

RWE

Leveraging Complementary Behaviors Between Vibration and Wear Debris Gearbox Condition Monitoring

NREL Drivetrain Reliability Collaborative

Golden, Colorado

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RWE Renewables

Agenda

Overview of Trial Project

Technology Review and Vendor Selection

Project Results

Benefits of Vibration and Wear Debris Monitoring

Project Overview

Problem: Many missed or late detections for planet bearings and spinning HSS bearings.

RWE initiated a trial with 2 new vibration CMS and a particle monitor system.

- **Test site:** RWE Operated Wind Farm, 2013 COD
 - **Turbine type:** Onshore, <2.0 MW, 1P2H Gearbox
 - **Native CMS:** CMS 1
 - **Trial Length:** Aug 2021 – Sep 2022
1. [118 turbines] **CMS 1**
 2. [118 turbines] **CMS 2**
 3. [10 turbines] **CMS 3**
 4. [84 turbines] **Particle Monitor**

Technology Review and Vendor Selection

- Types of *Online* Particle Detection

Particle Monitoring

Detects solid particles present in lubricating oils.

Identifies material shed from wear components to provide detection of failed components.

Will often provide size and mass estimates, which can give insights to the nature and severity of the failure.

Source: Poseidon Systems

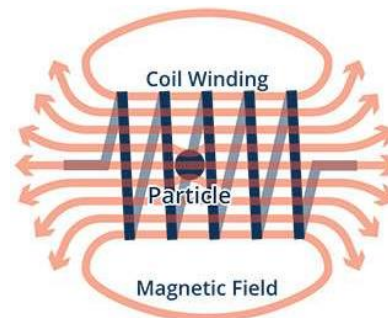
Inductive

Cannot detect very small particle sizes

Max particle size only limited by bore

Relatively simple and robust

Can separate Fe vs nFe



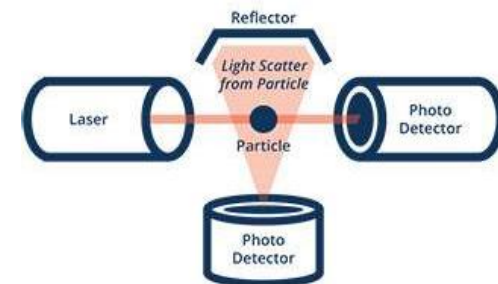
Optical

Can provide ISO 4406

Can detect very small particles (<math><4 \mu\text{m}</math>)

Max particle size limits (100 – 200 μm typ.)

Can be sensitive to bubbles, non-ferrous material, and some additives



Technology Review and Vendor Selection - Why We Chose Poseidon

Two primary requirements for the sensor: Cost and Minimum Particle Size

4 sensors considered that could detect $< 50 \mu\text{m}$ particles - all but Poseidon failed on cost

- Poseidon DM4500 (1x cost basis)
- Vendor 1 (2x cost)
- Vendor 2 (Optical, 3x cost)
- Vendor 3 (No quote)

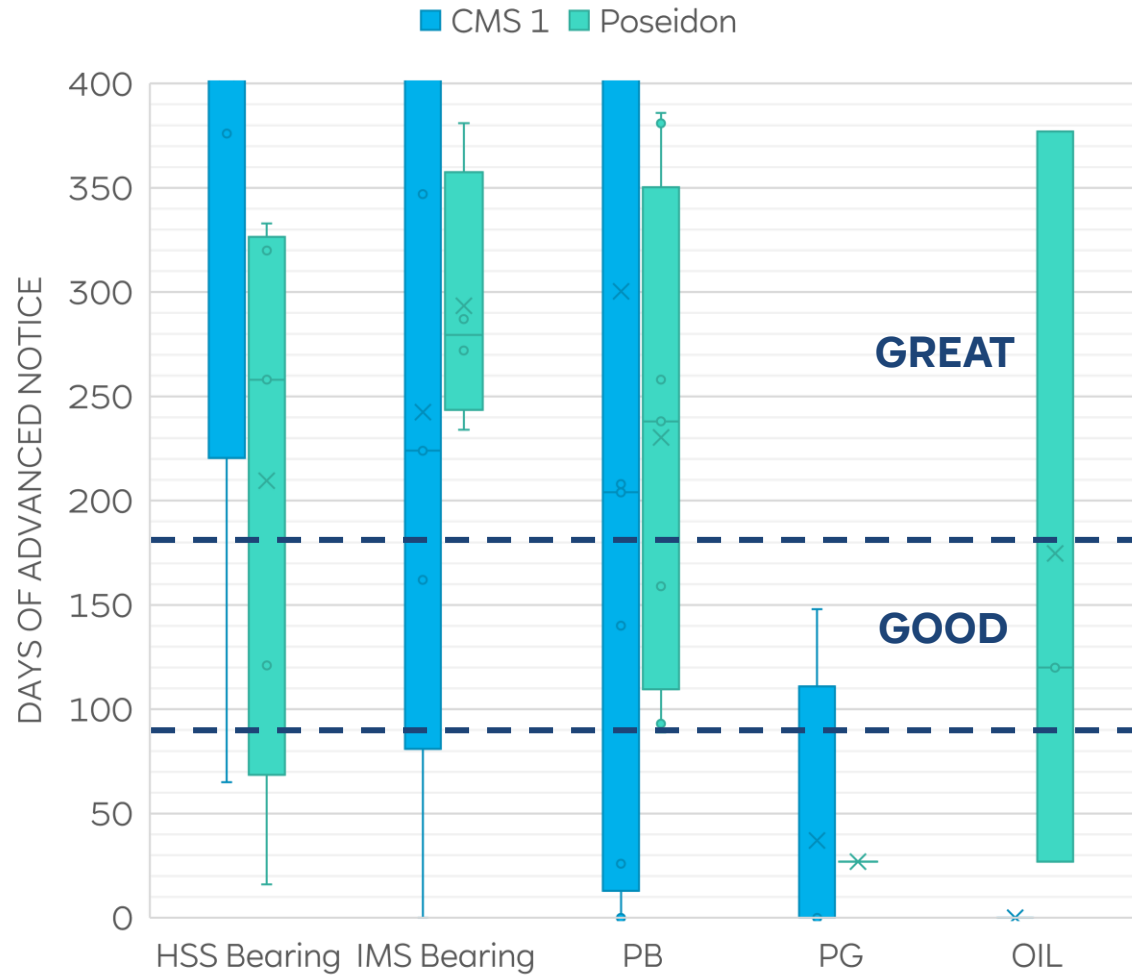
Advanced Features:

- Offers $40 \mu\text{m}$ minimum size
- Mass totalization
- Particle size binning

Project Results

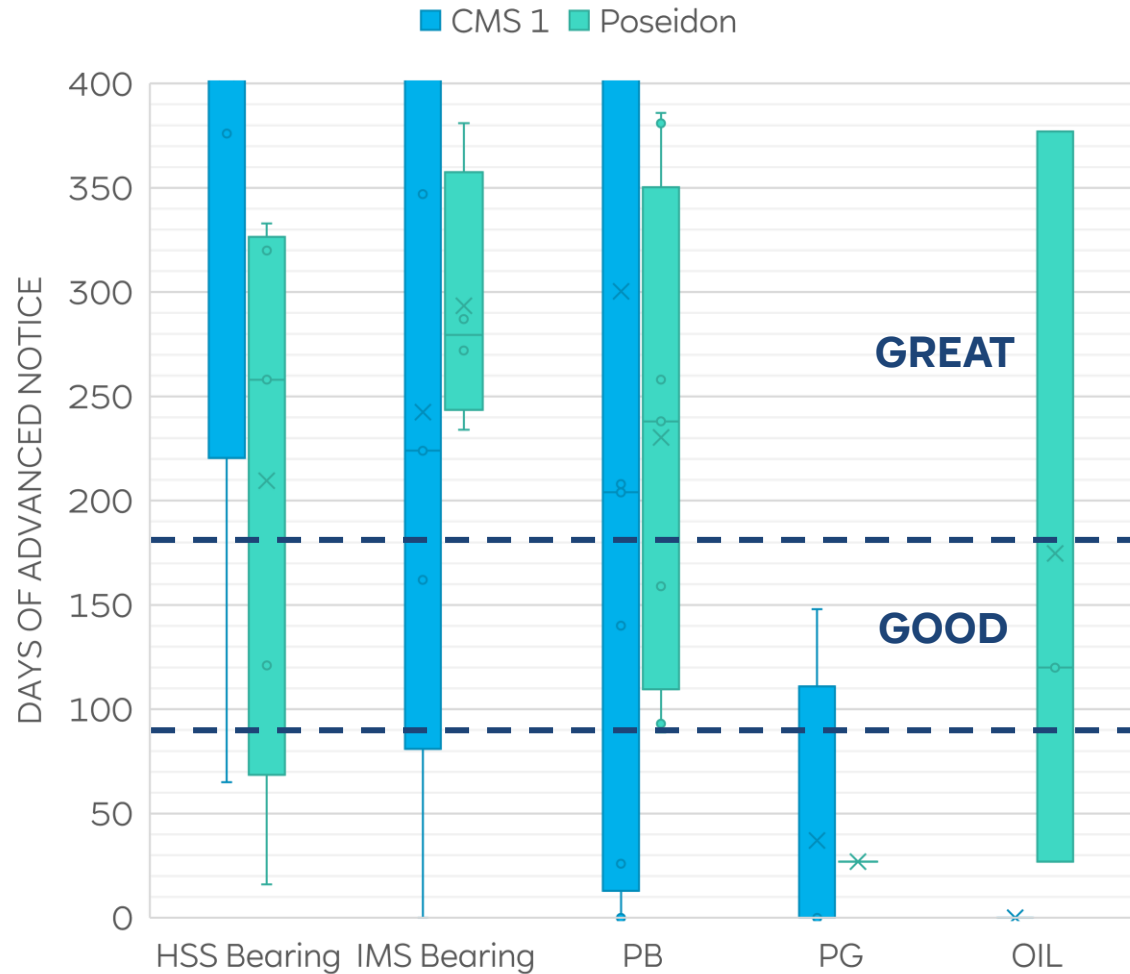
Project Results

How much warning do we have before a fault becomes critical?



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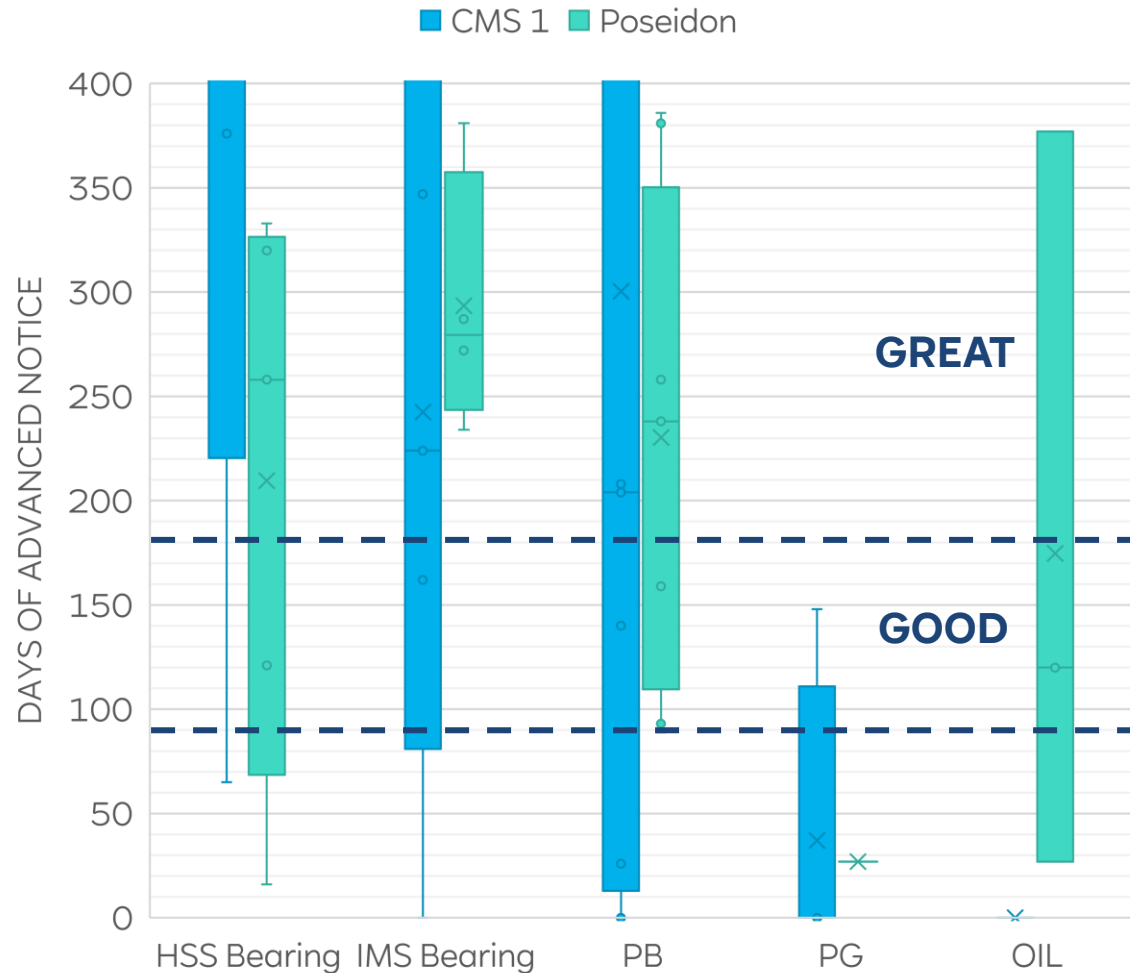
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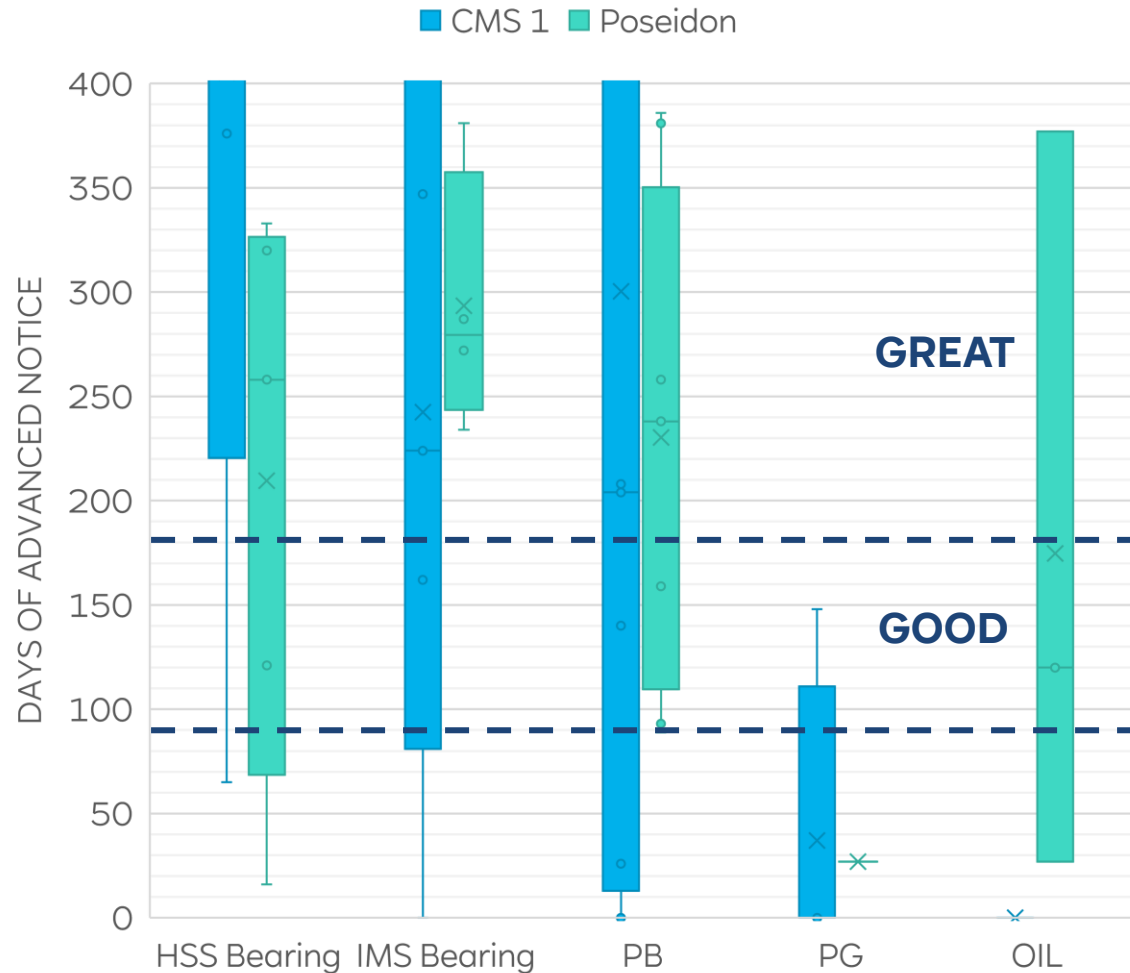
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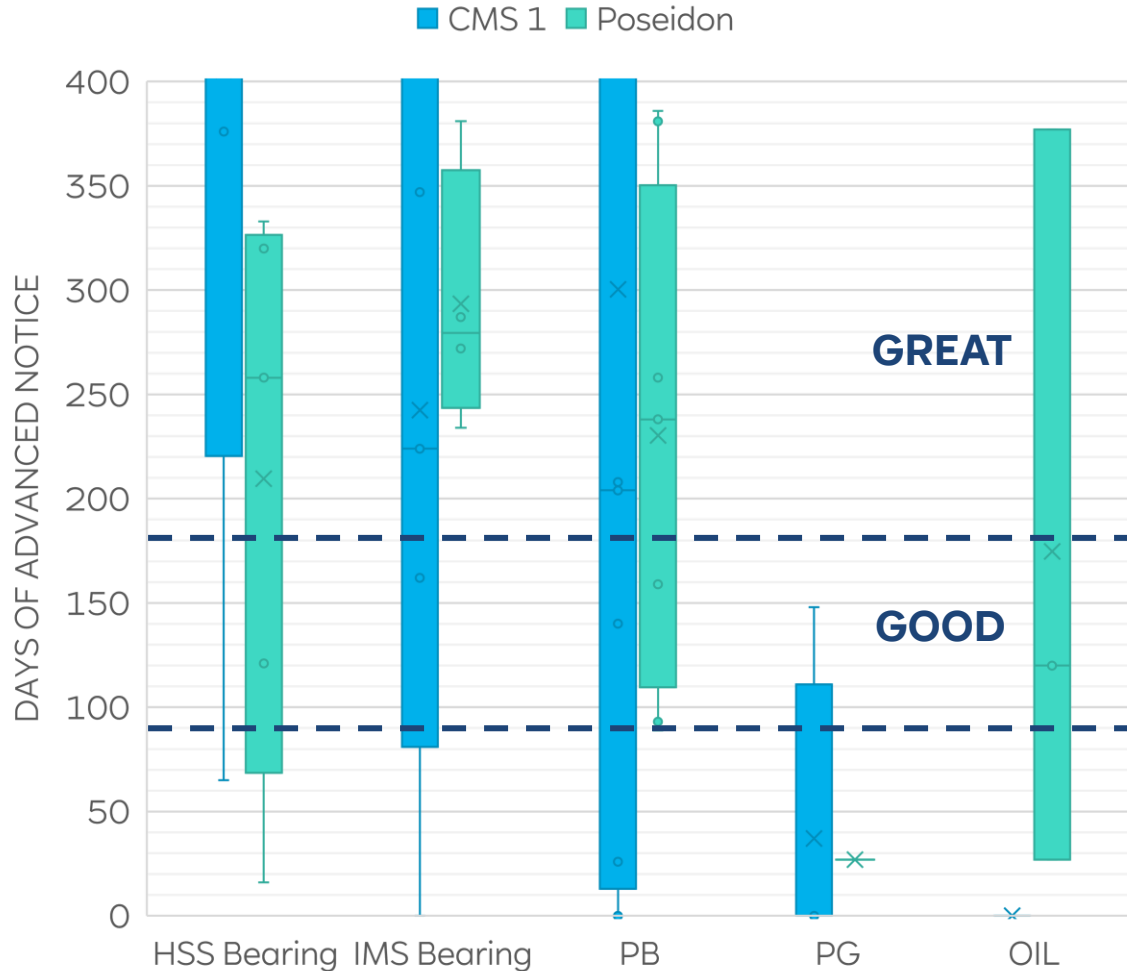
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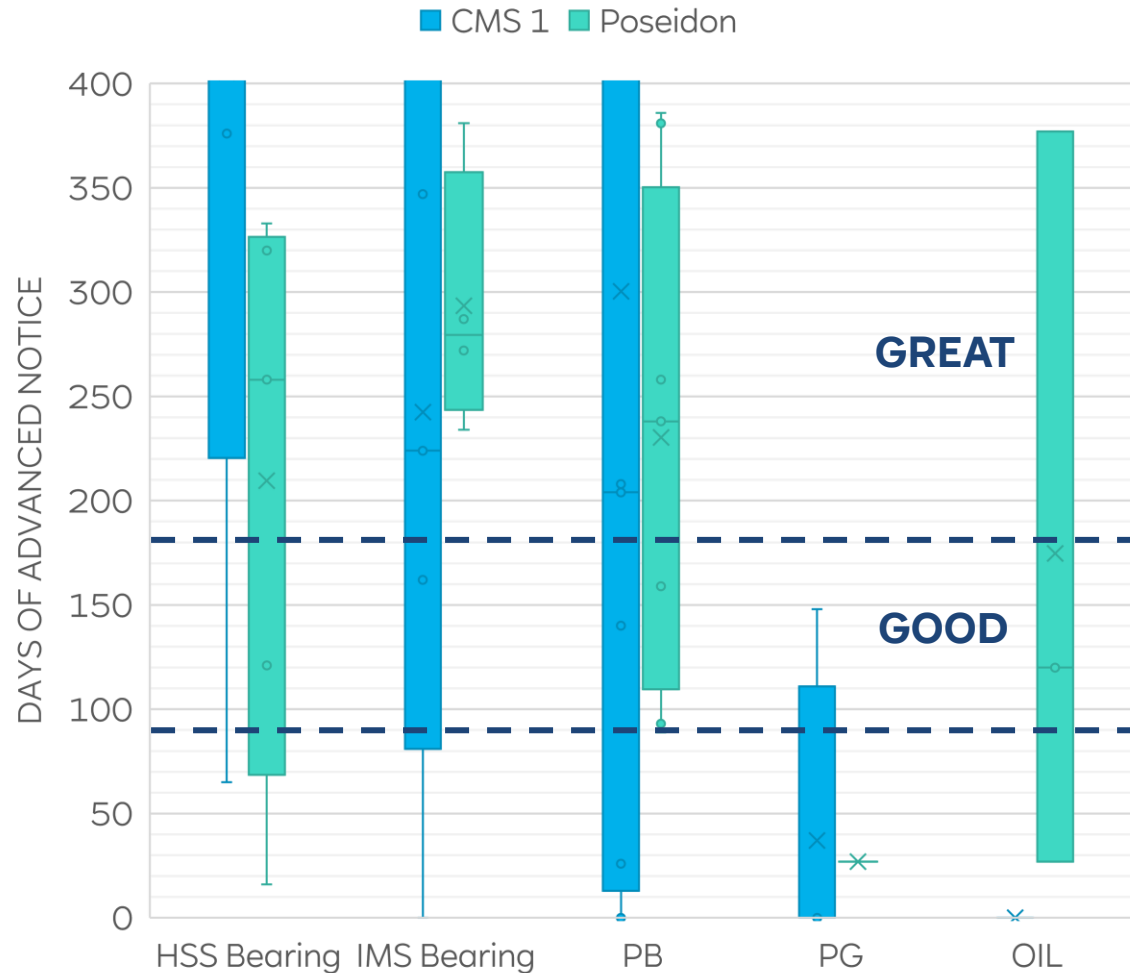
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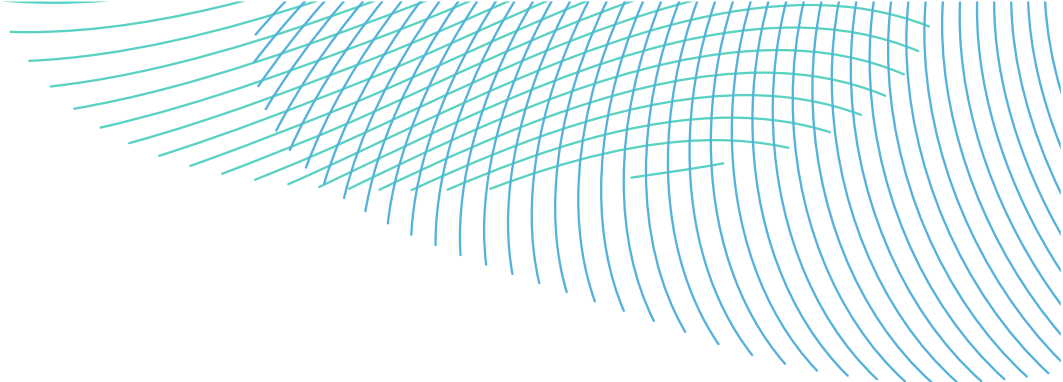
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For context, 38 different gearbox issues were identified in this trial!

Synergies between Vibration and Wear Debris Monitoring



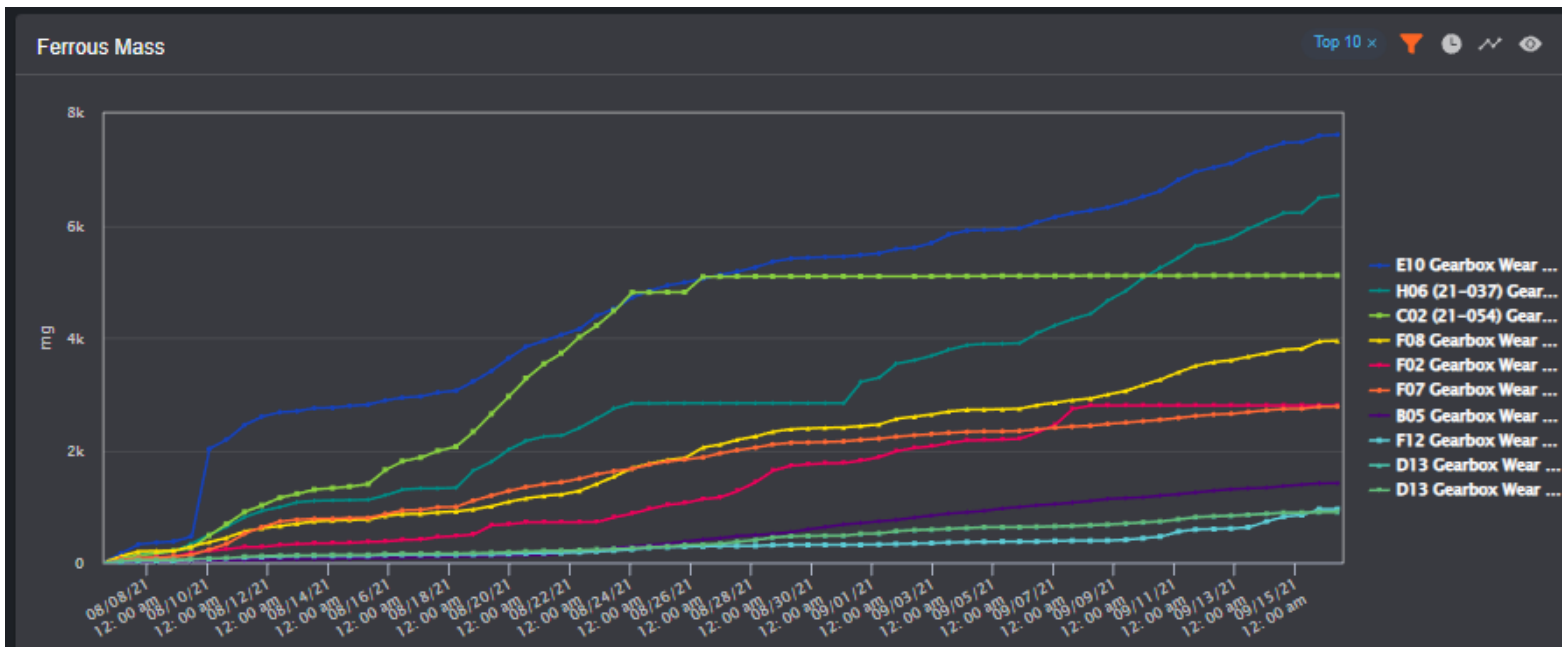
Synergies between Vibration and Wear Debris Monitoring

- 1. Fault Detection vs. Fault Severity
- 2. Reduction of Borescopes
- 3. Derate Effectiveness Feedback
- 4. Greater Failure Mode Coverage, “Catch-all”

Vibration and Wear Debris Synergies

1. Fault Detection vs. Fault Severity

While vibration can often detect faults earlier and their **location**, cumulative ferrous mass proved valuable in determining **severity** of failures. Mass production also gives us clear feedback on **RUL**.

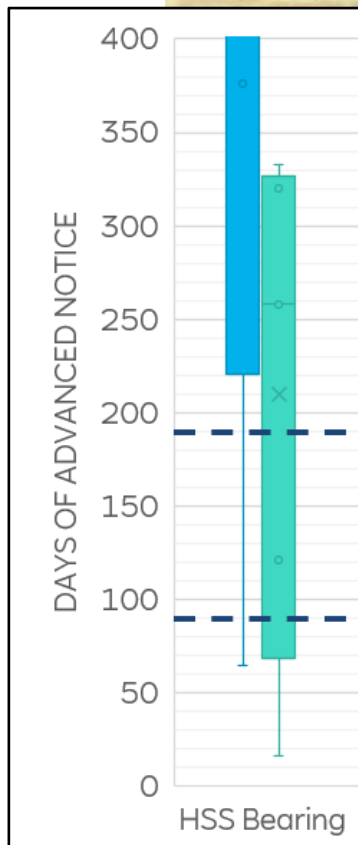


- **Prioritizing Site Work Schedule**
- **Addressing issues at the right time**
- Reduction of Inspections

Vibration and Wear Debris Synergies

1. Fault Detection vs. Fault Severity

Lack of severity indication in vibration CMS can lead to components being replaced too **early**.

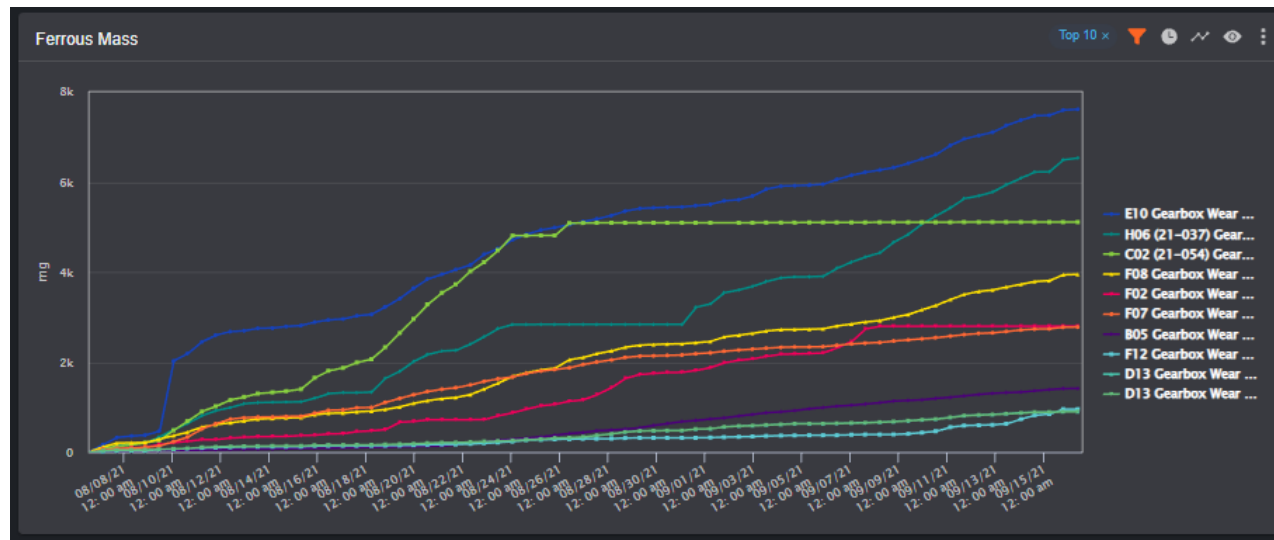


- Prioritizing Site Work Schedule
- **Addressing issues at the right time**
- **Reduction of Inspections**

Vibration and Wear Debris Synergies

2. Reduction of Inspections (i.e. borescopes)

Since severity in vibration can be difficult to gauge, we compensate by ordering additional inspections.



- Prioritizing Site Work Schedule
- Addressing issues at the right time
- **Reduction of Inspections**

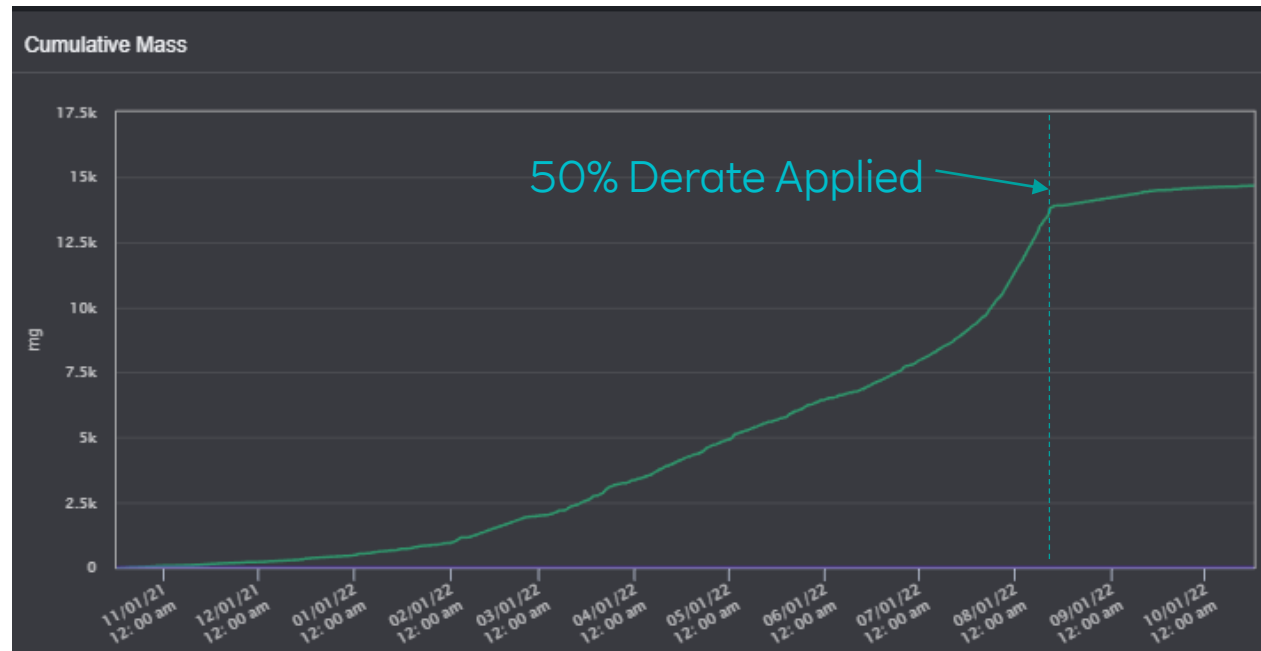
**Very high value for EOW inspection prioritization.
Also consider multi-stage planetaries.**

Vibration and Wear Debris Synergies

3. Derate Effectiveness Feedback

Ferrous mass totals provide great feedback if **derating is effective**.

Turbine G09 – IMS bearing failure: Effective derate, RUL extension successful.



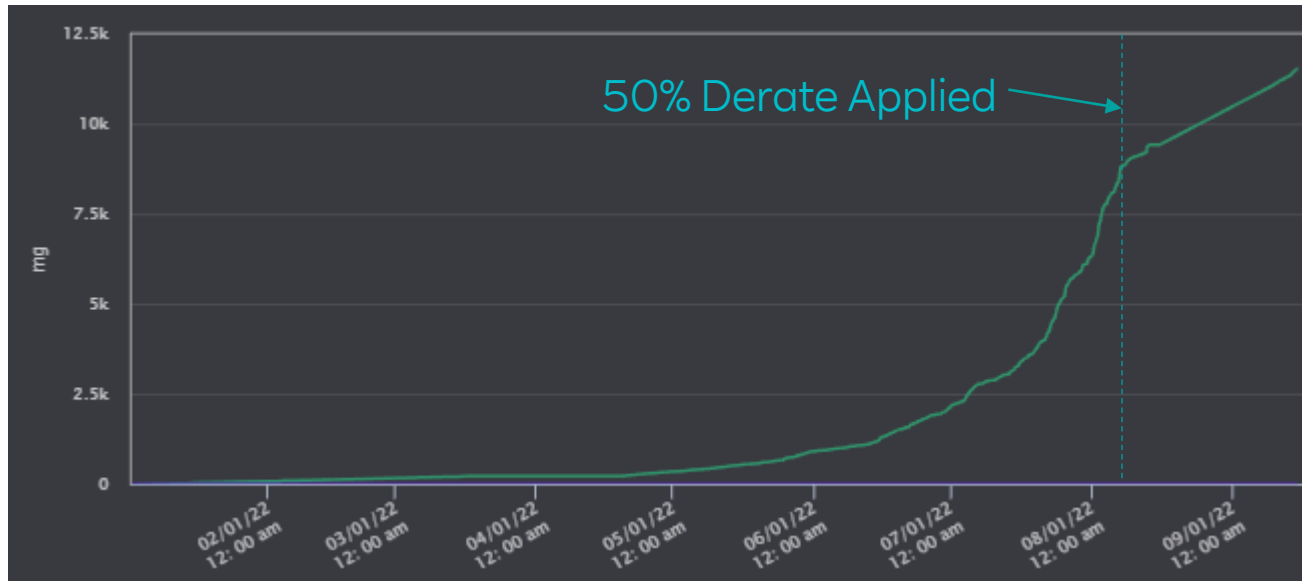
- **RUL extension**
- **Crane and Crew Bundling**
- Reduced risk of catastrophic failure

Vibration and Wear Debris Synergies

3. Derate Effectiveness Feedback

Ferrous mass totals provide great feedback if **derating is effective**.

Turbine A11 – Planet bearing failure: Derate not sufficient for significant RUL extension.



- RUL extension
- Crane and Crew Bundling
- **Reduced risk of catastrophic failure**

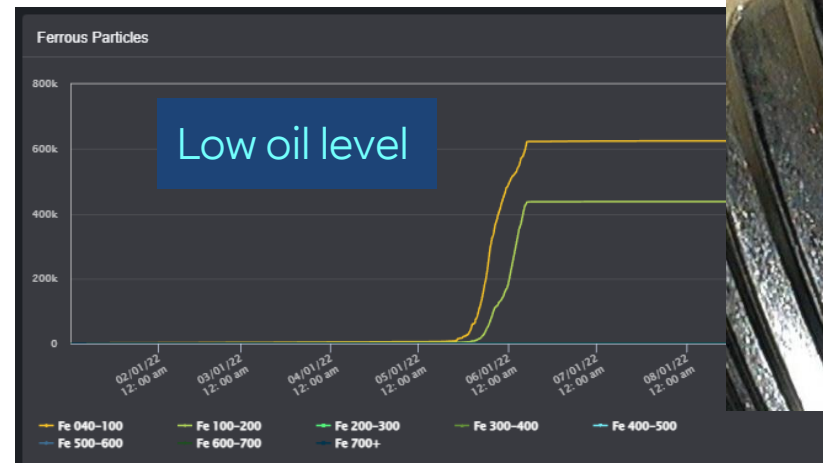
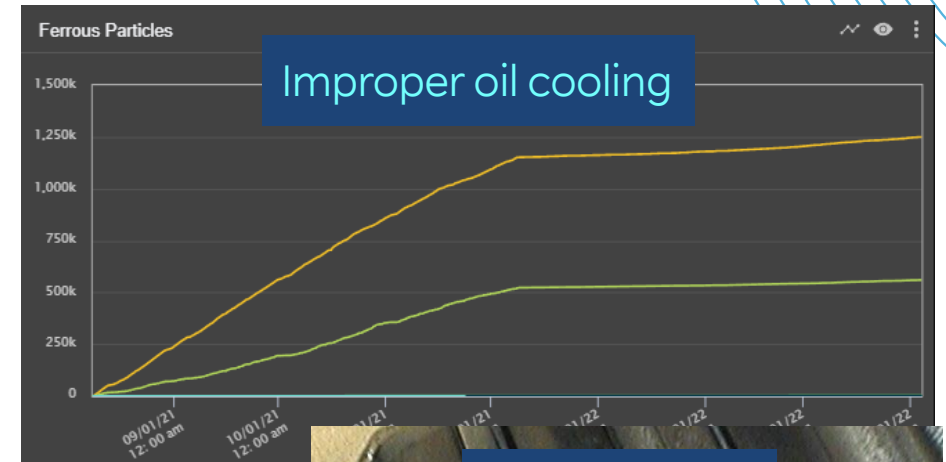
Vibration and Wear Debris Synergies

4. Greater Failure Mode Coverage – Oil Related Issues

Poseidon was the **only system** with ability to provide insights into failing **lubrication** conditions.

- 3 cases of failing lubrication were detected: overheating gearbox, low oil level, and oil reaching end of life
- In all cases, no other alarms or warnings were triggered in CMS, SCADA, or offline oil sampling.
- These detections are valuable: They potentially **eliminate** a failure from occurring in the first place

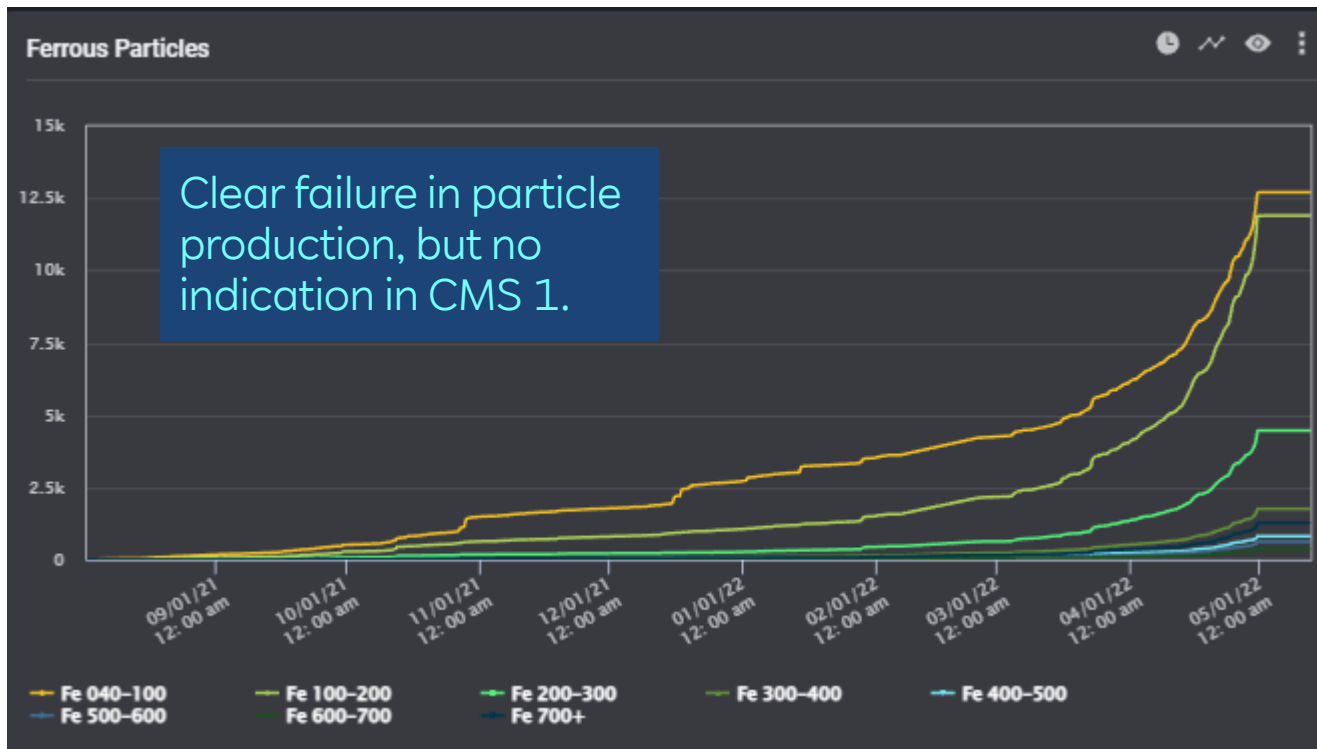
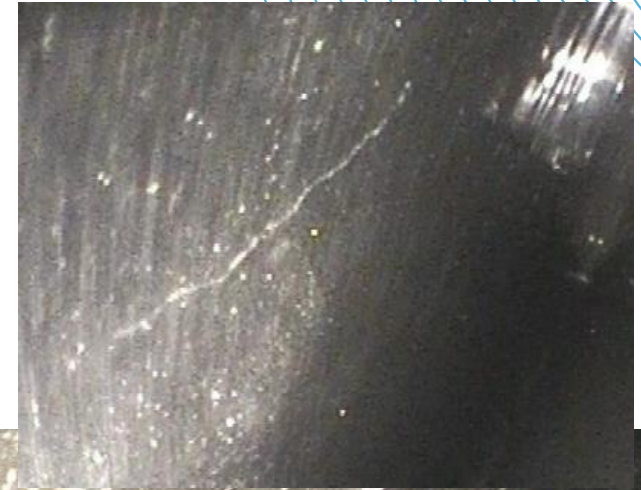
In all cases large amounts of sub-100 μm particles were generated, indicating a reduction of the EHL boundary layer



Vibration and Wear Debris Synergies

4. Greater Failure Mode Coverage – Planet Bearing OR

Tribal knowledge told us only inner races failed on planet bearings – likely because only inner race faults were ever visible in CMS. In reality, outer race failures were invisible in vibration.



Summary

Wear debris monitoring is an excellent complement to vibration CMS. It addresses many gaps inherent to vibration-based diagnosis.

Better indication of fault severity and RUL

Allow reduction of inspection by providing greater confidence in severity

Immediate feedback on effectiveness of derating

Coverage of failure modes often not visible to vibration CMS: EHL issues & planet bearings shown. Other modes also likely.

RWE

Thank You

Q & A