Integrating Grease Sampling and Analysis into Wind Turbine Maintenance

Main and Pitch Blade Sampling

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Grease Sampling

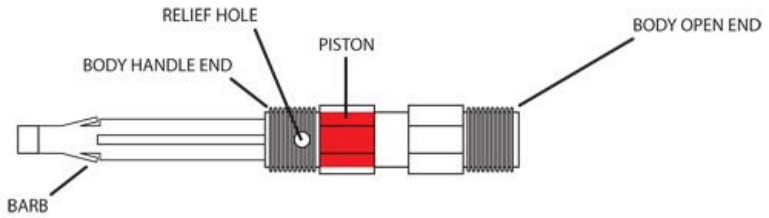
- Historically used during disassembly following failure
- Samples only available near access points, ports
- ASTM D7718 and D7918 designed for in-service grease sampling and analysis
- Projects initiated in USA and Denmark to test effectiveness of grease sampling

ASTM D7718 Standard Development

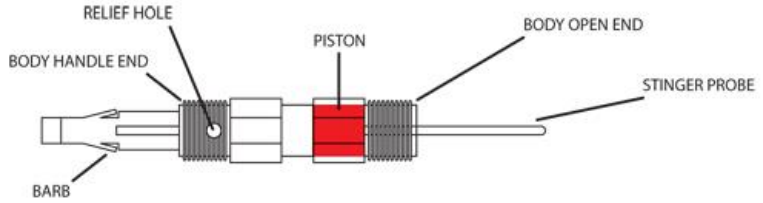
- Developed in 2009 and published in 2011
- Incorporation of grease sampling research
- Inclusion of historical methods for sampling with considerations and limitations
- Failed component sampling, care in obtaining sample or multiple samples
- Use of tubing, adequacy of suction alone, possibility of peripheral grease sampling
- Inclusion of new technologies for active and passive sampling

Grease Sampling - Scope of ASTM D7718

- In-service grease samples, various components
- “Passive” and “Active” sampling
- “Actuate” to take core samples



Passive Grease-Sampling Device (shown as Fig. 3 in ASTM D7718)



Active Grease-Sampling Device (shown as Fig. 1 in ASTM D7718)

Grease Sampling Devices

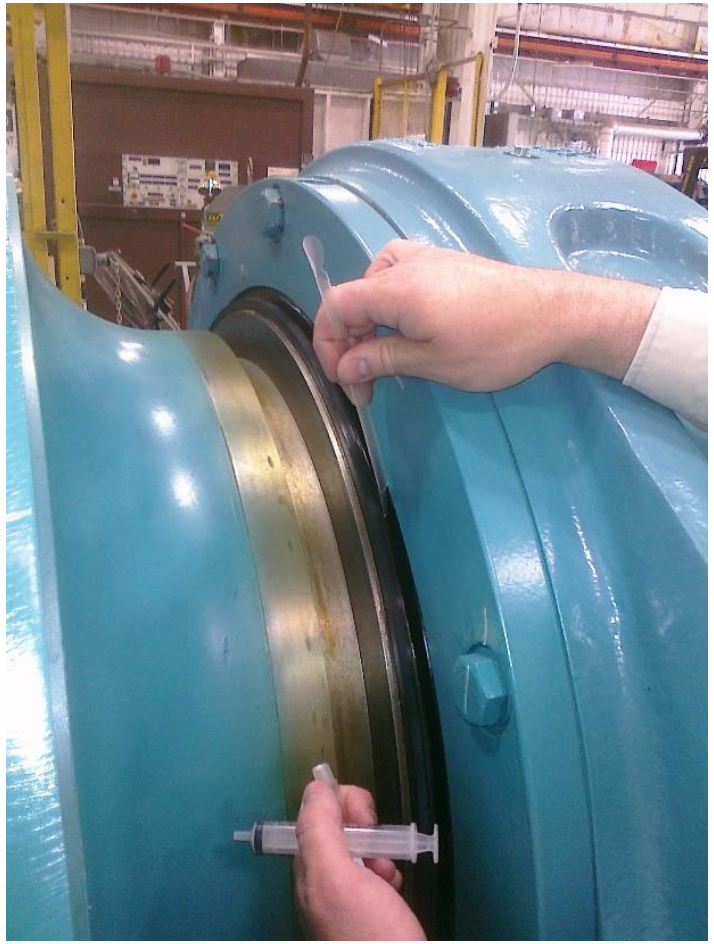
- Clear body and precision fit piston in standard configuration
- Can be attached to T-handle for precise sample location adjacent to bearing
- Designed to optimize the analysis process and allow low-volume analysis

Passive Grease Sampling Device

Passive Grease Sampling Device attached to a T-handle

Wind Turbine Grease Sampling Challenges

- Determining active zone
- Accessing active zone
  - Difference in bearing design
- Realistic sample size
- Handling challenges for analysis
- Development of ASTM D7718



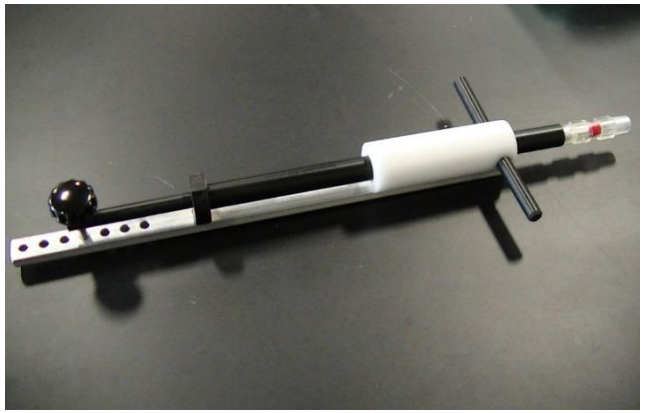
Sampling from a main bearing with no access plug

Acceptance and Use

- D7718 is basis for AWEA Recommended Practices for wind turbine sampling
  - RP-812 Grease Sampling - Main Bearing
  - RP-813 Grease Sampling - Generator Bearing
  - RP-814 Grease Sampling - Pitch Bearing
  - RP-815 Grease Analysis
- Recommended practices were developed in 2012 and revised at the end of 2016
- Utilized by Wind companies worldwide

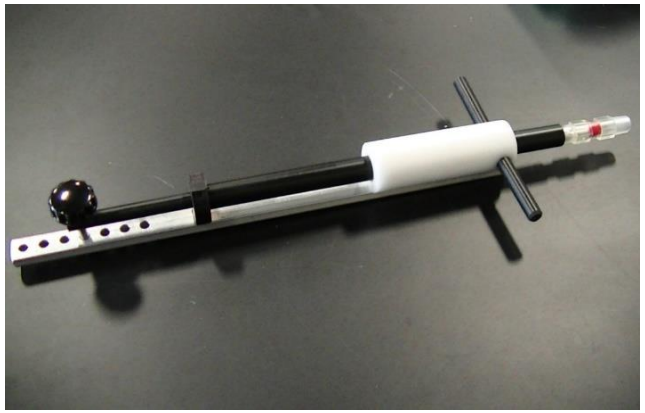
Wind Main Bearing Sampling: RP-812

- Grease flow dependent on temperature, bearing movement
- Grease Thief & T-handle used to capture live-zone grease
- Revised T-handle developed for Denmark Off-shore Wind Research Project
- Additional project for sampling Blade Bearings published in June 2016



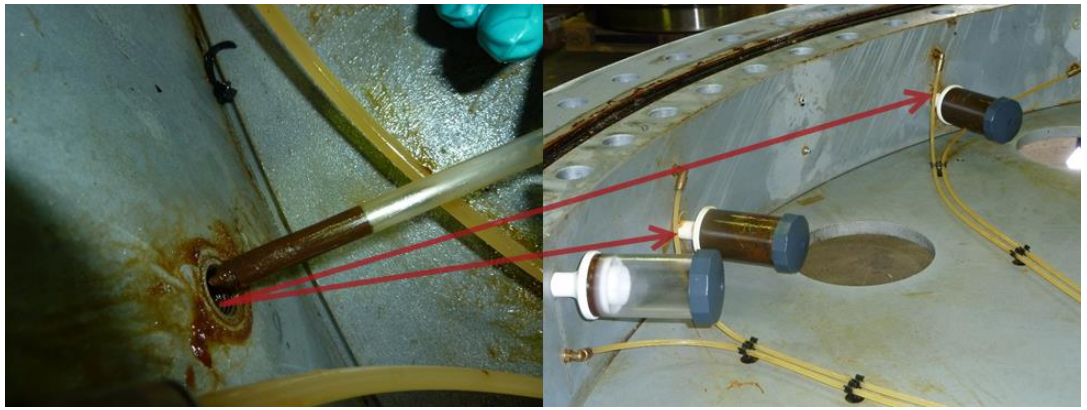
Wind Generator Bearing Sampling: RP-813

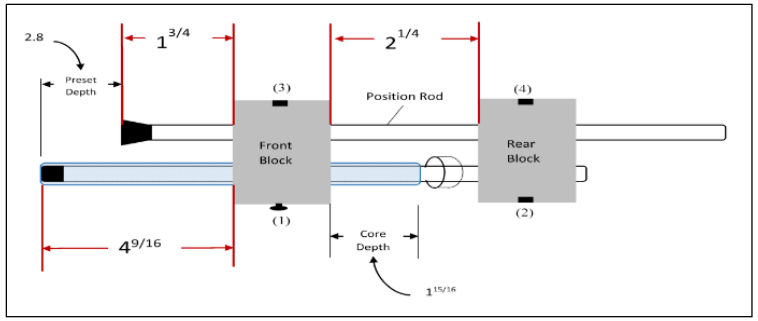
- Access typically at bottom drain chute
- Less critical than other locations due to higher speed of shaft
- Valuable in finding root-cause of lubrication issues such as wrong grease or contamination



Wind Blade Bearing Sampling: RP-814

- Sampling method developed from uptower efforts and on ground-level failed blade bearings at US wind farm
- Shop sampling of removed bearings from North Sea/Europe
- Use of GT Slim device for accessing smaller openings down to 8mm diameter clearance



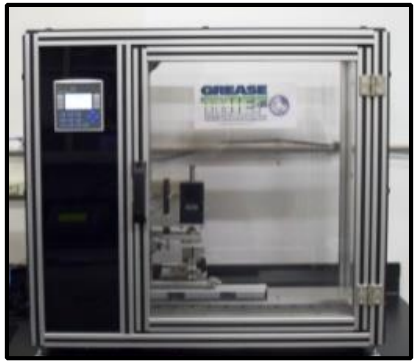


GT Slim Device

Analysis Techniques: ASTM D7918

- ASTM D7918 developed in 2010 and published in 2015.
- Current work item to add moisture and particle counting to testing procedures

Ferrous debris level



Die Extrusion

Colorimetry

Linear Sweep Voltammetry

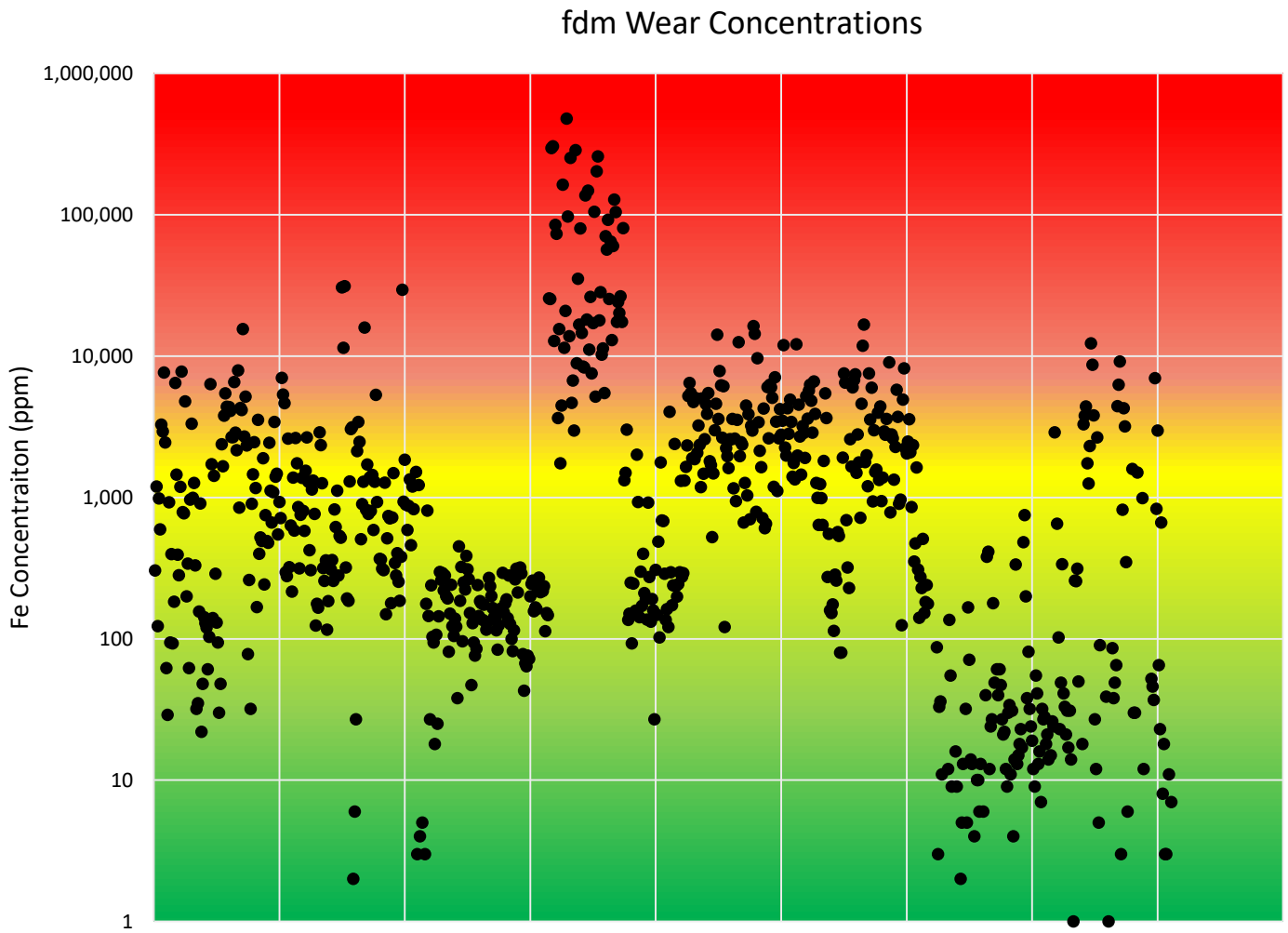
Elemental Spectroscopy

FTIR

Water in ppm

Analysis Techniques: RP-815

- Three levels of analysis test slates
  - Screening: for routine analysis
  - Exception testing: when problems are suspected
  - Environment specific: moisture, etc.



Value of Grease Analysis

- Screening analysis of entire wind turbine 2x/yr (up to 14 samples) for ~$350/yr
- Some problems can be corrected uptower for <$2000
- Single bearing failure can cost more than $350,000 for downtime, crane rental, replacement
- Feedback from grease analysis can be used to optimize lubricant use, saving further costs

Conclusions

- Sampling methods from ASTM D7718 proven in wind applications and captured in RPs 812-814
- Analysis techniques defined in D7918 proven through research projects and selection guidance found in RP-815
- Contamination or compromised lubrication can be traced to source and prevent systemic failures
- Wear levels can be compared in similar equipment, trended with routine sampling
- New tools are available to support smaller drain port sizes and/or blade bearing applications