● Technology Development on Coal Energy Conversion for Environment Burden Lowering Fuel (DME direct synthesis technology development)

1. Background of Technology Development

In viewing from both stabilized energy supply in Japan and effective use of her obtained energy resources, coal energy has been playing an important role there. And more efficient use of coal, as well as, lowering of its environmental burdens has become important policy issues in Japan. In addition, nowadays Japan depends chiefly on petroleum, used for transportation liquid fuel and for chemical raw stuff, although it is said in Japan that the peak supply of petroleum will come before the middle of 21^{st} century in a long-term prospect. In this regard, it is important for us to be prepared for preserving some petroleum alternating liquid transportation fuel and some chemical raw stuff sources.

Under these circumstances, the technology development of Di-Methyl-Ether (DME) manufacturing is believed to be necessary from the viewpoint of enlargement of select ability of both effective coal utilization and forms of energy uses, **as for a possible multi-purpose utilization of both coal including such low rank coals as brown coal, sub-bituminous coal, etc. which are abundant in the Asian regions, and coal bed methane (CBM) gas, which has a high anti-Global Warming potential and enable us to produce liquid fuel of hydrocarbons.**

2. Positioning & Purpose of Technology Development

DME has been manufactured conventionally as a chemical product by a dewatering reaction. However, it accompanies difficulty to produce cheap in a mass because it uses methanol as for its raw stuff.

The manufacturing method dealt by the technology development is excellent in its heat conductivity characteristics by adopting a slurry bed which enables easier temperature control together with an added shifting function to the dewatering catalyzer.

In other words, the technology has uniqueness **in manufacturing DME directly and highly efficiently using H_2 and CO gases.**

The purpose of the research is **to develop [DME direct synthesis technology] which is one of the component technology issues selected for practicalization of a widely applicable new and clean fuel called DME** made from coal or coal- bed- methane. A 5t/d scale DME manufacturing bench scale plant was installed at Kushiro colliery, Taiheiyo Coal Mining Co., Ltd. in order to run its operation tests for research to establish the DME synthesis technology.

Table 1 Comparison of Development Researches on DME Direct Synthesis Process

Inventor	NKK (Japan)	Air Products and Chemical (USA)	Haldor Topsoe (Denmark)
Raw Materials	Coal、CBM, Natural Gas	Coal	Natural Gas
Synthetic Gas Content (H_2/CO Ratio)	1	0.7	2
Type of Reactor	Slurry Bed	Slurry Bed	Fixed Bed
Reaction Conditions			
Temperature (℃)	250～280	250～280	210～290
Pressure (Kg/cm^2)	30～70	50～100	70～80
Catalizer	Methanol Synthetic＋Dewater＋SHIFT	Methanol Synthetic＋Dewater	Methanol Synthetic＋Dewater
DME Synthetic Reaction	$3CO + 3H_2 \rightarrow CH_3OCH_3 + CO_2$	$2CO + 4H_2 \rightarrow CH_3OCH_3 + H_2O$	$2CO + 4H_2 \rightarrow CH_3OCH_3 + H_2O$
Reaction Ratio (%)	55～60	33	18
DME Selective Ratio	90%	30～80%	60～70%
Recycle Ratio	2	4	8
Refining	Easy	Much Energy Consumption	Much Energy Consumption
Process of the Development (Capacity)	1989～：1kg/d Beaker 1995～：50kg/d Bench 1997～：5t/d Bench	1986～：Beaker 1991～：4t/d Pilot	1993～：50kg/d Bench

3. Contents of R & D

(1) 5 t/d Bench Plant

By implementing a bench scale DME manufacturing plant of 5t/d, the DME Synthesis technology is to be established.

(2) Back-Up Research

As for a back-up research of the 5t/d bench plant operation research, an operation study of a 50kg/d DME manufacturing plant (a small bench plant) is also to be undertaken to obtain and analyze more detailed experimental data. Furthermore, a computer simulation would undertake the basic reaction mechanism of the adopted catalyzer.

(3) Establishment of the Scale-Up Technology and Evaluation of the Total system

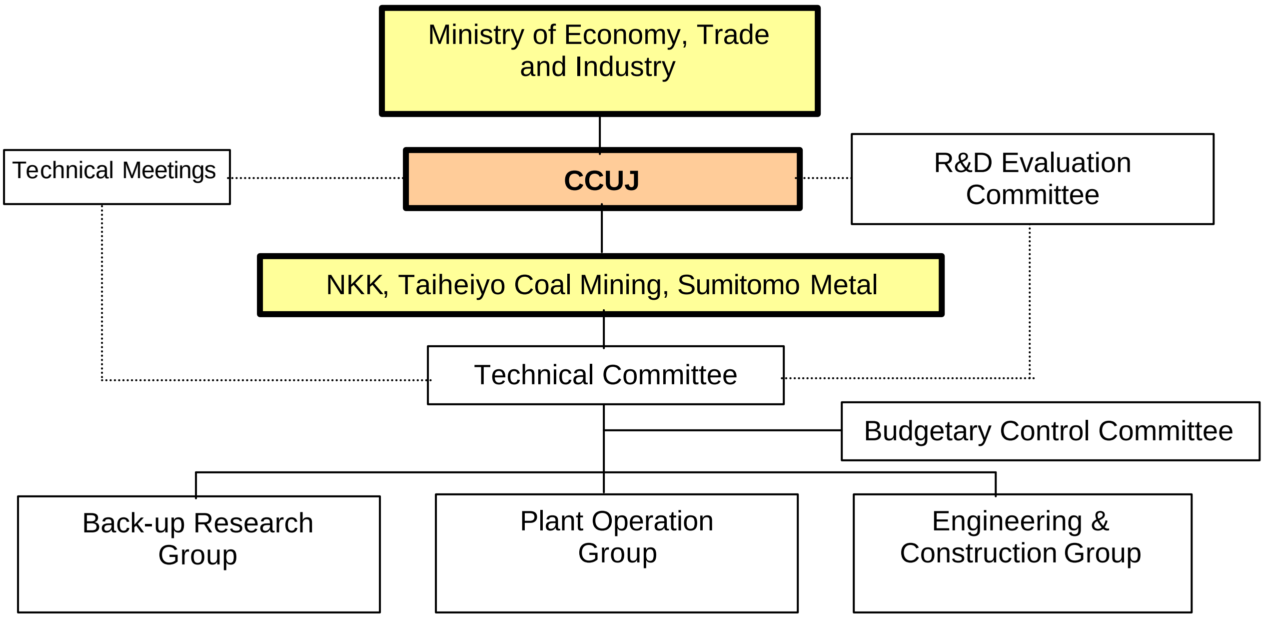
Scaling-up towards a commercial plant is to be studied, and its conceptual designing also be implemented

2. Schedule of the R & D

Table 2 Development Schedule

Content	Fiscal Year				Remarks
	1996	1997	1998	2000	
1. Study based on operation of 5t/d Bench Plan					Production Capacity of DME: 5t/d at maximum
(1) Basic Engineering	←→				
(2) Detailed Engineering & Construction		←——	——→		
(3) Plant Operation			←——	——→	
2. Back-up Research	←——	————	————	——→	
3. Establishment of Scale up Technology and Total System Evaluation				→	

5. Framework for the R & D



6. Results of the R & D

(1) R & D Results of the 1.5t/d Bench Plant Operation

Targets of the R&D	Results
①Operation Targets to be achieved a. Material Gas Reaction Ratio ≧50% b. DME Selective Ratio ≧90% c. Life Time of Catalizer ≧ 1 month d. Continuous Operation ≧ 1 month e. Gas Conversion Ratio ≧ 95% f. DME Purity ≧ 99% g. Operation using Coal Bed Methane only	a. Confirmed b. Confirmed c. Confirmed d. Confirmed (1650 hours in total) e. Confirmed f. Confirmed (99.5%) g. Confirmed
②Technical Verification a. Plant Performance and Total Material Balance • Clarification of both processes of reaction and separation • By-products and their effects • Each start and stop method of total processes b. Engineering of Slurry Bed type DME reactor • Temperature Control Method in the reactor • Flow conditions in the reactor • Dispersion status of catalyzer • Continuous insertion and pull-out mechanism of calyzer	• 98% accuracy was achieved on Material Balance and • No by-products was confirmed • Established as a total system • Confirmed that each temperature was kept equally inside the reactor • Necessary engineering data were acquired • Verified through actual operation
③ Implementation of tests on combustible characteristics of DME in comparison with other fuels	• Confirmed that the DME's combustible characteristics is equivalent to city gas (13A) • As for kinds of rubber, strength tests, etc. after soaking in DME were implemented

(2) Results of the Back-Up R & D

Targets of the R&D	Results
① Through implementation of detailed tests on reaction with 50kg/d small bench plant, detailed back-up data for engineering of 5t/d bench plant and its operation plan is to be acquired.	• Optimum mixing ratio of catalyzer to material gas was acquired • Oil media was selected • Optimum operation temperature and pressure was acquired • Optimum density of catalyzer was acquired • Operation plan was completed
② In order to establish the scale-up technology, various simulations based on simulation model on reactor model reflecting gathered basic data are to be implemented	• Confirmed that results of the simulations conformed to actual test data

(3) Establishment of Scale-Up Technology and Total System Evaluation

Targets of the R&D	Results
Feasibility Study for scale-up up to commercial plant size	Cost evaluation of DME in case of production made of coal at a commercial plant was implemented • 2,500t/d： CIF price 2.2¥/Mcal (equivalent to LPG) • 10,000t/d：CIF price 1.5¥/Mcal (equivalent to LNG)

7. Prospect of Commercialization

(1) Economy

During the initial stage of its commercialization after the establishment of the technology, DME would be probably manufactured at a mine site in some coal bearing countries, and the produced DME would be shipped by LPG tankers, etc. to Japan for fueling power stations there. In comparison with conventional thermal power generation, the DME combustion system requires higher preliminary treatment cost (coal gasification, DME manufacturing), but it has advantages as follows,

① **DME can be transported and stored as liquid fuel enabling high efficiency power generation (combined cycle power generation)**

② **It does not require de-SOX treatment of its flue gas and on some other reasons, DME power cost is presumed to become equivalent or less than that of conventional coal power generation.**

③ **Its coal yard and ash disposal will be also unnecessary which will give us a promising merit to construct a thermal power station in a close- to- urban location. And it will enable us to reduce transmission loss, either.**

(2) Marketability

In Japan, according to the current prospect, coal thermal power generation is estimated to increase up to about 24,000 MW by 2010. Meanwhile, DME firing PS of 500MW (efficiency 49%, operation rate 75%) consumes approximately 800 thousand tons of coal 75% per annum. In this regard, whenever DME thermal power is introduced step by step, potential market scale of DME consumption will be large in amount, which may become 3.9 million tons in its annual consumption in a case when 10% of coal thermal power (2400 MW) becomes replaced by DME. If we consider the expected adoption of this technology in overseas, the market for the DME synthesis technology would become larger.

(3) Spreading Influences

DME can be used for household utilizations as of alternative fuel to LPG. In China, DME has been under commercial distribution, which has been synthesized by methanol, a by-product coming from ammonium fertilizer manufacturing process. It suggests us that the process may contribute to us either for getting LPG in rather stable prices from the Middle East countries to which we lean a little too much in these days.

On the other hand, DME has advantageous features, as for a diesel engine fuel with no emission of sooth or SOx and considerably low in NOx emission level, which has been confirmed up to now. DME is expected today of its fuel use in transportation. DME is believed helpful in contributing to the stabilized supply of transportation energy in the Asian region. In the future, we can expect DME to be used for automobile fuel driven by Fuel Cell battery. In addition, it can be also presumed that DME will find further more usages as for chemical raw stuff materials, when DME price comes down close to the conventional fuel prices.

(4) Issues towards Commercialization

At present, DME is produced only about 10 thousand tons annually for the use of splashing in Japan. **In order to promote commercialization of DME, further technical development will be inevitably necessary, along with continuing survey and reviewing of such as proofing of the**

expected DME demand and better preliminary arrangement for its smoother supply and distribution, etc.

Table 3 Issues for Commercialization

Category	Required Item
Technology on Production	• Establishment of a system to supply huge volume of DME at economical price • Establishment of a technology to produce DME at 100t/d scale or more
Transportation & Distribution	• Reconstruction of facilities required in case of the fuel conversion from LPG to DME • Quality Control and Assurance at DME Gas Stations
Fuel for Automobile	• Solutions to prevent aeration from fuel supply system at hot temperature • Sealing techniques for prevention against leakage or wear and tear • Improvement of Lubricating ability by way of adding
Fuel for Electric Power Generation	• As for Boilers, solutions to prevent gas leakage, re-liquefaction and explosion • As for Gas Turbines, development of new combustors including burners
Fuel as a Substitution Fuel for LPG	• For the purpose of an adjuster of heat value of city gas, further study of combustibility conformity to various type of combustor and dew point in case of pressurized transfer
Fuel for Fuel Cell	• Performance of up-grading facility and high power & density • Restriction of passing ionic membrane and water balance • Improvement of efficiency

8. Flow Chart of 5t/d DME Bench Plant