High Temperature Performance with Alkylated Naphthalene

The 2nd Asian Industrial Lubricants Conference
Singapore
November 12 – 13, 2019
Presentation Outline

• Alkylated Naphthalene Background
• Physical/Chemical Properties
• Performance Evaluations
• Summary
Alkylated Naphthalenes

• High Performance Group V Base Oils

• Co-Base Oil
  • With other synthetics or Group II and Group III oils
  • To enhance thermal and oxidative stability, varnish control and additive response
  • To extend the lifetime of high-performance lubricants
Alkylated Naphthalene Structure

R1 to R8 are independently a linear or branched alkyl group or hydrogen.

The core naphthalene system consists of two fused six-membered rings with an electron rich conjugated π system.
Alkylated Naphthalene Synthesis

- Physical properties are a result of:
  - Number of carbons in the alkyl group (controlled by raw material selection)
  - Degree of branching of alkyl groups (controlled by raw material selection)
  - Number of alkyl groups on naphthalene ring (controlled by chemical processing)
Presentation Outline

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Aniline Point

- Alkylated naphthalenes can aid in solubilizing additives in non-polar base stocks
- Varying balances of Mono Alkylates and Poly Alkylates impart a variety of properties including, but not limited to:
  - Aniline point
  - Viscosity Properties
  - Volatility
  - Flash Point
## Alkylated Naphthalene Properties

<table>
<thead>
<tr>
<th></th>
<th>Viscosity @ 40°C</th>
<th>Viscosity @ 100°C</th>
<th>Viscosity Index</th>
<th>Aniline Point</th>
<th>Noack Volatility CEC L40</th>
<th>Pour Point</th>
<th>Flash Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>AN-7</td>
<td>22 cSt</td>
<td>3.8 cSt</td>
<td>22</td>
<td>40°C</td>
<td>39 wt%</td>
<td>&lt;-48°C</td>
<td>206°C</td>
</tr>
<tr>
<td>AN-8</td>
<td>36 cSt</td>
<td>5.6 cSt</td>
<td>90</td>
<td>42°C</td>
<td>12 wt%</td>
<td>-33°C</td>
<td>236°C</td>
</tr>
<tr>
<td>AN-15</td>
<td>114 cSt</td>
<td>13.5 cSt</td>
<td>115</td>
<td>94°C</td>
<td>2.2 wt%</td>
<td>-39°C</td>
<td>260°C</td>
</tr>
<tr>
<td>AN-19</td>
<td>177 cSt</td>
<td>18.7 cSt</td>
<td>119</td>
<td>103°C</td>
<td>1.4 wt%</td>
<td>-26°C</td>
<td>285°C</td>
</tr>
<tr>
<td>AN-23</td>
<td>193 cSt</td>
<td>19.8 cSt</td>
<td>118</td>
<td>N/A</td>
<td>&lt;1.0 wt%</td>
<td>-21°C</td>
<td>310°C</td>
</tr>
</tbody>
</table>
Performance Features of Alkylated Naphthalenes

• Thermo-oxidative stability
  • Excellent performance because of the electron-rich naphthalene ring

• System cleanliness
  • Excellent varnish control

• Volatility
  • Low volatility as compared to other base stocks

• Viscometrics and VI
  • A variety of viscosities with low pour points and good VI
Performance Features of Alkylated Naphthalenes

• Solvency
  • An intermediate aniline point that has the right balance of polarity
  • Good additive response
  • No surface competition with the additives

• Base oil modifying properties
  • Excellent compatibility with other base stocks to achieve balanced and enhanced performance

• Hydrolytic stability
  • No functional groups that can hydrolyze
Performance Features of Alkylated Naphthalenes

- Good lubricity/film thickness/reduced friction
- Good seal swelling properties
- Nuclear radiation resistance
- Good air release properties
- HX-1 Approvals – “Food Grade”
Main Applications

• Automotive and Stationary Engine Oils
• Automotive and Industrial Gear Oils
• High Temperature Chain Lubricants
• Paper Machine Oils
• Hydraulic Oils
• Circulating Oils/Turbine Oils/R&O Oils
• Screw Compressor Oils
• Heat Transfer Oils
• Windmill Oils and Greases
• Automotive and Industrial Greases
Presentation Outline

• Alkylated Naphthalene Background
• Physical/Chemical Properties
• Performance Evaluations
• Summary
Performance Evaluations

• Thermo-oxidative stability
  • Panel Coker
  • Rotating Pressure Vessel Oxidation Test (RPVOT)
  • Pressure Differential Scanning Calorimetry (PDSC)

• Hydrolytic Stability
  • Beverage Bottle Test

• Volatility
  • Thin Film
Performance Evaluations

• Friction
  • FZG

• Seal Swell
  • Volume Change

• High Temperature Chain
  • Evaporation
  • Varnish Control

• Plywood Manufacturing
  • Varnish Control
Performance Evaluations

• Grease
  • Lithium 12-Hydroxystearate
  • Lithium Complex
  • Polyurea
  • Aluminum Complex
Thermo-oxidative Stability
Panel Coker (FTM 791-3462)

<table>
<thead>
<tr>
<th></th>
<th>100% PAO (ISO VG 220)</th>
<th>10% AN-8 90% PAO</th>
<th>10% AN-15 90% PAO</th>
<th>10% AN-19 90% PAO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coking Value (mg)</td>
<td>9.0</td>
<td>1.0</td>
<td>3.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Temperature Conditions: Test Panel: 200°C; Oil Sample: 140°C
## Grp III (ISO VG 46) vs. Grp III Modified with AN

<table>
<thead>
<tr>
<th>Tests</th>
<th>0.7% R&amp;O Package 99.3% Group III</th>
<th>0.7% R&amp;O Package 15.0% AN-8 84.3% Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RPVOT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM D2272</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifetime, minutes</td>
<td>1339</td>
<td>1926</td>
</tr>
<tr>
<td><strong>CM Thermal Stability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM D2070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition of Steel Rod: Color</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Condition of Copper Rod: Color</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Total Sludge (mg/100 ml)</td>
<td>10.75</td>
<td>5.30</td>
</tr>
</tbody>
</table>
## Grp III vs. Grp III Mod with Ester and AN

<table>
<thead>
<tr>
<th>Tests</th>
<th>0.6% Add Pack*</th>
<th>0.6% Add Pack</th>
<th>0.6% Add Pack</th>
<th>0.6% Add Pack</th>
<th>0.6% Add Pack</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100% Group III*</td>
<td>78% Group III</td>
<td>78% Group III</td>
<td>78% Group III</td>
<td>100% AN-8</td>
</tr>
<tr>
<td></td>
<td>22% Ester***</td>
<td>11% Ester</td>
<td>11% AN-8</td>
<td>22% AN-8</td>
<td></td>
</tr>
<tr>
<td>RPVOT ASTM D2272</td>
<td>Lifetime, minutes</td>
<td>1194</td>
<td>1023</td>
<td>1179</td>
<td>1288</td>
</tr>
</tbody>
</table>

*Ashless package based on nitrogen-phosphorus-sulfur

**Group III ISO VG 46

***Saturated Polyol Ester
Alkylated Naphthalene Synergy with ADPA AO

<table>
<thead>
<tr>
<th>HX-1 Base Oils</th>
<th>PAO 10</th>
<th>White Oil</th>
<th>PAG</th>
<th>AN-19 Food Grade</th>
<th>Ester</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RPVOT, ASTM D2272</strong>&lt;br&gt;Lifetime (Minutes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (no AO)</td>
<td>55</td>
<td>31</td>
<td>15</td>
<td>76</td>
<td>115</td>
</tr>
<tr>
<td>+0.2% ADPA*</td>
<td>268</td>
<td>141</td>
<td>40</td>
<td><strong>905</strong></td>
<td>470</td>
</tr>
</tbody>
</table>

* Alkylated diphenylamine
PDSC Performance of AN Modified Group II
PDSC (ASTM D6186) 160°C, 500 psi oxygen

- 20% AN-19
- 80% Group II
- 20% AN-15
- 80% Group II
- 20% AN-8
- 80% Group II
- 100% Group II
PDSC Performance of AN Modified PAO
PDSC (ASTM D6186) 170°C, 500 psi oxygen

*ADPA = Alkylated diphenylamine
Hydrolytic Stability
Hydrolytic Stability (ASTM D2619)

Group II Base Oil (ISO VG 46) modified by adding 10% of different Group V Base Stocks

High Temperature Performance with Alkylated Naphthalenes
Volutility
## Thin Film Volatility

2 grams in aluminum pan for 24 hours

<table>
<thead>
<tr>
<th></th>
<th>Weight Loss, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>200°C</td>
</tr>
<tr>
<td><strong>AN-19</strong></td>
<td>8.5</td>
</tr>
<tr>
<td><strong>PAO 40 cSt</strong></td>
<td>17.9</td>
</tr>
<tr>
<td><strong>20% AN-19</strong></td>
<td>9.4</td>
</tr>
<tr>
<td><strong>80% PAO 40 cSt</strong></td>
<td>28.5</td>
</tr>
<tr>
<td><strong>20% Ester</strong></td>
<td></td>
</tr>
<tr>
<td><strong>80% PAO 40 cSt</strong></td>
<td></td>
</tr>
</tbody>
</table>
Volutility Results
10 grams in aluminum pan for 2 weeks at 120°C

- 100% PAO 8: 22.89%
- 100% AN-8: 9.08%
- 10% AN-8 in PAO 8: 2.46%
- 100% Polyol Ester: 18.52%
- 10% Polyol Ester in PAO 8: 15.53%
Friction Testing
FZG (ASTM D5182 Modified), Temp/Friction Study
Test Oils with 0.3% Antiwear Additive

Load Stage 1-6 are run in accordance to ASTM D5182. Load Stage 7 is applied for an 8-hour duration.
Seal Swell
Seal Swell (ASTM D471)

Alkylated naphthalenes will impart Seal Swell Properties to Non-Polar Base Oils.
High Temperature Chain Lubricants
High Temperature Chain Lubricants

Alkylated naphthalenes extend fluid lifetime by:

• Reducing volatility to retain the fluid longer
• Imparting thermal and thermo-oxidative stability to inhibit viscosity increase and varnish formation
### Chain Lubricant Market
Application and Base Fluid By Temperature

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Application</th>
<th>Suitable Base Fluids</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;150°C</td>
<td>Transport, agriculture, and mining equipment</td>
<td>Mineral Oil, Vegetable Oil, Diester, PAO, PAG</td>
</tr>
<tr>
<td>150 – 220°C</td>
<td>Bakeries</td>
<td>Water Soluble PAG, PAO, Ester, Alkylated Naphthalenes</td>
</tr>
<tr>
<td>180 – 250°C</td>
<td>Automobile &amp; beverage can painting</td>
<td>Trimellitate / Dimer Esters, PAO, Alkylated Naphthalenes</td>
</tr>
<tr>
<td>220 – 300°C</td>
<td>Plywood/textile/ceramic/plastic film manufacturing</td>
<td>Dimer / Polyol Esters Alkylated Naphthalenes</td>
</tr>
<tr>
<td>&gt;600°C</td>
<td>Pottery/brick/cement kilns</td>
<td>PAGs as carrier for solid lubricants (e.g. graphite)</td>
</tr>
</tbody>
</table>

**High Temperature Performance with Alkylated Naphthalenes**
Typical Chain Lubricant Formulation

• Base fluid with:
  0 – 20% Thickener / Tackifier / Adhesion Improver
    • Polymeric: PIB, VI improvers
  1 – 5% Antioxidant(s)
    • Combinations of aminics and phenolics
  0 – 5% Extreme Pressure / Antiwear
    • Phosphates, amine phosphates, S/P type (triphenyl ZDP, thiophosphate)
  0 – 1% Corrosion Inhibitor
    • Ferrous: Organic acids, partial esters, amides, sulfonates
    • Copper: triazoles, thiazoles
  0 – 0.1% Defoamer
    • Organics, silicones, modified siloxanes
Test Procedure

• Testing was conducted to determine if the addition of alkylated naphthalene to chain lubricant formulations would help with the high temperature performance.

• Test Method:
  • 3 g of test fluid are placed in an aluminum pan
  • Sample is heated at 260°C for 8 hours
  • Report:
    • % evaporation loss
    • Condition of fluid
**Reduction of Evaporation Loss to Retain Fluid**

<table>
<thead>
<tr>
<th>Blend Number</th>
<th>POE 1963*</th>
<th>97% POE 1963 3% AO Blend†</th>
<th>80% POE 1963 20% AN-19</th>
<th>77% POE 1963 20% AN-19 3% AO Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporation Loss 8 hours @ 260°C</td>
<td>94%</td>
<td>94%</td>
<td>71%</td>
<td>68%</td>
</tr>
</tbody>
</table>

AN-19 alone has an evaporation loss of 43%.

* POE 1963 is an ISO VG 68 polyol ester recommended for high temperature chain lubricants (180–300°C)
† AO Blend is a 50:50 mixture of alkylated diphenylamine with phenyl-alpha naphthylamine
## Evaporation Loss Results

<table>
<thead>
<tr>
<th></th>
<th>POE 1963</th>
<th>AN-19</th>
<th>80% POE 1963 20% AN-19</th>
</tr>
</thead>
</table>
| Evaporation Loss 8 hours @ 260°C | 94%      | 43%   | Theoretical: 84%
|                      |          |       | Actual: 71%            |
## Reduction of Evaporation Loss to Retain Fluid

<table>
<thead>
<tr>
<th>Blend Number</th>
<th>88% POE 1963 12% PIB 950</th>
<th>85% POE1963 12% PIB 950 3% AO Blend</th>
<th>68% POE 1963 12% PIB 950 20% AN-19</th>
<th>65% POE 1963 12% PIB 950 20% AN-19 3% AO Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blend Number</td>
<td>5 Hazy</td>
<td>6 Hazy</td>
<td>7 Clear</td>
<td>8 Clear</td>
</tr>
<tr>
<td>Evaporation Loss 8 hours @ 260°C</td>
<td>95%</td>
<td>96%</td>
<td>69%</td>
<td>69%</td>
</tr>
</tbody>
</table>

**POE 1963 alone has an evaporation loss of 94%.**
• The ester alone is clear (left). When 12% PIB was added to the ester the sample became hazy (middle); however, when 20% alkylated naphthalene was added in combination with PIB, the blend remained clear (right).
Samples Before Aging
Samples After Aging at 260°C for 8 Hours

- The lighter brown samples do not contain AN-19 and resulted in thin, hard varnish.
- The darker samples contain AN-19 and resulted in less evaporation leaving thicker/viscous but still liquid samples.
Alkylated Naphthalene Blends After Aging

- The viscosity of the samples that contain AN-19 increased after being heated, but the remaining samples were self-healing when scratched.
Alkylated Naphthalene Blends After Aging

- The samples that contain AN-19 flow after oxidation.
Varnished Blend Without Alkylated Naphthalene

- The samples without AN-19 created a hard varnish on the metal surface and were not self-healing when scratched.
Extended Service Life of an AN Modified POE

100% Polyol Ester ISO VG 68
Solid Varnish
No Extension Chain Seized

80% Polyol Ester ISO VG 68
20% AN-19
Dark Viscous Liquid
Full Extension - 2 Seconds

Coated and baked for 8 hours @ 260°C
Post-bake hanging performance

High Temperature Performance with Alkylated Naphthalenes
High Temperature Chain Lubricants

- The addition of AN-19 resulted in:
  - Sample clarity
  - Less evaporation loss
  - Varnish control
- The samples containing AN-19 remained liquid:
  - Retaining lubrication
  - Avoiding varnish flake off
Plywood Manufacturing
Conveyor Belt Oil for Plywood Manufacturing

Alkylated Naphthalenes:

• When used for the first time in a press, dissolved the deposits on drive roller friction liners that had formed from an oil previously used.
Plywood Manufacturing – Hot Presses

Operating Conditions:
Temperature: 240°C to 260°C

Production Speed: Up to 2 m/s

System Pressure: ~ 5000 kPa

Fluids Present: Lubricants, Release Agents and Adhesives
Plywood Manufacturing – Hot Presses

- Friction liners coated in heavy deposits from lubricant oxidation products and other contaminants

*High Temperature Performance with Alkylated Naphthalenes*
Cleaning of Equipment

High Temperature Belt Oil for Plywood Manufacturing

• Prior to using the belt oil containing AN-19, pictures were taken of the friction liners showing heavy deposits from oxidation products of the previously used oil.

• After 6 months of use with the belt oil containing the AN-19, it was observed that the oil was very dark and the friction liners were completely clean.

• The darkened oil containing the AN-19 that had dissolved the deposits was exchanged for fresh oil, and the deposit formation and oil darkening did not reoccur.
Removal of Deposits Formed from a Previous Oil

Before Fluid Change

6-Months after Fluid Change
with AN-19
Plywood Manufacturing

Cleaning of equipment by AN-19:
• Reduced unwanted noise, vibration and wear of the equipment
• Greatly reduced maintenance cost
Grease
# Properties of AN Modified Li 12-OH Grease

<table>
<thead>
<tr>
<th></th>
<th>PAO 10 (88%) Li 12-OH (12%)</th>
<th>AN-15 (93%) Li 12-OH (7%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color/Appearance</td>
<td>Tan / Smooth</td>
<td>Amber / Transparent</td>
</tr>
<tr>
<td>Oil Separation</td>
<td>4.10%</td>
<td>2.80%</td>
</tr>
<tr>
<td>Dropping Point</td>
<td>202°C</td>
<td>200°C</td>
</tr>
<tr>
<td>Viscosity @ -40°C</td>
<td>$4.0 \times 10^6$ mPa.s</td>
<td>$6.6 \times 10^6$ mPa.s</td>
</tr>
<tr>
<td>TGA</td>
<td>233°C</td>
<td>304°C</td>
</tr>
<tr>
<td>PDSC (500 psi O$_2$, 210°C)</td>
<td>400 W/g at 3.7 minutes</td>
<td>5 W/g at 5 minutes</td>
</tr>
</tbody>
</table>

High Temperature Performance with Alkylated Naphthalenes
Li 12-OH Grease – Color/Appearance

100% PAO Grease

Less thickener = improved low temperature properties
Bridging solvent = reduced opaqueness
Effective dispersant = smooth grease

100% AN-15 Grease
PDSC (ASTM D5483)

• Procedure:
  • Sample size 2.0 mg
  • Ramp 100°C/min to test temperature
    • 155 to 210°C
  • Equilibrate at test temperature
    • 2 minutes
  • Once equilibrated open O2 valve and pressurize to 500 psi
    • Within 2 minutes
  • Adjust O2 flow rate to 100 mL/min

Oxidation Induction time is calculated from when O2 valve is opened.
PDSC Explanation

![Graph showing heat flow and time with labeled stages: Initial Heat Ramp, Equilibration, Oxygen Add.](chart.png)
PDSC (ASTM D5483) at 180°C

Heat Flow (W/g) vs. Time (min)

- Li-12-OH / 100% Group III
- Li-12-OH / 100% PAO
- Li-12-OH / 10% AN-15 + 90% PAO
- Li-12-OH / 50% AN-15 + 50% PAO
- Li-12-OH / 100% AN-15

High Temperature Performance with Alkylated Naphthalenes
# Grease Oxidation Stability (ASTM D942)

<table>
<thead>
<tr>
<th>Grease Oxidation Stability</th>
<th>Li 12-OH / 100% PAO 10</th>
<th>Li 12-OH / 90% PAO-10; 10% AN-15</th>
<th>Li 12-OH / 50% PAO 10; 50% AN-15</th>
<th>Li 12-OH / 100% Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D942 Pressure Drop</td>
<td>38 psi @24 hours</td>
<td>9 psi @ 100 hours</td>
<td>0 psi @ 100 hours</td>
<td>16 psi @ 7 hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 psi @ 280 hours</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Performance of AN Modified Li Complex Grease

<table>
<thead>
<tr>
<th></th>
<th>3.35% Additive Package*</th>
<th>3.35% Additive Package*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tests</strong></td>
<td><strong>Base Grease</strong></td>
<td><strong>Lithium Complex Grease with 100% PAO 10</strong></td>
</tr>
<tr>
<td><strong>EMCOR (ASTM D6138)</strong></td>
<td>10% Synthetic Sea Water, 1 week</td>
<td>2 (some stain)</td>
</tr>
<tr>
<td><strong>PDSC (ASTM D5483)</strong></td>
<td>Onset Point, 500 psi, 200°C (min)</td>
<td>--</td>
</tr>
<tr>
<td><strong>Grease Oxidation Stability (ASTM D942)</strong></td>
<td>100 h, pressure drop (psi)</td>
<td>86</td>
</tr>
<tr>
<td><strong>Cone Penetration (ASTM D217)</strong></td>
<td>Unworked</td>
<td>298</td>
</tr>
<tr>
<td></td>
<td>60 Strokes</td>
<td>299</td>
</tr>
<tr>
<td></td>
<td>10,000 Strokes</td>
<td>303</td>
</tr>
</tbody>
</table>

*Additive Package contains: calcium sulfonate, ADPA, sulfurized olefin/fatty oil, ZnDTP, and tolyltriazole derivative
### Performance of AN Modified Li Complex Grease

<table>
<thead>
<tr>
<th>Tests</th>
<th>3.35% Additive Package*</th>
<th>3.35% Additive Package*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base Grease</strong></td>
<td>Lithium Complex Grease with 100% PAO 10</td>
<td>Lithium Complex Grease with 30% AN-19 ; 70% PAO 10</td>
</tr>
<tr>
<td><strong>Four Ball Weld (ASTM D2596)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 seconds, 25°C, 1800 rpm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK Load (kgf)</td>
<td>120</td>
<td>140</td>
</tr>
<tr>
<td>Weld Load (kgf)</td>
<td>140</td>
<td>160</td>
</tr>
<tr>
<td><strong>Four Ball Wear (ASTM D2266)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 hour, 75°C, 40kgf, 1200 rpm, (mm)</td>
<td>0.53</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>Copper Corrosion (ASTM D4048)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours, 100°C</td>
<td>2b</td>
<td>1b</td>
</tr>
<tr>
<td></td>
<td>1b</td>
<td>1a</td>
</tr>
<tr>
<td><strong>Grease Water Stability (DIN 51807-1)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 hours, 40°C</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 hours, 90°C</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

*Additive Package contains: calcium sulfonate, ADPA, sulfurized olefin/fatty oil, ZnDTP, and tolyltriazole derivative
Performance of AN Modified Li Complex Grease

PDSC (ASTM D5483) 200°C, 500 psi oxygen

Increased stability with **AN-19** in lithium complex thickened greases with PAO 10 base oil each containing 3.35% additive package*

*Additive Package contains:
- Calcium sulfonate
- Alkylated diphenylamine
- Sulfurized olefin/fatty oil
- Zinc dithiophosphate
- Tolyltriazole derivative

Graph showing the heat flow with time for Grease 1 (Control): 100% PAO 10 and Grease 2: 30% AN-19 70% PAO 10
## Performance of AN Modified Polyurea Grease

<table>
<thead>
<tr>
<th>Tests</th>
<th>Base Grease</th>
<th>8.05% Additive Package*</th>
<th>8.05% Additive Package*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tests</strong></td>
<td></td>
<td>8.05% Additive Package*</td>
<td>8.05% Additive Package*</td>
</tr>
<tr>
<td><strong>EMCOR (ASTM D6138)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% Synthetic Sea Water, 1 week</td>
<td>5</td>
<td>0 (some stain)</td>
<td>5</td>
</tr>
<tr>
<td><strong>PDSC (ASTM D5483)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Onset Point, 500 psi, 210°C (min)</td>
<td>17</td>
<td>51</td>
<td>27</td>
</tr>
<tr>
<td><strong>Grease Oxidation Stability (ASTM D942)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 h, pressure drop (psi)</td>
<td>4</td>
<td>--</td>
<td>0</td>
</tr>
</tbody>
</table>

*Additive Package contains: synergistic rust inhibitor blend, ADPA, sulfurized fatty acid ester, ashless dithiocarbamate, and tolyltriazole derivative*
# Performance of AN Modified Polyurea Grease

<table>
<thead>
<tr>
<th>Tests</th>
<th>Base Grease</th>
<th>8.05% Additive Package*</th>
<th>8.05% Additive Package*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Four Ball Weld (ASTM D2596)</strong></td>
<td></td>
<td>100% PAO 10</td>
<td>30% AN-19; 70% PAO 10</td>
</tr>
<tr>
<td>10 seconds, 25°C, 1800 rpm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK Load (kgf)</td>
<td>80</td>
<td>120</td>
<td>80</td>
</tr>
<tr>
<td>Weld Load (kgf)</td>
<td>100</td>
<td>140</td>
<td>100</td>
</tr>
<tr>
<td><strong>Four Ball Wear (ASTM D2266)</strong></td>
<td></td>
<td>0.60</td>
<td>0.58</td>
</tr>
<tr>
<td>1 hour, 75°C, 40kgf, 1200 rpm, (mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Copper Corrosion (ASTM D4048)</strong></td>
<td></td>
<td>1b</td>
<td>1b</td>
</tr>
<tr>
<td>24 hours, 100°C</td>
<td></td>
<td>1b/2a</td>
<td>1b/2a</td>
</tr>
<tr>
<td><strong>Grease Water Stability (DIN 51807-1)</strong></td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 hours, 40°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3 hours, 90°C</td>
<td>1/1.5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Additive Package contains: synergistic rust inhibitor blend, ADPA, sulfurized fatty acid ester, ashless dithiocarbamate, and tolyltriazole derivative*
Performance of AN Modified Polyurea Grease
PDSC (ASTM D5483) 210°C, 500 psi oxygen

Grease 1 (Control): 100% PAO 10

Grease 2: 30% AN-19
70% PAO 10

Formulated Grease 1

Formulated Grease 2

Increased stability with AN-19 in polyurea thickened greases with PAO 10 base oil, formulated greases contain 8.05% additive package*

*Additive Package contains:
- Synergistic rust inhibitor blend
- Alkylated diphenylamine
- Sulfurized fatty acid ester
- Ashless dithiocarbamate
- Tolyltriazole derivative
Performance of AN Modified Al Complex Grease
PDSC (ASTM D5483) 180°C, 500 psi oxygen

Grease 1 (Control):
9% Aluminum Complex Soap  
91% PAO 10

Grease 2:
9.5% Aluminum Complex Soap  
10% AN-19  
80.5% PAO 10

Grease 3:
8.5% Aluminum Complex Soap  
20% AN-19  
71.5% PAO 10

Increased stability with AN-19 in aluminum complex greases with PAO 10 base oil each containing 0.5% ADPA

ADPA = alkylated diphenylamine antioxidant

Greases courtesy of FedChem, LLC

High Temperature Performance with Alkylated Naphthalenes
Presentation Outline

• Alkylated Naphthalene Background
• Physical/Chemical Properties
• Performance Evaluations
• Summary
Summary – Why Use Alkylated Naphthalenes?

• Diverse viscosity range for flexibility in designing lubricants for a variety of applications
• Excellent thermal & thermo-oxidative stability
• Excellent varnish control
• Low volatility with higher viscosity
• Superior solubility characteristics than Group II, Group III and Group IV (PAO)
Summary – Why Use Alkylated Naphthalenes?

• Inherent hydrolytic stability
• Excellent additive response
• Good low pour point
• Good film thickness and film strength
• Good seal swelling
King Industries Offers

- Alkylated Naphthalenes
- Blends/Packages
- Friction Modifiers
- Antiwear Additives
- Antioxidants
- Extreme Pressure Additives
- Corrosion Inhibitors
- Rust Inhibitors
- Rust Preventives
- Technical Product Support

For more information, contact:

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