

### 3A2. Bituminous Coal Liquefaction Technology (NEDOL)

**In charge of 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.; NKK 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)

#### Outline of technology

##### 1. Outline of NEDOL Process development

The conceptual design of a 250 t/d pilot plant (PP) 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., consists of four stages: coal storage and pretreatment, liquefaction reaction, coal liquefied oil distillation, and solvent hydrogenation. Over the ten-year period from FY1989 to FY1998, the joint study team of Nippon Steel Corp., Mitsui Coal Liquefaction Co., Ltd., and Nippon Coal Oil Co., Ltd. conducted operational studies on 9 coal grades under 72 sets of 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 PP was launched in 1991 at Kashima Steelworks of Sumitomo Metal Industries, Ltd. (Kashima City, Ibaraki), requiring nearly five years for completion. The PP consists of five main facilities: the coal preliminary treatment unit, the liquefaction reaction unit, the coal-liquefied oil 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 liquefaction reaction and the yield of coal-liquefied oil in individual generations. As seen in the figure, 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.

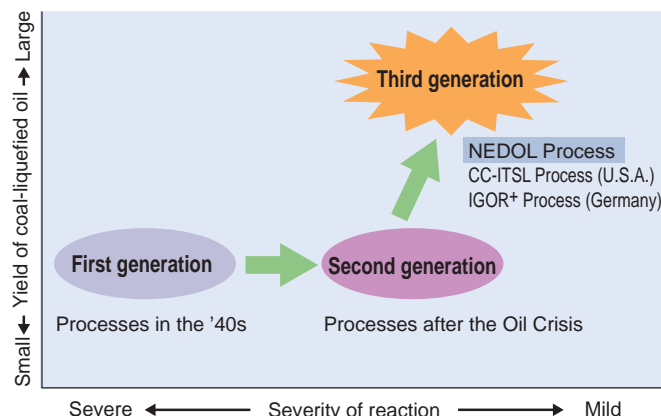


Fig. 1 Relation between the severity of liquefaction reaction and the yield of coal-liquefied oil

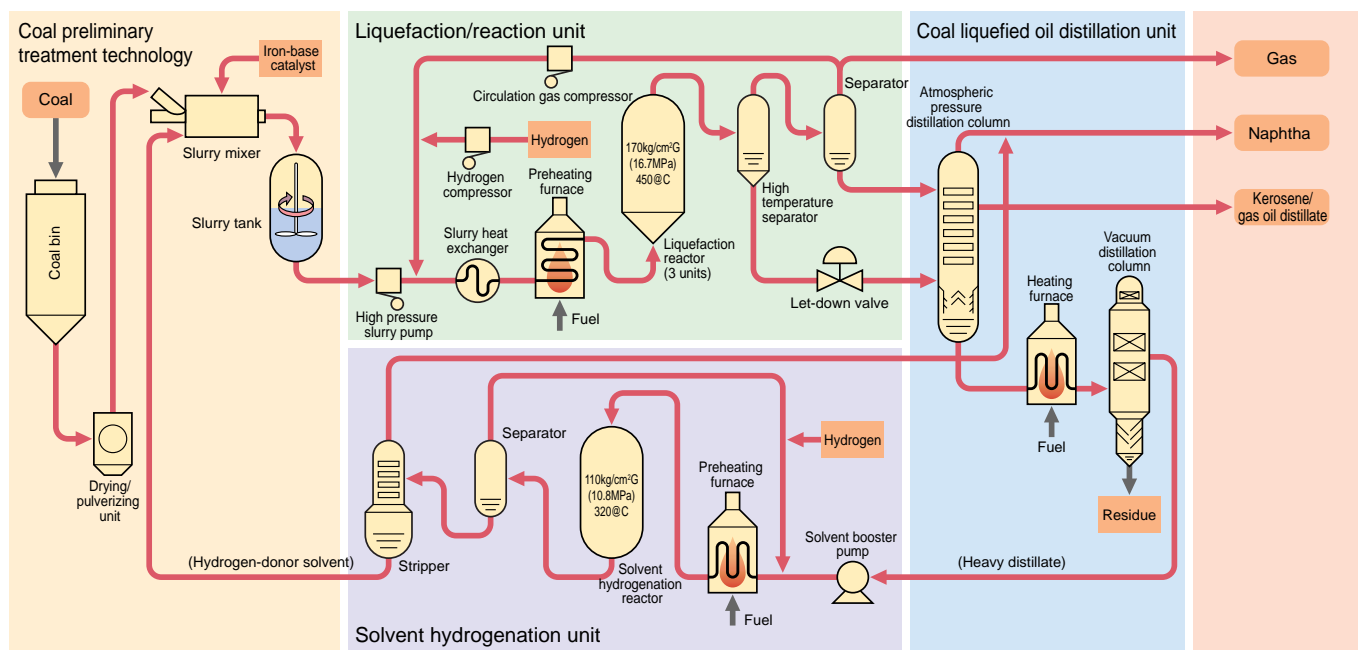


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### 3.Features of NEDOL Process

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) applicable to a wide range of coal grades, covering from sub-bituminous coal to low coalification grade bituminous coal.

Catalyst			
Liquefaction catalyst		Hydrogenation catalyst	
Catalyst composition Fe (wt%)	48.2	Catalyst composition Fe (wt%)	Ni-Mo/ $\gamma$ -Al <sub>2</sub> O <sub>3</sub>
S(wt%)	51.0	Specific surface area (m <sup>2</sup> /g)	190
Other(wt%)	0.8	Micropore volume (ml/g)	0.7
Specific surface area (m <sup>2</sup> /g)	6.1	Mean micropore size (nm)	14.5
Size of pulverized catalyst [D <sup>50</sup> ]( $\mu$ m)	0.7~0.8		

### 4.Typical reaction conditions of the NEDOL Process

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

### 5. Objectives and current progress of the pilot plant

Objective of the development	Target	Achieved result
1. Yield of coal-liquefied oil	For the operation standard coal, 50 wt% or higher yield of light to medium oils, and 54 wt% of higher total yield.	With the operation standard coal, there were 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 was 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 was 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 the operation standard coal.	Continuous operation of 80 days (1,920 hours) was achieved with the operation standard coal.
5. Range of applicable coal grades	Three coal grades or more.	Operation was conducted with wide range of degree of coalification: namely, Adaro coal, Tanitohalm coal, and Ikejima coal.

### 6. Research and development schedule of the NEDOL Process pilot plants

(Fiscal year)	~1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
		250 t/d PP design				150 t/d PP design			Construction				Operation			
	Core technology research and support study															

### 7. Result of the research and development

All the acquired data including the PP data, the basic research data, and the support study data were summarized in a technology package preparing 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 Total view of 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