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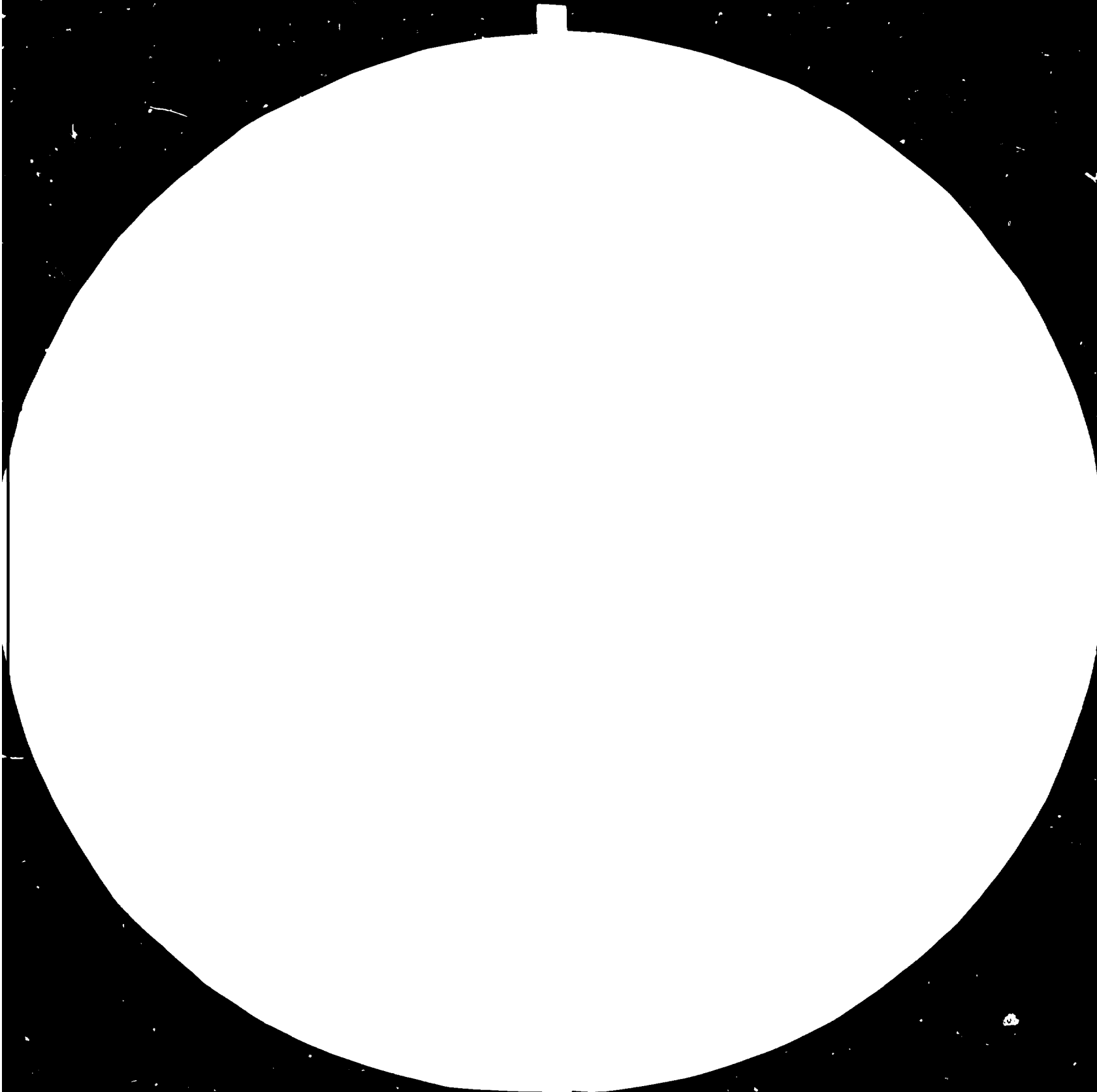
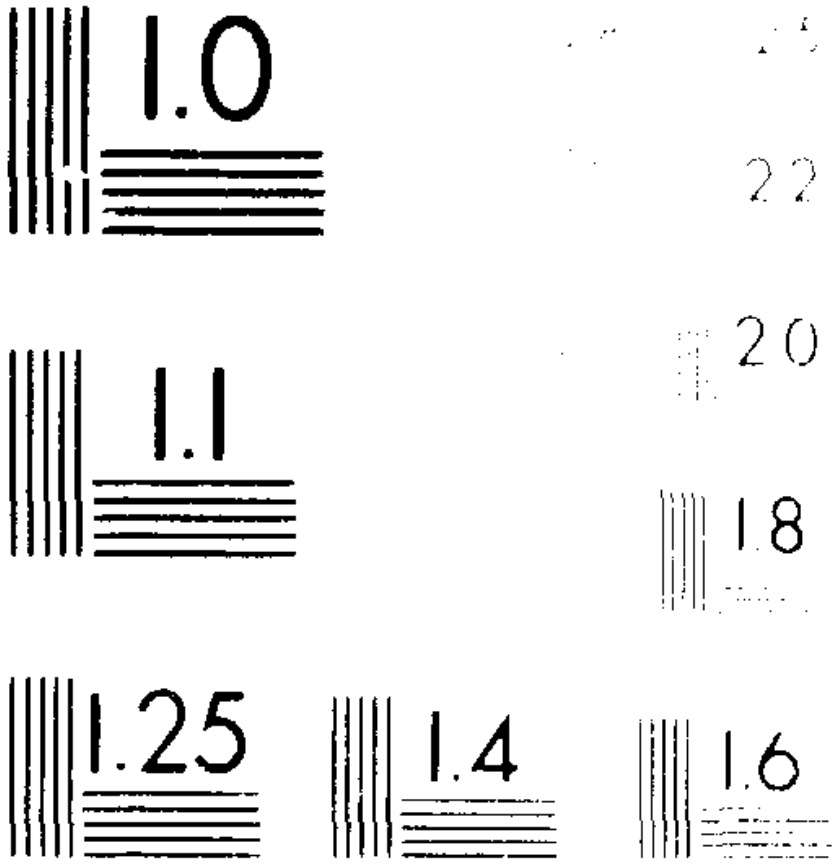
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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June 1984

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TECHNIQUES OF DIRECT COAL LIQUEFACTION

DP/CPR/80/048

CHINA

Technical Report*

Mission 12-19 April 1984

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 Peter F.M. Paul,

expert on upgrading techniques of coal liquefaction products

United Nations Industrial Development Organization

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ABSTRACT

This report concerns a seven-day mission to the Central Coal Mining Research Institute, Beijing. The mission formed a component of UNDP support for the Chinese project on Direct Coal Liquefaction (DP/CPR/80/048/11-58/32.1.C) which entered its second four-year phase during 1983. Work relating to SRC technology has progressed to the commissioning of a 20 kg slurry/hr process development unit of Japanese design. The scope of the programme has been widened to include other direct liquefaction processes and this consultancy included an exposition of processes developed in Britain. Topics covered in the series of seven coordinated lectures are listed. Characterisation of primary and secondary coal liquefaction products, evaluation of competing solid/liquid separation processes and the suitability of two-stage processes for the liquefaction of lignites received emphasis in discussions.

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INTRODUCTION

The programme on coal liquefaction at the Central Coal Mining Research Institute (CCMRI) in Beijing is funded by the Chinese government through the Ministry of the Coal Industry but, in addition, it has received support under the United Nations Development Programme (UNDP) since July 1980. The first four-year programme was completed during 1983. It included recruitment and training of technical staff, the acquisition of laboratory equipment, construction of a purpose-designed building (including a large experiment bay to house process development units), screening tests of Chinese coals regarding their suitability for liquefaction and, laterly, the acquisition of two SRC process development units (PDU).

The second phase of the CCMRI liquefaction programme was begun in 1983 and it is also partly sponsored by the UNDP. The programme provides for extended process development work making use of the two PDU but will not be limited to consideration of SRC technology. Increasing attention is to be given to other technologies for the direct liquefaction of coal, including the 'new' Germany technology and two-stage processes exemplified by those which have been developed by the National Coal Board in Britain.

This report concerns a short-term (7-day) mission to the CCMRI undertaken during April 1984, the main purposes of which were:

- to advise on the upgrading of coal liquefaction products
- to provide a systematic introduction to specific features of coal liquefaction techniques developed in some countries recognised as leading in coal liquefaction research
- to survey possible means of reducing the cost of liquefaction and their practical significance
- to assess the future prospects of coal liquefaction

RECOMMENDATIONS

On the bases of observations made and discussions with the CCMRI liquefaction project staff, the following recommendations are made:

1. In seeking to widen the study of direct liquefaction processes being developed abroad, through consultancy and collaborative agreements, CCMRI should include an approach to the British National Coal Board.

2. The study of competing liquefaction technologies, and the identification of sectors amenable to technical innovation, are greatly facilitated by process simulation. CCMRI should either devise or acquire a sufficiently comprehensive computer programme in order to contain the experimental programme.

3. Broadening the scope of the experimental programme to include catalysis for liquefaction and upgrading processes will necessitate monitoring of catalyst deactivation. For this work, CCMRI should acquire a scanning electron microscope.

4. As the emphasis on product upgrading increases, eg. work on hydrotreatment and reforming, CCMRI will find it advantageous to augment existing facilities for gas/liquid chromatography.

5. As a safety precaution, CCMRI should check that hydrogen detectors are fitted in the experiment bay and that the number of air changes is sufficiently high.

I. LECTURES AND DISCUSSION

A specially-prepared series of coordinated lectures, having the general theme - The British Apprcach to Coal Liquefaction - was presented to the CCMRI liquefaction project over six days and formed the 'core' for the discussion and exchange of information. Although it proved impractical for CCMRI to have the lectures translated in advance of the visit this was by no means an impediment, such was the proficiency and enthusiasm of the interpreter who was surprisingly conversant with the terminology. Even so, presentation of a lecture could take up to 3 hours, depending on its length and the number of illustrations.

Although the central theme of the lectures was the development of the National Coal Board's two direct liquefaction processes this was largely to provide a framework for comparing competing technologies through reference to the differences and similarities. (Topics covered by the lectures are listed in Annex 1).

In general, each lecture was followed by extensive discussion which, at times, was quite lively, indicating the enthusiasm and dedication of the project staff. Interest was expressed principally in aspects of the characterisation of primary and secondary coal liquefaction products, in the advantages and disadvantages of alternative solid/liquid separation processes and in the suitability of the NCB two-stage liquefaction processes for lignite feedstocks. The influence of American experience was evident in the views held by the project staff regarding separation processes.

It was soon apparent that, although the CCMRI programme has so far been predominantly concerned with the SRC approach to coal liquefaction, there is no commitment to develop an SRC process specifically, or indeed any particular liquefaction process. The main objective is to create a body of expertise familiar with all aspects of direct liquefaction processes. To that end, there is an interest in developing existing collaboration arrangements with West German organizations and an expressed desire to establish some form of collaboration with the British National Coal Board relating to liquefaction. (There already exists collaboration between the CCMRI and the National Coal Board's Mining Research Establishment). An undertaking was given to raise this proposal for consideration by the Directorate of the Coal Research Establishment.

II. LIQUEFACTION RESEARCH FACILITIES

A. Process Development Units

The two SRC process development units are located in the large experimental bay. There is adequate headroom and good access. A minor criticism might be that, to reduce the risk of a mishap on one affecting the other, there could have been greater separation of the units. Other safety provisions would be to fit detectors to monitor possible hydrogen leaks and to arrange a large number of air changes by forced circulation. (Mentioned here only because these provisions were not discussed during the tour of the experimental bay). All of the control instrumentation and data processing equipment is sensibly located in an adjoining control room.

The smaller, modular unit built by Xytel (capacity 5 kg slurry/hr), believed to be a replica of one supplied earlier to the Pittsburg Energy Research Center, has still to be commissioned. The unit is understood to be complete and there is apparently no commitment for Xytel to participate in its commissioning.

The larger PDU (capacity 20 kg slurry/hr), made available to CCMRI under an agreement between the Chinese and Japanese governments, has been commissioned and several runs of short duration have been completed satisfactorily. It was claimed that the accummulated operating time was 350 hrs.

The status of the PDU work is therefore much as reported by Ruether and Retcofsky at the time of their visit in October 1983.

The senior staff appeared confident that sufficient trained staff could be made vailable to permit extended operation of the PDU when necessary. Runs of short duration do not, of course, permit attainment of 'steady state' conditions.

The engineering staff expressed confidence that the vacuum distillation of high solids inventory slurries to recover liquid products should present few problems. Their attention was drawn, however, to the potential hazard of coking being induced by localised overheating.

B. Supporting equipment/analytical instruments

A conducted tour of the liquefaction project building revealed that the project has available adequate facilities to monitor the existing experimental programme. However, some of the equipment is not presently accessible as it was housed in the main laboratory building which is currently being modified by the construction of two additional floors and the necessary reinforcement of the original structure. This construction work has been delayed but is expected to be completed by October 1984.

Some duplication of the analytical equipment, particularly that for gas/liquid chromatography, will be necessary as work on the refining of the primary products, including hydrotreatment and reforming, is extended. In addition, should the intention to investigate other direct liquefaction processes be pursued, more emphasis is likely to be given to catalysis and, for such investigations, the acquisition of a scanning electron microscope would be recommended.

III. OTHER MAJOR CCMRI PROJECTS

There is considerable interest in augmenting the range of coals available for the production of metallurgical cokes and the Institute has conducted a programme on coal blending for some years. The existing experimental coke oven is equipped for stamped charges. The supporting laboratory facilities are generally good.

A second major project concerns the development of a pressurised, oxygen-blown slagging gasification process and a unit of 650 mm shaft diameter, capable of gasifying 500 kg coal/hr, has been designed by the Institute and was about to be commissioned. All of the components of the gasifier have been fabricated in China. One disadvantage, of course, might be difficulties in obtaining replacement parts. The gasification programme is justified on the probable requirement to provide further supplies of towns gas throughout China. Beijing is currently supplied by gas produced at coking plants associated with steel plants located some twenty-five miles away).

Interest was expressed in extending the scope of collaboration with other organisations engaged in coal utilisation research and development including carbonisation and gasification.

IV. CONCLUSIONS

On the basis of a 7-day visit to the CCMRI coal liquefaction project laboratories, with 6 days devoted to lectures and discussion and about 4 hours spent in touring the laboratories and pilot plant, it is probably pretentious to head this section 'conclusions'. Impressions might be more appropriate.

There is no question that the achievements of the past four years are remarkable. The construction of the laboratory, the acquisition of equipment and the training of staff within this timescale are sufficient testament to this progress. The enthusiasm of the youthful staff undoubtedly needs tempering with experience, as is evidenced by a degree of over-confidence. There was no real opportunity to assess how broadly-based is the background of technical and analytical data.

Whether or not there has been a conscious shift in the basic philosophy justifying the liquefaction project, the impression was gained that, rather than pursuing the development of a specific process, the intention is to build up a team of experts conversant with all aspects of direct coal liquefaction processes. When that objective has been achieved perhaps attention will be directed to evolving a process which may be particularly suited to Chinese coals and the pattern of energy demand evolving in China.

It was evident that the CCMRI wishes to promote further collaboration with organisations engaged in coal utilisation R&D, not necessarily under the aegis of the UNDP.

ANNEX 1 LIST OF TOPICS COVERED BY LECTURES

(General theme: The British Approach to Coal Liquefaction)

Incentives and objectives

Coal resources and reserves
The British coal industry
Changing pattern of energy utilisation
Incentives to develop coal liquefaction

Origins of the Liquid Solvent Extraction (LSE) process

Coal extraction for premium cokes and carbons
Classification of coals for solvent extraction
Development of a generalised system of ranking coals for liquefaction
Relationship between coal rank and extraction yield
Influence of maceral composition
Application of the classification system to larger scale operations
Electrode coke development programme
Status of the premium cokes and carbons development programmes

Origins of the Supercritical Gas Extraction (SGE) process

The phenomenon and its application to coal tar and coal
General principles regarding the solvent effect
Effective solvents for coal
Nature of the char residue
Yield and nature of the extract
Scales of operation during development
The 5-10 kg/hr Process Development Unit (PDU)
PDU performance
Solids separation
Depth of extraction
Effect of coal rank
Critical Solvent Deashing process

Coal extracts: separation and purity

Separation of coal extracts
Separation by filtration
Effect of digestion conditions
Effect of filtration conditions
Influence of filter membrane
Influence of particle sedimentation
Impurities in 'clean' coal extracts

Chemistry of coal extracts

Fractionation and analysis of extracts
Average chemical structures
Subsequent developments in extract characterisation
Distribution of asphaltene structure about the average
Solubility of supercritical gas extract fractions
Newer methods of characterisation of high molecular mass coal derivatives

Integrated LSE and SGE liquefaction processes

Development of hydrocracking
Characteristics of the hydrocracker distillates
Secondary refining
Refining of naphtha to gasoline
Refining of mid-distillate to diesel and jet fuels
Utilisation of hydrogen in the LSE liquefaction process

Development programme: conceptual commercial plants: economics

Aspects of process engineering design:

- Slurry preparation and presurisation
- Preheating and digestion
- Solids separation
- Hydrocracking
- Product separation

25 tonnes coal/day pilot plant designs:

- LSE pilot plant design
- SGE pilot plant design

Conceptual commercial plant designs

Process economics

ANNEX 2. LIST OF PRINCIPAL CCMRI STAFF MET

Mr. Yu Xiang, Deputy Director

Dr. Wang Yinren (formerly Director, Institute of Coal Chemistry)

Mr. Wu Chunlai, Head, Coal Liquefaction Project

Mme. Pang Weizhen, Office of International Cooperation

Mme. Lei Xiang Qin, Interpreter