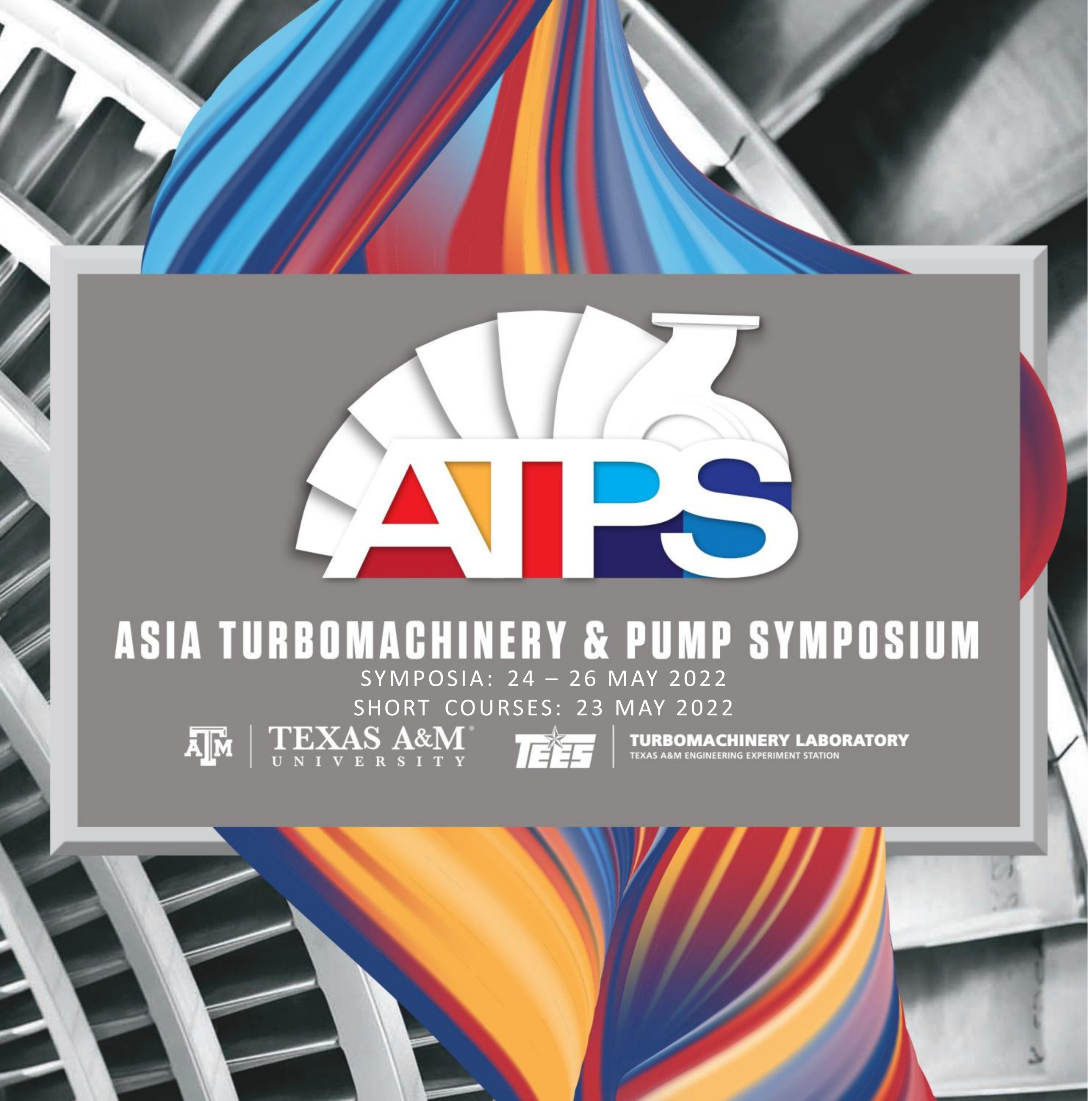

Detection of Broken Blade on Compressor

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Presenter 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 Global 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 University of Alberta and is an ASME Fellow. He currently serves as an Advisory Committee member to the Asia Turbomachinery & Pump Symposium.

Carl Feng Wang joined Shanghai SECCO Petrochemical Co. in 2003, serving as Maintenance Manager responsible for all the equipment maintenance for the company. He has also served as Machinery Manager, responsible for equipment reliability and condition monitoring. He has been collaborating closely with Bently Nevada to identify machinery malfunctions and avoid potential failures successfully.

Dr. Nicolas Peton joined GE in 2006 in the Machinery Diagnostic Services group. Previously he worked for two different 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

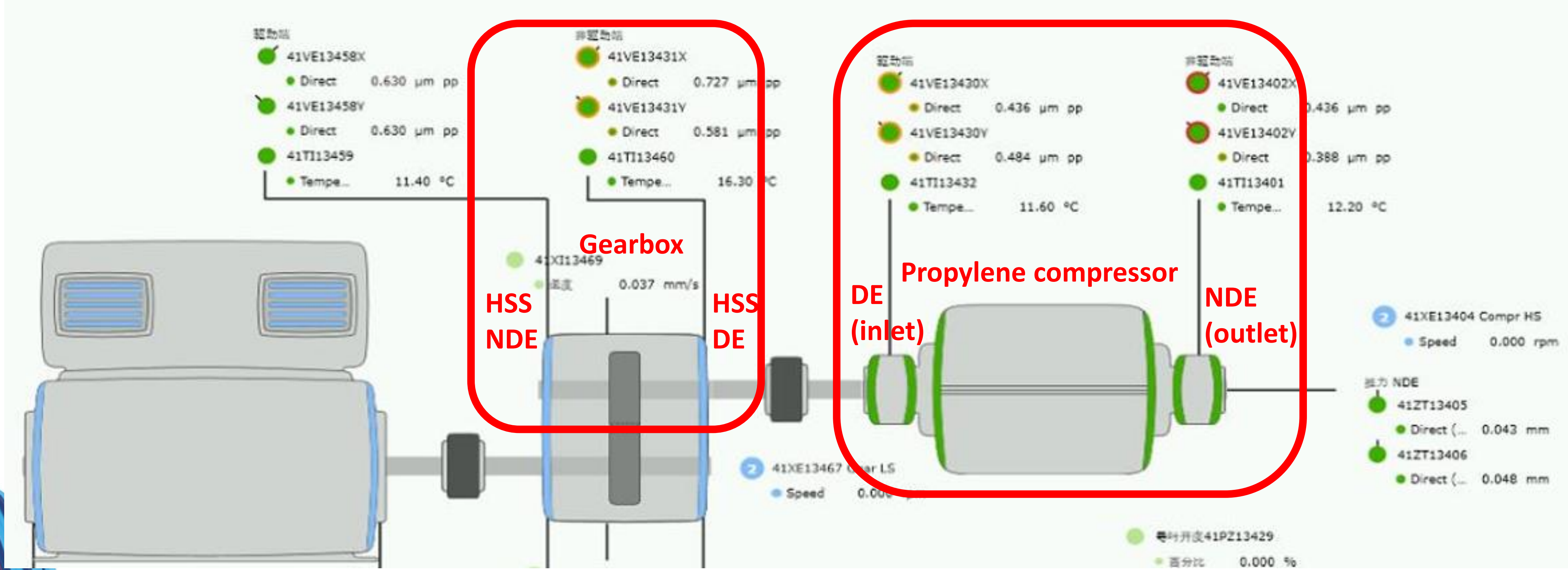
A sudden step change in vibration was observed on a 7400-rpm compressor with direct amplitude from 43 um pp to over 62 um pp (trip level) at NDE, thus tripping the unit. Vibration reached over 120 um pp at 4000 rpm, compared to normally 20 um pp during coast-down. Vibration excursion was dominantly due to the 1X component. It was noticed that thrust probe gap readings started to fluctuate 6 months prior to the vibration trip. A sudden change in unbalance was diagnosed, followed by an inspection. It appeared that a balance pipe started to leak earlier, causing the axial thrust force to fluctuate, as indicated by fluctuating thrust gap. It was possible that a piece of damaged fragments entered the gas flow and hit the 3rd stage blade, thus breaking the blade to lead to a sudden change in unbalance.

Outline

1. Introduction
2. Problem Statement
3. Data Review
4. Observations and Diagnostics
5. Conclusions and Recommendations
6. Inspection and Findings
7. Lessons Learned

1. Introduction

- A propylene compressor driven by a motor via gearbox and flexible coupling
- Supported by fluid film bearing bearings
- Rated speed of ~7400 rpm
- Vibration monitored by proximity probes at DE (inlet) and NDE (outlet) bearings with trip set as 58 um pp at DE, and 62 um pp at NDE.

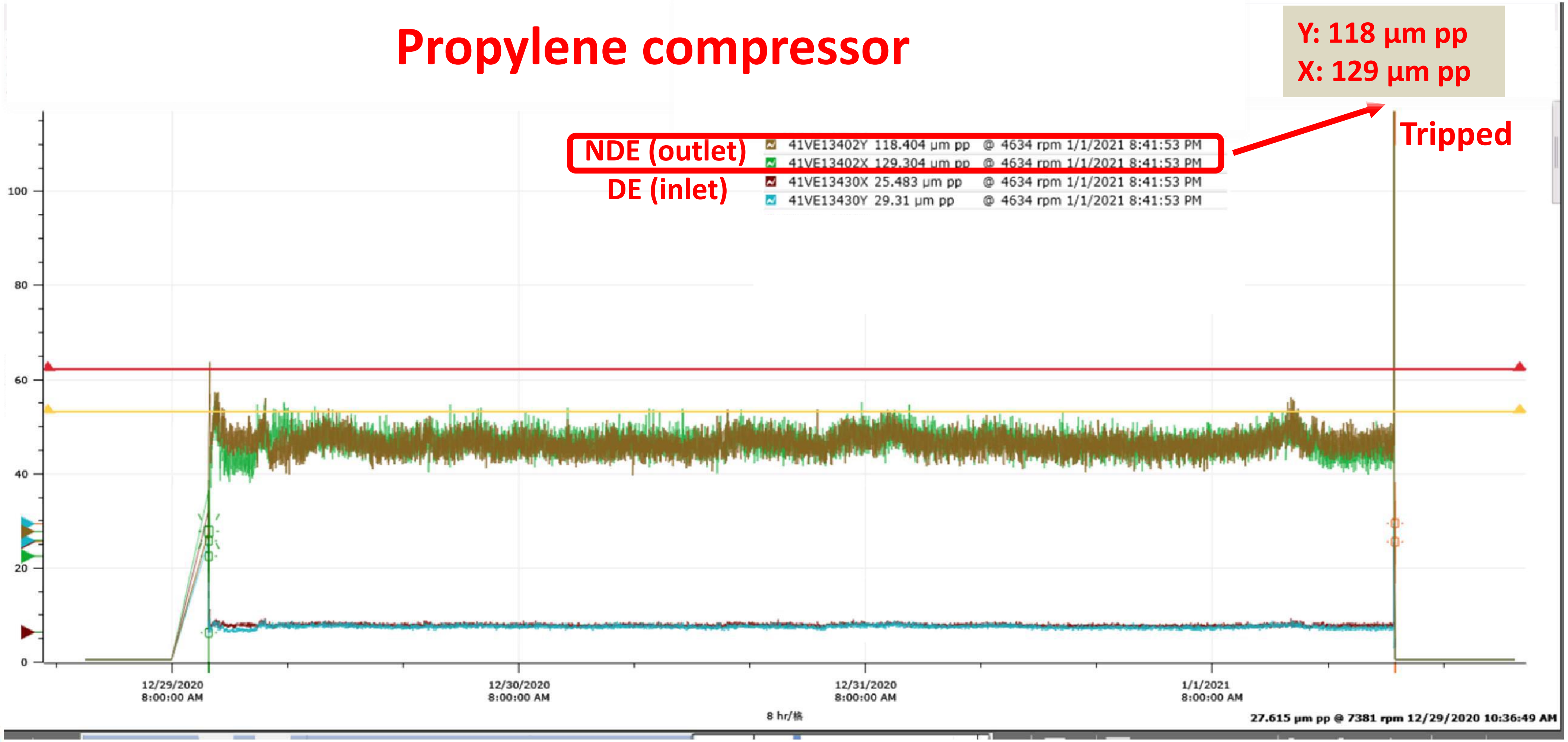


2. Problem Statement

- During normal operational condition, direct vibration suddenly changed from 43 um pp to over 62 um pp (trip level) at compressor NDE, thus tripping the unit.
- During coast-down, the vibration reached over 120 um pp at around 4000 rpm, compared to normally 20 um pp.
- Vibration excursion also occurred simultaneously at compressor DE as well, though at lower level.
- **What should we do?**

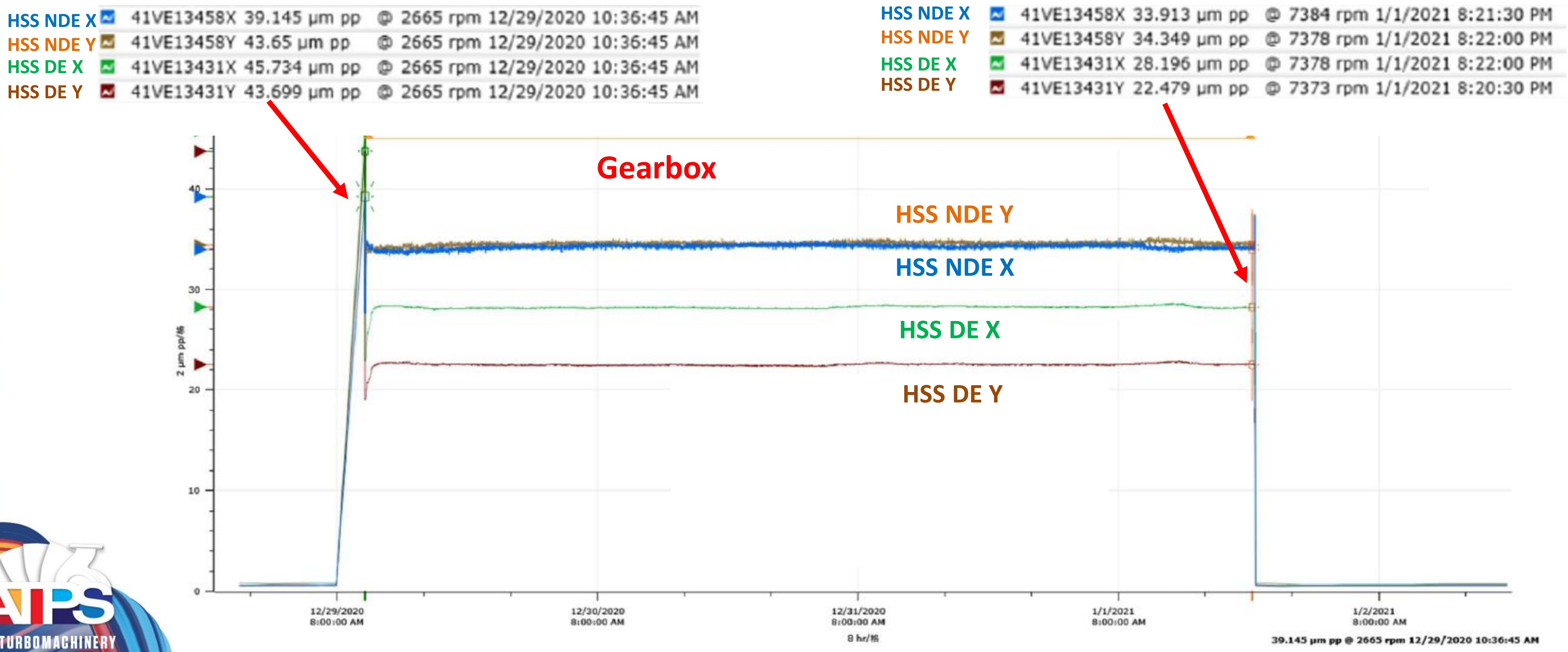
3.1 Data Review – direct vibration trend plots on compressor

- **Vibration excursion occurred after normal operation for more than 3 days.**
- **The level of vibration tripped the unit.**



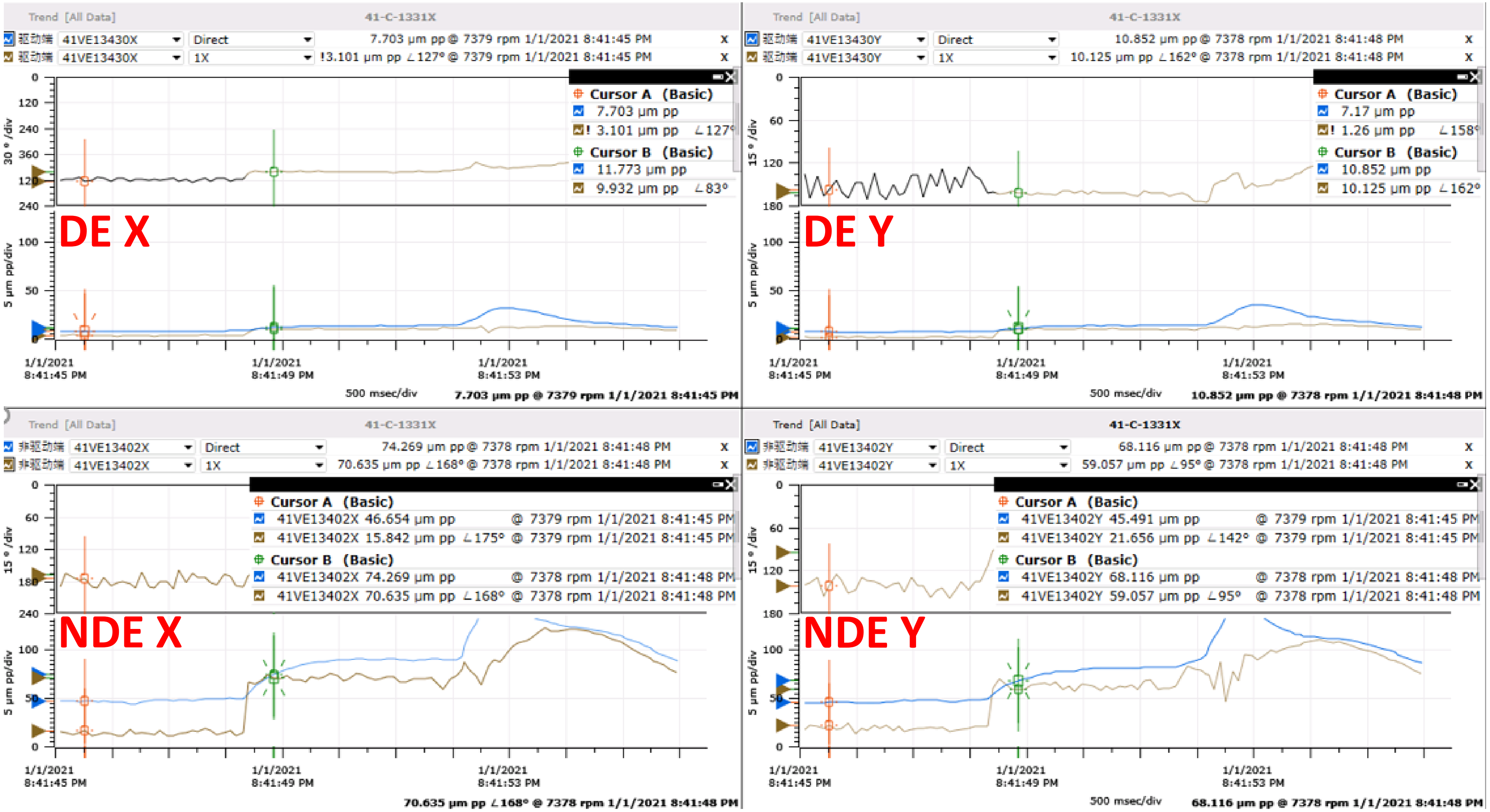
3.2 Data Review – direct vibration trend plots on gearbox

- No significant vibration change at high-speed shaft gearbox bearings
- Vibration level even lower during coast-down than during startup



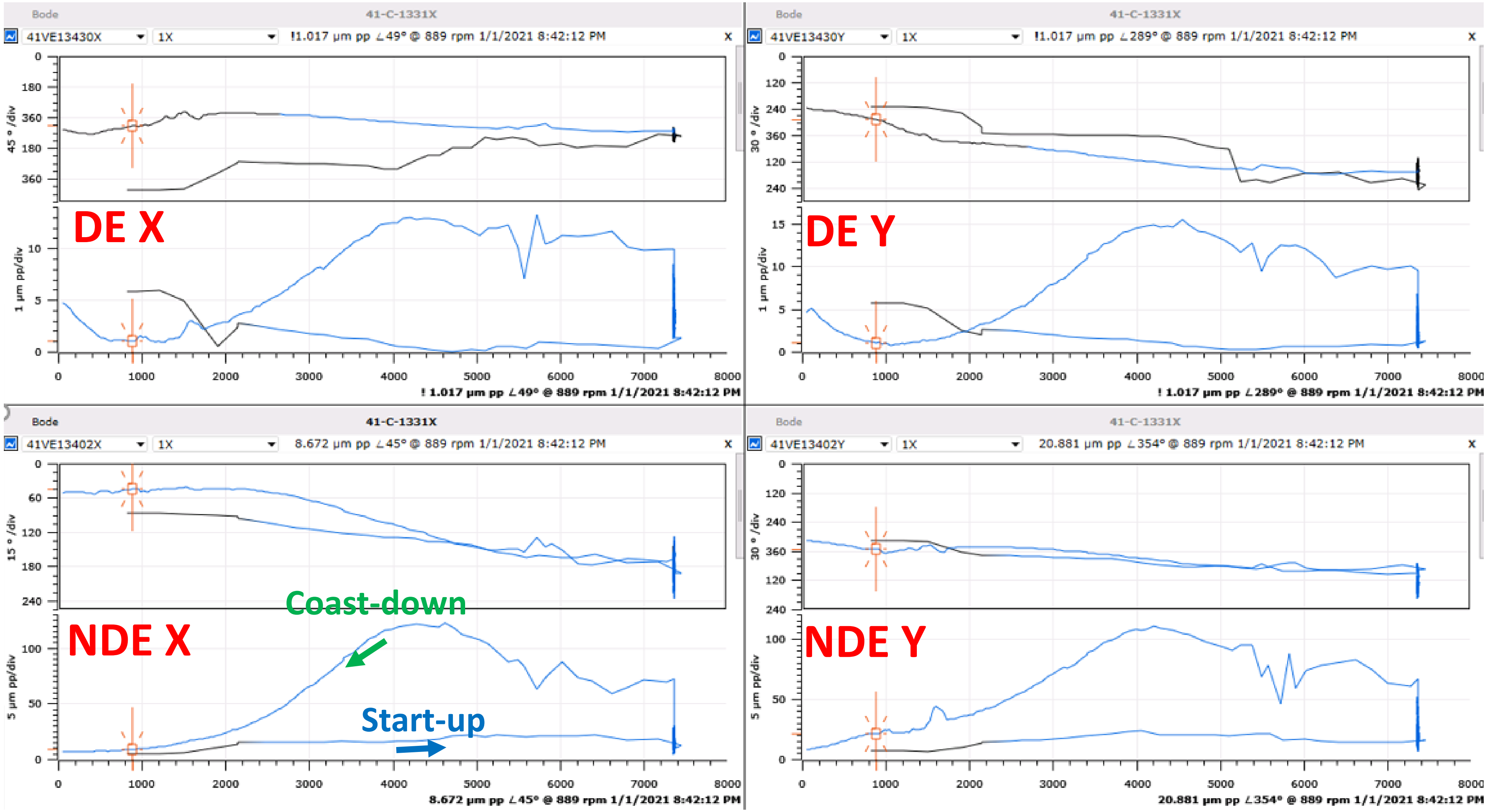
3.3 Data Review – vibration from each probe on compressor

- Vibration excursion occurred simultaneously from all 4 probes.
- Vibration excursion was due to 1X component.



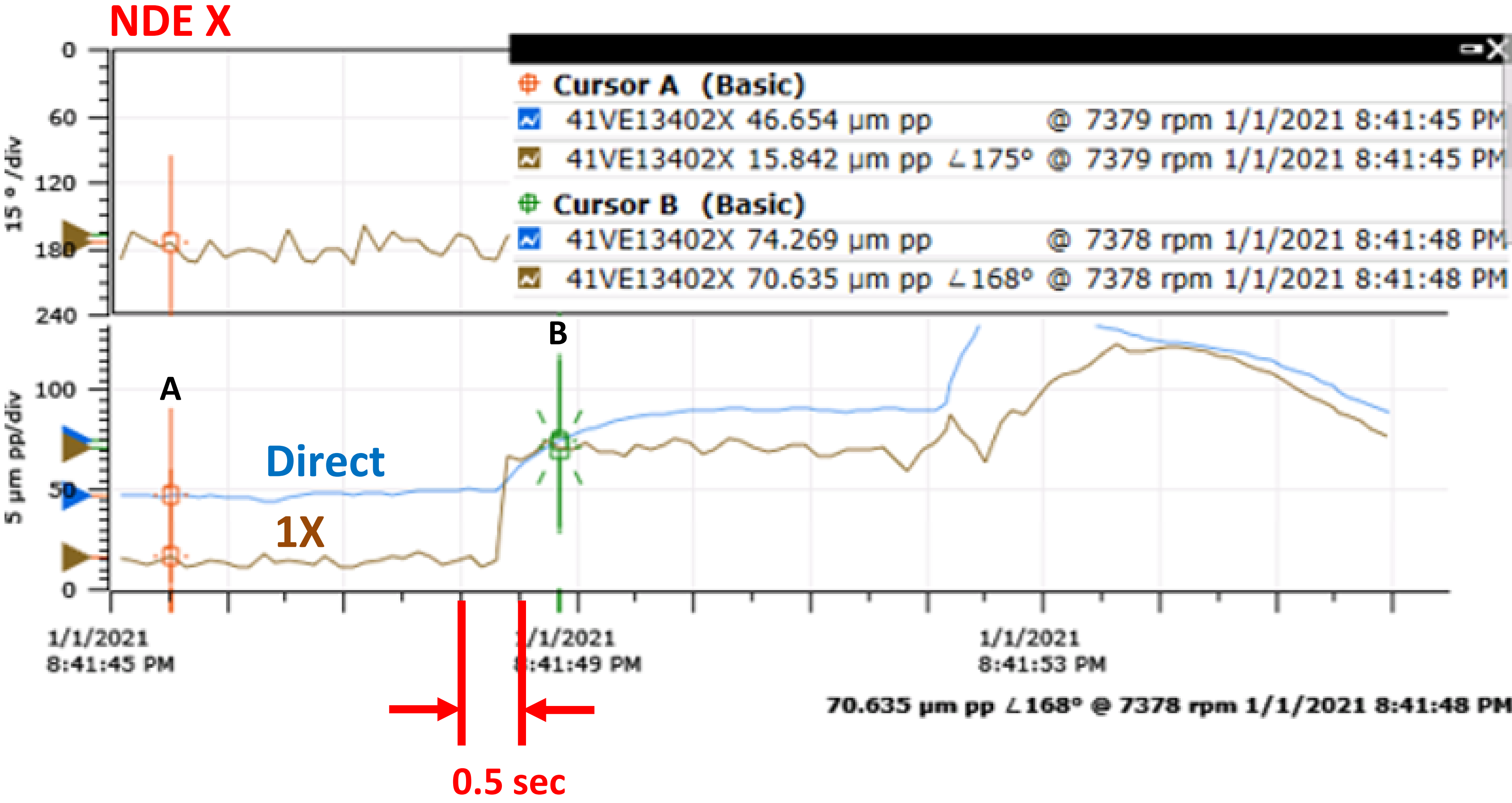
3.4 Data Review –1X Bode plots from each probe on compressor

- During **coast-down** after trip vibration even became higher. Much higher than **startup**.
- 1X vibration was measured 130 um pp at ~4000 rpm from NDE X.



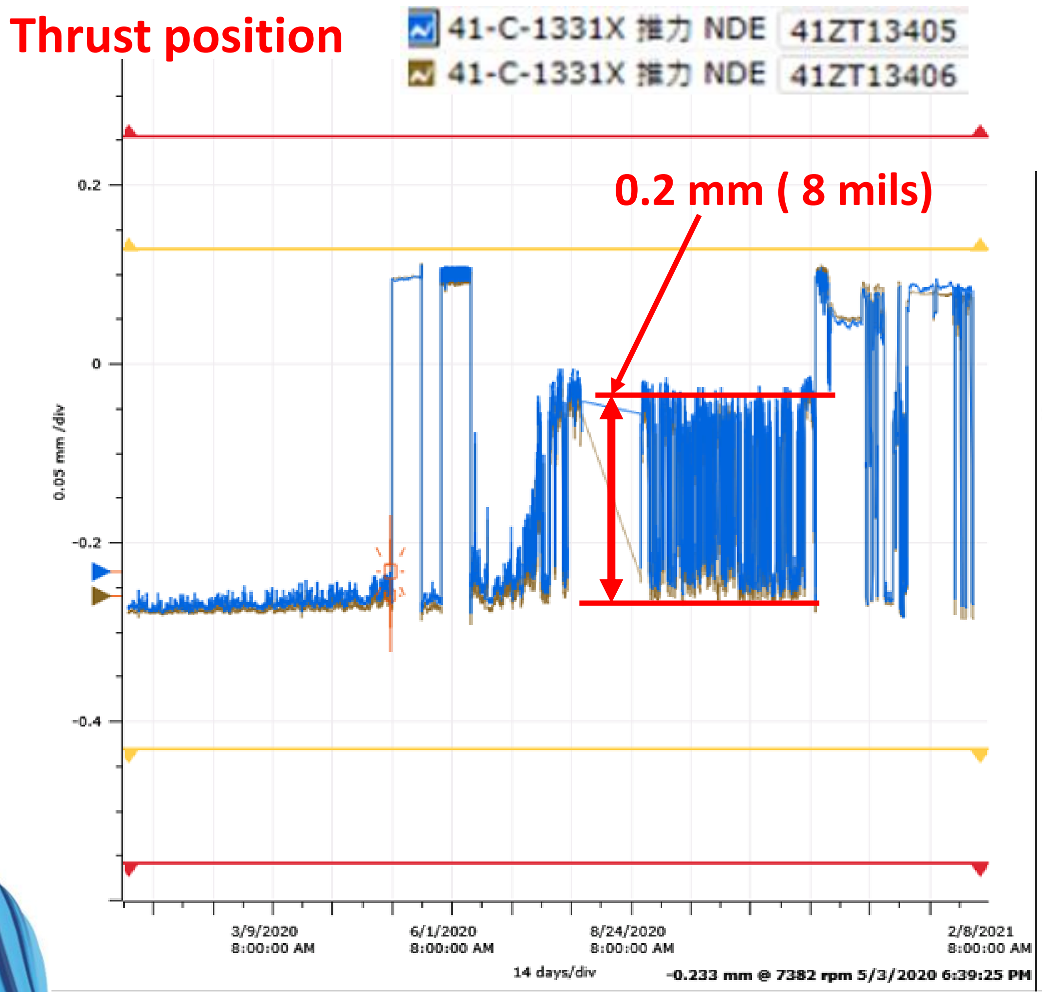
3.5 Data Review –examining the change at NDE X-probe

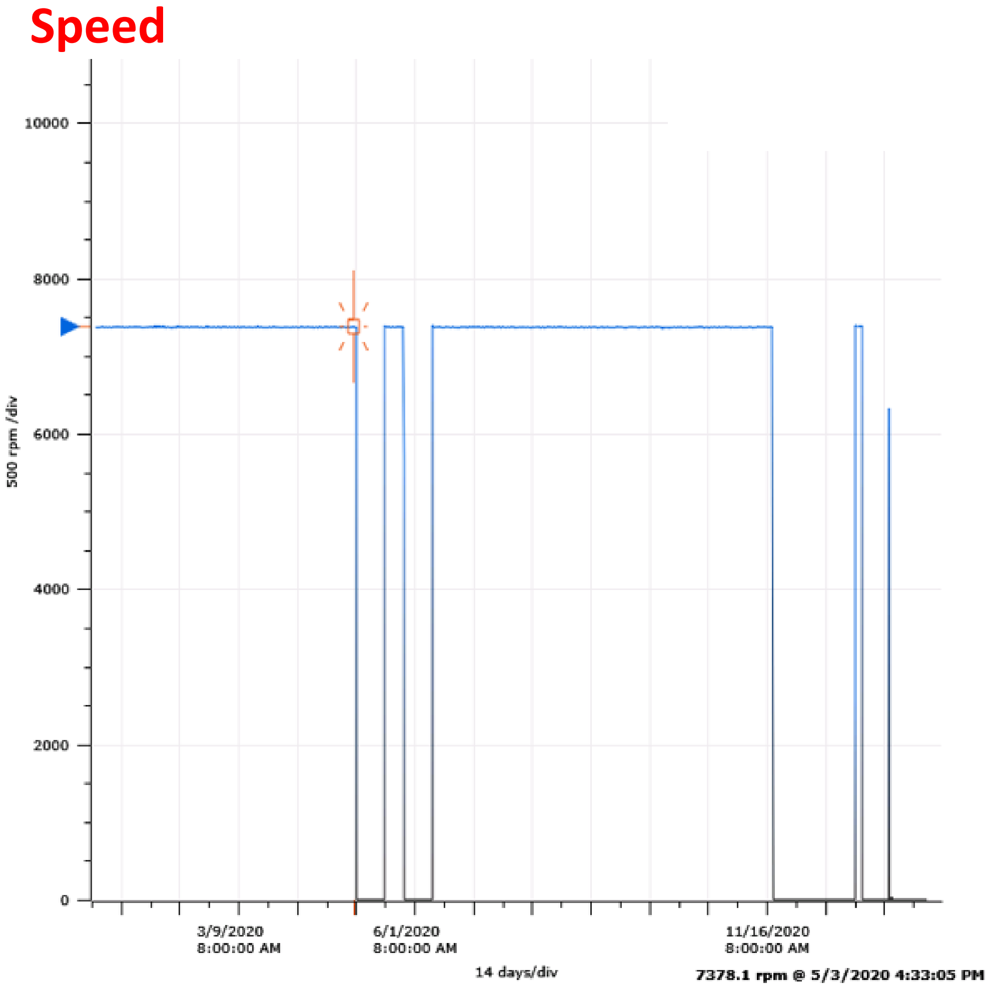
- The change occurred within <0.25 second in the plot.
- 1X vector changed from 16 um pp ∠175° to 71 um pp ∠168°



3.6 Data Review –thrust position on compressor

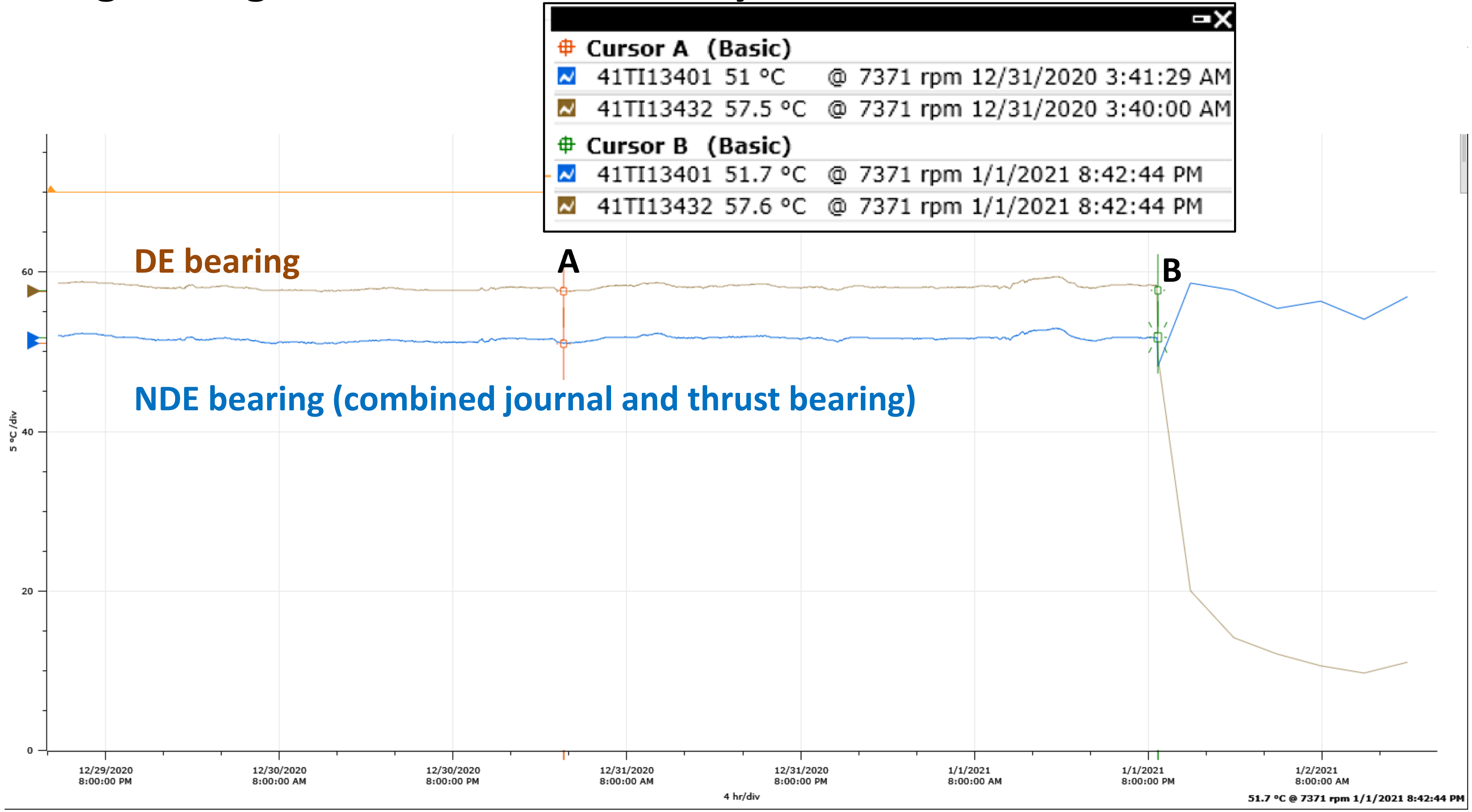
- Thrust position started to fluctuate 6 months prior to the current vibration trip.
- Is this behavior related to the vibration trip?





3.7 Data Review –Bearing metal temperature

- **Bearing (combined journal and thrust bearing) metal temperature remained normal.**
- **Thrust bearing damage seemed to be unlikely.**



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4.1 Observations and Diagnostics

Root-cause of vibration excursion:

- **Signal noise?**
  - Unlikely as the excursion occurred from all probes on the compressor plus maintained at high level. Predominantly due to 1X.
- **Rub?**
  - Possible rub during coast-down from increased slow roll during coast-down but cannot explain the step change
- **Sudden change in unbalance?**
  - Very likely as the change in vibration occurred instantaneously (within ¼ of second of sampling resolution)

4.2 Observations and Diagnostics

Root-cause of vibration excursion (Cont.):

- **Mass lost?**
  - Very likely
- **Why did thrust position fluctuate?**
  - Thrust force/position unstable, after ruling out thrust bearing damage from bearing metal temperature readings
- **Any association between mass lost and unstable thrust force/position?**
  - Needs inspection
- **Would balance resolve the issue?**
  - It might reduce the vibration but could cover the problem. It wouldn't be a good practice.

5. Conclusions and Recommendations

Conclusions:

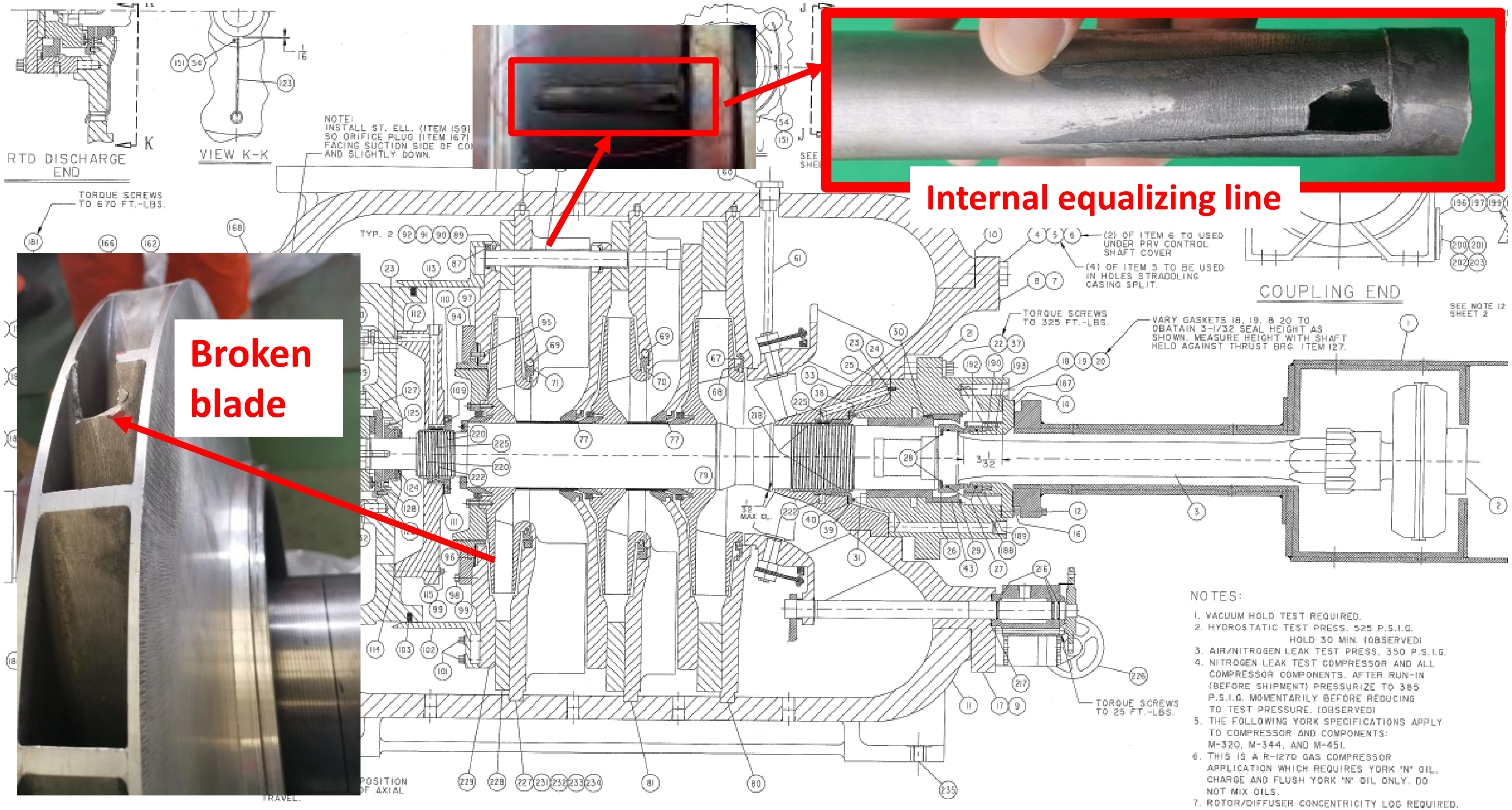
- A sudden change in unbalance must have occurred. Mass lost due to blade damage was highly suspected.
- Fluctuation in thrust position indicated malfunction in thrust balance system.

Recommendations:

- Stop running the unit.
- Inspect the compressor.

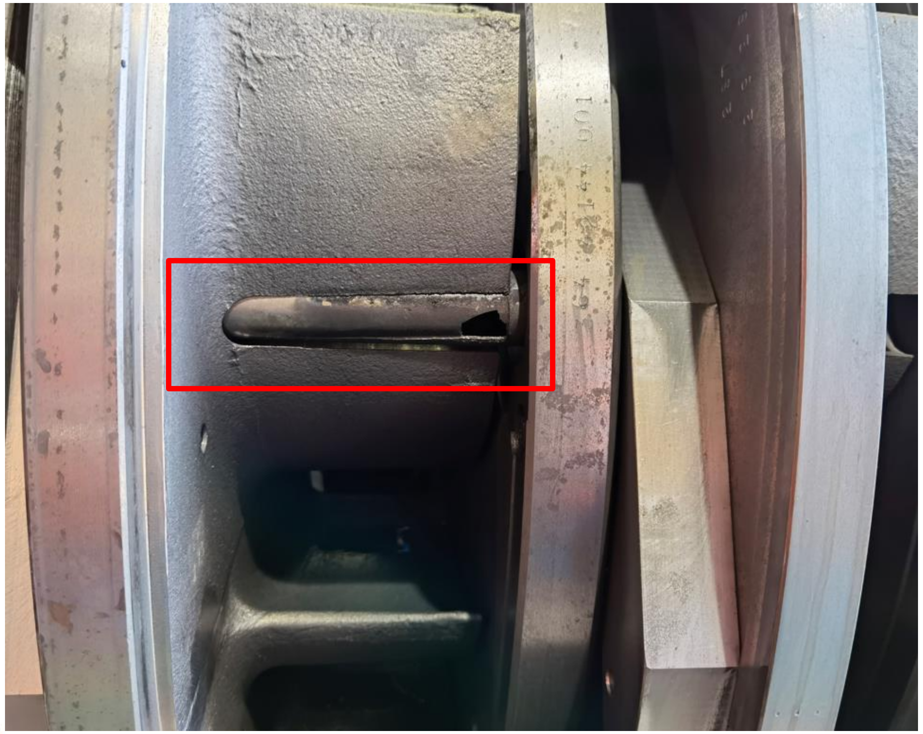
6.1 Inspections and Findings

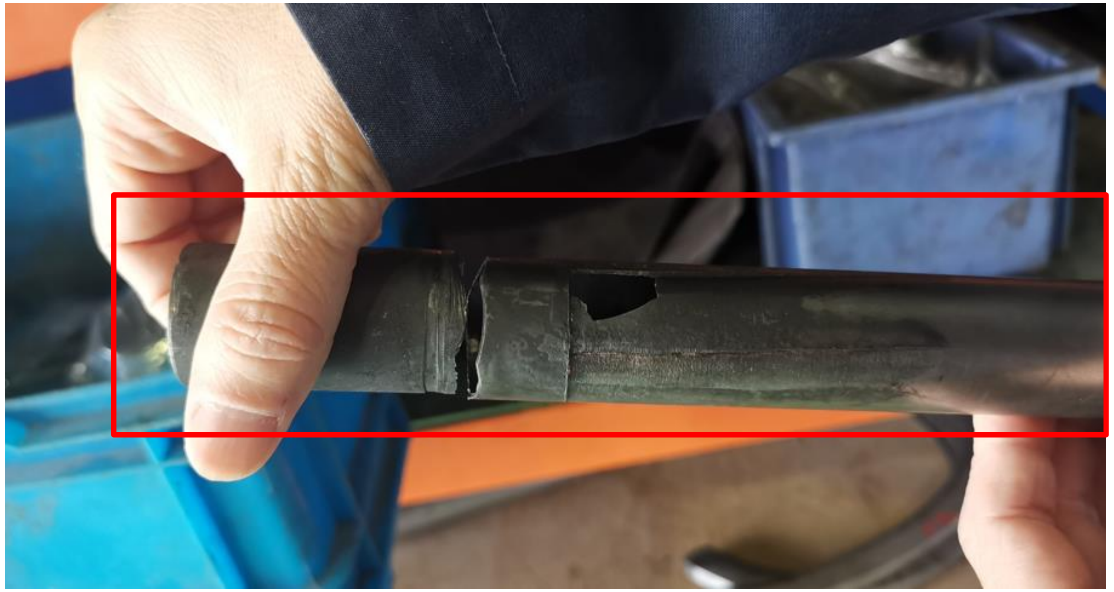
- The internal equalizing line or balance pipe started to leak, causing the thrust force/position to fluctuate, as indicated by fluctuating thrust gap readings.
- Though not confirmed, it was likely that a damaged piece entered the gas flow and then hit the 3rd stage blade, thus breaking the blade to lead to a sudden change in unbalance.



6.2 Inspections and Findings

- The balance pipe had been used for 7 years. It appeared that the corrosion due to flow-impact plus not enough thickness of the pipe itself, caused the pipe failure. It was also possible that its looseness might result in friction, causing the damage.
- The thickness of the newly-designed balance pipe was increased after this incident.
- The compressor then started up successfully after the newly-designed balance pipe was installed.





7. Lessons Learned

- Initial malfunction, though not significant in terms of severity level, may need attention and address it in time. In this case, the fluctuating thrust gap reading is a good example.
- All the data, including both vibration and process data, should be fully reviewed for diagnosis. In this case, normal bearing metal temperature indicates the problem was not on the thrust bearing, though thrust gaps were fluctuating.
- Never balance the rotor without understanding the root-cause of 1X vibration excursion. Doing so could conceal the original problem.

Thanks….. and Questions (?)