Grease Technology in Wind Turbine Applications

Castrol Tribol GR SW 460-1

Presented by:

Luis Blazquez

III Wind Farm Operators Forum
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Agenda

- Main Bearing Reliability - Context
- Grease Composition
  - Base Oils
  - Additives
  - Thickening Systems
- Grease Benchmarking
- Wind Turbine Applications and Challenges
- Product Development
- Grease Changeover Procedure
- Main Bearing Grease Analysis
**BEARINGs MAINTENANCE COST**
PLANNED VS UNPLANNED MAINTENANCE

Semi annual/annual planned maintenance

<table>
<thead>
<tr>
<th>EVOLUTION</th>
<th>COST</th>
<th>TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grease pitch and yaw bearings</td>
<td>USD 600 per wind turbine generator</td>
<td>12 man-hours</td>
</tr>
<tr>
<td>Grease main bearing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grease generator bearings</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Cost of component failures (hours/USD):

- **Electrical failures**
  - 7 man-hours
  - Cost per event USD 3,000

- **Pitch/yaw drive failure**
  - 15 man-hours
  - Cost per event USD 3,000

- **Gearbox repairs**
  - 40 man-hours
  - Cost per event USD 25,000

- **Main bearing failure**
  - 80 man-hours
  - Cost per event USD 180,000

- **Pitch bearing failure**
  - 65 man-hours
  - Cost per event USD 200,000

- **Gearbox replacements**
  - 65 man-hours
  - Cost per event USD 325,000

*Source: MAKE*

*Failure rate ~ 3%*
Monitor:
- You can’t improve what you don’t measure

**Improved Maintenance:**
- Through increased monitoring using grease analysis and CMS
- Ensure proper regreasing frequency is followed

**Lubricant based options to extend bearing life:**
- Understand the unique operational challenges of main bearings
- Benchmark current product performance in use
- Identify lab tests to correlate to field challenges and performance
- Formulate based on grease thickening systems, base oils and additive interactions / synergies
- Higher technology grease with unique surface improving qualities to maximize bearing life
What’s A Lubricating Grease?

ASTM defines Grease as:
“a solid to semi-fluid product or dispersion of a thickening agent in a liquid lubricant. Other ingredients imparting special properties may also be included”

- **Base oil (60-80%)**: performs the primary lubrication functions; kept within the thickener by a combination of Van der Waals and capillary forces.

- **Thickener (2-30%)**: fibrous/gel-like material to hold base oils and additives

- **Additives (0 -10%)**: liquid or solids to improve certain properties such as EP AW, Rust Inhibitors, VI improvers, tackiness/adhesion, etc.
Base Oils

- **Mineral Oils:**
  - Paraffinic, Group 1, 2 and 3
  - Naphthenic

- **Synthetic Oils:**
  - PAOs
  - Esters
  - PAGs
  - Silicone
  - PFPEs

- **Biobased oils**
  - Vegetable Oils
  - Vegetable Oils Derivatives
Complex Grease Thickening Systems
Lithium Complex, Calcium Complex

Lithium Complex is popular for high temperature applications:
- High dropping point (>300°C)
- High continuous operating temperature:
  - 150°C mineral based
  - 200°C synthetic based
- Excellent oxidation resistance

Advantages in wind turbine applications:
- Excellent mechanical stability
- Excellent oil separation properties
- Acceptability of the additives
- Broad compatibility with other grease types

\[\text{CH}_3\text{-(CH}_2\text{)}\text{5-CH}_2\text{OH-(CH}_2\text{)}\text{10-COOH} + \text{LiOH} \rightarrow \text{CH}_3\text{-(CH}_2\text{)}\text{5-CH}_2\text{OH-(CH}_2\text{)}\text{10-COOLi + H}_2\text{O} \]

1. Adipic acid
2. Sebacic acid
3. Azelaic acid

Micrograph (D): Lithium Complex Greases Using STRATCO® Contactor™ Reactor

Complexing agents
- Adipic acid
- Sebacic acid
- Azelaic acid
### Common Additives for Greases

<table>
<thead>
<tr>
<th>Additive</th>
<th>Purpose</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme Pressure (EP) &amp; Anti-wear</td>
<td>Prevent metal to metal contact under extreme pressure and temperature</td>
<td>ZDTP, phosphates, sulfurized fats</td>
</tr>
<tr>
<td>Anti Oxidants</td>
<td>Slow the oxidation (breakdown) process</td>
<td>ZDTP, hindered phenols, amines</td>
</tr>
<tr>
<td>Friction Modifiers</td>
<td>Reduce friction and increase efficiency</td>
<td>MoDTC, MoDTP, phosphorous, esters</td>
</tr>
<tr>
<td>Rust Inhibitors</td>
<td>Slow corrosion reactions</td>
<td>Phenolates, sulfonates</td>
</tr>
<tr>
<td>VI Improvers</td>
<td>Improve viscosity performance at low and high temperatures</td>
<td>Polybutadienes, OCP, Polyisobutilenes, PMA</td>
</tr>
<tr>
<td>Pour Point Depressants</td>
<td>Improve flow at low temperatures</td>
<td>Diverse Polymers</td>
</tr>
<tr>
<td>Solid Friction Modifiers</td>
<td>Reduce friction and increase efficiency</td>
<td>MoS2, Graphite, CaCO3</td>
</tr>
<tr>
<td>Tackifiers</td>
<td>Resist water/chemical wash out</td>
<td>High MW polymers</td>
</tr>
</tbody>
</table>
Wind Turbine Grease Applications

**GEARBOX TYPE**

- Pitch adjustment bearings
- Drive Train Main bearings
- Generator bearings
- Yaw system bearings

**DIRECT DRIVE**

- Main bearings
- Pitch adjustment bearings
- Yaw system bearings
• Boundary conditions are more common in the heavy duty industries due to low speeds, high loads and high temperatures.

• Primary function of lubrication is to supply a lubricating film preventing metal-to-metal contact in all conditions.

\[ N = \text{Stribbeck number} = 10^9 \times \frac{\text{viscosity} \times \text{speed}}{\text{load}} \]
Main Bearing Greases
Formulating to Meet the Challenges

Wind Turbine Main Bearing Grease Product Profile
- Withstand high loads and shock loads (including axial loads)
- Resist service wear and fretting wear
- Display low friction for energy saving and long component service life
- Resists shearing (good mechanical stability)
- Resists water ingress
- Resists corrosion attack
- Good mobility at low temperatures (easy start up)
- Controlled bleed rate and oil separation

Challenge
- Multiple test protocols and specifications
- Combining all ideas for such a grease into just ONE product
- May not meet the needs of other WT applications (ie. pitch, yaw)
- Requirements continue to change based on WT design
<table>
<thead>
<tr>
<th>Operating Conditions / Challenges</th>
<th>Grease Requirements</th>
<th>Potential Bench Tests to Indicate Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stop/Start and low speed</td>
<td>Wear protection, film thickness</td>
<td>FE8, SRV</td>
</tr>
<tr>
<td></td>
<td>Low friction - energy efficiency</td>
<td></td>
</tr>
<tr>
<td>Stand-still conditions and vibration</td>
<td>Resistance against fretting and fretting corrosion</td>
<td>Ripple IME, SNR FEB2, Fafnir, SRV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapidly changing loads</td>
<td>Load carrying/EP capability</td>
<td>FE8, SRV, 4-Ball EP</td>
</tr>
<tr>
<td></td>
<td>Low friction - energy efficiency</td>
<td></td>
</tr>
<tr>
<td>High thrust load/movement (main shaft bearing)</td>
<td>Wear protection</td>
<td>FE8, SRV</td>
</tr>
<tr>
<td></td>
<td>Low friction - energy efficiency</td>
<td></td>
</tr>
<tr>
<td>Water contamination (Condensation or environment /sea water)</td>
<td>Water resistance</td>
<td>Ripple with water and salt water, Emcor Rust Test</td>
</tr>
<tr>
<td></td>
<td>Corrosion protection (sea water)</td>
<td></td>
</tr>
<tr>
<td>Very long re-lubrication intervals</td>
<td>Long term shear stability</td>
<td>Worked Stability, Roll stability</td>
</tr>
<tr>
<td>Low start up temperatures</td>
<td>Low temperature start-up and running torque</td>
<td>Low temp torque, Flow pressure</td>
</tr>
<tr>
<td>Low temperature application</td>
<td>Low temperature pumpability</td>
<td></td>
</tr>
</tbody>
</table>
## Benchmark Program
### Commercially Available Products

<table>
<thead>
<tr>
<th>Product</th>
<th>COM A</th>
<th>COM B</th>
<th>COM C</th>
<th>COM D</th>
<th>COM E</th>
<th>COM F</th>
</tr>
</thead>
<tbody>
<tr>
<td>NLGI grade</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>WP [mm/10]</td>
<td>330</td>
<td>340</td>
<td>305</td>
<td>302</td>
<td>305</td>
<td>315</td>
</tr>
<tr>
<td>Base Oil Type</td>
<td>Syn/M</td>
<td>Syn/M</td>
<td>Syn</td>
<td>Syn</td>
<td>Syn</td>
<td>M</td>
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<tr>
<td>Base Oil ISO Grade</td>
<td>150</td>
<td>320</td>
<td>460</td>
<td>320</td>
<td>460</td>
<td>1000</td>
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<tr>
<td>Thickener type</td>
<td>LiCpx</td>
<td>LiCpx</td>
<td>LiCpx</td>
<td>Li-12-OH</td>
<td>LiCpx</td>
<td>Li-12-OH</td>
</tr>
<tr>
<td>Application (PDS)</td>
<td>M/P/Y</td>
<td>-</td>
<td>M/P/Y</td>
<td>M/P/Y</td>
<td>-</td>
<td>-</td>
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</table>

<table>
<thead>
<tr>
<th>Test</th>
<th>COM A</th>
<th>COM B</th>
<th>COM C</th>
<th>COM D</th>
<th>COM E</th>
<th>COM F</th>
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</thead>
<tbody>
<tr>
<td>Mechanical Stability</td>
<td></td>
<td></td>
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<tr>
<td>Corrosion</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Low Temp Property</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE8 - Wear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE8 – Temp /Torque</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripple Test - IME</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripple Osc Test no NaCl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ripple Osc Test with NaCl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SNR FEB2 Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAFNIR - ASTM D4170</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRV - ASTM D7594</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRV - ASTM D7594 @ 0°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Relative Performance Rating
- good
- medium
- poor
Benchmark Evaluation / Conclusions

- All the products tested had different characteristics for similar applications
  - Base Oils: Mineral, Synthetic, or Combinations
  - Base Oils ISO Grades: ISO 150, 320, 460 and 1000
  - Thickening systems: Lithium 12-OH and Lithium Complex
  - NLGI grades: 1, 1.5 and 2

- Performances in the identified lab tests (SRV, FE-8, etc.) varied widely

- Fretting Wear Tests: Correlations to field performance

- Development of a new grease candidate:
  - Starting with the thickening system
  - Additive interaction
  - Process optimization
  - Product testing and validation
## Benchmark Program
### Developing Grease Candidates

<table>
<thead>
<tr>
<th>Product</th>
<th>COM A</th>
<th>COM B</th>
<th>COM E</th>
<th>COM F</th>
<th>CAN 1</th>
<th>CAN 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NLGI grade</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
<td>1</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>WP [mm/10]</td>
<td>330</td>
<td>340</td>
<td>305</td>
<td>315</td>
<td>300</td>
<td>325</td>
</tr>
<tr>
<td>Base Oil Type</td>
<td>Syn/M</td>
<td>Syn/M</td>
<td>Syn</td>
<td>M</td>
<td>Syn/M</td>
<td>Syn/M</td>
</tr>
<tr>
<td>Base Oil ISO Grade</td>
<td>150</td>
<td>320</td>
<td>460</td>
<td>1000</td>
<td>320</td>
<td>320</td>
</tr>
<tr>
<td>Thickener type</td>
<td>LiCpx</td>
<td>LiCpx</td>
<td>LiCpx</td>
<td>Li-12-OH</td>
<td>Li-12-OH</td>
<td>Li-12-OH</td>
</tr>
<tr>
<td>Application (PDS)</td>
<td>M/P/Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>M/P/Y</td>
<td>M/P/Y</td>
</tr>
</tbody>
</table>

### Performance Ratings

- **Relative Performance Rating**
  - good
  - medium
  - poor

### Tests

- Mechanical Stability
- Corrosion
- Low Temp Property
- FE8 - Wear
- FE8 - Temp/Torque
- Ripple Test - IME
- Ripple Osc Test no NaCl
- Ripple Osc Test with NaCl
- SNR FEB2 Test
- FAFNIR - ASTM D4170
- SRV - ASTM D7594
- SRV - ASTM D7594 @ 0°C
WEAR PROTECTION, LONG-LASTING APPROACH: MICROFLUX TRANS PLASTIC DEFORMATION TECHNOLOGY*

FROM SACRIFICIAL PROTECTION...

...TO SURFACE MICROSMOOTHING
YOUR ADVANTAGE IN AN INDUSTRIAL WORLD

MICROFLUX TRANS PD TECHNOLOGY

STAGE 1

PROTECTION

PROTECTIVE LAYER FORMS IMMEDIATELY

STAGE 2

COMPRESSION

PROTECTIVE LAYER COMPRESSED, REDUCING FRICTION

STAGE 3

MICROSMOOTHING

ADDITIVES MIGRATE INTO METAL SURFACE
Wear Protection – FE8 Test

**FE8 TEST** - DIN 51819-2: Mechanical-dynamic testing in roller bearing test apparatus FE8

- Fill two tapered roller bearing (31312) with 200 mL grease/ bearing
- Mount on roller bearing test apparatus
- Temperature = RT, no cooling
- Duration = 500 h
- Speed = 75 rpm
- Axial load = 50 kN

<table>
<thead>
<tr>
<th>Property</th>
<th>COM A</th>
<th>COM C</th>
<th>COM E</th>
<th>CAN 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW50 [mg]</td>
<td>2.9</td>
<td>17.6</td>
<td>2.4</td>
<td>3.5</td>
</tr>
<tr>
<td>MK50 [mg]</td>
<td>22.5</td>
<td>57.1</td>
<td>30.1</td>
<td>9.0</td>
</tr>
<tr>
<td>Torque - Start [Nm]</td>
<td>24.1</td>
<td>15.3</td>
<td>17.7</td>
<td>11.4</td>
</tr>
<tr>
<td>Torque - Running [Nm]</td>
<td>17.6</td>
<td>5.7</td>
<td>7.2</td>
<td>5.7</td>
</tr>
<tr>
<td>Temp - max [°C]</td>
<td>106</td>
<td>57</td>
<td>87</td>
<td>46</td>
</tr>
<tr>
<td>Temp - Running [°C]</td>
<td>88</td>
<td>52</td>
<td>58</td>
<td>46</td>
</tr>
</tbody>
</table>
Ripple & Corrosion Protection
IME Aachen

Bearing: Four point contact ball bearing
(FAG QJ212.TVP)

Load: 70 kN
Test duration: 28 h (1 mio cycles)
Frequency: 10 Hz
Contamination: 1% NaCl at 6ml/min
Measurement: maximum ripple depth, average ripple depth, corrosion grade

Limits:
- RD-max ≤ 10 µm
- RD-av ≤ 3 µm
- Corrosion grade ≤ 2

<table>
<thead>
<tr>
<th>Product</th>
<th>COM A</th>
<th>COM B</th>
<th>COM C</th>
<th>COM D</th>
<th>COM E</th>
<th>COM F</th>
<th>CAN 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ripple Depth – Max [µm]</td>
<td>1.7</td>
<td>2.3</td>
<td>44.1</td>
<td>2.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripple Depth – Av [µm]</td>
<td>0.45</td>
<td>0.60</td>
<td>13.2</td>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrosion Grade</td>
<td>1.0</td>
<td>3.0</td>
<td>3.0</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SRV – Fretting Test ASTM 7594
(100N | 50Hz | 50°C | 0.3mm | 4h)

ASTM 7594-10 (100N/50Hz/50°C/0.3mm/4h)

<table>
<thead>
<tr>
<th></th>
<th>COM A</th>
<th>COM B</th>
<th>COM C</th>
<th>CAN 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball Scar Diameter, mm</td>
<td>0.40</td>
<td>0.73</td>
<td>0.41</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Ball Scar Diameter, mm: COM A = 0.40, COM B = 0.73, COM C = 0.41, CAN 3 = 0.33

Fretting D7594, $\mu$  | Scar Diameter, mm
# Benchmark Program

## Produce Trial Batch – Process Verification

<table>
<thead>
<tr>
<th>Product</th>
<th>COM A</th>
<th>COM B</th>
<th>COM E</th>
<th>COM F</th>
<th>CAN 1</th>
<th>CAN 2</th>
<th>CAN 3</th>
<th>CAN 3 Trial batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>NLGI grade</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
<td>1</td>
<td>1.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>WP [mm/10]</td>
<td>330</td>
<td>340</td>
<td>305</td>
<td>315</td>
<td>300</td>
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</tr>
<tr>
<td>Base Oil Type</td>
<td>Syn/M</td>
<td>Syn/M</td>
<td>Syn</td>
<td>M</td>
<td>Syn/M</td>
<td>Syn/M</td>
<td>Syn</td>
<td>Syn</td>
</tr>
<tr>
<td>Base Oil ISO Grade</td>
<td>150</td>
<td>320</td>
<td>460</td>
<td>1000</td>
<td>320</td>
<td>320</td>
<td>460</td>
<td>460</td>
</tr>
<tr>
<td>Thickener type</td>
<td>LiCpx</td>
<td>LiCpx</td>
<td>LiCpx</td>
<td>Li-12-OH</td>
<td>Li-12-OH</td>
<td>Li-12-OH</td>
<td>LiCpx</td>
<td>LiCpx</td>
</tr>
<tr>
<td>Application (PDS)</td>
<td>M/P/Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>M/P/Y</td>
<td>M/P/Y</td>
<td>M/P/Y</td>
<td>M/P/Y</td>
</tr>
</tbody>
</table>

**Mechanical Stability**

**Corrosion**

**Low Temp Property**

**FE8 – Wear**

**FE8 – Temp /Torque**

**Ripple Test - IME**

**Ripple Osc Test no NaCl**

**Ripple Osc Test with NaCl**

**SNR FEB2 Test**

**FAFNIR - ASTM D4170**

**SRV - ASTM D7594**

**SRV - ASTM D7594 @ 0°C**

<table>
<thead>
<tr>
<th>Relative Performance Rating</th>
<th>good</th>
<th>medium</th>
<th>poor</th>
</tr>
</thead>
</table>
Field Testing and Validation

- **Trial preparation**
  - Compatibility testing
  - Cleaning and flushing old grease
- **Baseline data**
  - Old grease analysis
  - Inspection photos
  - Temperature, vibration, and other data
- **Trial data**
  - Duration
  - Grease analysis
  - Inspection photos
  - Temperature, vibration and other data
Grease Compatibility
ASTM D 6185 Compatibility of Binary Lubricating Greases

**PRIMARY COMPATIBILITY TESTING:**

**Option 1: Greases A and B and 50:50 mixture.**
- Run DP, 100 K and HT Storage Stability.
- If all tests pass, make 10:90 and 90:10 mixtures and run same tests.
- If all tests pass, greases A & B are compatible per the primary criteria

**Option 2: Greases A and B, 10:90, 50:50 and 90:10 mixtures.**
- Run DP, 100 K and HT Storage Stability.
- If all the mixtures pass the 3 tests, Greases A and B are compatible as per the primary criteria

**SECONDARY COMPATIBILITY TESTING**
If additional testing is required depending on the criticality of the specification requirements, selection should be made from a list of the secondary tests (for example: Oil Separation, Four Ball EP, Four Ball Wear, Rust, Copper Corrosion, Fretting Wear, Water Washout, etc...)
Summary: Improved Grease Performance Yields Longer Bearing Life

Keys to making those improvements:

- Understand the unique operational challenges of wind turbines
- Benchmark current product performance in use
- Identify lab tests to correlate to field challenges and performance
- Formulate based on grease thickening systems, base oils, and additive interactions / synergies
- Optimize manufacturing process for better product performances
- Field testing and validation

- Ultimately the grease needs the identified key attributes for assuring adequate lubrication and long service life of wind turbine bearings
Wind Turbine Grease Summary
Main and Yaw Bearings

Grease designed to meet these requirements
✓ High shear stability for long life functionality
✓ Excellent bearing wear protection
✓ High load carrying capability
✓ Excellent low temperature start-up and running torque
✓ High water resistance
✓ Very good corrosion resistance (sea water)
✓ Good pumpability at low temperatures
✓ Excellent friction properties - energy efficiency
✓ Good Fretting/False Brinelling protection per SRV testing
CHANGEOVER PROCEDURE (GREASE)
MAIN BEARING CONFIGURATION

- SKF and Schaeffler FAG bearings
- Manual lubrication, no auto-lube system
- Lube cycle every 6 months using 2+ standard 14 oz. / 400 cc tubes
- The bearing capacity is about 30 lbs. of grease. Two 5-gallon pails are recommended to perform an effective purging of the bearing and to fill the reservoir.
CHANGEOVER PROCEDURE

- Remove lock ring, bolts for inspection cover and pull back cover
- If used, clean pail pump and follower plate. Install the new grease 5-gallon pail. Operate the pump until all old grease is purged from the outlet hose to waste.
- Remove old grease manually from in between rollers and take a used grease sample from between the rollers. Reinstall cover and lock ring.
- Operate the lube pump to fill and purge the bearing housing through the seals and bottom purge plug.
- After a while, a mixture of greases will be seen purging.
- Expect a total of around 20 lbs. of grease to be pumped into the bearing.
- Set the turbine to pinwheel at low rpm (1 – 2 rpm).
- Continue to pinwheel about 20 minutes until all grease has purged from the inspection ports. Around 12 lbs. should be purged.
- Pump the remaining new grease into the bearing through the button head grease fitting.
- Re-assemble all equipment, and clean and inspect the area.
- Put the turbine back into operation.

ALTERNATIVE PROCEDURE: Romax Insight has a hot oil grease flushing procedure that can remove up to 90% of used grease and iron particulate. Can be used when higher cleanliness is desired and incompatible greases are involved.
CHANGEOVER PROCEDURE

GREASE PERFORMANCE METRICS

**VISUAL**
Borescope every 3 months to look for smoothing or verify no damage has been caused by grease incompatibility or inadequate lubrication. Use the proper procedure, with pictures labeled with location.

**TEMPERATURE**
Ensure no main shaft bearing temperature alarms are triggered and trends do not begin to differ significantly from neighboring turbines.

**VIBRATION**
Compare vibration trends to historical data.

**GREASE SAMPLING**
Compare iron (Fe) trends.
Monitor Main Bearing Grease

Used Grease Analysis – What Is Important

- Correct Grease Sampling
  - Remove grease immediately inside port with clean rag or spatula.
  - Sample grease from between rollers with clean spatula or using your finger with a nitrile glove.
  - Use a Grease Thief
Particle Detection

NORMAL WEAR MODE

ABNORMAL WEAR MODE

Analytical Ferrography

Automatic Particle Counting

XRF Spectrometry

ICP Spectrometry

Wear Particle Size (μm)
**Grease Analysis**

- Only 5 g sample is required
  - Visual / colour
  - Water content
  - Acid Number
  - PQ wear index
  - XRF spectrometry
- Additional testing could include
  - FT-IR spectrometry
  - Analytical ferrography
  - Oil bleeding
  - NLGI class
## Grease Analysis Report

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### Report

**YOUR ADVANTAGE IN AN INDUSTRIAL WORLD**

**Industrial**

**IT'S MORE THAN JUST OIL. IT'S LIQUID ENGINEERING.**

---

**PQ Wear Index**: 148

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<td>Others</td>
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</table>

**Low alloy steel severe sliding wear particle**

**Bearing flake (70 µm)**

**Case hardened fatigue chunk**

**Carbonised contaminant**
Thank you!