COAL CONVERSION TECHNOLOGIES ON THE NEW SUNSHINE PROGRAM IN JAPAN

Akira Sugawara[1], Shigeru Kurosawa[1], Hiroaki Hatori[1], Kazufumi Saito[1], Yasuhide Yamada[1], Makoto Sugihara[1], Sadao Wasaka[2] Haruhiko Yoshida[2], Tomoyuki Seo[2], Takakazu Susuki[2], Mikiya Inoguchi[2] and Makoto Sohnai[2]

1) New Sunshine Program Promotion Headquarters, Agency of Industrial Science and Technology (AIST), Ministry of International Trade and Industry (MITI), 1-3-1 Kasumigaseki, Chiyoda, Tokyo 100, Japan.
2) Clean Coal Technology Center (CCTC), New Energy and Industrial Technology Development Organization (NEDO), 1-1-3 Higashi-Ikebukuro, Toshima 170, Japan.

Keywords: New Sunshine Program, coal gasification technologies, coal liquefaction technologies

ABSTRACT

Agency of Industrial Science and Technology (AIST) has been conducting R&D on coal conversion technologies in Japan. New Energy and Industrial Technology Development Organization (NEDO) has been carrying out some R&D projects on coal conversion technologies as a part of "New Sunshine Program" lead by AIST. Coal gasification technologies and liquefaction technologies are major concern for NEDO and the overview of the R&D projects updated is presented in this paper. In addition, a new project on coal hydrogasification technology are also outlined.

INTRODUCTION

AIST initiated the "**Sunshine Project**" to develop technologies associated with new energy in 1974 after the first oil crisis in 1973. In 1978, the "**Moonlight Project**" for energy conversion was started followed by the R&D Project on environmental technology in 1989. These projects were consolidated into the "**New Sunshine Program**" in 1993, aiming to develop the innovative technologies that could support the sustainable economical growth while solving energy and environmental issues. The R&D schedules of coal conversion technologies in the New Sunshine Program are shown in Table 1 [1, 2].

Both R&D of gasification and liquefaction started under the "**Sunshine Project**" have a long history (from 1974 for gasification and 1976 for liquefaction). By now, an integrated coal gasification combined cycle (IGCC) pilot plant with a capacity of 200 t/d demonstrated its capability in giving high thermal efficiency and environmental acceptability, while the operation of an 150 t/d coal liquefaction pilot plant is being carried out. Basic researches on coal liquefaction have been constantly conducted at national institutes and universities. The R&D of refining coal-derived liquids is still on the stage of laboratory scale. The project on coal hydrogasification started in 1996. This process produces methane directly from coal and hydrogen with BTX as co-products and is expected to have high efficiency, coal adaptability, environmental adaptability and cost competitiveness. The final target is to commercialize in 2010's [3].

Coal gasification technologies

In 1986, operation of a hybrid gasification pilot plant which employed a pressurized fluidized-bed gasifier feeding coal and heavy oil mixture was finished. The project demonstrated production of high calorific gas containing a high concentration of methane together with high energy efficiency comparable to other processes. Following the results of the hybrid gasification, a coal-based hydrogen production project (HYCOL) started in 1984. Pulverized coal is gasified into hydrogen and carbon monoxide in a gasifier under the condition of a pressure of 30atm and a temperature 1500℃ or above. Gasification is carried out in oxygen-blow one chamber and two-step spiral flow system. High purity hydrogen is then produced after processing carbon monoxide with shift-reaction and other processes. A pilot plant with a capacity of 20 t/d for

HYCOL was constructed in 1990. The operating research has been completed in 1993.

The history of R&D of IGCC is follows: In 1996, the 200 t/d pilot plant was disassembled after 5 years' operation test, and all data obtained is accumulated to discuss the possibility of construction of a demonstration plant. The organization which lead the R&D was reunified and is now working for the feasibility study of the demonstration plant. The study will continue for two years to conclude whether we should go further or not.

A feasibility study was started on coal hydrogasification technology that employs hydrogen as the gasifying agent and produces high calorific gases with high concentrations of methane in FY1990. A elemental study started in 1996.

Coal liquefaction technologies

There are two streams for R&D of coal liquefaction in Japan. One is the project for brown coal liquefaction which was conducted in Victoria, Australia from 1981 to 1990. The present work is to improve the liquefaction process to make it feasible for a commercial use [4]. The other is on bituminous coal liquefaction of which process is named as "**NEDOL Process**". After 4 years of construction, the pilot plant has started its official operation [5-7]. Some results of the operation will be presented at the ACS meeting. Seven runs of the plant are scheduled over two years and "**Technology Package of the NEDOL Process**" will be documented afterward. "**NEDOL Process**" is also being verified at process supporting unit (PSU) facilities in Kimitsu [8]. It still takes one year or so to start the operation of a 40 b/d PDU, which is now under construction to demonstrate the refining of coal-derived liquids so that it meets the requirements of petroleum market. Meanwhile, basic studies are pursuing the optimization of the hydrotreatment of coal-derived liquids in and the prevention of plugging during refining. We focus on the NEDOL process for coal liquefaction in this presentation.

EXPERIMENTAL

NEDO has been promoting a development of a coal liquefaction technology, since 1980, under "New Sunshine Program" and developed the "NEDOL" process that can attain high light oil yields under relatively mild conditions. The NEDOL process was realized in the 1 t/d PSU based on research and development work through autoclaves, bench scale plants and PDU scale plants. In the PSU, comprehensive experiments have been conducted with several kinds of coals and operating conditions and lots of significant data have been acquired. In parallel with the research and development in the PSU, the 150 t/d pilot plant (PP) was constructed for collecting scale-up data to demonstration and commercial plants. The construction of the PP was finished on July, 1996 and the operation was commenced.

The NEDOL process, shown in Figure 1, consists of four primary units, such as coal preparation unit, coal liquefaction unit, solvent distillation unit and solvent hydrogenation unit. The NEDOL process can attain high oil yield even in relatively low severity condition as shown in Table 2. It has been concluded that ultra fine iron catalyst and hydrogenated solvent bring this high oil yield. In the PSU operation, several kinds of coals have been liquefied and the efficacy of the NEDOL process has been demonstrated. Based on the results of the PSU, a standard coal for the PP operation was determined. Table 3 indicates the analytical data of the standard coal for the PP. The operation of the PP has been conducted in the conditions shown in Table 2 and with the standard coal shown in Table 3 and the results were compared with the results of the PSU conducted in the same conditions and with the same coal.

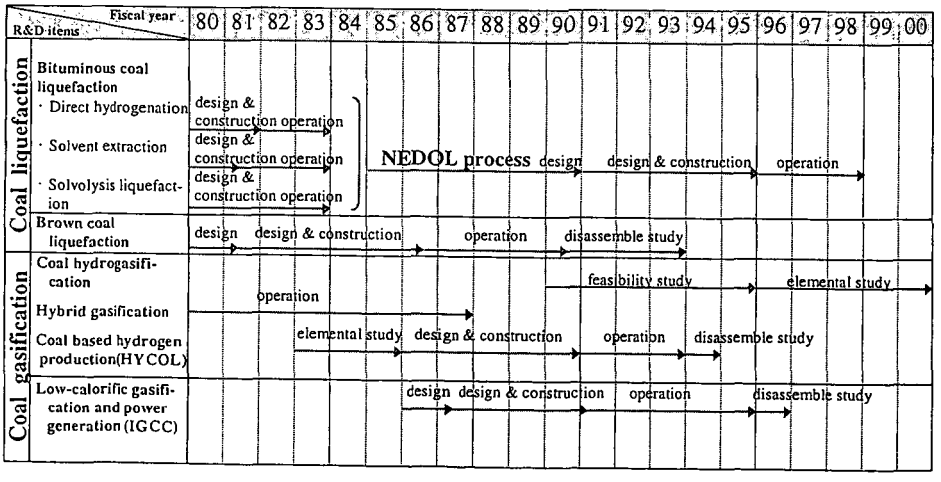
RESULTS AND DISCUSSION

The results of the PP operation were compared with the results of the PSU operation and the comparison result is indicated in Table 4. Although the results of the PP are not results on 100 % plant load, yields of the PP have a good correlation with the results of the PSU. The yields of the 80 % load in the PP imply that the yields of 100 % load in the PP can attain same yields as the PSU on the same liquefaction conditions. This indicates that scale up data for larger plant will be able to be acquired in comparison of the data between the PSU and PP.

REFERENCES

1. S. Kurosawa, in *Guidebook of New Energy Technologies* (Y. Adachi ed.), Ohm Press, Tokyo (1997) chapter 3.
2. S. Kurosawa, K. Saito and A. Sugawara, *Proceedings of 14th Japan-US Joint Technical Meeting on Coal Liquefaction & 9th Materials for Coal Liquefaction*, **1997**, 1-7.
3. T. Seo and K. Itoh, *ibid*, **1997**, 159-165.
4. K. Shimasaki, T. Okui, T. Kaneko, N. Komatsu and Y. Kageyama, *ibid*, **1997**, 55-65.
5. H. Yoshida, Z. Kamio and S. Wasaka, *ibid*, **1997**, 8-20.
6. Y. Namiki, H. Ishibashi, T. Takagi and M. Kobayashi, *ibid*, **1997**, 45-54.
7. H. Matsubara, M. Uchiyama, M. Miyake and T. Nishibayashi, *ibid*, **1997**, 150-158.
8. H. Kakebayashi, Y. Nogami, K. Inokuchi, M. Mochizuki and K. Imada, *ibid*, **1997**, 55-63.

Table 1. R&D schedule of coal conversion technologies on the New Sunshine Program



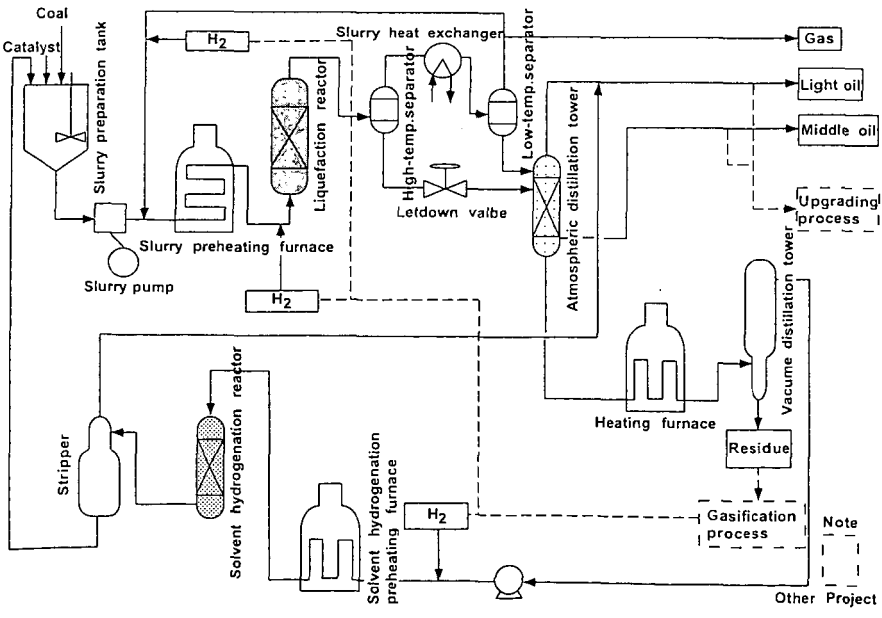


Figure 1. Diagram of NEDOL Process

Table 2. Typical liquefaction conditions

	Typical condition
Temperature	430 - 465 ℃
Pressure	150 - 190 kg/cm^{2}G
Catalyst	Ultra fine iron sulfide 2 - 3 wt%
Slurry concentration	40 - 50 wt% (dry coal)
Slurry residence time	1 hr
Gas/slurry ratio	500 - 700 Nm^3/t
Hydrogen conc. in recycle gas	85 vol %

Table 3. Typical coal analytical data for the PP operation

Proximate analysis (wt %)		Ultimate analysis (wt % daf)	
Moisture	3.8	C	76.4
Volatile matter	47.4	H	5.8
Fixed carbon	47.7	N	1.8
Ash	4.9	TS	0.3
		O	15.7

Table 4. Comparison of the yields between the PP and the PSU

	150 t/d PP		1 t/d PSU		
Plant load [%]	60	80	100	100	100
Temperature [℃]	450	450	450	465	465
Pressure [kg/cm^{2}G]	170	170	170	170	190
G/L [Nm^3/t]	700	700	700	700	900
Catalyst addition [wt %]	3	3	3	3	4
Residence time [hr]	1.67	1.25	1.0	1.0	1.0
Yields [wt % daf]					
Water	12	11	10.8	11.5	11.4
Gas	18	17	19.7	25.5	26.5
Oil	54	52	51.7	55.5	59.4
Residue	22	26	23.3	14.4	9.9
H_2 consumption	5.9	5.4	5.5	6.9	7.2
Total	105.9	105.4	105.5	106.9	107.2