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China.

TECHNOLOGIES OF DIRECT COAL LIQUEFACTION

DP/CPR/80/048

CHINA

Technical Report*

Mission 13-27 June 1985

Prepared for the Government of the People's Republic of China
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of

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United Nations Industrial Development Organization

Vienna

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SUMMARY OF VISIT

On June 11, 1985 I departed Salt Lake City, arriving in Tokyo on June 12, 1985. A three day stay in Tokyo was required due to lack of space on airlines traveling to China. The circumstances surrounding this delay are as follows:

Following acknowledgement of the date for the visit during the period 11-27 June 1985, I began inquiring about airline Schedules to China. Since UNIDO travel authorization is provided only 30 days prior to the date of departure, I found it impossible to book confirmed air space between Tokyo and Beijing. It was possible to obtain a reservation on a flight from Tokyo to Shanghai only on 15 June but no confirmation of a flight from Shanghai to Beijing was possible. Hence, I was "wait-listed" from Shanghai to Beijing. Thomas Cook Travel suggested that I fly to Tokyo and attempt to obtain booking on China Airlines (CAAC) while in Japan since CAAC does not have flight reservation capabilities on the international airline computer reservation system at this time. I attempted to obtain confirmed space by any means to arrive in Beijing but was unsuccessful. On June 15, just prior to departure to Shanghai (with no confirmed means of travel beyond Shanghai) confirmed space (first class only) became available on Japanese Air Lines. Hence, I was able to travel directly to Beijing in no other way in order to meet the itinerary agreed to with CCMRI.

In Beijing, I was met at the Airport by two representatives of CCMRI, Pang Weizhen, Office of International Cooperation and Chen Peng, Associate Director of the Academic Committee. They took me to the Friendship Hotel and arrangements were made for a visit to the Forbidden City on the next day, Sunday, June 16.

On Monday, June 17, I had the pleasure of visiting with Mr. Ouyang Yuan, Director of the Coal Liquefaction Project at CCMRI and members of the staff. Mrs. Lei Xiangqin served as interpreter. We discussed the status of the coal liquefaction project at CCMRI as well as the status of liquefaction projects in the United States. Following this meeting I was given a brief tour of the facilities of CCMRI. Later in the day I went to the UN offices to meet Mr. Albertus W. Sissingh UNPD Senior Industrial Development Field Advisor. This visit was very helpful in orienting me on the UNDP programs, recent industrial development in China, and the overall nature and purpose of my assignment at CCMRI. Mr. Sissingh was very professional as well as cordial in his orientation. During the course of this orientation I inquired of Mr. Sissingh about the possibility of responding to a request received, just prior to my departure from the U.S., to visit the Wuhan Institute of Physics, Academia Sinica. I had earlier discussed this matter with Mr. Ouyang Yuan who advised me that such a visit was acceptable to him if UNDP was agreeable. Mr. Sissingh gave his consent for the trip. Later that evening, Mr. Sissingh joined Mr. Ouyang Yuan and members of the CCMRI staff for a banquet.

The remainder of the week June 18-22 was spent at CCMRI giving lectures and holding group discussions with CCMRI staff and personnel from other institutions in Beijing. The following lectures were delivered:

Lecture 1. (June 18)	Fundamentals of NMR Spectroscopy in Liquids and Solids
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Lecture 2. (June 19)	NMR Analysis of Synfuels Liquids
Lecture 3. (June 20)	NMR of Solids
Lecture 4. (June 21)	Physical Properties and Chemical Structure of Coal Macerals
Lectures 5 & 6. (June 22)	Coal Macerals and Coal Structure

Those in attendance at the Lectures were:

<u>NAME</u>	<u>INSTITUTE</u>
Chu Sing Chung	Peking University
Ma Jun Qi	Aun Shan Thermal Energy Institute
Xi Xin Xan	Aun Shan Thermal Energy Institute
Pan Jing Qi	Department of Chemistry Peking University
Wang Yong Qi	Institute of Test and Analysis Guang Tong
Wu Xiao Hua	Qiqihar Light Industry College
Li Yan Lai	HuaDong Petroleum Institute
Lin Te Len	HuaDong Petroleum Institute
Zhai Shu Shun	Research Institute of Petroleum Processing
Yue Fan	Research Institute of Petroleum Processing
Zhou Ming	Central Coal Mining Research Institute

Chen Aili	Central Coal Mining Research Institute
Cher Ming Yu	Central Coal Mining Research Institute
Ma Jingsheng	Central Coal Mining Research Institute
Lei Xiangqin	Central Coal Mining Research Institute
Chen Peng	Central Coal Mining Research Institute

The lectures commenced at 0900 each day and lasted until 1200. Mrs. Lei served as interpreter. One to two hours in the afternoon were spent in group discussions of interpretation of NMR spectra and the application of NMR spectroscopy to coal liquefaction science.

A portion of the afternoon on two days was spent in the NMR laboratory at CCMRI. My main interest was in observing operating conditions and techniques on the Varian FT-80 NMR spectrometer that was purchased by UNDP funds. This laboratory was under the direction of Mrs. Chen Ming Yu. The laboratory environment was quite adequate and the personnel were familiar with proper operating techniques. I asked to see standard reference spectra and participated in a calibration run to assure myself that the instrument was operational and that appropriate operational and maintenance techniques were employed. I chose to go through these procedures because laboratory personnel had described previous maintenance difficulties. At the time of my visit the NMR instrument was operating according to manufacturer's specifications.

Later in the week a major part of one afternoon was spent touring the other laboratories of CMMRI. I was particularly interested in the coal liquefaction pilot plant and visited with the Japanese engineers present who were responsible for installation of the liquefaction hardware and control instrumentation. No operational runs were being made at the time of my visit. The major efforts at that time were in equipment testing and calibration.

On Monday, June 24, I traveled to Wuhan in response to a telegram request by Wu Qin-Yi, Director of the Wuhan Institute of Physics, Academia Sinica. The expenses for this trip were born by myself. The Wuhan Institute of Physics is the leading NMR laboratory in China and has been designated as a national laboratory for NMR development and service for China. The Vice Director of the Institute, Ye Chao-Hui will spend 6 months in the U.S. studying the operation of major NMR service laboratories. It is anticipated that he will visit our NMR laboratory at the University of Utah. On June 25 I gave a lecture on NMR spectroscopy of solids to approximately 40 scientists and technicians at the Wuhan Institute of Physics.

On June 26, I flew back to Beijing where I was hosted for lunch by Mr. Yu Xiang, Deputy Director of CCMRI.

On June 27, Madam Pang Weizhen and Chen Peng accompanied me to the airport and assisted in final arrangements for departure. Pang and Chen did a superb job in handling local arrangements and assuring that my visit was pleasant. Madame Pang was also very gracious in arranging special tours and visits for members of my family who accompanied me on the visit to China.

FINDINGS

In view of the relatively short duration of the visit, my findings should perhaps more appropriately be classified as observations. Inasmuch as my assignment was as an advisor in the use of NMR techniques, a detailed examination of the liquefaction program was not appropriate. However, some general observations will be made.

1. The Chinese government has made a major commitment to an overall program designed to ensure adequate supplies of energy for all parts of its rapidly expanding economy. Included in that commitment is an ambitious program to develop China's vast coal resources and provide a major portion of China's liquid fuels needs from coal liquefaction processes.

2. The present national plan consists of the following major activities:

- a) exploration
- b) characterization of the major coal resources
- c) batch autoclave testing of coals
- d) continuous reactor (PDU) testing of selected coals
- e) upgrading of coal-derived liquids
- f) preparation of plant design and feasibility study

Activities a-c have been pursued vigorously. Activity d) is underway and, given the complexity of operating continuous reactors, is progressing at a reasonable rate. While at CCMRI, the 20 Kg/hr unit purchased from Mitsui Engineering and Shipbuilding Company, Lt., of Japan, was undergoing minor engineering modifications. Prior to my visit this unit as well as the Xytel 5 Kg/hr had been used for several coal tests.

3. The personnel at CCMRI seemed to be capable, dedicated individuals who worked with a great deal of enthusiasm.

4. The support laboratories I visited were staffed by engineers and chemists who understood their mission. Several of the key personnel have visited and/or worked at major coal liquefaction facilities abroad.

5. The analytical instrumentation provided for the program is being used in an appropriate fashion.

6. The overall goals of the CCMRI program are sound and logical and desirable progression is being achieved.

RECOMMENDATIONS

The following items are of importance for consideration. It is recognized that some recommended measures could be implemented within a short time frame while others would require long term effort.

1. Access to scientific literature could be improved. I saw no evidence of a reading room or ready access to scientific journals and books.

2. The need for scientific exchange visits is ever present. While the number of CCMRI staff who have traveled abroad is impressive, this effort needs to continue and, perhaps, even be expanded. Long term visits abroad would in general be of more value for many of the staff than the shorter term "survey" visits. The

longer time commitments should provide in-depth study and working experience at operating laboratories abroad. Such time commitments would facilitate transfer of knowledge and, perhaps most importantly, experience back to CCMRI.

3. Two important areas of analytical capability should be addressed. In order to properly assess the quality of coal derived liquids produced and to evaluate the liquid upgrading work, sophisticated separation techniques will be needed. CCMRI should carefully evaluate the need for gas chromatography/liquid chromatograph separations. Carefully separated oil fractions will be essential to the evaluation of the processing of the upgraded coal derived liquids. In addition, a reasonable quality gc/mass spectrometer is needed to carry out routine analyses to complement the NMR and IR analyses.

4. As a result of my lectures, a great deal of discussion and excitement was generated over the use of high field NMR spectrometers and modern multiple pulse NMR techniques. The instrument currently available at CCMRI is a Varian FT-80 which operates at a frequency of 80 MHz for protons. This is a good, reliable instrument for routine organic chemical analysis. However, it was not designed to carry out the function of optimal analysis of coal derived liquids. While it is true that a great deal of useful information can be obtained on a low field instrument such as the FT-80, its usefulness is limited in the analysis of such complex mixtures as coal derived liquids. Some of the problems associated with complex mixtures can be ameliorated if

extensive separations work is carried out prior to NMR analysis. However, this is rarely an efficient solution to the problem. CCMRI needs access to a modern, multi-pulse, high field spectrometer if it hopes to optimize the analysis of coal derived liquids. Such an instrument, if available, would enable CCMRI personnel to obtain spectra using 1- and 2-dimensional pulse experiments such as DEPT, INEPT, COSEY, INADEQUATE, and J-coupled spectroscopy. These experiments would provide a great deal of detailed structural information on complex liquids. This information would be especially valuable when th liquid upgrading experiments get underway. This data would elucidate the details of structural change that occur and guide the design of optimal upgrading procedures.

5. A very fine NMR laboratory has been established in Wuhan at the Wuhan Institute of Physics, Academia Sinica. At the time of my visit, I was informed that this Institute was likely to be designated as a national NMR center for China. Amont other instruments, this laboratory has a Varian XL-200 NMR spectrometer which is capable of carrying out the modern multiple pulse experiments mentioned in 4, above. The operation frequency is 2.5 times higher than the FT-80 and, hence, would represent a major improvement in spectral resolution and sensitivity over the instrument available at CCMRI. In addition, the multi-pulse experiments referred to in 4 could be carried out on this instrument. In discussing possible use of the Wuhan facility with CCMRI personnel I was informed that the Institute could not

afford to pay for acquiring the data. In view of the potential value of multiple pulse data, I feel that every avenue should be explored to make meaningful support possible.

6. On the first day of my visit to CCMRI, I mentioned to Mr. Ouyang that a new concept in coal liquefaction technology was being developed at the University of Utah. This process is known as differential liquefaction. Some differential coal liquefaction procedures may be tailored to proven coal conversion and beneficiation technologies, e.g., gasification (→pyrolysis tar), coal drying (→low temp. distillate) or coal washing (→resin concentrate). In pyrolytic tar/char disproportionation processes, the char fraction can be blended with fresh coal to provide an excellent fuel for conventional combustion furnaces. Besides requiring relatively low capital investments, differential coal liquefaction schemes are generally characterized by the production of high grade, hydrocarbon-rich tars which need less refining and upgrading than the tars obtained by "total liquefaction" methods.

Mr. Ouyang expressed a keen interest in this technology and asked if I would provide him with additional information. Since this is a research program that is still relatively new, I told him that only a limited amount of data is presently available but that I would send him results and pre-prints as they become available. An exchange visit of a member of the CCMRI staff at the University of Utah within the next year's time may prove to be quite valuable to the Chinese coal liquefaction program in keeping abreast of this recent development in technology.