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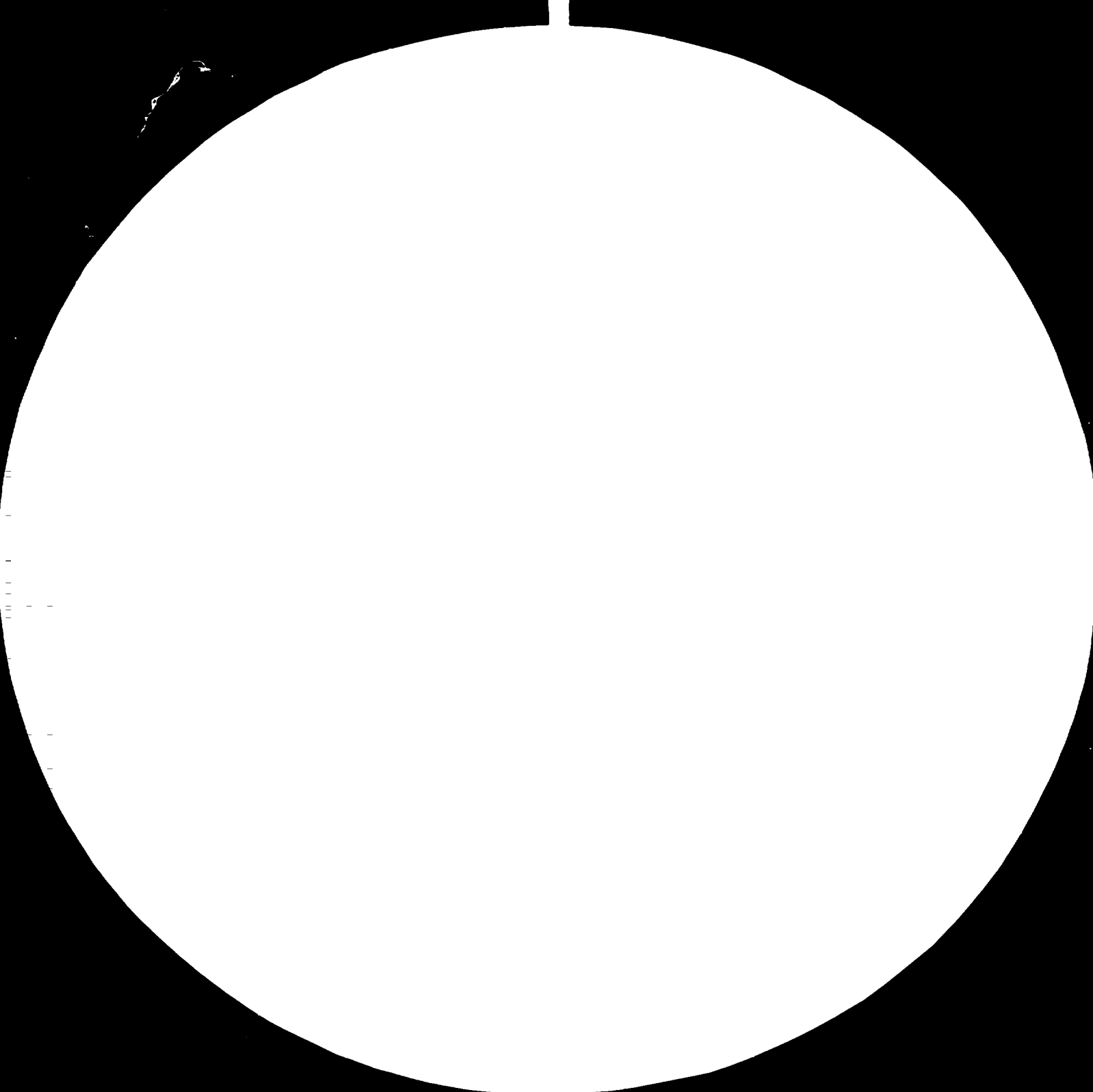

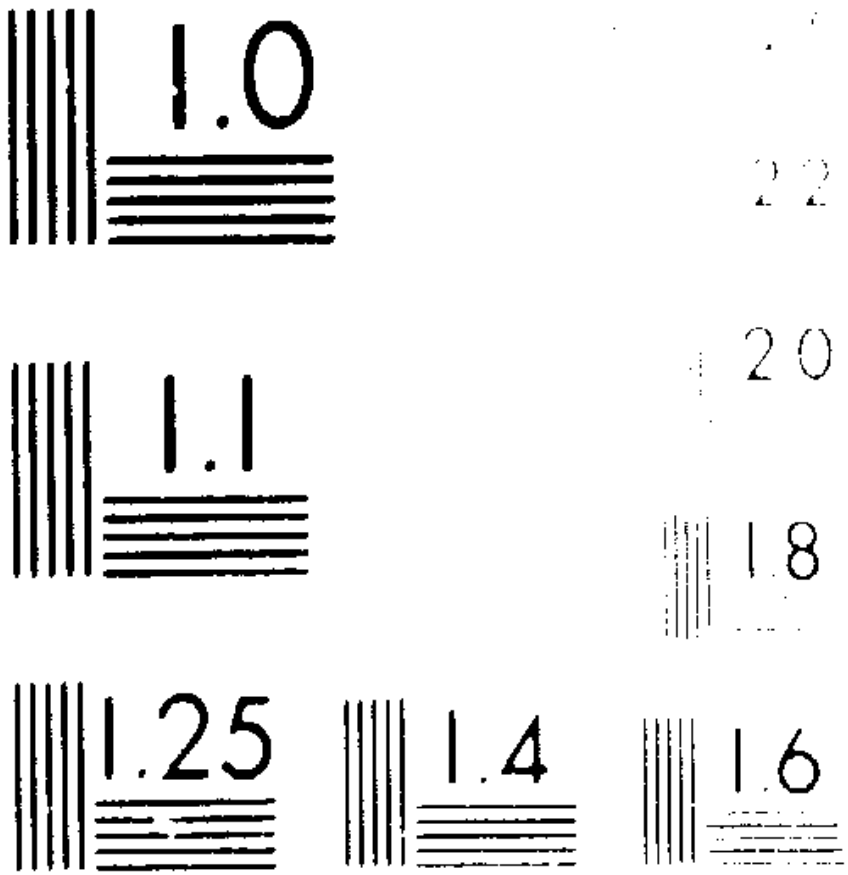
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June 5, 1982
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COAL LIQUEFACTION TECHNOLOGIES.

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CHINA

Technical Report

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

Based on the work of James K. Shou, expert
in the coal liquefaction processes and related technologies

United Nations Industrial Development Organization
Vienna

ABSTRACT

China has over 600 billion tons of coal resources. It would be desirable to develop liquefaction technology to convert coal into liquid fuel and chemicals. The purpose of this project is to introduce state-of-the-art information on coal conversion technologies to the developing countries. The objective of this 18-day assignment at the Central Coal Mining Research Institute (CCMRI) in Beijing, China, is to exchange coal liquefaction technical information and to review CCMRI's work in this field. CCMRI has adequate coal liquefaction research facilities, but its personnel still require practical training in pilot plant operation and analytical skills.

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INTRODUCTION

China has a vast supply of coal. The identified coal resources in China are over 600 billion tons. To make this source of energy available to the public and to other countries of the world, it would be necessary to convert it from its solid form to one that is more compatible with the present and future modes of transportation, industrial and domestic fuel needs.

A research program of coal liquefaction was started in 1979 with initial support from the Chinese government. The program has been jointly sponsored by the Chinese government and the United Nations Development Programme (UNDP) since July, 1980. A research plan has been established for the period 1979-1983. It includes the following objectives:

1. Select several candidate coals that are suitable for liquefaction processes.
2. Evaluate coal properties and products of liquefactions.
3. Obtain preliminary process and economic data for the design of advanced liquefaction plants.
4. Develop a process model for coal liquefaction.
5. Evaluate new materials of construction.
6. Promote a two-way exchange of coal liquefaction technologies with UNDP-assisted projects in other developing countries.
7. Train a staff of technical personnel assigned to liquefaction at home and abroad.

This report will review the on-going research program and facilities at the Central Coal Mining Research Institute (CCMRI) in Beijing, China. Technical and general information,

as well as some recommendations regarding this program, are included.

SUMMARY AND RECOMMENDATION

1. CCMRI has more than adequate coal liquefaction facilities and has sufficient manpower to operate them.
2. Current CCMRI liquefaction research should include effect of operating conditions on conversion and product quality.
3. A mid-range research program should emphasize two-stage coal liquefaction technologies.
4. A long-range research program should include studies of product upgrading and an appropriate catalyst.
5. CCMRI needs to improve its information services: such as computer on-line literature search, computer data acquisition, storage, and retrieval services.
6. CCMRI needs to develop its mid-rank research personnel so that they can become project leaders in the near future.

I. TECHNICAL INFORMATION EXCHANGE

A. Five Lecturing Sessions

As requested by CCMRI, I gave five lectures covering a wide range of coal liquefaction technologies and research methodology. In each lecture, a specific subject was presented in the morning. This was followed by a general discussion of the subject in the afternoon session. The five lecture subjects were as follows:

1. Liquefaction reaction mechanism and kenetics,
2. Liquefaction reactor (or dissolver) fluid dynamics,
3. Coal liquid upgrading and hydrotreating catalyst,
4. Data acquisition and analysis,
5. Equipment design and solid-liquid separation.

More detailed descriptions of these subjects are listed in Appendix.

B. CCMRI Research Program

CCMRI was established by the Chinese government in 1956 and is under the administration of the Coal Ministry. During the early years, CCMRI's research objective was mainly to analyze coals and to classify coals. There was no significant coal liquefaction research program until a few years ago.

CCMRI's current coal liquefaction program consists of:

1. Evaluation of liquefaction characteristics of Chinese coals,
2. Evaluation of coal slurring solvent on conversion,
3. Assessment of catalytic activity of coal minerals (mainly the pyrites),

4. Assessment of trace mineral elements effect on conversion.

C. Recommendation On Future Research

1. Evaluate process variables (temperature, space velocity and hydrogen partial pressure, etc.) effect on conversion.
2. Improve batch reactor apparatus and experimental technique so that short contact time liquefaction can be carried out.
3. Investigate tow-stage coal liquefaction technology.
4. Extend liquefaction research to include liquid product upgrading processes, hydrotreating catalyst, and solid-liquid separation processes.

II. LIQUEFACTION RESEARCH FACILITIES

A. Pilot Plant

By the end of 1982, CCMRI will have two liquefaction pilot plants. Each of these two bench scale continuous process development units can process 10 pounds of coal slurry per hour. One of the pilot plants is designed and built in the United States of America by the Chicago-based Xytel Corporation. The other pilot plant is designed and built by a Japanese company. Both of these pilot plants and other facilities will be housed in the newly-constructed liquefaction laboratory building.

These pilot plants are equipped with a microprocessor-controlled instrument and are capable of automatic data acquisition and data processing when it is interfaced and linked to a computer.

B. Batch Autoclaves

There are 6 autoclaves. Four of them are newly purchased from Autoclave Engineers, Inc., an American company based in Erie, Pennsylvania. Two older autoclaves are made in China. Limited spare parts are available for all of these autoclaves.

C. Supporting Equipment and Analytical Instruments

A coal sample preparation laboratory was established. This laboratory was equipped with a crusher/grinder, a polisher, a drying device, a petrographic properties analyzer, a polarizing microscope, etc.

There is also coal product preparation equipment, such as distillation columns, solvent extraction apparatus, density meters, viscosity measuring devices, etc.

Analytical instrumentation is also well established. Major equipment includes a nuclear magnetic resonnance analyzer, an elemental analyzer, gas and liquid chromatographs, a high performance liquid chromatograph, infra-red spectrometer, etc. Most of these are equipped with microprocessor-controlled instrumentation. A GC-mass spectrometer is in the purchase plan.

D. Recommendation

CCMRI has equipment purchased from the USA and other industrial countries. This equipment uses parts that are specified in either the English or the metric system. This dual specification makes parts repair and replacement a difficult task. In the future, CCMRI should purchase conversion kits (mainly fittings to convert the English system to the metric system) and machine tools that can modify English systems.

CCMRI is well equipped with analytical and process equipments. The main drawbacks are the lack of an experienced operators for the pilot plant and an insufficient reference data bank for the analytical basis. Therefore, CCMRI's immediate effort should be directed at personnel training and establishing a substantial analytical data bank.

III. MANAGEMENT AND INFORMATION SERVICES

A. Organization

CCMRI has been steadily expanding in its personnel and functioning groups. It has recently added an Economic Evaluation Division. The Coal Chemistry Division is also expanding. Under this division, a Physical Chemistry Department and an Engineering Department will be formed in the near future.

This organizational expansion reflects the Chinese government's emphasis on developing coal conversion technology and coal utilization. In view of the government's recent slow-down policy on a nationwide scale, CCMRI's continuing expansion has a significant meaning.

B. Employee Training Program

More than 20 recent college graduates were hired and were sent to school for 1 1/2 years of special training in the science and technology of coal liquefaction and gasification. They will become part of the research staff soon. The training will give these young engineers some practical experience and confidence in pilot plant operation. CCMRI has also recently accepted 4 graduate students under a cooperative educational program with several local universities.

Under UNDP sponsorship and other exchange programs, senior technical personnel have been sent to the United States for practical training.

C. Information Services

The Division of Technical Information at CCMRI has a library. It has a more than adequate collection of technical journals. The library's collection of technical text books and reference books is limited, however.

The division's information center provides services on slide preparation, foreign literature translation, internal unpublished paper file, etc. On the other hand, it does not have efficient literature search facilities, nor does it have computer data acquisition and processing capability.

D. Recommendation

CCMRI needs to strengthen its information services by staffing professional libraries and by improving literature search facilities. There is a Chemical Abstract computer data bank in the Ministry of Chemical Engineering. It would be a great asset if CCMRI could use this data bank through a computer terminal.

Management should emphasize developing mid-rank engineers--the near-future project leaders. Participation in the on-going UNIDO/UNDP training program should be adequate.

Research institutes or companies in the United States that may be considered for providing technical training are as follows:

1. University research departments or institutes:

   University of Kentucky's Institute for Mining and Minerals Research (IMMR) in Lexington, Kentucky

   University of Utah's Fuels Engineering Department, Salt Lake City, Utah

Pennsyslvania State University's Coal Research Section, University Park, Pennsylvania

Other universities well-known in coal research

2. United States Department of Energy Research Centers:

Pittsburgh Energy Research Center, Pittsburg, Pennsylvania

Oak Ridge National Laboratory, Oak Ridge, Tennessee

Bartlesville Energy Research Center, Barlesville, Oklahoma

Other centers and national laboratories that are still in operation.

3. Industrial research institutes that welcome outside sponsors:

Hydrocarbon Research, Inc., Trenton, New Jersey

Institute of Gas Technology, Chicago, Illinois

Battelle Memorial Laboratory, Columbus, Ohio

etc.

APPENDIX

Detailed Listing of Lecture Subjects

1. Liquefaction Reaction Mechanism and Kinetics
   - A. Review of liquefaction kinetics
     - a. Classical treatment of kinetics--known reactants and products
     - b. Liquefaction of coal--unknown coal structure and complex products
   - B. Coal dissolution phenomena
     - a. Physical dissolution--small molecules in micropores
     - b. Thermochemical disintegration--thermally activated bond breaking and hydrogen transfer
   - C. Coal liquefaction modeling
     - a. The asphaltene intermediate model
     - b. The sequential decomposition model
     - c. The parallel decomposition model
   - D. Liquefaction data analysis
     - a. Effects of coal rank and minerals in coal
     - b. Effects of process conditions
     - c. Effects of catalyst
     - d. Two-stage coal liquefaction technology

2. Liquefaction Reactor (Dissolver) Fluid Dynamics
   - A. Objectives of coal liquefaction fluid dynamics
     - a. Scale-up information for large reactor
     - b. Gas and liquid mixing phenomena
     - c. Catalytic bed expansion and phase hold-ups
   - B. Two-phase gas-slurry up-flow reactor
     - a. Packed bed reactor--Synth oil
     - b. Fluidized bed dissolver--Solvent Refined coal
   - C. Three-phase gas-liquid-solid fluidized bed reactor

a. Gas-liquid-coal fine fluidization--Solvent Refined coal
b. Gas-slurry-catalyst fluidization--H-coal

D. Small bench-scale three-phase fluid flow studies
a. Experimental limitations
b. Theoretical treatment of data and modeling

3. Coal Liquid Upgrading and Hydrotreating Catalyst

A. Hydrodesulfurization (HDS) and hydrodenitrogenation (HDN) background
B. HDS and HDN reaction mechanism
a. Model compound studies
b. HDS and HDN interaction
C. HDS and HDN kinetics
a. catalyst effect
b. process conditions effect
D. Industrial approaches on HDS and HDN
a. HDS catalyst
b. HDN catalyst
c. Upgrading of coal liquid
E. Coal liquefaction catalyst development
a. Catalyst deactivation
b. Bimodal pore size catalyst

4. Data Acquisition and Analysis

A. Data generation and collection
a. Automatic recording--for efficiency and completion
b. Manual recording--for checking and backing
c. Selection of important variables
d. Selection of measurement points
B. Treatment of raw data
a. Reproducibility of data
b. Precision and accuracy of data
c. Tabulation and grouping for documentation

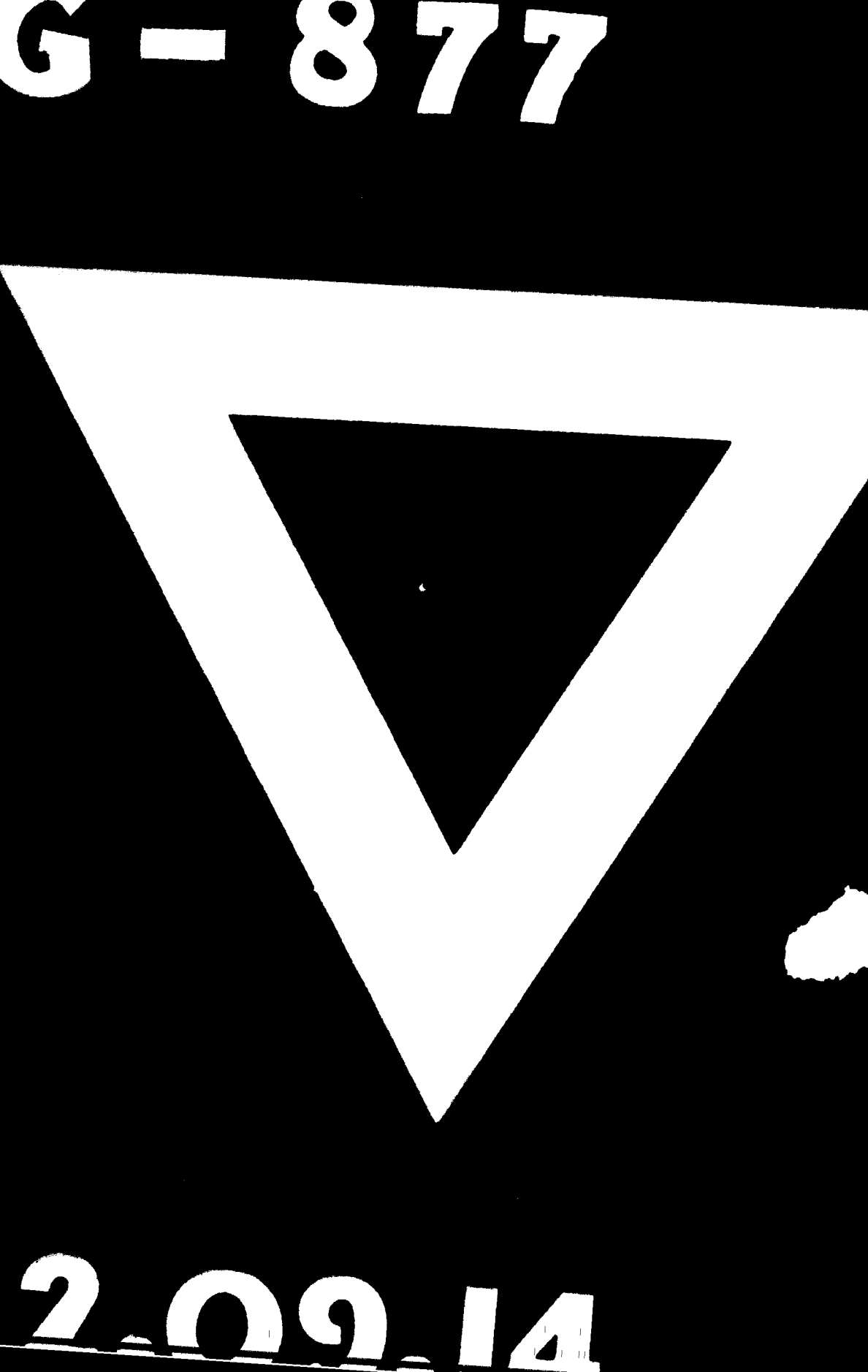
C. Interpretation and correlation of data
   a. Theoretical correlation
   b. Experimental correlation
   c. Graphic presentation of results
   d. Modeling

5. Liquefaction Equipment Design and Solid-Liquid Separation

A. Design co sideration and data
   a. Preheater
   b. Reactor
   c. Vapor-liquid separator

B. Thermodynamic data
   a. Solubility of hydrogen
   b. Solubility of hydrocarbon gases
   c. K-values calculation

C. Solid-liquid separation in coal liquefaction
   a. Precoat pressure filtration--limitation and improvement
   b. Anti-solvent de-ashing
      Review of fundamental research work
      Industrial application--Lummus Process
   c. Pressure-fluid extraction
      Wang and Shou's research findings
      Kerr-McGee Process--Critical Solvent De-ashing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