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ATLANTA
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CASE STUDY ON RESOLVING OIL WHIRL ISSUES ON GAS COMPRESSOR

John J. Yu, Ph.D.
Nicolas Péton
Sergey Drygin, Ph.D.

GE Oil & Gas

Abstract

- This case is a site vibration issue on a Gas compressor module. When machine was running at partial load condition, vibration at compressor DE and NDE bearings suddenly increased and tripped the machine.
- This case study outlines how the high vibration issue was successfully diagnosed using shaft relative vibration data.
- The high vibration of 346 um pp (14 mil pp), higher than nominal bearing clearances, was due to subsynchronous 0.37X component forward precession. Significant shaft centerline thermal influence was detected.
- Oil Whirl condition, was diagnosed at compressor bearings.
- Bearing modification was suggested to the OEM. Length/Diameter bearings ratio was decreased by pads machining from both sides. Follow-up tests after bearing modification confirmed no vibration issue afterwards at any load condition.

Machine Information

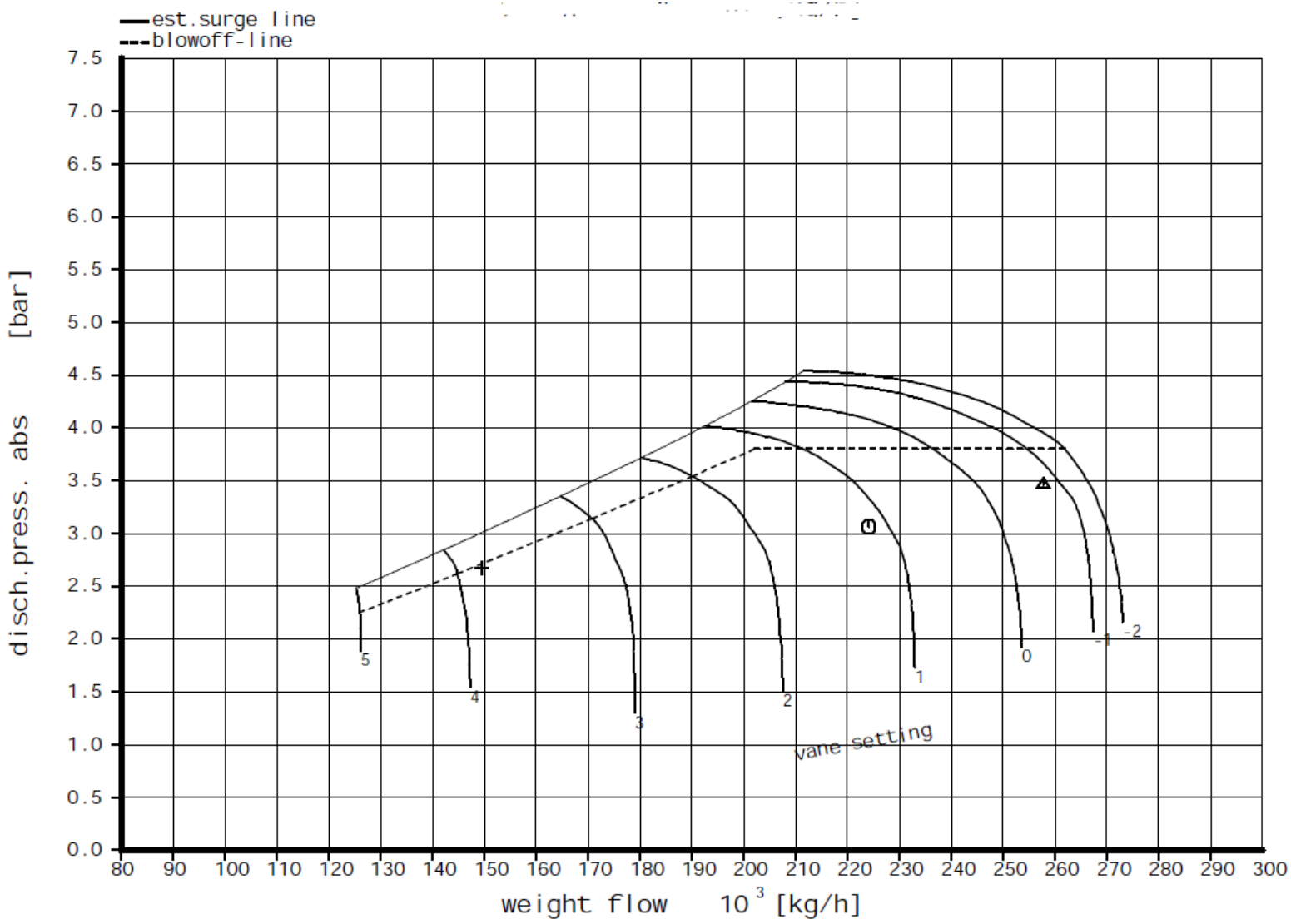
Machine Overview

Machine Information

Compressor Mechanical Data	
Motor Speed	: 1497 rpm
Compressor Speed	: 5877 rpm
Compressor 1st Lateral Critical Speed	**: 2786 rpm**
Compressor 2nd Lateral Critical Speed	: 9042 rpm
Rotating Direction View from Drive End	: Clockwise
Shaft Seal Type	: Labyrinth
DE Bearing Clearance	: **0.250-0.293 mm**
NDE Bearing Clearance	: **0.190-0.233 mm**
Compressor Bearing Type	: Plane Sleeve
Balance Piston Seal Clearance	: 0.85-1.07 mm

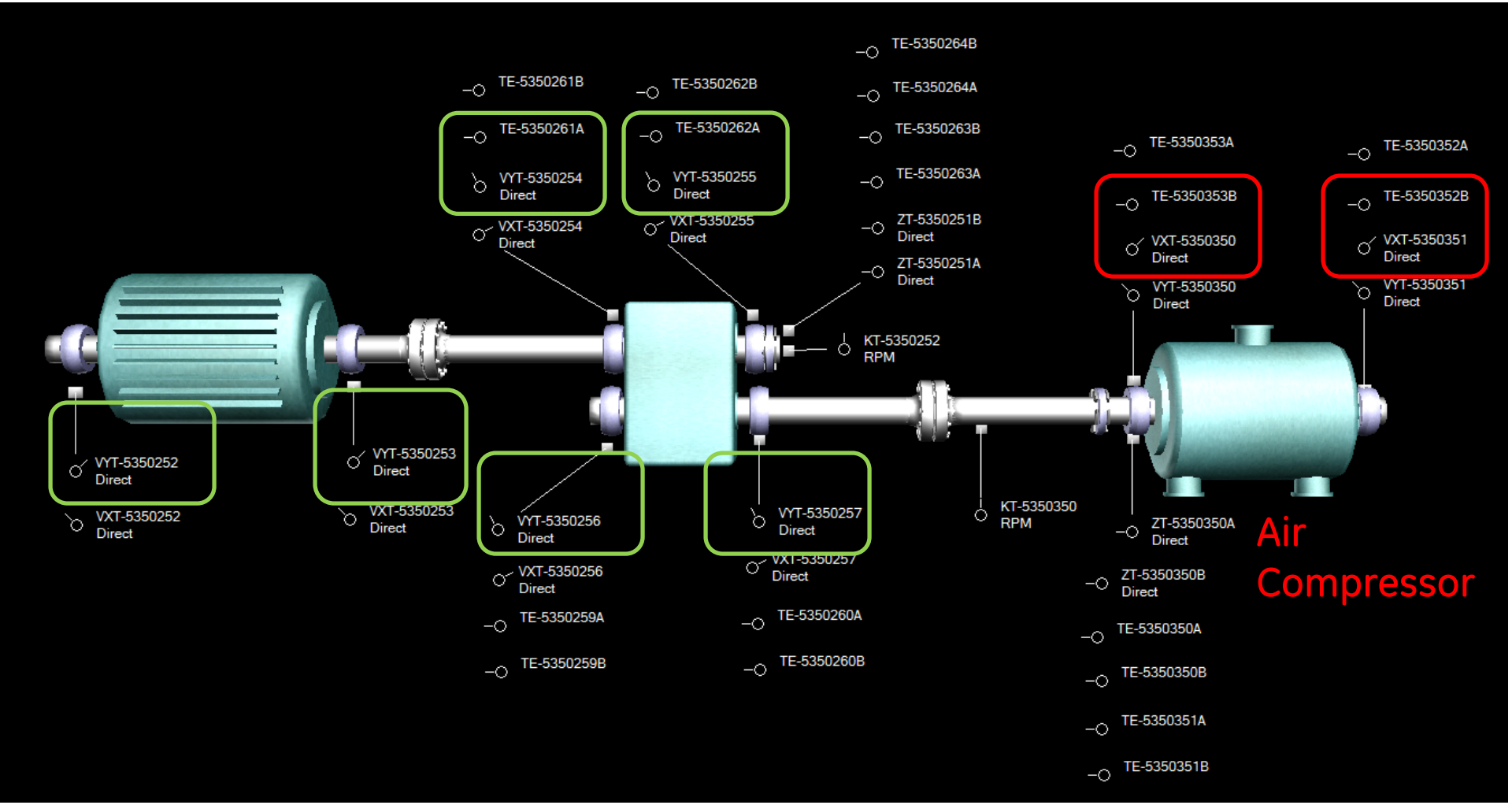
Design Operating Condition:	
Flow Rate	: 168685 m3/h (224144 kg/h)
Suction Pressure	: 0.99 Bar abs.
Suction Temperature	: 35 deg C
Discharge Pressure	: 3.063 Bar abs
Discharge Temperature	: 169 deg C

Design Operating Curve



Problem Description

Machine Trend Diagram



Background

When machine was running at partial load condition, vibration at compressor DE and NDE suddenly increased and tripped machine.

Example condition before the first tripped on 29th Dec 2015

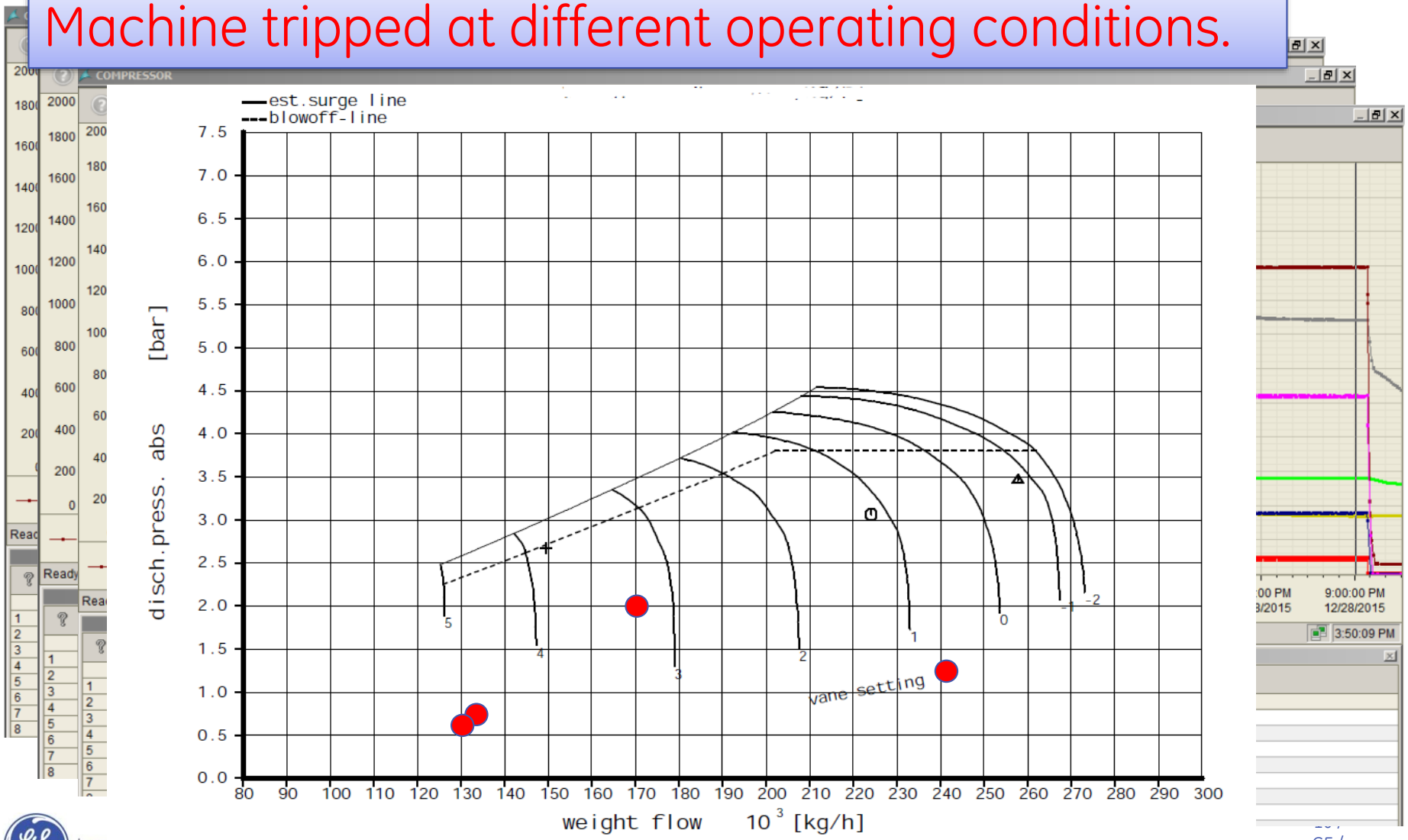
- Discharge pressure : 0.86 Barg
- Air Flow Rate : about 182000 kg/hour
- Discharge Temperature : about 125 deg C
- Suction Temperature : about 33 deg C

Example condition before the first tripped on 15th January 2016 (after realignment)

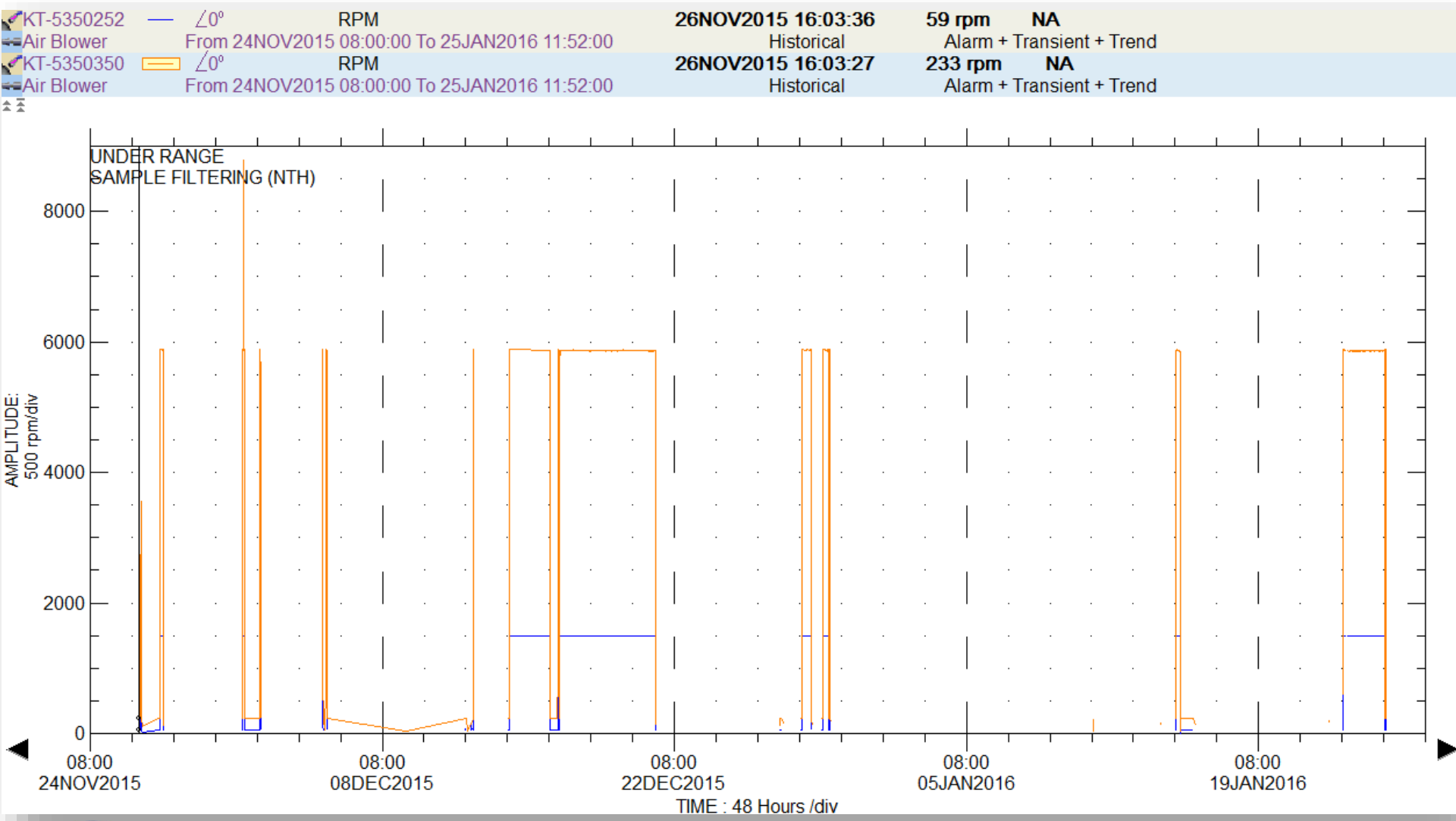
- Discharge pressure : 1.14 Barg
- Air Flow Rate : about 287000 kg/hour
- Discharge Temperature : about 152 deg C
- Suction Temperature : about 33 deg C

Process condition during trip events

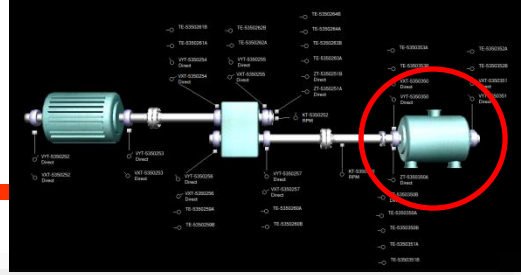
Machine tripped at different operating conditions.



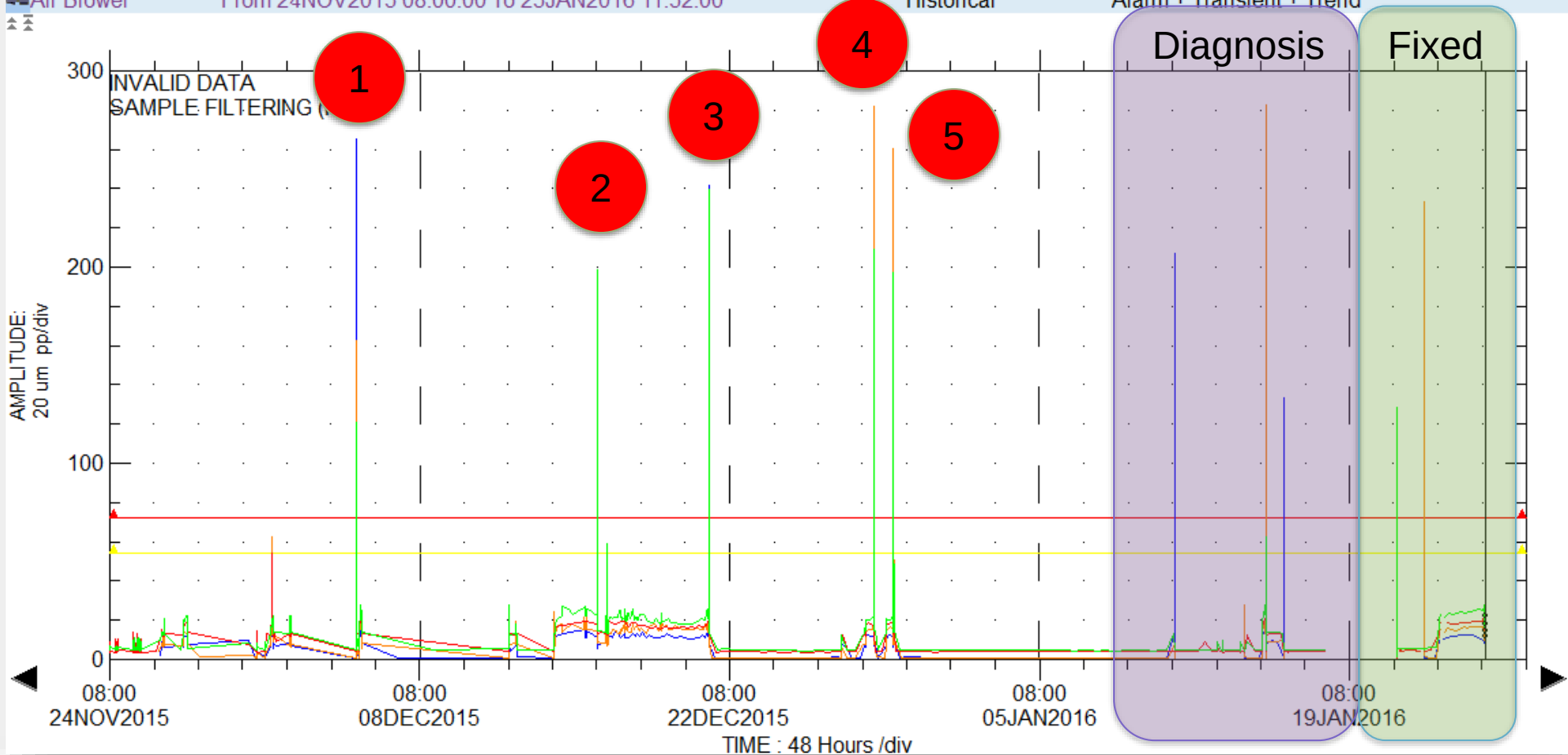
Shaft Speed Trend



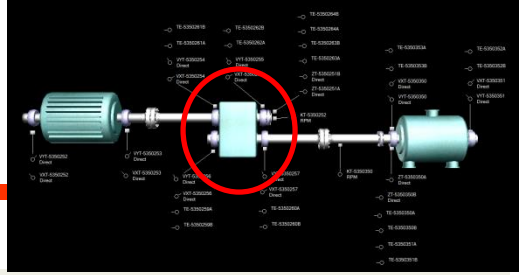
Compressor Overall Vibration (Abnormal)



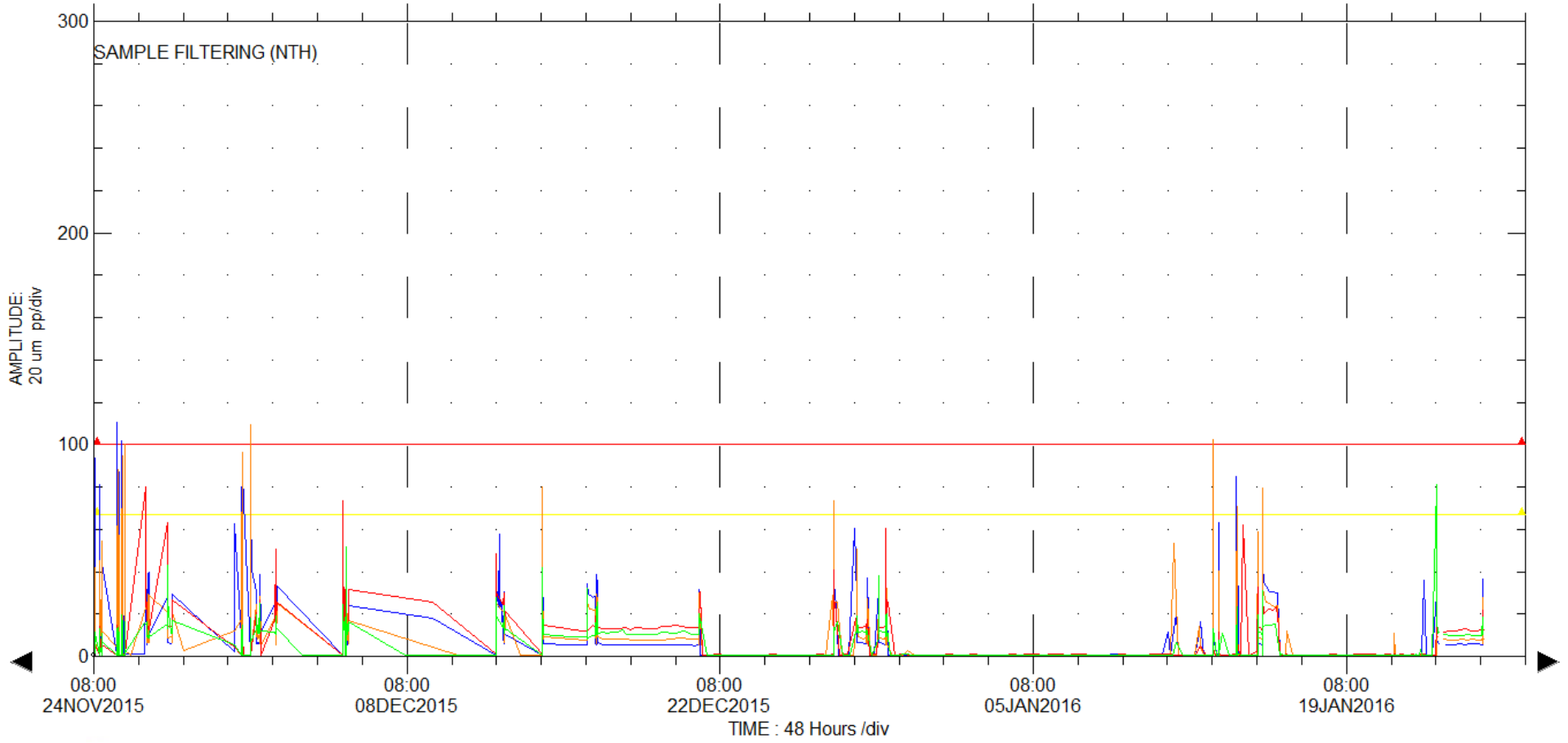
VXT-5350350	∠45°	Right	Direct	25JAN2016 11:52:00	12 um pp	5873 rpm
Air Blower	From 24NOV2015 08:00:00 To 25JAN2016 11:52:00				Historical	Alarm + Transient + Trend
VYT-5350350	∠45°	Left	Direct	25JAN2016 11:52:00	14 um pp	5873 rpm
Air Blower	From 24NOV2015 08:00:00 To 25JAN2016 11:52:00				Historical	Alarm + Transient + Trend
VXT-5350351	∠45°	Right	Direct	25JAN2016 11:52:00	18 um pp	5871 rpm
Air Blower	From 24NOV2015 08:00:00 To 25JAN2016 11:52:00				Historical	Alarm + Transient + Trend
VYT-5350351	∠45°	Left	Direct	25JAN2016 11:52:00	22 um pp	5875 rpm
Air Blower	From 24NOV2015 08:00:00 To 25JAN2016 11:52:00				Historical	Alarm + Transient + Trend



Gearbox Overall Vibration (Normal)

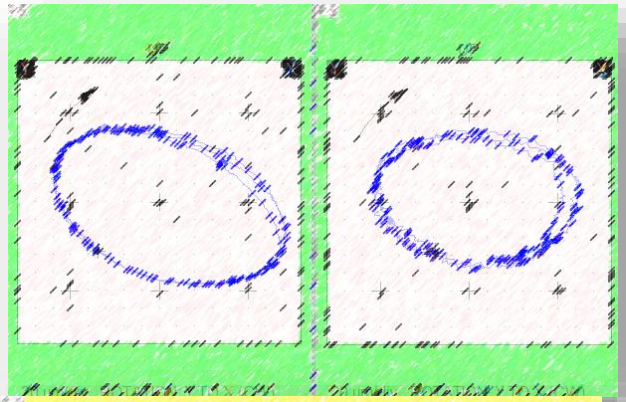


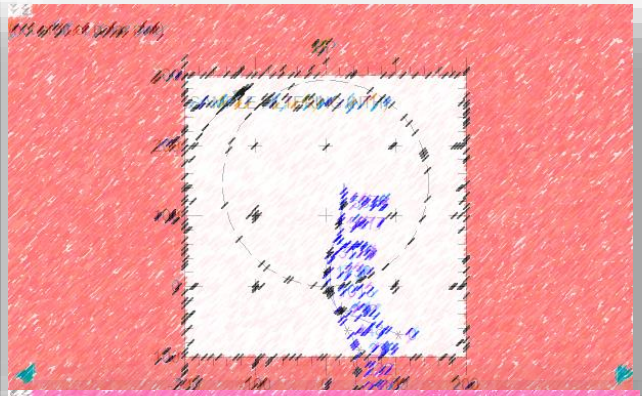
VYT-5350256	∠30°	Left	Direct	24NOV2015 08:00:00	1 um pp	0 rpm
Air Blower	From 24NOV2015 08:00:00 To 25JAN2016 11:52:00			Historical	Alarm + Transient + Trend	
VXT-5350256	∠60°	Right	Direct	24NOV2015 08:00:00	1 um pp	0 rpm
Air Blower	From 24NOV2015 08:00:00 To 25JAN2016 11:52:00			Historical	Alarm + Transient + Trend	
VYT-5350257	∠30°	Left	Direct	24NOV2015 08:00:00	1 um pp	0 rpm
Air Blower	From 24NOV2015 08:00:00 To 25JAN2016 11:52:00			Historical	Alarm + Transient + Trend	
VXT-5350257	∠60°	Right	Direct	24NOV2015 08:00:00	1 um pp	0 rpm
Air Blower	From 24NOV2015 08:00:00 To 25JAN2016 11:52:00			Historical	Alarm + Transient + Trend	

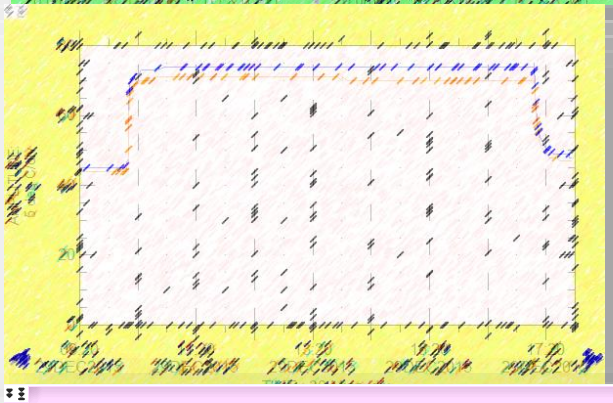


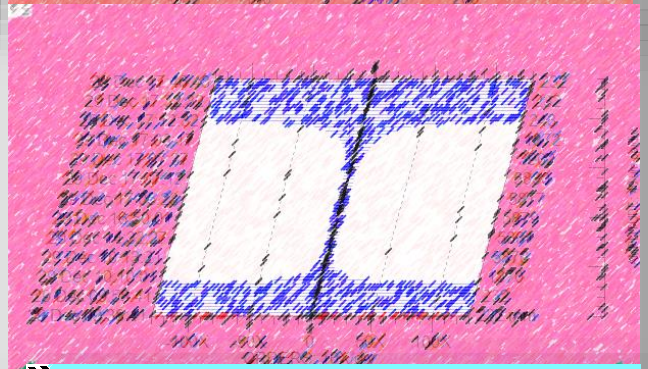
Data Analysis

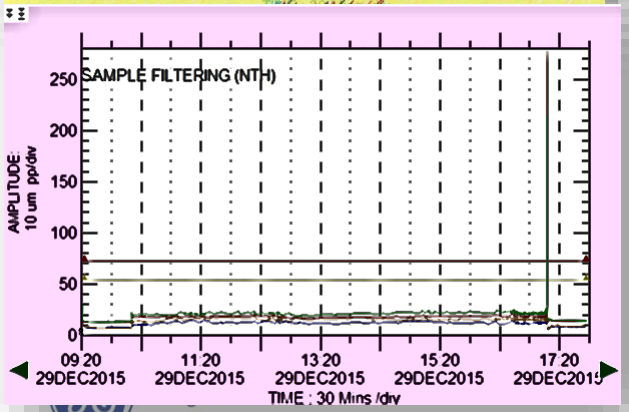
Overview

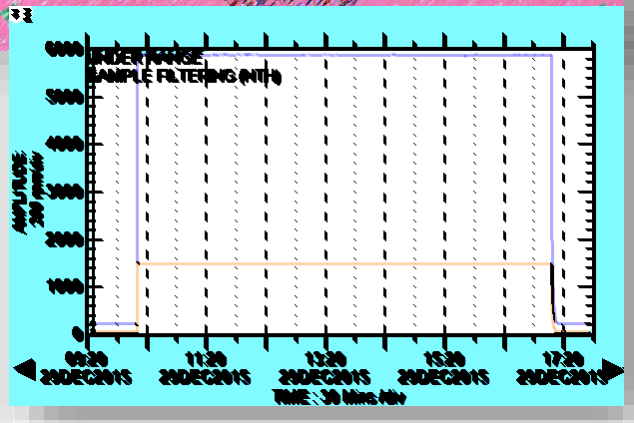






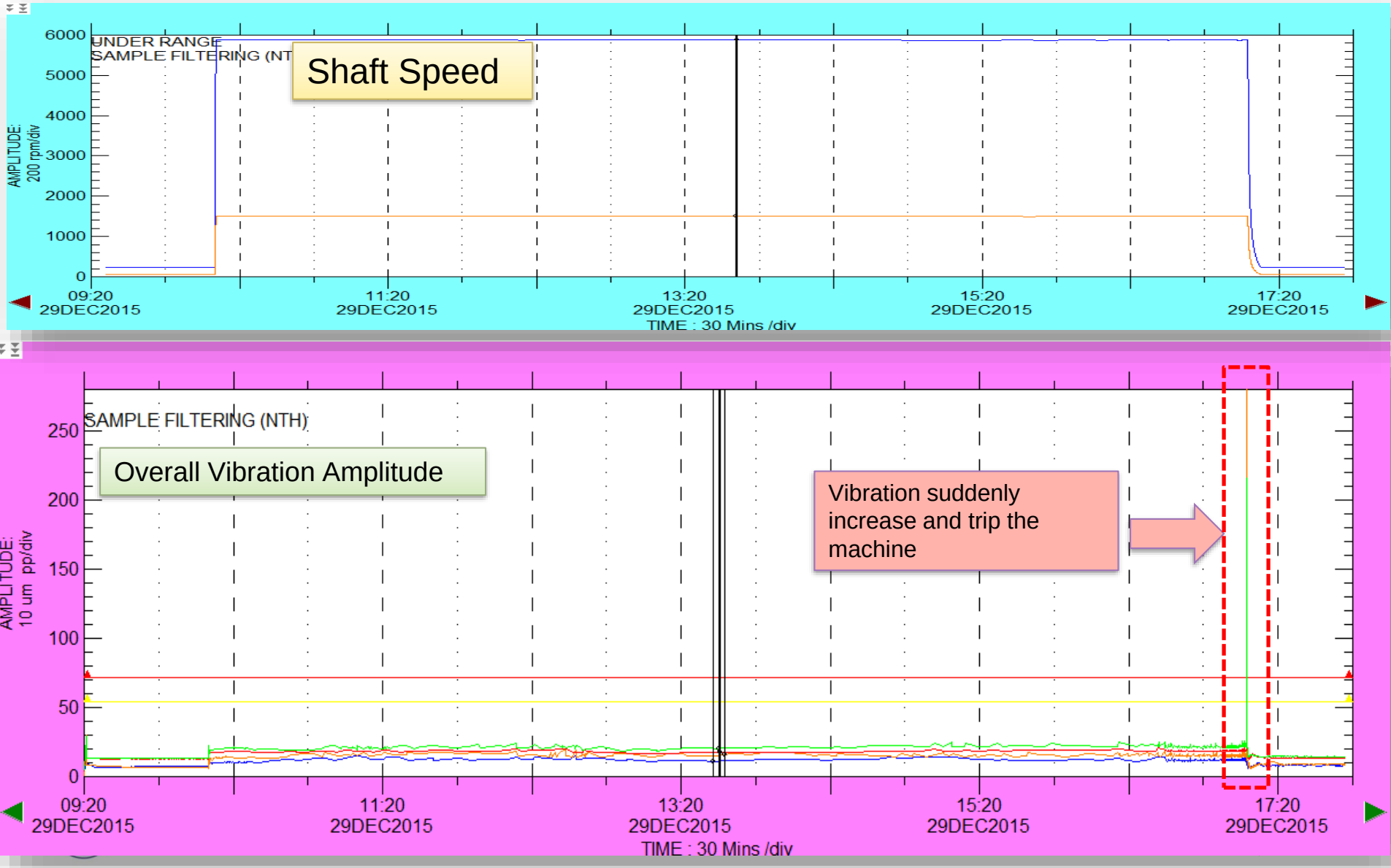




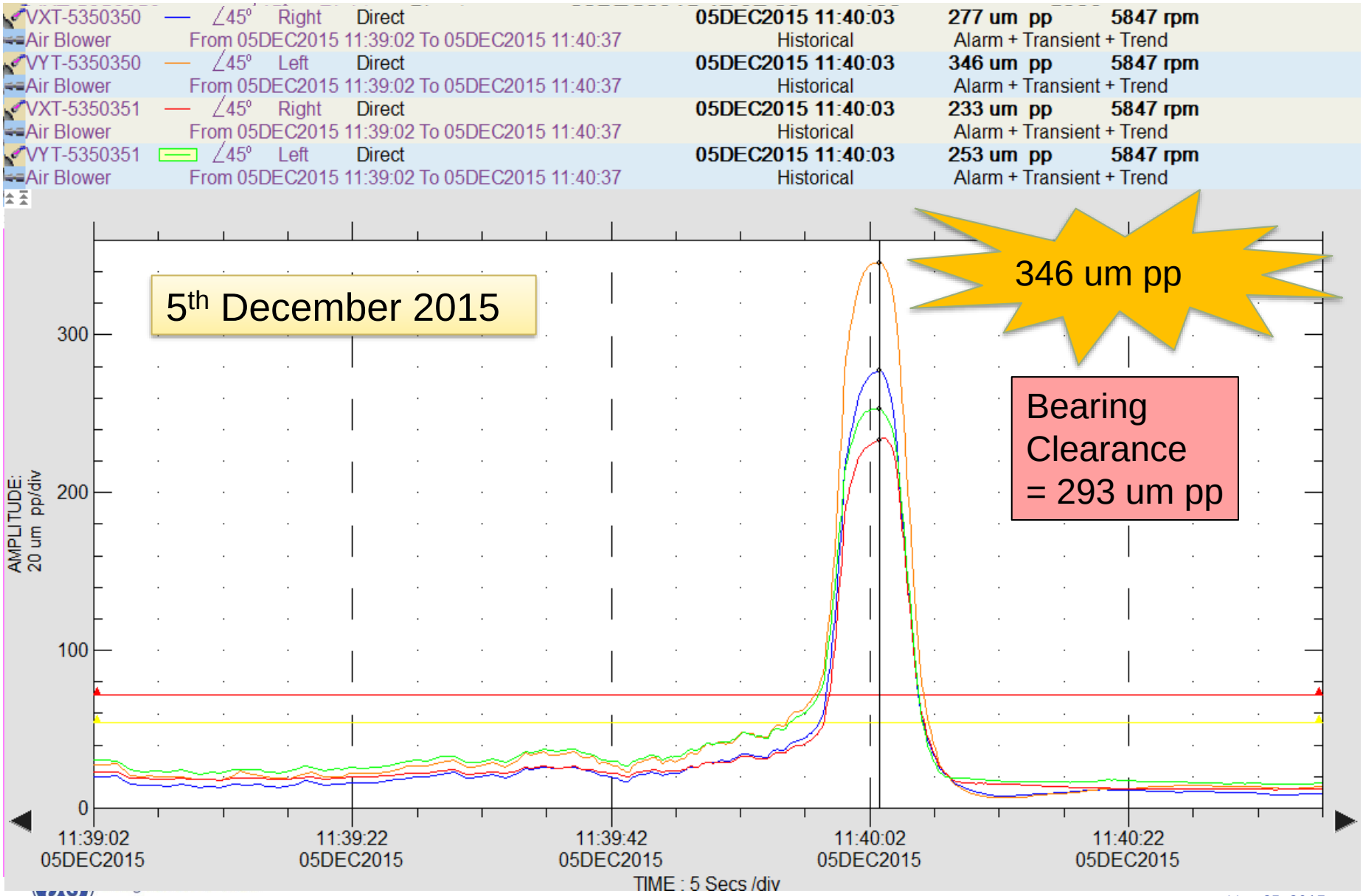


- Overview from 27 NOV
- **Air Blower data from 27 Nov 2015**
  - Blower Vibration
  - rpm
  - Blower Vib
  - Blower orbit
  - Blower Brg Temp
  - Blower Shaft Centerline
  - Blower Shaft Axial Position
- Air Blower data 01 DEC 2015 no Trip
- Air Blower data 02 DEC 2015 No Trip
- Air Blower data 05 DEC 20151100-1145 (TRIP)
- Air Blower data 05 DEC 2015 1424-1645 (Not Trip)
- Air Blower data 16 DEC 2015 0910 (Trip)
- Air Blower data 16 DEC 2015 1730-1930 (Trip NDE Y)
- Air Blower data 21 DEC 2015
- Air Blower data 28 DEC 2015 2108 (Trip)
- Air Blower data 29 DEC 2015 1707 (first trip)
- Air Blower data 29 DEC 2015 1707 (second trip)
- Air Blower data 29 DEC 2015 1707 (third trip)
  - Blower Vibration
  - rpm
  - Blower Vib
  - Blower orbit
  - Blower Brg Temp
  - Blower Shaft Centerline w rpm stamp
  - Blower Shaft Axial Position
  - Blower Shaft Centerline w Time stamp
  - Blower Shaft Centerline
- Air Blower data 29 DEC 2015 1707 (three cycle)
  - Blower orbit
  - Blower Brg Temp
  - Blower Shaft Centerline w rpm stamp
  - Blower Vibration
  - rpm
  - Blower Vib
  - Blower Shaft Axial Position
  - Blower Shaft Centerline w Time stamp
  - Blower Shaft Centerline
- Air Blower data current value
- Air Blower data 20160115 SU Aft reAlignment transient
- Franze Plot Session 1 Current Value
- Franze Plot Session 1 Historical Value
- all

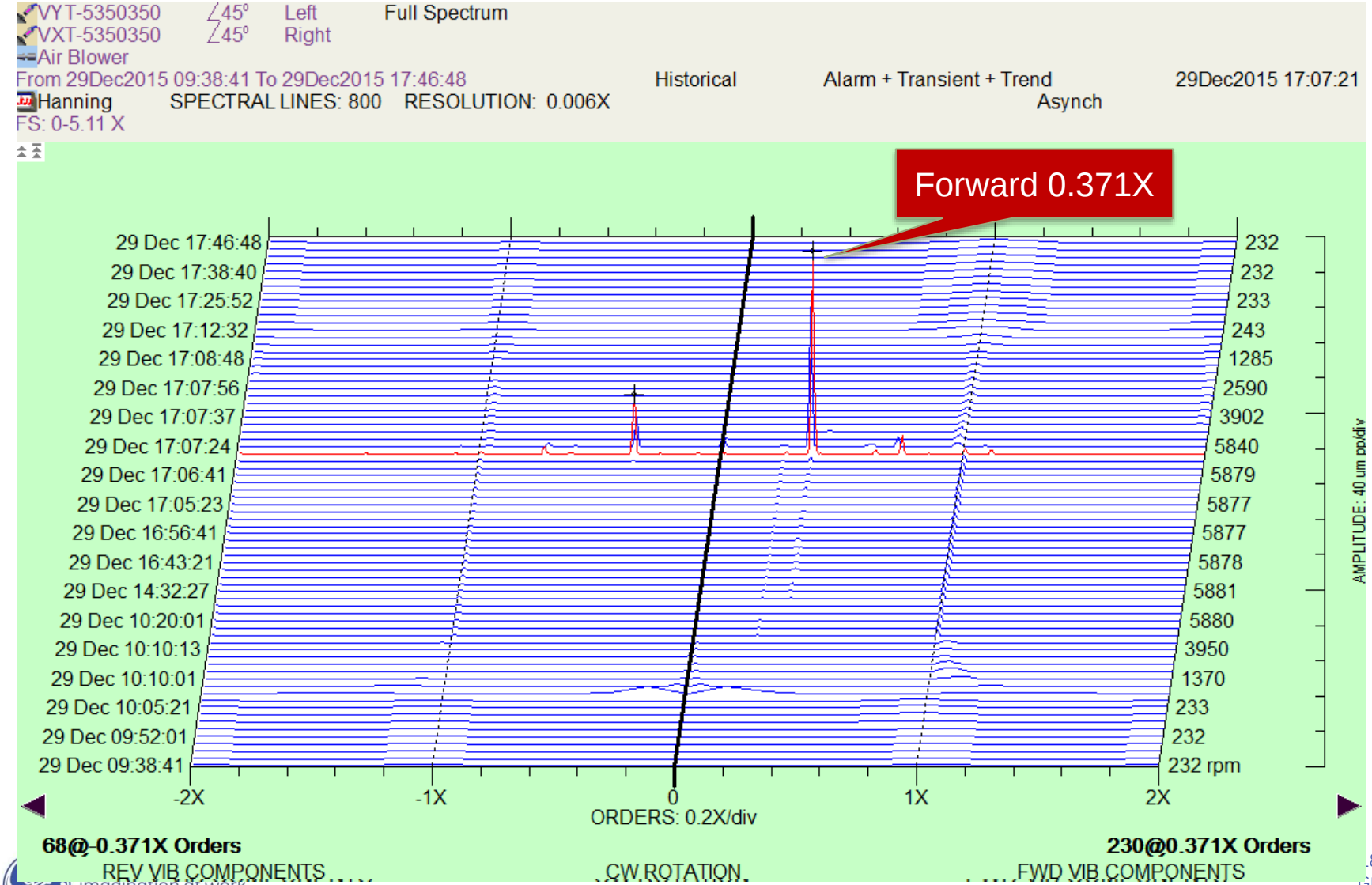
Shaft Speed vs. Vibration Amplitude Trends: Vibration suddenly increased



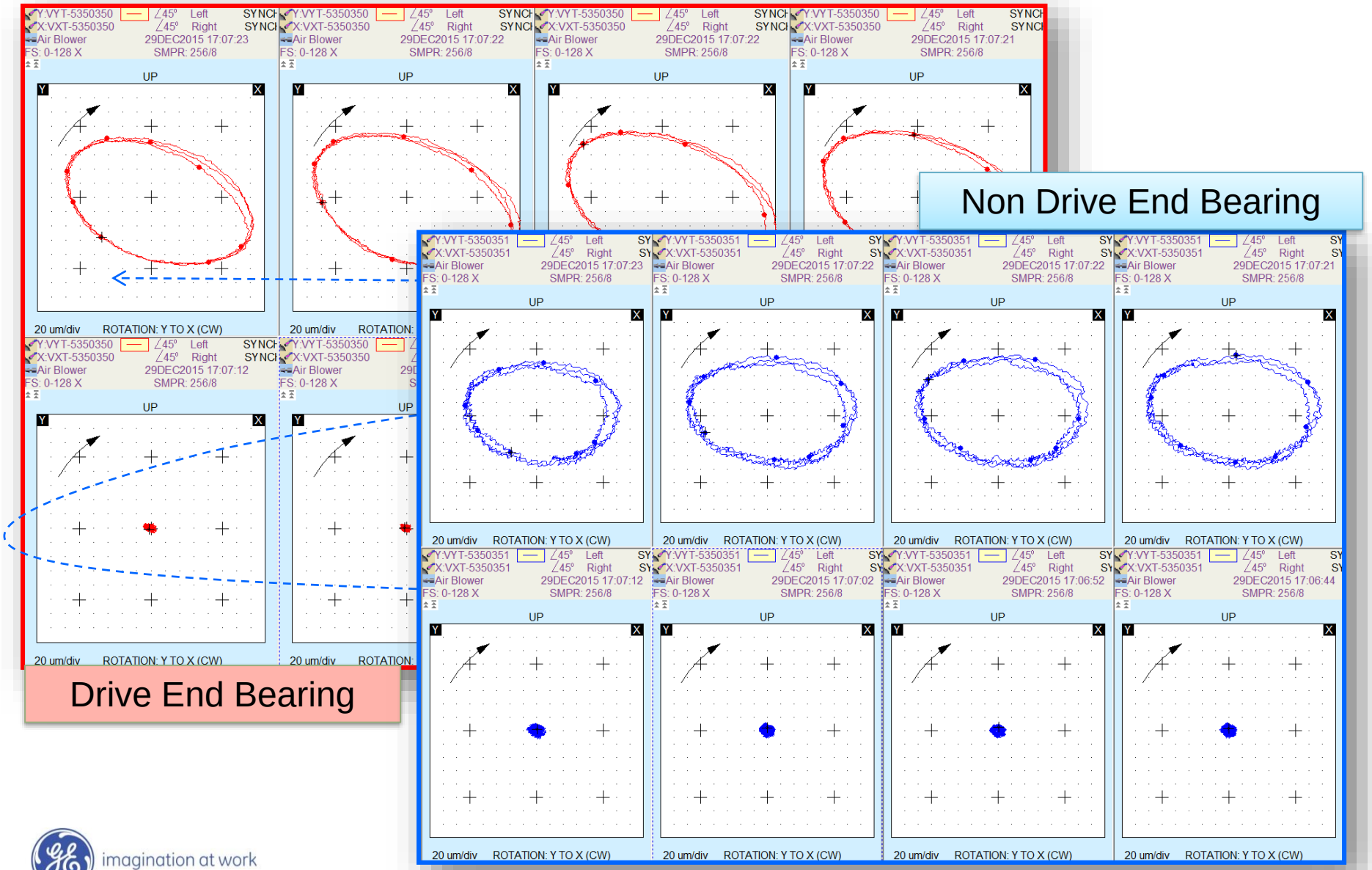
Vibration Amplitude: Higher than bearing Clearance (>293 um)



Vibration Spectrum: 0.371X Dominant



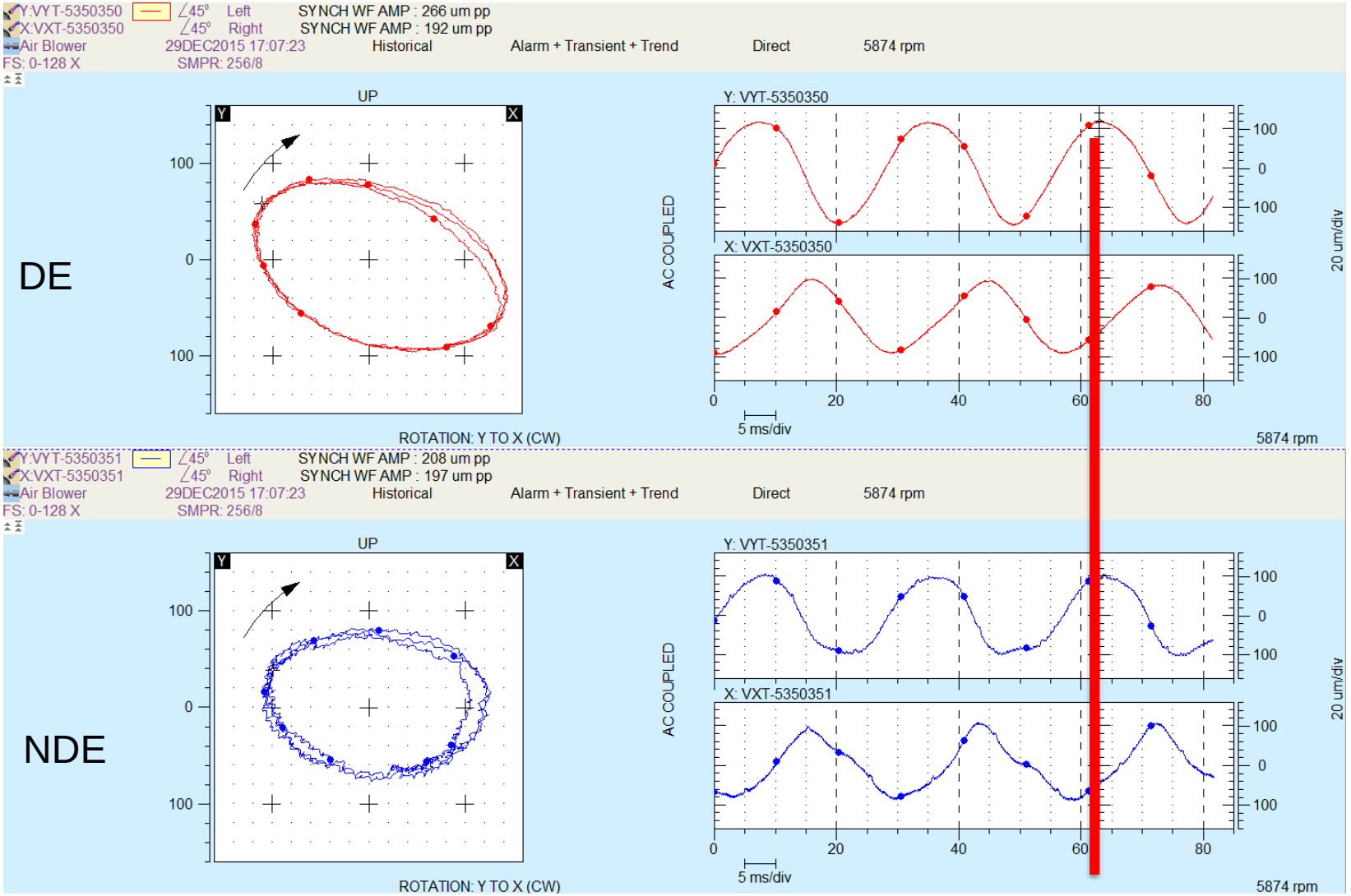
Dynamic Shaft Movement (Orbit): Big, Elliptic, Forward Precession



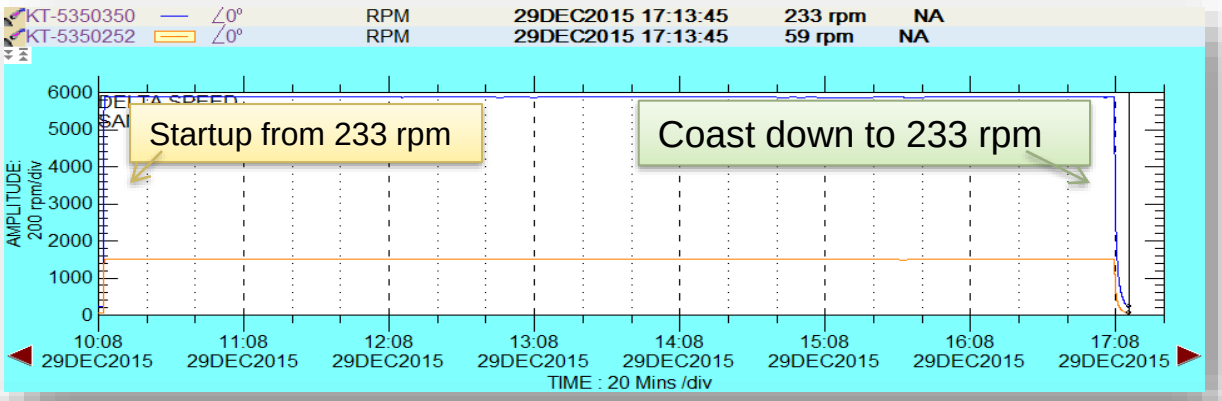
imagination at work

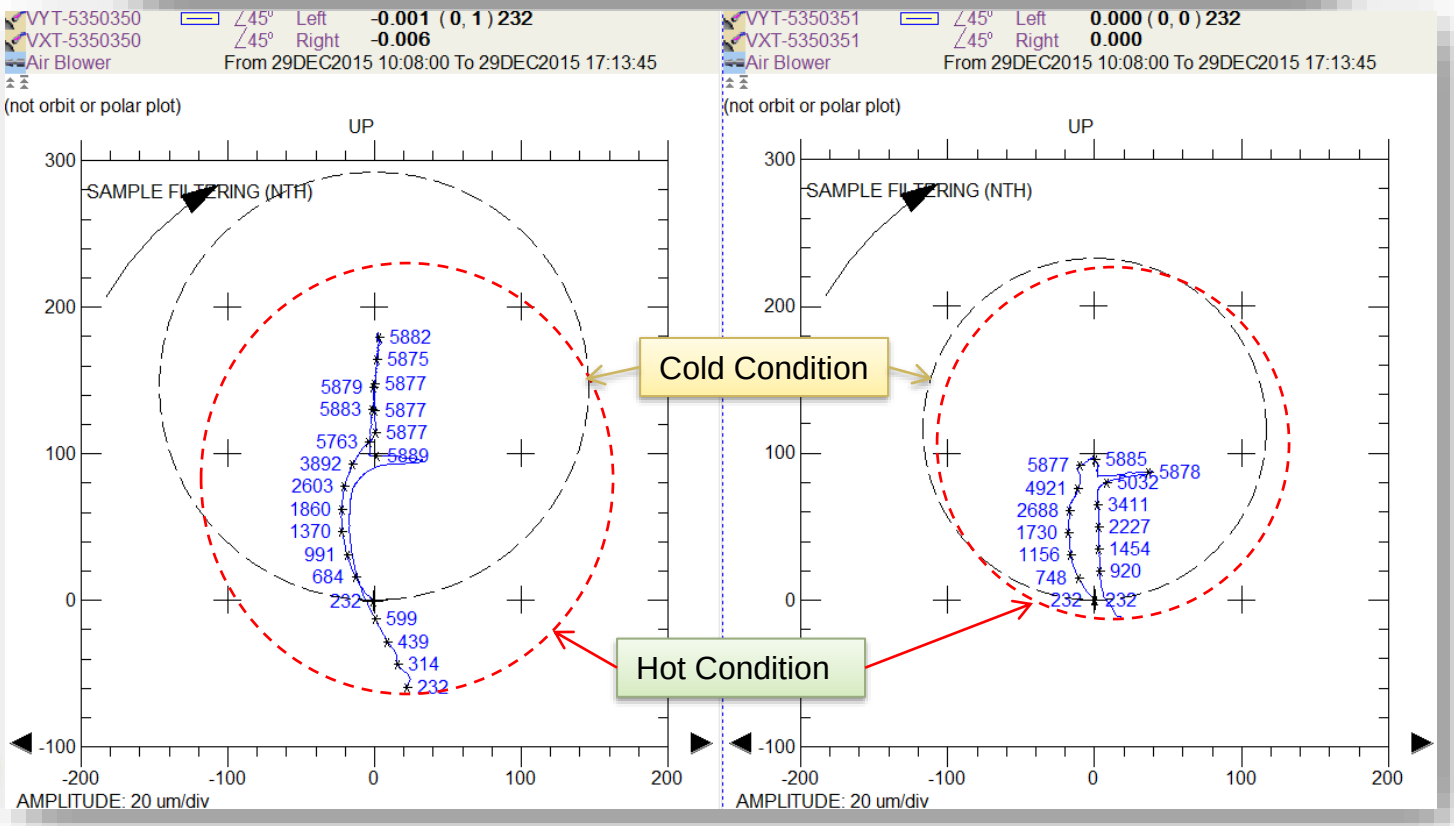
May 23, 2017

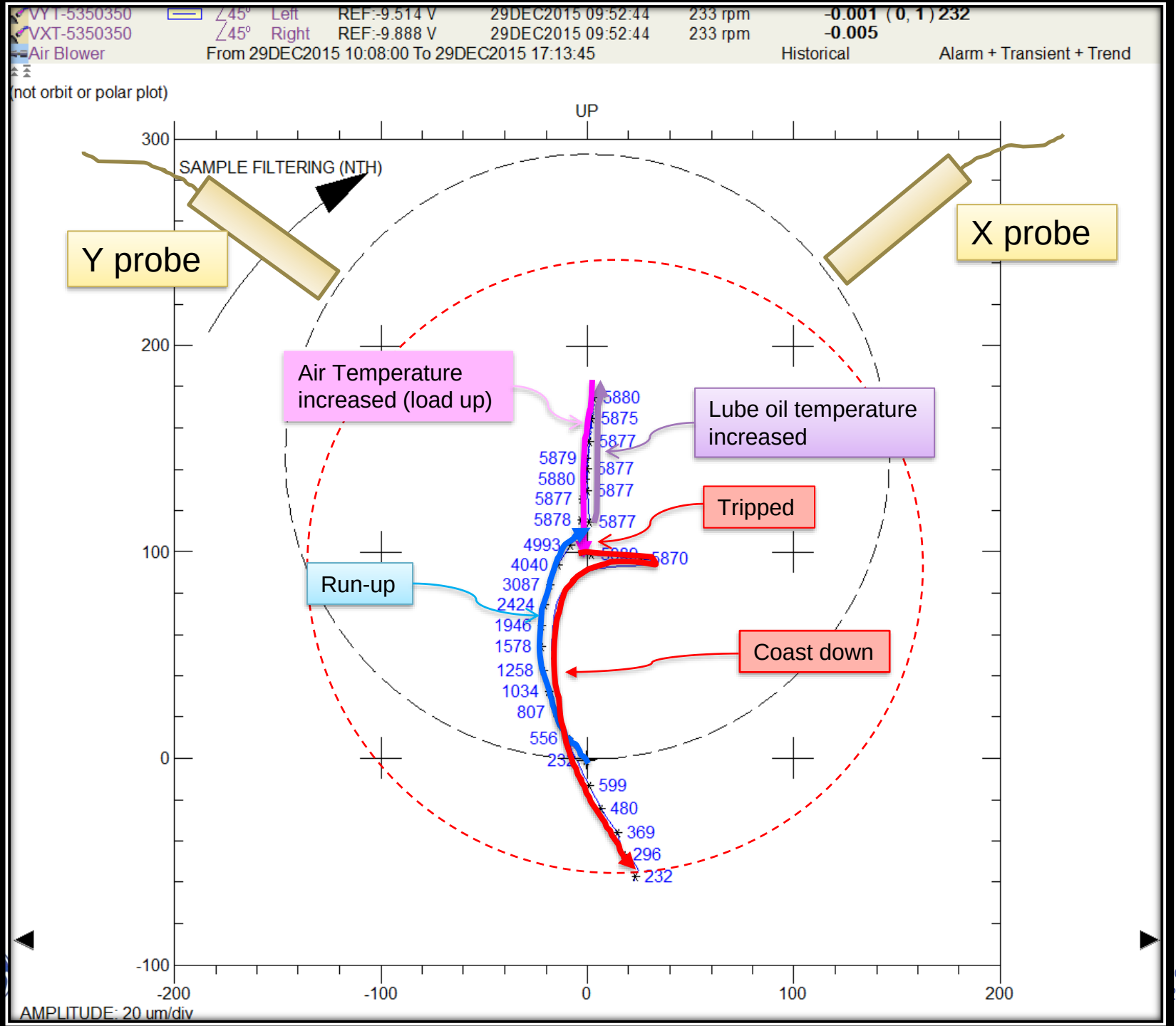
DE and NDE orbits: In-Phase



Average Shaft Centerline : Significantly Different btw Cold and Hot Condition






VYT-5350350 45° Left REF:-9.514 V 29DEC2015 09:52:44 233 rpm -0.001 (0, 1) 232
VXT-5350350 45° Right REF:-9.888 V 29DEC2015 09:52:44 233 rpm -0.005
Air Blower From 29DEC2015 10:08:00 To 29DEC2015 17:13:45 Historical Alarm + Transient + Trend
(not orbit or polar plot)
UP
SAMPLE FILTERING (NTH)
Y probe
X probe
Air Temperature increased (load up)
Lube oil temperature increased
Tripped
Run-up
Coast down
5880
5875
5877
5879
5877
5880
5877
5877
5878
5877
4993
5870
4040
3087
2424
1946
1578
1258
1034
807
556
599
480
369
296
232
300
200
100
0
-100
-200
-100
0
100
200
AMPLITUDE: 20 um/div

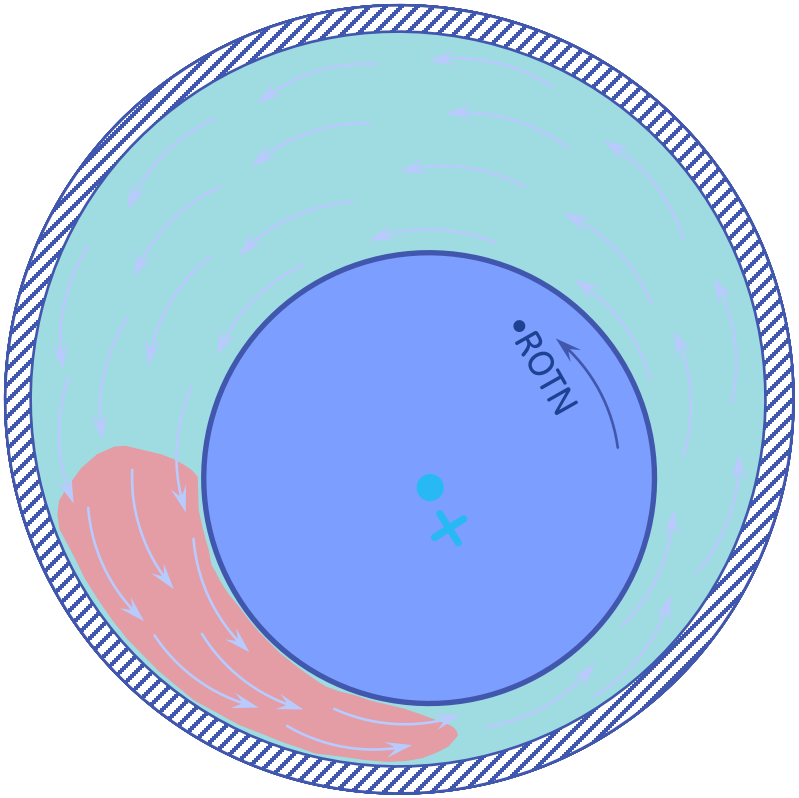
Diagnostics Summary

Vibration Information Summary

Amplitude	**:** More than Bearing Clearance (293 um)
Dominant Frequency	**:** 0.37X (2175 cpm) (< 1st Res Freq.)
nX Vector	**:** 0.37X, DE and NDE are in-Phase.
Shaft Position	**:** Near Bearing Center
Orbit Shape	**:** Slightly Elliptical Shape, Forward Precession

Fluid Induce Instability – Whirl
(most likely at DE bearing)

Fluid Whirl/Whip



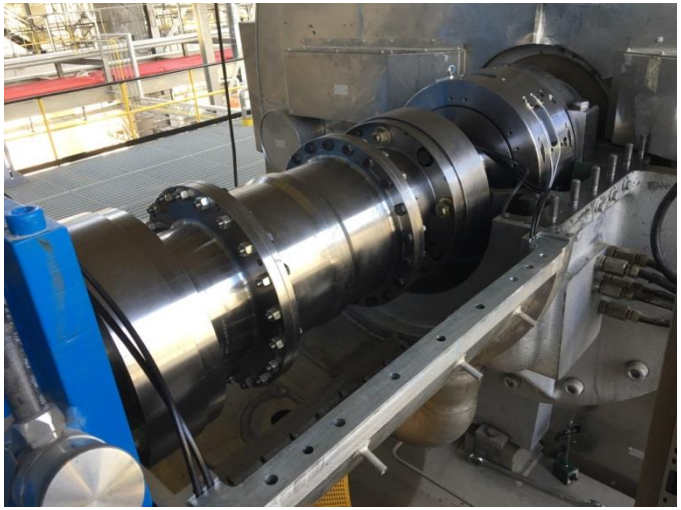
Immediate Recommendations

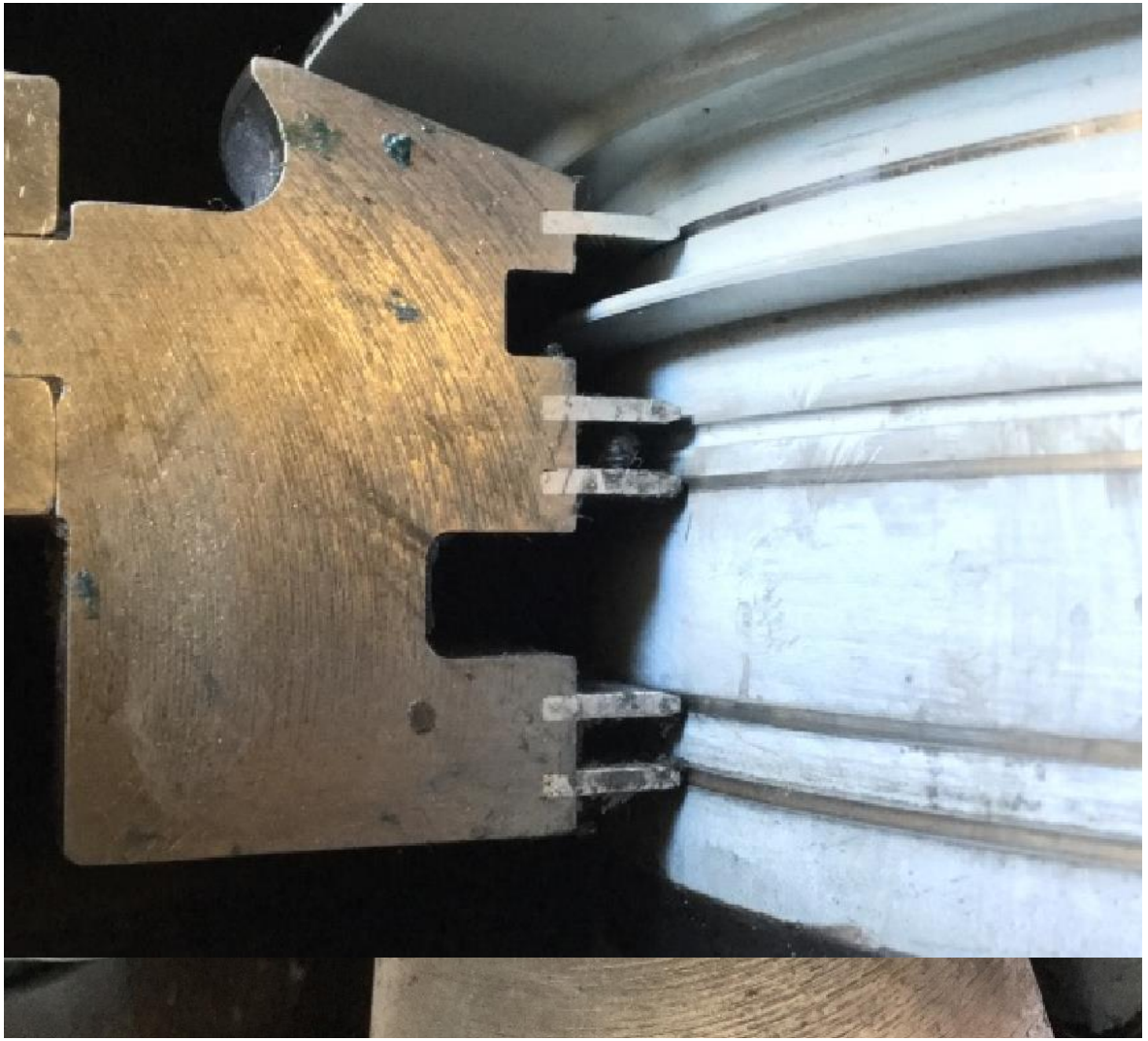
1. Inspect Bearing and Seal Components

2. Check piping support, if any restriction.

3. Confirm Alignment / Correction

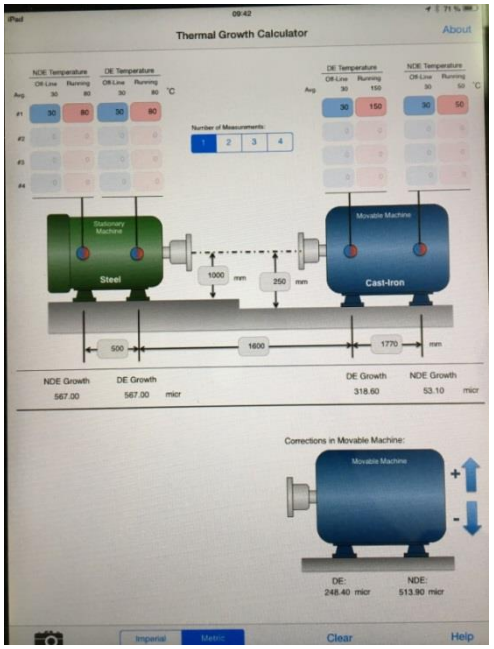
First Inspection

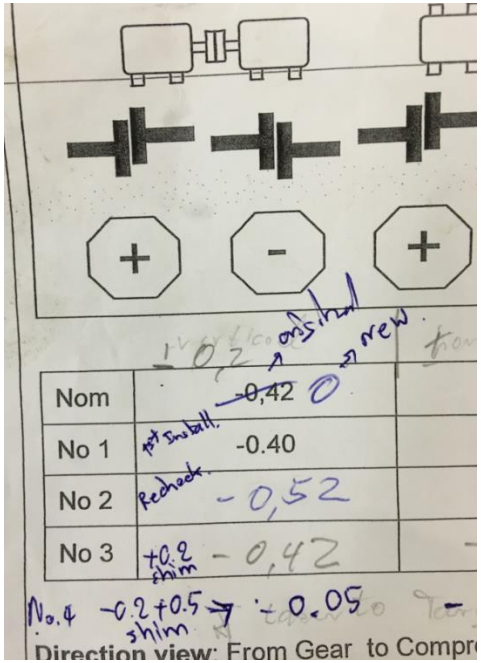




Piping Support inspection

Alignment Confirmation

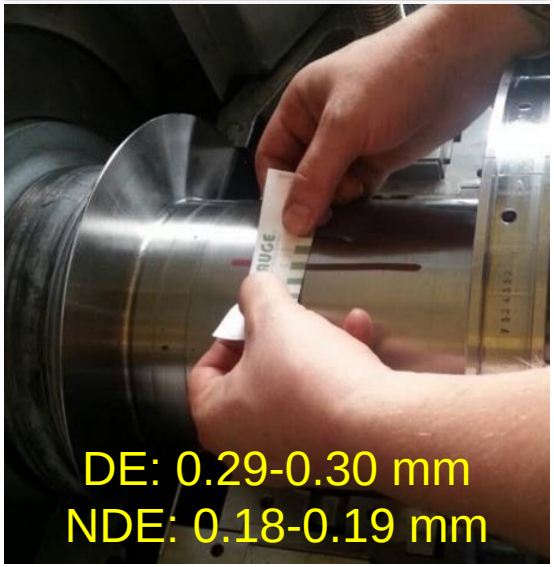




Bearing Inspection

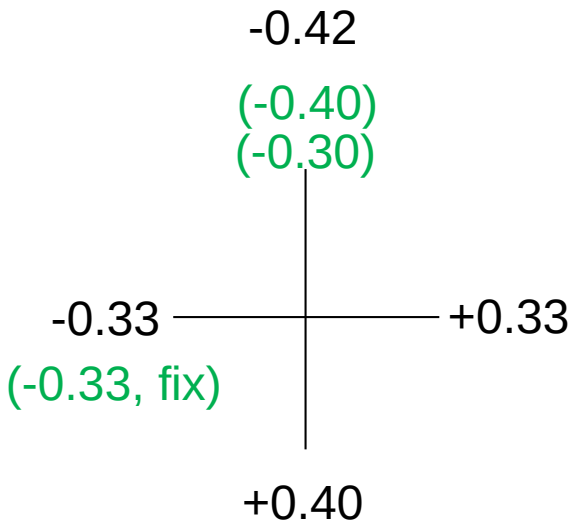
What else to fix the problem?

Excessive Bearing Clearance



NO

Coupling Misalignment



NO

After adjust alignment, problem still existed.

Bearing design issue

?

Needs to consult with the OEM

Corrective Action

Corrective Action

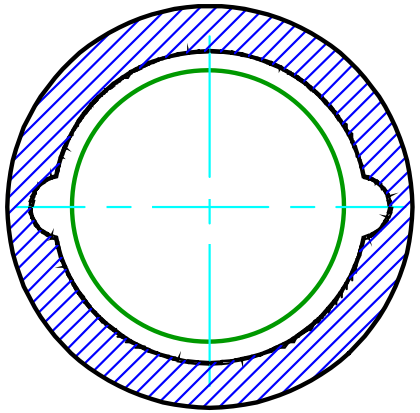
A. Adjust External Alignment (btw Coupling): This would help if problem is not severe. >> Already tried, but not successful.

B. Change Lube Oil Temperature: not permanent solution. >> system could not further decrease oil temperature.

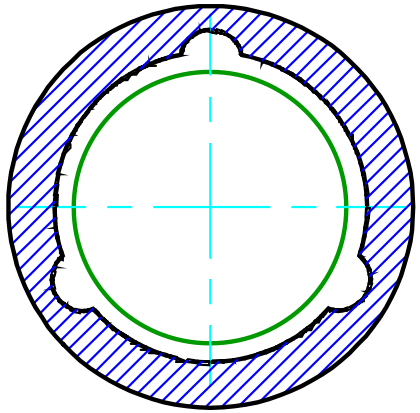
C. Decrease Lube Oil Flow Rate: Risk to damage other bearings.

D. Bearing Modification: must be designed and approved by machine manufacturer.

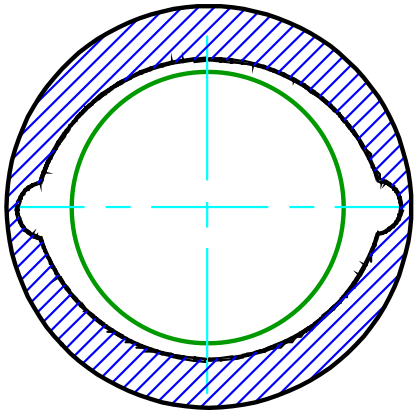
Bearing Design to break Circumferential Oil Flow Pattern



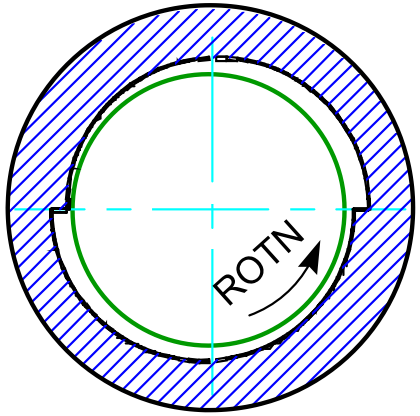
Two Axial-Groove



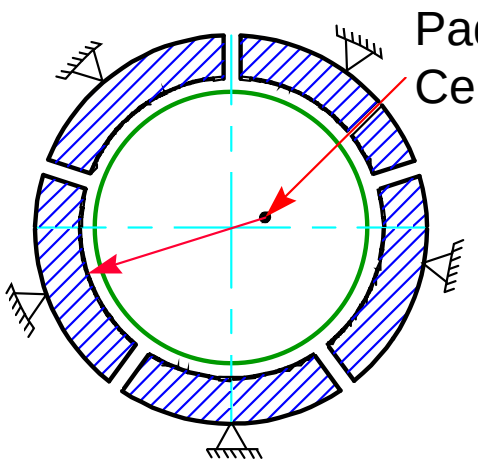
Three-Lobe



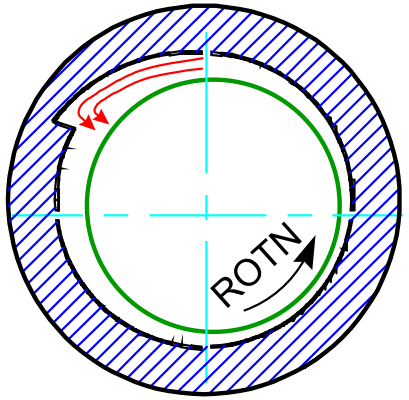
Elliptical



Offset Cylindrical

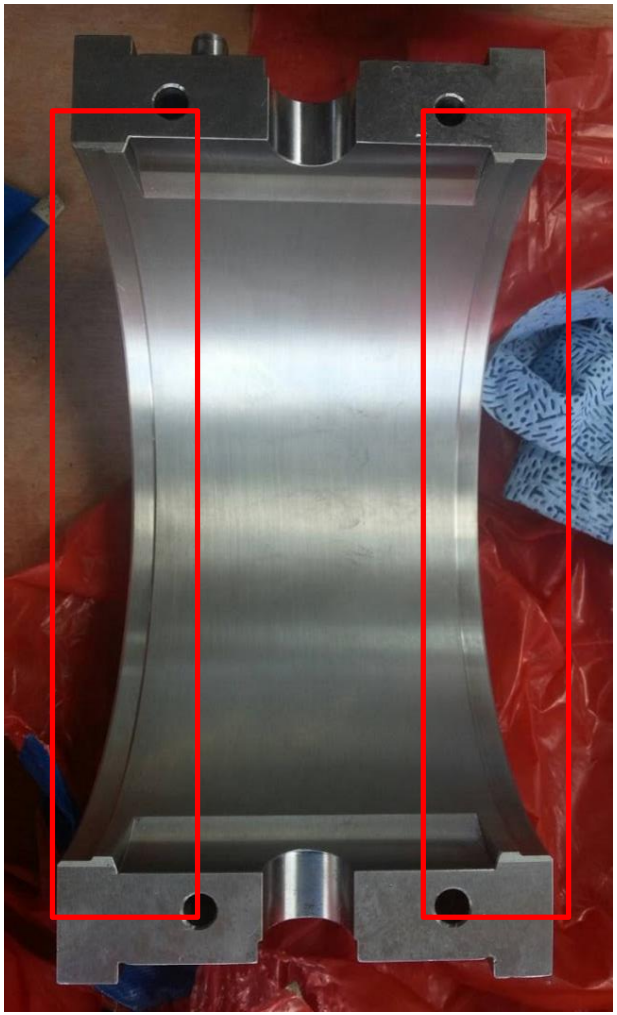


Tilting Pad



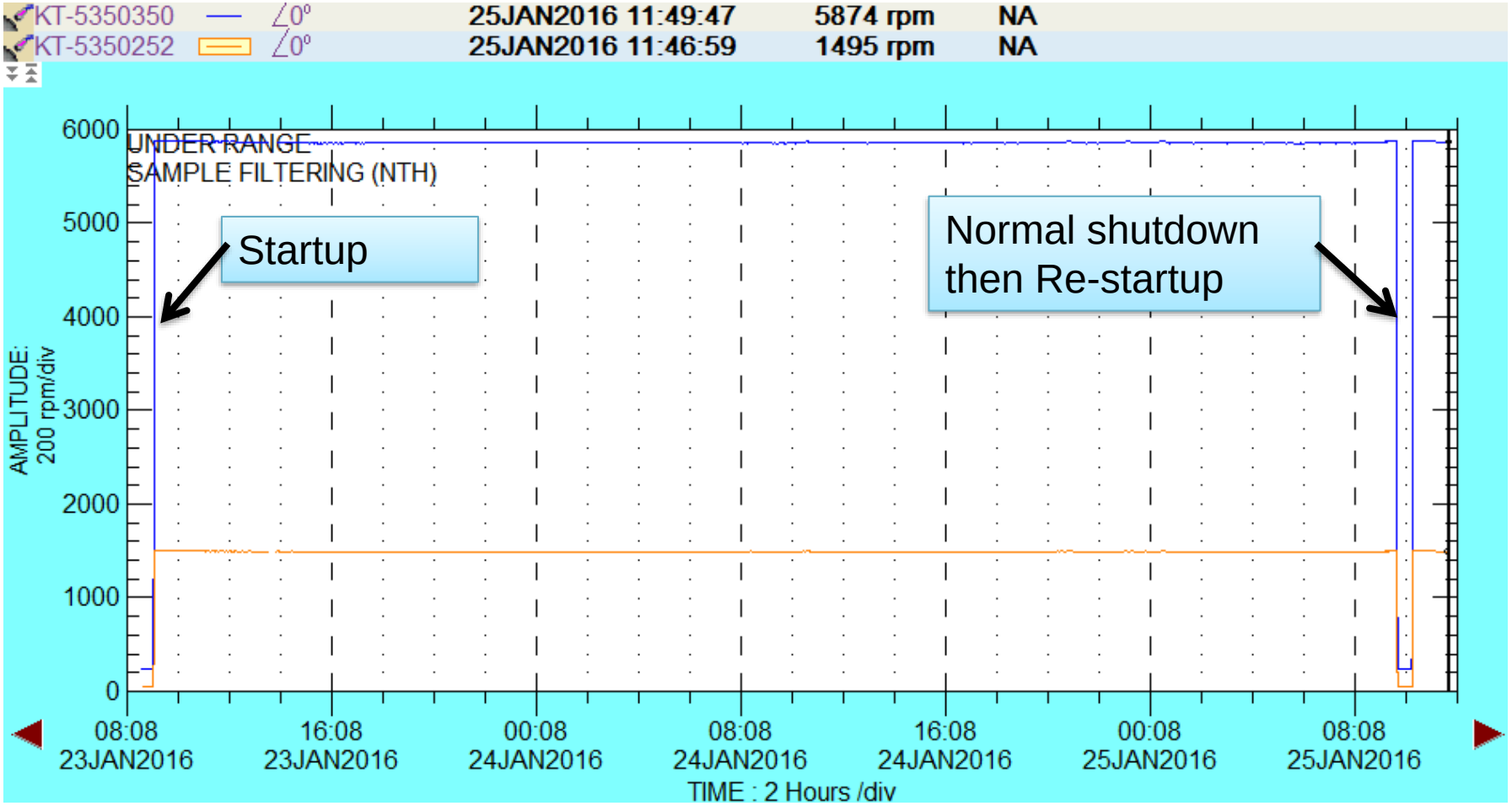
Pressure Dam

Solution
Bearing modification (suggested by OEM)

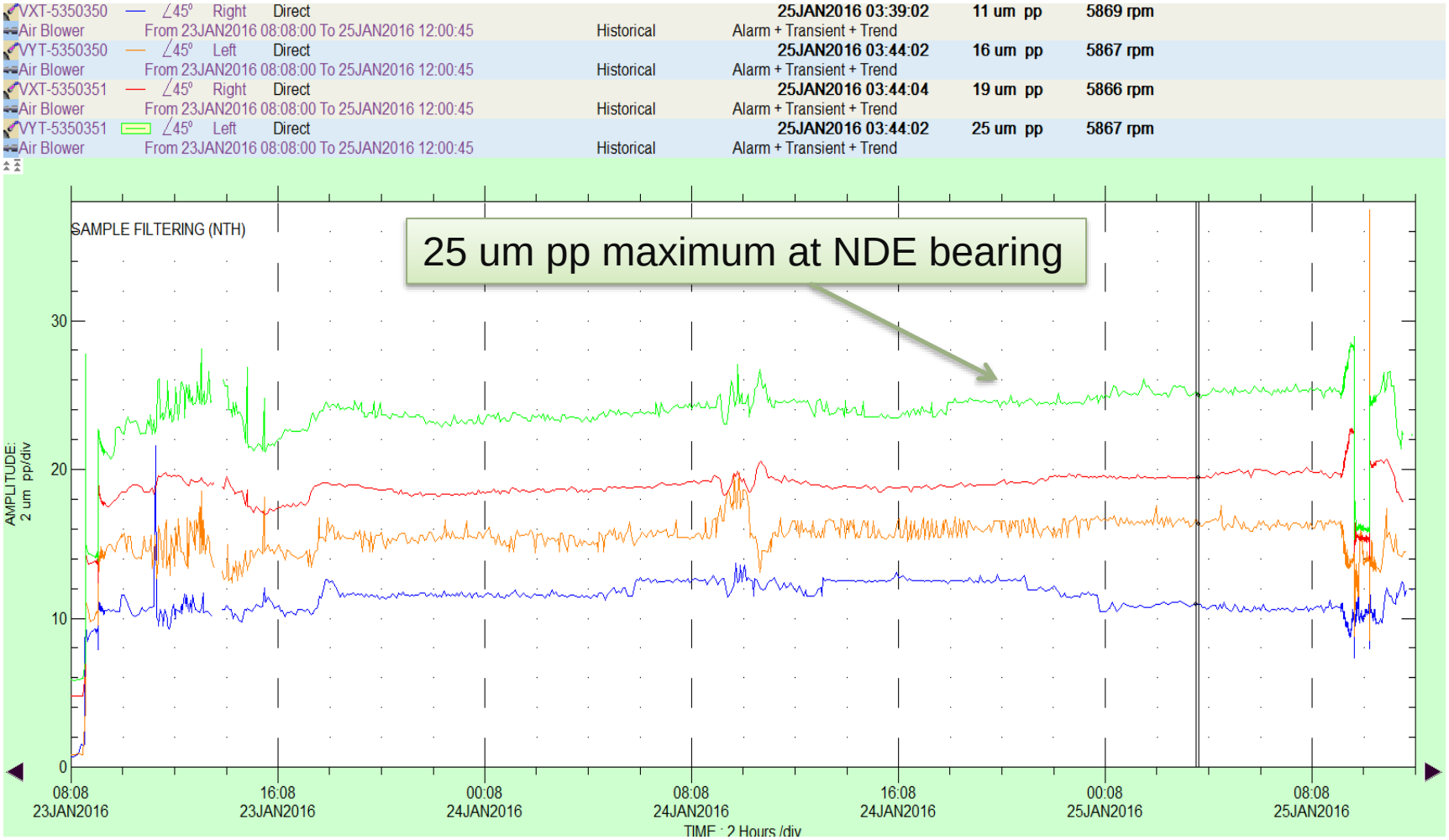


After bearing modification

Speed Trend

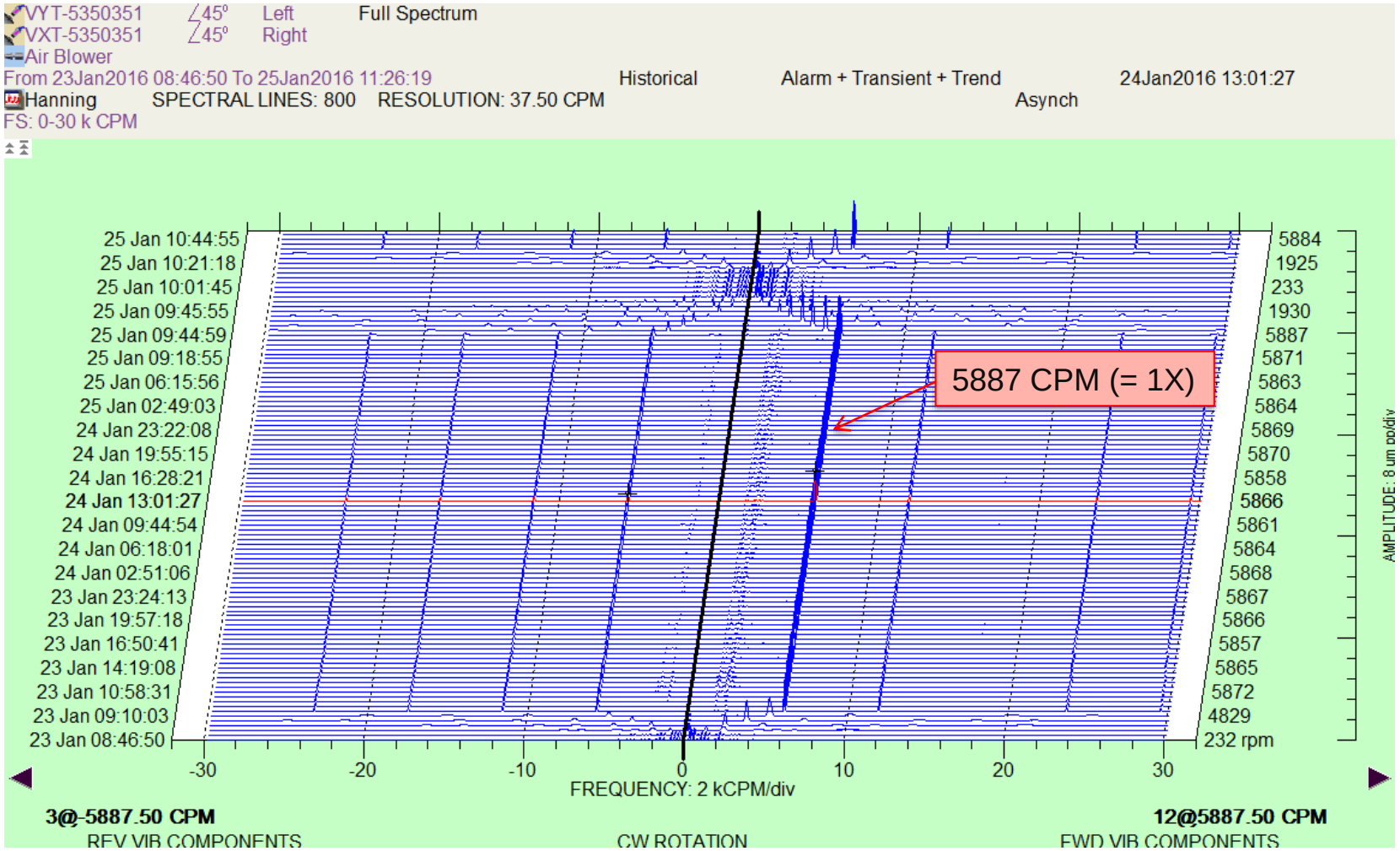


After bearing modification (Cont.)
Vibration Amplitude, 25 um pp (1 mil pp)



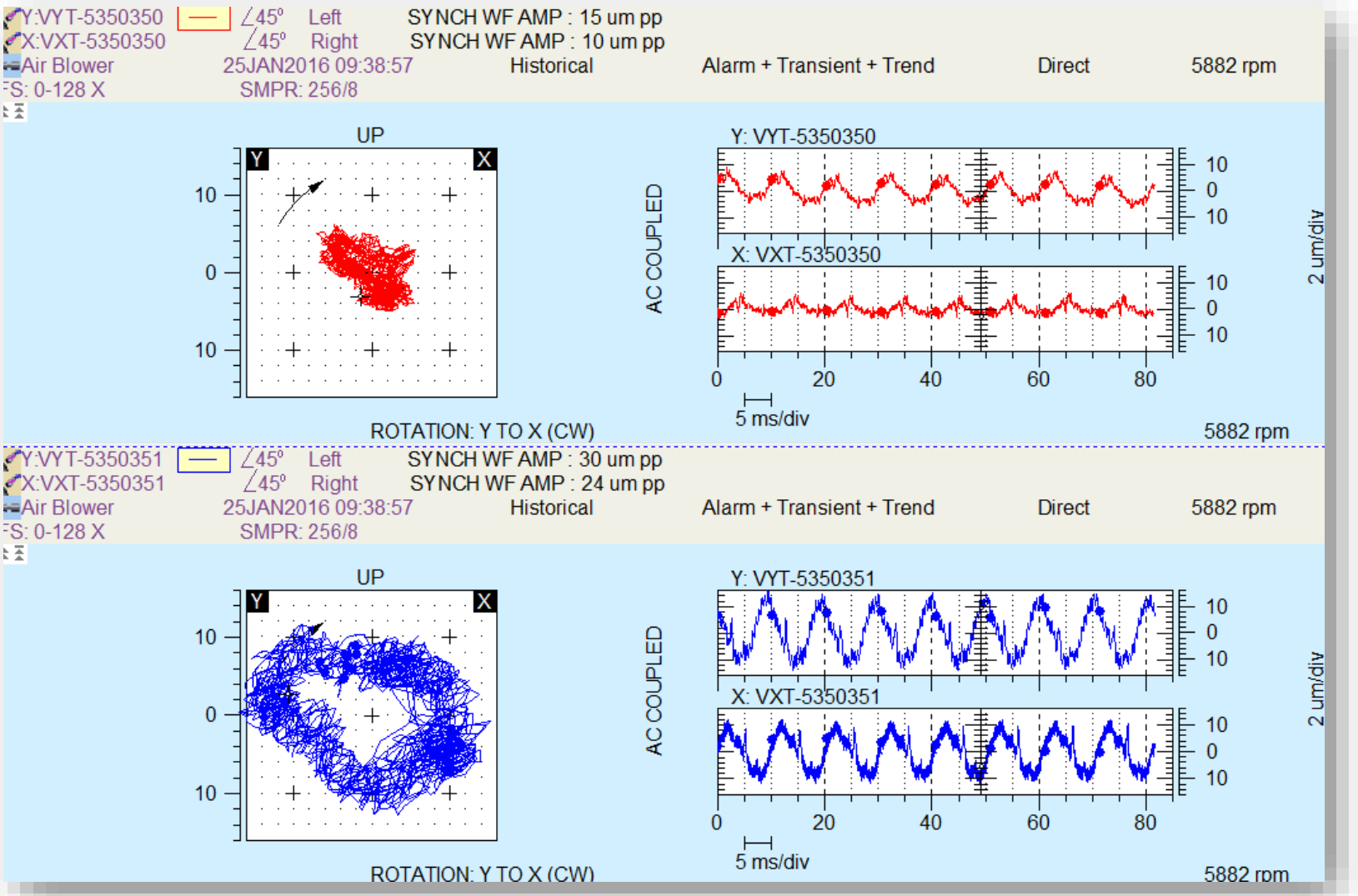
After bearing modification (Cont.)

Frequency, 1X dominant (normal)

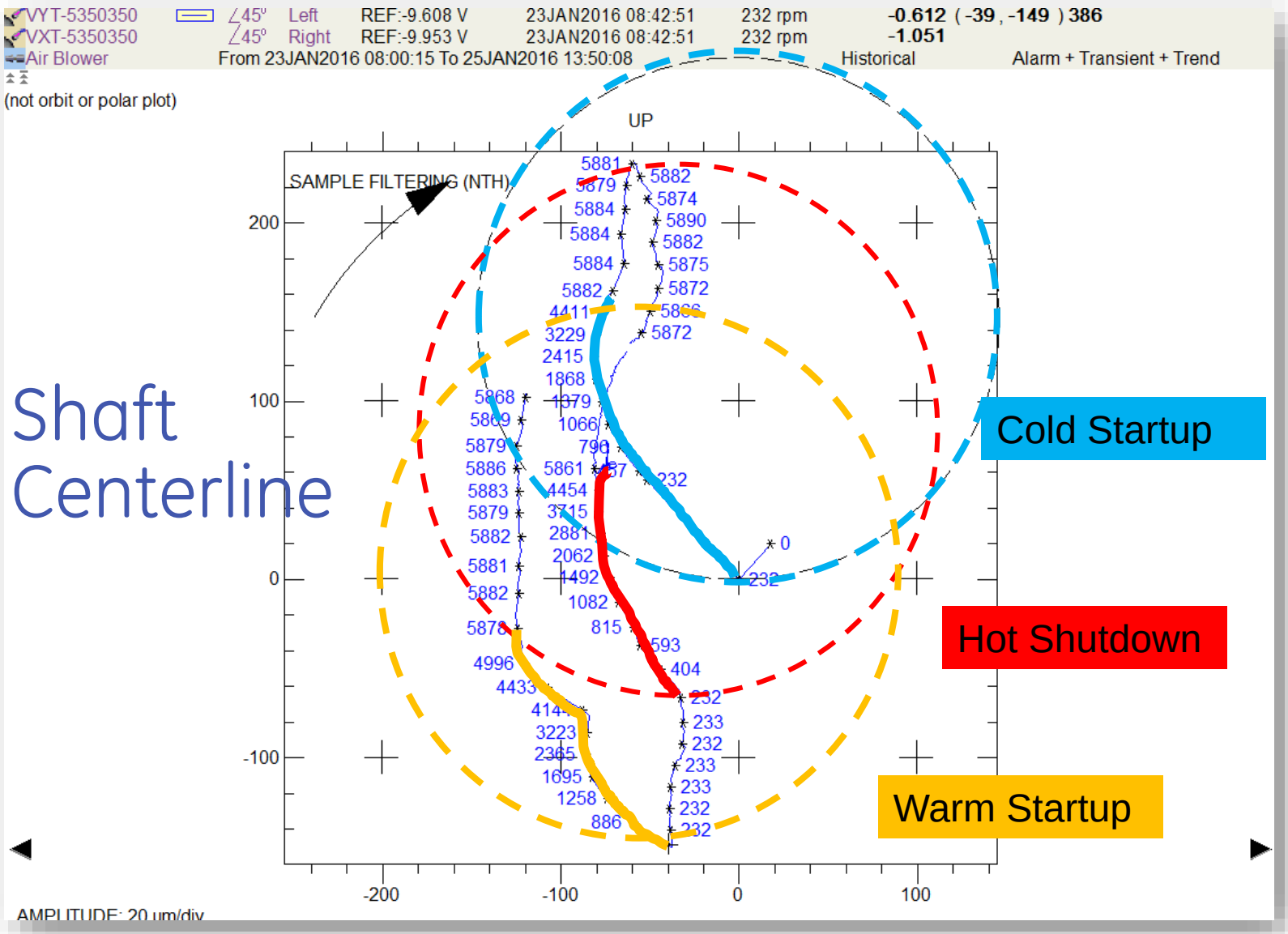


After bearing modification (Cont.)

Orbit plots shows normal dynamic shaft movement



After bearing modification (Cont.)



Discussions

- Oil whirl frequency tracks with speed, usually at < 0.5X (<50% running speed frequency). If the frequency is exactly ½ X, the instability is not oil whirl, instead it is parametric excitation (rub contact or bearing looseness).

- Oil whip frequency locks into one of the natural frequencies of rotor-bearing system, usually the lowest. As speed goes up, the frequency remains unchanged.

- Subsynchronous vibration could also be caused by aerodynamic instability such as stall or surge in compressors.

- Oil whirl/whip is affected by speed, bearing types and design, lube oil temperature and supply pressure, while aerodynamic instability in compressors is affected by flow condition.

The End

Thank You