4A2. Bituminous Coal Liquefaction Technology (NEDOL)

Research and development: New Energy and Industrial Technology Development Organization; Nippon Coal Oil Co., Ltd.
[Sumitomo Metal Industries, Ltd.; Idemitsu Kosan Co., Ltd.; Nippon Steel Corp.; Chiyoda Corp.; JFE Steel Corp.; Hitachi Ltd.; Mitsui Coal Liquefaction Co., Ltd.; Mitsui Engineering & Shipbuilding Co., Ltd.; Mitsubishi Heavy Industries, Ltd.; Kobe Steel, Ltd.; Japan Energy Co., Ltd.; Sumitomo Metal Mining Co., Ltd.; Asahi Chemical Industry, Co., Ltd.; Toyota Motor Corp.; Sumitomo Coal Mining Co., Ltd.; Nissan Motor Co., Ltd.; The Japan Steel Works, Ltd.; Yokogawa Electric Corp.; and The Industrial Bank of Japan, Ltd.]
Project type: Development of bituminous coal liquefaction technology, and development of NEDOL Process
Period: 1983-2000 (18 years)

Technology overview

1. Overview of NEDOL Process development

The conceptual design of a 250 t/day pilot plant began in FY1984. Owing to changes in economic conditions, however, the design of a 150 t/d PP began in FY1988. As a support study to the pilot plant, the operational study of a 1 t/d process support unit (PSU) was carried out. The 1 t/d PSU, constructed in FY1988 at Kimitsu Ironworks of Nippon Steel Corp., consisted of four stages: coal storage and pretreatment, liquefaction reaction, liquefied coal distillation, and solvent hydrogenation. Over the ten-year period from FY1989 to FY1998, a joint study team from Nippon Steel Corp., Mitsui Coal Liquefaction Co., Ltd., and Nippon Coal Oil Co., Ltd. conducted operational studies on nine coal grades under 72 conditions. Through the 26,949 hours of cumulative coal slurry operations, the stability and the overall operability of the NEDOL Process were confirmed, and optimization of the process was established. Finally, the necessary design data was acquired. Construction of the 150 t/d pilot plant was launched in 1991 at Sumitomo Metal Industries, Ltd.'s Kashima Steelworks (Kashima City, Ibaraki), requiring nearly five years for completion. The pilot plant consisted of five main facilities: the coal treatment unit, the consisted liquefaction reaction unit, the liquefied coal distillation unit, the solvent hydrogenation unit, and the hydrogen production unit.

2. Evaluation of NEDOL Process

Figure 1 shows the progress of coal liquefaction technology since before World War II, expressed by the relation between the severity of the liquefaction reaction and the yield of coal-liquefied oil by generation. As seen in Figure 1, the NEDOL Process is competitive with the processes in Europe and the United States in terms of technology, economics, and operational stability, and thus the NEDOL Process is one of the most advanced processes in the field, reaching a position to shift to commercialization in the shortest amount of time.

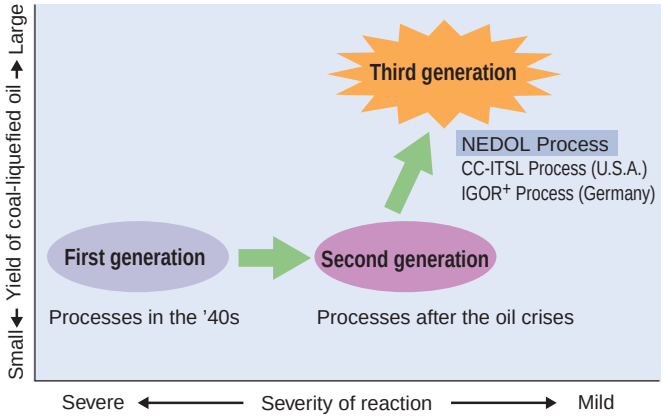


Fig. 1 Relation between the severity of liquefaction reaction and the yield of coal-liquefied oil

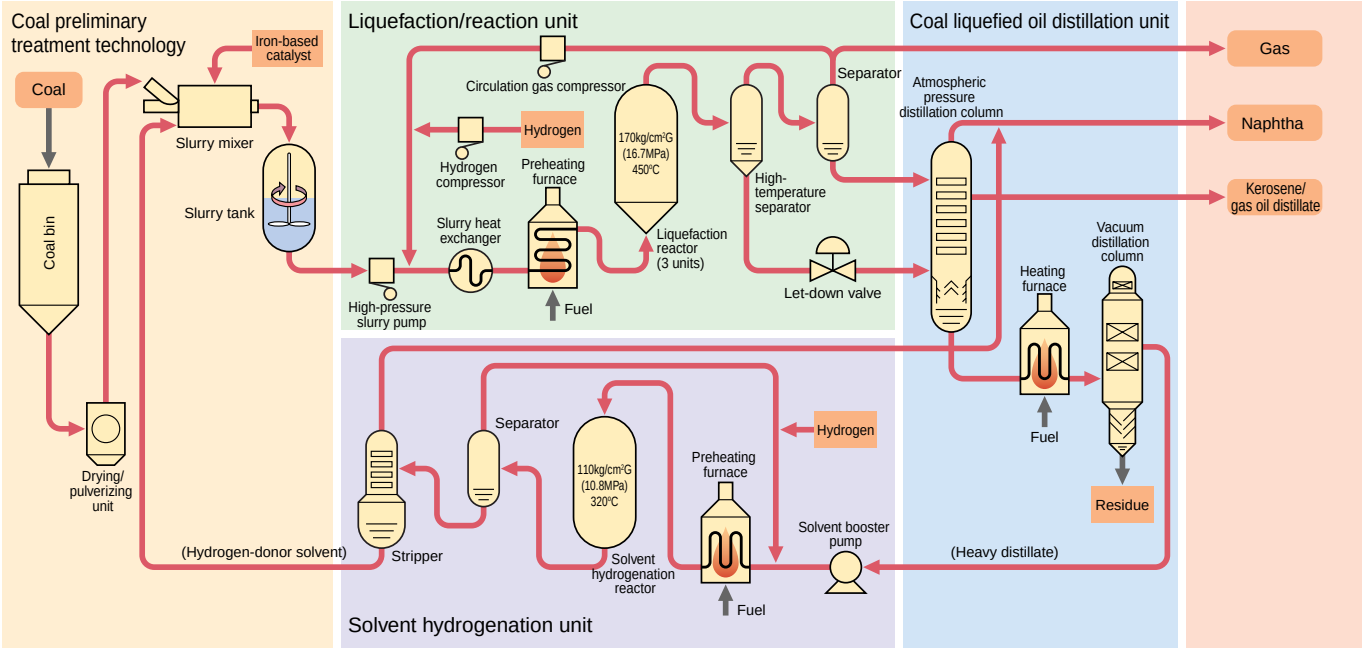


Fig. 2 Bituminous coal liquefaction process flowchart

3. Features of NEDOL Process

The NEDOL Process is a coal liquefaction process developed exclusively in Japan. The process has integrated the advantages of three bituminous liquefaction processes (Direct Hydrogenation Process, Solvent Extraction Process, and Solvolysis Process), thus providing superiority in both technology and economics. The advantages of the NEDOL Process include:

(1) attaining high liquid yield under mild liquefaction reaction conditions owing to the iron-based fine powder catalyst and to the hydrogen-donating solvent;

(2) producing coal-liquefied oil rich in light distillate;

(3) assuring high process stability because of the highly reliable core process stages; and

(4) applicability to a wide range of coal ranks, ranging from sub-bituminous coal to low coalification grade bituminous coal.

Catalysts			
Liquefaction catalyst		Hydrogenation catalyst	
Catalyst composition Fe (wt%)	48.2	Catalyst composition Fe (wt%)	Ni-Mo/ γAl_2O_3
S (wt%)	51.0	Specific surface area (m^2/g)	190
Other (wt%)	0.8	Micropore volume (ml/g)	0.7
Specific surface area (m^2/g)	6.1	Mean micropore size (nm)	14.5
Size of pulverized catalyst [D^{50}](μm)	0.7-0.8		

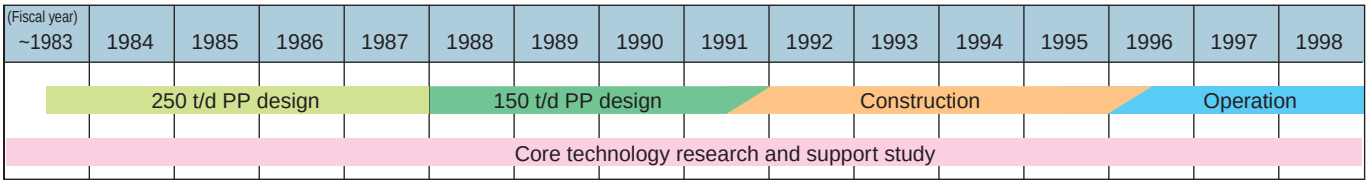
4. Typical reaction conditions of NEDOL Process

Liquefaction reaction				Solvent hydrogenation reaction			
Temperature	450°C	Slurry concentration	40 wt% (dry coal basis)	Temperature	320°C	Gas/solvent ratio	500Nm^3/t
Pressure	170kg/cm^2·G	Slurry retention time	60 min	Pressure	110kg/cm^2·G	Hydrogen concentration in recycle gas	90 vol%
Type of catalyst	Iron-base fine powder catalyst	Gas/slurry ratio	700Nm^3/t	Kind of catalyst	Ni-Mo-Al_2O_3		
Added amount of catalyst	3 wt%(dry coal basis)	Hydrogen concentration in recycle gas	85 vol%	LHSV	1 $hr^{(-1)}$		

5. Pilot plant: Objectives and achievements

Development objectives	Target	Achievements
1. Yield of coal-liquefied oil	For standard coal, 50 wt% or higher yield of light to medium oils, and 54 wt% of higher total yield	With standard coal, attained 51 wt% yield of light to medium oils, and 58 wt% of total yield
2. Slurry concentration	40-50 wt% of coal concentration in slurry	Stable operation achieved at 50 wt% of coal concentration in slurry
3. Added amount of catalyst	2-3 wt% (dry-coal basis) of added amount of iron sulfide-base catalyst	Operation conducted in a range from 1.5 to 3 wt% of added amount of iron sulfide-base catalyst
4. Continuous operation time	1,000 hours or more for standard coal	Continuous operation of 80 days (1,920 hours) achieved with standard coal
5. Range of applicable coal grades	Three coal ranks or more	Operation conducted with a wide range of coalification ranks, namely Adaro coal, Tanitohalm coal, and Ikejima coal

6. Research and development timetable of NEDOL Process pilot plants



7. Research and development results

All the acquired data, including the pilot plant data, the basic research data, and the support study data, were summarized in a technology package in preparation for practical application. At the Development and Assessment Committee Meeting for Bituminous Coal Liquefaction Technology in the Assessment Work Group of the Industrial Technology Council, held on December 22, 1999, the NEDOL Process was highly evaluated: "The NEDOL Process is at the highest technology level in the world, and has reached the stage where worldwide diffusion is expected." Thus, the development of coal liquefaction technology in Japan has already exited the research and development stage and entered the practical application stage. Furthermore, the developed materials and new processes are expected to significantly influence development in other industries.

Fig. 3 NEDOL Process pilot plant (150 t/d)

References

1) Sadao Wasaka: "Bulletin of The Japan Institute of Energy," 78 (798), 1999.
2) "Development of Coal Liquefaction Technology - A Bridge for Commercialization," Nippon Coal Oil Co., Ltd.
3) Haruhiko Yoshida: "Coal Liquefaction Pilot Plant," New Energy and Industrial Technology Development Organization.