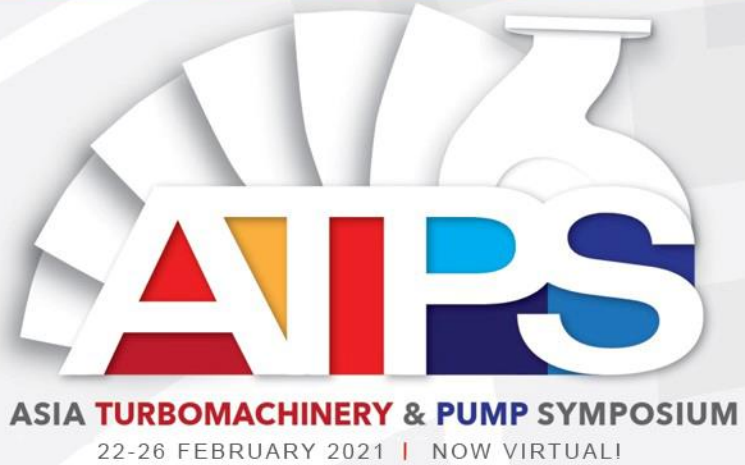


Steam Turbine Oil Seal Rub

Sheekar, Air Products and Chemicals

Patrick Smith, Air Products and Chemicals

TEXAS A&M UNIVERSITY | TEES TURBOMACHINERY LABORATORY TEXAS A&M ENGINEERING EXPERIMENT STATION | AIR PRODUCTS

Biographies

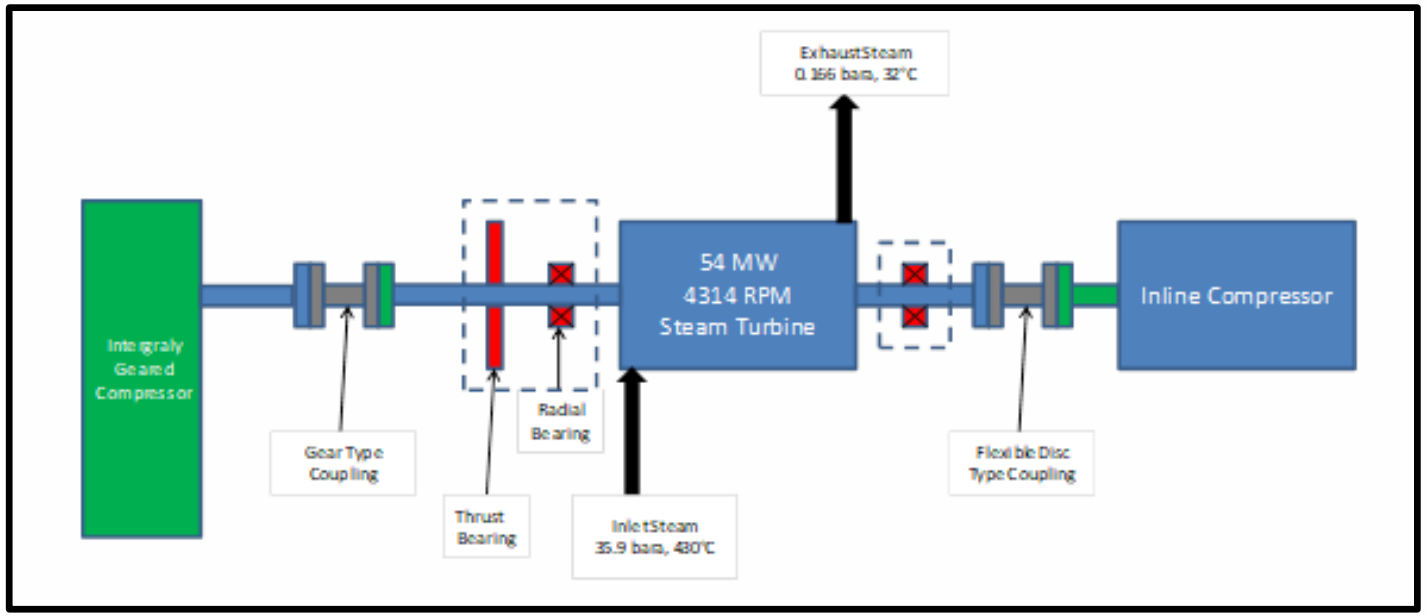
- **Patrick J. Smith** is a Principal Engineering Associate - Machinery in the Operational Excellence Technical Team at Air Products & Chemicals. He is also an AP Fellow. He is based in Allentown, PA and has over 35 years of rotating machinery experience.
- **Sheekar** is the Asia Operations Machinery Engineering Manager at Air Products & Chemicals. He is based in Singapore and has 35 years of rotating machinery experience.

Abstract

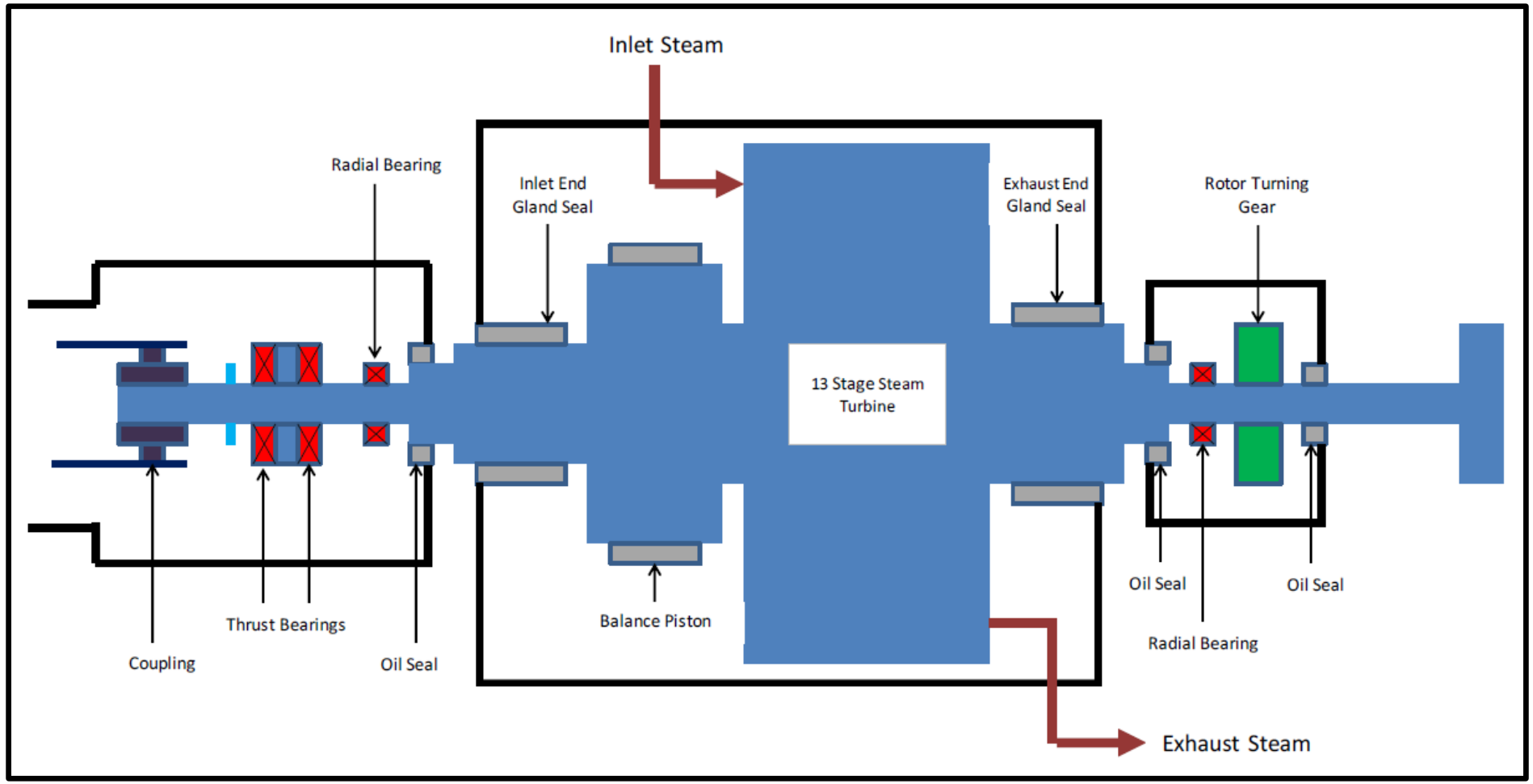
The purpose of this case study is to describe a problem with random, intermittent rotor vibration excursions in a large steam turbine. These types of problems can be very difficult to diagnose, especially when the vibration excursions are during steady state operation and are not coincident with any operational changes. Although the vibration excursion data was consistent with a light rub, other observations pointed to a coupling problem. It was a long process to finally find the problem was due to an oil seal rub. This case study demonstrates the complexity of random vibration excursions and how difficult they can do diagnose and solve.

Train Arrangement

- 54 MW, 13 stage, 4314 RPM, straight condensing turbine
- Installed in building
- Drives an inline compressor on one end and an integrally geared compressor on the other end.
- Gear type coupling between the steam turbine and the integrally geared compressor, and a flexible disc type coupling between the steam turbine and the inline compressor
- Inlet steam conditions
  - 35.9 bara and 430°C
- Exhaust steam c
  - 0.166 bara and 32°C



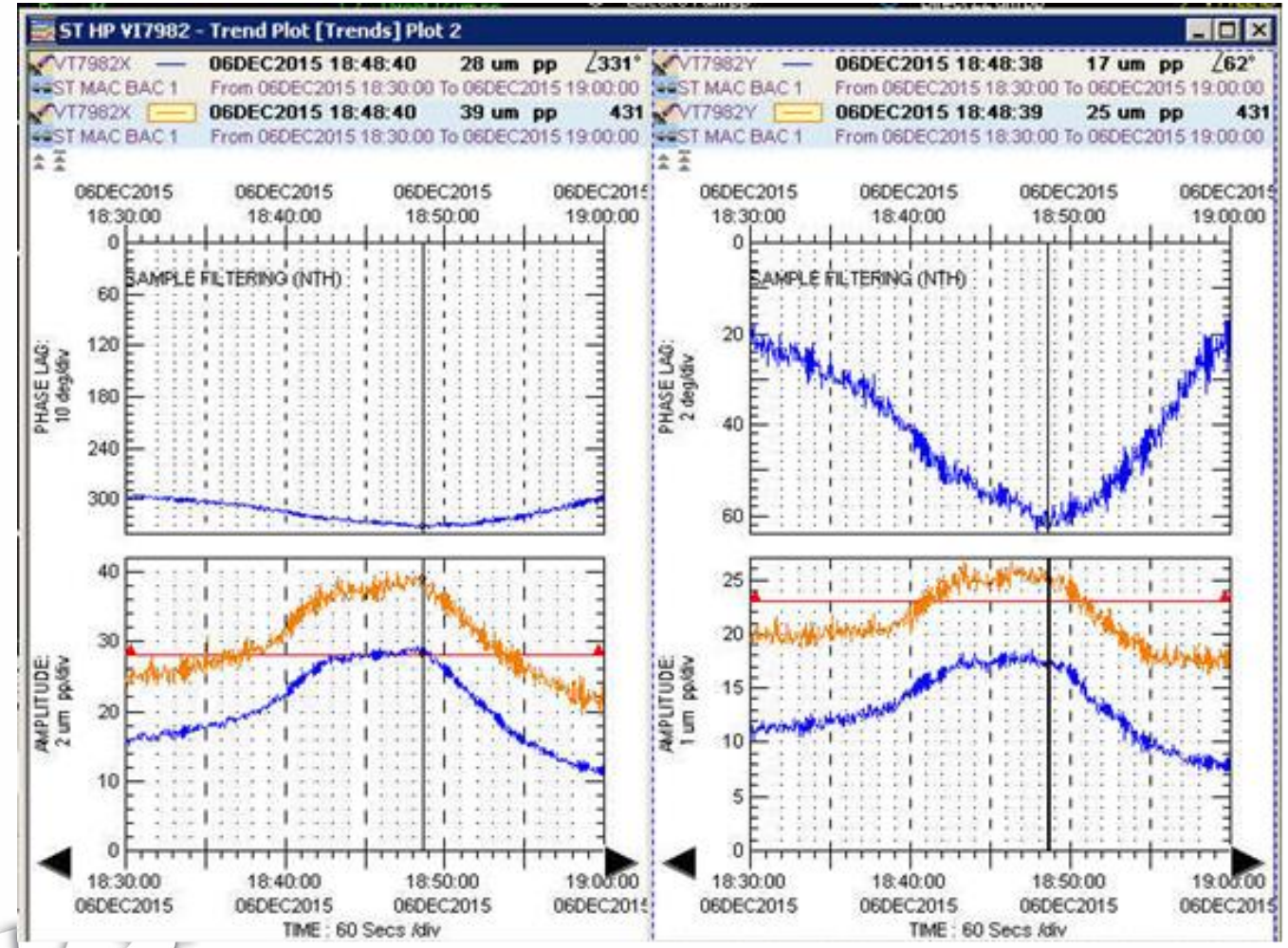
Steam Turbine Cross Section



History

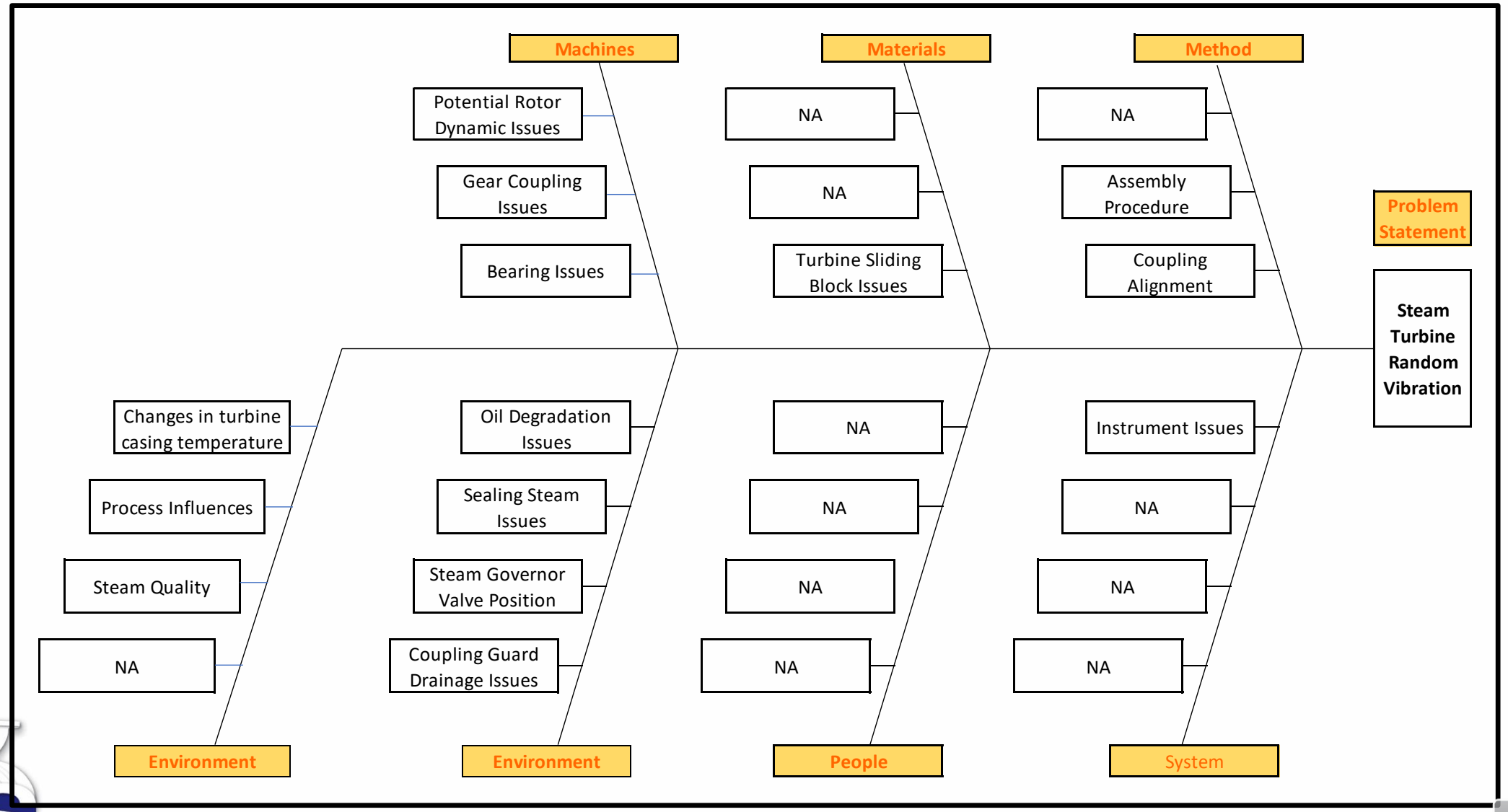
- Machine train was commissioned and ran for approximately three years without any significant steam turbine mechanical problems. Then, sudden, random steam turbine inlet end radial vibration excursions started occurring. The excursions would last for approximately 20 to 30 minutes after which the vibration would return to normal levels. A closer look at the trends revealed the following.
  - Gradual increase in steam turbine inlet end vibrations.
  - Vibration increase was due to an increase in the one times running speed component. There was also a moderate change in the phase angle.
  - No process changes at the time of the vibration excursions.
  - No changes in steam turbine radial bearing temperatures during the vibration excursions.
  - But, the steam turbine axial position would change and the active thrust bearing temperature would increase slightly.
  - And, during the vibration excursions, the integrally geared compressor drive end axial position would change slightly and the active thrust bearing temperature would increase by 17°C.

Typical Vibration Excursion

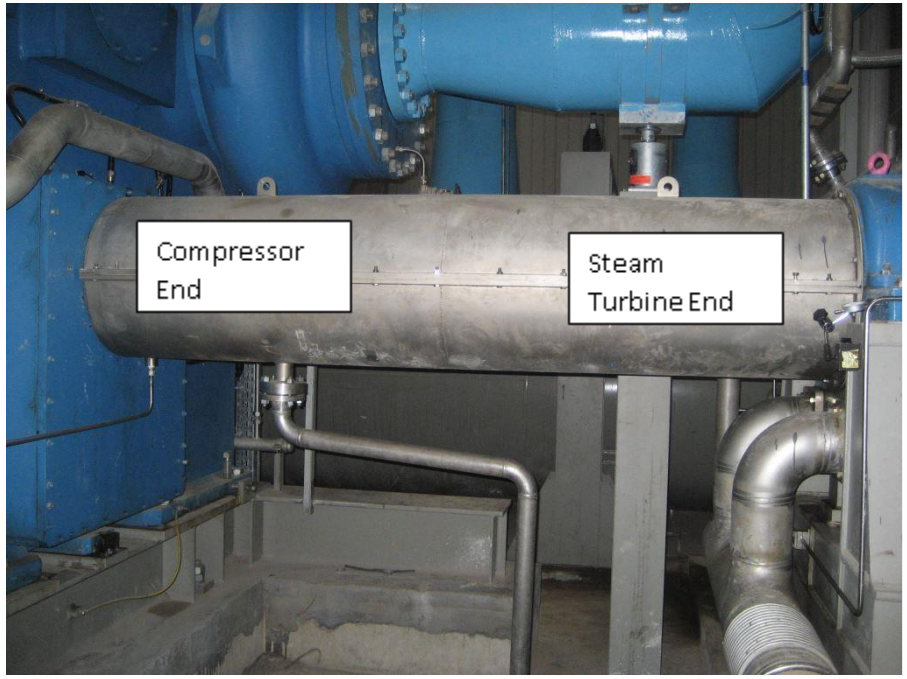


- During the vibration excursions:
  - The “x” vibration would increase to 40+ microns and the “y” vibration would increase to 30+ microns.
  - This was due to an increase in the one times running speed component. The phase angle also changed by approximately 30° to 40°.
- There were no process changes at the time of the vibration excursions.

Initial Assessment



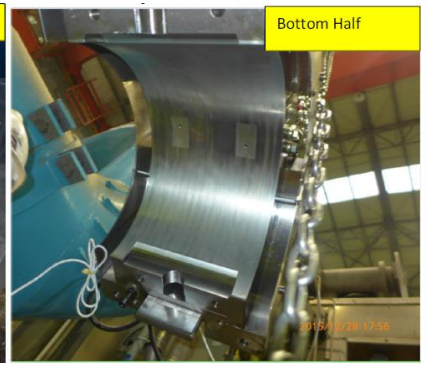
Coupling and Bearing Inspection



Steam turbine to integrally geared compressor coupling

Guard appeared to be pushing against compressor

Strange markings on the steam turbine end coupling gear teeth

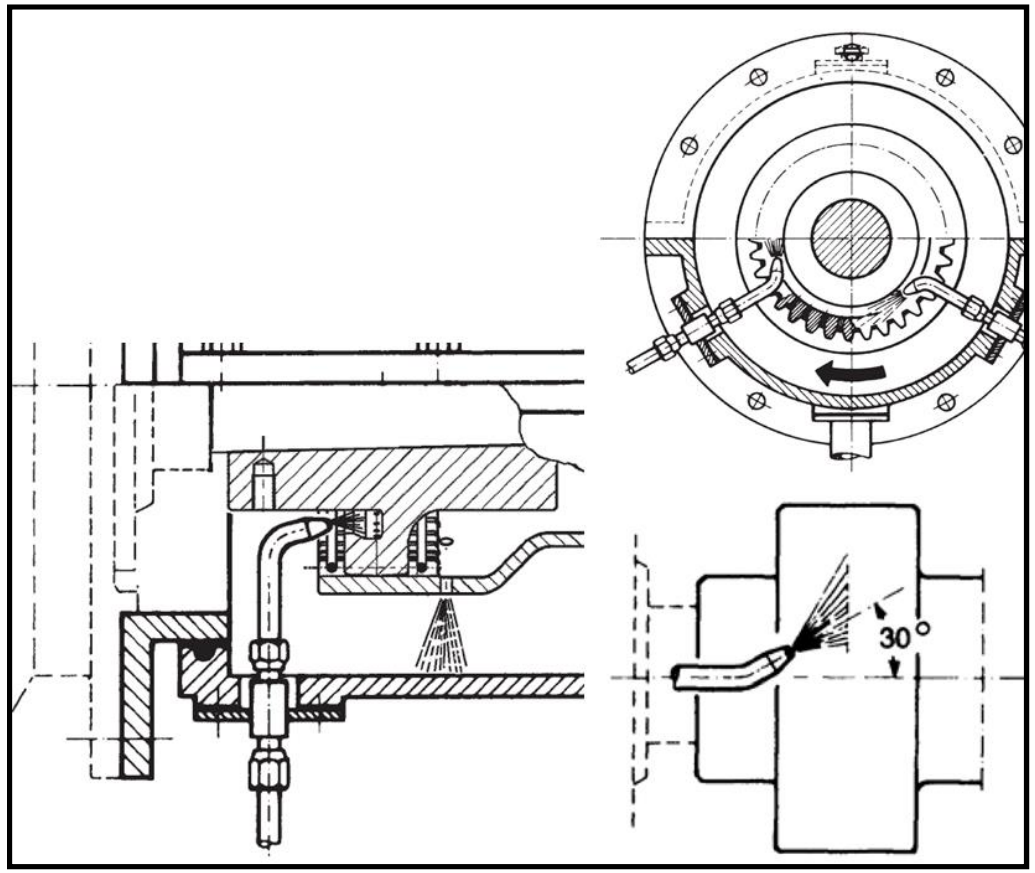


Steam turbine HP end Journal bearing – no issues

Investigation

- The shaft alignment was checked and found to be within design tolerances.
- The coupling guard appeared to be pushing against the compressor was cut to increase the cold gap clearance for turbine thermal growth.
- Dial gauges were installed around the turbine to look for signs of distortion or stuck sliding surfaces – nothing was found
- The process trends were scrutinized and the vibration excursions were not a result of any change in the process
- Steam quality trends were reviewed and there were no issues
- Rotordynamics and bearing design were reviewed – nothing was found
- The carbon brushes were inspected and were fine. But, the brushes were replaced anyway

Coupling Lubrication Nozzles and Drain Holes



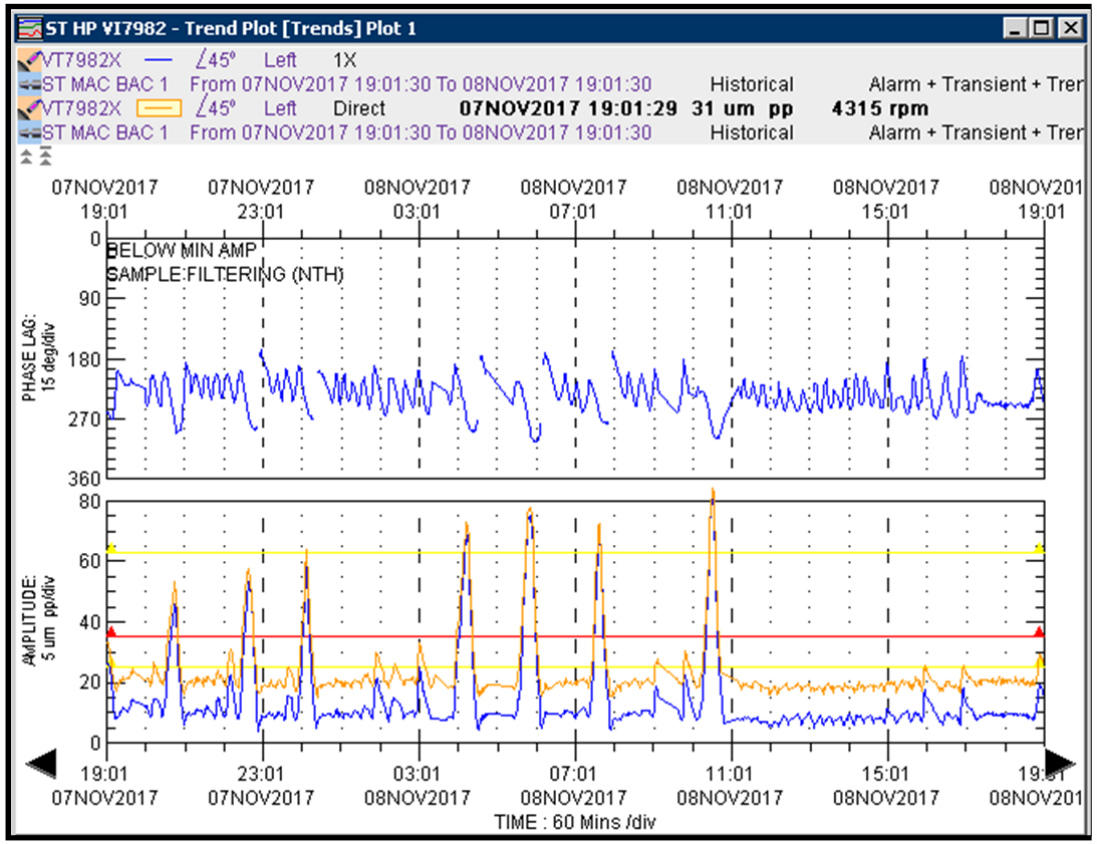
- Drain holes were inspected and not plugged
- Oil spray nozzles were not positioned properly

Assessment and Results

- Based on the discoloring of the gear teeth on coupling, occasional coupling gear teeth “lock-up” was identified as a possible cause. This could possibly be due to insufficient backlash.
- Backlash could not easily be checked with the installed coupling.
- Oil spray nozzles did not appear to be positioned properly and this was identified as a possible cause of the vibration excursions
- The steam turbine train was restarted, and the random vibration issues continued
- Based on these results, it was decided to replace the coupling with a spare and correct the oil spray nozzle orientation.
- Unfortunately, after replacing the gear-coupling and modifying of oil-spray nozzles, the random vibration spikes persisted.

Further Problems

- About six months after the coupling replacement, there was a step change in the frequency and magnitude of the vibration excursions.
- The vibration levels were fast approaching the trip set point.
- Then, a significant steam turbine inlet end bearing leak developed and it was decided to shut down the train to fix the leak and inspect the bearing.



Note spikes in vibration amplitude

Coking in Bearing Housing Oil Seal

Some insulation pads found missing around the sealing steam pipe

Assessment

- Oil coking at labyrinth oil seal resulted in rotor rubs. Once the rub occurred, the coking debris dropped and the rubbing stopped. This resulted in the random vibration.
- Oil coking at labyrinth oil seal was due to poor insulation at turbine section close to inlet end bearing

Conclusions

- The bearing housing oil seal was cleaned and insulation pads were added near the inlet end bearing.
- In addition, an air-purge was installed on the oil-seal labyrinth seal (provision already provided by OEM).
- Since making these changes, there have been no vibration excursions.
- It was concluded that the cause of the vibration excursions was due to light rubs caused by a build-up of deposits (oil coking) in the steam turbine inlet end bearing housing oil seal.
- The cause of the oil coking was excessive heat in the oil seal area due to missing insulation pads around the sealing steam pipe.

Lessons Learned

- Many causes were investigated and the fishbone diagram is a good tool for troubleshooting. Unfortunately, oil coking and a light rub in the bearing housing labyrinth oil seal was not identified as a possible cause.
- Although the vibration excursion data was consistent with a light rub, the changes on both the integrally geared compressor and steam turbine, and the coupling gear tooth markings indicated a possible problem with the coupling. Failure analysis is not an exact science and sometimes the initial assessment is wrong.
- This was a difficult problem to diagnose because many causes of intermittent vibration excursions share common symptoms.