BETTER USE OF HIGH QUALITY LUBRICANT
by Group III Base Oils

J. ROCK LEE
SK Group Overview

Holding Company
- SK Holdings

Energy & Chemicals
- SK Energy
  - SK E&S
  - SK Chemicals
  - SKC
  - SK Incheon Oil
  - Dopco
  - K-Power

Telecom
- SK Telecom
- SK C&C
- SK Telink
- SK Telesys
- Helio

Trading & Services
- SK Networks
- SK Engineering & Construction
- SK Shipping
- Sheraton Walkerhill
- SK Securities

Sales Ratio
- Energy & Chemicals: 51.1%
- Trading & Services: 25.3%
- Telecommunications*: 23.6%

- Sales: 73.7 billion USD
- Total Assets: 63.3 billion USD
- Employees: About 30,000

* Includes the sales from SK Networks
(Data in 2006)
History


Business Areas

Refining, Petrochemicals, Exploration & Production, Coal, Lubricants, etc.

Leading Energy & Petrochemical player in Korea

Largest refiner in Korea’s oil industry, holding over 1/3 of the market share, and leading Petrochemical, Lubricant player in Korea.

Globalization

SK Energy is in a transitive phase, increasingly penetrating into overseas markets with a view to becoming a major player in the Asia-Pacific region.

SK Corporation(Former SK Energy) has been ranked as 98th in Fortune Global 500 company list, 2007
**Summary of Business Divisions**

**PETROLEUM**
- Domestic market share: 34%
- CDU capacity: 1,115 m b/d
- Gas station: 4,185

**PETROCHEMICAL**
- Ethylene: 830,000 Ton/Yr
- Propylene: 540,000 Ton/Yr
- BTX: 3,600,000 Ton/Yr

**LUBRICANT**
- Lubricant: 4,000 B/D
- Base Oil: 20,000 B/D
- Grease: 6,000 Ton/Yr

**E & P**
- Engaged in 24 blocks in 14 countries
- Oil equivalent reserves: 510 million Bbl
- Production(E): 25,000 B/D
LUBRICANTS

- Production Capacity
  - Lubricants: 4,000 bbls/day
  - Grease: 6,000 tons/year

- No.1 player in Korea since 1968 in the competition of worldwide majors

- Premium brand name is ‘ZIC’

- Has a 30% M/S in engine oil market (Total 16% market share in Korea)

- Continuing to expand markets abroad

- Launched co-branding product named ‘ZIPEX’ with PT. PERTAMINA in Pakistan

BASE OIL

- World Top 10 Base Oil Suppliers
  - Capacity: 20,000 bbs/day

- 50% world M/S in Group III base oil market

- Brand name is ‘YUBASE’

- Has worldwide supply network for global customers

- Found JV with PT. PERTAMINA for new 350,000MT/year capacity refinery in Dumai
Introduction
### Base Oil Classification

<table>
<thead>
<tr>
<th>API Category</th>
<th>Viscosity Index</th>
<th>Saturates (%)</th>
<th>Sulfur (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>80-120</td>
<td>&lt; 90</td>
<td>&gt; 0.03</td>
</tr>
<tr>
<td>Group II</td>
<td>80-120</td>
<td>≥ 90</td>
<td>≤ 0.03</td>
</tr>
<tr>
<td><strong>Group III</strong></td>
<td><strong>120 +</strong></td>
<td><strong>≥ 90</strong></td>
<td><strong>≤ 0.03</strong></td>
</tr>
<tr>
<td>Group IV</td>
<td></td>
<td>PAO</td>
<td></td>
</tr>
<tr>
<td>Group V</td>
<td></td>
<td>All others</td>
<td></td>
</tr>
<tr>
<td>Item</td>
<td>ASTM Method</td>
<td>YUBASE 4</td>
<td>YUBASE 6</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-------------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>KV @ 40° C, cSt</td>
<td>D445</td>
<td>19.6</td>
<td>36.9</td>
</tr>
<tr>
<td>KV @ 100° C, cSt</td>
<td>D445</td>
<td>4.25</td>
<td>6.46</td>
</tr>
<tr>
<td>Viscosity Index</td>
<td>D2270</td>
<td>123</td>
<td>130</td>
</tr>
<tr>
<td>NOACK Volatility, wt%</td>
<td>D5800</td>
<td>14.7</td>
<td>7.1</td>
</tr>
<tr>
<td>Pour Point, °C</td>
<td>D92</td>
<td>-15</td>
<td>-12</td>
</tr>
<tr>
<td>Flash Point, °C</td>
<td>D97</td>
<td>230</td>
<td>240</td>
</tr>
</tbody>
</table>
Global Base Oil Demand

- 2000: 2% Group III, 4% Group II, 7~8% Group I
- 2005: 2% Group III, 4% Group II
- 2010: 7~8% Group I
- 2015: 10~% Group II, 10~% Group III

[KMT]
Who makes Group III Base Oils

TOTAL PRODUCTION CAPACITY: 47,000 BPD

Merchant Players

Source: Lubes n Grease, 2006
## Refining Trends in Base Oil Composition

<table>
<thead>
<tr>
<th>Chemical Type</th>
<th>Structure</th>
<th>VI</th>
<th>Pour</th>
<th>Oxidation</th>
<th>Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Paraffin (Wax)</td>
<td></td>
<td>Very High</td>
<td>Solid @50°C</td>
<td>Excellent</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~175</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iso-Paraffins with Branched chains</td>
<td></td>
<td>High</td>
<td>Good</td>
<td>Excellent</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iso-Paraffins with highly branched</td>
<td></td>
<td>Good</td>
<td>Good</td>
<td>Excellent</td>
<td>Low</td>
</tr>
<tr>
<td>chains (PAO's)</td>
<td></td>
<td>~130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cyclo-Paraffins- single ring with</td>
<td></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Low</td>
</tr>
<tr>
<td>long chains</td>
<td></td>
<td>~130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naphthenes, poly condensed</td>
<td></td>
<td>Poor</td>
<td>Good</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monoaromatics, long chains</td>
<td></td>
<td>Poor</td>
<td>Good</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>~60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyaromatics</td>
<td></td>
<td>Very Poor</td>
<td>Good</td>
<td>Very Poor</td>
<td>Very High</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;0</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Compositions Comparison

- YUBASE
  - High Isoparaffin Content
  - Some Naphthenic Compound
  - Small or Zero Aromatic

- Group I
  - Low Isoparaffin Content
  - Some Naphthenic Compound
  - High Aromatic
Performance Comparison

Low Temp. Performance: CCS Viscosity[cp]

- @-20°C
- @-25°C

<table>
<thead>
<tr>
<th></th>
<th>SR 150N</th>
<th>HT 150N</th>
<th>YU-6</th>
<th>PAO 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>2100</td>
<td>2000</td>
<td>1520</td>
<td>900</td>
<td>1450</td>
</tr>
<tr>
<td>4500</td>
<td>4000</td>
<td>2710</td>
<td></td>
<td></td>
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</tbody>
</table>

Oxidation Performance: RBOT[min] ¹)

<table>
<thead>
<tr>
<th></th>
<th>SR 150N</th>
<th>HT 150N</th>
<th>YU-6</th>
<th>PAO 6</th>
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<tbody>
<tr>
<td>185</td>
<td>250</td>
<td>520</td>
<td>535</td>
<td></td>
</tr>
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</table>

Oxidation Performance: PCT[mg] ²)

<table>
<thead>
<tr>
<th></th>
<th>SR 150N</th>
<th>HT 150N</th>
<th>YU-6</th>
<th>PAO 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>158</td>
<td>149</td>
<td>58</td>
<td>32</td>
<td></td>
</tr>
</tbody>
</table>

Oil Consumption: Noack [wt%] ³)

<table>
<thead>
<tr>
<th></th>
<th>SR 150N</th>
<th>HT 150N</th>
<th>YU-6</th>
<th>PAO 6</th>
</tr>
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<tbody>
<tr>
<td>17</td>
<td>16.5</td>
<td>7.3</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

¹) ASTM D2270, + 0.3wt% Antioxidant
²) 10.3% A3/B3 DI Additive + 10% VII
³) 250°C, 1hr
Major Features of Group III Base Oils

Features

- Low Wax
- Very High VI

- Low Volatility
- Narrow Boiling Ranges

- High Saturates
- Good Additive Response

- Very High VI
- Low Aromatics

- Low Aromatics
- Low volatility

High Quality Base Oils
Lubricating Advantages by Group III Base Oils

<table>
<thead>
<tr>
<th>Features</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Better Low Temp. Performance</td>
<td>• Low Wax</td>
</tr>
<tr>
<td>• Low Oil Consumption</td>
<td>• Very High VI</td>
</tr>
<tr>
<td>• Higher Flash Points</td>
<td>• Low Volatility</td>
</tr>
<tr>
<td>• Higher Thermal/Oxidative Stability (Longer life)</td>
<td>• Narrow Boiling Ranges</td>
</tr>
<tr>
<td>• Good Friction Behavior • Wear Reduction</td>
<td>• High Saturates</td>
</tr>
<tr>
<td>• Environmentally Friendliness</td>
<td>• Good Additive Response</td>
</tr>
<tr>
<td>• Low Aromatics</td>
<td>• Very High VI</td>
</tr>
<tr>
<td>• High Saturates</td>
<td>• Low Aromatics</td>
</tr>
<tr>
<td>• Low Volatility</td>
<td>• Low volatility</td>
</tr>
<tr>
<td>• Narrow Boiling Ranges</td>
<td></td>
</tr>
<tr>
<td>• Low Wax</td>
<td></td>
</tr>
<tr>
<td>• Very High VI</td>
<td></td>
</tr>
<tr>
<td>• Low Aromatics</td>
<td></td>
</tr>
<tr>
<td>• Low volatility</td>
<td></td>
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</tbody>
</table>

High Quality Lubricants
Benefits Using High Quality Lubricants

- Reduce Fuel Costs
- Reduce Lubricant Costs
- Reduce Emissions
- Reduce Maintenance Costs
- Reduce Personal and Social Costs
Challenges for Lubricant Companies

ADDITIVES

- Emission
- Fuel Economy
- Backward Compatibility
- API Grade
- Ash
- Wear
- Oxidation
- OEM Specifications
- Viscosity
- Deposit
- Synthetic?
- Soot
- Low Temperature Performance
- ACEA Sequence
- Phosphate
- Sulfur

FORMULATOR’S CONCERN

BASE OILS
<table>
<thead>
<tr>
<th>Year</th>
<th>US</th>
<th>Japan</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>ILSAC GF-4</td>
<td>API CI-4+</td>
<td>GM Dexron IIIH</td>
</tr>
<tr>
<td>2005</td>
<td>Gasoline</td>
<td>Diesel</td>
<td>Gasoline</td>
</tr>
<tr>
<td>2006</td>
<td>API CJ-4</td>
<td>GM Dexron VI</td>
<td>Diesel</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
<td>Gasoline</td>
</tr>
<tr>
<td>2008</td>
<td></td>
<td></td>
<td>ACEA ?? MB 229.??</td>
</tr>
<tr>
<td>2009</td>
<td>ILSAC GF-5</td>
<td></td>
<td>ACEA ?? MB 228.??</td>
</tr>
</tbody>
</table>
Demand Drivers for High Quality Lubricants

**Legislation**
- Emissions
- Energy Saving

**Consumers**
- Extended Drain Intervals
  - Fuel Economy
  - Price Efficiency

**OEMs**
- Engine Durability / Cleanliness
- Higher Operation Temperatures

**Lubricant Manufacturers**
- Product Differentiation
  - Cost Efficiency

**Global Economy**
- Economy Growth
- Vehicle Changes

SK energy

YUBASE
Demand Drivers for High Quality Lubricants

Legislation

- Set Emission Target
- Reduce PM/NOx/SAPS
- Increase Fuel Economy

OEMs

Emissions Standards - Passenger Car Diesel -

- Euro 3
- Euro 4
- US Tier 2 bin 5
- Euro 5

Source: Lubrizol
Legislation

- Set Emission Target
- Reduce PM/NOx/SAPS
- Increase Fuel Economy

OEMs

ILSAC: Phosphorus Content Limit

- GF-1: 0.12 max
- GF-2: 0.10 max
- GF-3: 0.10 max
- GF-4: 0.08 max

P content in oil (wt%)


Source: Lubrizol
Legislation

- Set Emission Target
- Reduce PM/NOx/SAPS
- Increase Fuel Economy

OEMs

Demand Drivers for High Quality Lubricants

ILSAC : Fuel Efficiency Requirement

Source: Lubrizol
Demand Drivers for High Quality Lubricants

**Legislation**
- Set Emission Target
- Reduce PM/NOx/SAPS
- Increase Fuel Economy

**OEMs**
- Newly Designed Engines
- Severer Operating Condition
- After-treatment Devices

**Lubricant Manufacturers**
Lubricating Conditions & Measures

Cranking, Startability
- CCS, KV@40°C

Fuel Economy

Pumpability
- MRV, Brookfield

Oil Consumption
- NOACK, KV@100°C

Wear
- HTHS, TBS

Shear Rate
- Low to High

Temperature
- Low to High

Major Performance Test Item

LTHS

HTHS
Mono-grade vs. Multi-grade

General Benefits of Multi-grade Lubricants
- Good Startability
- Better Bearing Lubrication
- Reduced Oil Consumption
- Better Fuel Economy

- SAE 40
- SAE 10W/40
- SAE 10W
Viscosity Index

- High Viscosity Index
- Low Viscosity Index

Temperature
- Low
- High
Viscosity Index

Solutions to Increase Viscosity Index

- Viscosity Modifier
- High Viscosity Index Base Oils

Consideration Points

- Formulation Economics
- Toxicity
- Impacts on Other Performance
**Fuel Economy Improvement**

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**ILSAC : Fuel Efficiency Requirement**

**Fleet Car Trial - Average Fuel Savings**

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Seq.VI F/E improvement % (vs. 20W30)

- 5W20 & 0W20
- 5W30 & 0W30
- 10W30

---

Seq.VIB F/E improvement % (vs. 5W30)

GF-1, GF-2, GF-3, GF-4

---

Relative Fuel Saving

5W/30, 10W/40, 15W/40, 15W/50, 20W/50

---

High Sheer Viscosity

Demand Drivers for High Quality Lubricants

- Longer Drain Intervals
- Better Fuel Economy
- Price Efficiency

MONO GRADE

20W-XX

15W-XX

10W-XX

5W-XX

0W-XX

Better FUEL ECONOMY
High Quality Base Oils

- Cost Efficiency
- ‘Synthetic’ Claims
- Product Differentiation
- Operational Conveniences

Lubricant Manufacturers
High Quality Base Oils

Demand Drivers for Group III Base Oils

Features

- Very Low Sulfur (≤ 0.03 %)
- Very High Viscosity Index (120 + )
- Excellent Low Temperature Performance
- Low Volatility & High Flash Point
- Excellent Thermal and Oxidative stability

※ Can be marketed as ‘Synthetic’

Group III Base Oils
Group III Base Oil Production History

Production Capacity
47K BD

Group III Base Oil Merchant Market

![Graph showing demand and supply trends from 2003 to 2015.]

- **Demand (Case 1 & 2)**
- **Supply**
- **Supply by SK energy**
Quality Differentiation in Group III Base Oils

Viscosity Index

<table>
<thead>
<tr>
<th></th>
<th>Gr- I 100N</th>
<th>Gr- II 100N</th>
<th>Gr- III 4cSt</th>
<th>New YUBASE4</th>
<th>PAO4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>130</td>
<td>140</td>
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NOACK

<table>
<thead>
<tr>
<th></th>
<th>Gr- I 100N</th>
<th>Gr- II 100N</th>
<th>Gr- III 4cSt</th>
<th>New YUBASE4</th>
<th>PAO4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>20</td>
<td>18</td>
<td>16</td>
<td>14</td>
<td>12</td>
</tr>
</tbody>
</table>
Summary for High Quality Lubricants

- **Technical Needs**
  - Drive Towards Lighter Viscosity Multigrades
  - With Tightened Approval Specifications in Lube Industry
  - Limitation of using Harmful Additives to meet Demanding Performance

- **Marketing Needs**
  - Drive Cost effective, ‘Synthetic’ labeling High Quality Lubricants
  - Is Encouraged by availability of large volumes of Group III/GTL production
Market Forces of High Quality Base Oils

Group III Base Oils → High Quality Lubricants

- Fuel Efficient
- Longer Drain Intervals
- Environment Friendly
- Engine Protective

→ Reduce Personal and Social Costs
THANK YOU FOR YOUR ATTENTION!