GTL Technology

조용래 수석연구원

(SK 대덕기술원 윤활유Lab.)

GTL Technology

Oct. 6, 2005

Y. R. CHO
Principal Research Scientist

SK Corporation

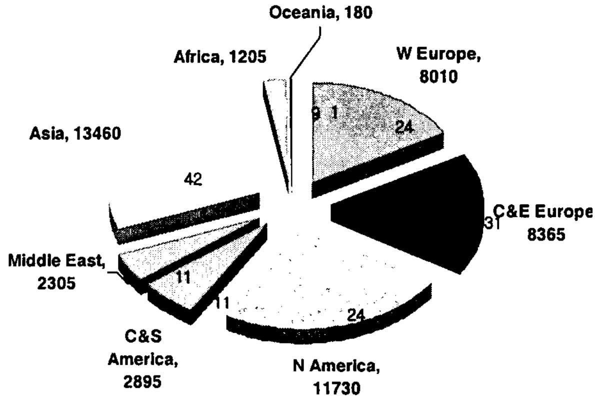
Contents

1. Global Base Oil Market
2. Overview of GTL Process
3. GTL Process
4. GTL Base Oil Process
5. GTL Base Oil Product
6. Economics of GTL Process
7. GTL Technology Impact on Market
8. Summary and Discussion

I. Global

World Base Oil Supply (000MT/y, No. of Plant, 2004)

- ➢ **Design Capacity: 48,150**
- ➢ **Operating Capacity: 34,900**



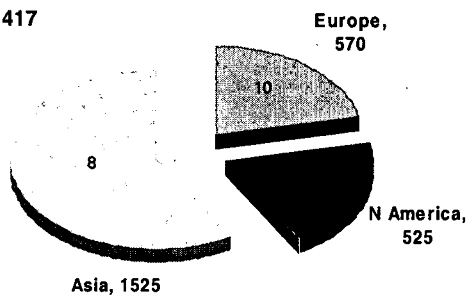
SK Corporation

I. Global

API Group III Base Oil Supply (000MT/y, No. of Plant, 2004)

- ➢ **Design Capacity: 2,620**
- ➢ **Purchasing Market Size: 1,000~1,100**

- ➢ **PAO Manufacturing Capa.: 417**



SK Corporation

I. Glob

Supply and Demand

- Lubricants market is potentially over-supplied with base oils
- Base oils demand is growing only slowly
- Total over-capacity of base oils is shrinking by older and less efficient facilities are closed
- Most new or upgraded plants are producing high quality (Group II and/or Group III) base oils

SK Corporation

I. Globa

GTL Base Oil Manufacturing

- Underway 3 Projects: 2,395 (000MT/y, 2004)
- 10 GTL Projects up to y2010
- Similar quality to PAO

Company	Location	Capacity, 000 MT/y	Remarks
ExxonMobil	Ras Laffan, Qatar	1520	Start in 2011
SasolChevron	Ras Laffan, Qatar	400	Start in 2008
Shell	Ras Laffan, Qatar	475	Start the end of 2009
		2395	Total

SK Corporation

2. Overview of

History of GTL Process

- In 1923, Franz Fisher and Hans Tropsch developed to produce liquid hydrocarbon (mainly oxygenates) from synthesis gas over Fe catalyst
- During 1930's, FT process was applied to produce chemicals.
- The process that is designed to produce liquid fuels from coal derived synthesis gas was originally used in Germany in world war II (Germany relied on synthetic fuels for 75% of its needs)
- Since 1950, Sasol Ltd. developed further and used it commercially.
- Main focus of recent (over the last 15years) attention is to produce fuels and waxes from surplus natural gas
- Main product is low sulfur (<10ppm) diesel and waxes can be used to high quality base oil by hydro-isomerization

SK Corporation

2. Overview of

Current GTL Plant

- Sasol
  - Mossel Bay, South Africa
  - 30,000BD, 1993
  - Fuels, Waxes
- Shell
  - Binturu, Malaysia
  - 14,700BD, 1993
  - Feeds for Chemicals, Waxes for lube base oils

3 (4)

SK Corporation

2. Ove

Background of Recent GTL Project

Monetizing Strained Natural gas

- Many oil fields re-injected gas to produce more crude oils over the last 20 years and is recently re-produced in increasing amounts
- Global reserves of natural gas are much larger than crude oil reserves
- Surplus of Natural gas

Environment Issues

- Low sulfur (<10ppm) fuels in Western Europe and North America (2005)
- Penalty to flaring of natural gas

SK Corporation

2. Ove

Global Reserves of Natural Gas (Production Ratios, 2003)

Country	Years	Country	Years
Iraq	750	Kazakhstan	150
Qatar	490	Venezuela	150
Iran	355	Bolivia	125
Libya	230	Saudi Arabia	110
Nigeria	195	Russia	81
Abu-Dhabi	180	......	
Azerbaijan	175	US	10
Kuwait	170	UK	6 3 (4)

Source: CPS, Oxford Univ.

SK Corporation

3. GT

Which companies are developing GTL Processes ?

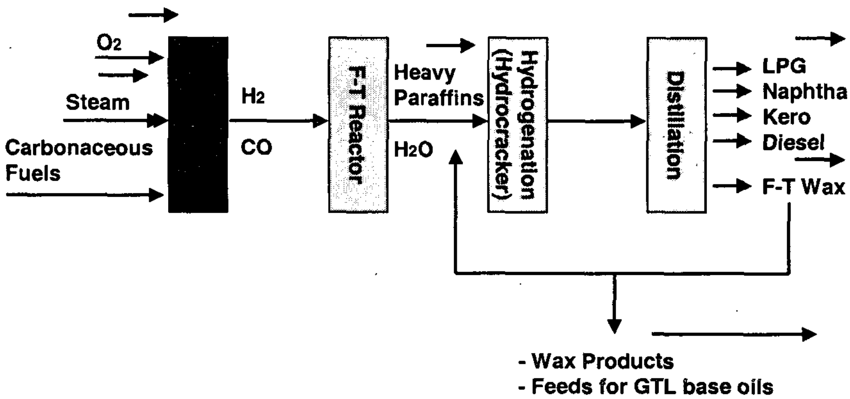
- Shell
- SasolChevron
- ExxonMobil
- BP
- ConocoPhillips
- Statoil
- Syntroleum
- Rentech

3 (4)

SK Corporation

3. GTL

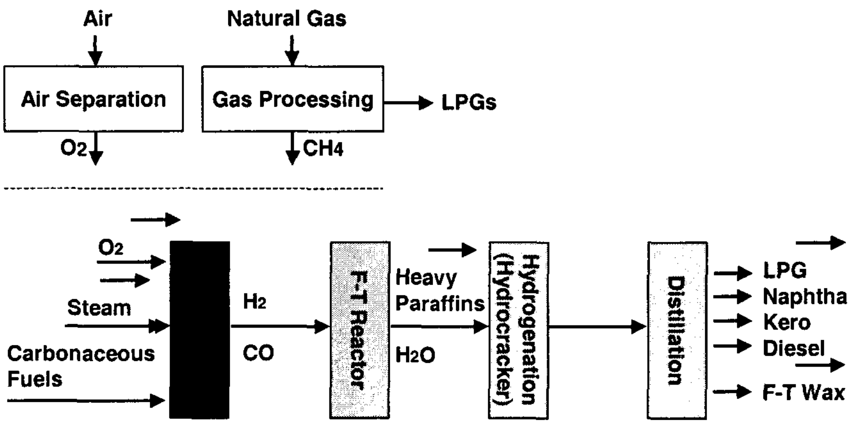
General Scheme of GTL (or CTL) Process



SK Corporation

3. G

Step I: Production of Synthesis Gas



SK Corporation

3. GTL

Production of Synthesis Gas

- Syngas (H_2 + CO) is from carbonaceous fuels, oxygen and/or steam
- Carbonaceous fuels are including Coal, Petroleum coke, Heavy residue and Bitumen
- Syngas from natural gas is much economic and the hydrogen to carbon ratio in natural gas is ideal for the next step Fischer-Tropsch process
- Two alternative processes: Partial Oxidation, Steam Reforming

Syngas Process				
Partial Oxidation	ExxonMobil, Shell, Sasol, Rentech	O_2	No catalyst	H_2 62 : CO 35 : CO_2 3
Steam Reforming	BP, Rentech, Sasol	H_2O	Ni Catalyst	H_2 75 : CO 15 : CO_2 10
Autothermal Reforming	Syntroleum	Air	POX + Steam reforming	H_2 34 : CO 17 : CO_2 2 : N_2 47

SK Corporation

Comparison of Synthesis Gas Processes

Partial Oxidation

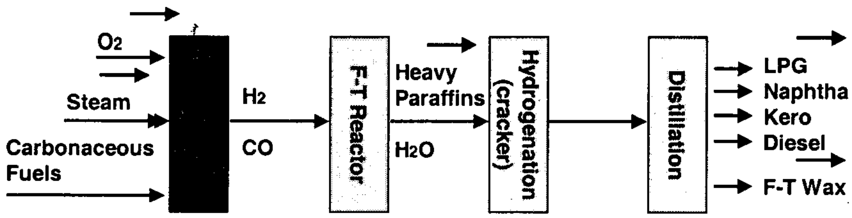
- Thermally efficient (exothermic reaction, no steam needed)
- Lower amount of feed required per unit of final product
- High capital cost
- Pure oxygen needed
- Solid coke can be a problem
- Wide range of feeds: natural gas, bitumen, residue, coal and coke

Steam Reforming

- Widely used
- External heat needed
- Catalyst and steam needed
- No coking
- Lower operation temperature
- Feed: low sulfur feedstock like natural gas

Now most companies use Auto Thermal Reforming than Steam Reforming

Step II: Fisher-Tropsch Reaction



3. GTL

Fischer-Tropsch Reaction

- H_2 to CO ratio can affect chemical composition of F-T product
- Catalysts: Co, Fe
- Iron cat is more tolerant to S and useful for low H_2:Co ratio from Coke, Coal, Bitumen, Fuel oil and low BTU natural gas feedstocks
- Cobalt cat is useful for high H_2:Co ratio from higher BTU natural gas, mixed natrural gas/ steam feedstocks
- Germans used Co cat. for coal and Sasol is using Fe cat. for natural gas

Sasol	Developed Co Using Fe
ExxonMobil, Shell, Syntroleum	Co
Rentech (lisensed to Texaco)	Fe

SK Corporation

3. GTL Proc

Fischer-Tropsch Reactors

- Fixed beds
- Fluidised beds
- Fixed-fluidised beds
- Slurry (or three phase)

Fixed beds	BP, Shell, Sasol, Syntroleum
Fluidised beds	Sasol, Syntroleum
Fixed-fluidised beds	Sasol
Slurry (three phase)	ExxonMobil, Rentech, Sasol, Shell, Syntroleum

SK Corporation

3. GT

Fischer-Tropsch Reaction Product

Main Products

- Oils and waxes
- Liquid : Solid ratio -> 50:50 ~ 80: 20
- No S, N and Aromatics
- Mainly n-Paraffins and iso-paraffins with some oleffins and alchols
- Very few (or no) naphthens

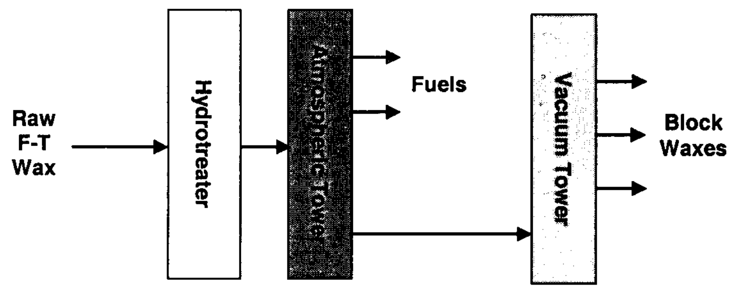
By Products

- Tail gas (H_2, CO, CO_2, Methane, Ethane, Butane)
- Water
  - Fe cat.: 0.7MT/ MT of Product
  - Co cat.: ~1.2MT/ MT of Product
- H_2, Hydrocarbons can be used in generation of electricity
- H_2, CO can be recycled to Syngas reactor
- Excess heat can be used power generation or in desalt of sea water

SK Corporation

4. GTL

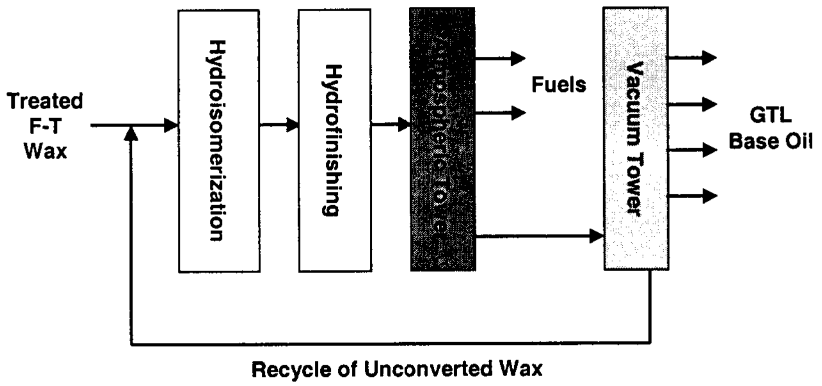
Step I: Treating of F-T Wax



SK Corporation

4. GT

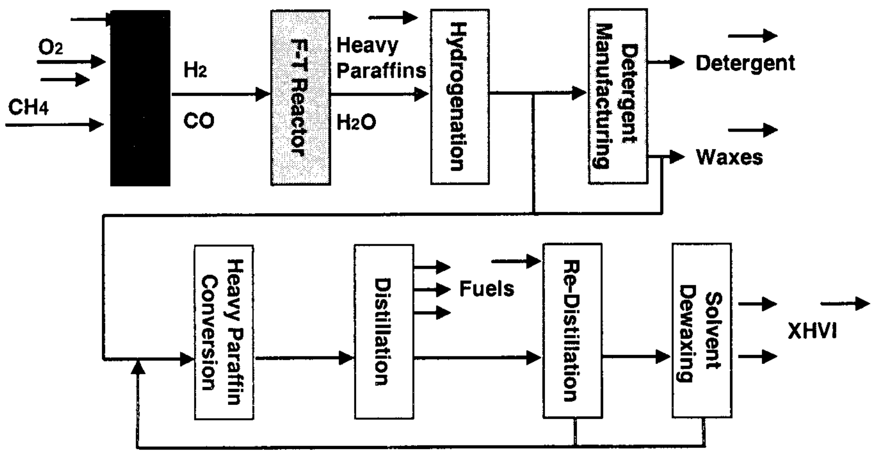
Step II: GTL Base Oil Production



SK Corporation

4. GTL

Showa Shell's XHVI Base Oil Process



SK Corporation

5. GTL Base Oil

General Property of GTL Base Oil

- Synthetic
- Better than Group III+ base oils
- VI: 140~160
- Good pour point: typical -21℃
- Low volatility: equal to PAO
- Excellent oxidation and thermal stability

3 (4)

- No S, N, Aromatics and Naphthenes
- Good additive response
- Viscosity gradfes: 2, 3, 4, 6, 8, 10, 12 cSt (No Bright Stock)

SK Corporation

5. GTL Base Oil

4 cSt Grades

	Group III+	PAO	GTL Lube
KV @100℃, cSt	4.0	3.9	4.0
KV @40℃, cSt	16.6	16.8	16.2
KV @-40℃, cSt	solid	2460	-
VI	144	129	151
CCS @-25℃, cP	-	<900	800
Pour Point, ℃	-18	-70	-21
Flash Point, ℃	225	215	-
Sulfur, ppm	200	0	0
Noack Volatility, wt%	16	12	13
Composition Cp/Cn/Ca	98/2/0	100/0/0	100/0/0

Source: CPS, Oxford Univ.

SK Corporation

5.

8 cSt Grades

	Group III+	PAO	GTL Lube
KV @100℃, cSt	7.9	7.7	8.0
KV @40℃, cSt	44.8	46.3	44.1
KV @-40℃, cSt	solid	18200	-
VI	148	136	155
CCS @-25℃, cP	-	1800	-
Pour Point, ℃	-18	-57	-21
Flash Point, ℃	-	258	-
Sulfur, ppm	0	0	0
Noack Volatility, wt%	6	3	3 (4) 4
Composition Cp/Cn/Ca	100/0/0	100/0/0	100/0/0

Source: CPS, Oxford Univ.

SK Corporation

6. Econo

GTL Process

- Low thermal efficiency (max 65%) than crude oil refinery
- Price of natural gas feedstock:
  must be low for GTL product than crude oil products
- Able to compete with crude oil products at over US$20 of crude oil price
- For the production of 1 barrel of oil products, the cost of gas supply needs 10 times of natural gas feedstock price per million BTU
- Plant economics are attractive for 'strained' natural gas that has not got local market or pipeline distribution system

SK Corporation

6. Econo...

GTL Plant Location

- GTL projects provide three opportunities

  - To convert Low value gas into easily transported products
  - To produce low-sulfur / low aromatics transportation fuels
  - To produce high value added waxes and lube base oils

- Europe, North America and Libya has local market or gas pipeline networks

- Hence below areas may be suitable
  - Abu-Dhabi, Australia, Bolivia, Malaysia, Iran, Iraq, Kuwait, Nigeria, Saudi Arabia, Qatar, Venezuela and Alaska

SK Corporation

6. Econo...

GTL Plant Size

- GTL plant has higher capital cost and operating cost than conventional crude oil refinery

- In 2003, Shell did claim
  - EPC cost of 75,000 bpd GTL plant: $20,000/ bpd ($50,000 in 1987)

- Improved EPC cost can provide the economics of GTL plant scale at over 35,000 bpd

- 80,000 bpd GTL plant is to produce

  - Gas: 2,000 bpd (10,000 MT/y)
  - Naphtha: 12,000 bpd (610,000 MT/y)
  - Diesel: 50,000 bpd (2.5 million MT/y)
  - Wax/ Base oil: 16,000 bpd (810,000 MT/y)

- 10 GTL projects up to 2010

SK Corporation

6.

Current GTL Plant Projects

Company	Location	Target Completion
Shell	Bintulu, Malaysia Qatar Indonesia	1996 2009 2010 ?
ExxonMobil	Ras Laffan, Qatar	2011
SasolChevron	Escravos, Nigeria Ras Laffan, Qatar NW Shelf, Australia	2005 2008 2009 ?
BP	Alaska	2007 ?
Syntroleum	Sweetwater, Australia Talaru, Peru	2005 (abandoned in 2002) 2007 ?
Rentech	Bolivia Indonesia	? ?

* *Sasol: developing 2 CTL plants in China*

SK Corporation

7. GTL

Impact on Petroleum Industry

- **80,000 bpd GTL plant**

	World Market (000MT/y)	1 GTL Plant	5 GTL Plants
Diesel	770,000	2,550 (0.3%)	12,750 (1.5%)
Base Oil	35,500	810 (2.3%)	4,050 (11.4%)
Group III/III+	1,000	810 (81%)	4,050 (405%)

* *Consideration: demand of Group III base oils ??*

* Source: CPS, Oxford Univ.

SK Corporation

7. GTL

Impact on Base Oil Market

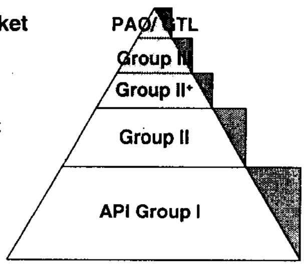
- Current GTL Lube Projects can be a reason of over-supply for high quality base oil market
- In terms of quality, Group IV (PAO) base oils are most severely affected by
  - PAO manufacturing capacity: 417,000MT/y
  - PAO plants working ratio: ~75%
- Group III base oils will have to compete with Group II, II+
- Group I base oils as well will be under more severe competition than now
- Main areas for manufacturing of high quality base oils would be Middle East, Asia and South America

SK Corporation

7. GTL

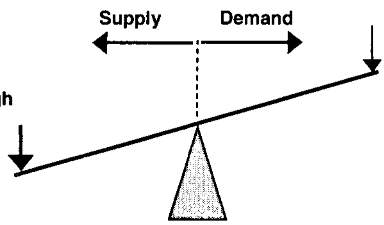
Impact on Base Oil Market

Oversupply of high quality base oils can put Group III in lower performance tiers



Increasing demand of high quality base oils can put Group III in premium tiers

Increasing supply of high quality base oils
- Group II+, III
- GTL based
- New PAO products



For supply/ demand balance, performance upgrades and new products development in finished products are needed

SK Corporation

8. Sum

- GTL wax/ lube plant is a separate investment decision
- GTL plant will primarily produce diesel fuels once crude oil price is high
- However, the future scale of GTL plants could have a major impact on the pattern of base oil supply and quality
- If demand of high quality base oils is not increased in near future, these GTL base oils are likely to put severe competition on all other base oils
- Group IV (PAO) and Group III base oils will be much affected by, however PAO is still useful in low temperature application area
- Some economic Group I plant will remain to produce BS and waxes
- Paraffin wax industry is not much affected by GTL wax
- GTL base oil seems that it has lack of solvency power, it may need some Ester in finished product formulation with full GTL base oil to improve additive solubility and seal compatibility

SK Corporation

Reference

- History of GTL Technology, Jim Rockwell of Conoco Inc., NPRA 2001
- GTL Manufacturing Economics, Get S. Agashe, William R. Downey and George A. Morvey of Kline & Company, NPRA 2001
- GTL Process for Base Oil Manufacture, R David Whitby of Pathmaster Marketing Ltd., Oxford CPS Princeton Program, 2005
- GTL Technology Gains Momentum, Gerald Parkinson, Fuels & Lubes International, ¾ 2005

SK Corporation