Agenda

ESD defined

Lube oil conductivity

ESD test rig evaluations

Field & test stand performance examples

Conclusions
ESD - Hydrocarbons Charging

• Accumulated charge in fluid can discharge to conductive part of circulation system

• Nonconductive filter material may acquire a charge acting like a capacitor until the voltage is great enough to overcome gap and discharge to lower potential component of system

• A clicking or rattling sound in the circulation system caused by sparking indicates this cycle of charging and discharging

• Can be a safety concern – ie. Hydrogen compressors

• Can create holes in filters, decreasing contaminant removal

• “May” accelerate oxidation and deposits
API RP 2003 - Influence of Conductivity

• API RP 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents
  “Generally, liquids with conductivity greater than 50 picosiemens / meter (pS/m) do not accumulate static charges…”

  Low Conductivity < 50 pS/m  High Conductivity > 50 pS/m

• There are other conductivity guidelines referenced in related industry articles
Base Oil and Additive Influence on Conductivity

- Minimal base oil influence - it’s the **additives**
- Non zinc hydraulic oils can be high conductive

<table>
<thead>
<tr>
<th>ISO 46 Hydraulic Oil – Primary base oil and AW package</th>
<th>pS/m ASTM D 4308</th>
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<tbody>
<tr>
<td>ZDDP in Group I</td>
<td>226</td>
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<tr>
<td>Non zinc - Group III</td>
<td>119</td>
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<table>
<thead>
<tr>
<th>ISO 32 Turbine Oil - Primary base oil API group</th>
<th>pS/m ASTM D 4308</th>
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<tbody>
<tr>
<td>Oil B - Group I</td>
<td>4</td>
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<tr>
<td>Oil F - Group II</td>
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<tr>
<td>Oil E - Group II</td>
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<td>Oil D - Group II</td>
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<td>Oil I - Group II</td>
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<td>Oil G - Group II</td>
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<td>Oil H - Group III</td>
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<td>Oil K - Group III</td>
<td>111</td>
</tr>
<tr>
<td>Oil J - Group IV (PAO)</td>
<td>6</td>
</tr>
</tbody>
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ESD Test Rig
Low Conductive Turbine Oil Reaches 50K Service Hours

Low conductive oil (16 pS/m) in two GE Frame 7FA’s

• Both turbines with servo valve varnish issues starting at approx. 20,000 service hours using a well known API Group I turbine oil (4 pS/m)

• Both turbines now above 50,000 service hours without issue

• No audible or visual signs in filters of ESD

• Oil analysis and visual inspections are very good
High Conductive Turbine Oil - Deposits Found

High conductive oil (286 pS/m) in GE Frame 7FA

- Filter media removed and deposits extracted using toluene, yielding 13.9g deposit - 58% soluble /42% insoluble material

- No signs of ESD
Proprietary Valve Varnish Rig Test to Create Varnish

Valve Varnish Rig Test:
- Evaluates Varnish Control
- Rig Configuration
  - Oil circulation system containing a reservoir, pump, heat exchanger, filter, and control valves
  - Utilizes cyclic on / off operation to simulate real world conditions

This rig test is a turbine oil performance test that:
- Helps develop high-performing turbine oils
- Replicates real world conditions, hence more relevant than glassware tests
Valve Varnish Rig Test – No Signs of ESD

Additional Monitoring Parameters:
System cleanliness merit ratings:
• 10 (Clean) – 0 (Dirty)
• Filter cleanliness at EOT
• Reservoir cleanliness at EOT
In-service oil condition monitoring analysis:
• Including ultra centrifuge deposit rating
GE Gas Turbine Last Chance Filter - New

New Last Chance Filter internal at 220X30

New Last Chance Filter internal at 220X200
ESD – Our Experience

• Not seen as a leading contributor to varnish deposits

• May impact turbine oil service life with extended active ESD
  • Below 70F (21C) and low micron, ungrounded filters

• May be a safety consideration

• May impact filter life and effectiveness
ESD – Mitigation, if needed

• System grounding (filtration system, piping, reservoir)

• Minimize cold oil circulation

• Minimize entrained air

• Increase oil relaxation time

• Use low flow density and anti-spark filters

• Use high conductivity lubricants
Much is being said about ESD but full effects are not fully understood

Additive chemistry has the major influence on conductivity

High and low conductivity turbine oils have been rig tested to demonstrate ESD

Field and test stand experience show no correlation between ESD and varnish

If needed, ESD mitigation is available