The Low Viscosity Engine Oil Challenge

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Abstract

- Engine oils require low viscosity for fuel economy contributions
- High quality base oils assist with achieving both low temperature and volatility requirements
- The selection of high quality base oils has continued to increase with new qualities and supply sources
- This presentation will look at the available options to blenders, based on domestic and import alternatives
Presentation Outline

- **The Move to Lower Viscosity Oils**
  - Global Demand
  - Technical Considerations
  - Current Progress

- **How to Formulate Low Viscosity Oils**
  - The Role of Base Stocks
  - Options to the Formulator

- **Low Viscosity Oils in the Americas**
  - Readiness to Move Forward
  - Challenges and Opportunities
  - Education

- **Summary and Conclusions**
Global Lubricants From 40,000 Feet

- The lubricants industry is in the midst of change despite the appearance of “no change”
  - Global demand flat to *slightly* increasing
  - Regional demand shifting
    - Asia growth offset by declines in North America and Europe

<table>
<thead>
<tr>
<th>Region</th>
<th>2004</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>30.2%</td>
<td>↓</td>
</tr>
<tr>
<td>Europe</td>
<td>29.1%</td>
<td>↓</td>
</tr>
<tr>
<td>Asia</td>
<td>29.1%</td>
<td>↑</td>
</tr>
<tr>
<td>Demand, MMT</td>
<td>37.8</td>
<td>38.6</td>
</tr>
</tbody>
</table>

- Technical changes significant
  - Automotive industry driving change
  - Industrial oils along for the ride!
- Base oil industry changing to meet technical demands
Global Lubricant Demand in Process of Redistribution

- Asia-Pacific now represents largest region with continued growth (China, India influence)
  - North America shows some decline but more due to use of higher quality lubricants (and reduced usage)
Technical Demands Automotive Focused

- Low SAE grades
- Low viscosity base stocks
- Friction modifiers
- Group II, III, III+, IV, V
- Low sulfur, SAPS
- High saturates
- Low Noack
- Group II, II+, III, III+, IV, V

Technical changes impacting automotive lube design

- New SAE grades, additive chemistries, complimentary base stocks
Achieving Fuel Economy

- Improvements to fuel economy associated with basic viscometrics
  - Lower viscosity improves fuel economy
    - Reduced friction
    - Also expressed as reduced emissions (CO₂)
  - Lower viscosity creates challenges
    - Increased wear
    - Increased volatility
- Challenges can be met
  - Improved additive chemistry
  - Higher quality base stocks
    - VI the key!

![Graph showing relationship between viscosity and temperature with higher VI at lower temperature.](image)
Fuel Economy is Global and Rapidly Rising

- Fuel economy expressed by mpg or CO₂ emissions
- Lubricants only one part of the fuel economy challenge
Base Oil Quality Aligning with Finished Demand Technical Needs

- Group II-III capacity shows significant and sustained growth to support automotive industry demands
  - Group III supporting PCMO and fuel economy
  - Group II supporting HDEO and emissions-durability
  - Excess supply spills into other product applications

![Capacity Changes](chart1)

![Demand by Application](chart2)

Sources – LNG, KEPC
North American PCMO Demand Has Shown Significant Change to Meet FE Challenge

- Change however takes time!
  - Nearly 20+ years for low viscosity demand to exceed high viscosity demand

Sources – AFPM, KEPC, Infineum

Low Viscosity ≤ SAE 5W-XX
High Viscosity ≥ SAE 10W-XX
How Has Formulations Changed to Meet the Fuel Economy Challenge

- Base oil qualities changing to meet the fuel economy challenge
  - API Groups established (1992-1995)
  - Solvent processing changing to hydروprocessing
The Lubricants Industry is Changing  
North America - 1985

**Average Base Oil Quality Needs - 1985**

<table>
<thead>
<tr>
<th></th>
<th>PCMO</th>
<th>HDEO</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>KV @ 40°C, cSt</td>
<td>37.5</td>
<td>50</td>
<td>85</td>
</tr>
<tr>
<td>KV @ 100°C, cSt</td>
<td>5.9</td>
<td>7.9</td>
<td>9.8</td>
</tr>
<tr>
<td>SUS @ 100°F</td>
<td>195</td>
<td>310</td>
<td>445</td>
</tr>
<tr>
<td>VI</td>
<td>97</td>
<td>95</td>
<td>93</td>
</tr>
</tbody>
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Industrial = hydraulic, compressor, gear, general purpose

Sources – AFPM, Infineum, KEPC
The Lubricants Industry is Changing

North America - 2015

PCMO - 2015

Industrial - 2015

HDEO - 2015

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<tr>
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<th>HDEO</th>
<th>Industrial</th>
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<tbody>
<tr>
<td>KV @ 40°C, cSt</td>
<td>25</td>
<td>38</td>
<td>80</td>
</tr>
<tr>
<td>KV @ 100°C, cSt</td>
<td>4.8</td>
<td>6.1</td>
<td>9.5</td>
</tr>
<tr>
<td>SUS @ 100°F</td>
<td>130</td>
<td>200</td>
<td>410</td>
</tr>
<tr>
<td>VI</td>
<td>113</td>
<td>103</td>
<td>96</td>
</tr>
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Industrial = hydraulic, compressor, gear, general purpose

Sources – AFPM, Infineum, KEPC

Key events

Multi-grade introduction - HDEO
Growth of low SAE grades - PCMO
North American Base Oil Industry Has Changed to Meet Automotive Needs

- Hydroprocessing now represents major source for North American paraffinic base oils

<table>
<thead>
<tr>
<th>PCMO Base Oil Quality Changes</th>
<th>1985</th>
<th>2015</th>
<th>Change, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>KV @ 40°C, cSt</td>
<td>37.5</td>
<td>25.0</td>
<td>-33.3</td>
</tr>
<tr>
<td>KV @ 100°C, cSt</td>
<td>5.9</td>
<td>4.8</td>
<td>-18.6</td>
</tr>
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<td>130</td>
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<tr>
<td>VI</td>
<td>97</td>
<td>113</td>
<td>+16.5</td>
</tr>
</tbody>
</table>

- Despite changes, NA is *not* a major Group III source

Sources – AFPM, LNG, KEPC
Base Stock Composition Changing for Automotive Industry

- Hydroprocessing (Group II, III) eliminates aromatics and large ring naphthenes; increases saturates
- Hydroprocessing creates iso-paraffins
  - Iso-paraffins $\rightarrow$ Viscosity Index

Aromatics/Thiophenes $\rightarrow$ Polycycloparaffins $\rightarrow$ Monocycloparaffins $\rightarrow$ Iso-paraffins
Formulating Engine Oils
Engine Oils and Formulation Sciences

- Engine oils formulated from three main components
  - Finished oil properties represent contributions from each component
  - e.g. CCS, Noack volatility

- Viscometrics and volatility characteristics can be managed through base oil selection
Each SAE grade has a target base oil quality
Key properties - Noack volatility, CCS viscosity

Source – KEPC
How Do I Get the Right Base Oil Properties?

- Each SAE viscosity grade has a target base oil quality
  - KV, VI, CCS, Noack volatility
  - Additive dependent
- Challenge is to find correct base stock combination to meet target qualities in the most cost effective manner
- What is blended base oil quality target for SAE 5W-20/30?
  - KV @ 100°C ~4.8 cSt
  - VI ~113 to 116
  - CCS @ -20°C ~1,000 cP
  - Noack Volatility ~15 wt%
  - Group II (saturates, sulfur, VI)
Formulating Thin Engine Oils - Options

1. Group II⁺ and Group II
   - Reference (base case)
   - Group II⁺ “unofficial” (API, ATIEL)
   - Described as 110 to 119 VI
   - Originally designed for North American PCMO market in mid 1990s
     ▪ ILSAC GF-2 initially; still applicable with ILSAC GF-6

2. Group III and Group II (I)
   - Combination simulates Group II⁺
   - Ideal for companies with Group II production capacity
   - “Synthetic” labelling opportunity
   - Concept can be extended to Group I
     ▪ Saturates and sulfur limitations
     ▪ Remains a NA opportunity

Higher blend stock quality aligns with increasing Group II demand for given formulation.
Formulating Thin Engine Oils - Options

3. Group III+ and Group II
   - Group III+ “unofficial” (API, ATIEL, ≥130 VI)
   - Combination simulates Group II+
   - Reduced availability (vs Group III)
   - Higher quality allows formulation of lower and future SAE grades
   - “Synthetic” labelling opportunity

4. GTL and Group II
   - GTL classified as Group III (i.e. III+)
   - Limited opportunity (one source, internal use)
   - Other potentials (e.g. NA shale gas)?

5. Group IV and Group II
   - Combination simulates Group II+
   - Highest quality option, formulation impact
   - Highest component cost option
   - “Synthetic” labelling opportunity

Higher blend stock quality aligns with increasing Group II demand for given formulation
How Does Choice Affect Economics?

- Each option has its advantages
- Challenge is to find the lowest cost formulation with the highest return value
  - Includes technical value, marketing value, logistical value, etc.
- If Group II* and Group II is the base line, why consider alternatives if blended costs are higher?
  - Extend formulation flexibility
  - Synthetic, part synthetic marketing
  - Increase internal base oil usage if a producer has a finished oil business
  - Target future qualities, performance levels beyond NA (e.g. Europe approvals including OEMs)
Running the Economics

Case Study

➢ Use ICIS market (versus posted) pricing from December 2016
  ▪ Group II 100N and 220N
  ▪ Group II+ 110N
  ▪ Group III 4 cSt

➢ Estimate quality differential for Group III and Group III+
  ▪ Historical postings not applicable

➢ Incorporate quality changes as VI increases
  ▪ Lower CCS, lower Noack, lower KV @ 100°C

➢ Target a consistent blended base oil quality
  ▪ KV @ 100°C, VI, CCS, Noack

Can the economics work?
Running the Economics

Case Study

- Use ICIS market (versus posted) pricing from December 2016
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- Estimate quality differential for Group III and Group III+
  - Historical postings not applicable
- Incorporate quality changes as VI increases
  - Lower CCS, lower Noack, lower KV @ 100°C
- Target a consistent blended base oil quality
  - KV @ 100°C, VI, CCS, Noack

Can the economics work? YES!
Preparing for Thinner Oils?

- Need to look at this from several perspectives
  1. Do you have the raw materials?
  2. Do you have the correct approvals?
  3. Do you have the correct demand?
  4. Do you have the correct logistics?
  5. Are the customers properly educated?
Is North America Ready for Thinner Oils?

1. Raw Materials
   - North America has multiple sources for Group II and II⁺
   - US has no Group III production
     - Imports required from Canada, Asia-Pacific (South Korea, SE Asia), Middle East (UAE, Qatar, Bahrain), Europe and most recently Russia

   ![Raw Materials](image)

   - 2016 Rated Capacity Sources - AFPM, LNG
   - 2015 US Imports 26.5 Million Barrels Sources - AFPM, LNG
Numerous Group III sources targeting US market

US trade agreements may impact future sourcing

From South Korea
From SE Asia
From Canada
From W. Europe
From C/E Europe
From Middle East
From South Korea
From SE Asia
Preparing for Thinner Oils?

- **Raw Materials**
  - Wide selection available (Group II⁺, Group III, Group III⁺)
  - Most medium and heavy viscosity grades Group III⁺ quality (i.e. ≥130)

![Viscosity Index Diagram]

Source – KEPC
Is North America Ready for Thinner Oils?

2. Approvals
   - Most new base oil slates fully tested and approved in multiple products and quality levels
     - API, ACEA, OEM, etc.
   - Lack of testing and performance demonstration limits value, profit and marketability (to producer)
     - Buyers/formulators can benefit
   - Testing is expensive
     - Who’s responsible for approvals?
     - Base oil supplier, additive company, customer, combination?

☐ Approvals ✓
3. Market Demand

- Growth in synthetic and part synthetic engine oils growing
  - How much mineral oil is really part synthetic?
- Gradual transition beginning with HDEO

![Market Demand Chart]

- SAE 0W-20 17%
- SAE 5W-20 22%
- SAE 5W-30 37%
- SAE 10W-30 3%
- SAE 15W-40 Other 1%

**Source - IHS**

**NOLN – 2016 Oil Change Plus Demand**
Is North America Ready for Thinner Oils?

4. Logistics
➢ Blenders have expanded base stock options to meet finished product offering
➢ Options require analysis (cost, marketing strategy, etc.)
➢ Tank management a challenge but also an opportunity

Choices - 1985

Group I
- S150N
- S500N
- S150 BS

Choices - 2016

Group I
- S150N
- S500N
- S150 BS

Group II
- 110 HC
- 220 HC
- 500 HC

Group III
- 4 cSt
- 6 cSt
- 8 cSt

3 Tank Saga

Group I, II, II+, III, III+
PAO, Bio-Base, etc.

What do I use?

Group IV – V
Bio-Base, etc.
Balancing Base Oils – Value of Group III–III⁺

- **Group II⁺ used to meet viscometrics-volatility (110N – 120N)**
  - Group II⁺ not synthetic
  - Resultant products “conventional”
  - Blend ratios are estimates
    - Will change with quality of Group II Mid Viscosity base oil (220N) and DI/VM
  - With Group I, blend ratios would be different
Balancing Base Oils - Switching Group II⁺ to III-III⁺

**Base Case Group II⁺**

- Group II⁺
- Group II Mid Viscosity

**Advanced Case Group III-III⁺**

- Group III-III⁺
- Group II Mid Viscosity

4.8 cSt @ 100°C KV
114 VI
15 wt% NOACK
1820 cP @ -25°C CCS

SAE 5W-20 Conventional

SAE 5W-30 Conventional

Red = New product options

SAE 5W-0W/20/30 Synthetic

SAE 0W-20/30 Synthetic

SAE 5W-20 Conventional Part Synthetic

SAE 5W-20/30 Part Synthetic
Is North America Ready for Thinner Oils?

5. **Customer Education**
   - Need to make customers aware of thin oils and when to use
   - API one of many groups to educate the industry

Do you use thin or thick oil? Do you use thin or thick oil?

[Image: Customer Education]

- [ ] Customer Education ✔

[Image: Thin to Thick]

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Source – Norm Shephard

Petroleum Consulting
Is North America Ready for Thinner Oils?

- **Scorecard results**

<table>
<thead>
<tr>
<th>Item</th>
<th>Ready?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Materials</td>
<td>Yes</td>
<td>Many sources (Group II domestic, Group III import)</td>
</tr>
<tr>
<td>Approvals</td>
<td>Yes</td>
<td>In most instances</td>
</tr>
<tr>
<td>Demand</td>
<td>Yes</td>
<td>Strong and growing</td>
</tr>
<tr>
<td>Logistics</td>
<td>Yes</td>
<td>Case by case review required</td>
</tr>
<tr>
<td>Education</td>
<td>Yes</td>
<td>Region adopting use of thin oils</td>
</tr>
</tbody>
</table>

KEPC - Yes
Conclusions

- Automotive industry leading the shift towards the use of thinner oils
- Higher quality base stocks required to meet the low viscosity requirements of fuel economy specifications
  - Several viable options available to the customer
  - Separate analysis of logistics, cost and marketing required
- North America has components to blend thin oils
  - Finished oil demand strong and growing
  - Group II⁺ available domestically from several sources
  - Availability of Group III and III⁺ imports
  - Customer education advanced but still necessary
Thank you
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