STLE 2018
Turbine Oil Developments

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BSME, CLS, OMA 1
Topics

• Formulation advancements
  • Degradation prevention and
  • Deposit prevention

• Examples of special applications
  • Combustion turbine – no rust inhibitor, no water sep
  • Steam turbine bowser vs. coalescing filter vs. vacuum dehy / Ultidri

• Filtration impact

• Tailored oils for specific applications

• Chevron product line
Current formulation changes have a Varnish focus

• 1983 – 2003 Move from Group I to II
  • Huge leap in oxidation stability (less degradation)
  • Resulting increase in varnish reports
    • Formulation challenges
    • Lower stability for varnish precursors

• Varnish reduction approaches
  • Prevent degradation – front end - antioxidants
  • Prevent deposits – back end – detergent / dispersants, solvency enhancers
Formulating Turbine Oil for High Performance

![Graph showing antioxidant stability, deposit resistance, and oxidative resistance for different turbine oils. The graph compares Chevron IND16051, Chevron IND16052, and Chevron IND16053.]
Preventing degradation

• Antioxidant improvements
  • Phenol only
  • Phenol + Amine
  • Amine – trending toward alylkated amines

• Additive reactions
  • Rust inhibitors and antioxidants

• Conductivity enhancers
  • Often aromatic
  • Testing indicates their effective life is limited
Antioxidant improvements

DRY TOST D7873 AT 1000 HOURS

Cincinnati Machine (CM) Thermal Stability Test A (Fives Cincinnati)
Preventing deposits

• Detergent / dispersant
  • Traditionally affect water separability

• High varnish solvency
  • PAG turbine oil
  • Oil soluble PAG as top treat

• Synthetic Solvency Enhancers – alkylated naphthalene
  • Good seal compatibility / good stability
  • Minor water separability impact

Leading toward special oil for specific applications?
Detergent dispersant

• Significantly reduces deposits
• Compatibility with acidic rust inhibitors?
• Impacts on water separability?
• How long will it last?
High varnish solvency – PAG lubricant

- Keeps degradation byproducts dissolved well
- Mineral oil compatibility test – surprisingly good
- Low RPVOT oxidation life test
- Poor paint compatibility
- No water separability 2000 – 7000 ppm “normal”
- Poor hydrolytic stability
- Mid use varnish potential good
- End of life varnish similar to mineral oil
### Fresh PAG

<table>
<thead>
<tr>
<th>Condition</th>
<th>ASTM D7843</th>
<th>9 year Group II</th>
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<tbody>
<tr>
<td>D7843 (dE) no IPA</td>
<td>9</td>
<td>29.3</td>
</tr>
<tr>
<td>D7843 (dE) with 25 IPA</td>
<td>4.4</td>
<td>7.3</td>
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# PAG / mineral comparison

<table>
<thead>
<tr>
<th></th>
<th>PAG</th>
<th>Group II</th>
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<tbody>
<tr>
<td>Beginning RPVOT</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>AN @ 25% RPVOT</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>VPR @ 25% RPVOT</td>
<td>68</td>
<td>74</td>
</tr>
<tr>
<td>Beyond end of test MPC</td>
<td>80+</td>
<td>80+</td>
</tr>
</tbody>
</table>

- **Degrade how fast?**
  - PAG: 25
  - Group II: 3

- **Acid number skyrockets**
  - Both poor

- **Beyond end of test MPC**
  - Both fail

**9 year samples**

<table>
<thead>
<tr>
<th></th>
<th>PAG</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC ASTM 7843 no IPA</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td>MPC ASTM 7843 25% IPA (modified as per ACT)</td>
<td>4.4</td>
<td>7</td>
</tr>
</tbody>
</table>

- Some difference but not bad
- Similar

<table>
<thead>
<tr>
<th></th>
<th>PAG</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demulsibility</td>
<td>0</td>
<td>37/40/3</td>
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<tr>
<td>Water ppm</td>
<td>4000</td>
<td>100</td>
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</table>
High varnish solvency – Oil Soluble PAG

• Used as top treat
• Works for cleaning varnish
• Cannot be used with most resin varnish removal
• Longer term problematic
  • Separates into 2-phase system
  • Polarity pulls antioxidants from the mineral oil
  • Causes screen and filter plugging
Solubility in mineral oil is not apparent. Polar component (OSP) appears to pull antioxidants from mineral oil accelerating mineral oil degradation.
Synthetic Solvency Enhancers

• Used in OEM formulations for additive solubility (PAO)
• Retains degradation byproducts in solution
• Stable (not volatile like solvents)
• Can be top treated – conservative
• Slight water separability change
• Works with some resin varnish removal
Filtration impacts

• Resin will remove most rust inhibitors
• Depth media may remove foam inhibitors
• Vacuum dehydration may remove aromatic conductivity enhancers

• Upgrading water removal – less water separability importance
  • Bowsers
  • Coalescing filters
  • Centrifuge
  • Vacuum dehydration
  • Membrane technology
The Future

• Boutique oils for specific R&O applications
  • Is water a concern?
    • Balance deposit performance and water sep performance
    • Choose good varnish oil and upgrade water removal technology
  • Is rust a concern? – no R in R&O
    • Construction materials
      • Stainless steel / carbon steel / aluminum
      • Plastics and composites
  • Is foam a concern?
    • Leave out the inhibitor
    • Balance foam vs air entrainment performance
    • Larger, slower reservoirs for settling
Successful Turbine Oil Selection

1) Understand what performance is needed for your application
2) Ensure the Lubricant meets the OEM requirements
3) Understand how the oil is delivered and chain of custody to ensure no contamination takes place
4) Work with a lubricant supplier who offers comprehensive support

Example: Path of lubricant in a steam turbine.
## Sampling optimization – ASTM D4378-13

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Cost</th>
<th>Steam</th>
<th>Gas</th>
<th>Term</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>$0</td>
<td>daily</td>
<td>100 hr</td>
<td>Short</td>
<td>Seldom done</td>
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<tr>
<td>Color</td>
<td>$0</td>
<td>weekly</td>
<td>200 hr</td>
<td>Short</td>
<td>Seldom done</td>
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<td>Acid NO.</td>
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<td>3 months</td>
<td>1000 hr</td>
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<td>Annual</td>
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<tr>
<td>Water Content</td>
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<td>3 months</td>
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<td>Short</td>
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<tr>
<td>Particle Count</td>
<td>$20</td>
<td>3 months</td>
<td>1000 hr</td>
<td>Short</td>
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<tr>
<td>Viscosity</td>
<td>$5</td>
<td>6 months</td>
<td>500 hr</td>
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<tr>
<td>Rust Test</td>
<td>$60</td>
<td>12 months</td>
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<td>Long</td>
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<tr>
<td>RPVOT / RULER / FTIR</td>
<td>$300</td>
<td>12 months</td>
<td>2000 hr</td>
<td>Long</td>
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<tr>
<td>ICP metals</td>
<td>$10</td>
<td>-</td>
<td>-</td>
<td></td>
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<tr>
<td>MPC</td>
<td>$200</td>
<td>-</td>
<td>-</td>
<td>Long</td>
<td>Selective</td>
</tr>
<tr>
<td>Water Separability</td>
<td>$40</td>
<td>-</td>
<td>-</td>
<td>Short</td>
<td>Selective</td>
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<tr>
<td>Foam test</td>
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<table>
<thead>
<tr>
<th>Frequency</th>
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<tbody>
<tr>
<td>Quarterly</td>
<td></td>
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<tr>
<td>Annual</td>
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</table>
Tailoring analysis focus

• Steam turbines
  • Watch water content closely – online monitoring?
  • Stretch degradation longer (RPVOT, RULER, FTIR)

• Gas turbines
  • Degradation annually to trend
  • Varnish potential has increased importance
    • May change with solubility enhancers / detergent dispersants
    • Water separability not very important

• Rust test (ASTM D665)
  • Additive will naturally deplete over 2 years
  • Resin will remove polar rust inhibitors

• ICP / metals mostly for wear and contamination
Summary

• Turbine oil is a simple formula
• Formulation is not simple
• Determine your primary performance focus then evaluate oils
• Real world performance results lag testing by 10-20 years