Group III Base Stock
Technology and Performance

ICIS Conference, London
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M G Brown
J Z Trocki
Agenda

• SK Lubricants Introduction
• Group III Base Stocks
  – Manufacturing Processes
  – Properties and Composition
  – Some Performance Features
• Future Lubricant Requirements
  – Fuel Economy
SK Lubricants

- World’s largest Group III base stock manufacturer
- Production in Ulsan, Korea and Dumai, Indonesia
- Global sales and distribution network
Future of SK Base Oils

- New capacity announcements in 2010
- Maintains global leadership in global Group III supply

Production Capacity: 2,600k Mt (by 2014)
Several approaches to make Group III base stocks

- **VGO <30% wax**
  - Lube HC
  - Fuel HC
  - FUEL
  - HydroCracker bottoms
  - Catalytic DeWaxing
  - Solvent Extraction
  - Solvent Dewaxing
  - Group III HB/CDW
  - Group III HB/SDW
  - Group III HDT/CDW

- **Waxy VGO 40-60% wax**
  - HydroTreating
  - Catalytic DeWaxing
  - Solvent Dewaxing
  - Group III HB/CDW
  - Group III+ SDW
  - Group III+ CDW

- **Slack wax >70% wax**
  - Wax Isomerisation
  - Wax Dewaxing
  - Catalytic DeWaxing
  - Group III+ SDW
  - Group III+ CDW
Group III’s have different properties

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
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<tbody>
<tr>
<td>Group</td>
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<tr>
<td>KV@100°C, cSt</td>
<td>4.26</td>
<td>4.31</td>
<td>4.30</td>
<td>4.10</td>
<td>4.23</td>
<td>3.89</td>
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<td>129</td>
<td>126</td>
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<td><strong>140</strong></td>
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<td>CCS@-30°C, cP</td>
<td>1590</td>
<td>1510</td>
<td>1470</td>
<td><strong>1100</strong></td>
<td>1640</td>
<td><strong>730</strong></td>
<td><strong>1650</strong></td>
<td>710</td>
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<tr>
<td>Noack, %wt</td>
<td><strong>15.8</strong></td>
<td>14.3</td>
<td>15.1</td>
<td>13.1</td>
<td>14.5</td>
<td>13.2</td>
<td><strong>11.1</strong></td>
<td>13.0</td>
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API and ATIEL Base Stock Definitions

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>VI</td>
<td>≥120</td>
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<tr>
<td>Saturates, %</td>
<td>≥90</td>
</tr>
<tr>
<td>Sulphur, %wt</td>
<td>≤0.03</td>
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</table>
Key formulating properties

Viscosity Index

CCS@-30°C, cP

Noack Volatility, %wt

Kin Visc@100°C, cSt
Group III’s have different compositions

<table>
<thead>
<tr>
<th>Group</th>
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<tbody>
<tr>
<td>Group III</td>
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<td></td>
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<td>IV</td>
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<tr>
<td>Isoparaffins</td>
<td>60.9</td>
<td>71.0</td>
<td>67.9</td>
<td>85.4</td>
<td>61.9</td>
<td>93.4</td>
<td>77.0</td>
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<tr>
<td>1-ring cyclo</td>
<td>20.4</td>
<td>8.7</td>
<td>14.7</td>
<td>6.5</td>
<td>18.9</td>
<td>2.0</td>
<td></td>
<td></td>
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<tr>
<td>2-ring cyclo</td>
<td>12.0</td>
<td>9.3</td>
<td>10.1</td>
<td>5.2</td>
<td></td>
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<tr>
<td>3,4,5-ring cyclo</td>
<td>6.3</td>
<td>9.5</td>
<td>6.9</td>
<td>2.7</td>
<td>6.9</td>
<td>1.3</td>
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</table>

![Chemical structures of different groups](image-url)
Comparative ring analysis

<table>
<thead>
<tr>
<th></th>
<th>0-ring</th>
<th>1-ring</th>
<th>2-ring</th>
<th>3,4,5</th>
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<tr>
<td>A</td>
<td>60.9</td>
<td>20.4</td>
<td>12</td>
<td>6.3</td>
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<tr>
<td>B</td>
<td>71</td>
<td>8.7</td>
<td>9.3</td>
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<td>C</td>
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<td>E</td>
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<tr>
<td>F</td>
<td>93.4</td>
<td>2</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td>G</td>
<td>77</td>
<td>12.8</td>
<td>7.5</td>
<td>3.1</td>
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<tr>
<td>I</td>
<td>98.9</td>
<td>0</td>
<td>0.2</td>
<td>0.4</td>
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</tbody>
</table>
Different processes impact lubricant performance?

Feedstock → Composition → Performance

[Images of refinery, molecular structures, and engine parts]
Future lubricant performance needs

- Legislation
- Consumers
- Commercial Operators
- OEMs

Maintain ODIs

Increasing Oil Stress

Biofuels

Protect Exhaust After treatment

Fuel economy
### Seal compatibility – formulated PCMO

<table>
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<tbody>
<tr>
<td><strong>Group</strong></td>
<td></td>
<td></td>
<td></td>
<td>Group III</td>
<td></td>
<td></td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td><strong>Aniline Point, °C</strong></td>
<td>115.7</td>
<td>115.8</td>
<td>116.7</td>
<td>118.4</td>
<td>115.3</td>
<td>118.8</td>
<td>119.2</td>
<td>120.0</td>
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</table>

**Volume Change %**

**Hardness Change**
Traction Coefficient across & within base oil group

- Gp III can offer advantage over Gp II
- Some Gp III's can be better than others
- Gp III choice for future Fuel Economy critical
• Different processes to manufacture Group III base stocks
• Composition and performance can vary
• How does this impact interchange decisions?
• Properties within Group III classification can affect key lubricant performance parameters
FUEL ECONOMY ENGINE OILS –

NEXT STEP … LOWER OPERATING VISCOSITIES

Mike Brown
SKL Americas
Governments lead innovation

“CAFE requirements by 2016 will be 35.5 mpg! (≒15.1 km/L)”
- May 19, 2009

<table>
<thead>
<tr>
<th>Miles per gallon</th>
<th>2011 CAFE</th>
<th>2016 CAFE</th>
<th>Increase</th>
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<tbody>
<tr>
<td>Cars</td>
<td>27.5</td>
<td>42</td>
<td>53%</td>
</tr>
<tr>
<td>Light duty trucks</td>
<td>24</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Combined Fleet</td>
<td>27.3</td>
<td>35.5</td>
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</table>
OEMs Continue Down-shifting from 10W-30

Why? → For more fuel economy, lower CO₂ emissions.

But, where will they go below SAE 5W-20 and 0W-20?

<table>
<thead>
<tr>
<th>OEM</th>
<th>0W-20</th>
<th>5W-20</th>
<th>5W-30</th>
</tr>
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<tbody>
<tr>
<td>Toyota</td>
<td>1.8L, 2.4L, 2.5L, 2.7L, 4.0L, 4.6L, 4.8L, 5.7L</td>
<td>Main Grade</td>
<td>1.5L, 3.5L</td>
</tr>
<tr>
<td>Ford Cars, Trucks</td>
<td></td>
<td>Main Grade</td>
<td>4.0L 5.4L (5W-50)</td>
</tr>
<tr>
<td>GM, Chevrolet Cars, Trucks</td>
<td></td>
<td></td>
<td>Main Grade</td>
</tr>
<tr>
<td>Honda</td>
<td>Civic Hybrid: 1.3L, Insight</td>
<td>Main Grade</td>
<td></td>
</tr>
<tr>
<td>Nissan</td>
<td>Altima Hybrid 2.5L</td>
<td></td>
<td>Main Grade</td>
</tr>
<tr>
<td>Hyundai</td>
<td></td>
<td>Main Grade</td>
<td></td>
</tr>
<tr>
<td>Chrysler</td>
<td></td>
<td>Main Grade</td>
<td>2.4L turbo (xW-40) 3.5L (10W-30)</td>
</tr>
</tbody>
</table>

Source: Motor Information Systems: 2009 and 2010 model years
Lighter Oil Viscosity Increases Fuel Economy

ILSAC GF-5, API SN Additive System

Seq VID Test Matrix Results

<table>
<thead>
<tr>
<th>SAE xW</th>
<th>Minimum Viscosity, mPaS</th>
</tr>
</thead>
<tbody>
<tr>
<td>xW-20</td>
<td>2.6</td>
</tr>
<tr>
<td>xW-30</td>
<td>2.9</td>
</tr>
</tbody>
</table>

% FEI Sum, fuel economy vs. HTHS Viscosity, mPaS @ 150 C

Tech 1
Tech 2
Tech 3

Linear (Tech 1)
Linear (Tech 2)
Linear (Tech 3)
More Fuel Economy From Lighter Grades

European ACEA Gasoline Products

Estimated change in fuel economy improvement in the M111FE test compared to a typical 3.5 cP SAE 5W-30 passenger car engine oil used in OEM factory fill.

Source: M. Boyer, Lubrizol UEIL presentation, October 2010
Proposed New Grades for SAE J300

Goal: Extend SAE J300 to lighter engine oil viscosities**

- SAE 40: 3.5/3.7 cP minimum
- SAE 30: 2.9 cP minimum
- SAE 20: 2.6 cP minimum

- SAE 15: 2.3 cP minimum
- SAE 10: 2.0 cP minimum
- SAE 5: 1.7 cP minimum

** SAE Paper: 2010-01-2286: Extending SAE J300 to Viscosity Grades below SAE 20
Marketers already launched products beyond current SAE grades to get greater fuel economy and lower CO$_2$ emissions.

Characterize their products 0W-10 without a formal definition.
Another issue: Volatility Losses

Lower viscosity engine oils can be subject to high volatility losses depending on the base oils used in their formulation.

![Volatility Loss of Several Claimed 0W-10 Engine Oils](image)

Noack Test, %Loss at 250°C

Data from IOM
Used with IOM permission
• The proposed grades can be made with today’s quality of base stocks.

<table>
<thead>
<tr>
<th>SAE proposed</th>
<th>Group III</th>
<th>Group II</th>
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<tbody>
<tr>
<td>xW-15</td>
<td>0W- and 5W-</td>
<td>5W- only</td>
</tr>
<tr>
<td>xW-10</td>
<td>0W- and 5W-</td>
<td>5W- only</td>
</tr>
<tr>
<td>xW-5</td>
<td>0W- only</td>
<td>--</td>
</tr>
</tbody>
</table>

• Noack volatilities in the range of 11 to 14% weight loss expected.

• Engine durability needs to be examined by stakeholders (OEMs, additive companies, marketers) in the development of low friction engines.

• Defining new SAE viscosity grades will help reduce consumer confusion even though marketers already launched 0W-10 products.
Changing Vis Grade Alone: Not the Complete Solution

The solution is:

- The right balance of base stocks and additives in uniform SAE grades.
- Uniform SAE grade engine oils approved in low friction engines.

Harmony
SUMMARY – Fuel Economy

• OEMS desire more fuel economy with new engines capable of durable lubrication with lighter viscosity grade oils.

• SAE Engine Oil Viscosity Classification group has proposed new oil grades lighter than SAE 20, using 0.3 cP steps based on high temperature, high shear viscosity properties.

• Marketers already launched “0W-10” grades covering a broad range of viscosities.

• Need a SAE J300 classification soon to minimize confusion and enable stakeholders to develop consistent fuel economy engine oils.
T H A N K Y O U

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