초청강연

# 고급기유 및 그 응용제품의 개발동향

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# 고급 기유 및 그 응용제품의 개발 동향

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## Outline

1. Global Trends
   - Emissions, Fuel Economy
2. Technology Trends
   - Lubricants Requirements
   - Base Stock Implications
3. High Quality Base Stock
   - SK's Experience
4. Application of Group III Base Stock
   - PCMO, HDDO
5. Overview of Lube Supply & Demand
   - Base Stock & Lubricants
6. Conclusions

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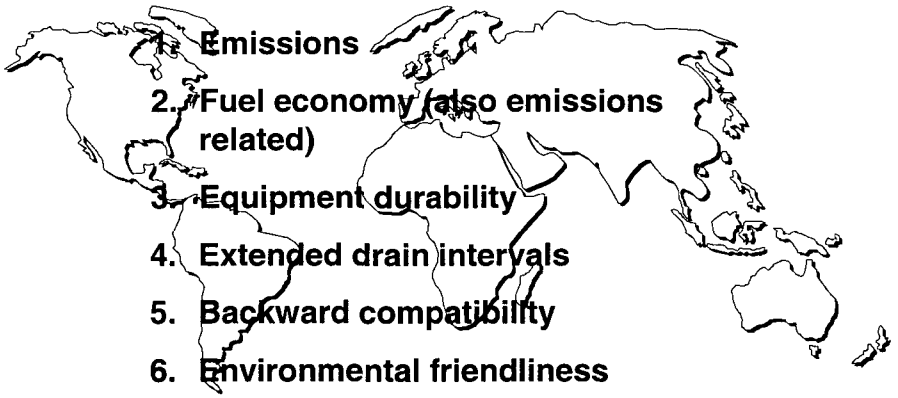
## Global Activities Influencing Lubricant and Base Stock Quality



1. Emissions
2. Fuel economy (also emissions related)
3. Equipment durability
4. Extended drain intervals
5. Backward compatibility
6. Environmental friendliness

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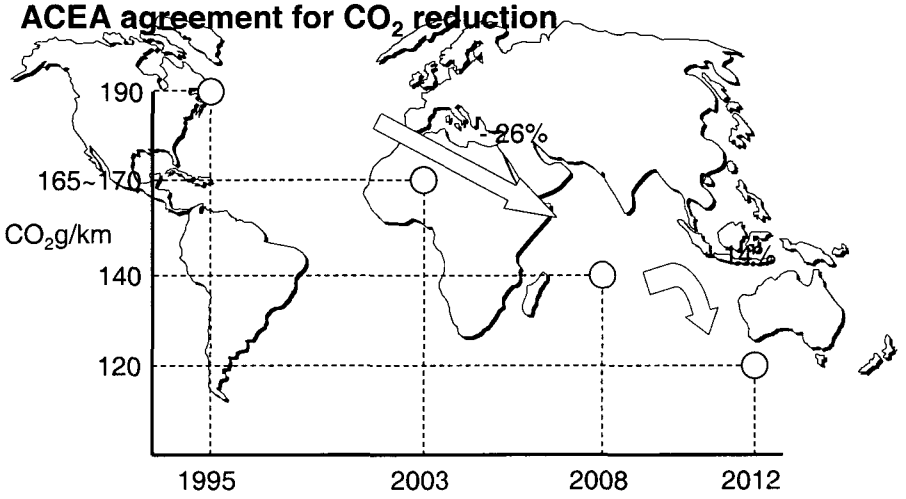
## Emissions Is a Global Issue Impacting Automotive Equipment

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* ACEA : European automotive manufactures association

## Emission and Fuel Economy of Passenger Cars

▶ Emission regulation getting severe

| | | CO | HC | NOx |
|---|---|---|---|---|
| Japan | Current | 1.15 | 0.14 | 0.11 |
| | From 2005 | 1.15 | 0.05 | 0.05 |
| Korea | From 2001 | 2.11 | 0.16 | 0.25 |
| | From 2003 | 2.11 | 0.047 | 0.12 |
| Europe | Euro II (2000) | 2.3 | 0.2 | 0.15 |
| | Euro III (2005) | 1.0 | 0.1 | 0.08 |

▶ Fuel economy target getting higher

o **Super Fuel Economy Oil (SFEO)** : Seq. VIB + Alpha (in-house test)
- Korean OEM start to develop SFEO with GF-4 performance to apply from 2005
- Japanese OEM already developed and applied SFEO

o **Lowered viscosity** to meet fuel economy : 0W20 / 5W20 / 5W30

o Japanese 2010 fuel economy target : 15.3 Km/L (21.4% improvement from 1995)

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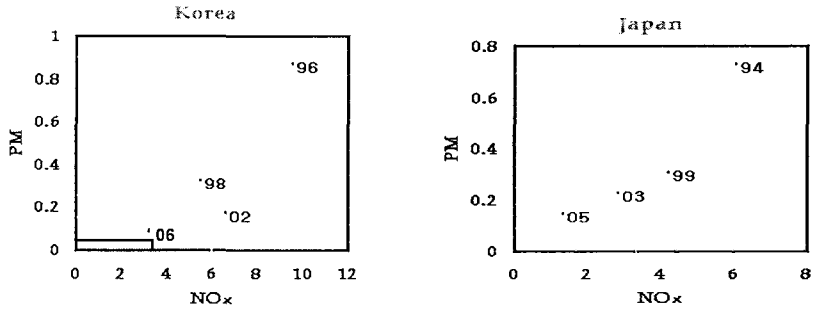
## Emission Regulations of Diesel Cars

1. Heavy Duty Diesel Emission Regulations in the Korea and Japan




2003 : EURO III Equivalent
2006 : EURO IV Equivalent

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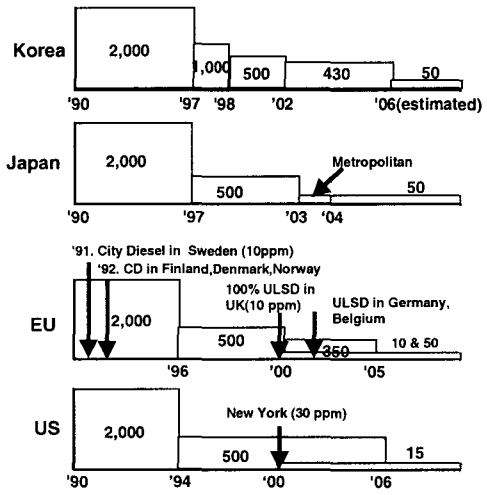
## Sulfur Regulation in Diesel Fuel

2. Sulfur Contents in Diesel Fuel in Korea and Japan

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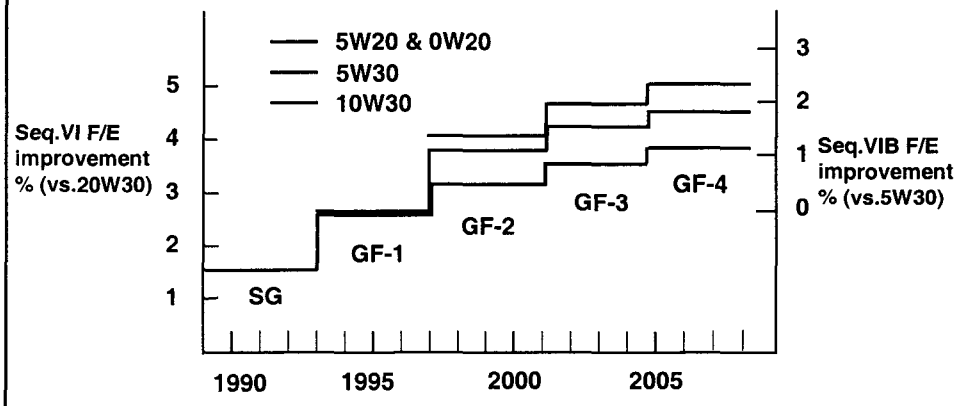
## Lubricants Improvement

### Fuel economy




ILSAC : Fuel Efficiency Requirement

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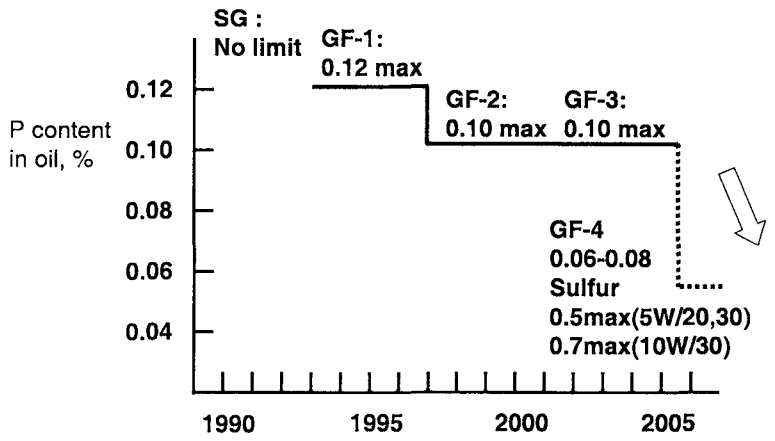
## Lubricants Improvement

### Emission system compatibility : Phosphorus Limit

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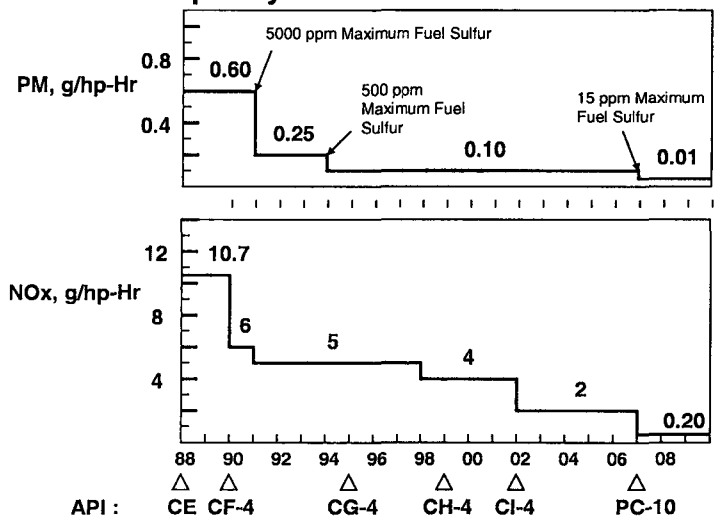
ILSAC : Phosphorus Content Limit

## Lubricants Improvement

### Stepped reduction in exhaust emission with stepped increase in oil quality

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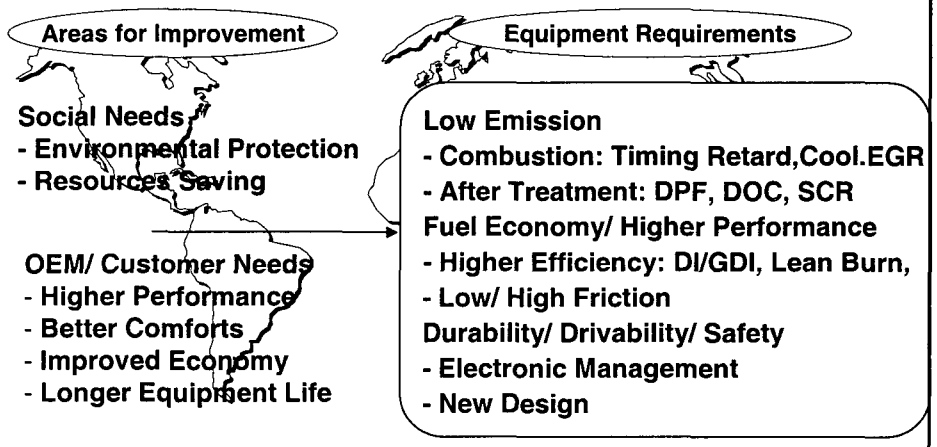
## Global Automotive and Industrial Trends

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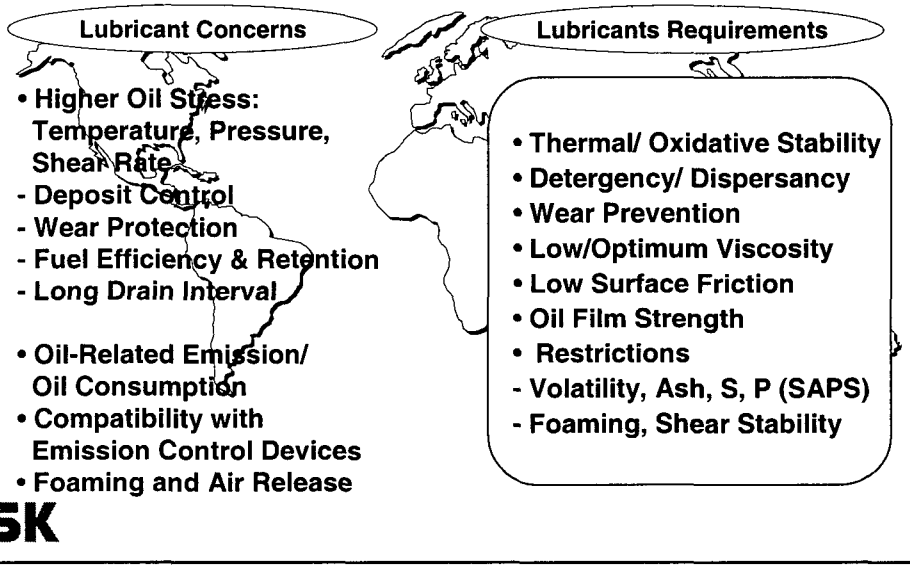
## Global Lubricant Concerns and Requirements

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## Lubricant Trends - Overview

- Performance specifications to meet OEM equipment and mandated regulations will result in the following product improvements:
  - Thermal and Oxidative Stability
  - Sludge and Varnish Control
  - "Fill for Life"
  - Reduced Volatility (Emissions)
  - Low Viscosity (Fuel Economy – CAFE)
  - Low-Temperature Viscometrics
  - High-Temperature Film-Forming Capability
  - Environmentally Friendly
- Continued shift towards highly saturated base stocks to compliment additive technology to meet performance challenges

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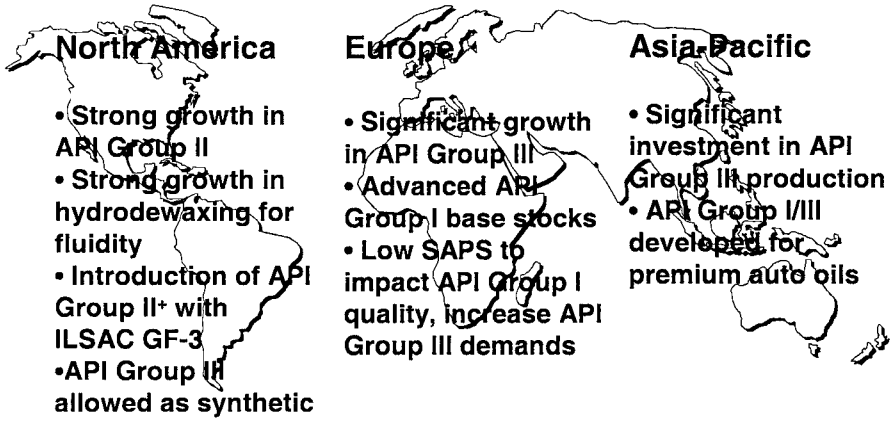
## Global Activities - Base Oil Implications



**North America**

- **Strong growth in API Group II**
- **Strong growth in hydrodewaxing for fluidity**
- **Introduction of API Group II+ with ILSAC GF-3**
- **API Group III allowed as synthetic**

**Europe**

- **Significant growth in API Group III**
- **Advanced API Group I base stocks**
- **Low SAPS to impact API Group I quality, increase API Group III demands**

**Asia-Pacific**

- **Significant investment in API Group III production**
- **API Group I/III developed for premium auto oils**

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## High-Quality Synthetic Base Oils

- **Four categories of high quality base oils can satisfy stringent performance requirements**

1. **Hydrocarbon-type Synthetics: Poly Alpha Olefins (API Group IV)**
2. **Ester-type Synthetics: Di-esters, Poly-ester (API Group V)**
3. **Wax-isomerized Base Oils: GTL wax, Slack Wax (API Group III+)**
4. **Severely Hydro-Cracked Base oils (API Group II+, III):**
   - **Fuels Hydro-Cracker Bottom**
   - **Lubes Hydro-Cracker**
   - **Hydrocracking with solvent extraction**

**The Most Economic Production Route**

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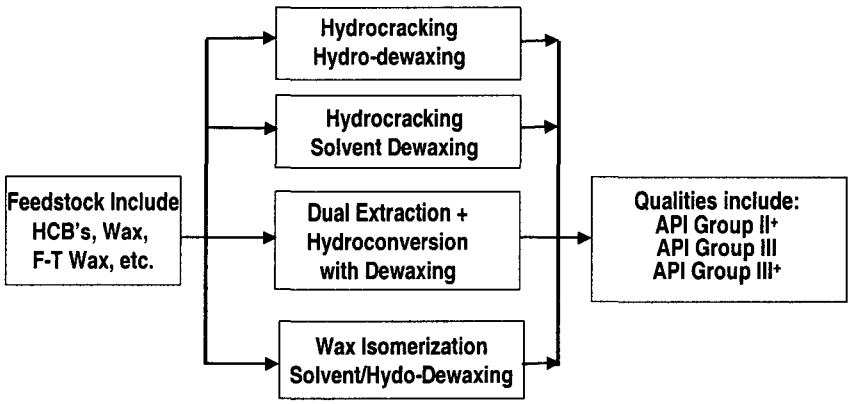
## Several Technologies Available to Meet High Quality Base Stock Requirements




- Most of key API Group III stocks use hydroprocessing and hydrodewaxing
  - SK Corporation, S-Oil, ChevronTexaco, Motiva, Petro-Canada, Fortum

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## Features of API Group III Base Oils

- Low Volatility, High Flash & Fire Point
  - Narrow-Cut
- Excellent Thermal and Oxidative stability
  - Maximum Saturation & Purity
  - Near zero Aromatics, Sulfur-, Nitrogen-, Oxygen-Containing Compounds
- Excellent Low temperature fluidity
  - High Paraffin Contents , Deep De-waxing
- Inherent High Viscosity Index
- Excellent Additive Response, Optimum Solubility and Seal Compatibility
- Can be marketed in most areas as 'synthetic'

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## SK Corporation Base Oil History

- 1st commercial facility operated at SK's Ulsan refinery in Oct.1995 with 3,500 bpd of VHVI base oils named Yubase.
- Presently, about 8,700 bpd are produced through step-by-step investments to increase its capacity and yield.
- 2nd plant is scheduled to begin operations 2Q'04
  - Reflects capacity increase to 15,000 bpd.

- Recycled hydrocracker residue is utilized as feedstocks
- All hydro-processing: 1st utilization of catalytic dewaxing fuels hydrocracker bottom oils and high pressure HDT
- Economic and Licensed Owned Process:
  - Integration of fuels hydrocracker and lube process,
  - Low investment and operating cost

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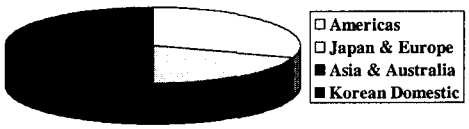
## SK Refining Capacity and Region Focus

- Ulsan #1 plant @ 8,700 BPCD
  - Current production has global focus




- Ulsan #2 plant @ 6,000 BPCD
  - Production to support export market
    - Full Yubase slate
    - Fungible with Ulsan #1 production
    - Excellent long term fit for NA and European markets

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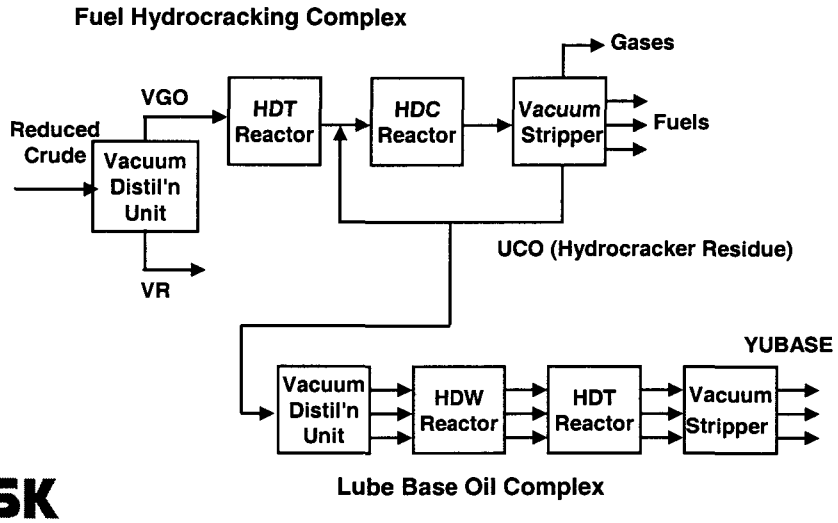
## SK's UCO Process of Group III (FHC) Base Oils

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## Typical Properties for Yubase API Group II and III Base Stocks

| Base Stock | ASTM Method | Yubase L3 | Yubase 3 | Yubase 4 | Yubase 6 | Yubase 7 |
|---|---|---|---|---|---|---|
| Appearance | Visual | C&B | C&B | C&B | C&B | C&B |
| Density, kg/L | D1298 | 0.8324 | 0.8299 | 0.8338 | 0.8423 | 0.8463 |
| KV @ 40°C, cSt | D445 | 12.73 | 12.43 | 19.57 | 36.82 | 43.54 |
| KV @ 100°C, cSt | D445 | 3.12 | 3.12 | 4.23 | 6.52 | 7.18 |
| Viscosity Index | D2270 | 105 | 112 | 122 | 131 | 126 |
| NOACK Volatility, wt% | D5800 | 36 | 36 | 14.5 | 7 | 4.2 |
| Pour Point, °C | D92 | -45 | -24 | -15 | -15 | -15 |
| Flash Point, °C | D97 | 190 | 204 | 230 | 240 | 260 |

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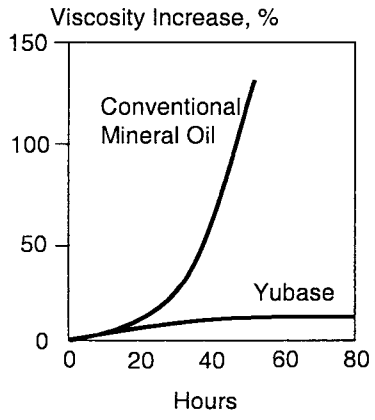
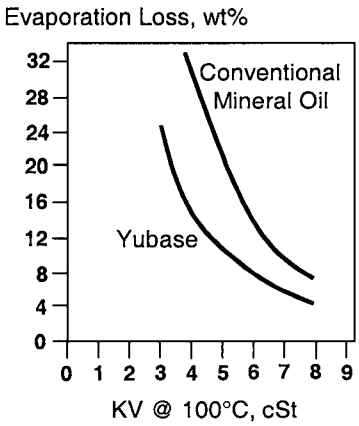
## YUBASE Advantage

***Lubricants Trends***

### Oxidation Stability




### Volatility (Oil consumption)

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## API Group III Options for N.A. PCMO - ILSAC GF-3/API SL, 5W30 - Physico-chemical Properties

| Oil Code | Oil A | Oil B | Oil C |
|---|---|---|---|
| Base oil blend(Group) | III | II &II | I & III |
| KV @ 40°C, cSt | 58.07 | 63.70 | 59.70 |
| KV @100°C, cSt | 10.19 | 10.55 | 10.25 |
| CCS @ -30°C, cP | 4,630 | 5,860 | 5,120 |
| CCS @ -35°C, cP | 9,045 | 12,085 | 11,180 |
| MRV @-35°C, cP | 17,000 | 23,100 | 28,500 |
| HTHS@150°C, cP | 3.03 | 3.08 | 2.95 |
| Volatility(Noack),wt% | 12.0 | 13.1 | 14.7 |

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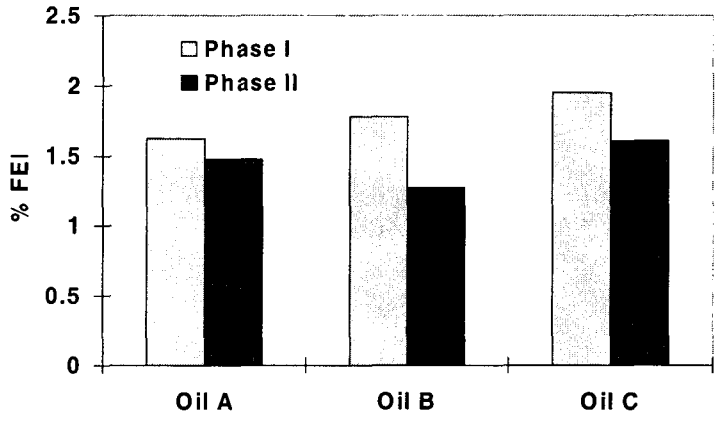
## Group III base oils for PCMO (ILSAC GF-3/API SL, 5W30) - Fuel Economy (Sequence IVB)

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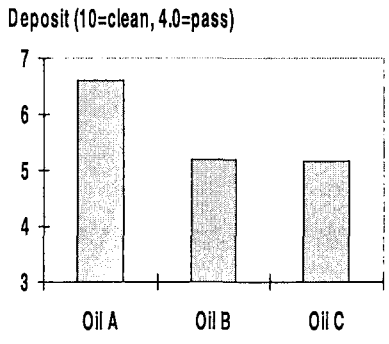
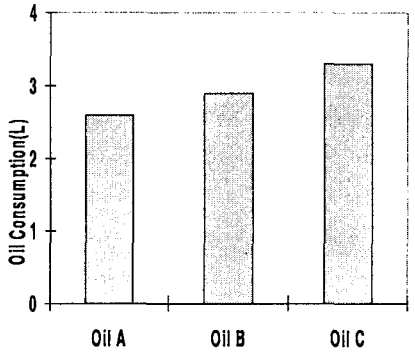
## Group III base oils for PCMO (ILSAC GF-3/API SL, 5W30) - High Temperature Oxidation Stability (Sequence IIIF)

**Weighted Piston Deposit Ratings**




**Oil Consumption**

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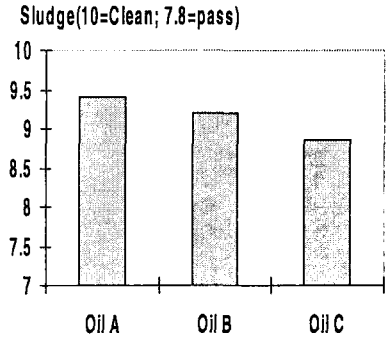
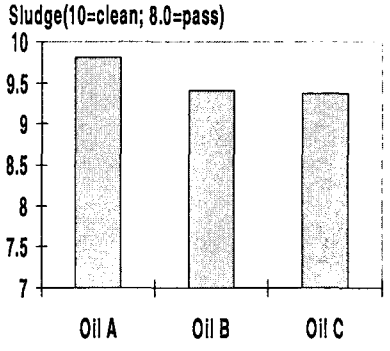
## API Group III base oils for PCMO (ILSAC GF-3/API SL, 5W30) - Low Temperature Sludge (Sequence VG)

**Average Engine Sludge**




**Rocker Cover Sludge**

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## Conclusions from PCMO Study

- ILSAC GF-3 sequence engine tests were conducted using engine oils formulated with Group III and conventional-mixed base oils. The following was found:
- Group III base oil results in better performance, especially in fuel economy retention, oxidation and sludge control than the combination of group III with I or II.
- Meanwhile, other performance showed no considerable differences..

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## Approval of API SL/ ILSAC GF-3 PCMO

| | 5W-20 | 5W-30 | 10W-30 | Spec.(5W) |
|---|---|---|---|---|
| Yubase 4,wt% | 70.0 | 85.0 | 20.0 | |
| Yubase 6,wt% | 30.0 | 15.0 | 80.0 | |
| Additives | Balanced | <- | <- | |
| - Seq.Engine Tests | IIIF,VIB | IIIF,VG, VIII,VIA,VIB | IVB | |
| - Viscosity@100C,cSt | 7.95 | 10.19 | 10.53 | 5.6~9.3~12.5 |
| - CCS @-30C,cP | 4,264 | 4,630 | 7,410 | 6,600 max |
| @-35C,cP | 8,255 | 9,045 | - | 6,200 min |
| - MRV TP-1@-35C,cP | 12,500 | 17,000 | 13,300(-30C) | 60,000 min |
| - HTHS Viscosity,cP | 2.6 | 3.03 | 3.23 | 2.6/2.9 min |
| - Noack Volatility,% | 10.5 | 12 | 8.2 | 15 max |
| - TEOST(MHT-4) Deposit Weght, mg | 39.9 | 38.0 | 40.1 | 45 max |

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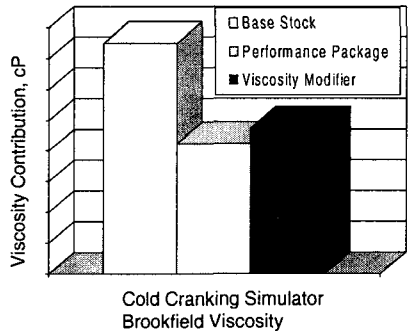
## Formulation Principles - Finished Oils

- Rapid changes in automotive performance creating significant opportunity for hydroprocessed base stocks
  - Low temperature fluidity
  - SAE grade optimization
  - Fuel economy
  - Shear stability
  - Volatility




***Challenge – How to achieve economically and profitably?***

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## YUBASE Advantage

### Advantage over Group II and II+ in ILSAC GF-3 (API SL)

| | Oil A | Oil B | Oil C | Oil D | Oil E |
|---|---|---|---|---|---|
| | Gp III 100% 5W-30 | Gp II+ 100% 5W-30 | Gp II+ 100% 5W-30 | Gp II 100% 5W-30 | Gp II & III 5W-30 |
| **Formulation, % weight** | | | | | |
| GF-3 Additive | 10.35 | 10.35 | 10.35 | 10.35 | 10.35 |
| Viscosity Modifier | **4.5** | 4.5 | **5.5** | 5 | 5 |
| API Group II (100N) | | | | 75 | 35 |
| API Group II (260N) | | | | 25 | |
| API Group II+ (4.5cSt) | | 50 | 60 | | |
| API Group II+ (6 cSt) | | 50 | 40 | | |
| API Group III (4 cSt) | 50 | | | | |
| APIO Group III (6 cSt) | 50 | | | | 65 |
| **Test Result** | | | | | |
| Formulation Viscosity @ 100℃, cSt | 10.1 | **9.91** | 10.2 | 9.3 | 10.67 |
| Base Oil Viscosity @ 100℃, cSt | 5.4 | 5.2 | 5.1 | 4.7 | 5.56 |
| Formulation Viscosity Index | 159 | 150 | 152 | 143 | 152 |
| CCS @ -30℃; 6600 cP, max. for 5W | 5410 | **7191** | 6480 | 6324 | 6386 |
| CCS @ -35℃; 6200 cP, max. for 0W | 10032 | 12188 | 11121 | 11383 | 11493 |
| Noack volatility, wt% | 10.8 | 9.2 | 10.4 | **23.6** | 14.6 |

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## Blended Base Oil Requirements for Current ILSAC GF-3 PCMO Products

| SAE Grade (No. of Blends) | 5W-20 (4 Blends) | 5W-30 (5 Blends) | 10W-30 (4 Blends) |
|---|---|---|---|
| Average Base Oil Blend Properties | | | |
| KV @ 100°C, cSt | 4.6 | 4.8 | 5.7 |
| Viscosity Index | 118 | 114 | 105 |
| CCS Viscosity @ -25°C, cP | 1365 | 1810 | 4000 |
| CCS Viscosity @ -20°C, cP | - | - | 2185 |
| NOACK Volatility, wt% | 14.8 | 14.3 | 14.3 |
| Base Oil Composition, % | | | |
| API Group I, II | 0 | 0 – 45 | 65 – 100 |
| API Group II+ | 100 | 55 – 100 | 0 – 35 |
| API Group III | 0 | 0 | 0 |

***Based on Lubrizol 20000 & 20000A DI***

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## Yubase Provides Significant Formulation Flexibility in PCMO and HDMO Products

| SAE Grade (No. of Blends) | 5W-30 Conventional (5 Blends) | 5W-30 Synthetic (Yubase) | 10W-30 Conventional (4 Blends) | 10W-30 Synthetic (Yubase) |
|---|---|---|---|---|
| Average Base Oil Blend Properties | | | | |
| KV @ 100°C, cSt | 4.8 | 5.5 | 5.7 | 6.5 |
| Viscosity Index | 114 | 130 | 105 | 130 |
| CCS Viscosity @ -25°C, cP | 1810 | 1800 | 4000 | 2815 |
| CCS Viscosity @ -20°C, cP | - | - | 2185 | 1630 |
| NOACK Volatility, wt% | 14.3 | 9.5 | 14.3 | 7.3 |

***Based on Lubrizol 20000 & 20000A DI***

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## Impact of GF-4 on Group III

- Severity of the Seq IIIG => Limitation on the use of Group I Base stocks.
- Increase performance in the VIB (Fuel Economy) may pose challenge to high VI stocks.

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## Development of High Quality Base Stocks

Projected base stock changes ILSAC GF-4 vs GF-3

1. SAE 0W-20 (New Grade in GF-4)
   - ILSAC GF-4 to require API Group III with some PAO
2. SAE 5W-20
   - ILSAC GF-3 and ILSAC GF-4 to remain based on API Group $II^+$
3. SAE 5W-30
   - Presently formulated on API Group $II^+$ with Gp II and I (limited)
   - ILSAC GF-4 to see increase in API Group $II^+$ concentration with API Group II only (no Group I)
4. SAE 10W-30/40
   - Presently formulated on Group I and II with some $II^+$
   - ILSAC GF-4 to see slight increase in API Group $II^+$ content but considerable shift from API Group I to API Group II

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## Opportunity to Develop New API Group I+ Based on Yubase Group III and Group I

| SAE Grade | 5W-20 | 5W-30 |
|---|---|---|
| Blended Base Oil Properties | | |
| KV @ 100°C, cSt | 4.6 | 4.8 |
| Viscosity Index | 117 | 114 |
| CCS Viscosity @ -25°C, cP | ~1365 | ~1865 |
| NOACK Volatility, wt% | 14.8 | 15.1 |
| Base Oil Composition, % | | |
| API Group I | 30 | 50 |
| API Group II+ | 0 | 0 |
| API Group III (Yubase 4,6) | 70 | 50 |

*Based on Lubrizol 20000 & 20000A DI*

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## Approval of Premium European/North American PCMO

| | 5W-30 | 5W-30 | 5W-30 | 5W-40 | 5W-40 |
|---|---|---|---|---|---|
| Yubase 4 | 69.0 | 83.0 | 98.1 | 65.6 | 72.8 |
| Yubase 6 | 31.0 | 17.0 | 1.9 | 34.4 | 27.2 |
| Additives | Balanced | <- | <- | <- | <- |
| Performance | | | | | |
| • API | SL/CF | SL/CF | SL/CF | SL/CF | SL/CF |
| • ACEA | - | A1/A5/B1 | +B5 | A3/B3 | A3/B3/B4 |
| • MB | - | | - | 229.1 | 229.3 |
| • VW | - | | - | 502/505 | 502/505 |
| • Porsche | - | | - | Porsche | Porsche |
| • BMW Long Life | - | | - | - | LL-98 |
| • Opel GM | - | | - | - | LL-B-025 |

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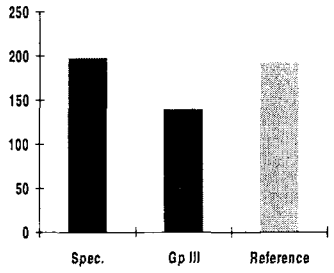
## API Group III Provides Excellent Response in VW T-4 Engine Test

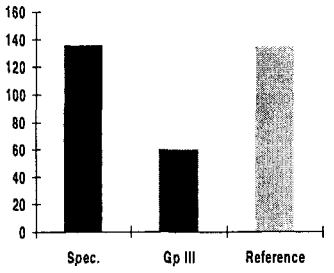
### Oxidation Stability

Engine Test

**- VW T-4 (Oxidation, piston cleanliness, MB 229.3, VW502.00)**




KV 40ºC, cSt




Viscosity Increase(40ºC, %)

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## Performance of ACEA E2/E3/E5, MB 228.3 HDDO

| | | | |
|---|---|---|---|
| **Viscosity Grade:** | **10W-40** | Base Oils: Yubase 6 + 8 | |
| Viscosity@100°C | 14.0 cSt | CCS @-20°C | 3070 cP |
| HTHS Viscosity | 3.85 cP | Noack Volatility | 7.6 % |

| | Requirements | E3/228.3/228.5 | Results |
|---|---|---|---|
| OM 364LA | Bore Polish, % | 1.0 / 1.0/ 0.5max | 0.3 |
| | Average Piston Merit | 45 / 45 / 50 min | 58.8 |
| | Cylinder Wear,um | 3.0 / 3.0/ 2.5max | 1.3 |
| | Sludge Merit | 9.5 / 9.5/ 9.6min | 9.7 |
| | Oil Consumption,kg | 12 / 12 / 10 max | 8.7 |
| OM 602A | Cam Wear,um | 50 / 45 / 45 max | 6.8 |
| | Cylinder Wear,um av | NR / 15 / 15 max | 6.5 |
| | Bore Polish, % av | NR / 4.5/ 3.0max | 0.2 |
| | Piston Cleanl. Merit | NR / 24 / 26 min | 30.8 |
| | Engine Sludge Merit | NR / 8.9/ 9.0min | 9.5 |
| | Viscosity Inc.@40°C,% | NR / 70 / 60 max | 16.9 |
| | Oil Consumption,kg | NR / 10 / 10 max | 5.8 |

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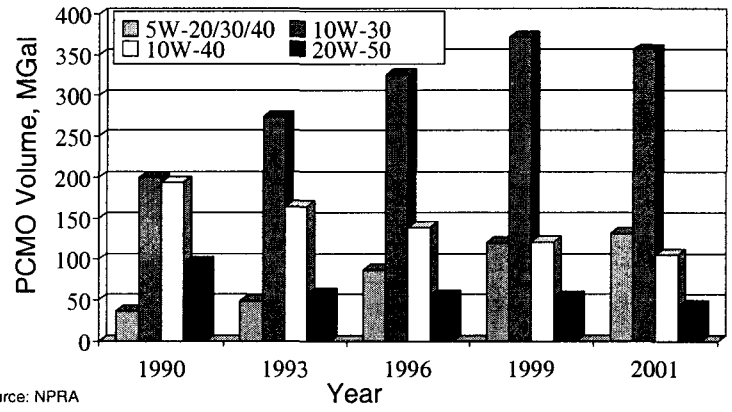
## PCMO Market Shows Continued Shift To Lower Viscosity SAE Grades

• Introduction of SAE 5W-20 with ILSAC GF-3 and SAE 0W-20 growth with ILSAC GF-4 reconfirms industry commitment to lower SAE grades




Source: NPRA

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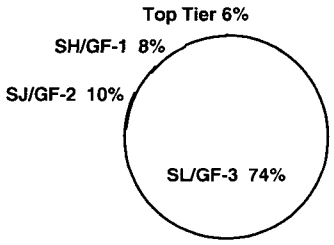
## Gasoline Engine Oil in Korea/Japan

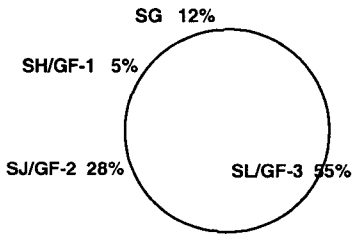
1. Current Market Features

**Korea**




o SL/GF-3 dominates
o Top tier market is growing
- ex. 5W40 with ACEA and European OEMs
o SJ, SH are mainly OEM's factory fill oil

**Japan**




o SL/GF-3 dominates
o Fuel Economy oil grade (5W20) is emerging
o 10W30 grade dominates (>60%)
o Lower grade (below SH) is still existing

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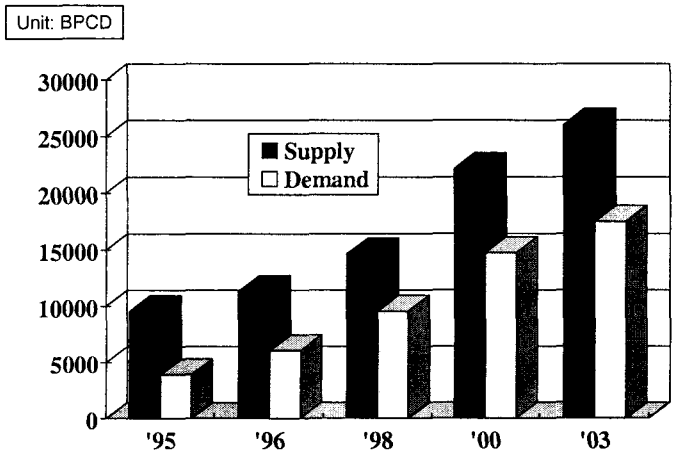
## VHVI Base Oils - Supply vs Demand

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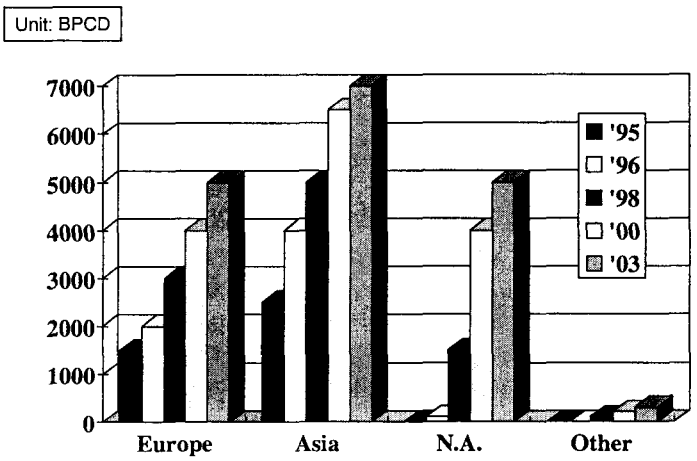
## VHVI Base Oils - Demand (Most Likely)

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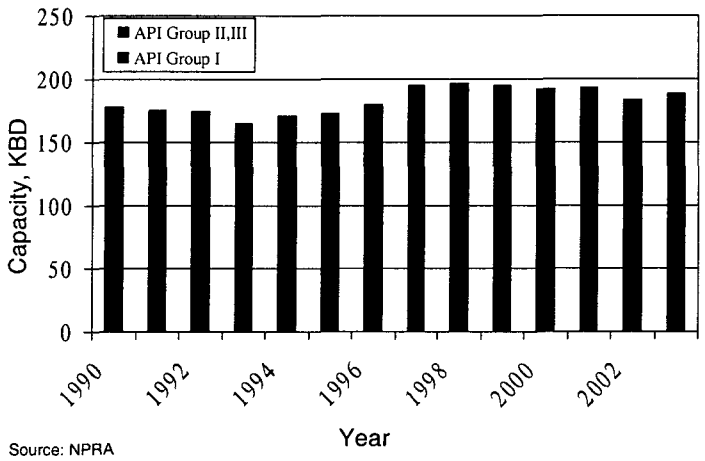
## North American Base Stock Capacity Shows Continued Shift Towards API Group II, II+ and III




Source: NPRA

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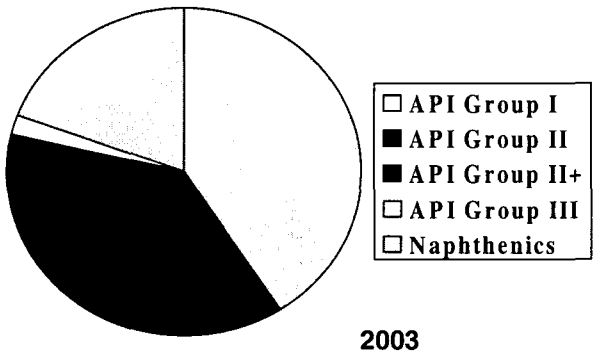
## API Group III Remains Minor Component in North American Base Oil Industry




**2003**
**Total Capacity**
**232.4 KBD**

Source: NPRA, Lubricants World

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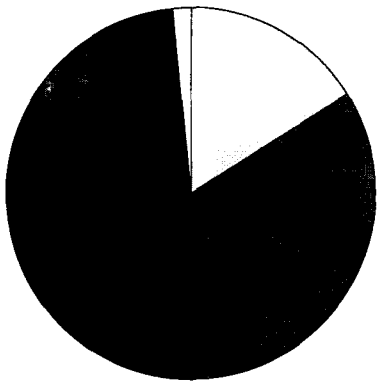
## Asia-Pacific Leading API Group III Base Oil Producer




2002 Estimated
Global Production
27.8 KBD

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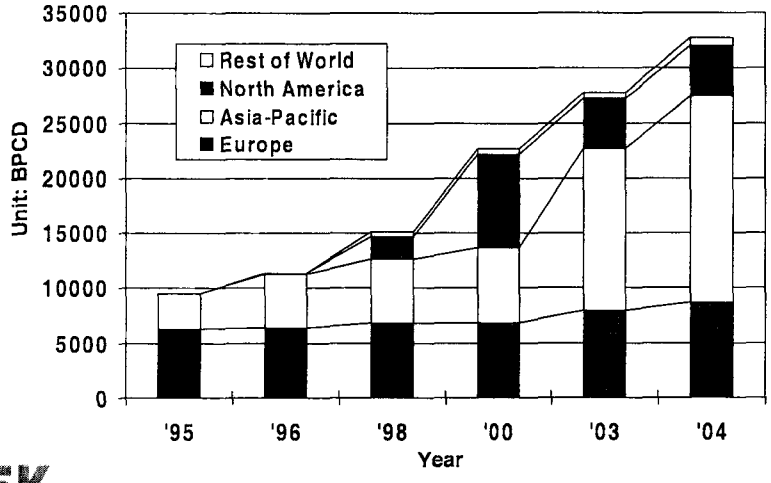
## Asia-Pacific Leads in API Group III Supply

- New capacity in 2004 to include SK Corp, ExxonMobil and Lukoil
  - BP to exit API Group III manufacturing

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## VHVI Base Oils - Future

- ❑ VHVI based Lubricants will grow in Market Share
- ❑ Automotive Applications appear to be in a 'Real' Growth Phase
  - ILSAC GF-3: Noack Volatility - 15% max. (GF-2: 22%)
  - ILSAC GF-4: Enhanced Performance and Retention of Fuel Economy
- ❑ Severe Applications will be benefit from VHVI base oils
- ❑ Replacement for PAOs
  - Cost Effective than PAOs in achieving Synthetic Performance

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## VHVI Base Oils - Today & Tomorrow

- ❑ Today
  - Compatible to PAO Quality, but limited Viscosity Grades & Applications
  - Better Economics than PAO
  - Niche Market
- ❑ *Tomorrow*
  - *API Group I Base Oil will maintain as Mainline Product*
  - *VHVI Base Oils demand will be increased with API Group II Base Oil*
  - *Big potential Supply Capability of VHVI Base Oils*
  - *PAO will maintain its merit as Synthetic*

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# 논 문 발 표

## Session I(A) 마찰 · 마멸