Group III Base Oils - What’s on the Horizon?

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Contents

1. Macro Analysis: Group III Demand
2. Impact of Key US Regulations
3. Impact of Consumer Trends
4. Upcoming Group III Expansions
5. Conclusions
Group III Applications

Applications:
- Engine Oils, 83%
- ATF, 7%
- Industrial Oils, 8%
- Others, 2%

Source: SK Lubricants
Macro Analysis –
Group III Base Oil Demand

Group III actual demand likely to be BIGGER than forecast
Group III Demand by Region

2010 to 2015: +12.2% pa growth rate adjusted for economic slowdown

Source: SK Lubricants
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**US Regulation – Auto Gasoline**

Gasoline engine CAFE requirements by 2016

35.5 miles per gallon (15.1 km/L).


**CAFE = Corporate Average Fuel Economy**

<table>
<thead>
<tr>
<th>Miles per gallon</th>
<th>2011 CAFE</th>
<th>2016 CAFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>27.5</td>
<td>42</td>
</tr>
<tr>
<td>Light duty trucks</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Combined Fleet</td>
<td>27.3</td>
<td>35.5**</td>
</tr>
</tbody>
</table>

**On April 1, 2010, EPA & NHTSA finalized on 34.1 mpg giving credits for A/C improvements and using footprints for each make and model sold.**
# OEMs Shift To Lower Viscosity

<table>
<thead>
<tr>
<th>OEM</th>
<th>0W-20</th>
<th>5W-20</th>
<th>5W-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota</td>
<td>Main Grade</td>
<td></td>
<td>1.5L, 3.5L</td>
</tr>
<tr>
<td>Ford Cars, Trucks</td>
<td></td>
<td>Main Grade</td>
<td>4.0L SOHC, 3.5L,</td>
</tr>
<tr>
<td>GM, Chevrolet Cars &amp; Trucks</td>
<td></td>
<td></td>
<td>Main Grade, dexos™1</td>
</tr>
<tr>
<td>Honda</td>
<td>Main Grade</td>
<td>2.4L Element, 3.5L Ridgeline, 3.7L MDX</td>
<td></td>
</tr>
<tr>
<td>Nissan</td>
<td></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 (0W-40), 3.6L, 3.5L (10W-30)</td>
</tr>
</tbody>
</table>

**Where can OEMs go below SAE 0W-20 to get more fuel economy?**

Source: OEMs, 2011, 2012 model years
Lower Viscosity Increases Fuel Economy

Lower viscosity (HTHS viscosity) is the proven road to more fuel economy for newer, low friction engines.

ILSAC GF-5, API SN Additive Systems

Seq VID Test Matrix Results

Fuel Economy, % FEI Sum

HTHS Viscosity , mPaS @ 150 C

Lower viscosity (HTHS viscosity) is the proven road to more fuel economy for newer, low friction engines.
Proposed Grades for SAE J300

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

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

*16” 2.3 cP minimum
*12” 2.0 cP minimum
*8” 1.7 cP minimum

New grade for GF-6

Future grades in development

** SAE Paper: 2010-01-2286: Extending SAE J300 to Viscosity Grades below SAE 20
New SAE Oil Grade ➔ xW-16

- Some JAMA ‘genuine’ oils deliver more fuel economy
- Requested new SAE grades with uniform specifications
- ILSAC GF-5 doesn’t apply to SAE xW-16 grades, yet, ILSAC GF-6 (1/1/2016?) will add a new category for them

Next Generation: ILSAC GF-6B

Performance standard for SAE 0W-16, 5W-16 oils

Expectation ➔ MORE FUEL ECONOMY

Challenges ➔ Use only in specific vehicles

ILSAC = International Lubricant Standardization and Approval Committee
### Examples of SAE 0W-16

Very similar to SAE 0W-20, but with less Viscosity Modifier

<table>
<thead>
<tr>
<th></th>
<th>SAE 0W-20</th>
<th>SAE 0W-16 Same BoV</th>
<th>SAE 0W-16 Lower BoV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group III Base Oil Viscosity, cSt@100°C</td>
<td>4.75</td>
<td>4.75</td>
<td>4.13</td>
</tr>
<tr>
<td>ILSAC GF-5 DI</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Viscosity Modifier, wt%</td>
<td>6.75</td>
<td>3.75</td>
<td>5.25</td>
</tr>
<tr>
<td>Finished Oil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KV, cSt@ 100°C</td>
<td>8.7</td>
<td>7.3</td>
<td>7.3</td>
</tr>
<tr>
<td>HTHSV, cP@ 150°C</td>
<td>2.62</td>
<td>2.34</td>
<td>2.36</td>
</tr>
<tr>
<td>CCSV, cP@-35°C</td>
<td>5,269</td>
<td>4,969</td>
<td>3,850</td>
</tr>
</tbody>
</table>

Source: SAE 2010-01-2286, Table 6
ILSAC GF-6 Raises the Bar

- More fuel economy
  - Viscosity control and friction modifier effectiveness throughout the service interval
- “Robust” oil performance to protect engines
  - 4 new Sequence engine tests (Seq III, IV, V, VI)
- Plus, attention to 3 new areas of OEM concerns
  - LSPI- low speed engine pre-ignition in smaller displacement and boosted intake (turbo) engines
  - Idle Stop engine wear protection – timing chains, valve train
  - Oil aeration limits – for new and used oil
Link between Viscosity Increase and Oil Volatility?

- Viscosity increase as oil ages in service reduces fuel economy
- Oil volatility has a direct impact on oil viscosity increase due to the evaporation of light base oil components
- Sequence IIIG engine test
  - high intake air temperature
  - high operating loads
  - long test length
  - reduced oil additions
- ILSAC GF-6 seeks a 100% limit on “end of test” viscosity increase vs 150% limit for GF-5
- Will Sequence IIIH engine have same behavior as Sequence IIIG?
Sequence IIIG Engine Test

- Citation below** is for a (15% Noack) 5W-30 with Group II+ base oil
- 70% of the viscosity increase is due to evaporation of oil**

** SAE 2007-01-1961, Boffa and Hirano, Chevron Oronite, “Formulation Impacts on Sequence IIIG Viscosity Increase”
Higher VI base stocks $\rightarrow$ Lower oil volatility
Lower oil volatility reduces % viscosity increase

** SAE 2007-01-1961, Boffa and Hirano, Chevron Oronite, “Formulation Impacts on Sequence IIIG Viscosity Increase”
Fuel Economy vs. “Extended” (GM EOLS) Oil Change Intervals

- Viscosity increase is negligible in most types of service with high-quality (dexos, GF-5) oils
- Friction modifier depletion is relatively minor with oils showing good FE retention in the Sequence VI test
- Quantifying effect in vehicle dyno tests

During Q&A, GM confirmed 13% max Noack was an essential property of the dexos™ engine oil to obtain
- negligible viscosity increase
- retained fuel economy

STLE, May 7, 2012
Fuel Economy – An OEM’s Perspective
Slides used with permission of GM
US Regulation – Truck HD Diesel

EPA & NHTSA : Finalized Aug 9, 2011

• Improves truck fuel economy and reduces GHG emissions
• Voluntary compliance period 2014-2015 MY
• Mandatory compliance beginning with 2016 MY

Semitrucks  HD pickups/vans  Vocational trucks

EPA = Environmental Protection Agency
NHTSA = National Highway Traffic Safety Administration
PC-11: Adds a Fuel Economy Category

- PC-11 is the Proposed Category to replace API CJ-4
  - CJ-4 has a minimum HTHS viscosity of 3.5 cP
    although most 15W-40 HDDEO products are in the range of 3.7 to 4.2 cP HTHS viscosity

- Fuel economy grades are likely to have HTHS viscosity range of 2.9~3.3 cP HTHS viscosity

- Fuel efficient HDD oils will need Group III to balance high DI package treats (ashless dispersants for soot)

- How much, depends on DI and VM appetites in PC-11 performance standard
  - Group III could be 80% or more of the base oil mix for 5W-30
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Full Synthetics Sales Increased

Full Synthetics meet very demanding performance standards. Group III and IV base stocks are required to achieve those standards.

<table>
<thead>
<tr>
<th>Percentage</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional/synthetic blend</td>
<td>72</td>
<td>68</td>
<td>70</td>
<td>59</td>
</tr>
<tr>
<td><strong>Full synthetic</strong></td>
<td>10</td>
<td>12</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>High mileage (*)</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Diesel engine oil</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Re-refined/&quot;Green&quot;</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

(*) Use Group III in the product to reduce oil volatility and oil consumption in high mileage engines.

Source: LT30 Operator Category, National Oil and Lube News, Sept 2012
Synthetic Tiers Shifting

Grps III, IV

- Synthetic
- Synthetic: Full, Blend
- Premium Synthetic
- Ultimate Synthetic

Grps I, II, III

- Conventional Oil
- High Mileage
- High Mileage
- High Mileage

Historical

- 5W-20, 5W-30, 10W-30
- 2001
- 2009
- 2012
SAE 0W-20 needs higher VI base stocks (Groups III, IV)

<table>
<thead>
<tr>
<th>Percentage of SAE Grades</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>0W-20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>5W-20</td>
<td>21</td>
<td>24</td>
<td>27</td>
<td>23</td>
</tr>
<tr>
<td>5W-30</td>
<td>49</td>
<td>46</td>
<td>48</td>
<td>44</td>
</tr>
<tr>
<td>10W-30</td>
<td>19</td>
<td>17</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>5W-40, 15W-40</td>
<td>10</td>
<td>11</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

200 million gasoline vehicles in USA
13 million new car sales in 2011, 15 million rate for 2012
Average vehicle life >10 yrs

Source: LT30 Operator Category, National Oil and Lube News, Sept 2012
### Sales of GM dexos™ 1 5W-30

GM dexos™ products use Group III base stocks to reduce Noack volatility <13.0% and achieve dexos™ engine performance.

<table>
<thead>
<tr>
<th>Percentage</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LT30 Stores</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operators offering dexos™-licensed oils</td>
<td>77</td>
<td>76</td>
</tr>
<tr>
<td>Customers buying dexos™-licensed oils</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td><strong>MT30 Stores</strong></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Source: National Oil and Lube News, Sept 2012
Consumers want power and fuel economy

- Engine designs evolve to get more fuel economy
  - Smaller displacement
  - Turbocharged
  - Variable Camshaft Timing (VCT) 
  - Direct fuel injection
  - Coated piston rings
  - Hybrid power train

- Engine oil technology evolves
  - Additive technologies
  - Higher VI base stocks for low volatility, increased thermal stability
  - Engine oil as hydraulic oil in VCT hardware
Base Oil Quality Response

Fuel Economy

- Friction Modifiers
  - Good Additive Response
  - SAE 0W vs 5W Viscosity
    - Higher Viscosity Index

Performance Demands

Desirable Base Oil Properties
Low Engine Oil Volatility Resists Viscosity Increase

Higher VI, Narrow-cut Grades

Longer Drain Interval

Oxidation & Sludge Control

More DI Additives

Good Additive Response

Performance Demands

Desirable Base Oil Properties
Base Oil Quality Response

ILSAC GF-5, -6, Synthetics, (GM dexos™)

Less Deposits, Reduced Wear, Tougher Tests, Turbo Proven

Low Oil Volatility

High Oxidation Stability

Performance Demands

Desirable Base Oil Properties
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Expanding Group III Supply

- Fuels Hydrocrackers (HCR) provide a major volume of feed stocks for Group III base oils
  - Existing HCR and new LS Distillate Fuel units
  - Different feed stocks and Group III process schemes

- Fischer –Tropsch process (Gas To Liquids) Group III

- New Group III Players & Traders entering the market

- Interchange across Group III slates must be proven according to API, ATIEL and OEM rules

- Global coverage increasing by leading suppliers having multiple plants
Increasing HCR Feedstocks

Feedstock Availability for Group III Base Oil

Source: Global Refinery Hydrocracking Units to 2012
Capacity vs Supply

Nameplate Capacity
- Public domain
- Some information not accurate

Operating Rate
- Feedstock economics
- Refinery competency
- Proven track record

Stream Day
- Reliability
- Maintenance T/A
- Accidents, Weather, Earthquakes, Political interruptions

Yield
- Consistent quality
- Pipelines to Global Markets

Base Oil Actual Supply

Group III actual supply likely to be SMALLER
Group III supply continues to grow

- New Group III plants have started production:
  - Neste-Bapco in Bahrain (8,000 Bpd)
  - Shell in Qatar (11,000 Bpd)
  - SKL-JX in South Korea (10,000 Bpd)
- Takreer, Abu Dhabi in 2013 & SKL-Repsol, Spain in 2014
- Will Chinese National Oil Majors and other new players produce Group III or just Group II?
- Announcements are based on nameplate, not actual operation
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Conclusions

- Consumer trends: more synthetics, more synthetic tiers
- OEMs: lower viscosity SAE 0W-20 and lower volatility dexos™ 5W-30 increasing Group III demand
- SAE J300 expanding to SAE xW-16
- Engine designs evolving to increase power and fuel economy
- Lower viscosity oils and more robust formulations (ILSAC GF-6, PC-11) increase Group III demand
- Group III supplies expanding
Thank you

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