

Mitigating Oxidation and Varnishing in Turbines and Heavy Equipment

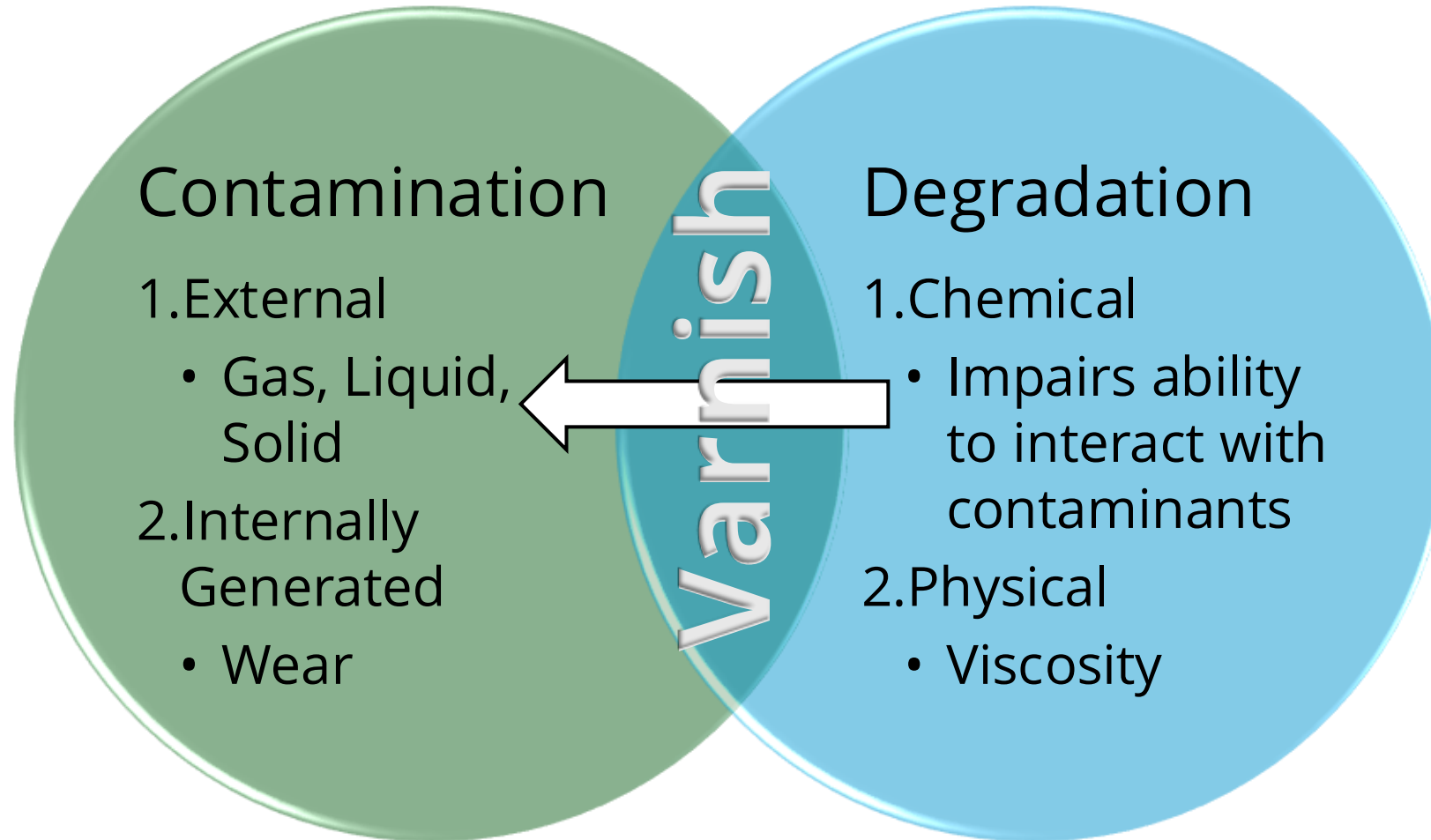
Part I: Background, History, Problems

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Turbine Oil Degradation

Factors Impacting Turbine Oil Performance



Turbine Oil: Modes of Degradation

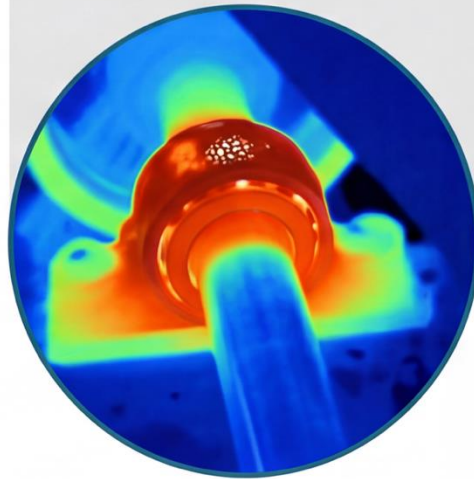
Oxidation

- Oxidation
- Ultraviolet



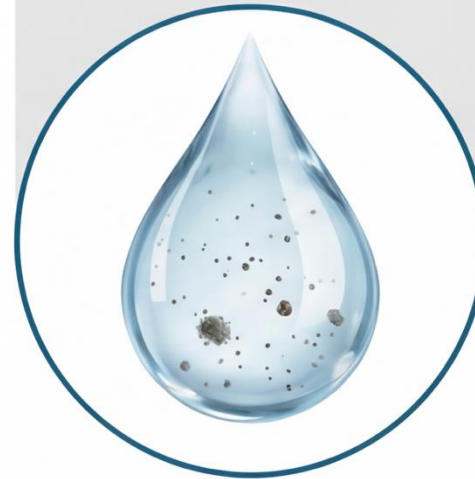
Thermal Degradation

- ESD
- Microdieseling
- Hot Spots
- Shear Stress



External Contaminants

- Gas
- Solid Particles
- Water



Other

- Additive drop-out
- Incompatibility



Oxidation is the most common form of turbine oil degradation



Antioxidants are like an Apple's skin

What do we mean by Varnish?

There are dozens of different chemistries that make up deposits, based:

- Operating conditions of the machine/equipment
- Formulation of the fluid
- Contamination that influence fluid degradation pathways.

Varnish is an oil-derived deposit.



Oil Deposits Characteristics

Sludge

Mechanisms: Oxidation + Moisture
Temperature formed: 60-180°C
Oxygen content: High
Appearance: Sticky, amorphous

Cold Varnish

Mechanisms: Oxidation
Temperature formed: 60-180°C
Oxygen content: Moderate
Appearance: Thin, glossy brown film.

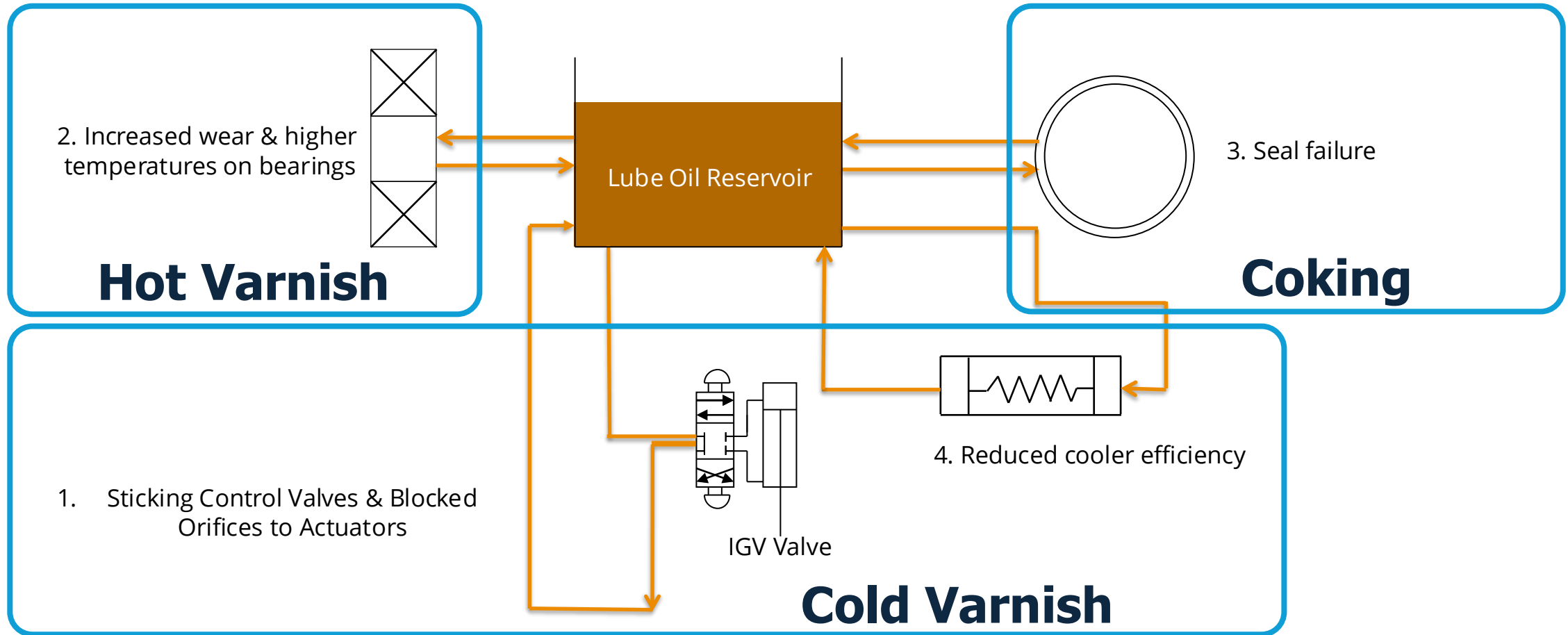
Hot Varnish

Mechanisms: Thermal Degradation
Temperature formed: 180-250°C
Oxygen content: Low
Appearance: Dark Brown/Black hard deposit.

Coke

Mechanisms: Pyrolysis
Temperature formed: >300°C
Oxygen content: Almost none
Appearance: Brittle, black carbon

Common Varnish Problems

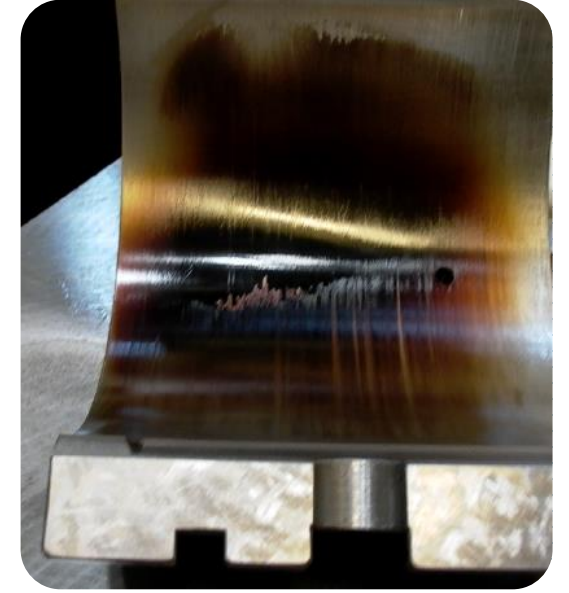
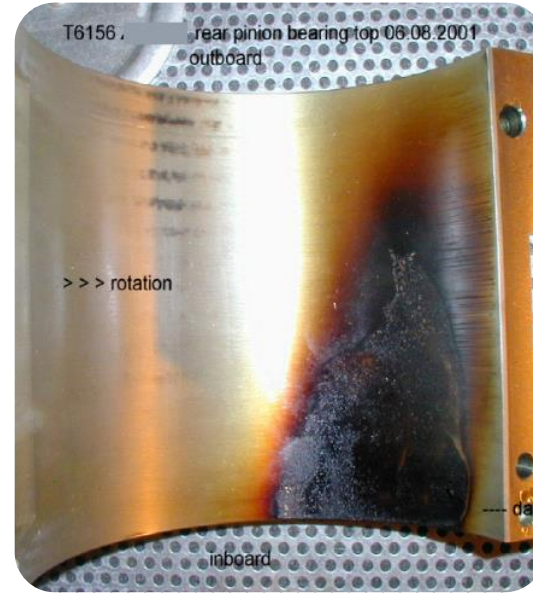
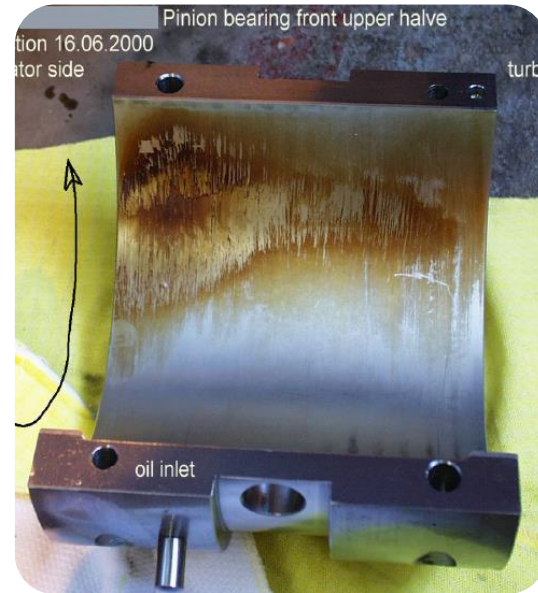




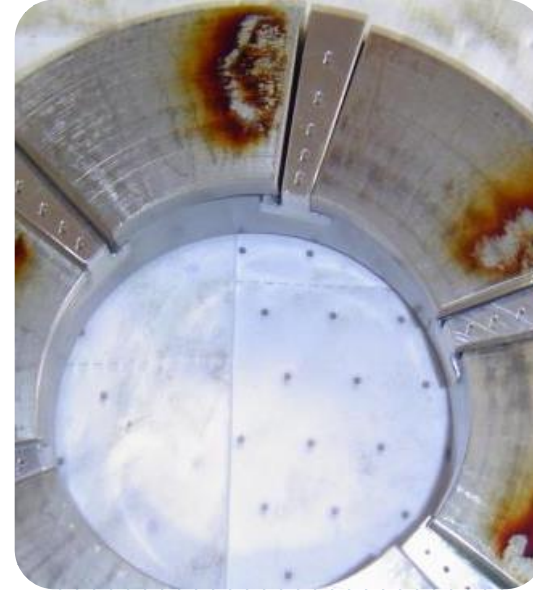
Varnish Causes Bearing Temperature Increases

- Varnish acts as an insulator, preventing lubricants from performing one of their most important tasks: cooling.
- Varnish is commonly found in journal and thrust bearings in rotating equipment.
- A common signature for varnish-induced bearing temperature excursions is a sawtooth graph.

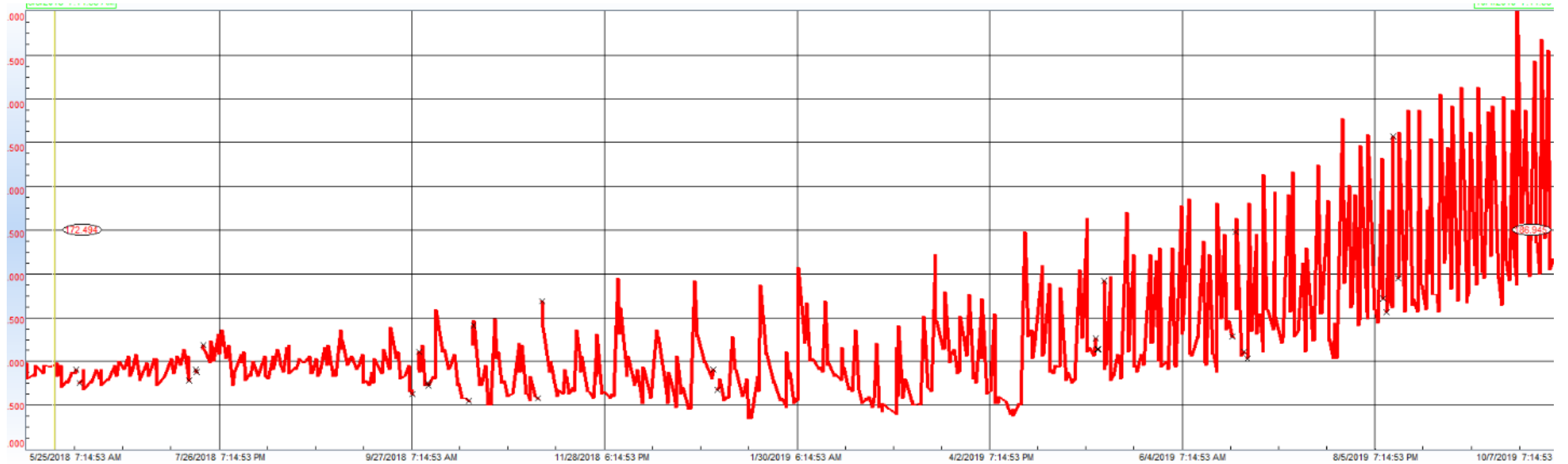
Evidence of Varnish Increasing Wear Rates



Thrust Bearings Coated with Deposits and Visible Signs of Wear



Varnish-derived Temperature Excursions

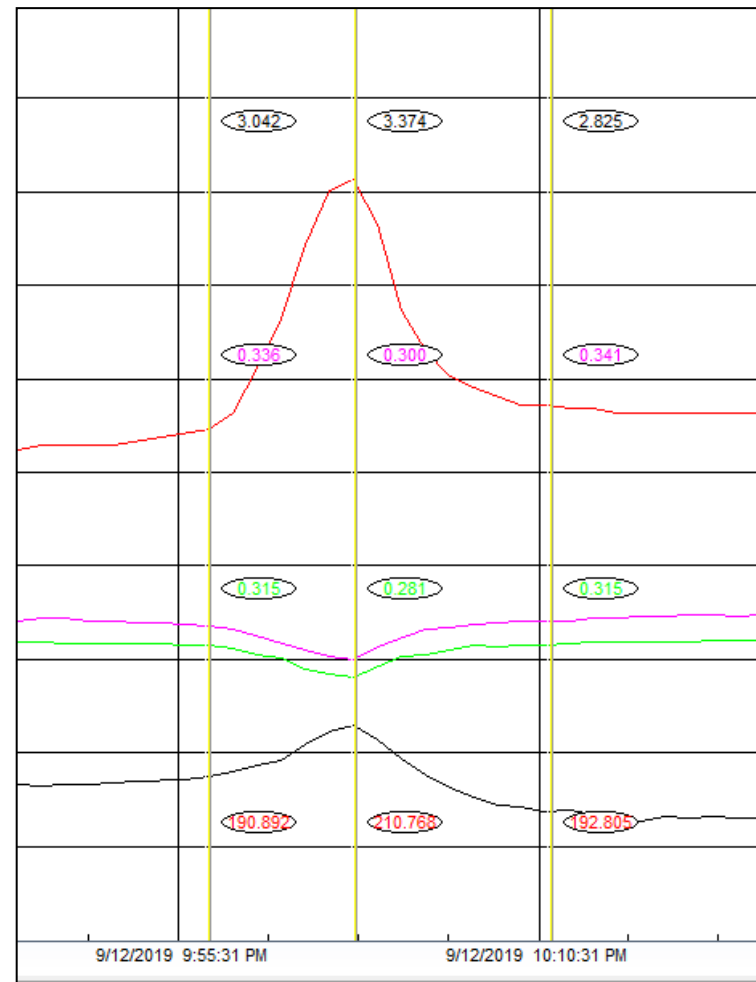


- Radial bearing temperatures showed a steady increase as seen in the 500-day trend below.
- The trend resembles a sawtooth graph with progressively more extreme temperature spikes.

Relationship between Temperature and Rotor position during Temperature excursion

Bearing temperature increases as the varnish layer grows due to its insulating properties.

Correlation between bearing temperature and rotor position suggests that as the varnish layer increases, the rotor also moves away from center.

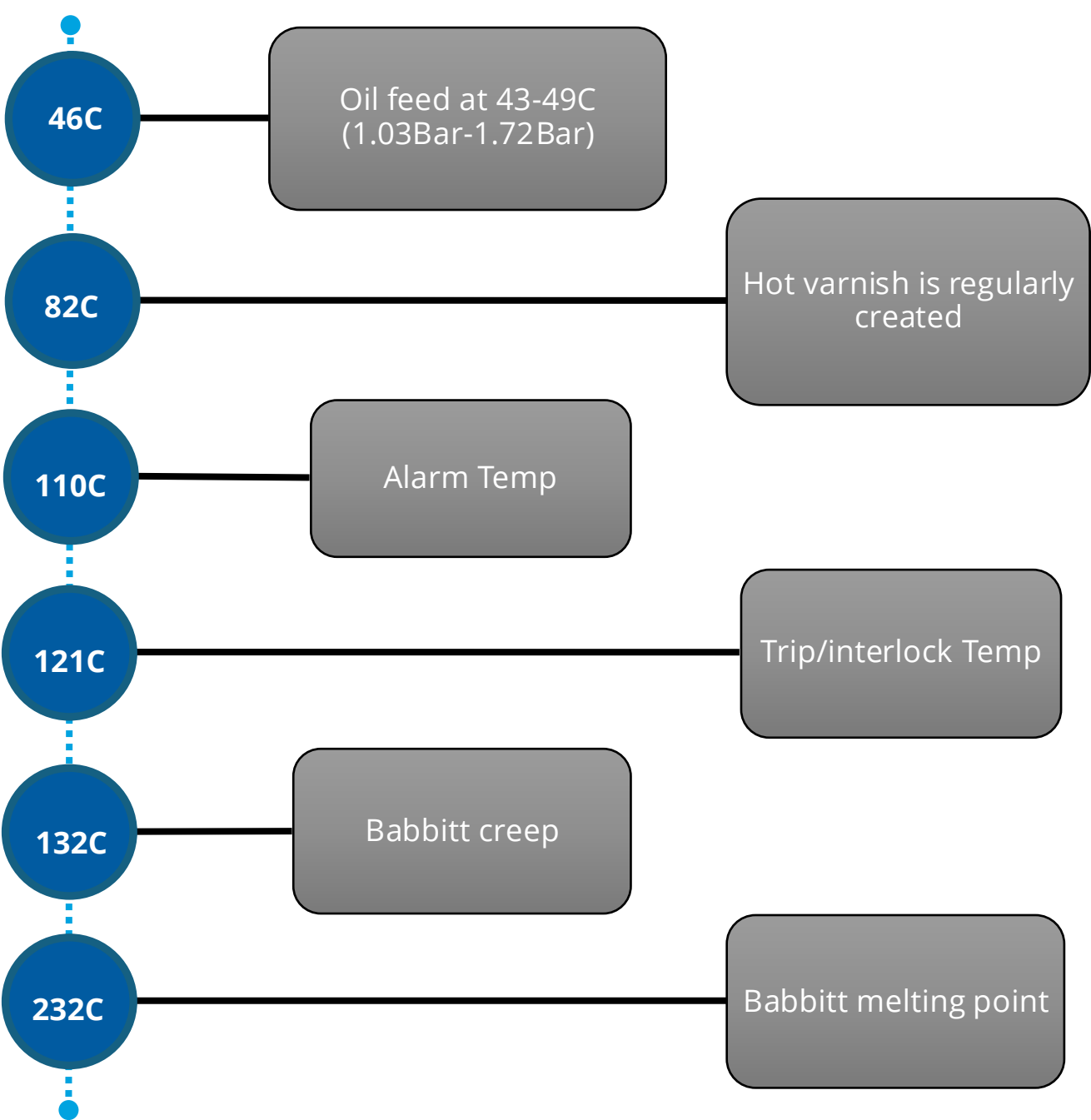
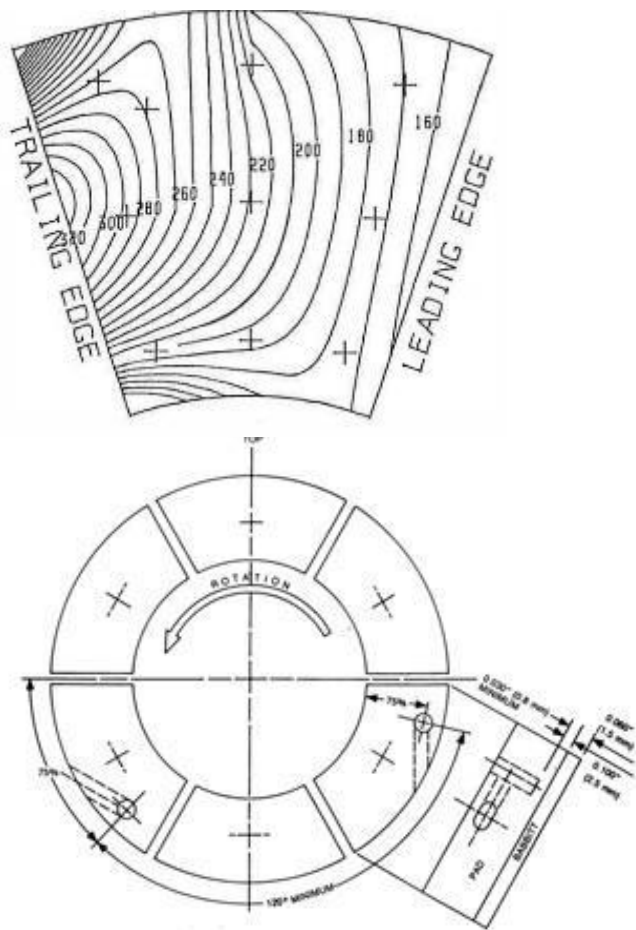


Vertical shift in rotor position

Bearing Temperature Spike

Notable temperatures

@bearing (API 670)



Experience – Heavy Duty Gas Turbine

- After operation of units for few years (20k to 30k EBH), operator began to observe varnish related degradation in the Turbine oil.
- Following were the key observations:
 - Progressive darkening of lube oil.
 - MPC (Membrane Patch Colorimetry) gradually increasing in range of 40-50.
 - Additives depletion observed.
 - Gradual increase in TAN observed indicating increase oxidation.
 - Varnish observations on the bearing and oil tank as well.
- Immediate mitigation: VRU units installed.

Continued....



Figure 1- EE L/H Bearing, Overview (1)

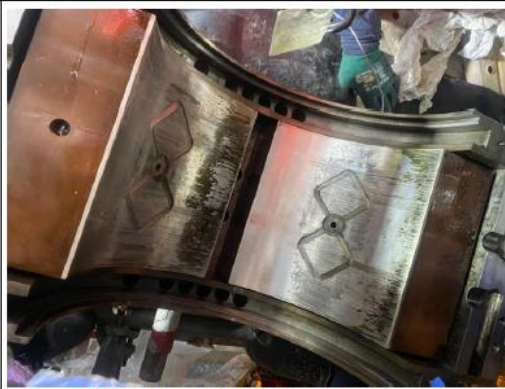


Figure 2- EE L/H Bearing, Overview (2)

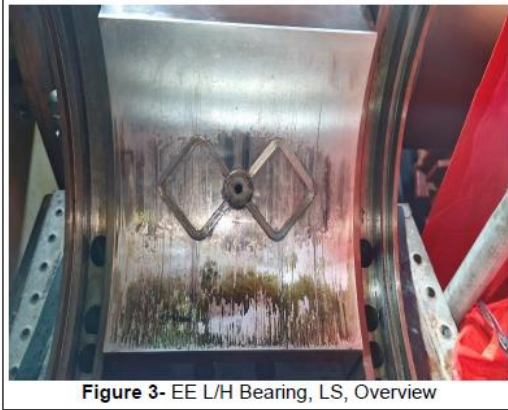
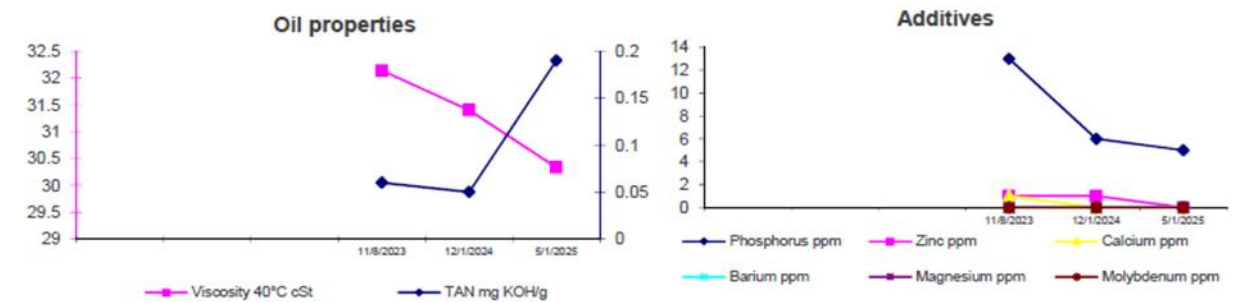
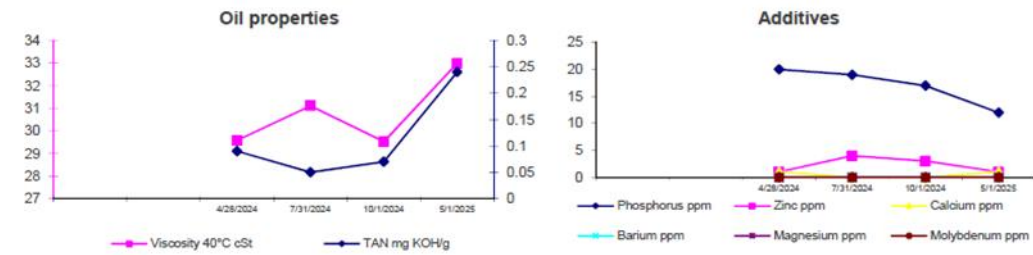
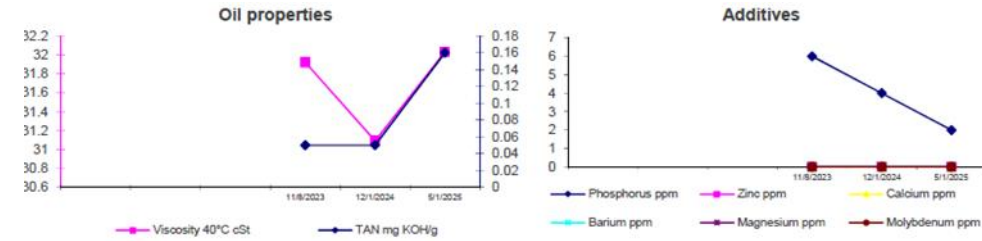


Figure 3- EE L/H Bearing, LS, Overview



Figure 4- EE L/H Bearing, LS, Detail



Lessons learned

- Condition monitoring of Turbine oil using both MPC & RULER together.
- During lube oil selection phase for heavy duty applications, more care shall be taken in looking at oxidation resistance capabilities of Lube oil.
- One of the popular method in industry is to look at TOST (also Dry TOST) test results (Turbine Oil Stability test, ASTM D-943) during selection phase.
- A survey was done to benchmark practices among different users of H/D GTs in the region, recently most users started mandating selecting Turbine oil with TOST > 10,000 hours.

How MPC & RULER work together

