PHM of Oil: Challenges in Offline Analysis

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POSEIDON SYSTEMS

Protecting Your Critical Assets

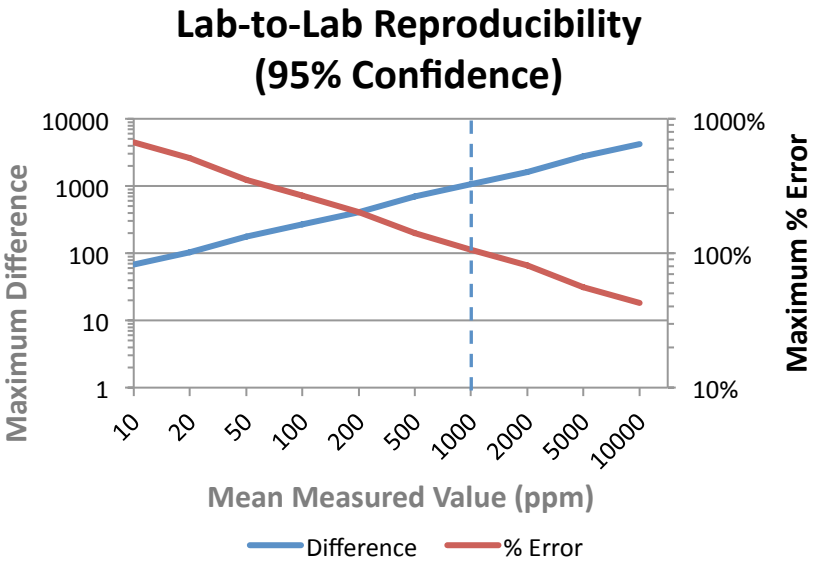
Challenges in Oil Analysis

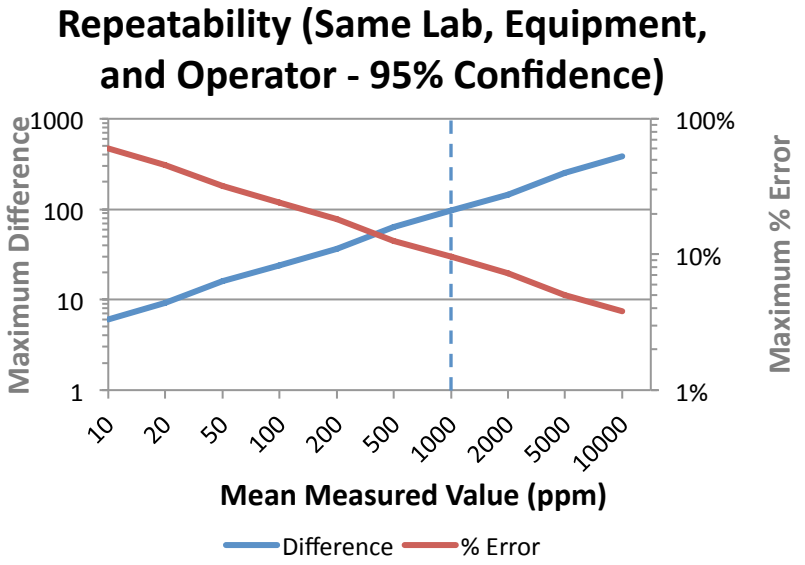
- Selecting the right tests for the oil/application
  - Make sure the right methods are employed
  - Bundled packages may substitute an inferior method to provide a lower cost offering
- Selecting the right condemning limits for your application
- Collecting a representative, uncontaminated sample
- Test repeatability and reproducibility
  - Consistently use the same lab and same methods

Water Contamination Analysis

- Many ways to evaluate water contamination
  - Visual, crackle test, calcium hydride kits, Dean and Stark method, FTIR, volumetric titration, coulometric titration
- Most recommended method is ASTM D6304 method C – Coulometric Karl Fischer Titration with Codistillation
- Provides measure of water in a sample in units of mg/kg (ppm)
- Surprisingly poor repeatability and reproducibility tolerances
  - $Repeatability = 0.03813*X^{0.60}$
  - $Reproducibility = 0.4243*X^{0.60}$
  - X is the mean measured value of a sample in %

ASTM D6304 Reproducibility/ Repeatability

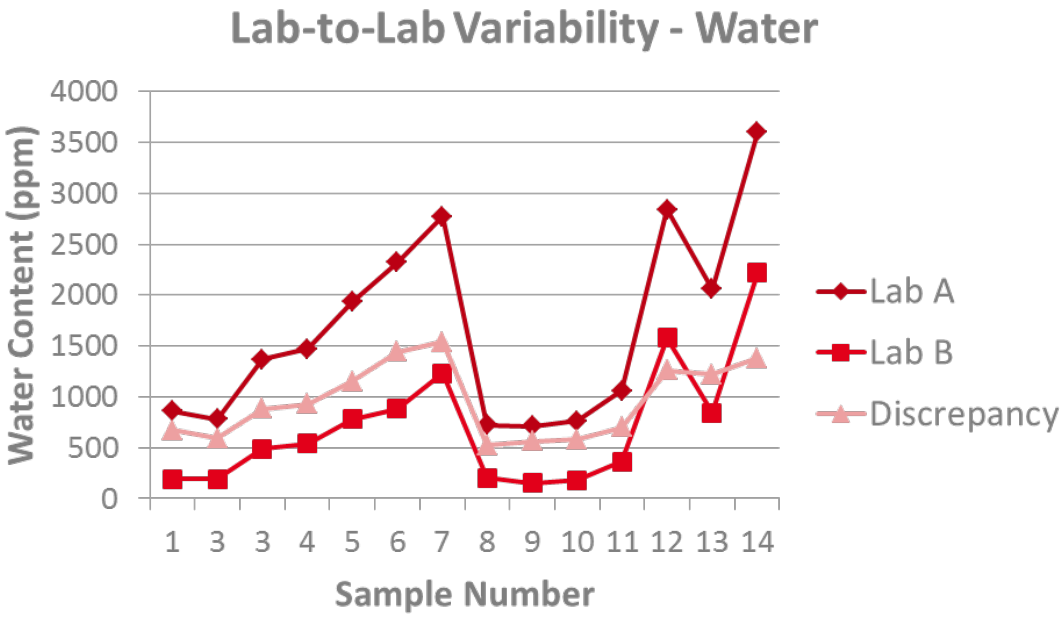




- These calculations estimate best case and worst case tolerances for a sample
- E.g. 1000ppm sample
  - Lab-to-lab range is +/-532ppm
  - Measurement-to-measurement range is +/-48ppm
- Even using the same lab, infrequent sampling can push expected tolerances toward reproducibility numbers

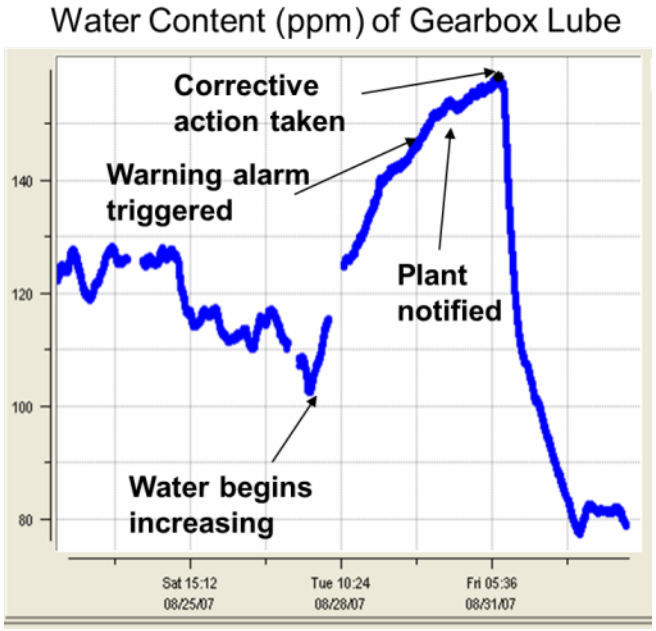
Example Lab-to-Lab Variability

- 14 identical samples split between two labs
- Same ASTM test method specified for both labs
- Major discrepancy in the two sets of results



Benefits of Online Water Contamination Monitoring

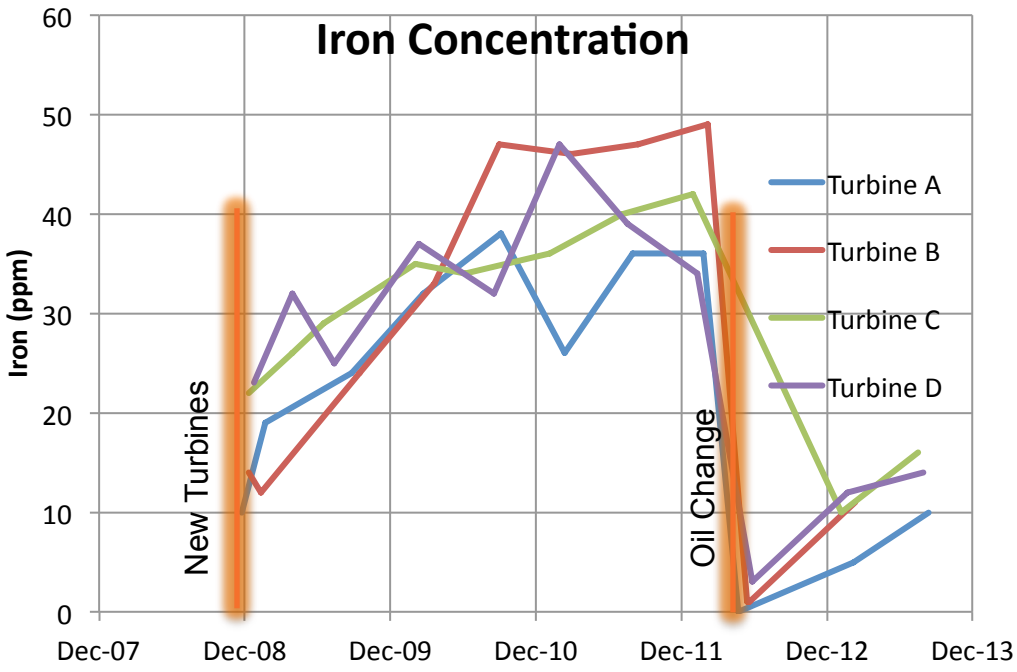
- Get detailed insight to daily/ seasonal fluctuations in water contamination levels
  - Is your lubricant staying sufficiently dry?
  - Are your current defenses sufficient?
- Detect water intrusion events when they occur
- Identify units with malfunctioning breathers and/or dehydrators
- Proactively address water contamination problems before they impact lubricant performance



Offline Analysis: Iron Concentration

- Iron concentration values trend with age of oil
  - Particles “seen” by ICP are sub 3µm
  - Filter does not remove particles this small
- Useful for evaluating the health of the lubricant but not the equipment

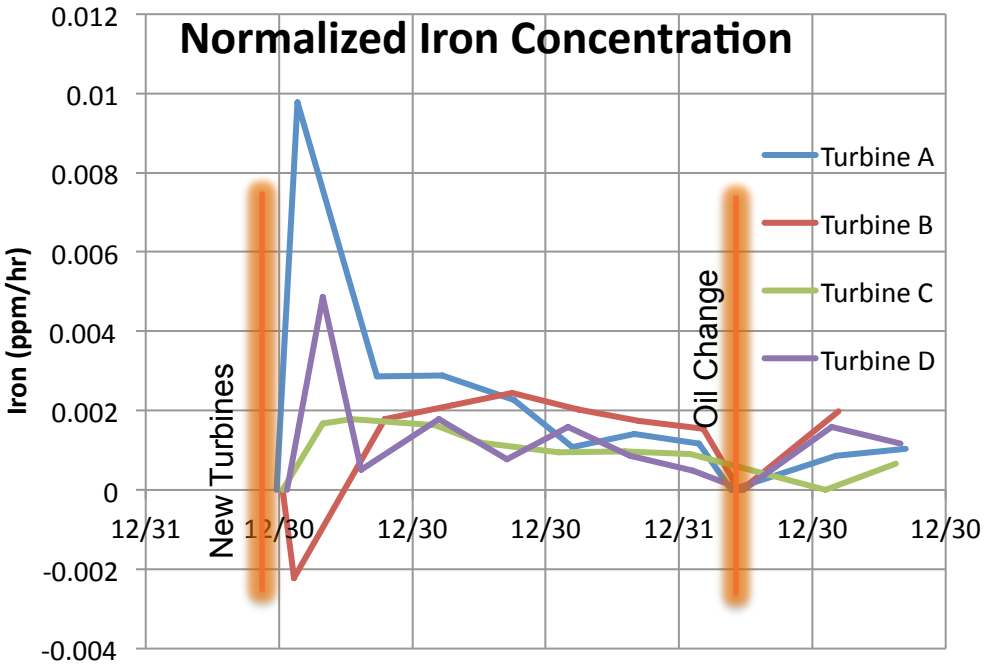
Oil Analysis Trends from 2 Faulted and 2 Healthy Turbines



Turbine A, B are faulty
Turbine C, D are healthy

Offline Analysis: Iron Concentration

- Normalize by oil age to evaluate rate of iron generation
- Decreasing trend over time as gearbox surfaces smooth
- Could be useful for filter performance analysis
- Not useful for gearbox health analysis



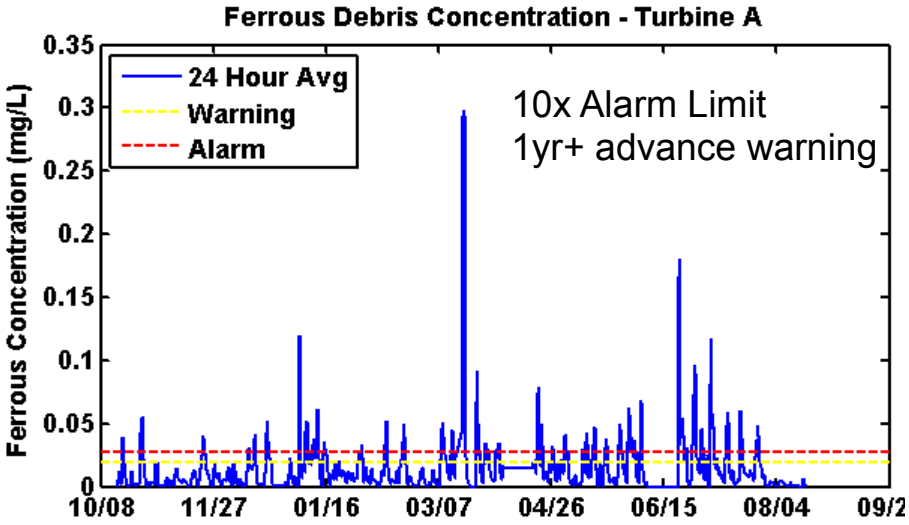
Turbine A, B are faulty
Turbine C, D are healthy

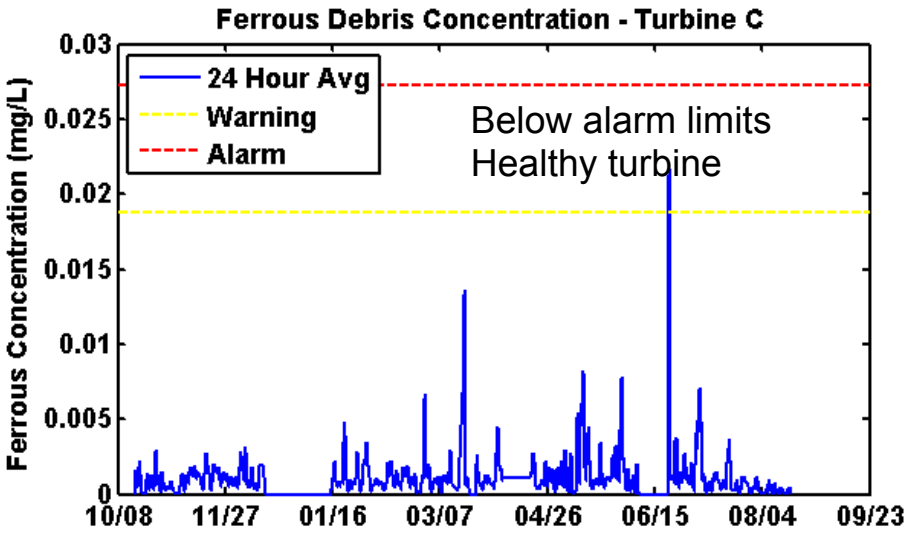
Offline Analysis: Particle Count

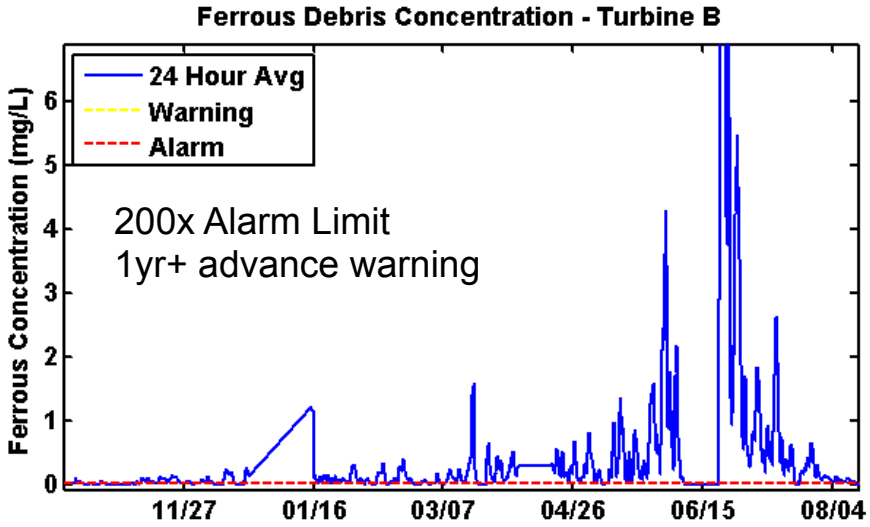
- Offline particle count shows similar lack of information
- Results are confounded by nonmetallic contaminants
- Latest samples to the right indicate the two faulty turbines are healthier than the two healthy turbines!

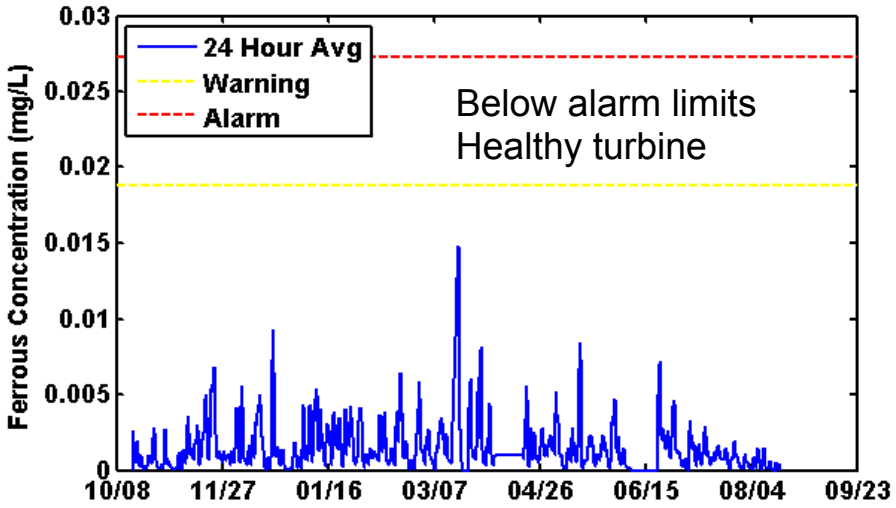
Turbine A	Feb-12	May-12	Mar-13	Sep-13
25-50µm	450	405	946	180
50-100µm	90	30	165	45
100µm+	15	0	15	0
Turbine B	**Sep-11**	**Mar-12**	**Jun-12**	**Mar-13**
25-50µm	135	255	1471	180
50-100µm	0	0	45	15
100µm+	15	0	0	15
Turbine C	**Aug-11**	**Jan-12**	**Feb-13**	**Aug-13**
25-50µm	135	300	586	1096
50-100µm	0	60	0	165
100µm+	0	15	0	120
Turbine D	**Jan-12**	**Jul-12**	**Feb-13**	**Aug-13**
25-50µm	4039	8333	721	405
50-100µm	285	480	45	75
100µm+	15	105	45	30

Online Wear Debris Monitoring



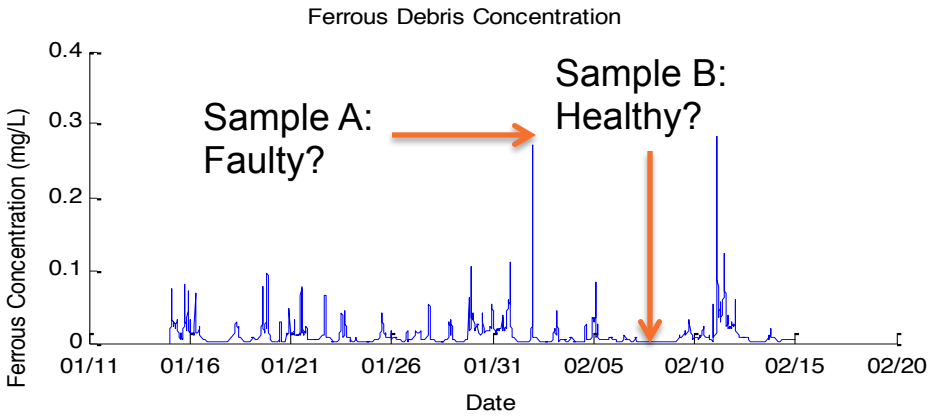






Why is Online Monitoring Required for Gearbox Health?

- Wear metal generation is a stochastic process
- Exceedingly low probability of catching wear metal in a small oil sample
  - Probability of catching 1 wear particle greater than 100μm on turbine A in a 4oz sample is less than 1%!
- Impractical to analyze larger samples or sample more often



Wear metal concentrations vary dramatically based on operating conditions. Accurate conclusions cannot be drawn from small samples of oil.

Combining Online and Offline Monitoring

- The best lubricant health management approach combines online and offline methods
- Use the strength of real-time data to…
  - Reliable monitor asset health
  - Reduce response time
  - Optimize sampling and drain intervals
  - Validate offline analysis
- Use the strength of laboratory analysis to…
  - Provide detailed understanding of lubricant condition and breakdown
  - Verify suitability of the lubricant
  - Validate online analysis

THANK YOU!

QUESTIONS?

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