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LIQUEFACTION OF COAL

DP/CPR/83/002/11-01

People's Republic of China

Technical Report *

Prepared for the Government of China
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of James J. Lacey,
Expert in the Construction & Operation of
Process Development Units (PDU's) and
Coal Liquefaction Process Technology

Backstopping Officer: R.O. Williams, Chemical Industries Branch
United Nations Industrial Development Organization
Vienna

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November 4, 1988
ENGLISH

TRIP REPORT - CHINA

ABSTRACT

Project DP/CPR/83/002/11-01

October 23-30, 1988

This report covers a trip that included five days in Beijing, China, for the purpose of strengthening and supporting the Chinese government's ongoing research and development program in the area of direct coal liquefaction. This work is being carried out at the Central Coal Mining Research Institute (CCMRI) in Beijing. The author of this report serves as Technical Adviser and a member of a Technical Committee whose duties are the following:

1. Review the R&D activities of the project, and report, monitor, and evaluate progress.
2. Advise the Chinese government through their National Project Director on the annual work program for the project, with the aim of keeping proper perspective with developments in other countries.
3. Recommend to the Chinese government, UNDP, and the executing agency on the utilization of UNDP funds in the most efficient way to achieve the project objectives.

This report summarizes the fourth annual meeting of the above-mentioned Technical Committee and is organized in a daily journal format for the period covered by this trip. Particular emphasis is placed on documenting the progress in 1988 and the 1989 plans for this project. A determination was made regarding the required UNIDO inputs in terms of Consultants, Fellowships, Study Tours, and Equipment.

SUMMARY

This trip covered the period of October 23-30, 1988. My time in Beijing, China, was spent at the Central Coal Mining Research Institute (CCMRI). My duties were covered by DP/CPR/83/002/11-01 and involved my serving as the Technical Adviser to the committee reviewing the Chinese government's present research and development program on direct coal liquefaction being carried out at the CCMRI. My responsibilities were as follows:

1. Review progress of project activities.
2. Advise on project activities for next year.
3. Make recommendations to the Chinese government and the UNDP.

The overall aim of this program is to proceed orderly from laboratory to commercial scale. It is planned that several candidate coals will be evaluated and a suitable direct liquefaction process selected for commercialization. The overall plan proposes the following:

1. Evaluate various types of Chinese coals and select several for hydrogenation.
2. Investigate the liquefaction characteristics of the candidate coals, and obtain quantitative data for the design of larger systems.
3. Investigate the formation of suitably stable slurries that can be pumped to the reactor without separation.
4. Carry out experiments on selection and preparation of the recycle solvent.
5. Develop laboratory methods for the separation of coal liquids, and determine their chemical structures.
6. Evaluate different coal liquefaction catalysts.
7. Study techniques for the upgrading of coal liquids to obtain lighter, more stable products.

This trip report covers the items discussed at the annual meeting of the Technical Committee, at which time the 1988 Progress Report and the 1989 Work Plans were discussed and approved. A plan for the 1989 UNIDO inputs (Consultants, Fellowships, Study Tours, and Equipment) was finalized.

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INTRODUCTION

The period covered in this report is October 23 to October 30, 1988. I served as a member of the Technical Committee established to strengthen and support the Chinese government's present research and development program on techniques of direct coal liquefaction carried out at the Central Coal Mining Research Institute (CCMRI) in Beijing, China. The committee consists of three members, and I functioned as the Technical Adviser under job description DP/CPR/83/002/11-12. In addition to serving on the Technical Committee, I gave lectures and advice on various aspects of coal liquefaction technology of interest to the Chinese research scientists and engineers.

The long-term objectives of this project are the utilization of China's vast coal resources and the development of industrial-scale technologies for the conversion of lignites and bituminous coals to liquid fuels and chemical feedstocks. This project (Techniques of Direct Coal Liquefaction) has been listed as one of the key projects in the National Research and Development Program of the Chinese government. Their major goals are the following:

1. Evaluate various types of Chinese goals, and select those best suited for hydrogenation.
2. Investigate the behavior of the selected coals using autoclaves and continuous process development units (PDU) to obtain quantitative data for the design of larger systems.
3. Investigate the formation of a stable slurry that can be transported to the reactor without separation of the solid and liquid phases.
4. Carry out experiments on the preparation of recycle solvent.
5. Develop laboratory methods for the separation of coal liquids and determination of their chemical structures and properties.
6. Evaluate different catalysts for use in coal liquefaction.
7. Study techniques for upgrading coal liquids to obtain light, stable, and useful products.

The overall aim of the Chinese government's program is to go from the laboratory to the commercial scale. The goal of their project is to thoroughly evaluate several candidate coals and select a suitable direct liquefaction process for commercialization.

DISCUSSION

This report is organized on a daily journal basis, followed by conclusions and recommendations. Discussions with many Chinese workers are summarized, with particular emphasis on their plans and needs.

Day 1 - Sunday, October 23, 1988

Left Pittsburgh, Pa. (U.S.A.), and flew to Tokyo, Japan.

Day 2 - Monday, October 24, 1988

Arrived in Tokyo for a scheduled overnight stay.

Day 3 - Tuesday, October 25, 1988

Flew to Beijing, China, from Tokyo, Japan. Was met at the airport by Mrs. Pang Weizhen, an engineer with CCMRI working in their Office of International Cooperation. She was extremely helpful during my entire stay in Beijing and greatly aided me in all my technical discussions.

We discussed in some detail the long-term objectives of their particular project. It is part of an overall program for the utilization of the country's coal resources. They intend to develop industrial-scale technologies for the conversion of lignites and bituminous coals to liquid fuels and chemical feedstocks. These coals are not normally suitable for power production or steelmaking but can be utilized for industrial and domestic fuel needs if converted via suitable liquefaction technology.

Their program entitled "Techniques of Direct Coal Liquefaction" has been listed as one of the key projects in the National Research and Development Program. The goals of this program are as follows:

1. Establish laboratories, conduct basic research, evaluate the liquefaction characteristics of Chinese coals, and select suitable liquefaction technologies.
2. Perform basic research, and conduct pilot-plant studies to obtain design data for the construction of large-scale coal liquefaction plants.
3. Construct a commercial coal liquefaction plant in the 1990's.

Day 4 - Wednesday, November 26, 1988

The first order of business was to meet with Dr. Kenneth S. Stephens, the Senior Industrial Development Field Adviser for UNDP concerning my financial matters (per diem arrangements) for my stay in Beijing. After completing the required UNDP administrative details, we went to the CCMRI to begin our technical meetings and plan our agenda for the week. Since this is a "coal project," it is under the Central Coal Mining Research Institute (CCMRI) headquartered in Beijing. The CCMRI is responsible for all coal research in China and is organized into the following institutes:

1. Beijing Research Institute of Mine Construction
2. Beijing Research Institute of Coal Mining
3. Beijing Research Institute of Coal Chemistry
4. Research Institute of Economy
5. Branch of Geology and Exploration
6. Tangshan Branch (Coal Preparation)
7. Shanghai Research Institute
8. Taiyuan Branch
9. Fushun Research Institute
10. Chongqing Research Institute
11. Nanjing Research Institute
12. Research Institute of Blasting Technology
13. Hangzhou Research Institute
14. Changzhou Research Institute of Automation
15. Changzhou Development and Manufacturing Center
16. Computer Center

Central Coal Mining Research Institute is spread throughout the coal mining areas of the country and employs 7,800 people, 1500 of whom are located in Beijing.

Because the UNIDO project involves coal liquefaction, it is handled by the Beijing Research Institute of Coal Chemistry (BRICC). All coal liquefaction work in China is done by the BRICC. The Director of the BRICC is Mr. Dai Hewu. Its Deputy Director is Mr. Wu Chunlai, who is the National Project Director. The BRICC is composed of seven labs and one section:

1. Coal Analysis Lab
2. Coal Properties Lab
3. Coal Gasification Lab
4. Coal Liquefaction Lab
5. Coal Combustion Lab
6. Coking Lab
7. Special Processes Lab
8. Design Section

The BRICC employs about 270 people. The larger "labs" (coal liquefaction, gasification) are staffed with about fifty people, while the smaller "labs" have about ten people.

We discussed the plan for the remainder of the week. These discussions were led by Mr. Wu Chunlai, the National Project Director (NPD) and a member of the Technical Advisory Committee for the UNDP-funded coal liquefaction project. Mr. Wu briefly summarized the objectives, the accomplishments to date, and the plans for the future. During all meetings, the following were present:

- o Mr. Wu Chunlai - Deputy Director, BRICC and NPD
- o Mrs. Pang Weizhen - CCMRI International Office
- o Mr. J.J. Lacey - U.S. DOE, UNIDO Consultant

The proposed weekly schedule included a tour of the BRICC labs, followed by Technical Committee meetings. The annual Tripartite Review Meeting was planned for Thursday, October 27, 1988, and would include representatives from the following:

1. Ministry of Foreign Trade
2. Ministry of Coal Industry
3. UNDP
4. UNIDO

We reviewed the coal liquefaction facilities of the BRICC. Their pilot-plant facilities included three continuous-process units (CPU):

- CPU #1 - NEDO Unit, 20 kg/hr coal slurry
- CPU #2 - Xytel Unit, 5 kg/hr coal slurry
- CPU #3 - German Unit, 15 kg/hr coal slurry

Twenty kilograms/hour is about 1/2 ton/day. All slurries are 1/3 coal. The Xytel unit has been modified to upgrade the product from the other two units. The NEDO unit was modified to include facilities for hydrogen recycle, solvent recycle, computer control, and a tube-type reactor. The German unit (Saarberg-Veba Oil) is complete from coal grinding to product distillation and features hydrogen and solvent recycle, computer control, and a tube-type reactor.

The New Energy Development Organization (NEDO) unit (CPU #1) was built by Mitsui Engineering and Shipbuilding Co., Ltd., of Japan, and has proven very valuable in coal screening and process technology assessment studies. The German unit (CPU #3) is primarily used for technology assessment studies. The Xytel unit (CPU #2) is used solely for product (from CPU #1 and #3) upgrading studies. A summary of the program is as follows:

1. The effort was established as a key project in the national R&D program for China in 1979. In 1980, the project "Techniques of Direct Coal Liquefaction" was funded by UNDP at a level of \$700K. This was Phase I (1980-1983).
2. During 1981 an agreement was signed with NEDO of Japan to provide a continuous-processing unit (CPU #1). This unit has been in operation since March 1983.
3. In 1984, an agreement was signed with West Germany (the Saarberg-Veba Oil organization) to provide another continuous-processing unit (CPU #3). The equipment was delivered in 1985, and operations began in 1986.
4. A unit from the United States was provided by the Xytel Corporation (CPU #2) for upgrading studies on the products from CPU #1 and #3.

5. Phase I ended in 1983. During 1984, plans were drafted for Phase II, which began in January 1985 and will run for four years (1985-1988).
6. Phase II is funded at \$800,000, with the UNDP contributing \$600,000, and the Chinese government contributing \$200,000. The Technical Committee will function during Phase II, which runs from January 1985 to December 1988.

Day 5 - Thursday, October 27, 1988

The Tripartite Meeting held this day was attended by the following:

- o Mr. Wu Chunlai, CCMRI (National Project Director)
- o Mrs. Pang Weizhen, CCMRI
- o Mr. Kenneth Stephens, UNDP
- o Dr. Wang Yinren, Consultant
- o Mr. J.J. Lacey, UNIDO (DOE) (Technical Adviser)
- o Mr. Sun Yongfu, Ministry of Foreign Economic Relations and Trade

The purpose of this meeting was the annual review of this project "Techniques of Direct Coal Liquefaction." An item left over from Phase I was the Differential Thermal Analyzer (DTA), which has never performed satisfactorily and has been returned to the Japanese manufacturer on two occasions. It was recommended that the Chinese continue to contact the manufacturer to recover the purchase price in the form of different equipment.

The first order of business was a discussion of the 1988 results by Mr. Wu, the National Project Director. The 1988 results can be summarized as follows:

1. The continuous process development units (CPU #1 and #3) were used in evaluating coals and assessing coal liquefaction technology. These units continue to be the main approach for coal liquefaction research and development. The CPU #2 was used to upgrade coal liquids produced by the #1 and #3 units.
2. Tests of the liquefaction characteristics for several new types of coal were conducted with autoclaves. Catalyst-screening studies using iron-based catalysts were also conducted with the autoclaves.

Regarding consultants, fellowships, and study tours, the following was accomplished over the years:

1. Consultants

- a. Mr. James J. Lacey, Pittsburgh Energy Technology Center, U.S. DOE, came to China three times as a technical adviser for the project to attend meetings of tripartite review on December 1-7, 1986, November 22-28, 1987, and October 25-30, 1988.
- b. Professor Yuzo Sanada, Hokkaido University of Japan, gave lectures and advice on "Catalytic Coal Liquefaction Technology" on April 30 - May 11, 1986.
- c. Dr. Etsuro Nakamura, Director of National Research Institute for Pollution and Resources, Japan, gave lectures and advice on "Upgrading of Coal Liquids" on October 2-13, 1986.
- d. Dr. Ted Teo, University of British Columbia, Canada, gave lectures and advice on "Separation and Structural Analysis of Liquid Oil" on November 21 - December 1, 1986.
- e. Mr. Thomas Torkos, Pittsburgh Energy Technology Center, U.S.A, gave lectures and advice on "Two-stage Coal Liquefaction Technology" on April 10-17, 1988.
- f. Dr. Ingo Romey, Bergbau-Forschung, Essen, FRG, gave lectures on advice on "Liquefaction Reaction Kinetics" on May 2-12, 1988.
- g. Dr. Helmut Wuerfel, GfK Gesellschaft fuer Kohleverfluessigung mbH, FRG, gave lectures and advice on "Pyrosol Coal Liquefaction" on September 7-17, 1988.

2. Study Tours

- a. A 4-person group went to U.K. and Poland to study coal liquefaction and utilization on February 14 - March 9, 1987 (3 weeks).
- b. A 4-person group went to the U.S. to study two-stage liquefaction technology on February 27 - March 13, 1988 (2 weeks).
- c. A 4-person group went to the FRG and France to study the status and developing trends of European coal technology on August 29 - September 18, 1988 (3 weeks).
- d. A 4-person group is going to Australia and New Zealand to study brown coal liquefaction pilot plants on November 4-26, 1988 (3 weeks).

3. Fellowships

- a. A 4-person group went to the U.S. for training on the structural analysis techniques of liquefaction products for 4 months (October 1, 1986 - January 27, 1987).
- b. A 4-person group went to Japan for training on liquefaction catalysts for 2 months (April 5 - June 6, 1987).
- c. A 4-person group went to the FRG for training on the Pyrosol liquefaction process for 2 months (October 13 - December 13, 1988).
- d. A 4-person group will go to Japan for training on the scale-up techniques of liquefaction process for 2 months (September 1989 - October 1989).

Day 6 - Friday, October 28, 1988

We reviewed the past work of the Technical Committee. In general, the following tasks were performed:

1. Reviewed progress of the project
2. Advised on project activities
3. Made recommendations to China/UNDP

With respect to monitoring and evaluating the final overall progress for the entire duration of the project, it was decided that the Technical Committee will meet in October 1989. At this time, the final progress report will be approved.

Day 7 - Saturday, October 29, 1988

The day was spent in transit flying from Beijing to Dallas, Texas, via Tokyo. The long flight afforded the opportunity to make the final revisions to this report.

Day 8 - Sunday, October 30, 1988

This was the final day of my trip, and I flew from Dallas, Texas, to Pittsburgh, Pa. (U.S.A.).

CONCLUSIONS

During my trip to Beijing (October 23-30, 1988), I participated as the Adviser to the Technical Committee. The purpose of this committee is to strengthen and support the Chinese government's on-going R&D program in "The Techniques of Direct Coal Liquefaction." This work is being carried out at the Central Coal Mining Research Institute (CCMRI) in Beijing, China. The Technical Committee was established for the duration of the project to facilitate its successful implementation. The project is scheduled to run through December 1988.

As the Technical Adviser (Job Description DP/CPR/83/002/11-01), my duties during the committee meetings were as follows:

1. Review the R&D activities. Report, monitor, review, and evaluate the project.
2. Advise the Chinese government through their National Project Director on the Annual Work Plan.
3. Recommend to the Chinese government and UNIDO the specific utilization of UNDP funds in the most efficient way.
4. Keep the program in its proper perspective in relation to the developments in other countries.

This particular project, "Techniques of Direct Coal Liquefaction," has been listed as a key project in the National Research and Development Program for China. Its major goals are the following:

1. Establish laboratories, conduct basic research, evaluate characteristics, and select suitable liquefaction technologies for Chinese coals.
2. Conduct basic research, scale up results, and obtain necessary design and construction data.
3. Construct a commercial coal liquefaction plant.

This project is part of an overall Chinese plan for the utilization of the country's coal resources and the development of industrial-scale technologies for the conversion of lignites and bituminous coals of high volatile and sulfur contents to liquid fuels and chemical feedstocks. These resources, which are normally not suitable for other purposes (power production or steelmaking), can then be utilized in a manner compatible with the fuel needs of industries, households, and future modes of transportation.

Based on the results of the Technical Committee meetings, the following objectives were satisfied:

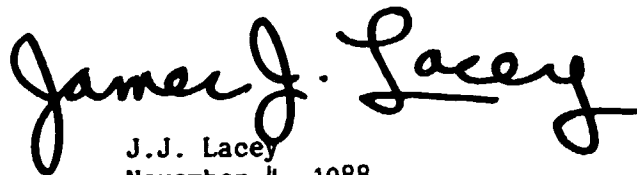
1. Evaluated various types of Chinese coals, and selected those best for hydrogenation.
2. Investigated the liquefaction behavior of the selected coals in autoclave experiments.
3. Investigated the formation of a stable slurry that can be transported without phase separation.
4. Carried out experiments on selection and preparation of the hydrogenation solvent.
5. Developed laboratory methods for the separation of coal liquids, and determined their chemical structures and properties.
6. Evaluated different coal liquefaction catalysts.
7. Studied techniques for upgrading of coal liquids to obtain lighter, more stable products.

The Chinese government's R&D program is well planned and should carry the work from the laboratory to commercial application. By the end of this project, several candidate coals will have been evaluated, and a suitable direct liquefaction process selected for commercialization. It was concluded that the Technical Committee should meet one more time to review and approve the final Progress Report. This final Technical Committee meeting should be scheduled in conjunction with the final Tripartite Meeting planned for October 1989 in Beijing, China, at the CCMRI.

RECOMMENDATIONS

Based on the discussions with the staff of the CCMRI and the BRICC, the following recommendations are made for future use of their coal liquefaction facilities:

1. The autoclave work should be directed at catalyst screening.
2. The NEDO unit (CPU #1) should be used to perform process technology assessments.
3. The Xytel unit (CPU #2) should be used for product oil upgrading.
4. The FRG unit (CPU #3) should be used for technology evaluations.
5. The plans for Consultants, Fellowships, and Study Tours were well developed and executed.
6. The Study Tours were concentrated at large-scale direct coal liquefaction installations.
7. The emphasis should now be on economic surveys to evaluate the feasibility of constructing commercial coal liquefaction plants in China.
8. The Technical Committee should meet one last time at the final Tripartite Meeting scheduled for October 1989 in Beijing, China.



J.J. Lacey
November 4, 1988