How a high quality Turbine Oil can help reduce Downtime
Key Functions of a Turbine Oil

• Lubricate and remove the heat from key turbine elements (thrust and journal bearings, gear reducers, etc...)

• Act as a power transmission fluid at the start-up of the turbine

• Supply the hydraulic circuit of the regulation system
Reducing Downtime - a practical example

- A 1% improvement in downtime represents a production increase of 1000 bbls/day
- Turbines are one of the greatest sources of unscheduled downtime.
- Offshore turbines represent the greatest challenge
- A goal of < 1% unscheduled downtime for turbines should be achievable.
- With reducing condensate an increasing reliance on gas lift means turbine downtime needs to be as low as possible.
Reducing Downtime - a practical example

- Over two years 99 turbines (on-shore and off-shore) were changed from a basic good quality turbine oil to a higher quality oil based on Group II basestocks.
- Progressive decline in top up volume (up to 10% in wet sealed machines)
- Turbine main bearings show no evidence of staining or wear - this used to be seen
- Much less sludge and longer filter life
- Vibration reduced
## Turbine Oil Key Performance Features

<table>
<thead>
<tr>
<th>Application Need</th>
<th>Lubricant Feature</th>
<th>Potential Benefit/Implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long oil life</td>
<td>Outstanding oxidation stability</td>
<td>Avoid replacing oil</td>
</tr>
<tr>
<td>High reliability</td>
<td>Low sludge/deposit</td>
<td>No control valve «stick»</td>
</tr>
<tr>
<td>Tolerate water contamination (steam)</td>
<td>Good rust protection and demulsibility</td>
<td>No filter Blockage</td>
</tr>
<tr>
<td>Tolerate air contamination</td>
<td>Good air release and foaming properties</td>
<td>Component life</td>
</tr>
<tr>
<td>Protect gear systems</td>
<td>Antiwear Protection</td>
<td>Oil life/ Oil Circ. System operation</td>
</tr>
<tr>
<td>Common reservoir gas &amp; steam</td>
<td>Combine high temp deposit performance with good demulsibility</td>
<td>Component life</td>
</tr>
<tr>
<td>Low Environmental Impact (water turbine)</td>
<td>Good Ecotoxicity</td>
<td>Product / design rationalisation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>safe for aquatic life</td>
</tr>
</tbody>
</table>

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Critical Concerns in Turbine Lubrication

- LARGE EXPENSIVE SYSTEMS
- CONTINUOUS OPERATION ESSENTIAL
- LARGE SUMP VOLUMES
- EXTREMELY EXPENSIVE DOWNTIMES

LONG TERM CONSISTENT LUBRICANT PERFORMANCE ESSENTIAL

- HIGH QUALITY BASESTOCKS
- HIGH QUALITY TURBINE OIL
- CAREFULLY BALANCED QUALITY ADDITIVE COMBINATION

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## Performance Characteristics for Turbine Operation

<table>
<thead>
<tr>
<th></th>
<th>Steam Turbine</th>
<th>Water Turbine</th>
<th>Gas Turbine</th>
<th>Combined Cycle Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Life</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>HT Operation</td>
<td></td>
<td></td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Water Tolerance</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Demulsibility</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Anti-Rust</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anti-Wear</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Anti-Foam</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Air Release</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Low Volatility</td>
<td></td>
<td></td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Low Sludging</td>
<td>++</td>
<td>+</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>

* Required by Some Builders
Turbine Oil Formulation - Keys to Balance

- **Base Oil Quality is Critical**
  - Solvent Refined/Hydroprocessed/Synthetic

- **Additive Selection for Best Overall ("Balanced") Premium performance for Desired Application**
  - Additive quantity is very low compared to other industrial oils (higher additive content can lead to sludge)
**Turbine Oil Formulation**

**Components / Performance Relationships**

**Oil Characteristics**
- Oxidation stability
  - No change in viscosity
  - No deposits building
  - Color stability
- Air tolerance
  - Good air release
  - Good antifoam properties
- Water tolerance
  - Good antitrust and anticorrosion protection
  - Good demulsibility
- Wear Protection (optional)
  - Non-aggressive EP/antiwear to protect gear reducers

**Key Parameters**
- Base stocks quality
- Antioxidant
- Base stocks
- Base stocks/defoamant
- Rust & corrosion inhibitors
- Base stocks/demulsifier
- Base Stocks/antiwear agents

Total additive content <2%

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Turbine Oil Formulation

Hydroprocessed Base Stocks Benefits:

• Better oxidation stability
• Better response to additives
• Better color stability in service

But : Lower solvency than conventional turbine stocks

⇒ a balanced additive system is essential
Base Stock Manufacture

Turbine Oil Base Stocks

Chemical Synthesis → Gp. IV PAO

Isomerize Hydrotreat → Gp. III

Automotive Quality used in Industrial Lubes Gp. I

Vac. Dist. → Extract Aromatics

Cat/Sol Dewax → Hydrofinish

Hydrotreat → HDP Gp. II

Turbine SPN Gp. I
## Base Oil Categories and Characteristics

<table>
<thead>
<tr>
<th>API Group</th>
<th>Saturates %</th>
<th>Sulfur %</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I</strong></td>
<td>&lt;90</td>
<td>&gt;0.03</td>
<td>80-120</td>
</tr>
<tr>
<td>(Solvent Refined)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group II</strong></td>
<td>&gt;/=90</td>
<td>&lt;=0.03</td>
<td>80-120</td>
</tr>
<tr>
<td>(Hydroprocessed)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group III</strong></td>
<td>&gt;/=90</td>
<td>&lt;=0.03</td>
<td>120+</td>
</tr>
<tr>
<td>(Severely Hydroprocessed/ Catalytic dewaxing)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group IV</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>is Polyalphaolefins (PAO)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>API Group</th>
<th>Aromatics</th>
<th>Sulfur</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I</strong></td>
<td>15-30%</td>
<td>0.2-0.5%</td>
<td>20-50 ppm</td>
</tr>
<tr>
<td><strong>Group II/III</strong></td>
<td>&lt;5%</td>
<td>&lt;0.005%</td>
<td>&lt;1 ppm</td>
</tr>
</tbody>
</table>
Base Stock Categories and Distinctions

**API Category**
- **Grp I**
- **Grp II/III**
- **Grp IV**

**Process**
- Solvent Refined
- Hydro-processed
- Chemical synthesis

**Significance**
- **Grp I**
  - Used in Lubricant design for decades
  - Least expensive
  - Fair Stability Pour & Volatility
- **Grp II/III**
  - Good Low Temp.
  - Improved Oxidation/Thermal Stability
  - Fair-Poor Solvency
  - Limited Visc. Range
- **Grp IV**
  - Superior Low Temp.
  - Excellent Oxidation/Thermal Stability
  - Energy Efficiency

*Lower aromatics sulfur, and nitrogen*
*Higher Viscosity Index*
*Low Volatility*

*Pure material no sulfur and nitrogen*
*Higher Viscosity Index*
*Lower Volatility*
Antioxidant Technology

- Antioxidants protect the lube oils from oxidation

- The two major types of antioxidants are: arylamines and hindered phenols

- Antioxidancy effectiveness is influenced by:
  - Additive treat levels in the oil
  - Additive Chemical Structure (MW)
  - Temperature of the inhibited oil in-service

- Carefully selected and tested phenol-amine antioxidant additive systems can offer better protection than either antioxidant type alone.
Antioxidant Technology

What are the Advantages and Benefits of Complex vs Single Antioxidant Systems?

– Effective over a wider temperature range compared to phenols or amines antioxidants alone

– Synergistic combination show higher performance as measured by oxidation tests, such as RBOT, TOST and PDSC, at lower additive treat levels than could be achieved with a single type.

– Allows one to maximized benefits and minimize drawbacks

– Antioxidant Regeneration

Balancing benefits and side effects is the key!
## Anti-oxidant Technology

Comparison of complex vs single antioxidant systems

<table>
<thead>
<tr>
<th></th>
<th><strong>Advantages</strong></th>
<th><strong>Drawbacks</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phenol only</strong></td>
<td>Work at low to mild temps</td>
<td>Volatile at high temps (&gt;100C)</td>
</tr>
<tr>
<td></td>
<td>Good color stability</td>
<td>High MW less soluble in oil</td>
</tr>
<tr>
<td></td>
<td>Low sludge tendency</td>
<td></td>
</tr>
<tr>
<td><strong>Amine only</strong></td>
<td>Work at mild to high temps</td>
<td>Poor color stability vs phenols</td>
</tr>
<tr>
<td></td>
<td>Low volatility</td>
<td>Sludge tendency</td>
</tr>
<tr>
<td></td>
<td>High RBOT response</td>
<td></td>
</tr>
<tr>
<td><strong>Mixed Phenol-Amine (w/balanced synergy)</strong></td>
<td>Work at low to high temps</td>
<td>Minimal</td>
</tr>
<tr>
<td></td>
<td>Fair to Good Color Stability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low sludge tendency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low volatility</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A/O regeneration (RBOT retention)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Better stability at low % vs single A/O</td>
<td></td>
</tr>
</tbody>
</table>
Key Turbine Oil Performance Tests

- Oxidation Stability
  - TOST (D943), RBOT (D2272), CIGRE (ISO DIS 4263/M1297))
  - Property Retention Test (PRT, 71° or 90°C), OCST (M1568/P10)

- Multimetal Corrosion and Antirust Protection
  - ASTM Rust (D665B, sea water)
  - Copper Corrosion (D130)

- Air and Water Separability, Filterability
  - ASTM Foam (D892) - Air Release (D3427)
  - Demulsibility (D1401) - Filterability (M1082)

- Deposit Control (Additive and Oxidation Product Solubility)
  - 100°C Oven Storage Test (P26)
  - Property Retention Test (PRT) - overall oil durability

- Antiwear Performance
  - FZG gear test (DIN 51354)