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December 1987
ENGLISH

# LIQUEFACTION OF COAL

DP/CPR/83/002/11-01/J13424

CHINA

## Technical Report: Coal Liquefaction Technical Adviser (Construction & Operations)

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

Based on the work of James J. Lacey,
expert in the Construction and Operation of
Process Development Units & Coal Liquefaction Process Technology

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December 10, 1987
English

## ABSTRACT

Project DP/CPR/83/002/11-01/32.1.I
November 20-30, 1987

This report covers a trip that included seven days in Beijing, China, for the purpose of strengthening and supporting the Chinese government's on-going 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. To review the research and development activities of the project and report, monitor, review, and evaluate the progress over a four-year period (1985-1988).

2. To advise on the annual work program with the aim of keeping it in its proper perspective in relation to developments in other countries.

3. To recommend to the Chinese government, UNDP, and the executing agency (UNIDO) the specific utilization of UNDP funds in the best manner to achieve the project objectives.

This report summarizes the third 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 approved 1987 Progress Report and 1988 Work 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 November 20-30, 1987. My time in Beijing, China, was spent at the Central Coal Mining Research Institute (CCMRI). My duties were covered by DP/CPR/83/002/11-01/32.1.I and involved my serving as the Technical Adviser to the committee reviewing the Chinese government's present research and development program on coal liquefaction being carried out at the CCMRI.

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 for 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 hydrogenation 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 1987 Progress Report and the 1988 Work Plans were discussed and approved. A detailed plan for the 1988 R&D work was established and recommendations for UNIDO inputs (Consultants, Fellowships, Study Tours, and Equipment) were finalized. Milestones required for evaluating and monitoring the project were also established for the duration of the effort.

# TABLE OF CONTENTS

RESTRICTED

December 10, 1987
English

## INTRODUCTION

The period covered in this report is November 20 - November 30, 1987. I served as the Technical Adviser and 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), Beijing. The committee consists of three members, and I functioned as the Technical Adviser under job description DP/CPR/83/002/11-01/32.1.I. In addition to serving on the Technical Committee, I gave lectures and advice on 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. They intend to accomplish the following goals:

1. Establish laboratories, conduct basic research, evaluate the liquefaction characteristics of Chinese coals, and select suitable liquefaction technologies.

2. Conduct basic research and scale up to obtain the necessary data for construction of a commercial coal liquefaction plant.

3. Plan for the construction of a commercial coal liquefaction plant in the 1990's.

## DISCUSSION

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

### Day 1 - Friday, November 20, 1987

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

### Day 2 - Saturday, November 21, 1987

Arrived in Tokyo for a scheduled overnight stay.

### Day 3 - Sunday, November 22, 1987

Flew to Beijing from Tokyo. 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.

Day 4 - Monday, November 23, 1987

The first order of business was to meet with 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 CCMRI to begin our technical meetings and plan our agenda for the week.

By way of background, because this is a "coal project" it is under the Ministry of Coal Industry (MCI). One of several organizations in MCI is the Central Coal Mining Research Institute (CCMRI) headquartered in Beijing. The CCMRI is the R&D arm of the MCI, and is responsible for all coal research in China. It is organized into the following sixteen institutes:

1. Beijing Research Institute of Mine Construction
2. Beijing Research Institute of Coal Mining
3. Beijing Research Institute of Coal Chemistry (coal analysis, coking, coal gasification, coal liquefaction, and combustion)
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

The two Deputy Directors for the CCMRI are Mr. Yu Xiang and Mr. Zhang Shingtou. Mr. Yu is in charge of R&D planning, while Mr. Zhang is responsible for implementation. This project is under the direction

of Mr. Zhang. The Central Coal Mining Research Institute is spread throughout the coal mining areas of the country and employs 7,800 people, of which 1,500 are located in Beijing.

Because the UNIDO project involves coal liquefaction, it is handled by the Beijing Research Institute of Coal Chemistry (BRICC). The Director of the BRICC is Mr. Dai Hewu. All coal liquefaction work in China is done by the BRICC. Its Deputy Director is Mr. Wu Chunlai, who is the National Project Director. The BRICC is composed of seven labs and one section, and employs about 270 people. The labs are the following:

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 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 of the Technical Committee, the following were present:

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

The proposed weekly schedule included a tour of the BRICC labs, followed by Technical Committee meetings. The annual Tripartite Review Meeting with representatives from the following organizations was planned for Friday:

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

Day 5 - Tuesday, November 24, 1987

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

1. NEDO Unit (CPU #1) 20 kg/hr coal slurry
2. Xytel Unit (CPU #2) 5 kg/hr coal slurry
3. German Unit (CPU #3) 15 kg/hr coal slurry

Twenty kg/hr is about 1/2 ton/day. All slurries are 1/3 coal. The Xytel unit was modified to upgrade the product from the other 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 also 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 utilized solely for product (from CPU #1 and #3) upgrading studies.

Day 6 - Wednesday, November 25, 1987

The day was spent at CCMRI, and we discussed the 1987 Annual Report and the 1988 Work Plan. The discussions were lead by Mr. Wu. The first order of business was a summary of the history of the project:

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 and was Phase I (1980-1983).

2. During 1981 an agreement was signed with NEDO of Japan to provide a 20 kg/hr slurry feed (1/3 coal) continuous-processing unit (CPU #1). This unit has been in operation since March 1983 for over 2000 hours on eight different Chinese coals.

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 Corp. (CPU #2). It was designed to process 5 kg/hr slurry (1/3 coal). The unit was modified 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.

The first order of business was a discussion of the 1987 results by Mr. Wu, the National Project Director. We reviewed this report, offered suggested revisions, and then approved it in final form for presentation at the Tripartite Meeting on Friday.

The 1987 results can be summarized as follows:

1. The continuous liquefaction 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. During 1987, a recycle solvent/hydrogen system was installed (on CPU #1) for the assessment of various coal liquefaction process technologies. Several runs (on CPU #3) with German process technology were also conducted during 1987. 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.

3. The Differential Thermal Analyzer (DTA), ordered by UNDP in Phase 1, was still in Japan for repairs. This DTA has not performed for BRICC. It was originally delivered in 1981 but was returned to Japan in September 1981. It was repaired and returned in early 1984, but sent back a second time in late 1984. It was due back in 1986 but was never delivered. Because this unit cost $70,000 in 1981 and has never performed satisfactorily, the Chinese should insist that the vendor supply new, reliable equipment.

This essentially concluded the discussion of the 1987 work. As a sidelight, Mr. Wu indicated that all work in direct coal liquefaction in China is the responsibility of the CCMRI and is conducted by the BRICC using about 100 of their 270 people. A small amount of direct coal liquefaction work is done at Qinghua University, Taiyuan Polytechnic College (Shanxi), and Shanghai College of Chemical Engineering, and is overseen by BRICC.

Day 7 - Thursday, November 26, 1987

The day was spent in a discussion of the 1988 Work Plan. Work is continuing in processing coals, screening catalysts, and upgrading the liquid products. Autoclave screening of various disposable catalysts

for coal liquefaction and coal liquids will be continued in 1988. More Chinese Coals will be screened on CPU #1 (NEDO). The CPU #3 (FRG) will be used to evaluate and assess the German technology. The CPU #2 (Xytel) will be used to upgrade the coal liquids produced by CPU #1 and CPU #3. The GC/MS installed in 1987 will be applied to analyzing coal liquids in 1988.

Regarding consultants, fellowships, and study tours, the following was decided:

1. Technical Committee (Post 11-01) meeting is scheduled in Beijing in October 1988.

2. Techniques of Two-Stage Coal Liquefaction (Post 11-52) for two weeks in 1988 should be filled by Mr. T.M. Torkos of PETC, U.S.A.

3. Kinetics of Liquefaction Reactions (Post 11-54) for two weeks in 1988 should be filled by Dr. Ingo Romey, Bergbau Forschung, West Germany.

4. Liquefaction Reaction Engineering (Post 11-55) for two weeks in 1988 should be filled by Dr. Helmut Wuefel of Saarberg GmBH, West Germany.

5. Training in Japan on Scaling-Up Techniques of Liquefaction Processes (Post 31-03) should be for four people for two months in late 1988.

6. Training on Modifications of Continuous Process Units (Post 31-04) has been scheduled for 1988. It is for four people for two months to Saarberg.

7. Two-Stage Liquefaction Techniques (Post 32-02) for four people for three weeks is planned for early 1988 and will be in the United States, including PETC.

8. A study of the status and development trends in coal liquefaction (Post 32-04) will involve four people for three weeks and is scheduled for mid-1988 in Europe (West Germany and Russia).

9. A study in pilot plants in Australia and New Zealand should involve four people for three weeks.

10. The technical committee will now consist of

    (a) National Project Director (Mr. Wu)
    (b) UNIDO Official (Mr. Williams)
    (c) Technical Adviser (Mr. Lacey)
    (d) Chinese Consultant (Dr. Wang)

The tasks will continue to be the following:

(a) Review progress on project
(b) Advise on project activities
(c) Make recommendations to China and the United Nations

The committee will meet again in Beijing in October 1988.

This concluded the formal discussions. We next discussed the proposed involvement of Mr. Torkos (Post 11-52 Two-Stage Liquefaction) of PETC for 1988. It was recommended that Study Tour (Post 32-02) be scheduled before the visit of Mr. Torkos. After the Chinese Study Tour at PETC, Mr. Torkos (Post 11-52) will be better prepared for his visit to China.

The rest of the day was spent at the UNDP Office in a review of the detailed plan for the R&D work for 1988 to be presented at the Tripartite Review Meeting on Friday, November 27, 1987. Special emphasis was placed on assuring that the Work Plan specifies the UNIDO inputs needed in terms of Consultants, Fellowships, Study Tours, and Equipment.

With respect to monitoring and evaluating work progress for the entire duration of the project, it was decided that the Technical Committee will meet yearly in October to review the past year's work and plan the upcoming year's schedule. At this time, the past year's progress report will be prepared and approved. The upcoming year's work plan will also be discussed and approved at these meetings. These approved reports can then be presented at the Tripartite meeting for final discussion, approval, and acceptance.

Day 8 - Friday, November 27, 1987

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

- Mr. Wu Chunlai, CCMRI (National Project Director)
- Mrs. Pang Weizhen, CCMRI
- Mr. Herbert Berstock, UNDP
- Dr. Wang Yinren, Consultant
- Mr. J.J. Lacey, UNIDO (DOE) (Technical Adviser)
- Mr. R. Williams, UNIDO (Vienna)
- Ms. Liang Dan, Deputy Division Chief (The China International Center for Economic and Technical Exchange

The purpose of this meeting was the annual review of this project "Techniques of Direct Coal Liquefaction." A 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 contact

the manufacturer to recover the purchase price in the form of different models of the same equipment.

On the subject of Phase II, the 1987 progress report was read, discussed, and approved by the Technical Committee. Considerable progress was made during 1987, particularly in the areas of equipment delivery, check-out, and operation.

Concerning the 1988 Work Plans, considerable discussion was devoted to ensuring that these plans were reasonable with respect to schedule and that they were broad enough to be in agreement with the Chinese Seventh 5-Year Plan certified in January 1986 that covers the period of 1986-1990. Particular emphasis was placed on specifying, in considerable detail, the required UNIDO inputs regarding Equipment, Consultants, Fellowships, and Study Tours. For equipment, it was agreed that the approved budget has been utilized fully. On the subject of Consultants, Fellowships, and Study Tours, the plans are rather ambitious and call for implementation of some aspects in early 1988. The Chinese were requested to get the appropriate job descriptions into UNIDO as soon as possible. The Technical Committee approved the 1988 Work Plans.

After the meeting, a detailed tour was arranged to review the mechanical progress of the following continuous process units: CPU #1 Japan (NEDO), CPU #2 U.S.A. (Xytel), and CPU #3 Germany (Saarberg) The NEDO unit has been modified for computer control. The Japanese had three people (one engineer and two technicians) on-site at CCMRI participating in these modifications. The U.S.A. unit was modified for product oil upgrading work to process the production from CPU #1 and #2. The work on CPU #3 was complete. After the tour, the Technical Committee scheduled the next meeting in Beijing in October 1988.

Day 9 - Saturday, November 28, 1987

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

Day 10 - Sunday, November 29, 1987

A day of rest was in order after a long journey. Spent the day finalizing this report.

Day 11 - Monday, November 30, 1987

This was the final day of my trip, and I flew from San Francisco to Pittsburgh, PA (U.S.A.).

## CONCLUSIONS

During my stay in Beijing (November 22-28, 1987), I participated as the Technical Adviser to the Technical Committee, whose goal 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), Beijing. The Technical Committee has been established for the duration of the project (4.0 years) to facilitate its successful implementation. The project is scheduled to run through December 1988.

As the Technical Adviser (Job Description DP/CPR/83/002/11-01/32.1.I), my duties during the committee meetings were the following:

1. To review the R&D activities, and to report, monitor, review, and evaluate the project.

2. To advise the Chinese Government through their National Project Director on the Annual Work Plan.

3. To recommend to the Chinese Government and UNIDO on the specific utilization of UNDP funds in the most efficient way to achieve the project objectives.

4. To keep the program in its proper perspective in relation to 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 the characteristics, and select suitable liquefaction technologies for Chinese coals.

2. Conduct basic research, scale up results, and obtain the necessary data for the design and construction of a commercial coal liquefaction plant.

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 steel making), 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 are being satisfied:

1. Evaluate various types of Chinese coals and select those best for hydrogenation.

2. Investigate the liquefaction behavior of the selected coals in autoclave experiments.

3. Investigate the formation of a stable slurry that can be transported without phase separation.

4. Carry out experiments on selection and preparation of the hydrogenation solvent.

5. Develop laboratory methods for the separation of coal liquids and determine their chemical structures and properties.

6. Evaluate different coal liquefaction catalysts.

7. Study techniques for upgrading of coal liquids to obtain lighter, more stable products.

The 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 thoroughly, and a suitable direct liquefaction process selected for commercialization.

A detailed plan for the 1988 R&D work was determined and the required UNIDO inputs were specified regarding Consultants, Fellowships, and Study Tours.

In respect to project monitoring, it was concluded that the Technical Committee should meet annually to review and approve the past year's Progress Report and determine the Work Plan for the coming year. The Technical Committee meetings should be scheduled to be held in conjunction with the yearly Tripartite Meeting. The next meeting is scheduled for October 1988 in Beijing at CCMRI.

## RECOMMENDATIONS

Based on the discussions with the staff of the CCMRI and the BRICC the following recommendations seem to be in order:

1. The autoclave work should continue to be directed at catalyst screening to determine an active catalyst that is abundant and inexpensive.

2. The modified NEDO unit (CPU #1) should be used to perform process technology assessments.

3. The Xytel unit (CPU #2) should continue to be used for product oil upgrading.

4. The FRG unit (CPU #3) has proven to be a valuable processing tool for technology evaluations. Operation of this unit should be given top priority in 1988.

5. The GC/MS was operated in 1987. This will prove useful in analyzing coal liquids. The operation of CPU #1 and #3, combined with the upgrading potential of CPU #2, will rely on this GC/MS during 1988.

6. The DTA unit ordered from Japan has never performed satisfactorily. I would recommend that this unit remain in Japan and that the purchase price be refunded to the Chinese to purchase additional equipment.

7. The plans for Consultants, Fellowships, and Study Tours were well developed into 1988. I would recommend that every effort be made to arrange the scheduling in order to obtain the maximum benefit.

8. In respect to Study Tours, I would recommend that these be concentrated at the installations where large-scale operations involving direct coal liquefaction are taking place.

9. Areas that should start receiving emphasis are the conduct of economic surveys and the study of direct coal liquefaction technology to evaluate the feasibility of constructing commercial coal liquefaction plants in China.

10. Because the 1988 Work Plans call for Consultants, Fellowships, and Study Tours in early 1988, it is recommended that the Chinese submit the documentation (job descriptions, etc.) to UNIDO for these efforts as soon as possible.

11. The Technical Committee should meet on an annual basis to review the progress during the year and approve the work plans for the coming year. The Technical Committee should meet at the annual Tripartite Meeting scheduled for October 1988.

James J. Lacey

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