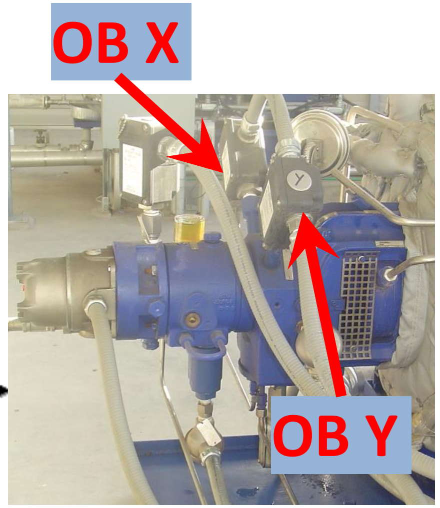
- **Normal orbit orientation (major axis aligned to 10 o'clock position)**
- **Low vibration amplitude (less than 2 mil pp)**

7.7 Resolution and Final Vibration Results









Normal shaft centerline plots
(no significant horizontal shift)

8. Lessons Learned

- In addition to shaft centerline plots, orbit plots can also be used as an important tool to help diagnose misalignment issues.
- If horizontal alignment is correct and the machine is not running close to a resonance speed, an orbit major (longer) axis should be orientated at around 10 o'clock position for clockwise (CW) shaft rotation, and around 2 o'clock position for counter-clockwise (CCW) shaft rotation.
- The misalignment was likely caused by piping strain, as indicated by loose bolts on the pump connection to the foundation.
- If balance is performed without good alignment condition, either vibration could remain no improvement or a misalignment issue be hidden.
- Without knowing the horizontal misalignment issue, the worn bearing would not have been known or replaced in this case.

Thanks….. and Questions (?)