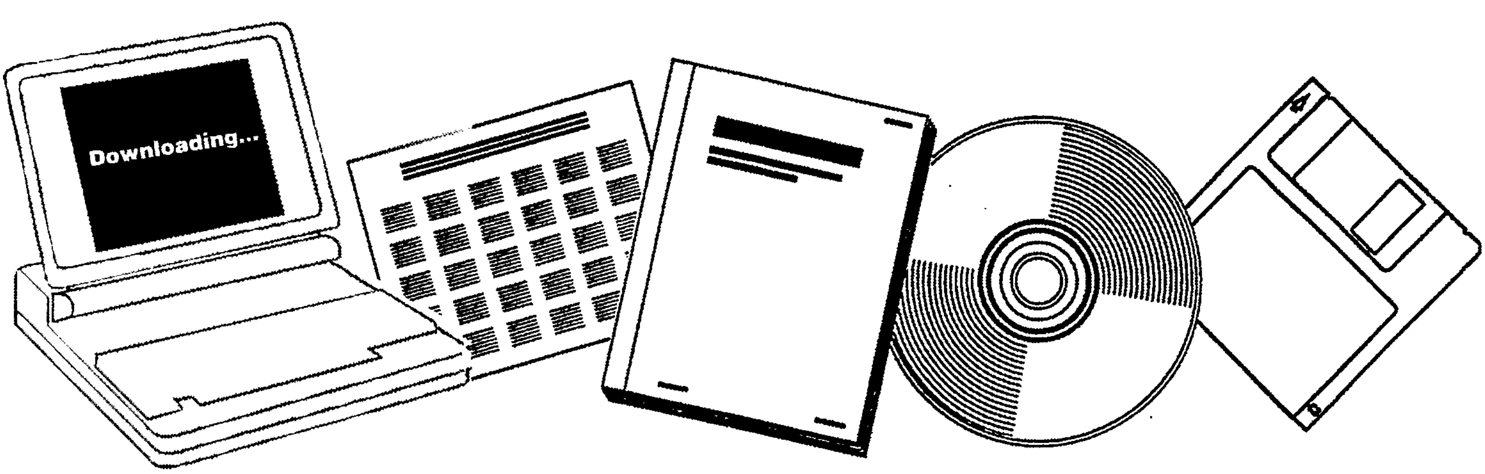
PRELIMINARY DESIGN SERVICES COAL CONVERSION DEMONSTRATION PLANTS. RESEARCH AND DEVELOPMENT REPORT NO. 114, ANNUAL REPORT, JANUARY--DECEMBER 1975

PARSONS (RALPH M.) CO., PASADENA, CALIF

MAR 1976



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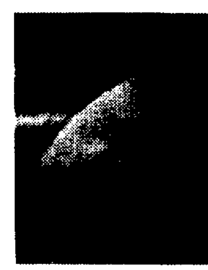

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PRELIMINARY DESIGN SERVICES COAL CONVERSION DEMONSTRATION PLANTS

RESEARCH AND DEVELOPMENT REPORT NO. 114
ANNUAL REPORT
FOR THE PERIOD: JANUARY–DECEMBER 1975

Prepared by:

THE RALPH M. PARSONS COMPANY

100 West Walnut Street

Pasadena, California 91124

Under Contract No. E(49-18)-1775

March 1976

Prepared for

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

WASHINGTON, D.C. 20545

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PRELIMINARY DESIGN SERVICES

RESEARCH AND DEVELOPMENT REPORT NO. 114

ANNUAL REPORT

For the Period: January - December 1975

Prepared by:

The Ralph M. Parsons Company
100 W. Walnut Street
Pasadena, California 91124

For:

Energy Research and Development Administration
Washington, D.C. 20545

Under Contract No. E(49-18)-1775

March 1976

ANNUAL REPORT

PRELIMINARY DESIGN SERVICES

THE RALPH M. PARSONS COMPANY

I. OBJECTIVES

An overall key objective of this work is to assist Energy Research and Development Administration Fossil Energy Division (ERDA-FE) to develop commercial coal conversion plants that will provide realistic future U.S. energy options using coal. Specific objectives are to develop preliminary designs that indicate design/operating characteristics and projected economics of commercial scale, multiproduct coal conversion complexes, including captive coal mines, using selected ERDA-FE R&D program data as a basis for developing preliminary designs.

II. IMPACT ON COAL CONVERSION TECHNOLOGY

Primary impact of this work is to provide ERDA-FE with a cohesive preliminary definition of the expected characteristics and projected economics of future commercial coal conversion complexes.

The designs developed include complete preliminary process designs; materials and thermal efficiencies; preliminary definition of equipment characteristics; construction materials; environmental control facilities; plant site and mining requirements; interfacing of the coal mine with process plant; operating requirements; and projected economics complete with influence of key economic parameters such as capital investment, operating costs, and raw materials consumption. The project provides:

(1) Basis for analysis of capital costs impact, operating costs, and reliability factors of future coal conversion facilities

(2) Assistance in defining specific requirements for additional data and development experience on the pilot plant scale to provide assurance of reliable and economical future operation of these complexes

(3) Sufficient detail to permit periodic quantitative revision and updating as new and improved data and process concepts are developed in the program

(4) Quantitative economics basis for selection of preferred process alternates

III. PRESENT WORK AND ACCOMPLISHMENTS

Accomplishments in 1975 include:

(1) Submission of a report describing the conceptual design and economic evaluation of a COED-based coal conversion complex

(2) Progress on three additional designs that were begun in January 1975:

(a) Oil/gas

(b) Fischer-Tropsch, U.S. version

(c) Coal-oil-gas (COG)

(3) Compilation of additional background for the design work during a visit to the SASOL plant to discuss Fischer-Tropsch technology

(4) Completion of 8 process alternate economic comparison studies

(5) Preliminary definition of procedures to obtain a 70% thermal efficiency for a Fischer-Tropsch plant

(6) Presentation of invited testimony to U.S. Senate hearings on the ERDA budget, particularly on the subject of proposed demonstration plant program, with suggestion that the program should have $2 to 5 billion funding to effectively demonstrate performance reliability, economics, and functional product performance for this technology

(7) Completion of 10 papers/presentations in support of the ERDA coal-conversion development program, including:

(a) Description of procedures for production of chemical and petrochemical feedstocks from coal, and the potential impact of this technology on the chemical/petrochemical industry

(b) Summary of data requirement recommendations for scale up of coal conversion processes from pilot plant to commercial-scale operations

Further details on key elements of the programs are described in the following sections. Also, reports of activities for the first three quarters and a detailed report on our activities for the fourth quarter of 1975 are appended hereto.

A. COED Conceptual Commercial Plant

Work was completed in 1975 on a preliminary design and economic evaluation for a commercial complex to mine high-sulfur coal and produce low-sulfur synthetic crude oil (syncrude), electrical energy, and sulfur, using COED-based pyrolysis technology for the coal-conversion portion of the complex. An artist's conceptual drawing of the facility is shown in Figure 1 and a simplified block flow diagram of the process is shown in Figure 2. The detailed results were published as ERDA R&D Report No. 114, Interim Report No. 1.

The industrial complex consists of a large captive coal mine supplying the feed material to a coal preparation plant, which in turn supplies approximately 25,000 TPD of clean, washed coal to a COED-based pyrolysis coal conversion plant. In a typical case, a COED facility produces approximately 28,000 BPD of 25°API, 0.1% sulfur syncrude plus low-sulfur fuel gases, as well as byproduct sulfur. Fuel gases are fed to a close-coupled electrical power generation plant that produces electricity for inplant use plus 830 MW for export. It also produces steam for captive use in the complex.

The design provides operating flexibility to process coal showing a range of analyses, which might be expected over the course of a 20-year operating life. This distinguishes the design from others that have been based on a single typical coal analysis and that might be called single feed source or "point" designs. The use of a fixed coal feed rate and variable coal characteristics requires higher fixed capital investment to provide the necessary flexibility. It also results in variable product rates.

The estimated fixed capital investment for the complex is $1 billion in first-quarter 1974 dollars. The total capital investment is estimated to be $1.125 billion. This includes the cost of initial raw materials, catalysts and chemicals, allowance for startup and land acquisition, and initial working capital. Typical required selling prices for the mixed syncrude plus electrical power product slate at 10% discounted cash flow (DCF) rate of return, after byproduct sulfur credit, are as follows:

Syncrude ($/bbl)	Electricity (mil/kWh)
10	32
15	25
18	20
26	10

Sensitivities of required selling prices to profitability and to key economic parameters were reported.

B. Oil/Gas Plant Design

The oil/gas concept recognizes that methane and other light hydrocarbons are produced during coal liquefaction and that some methane is made during the gasification step to produce synthesis gas and, subsequently, hydrogen for use in the hydroliquefaction step. To further develop this technology, a conceptual design and economic evaluation is being prepared for a large complex to convert coal to low-sulfur liquid/solid products plus substitute natural gas (SNG). The complex would be a grass-roots facility, with captive coal mine to produce products consisting of low-sulfur oils, SNG, and high-purity sulfur. Feed rate is planned to be 40,000 TPD of clean washed coal. Figure 3 shows a simplified block flow diagram depicting the key process steps.

During predesign studies leading to development of the design basis, quantitative economic analyses of eight process alternates were completed. Examples include use of syngas vis-a-vis hydrogen as liquefaction agent, amount of SNG production, and use of sour vis-a-vis sweet shift operation. Methods of varying the oil/gas ratio from 2/1 to 6/1 were defined, based on product Btu basis. The design work is in an advanced stage at this time.

C. Fischer-Tropsch Conceptual Commercial Plant

The development of a conceptual design and economic evaluation of a Fischer-Tropsch plant to be responsive to U.S. energy and economic demands is well underway. The present work is an extension of earlier studies made by Parsons in response to an ERDA request to determine if there was a place for Fischer-Tropsch technology in future U.S. synthetic fuel production plans, and if so, what role it might play.

The Fischer-Tropsch conceptual design and economic evaluation currently being developed by Parsons represents a more comprehensive effort to describe a facility to produce synthetic fuels from coal, which will be responsive to future U.S. fuel demands and economic requirements. It will produce a liquid plus SNG product slate with total energy value of 500 billion Btu/day. It will consist of two process trains. Detailed process analysis results have defined procedures to achieve a 70% thermal efficiency as compared to efficiencies in the 50 to 60% range for prior work. A simplified block flow diagram is shown in Figure 4.

D. COG Plant Design

The objective of this effort is to develop a preliminary design of a coal conversion plant to produce liquid and gaseous fuels as principal products. Processes employed in the plant design will be the result of economic selections from the available candidate coal conversion processes. A second objective is the development of a computer simulation model capable of calculating material and heat balances as well as estimating overall utility balances for a number of coal conversion processes.

The computer process model is now operational and is being used to evaluate various COG candidate processes. At the same time, the program is being expanded and adapted as new applications are developed.

Screening economic estimates for candidate processes are being prepared. The necessary process data for preparation of these estimates are being obtained from the various process originators. The design and economic evaluation is scheduled for completion in calendar year 1977.

E. Supporting Activities

Support activities for the design work include:

(1) Equipment Development:

(a) Objective: To define equipment development programs to ensure future reliable and viable operation of coal conversion processes.

(b) Status: Major activity has centered on liquid/solid separation, gas/solid separation, solids feed to gasifiers, and filter cake drying equipment.

(2) Construction Materials:

(a) Objective: To define materials of construction with adequate performance and acceptable cost for use in coal conversion plants.

(b) Status: An active role was played in the ERDA Materials Evaluation and Materials Property Council Development Programs. The performance of materials in pilot plant operations was monitored and materials were continually selected for the designs Parsons has in progress.

(3) Environmental Factors:

(a) Objective: To define facilities and procedures required for operation of environmentally acceptable coal conversion plants.

(b) Status: One paper was presented at the Joint Power Generation Conference describing procedures for control of gaseous emissions for the COED design. The oil/gas and Fischer-Tropsch designs are being reviewed as they are being developed to ensure conformance with environmental requirements.

F. Publications and Presentations

A list of 10 publications and presentations resulting from our work is attached to this report as Table 1.

G. Plans for 1976

Preliminary designs/economic evaluations will be completed and reports will be issued for the oil/gas and Fischer-Tropsch technologies. The COG design should be well advanced, leading to completion and reporting in calendar year 1977. The progress of the SRC pilot plant work will be monitored and a commercial plant design will start in October 1976. Work will begin on preliminary designs for a facilities complex to demonstrate the commercial feasibility of a variety of promising coal conversion processes.

Process simulation capability, equipment development, environmental factor requirements, and materials of construction definitions will be advanced. Emphasis on definition of economically viable coal conversion commercialization procedures will continue.

Table 1 - Publications, Presentations

1. O'Hara, J.B., "Coal Conversion," Presentation to the United States Senate Committee on Interior and Insular Affairs Subcommittee on Energy Research and Water Resources, at Washington, D.C., March 3, 1975.

2. O'Hara, J.B., Jentz, N.E., and Papso, J.E., "Survey of Coal Liquefaction Products Including Suitability as Petrochemical Feedstocks," presented at the Seventy-Ninth National Meeting of American Institute of Chemical Engineers, Houston, Texas, March 18, 1975.

3. O'Hara, J.B., Cumare, F.E., and Rippee, S.N., "Potentials for Synthetic Fuels from Coal by the Fischer-Tropsch Process," presented at the Seventy-Ninth National Meeting of American Institute of Chemical Engineers, Houston, Texas, March 18, 1975.

4. O'Hara, J.B., "Coal Conversion - An Overview of Status and Potential," presented at Los Angeles Council of Engineers and Scientists Energy Symposium, Los Angeles, California, April 3, 1975.

5. O'Hara, J.B., Jentz, N.E., and Hervey, G.H., "Commercial Coal Conversion Plant Design, Translation from Pilot to Commercial-Scale Plants," presented at the Clean Fuels from Coal Symposium II, Chicago, Illinois, June 26, 1975, sponsored by Institute of Gas Technology.

6. O'Hara, J.B., Cumare, F.E., and Rippee, S.N., "Synthetic Fuels from Coal by Fischer-Tropsch," *August 1975 Coal Processing Technology Manual, Volume II*, prepared by the Editors of Chemical Engineering Progress.

Table 1 - Publications, Presentations (Contd)

7. Loran, B.I., O'Hara, J.B., Jentz, N.E., and Hincks, H.F., "Gaseous Environmental Factors in Coal Pyrolysis Plant Design," paper presented to the ASME/IEEE Joint Power Generation Conference at Portland, Oregon, October 1, 1975.

8. Loran, B.I., et al., "Gaseous Environmental Factors in Coal Pyrolysis Plant Design," published by American Society of Mechanical Engineers as Publication No. 75-PWR-3.

9. O'Hara, J.B., Hervey, G.H., Fass, S.M., and Mills E.A., "Oil/Gas Plant Design Criteria," presented at the American Institute of Chemical Engineers Sixty-Eighth Annual Meeting, Los Angeles, California, November 19, 1975.

10. O'Hara, J.B., Bela, A., Jentz, N.E., and Khaderi, S.K., "Fischer-Tropsch Plant Design Criteria," presented at the American Institute of Chemical Engineers Sixty-Eighth Annual Meeting, Los Angeles, California, November 19, 1975.

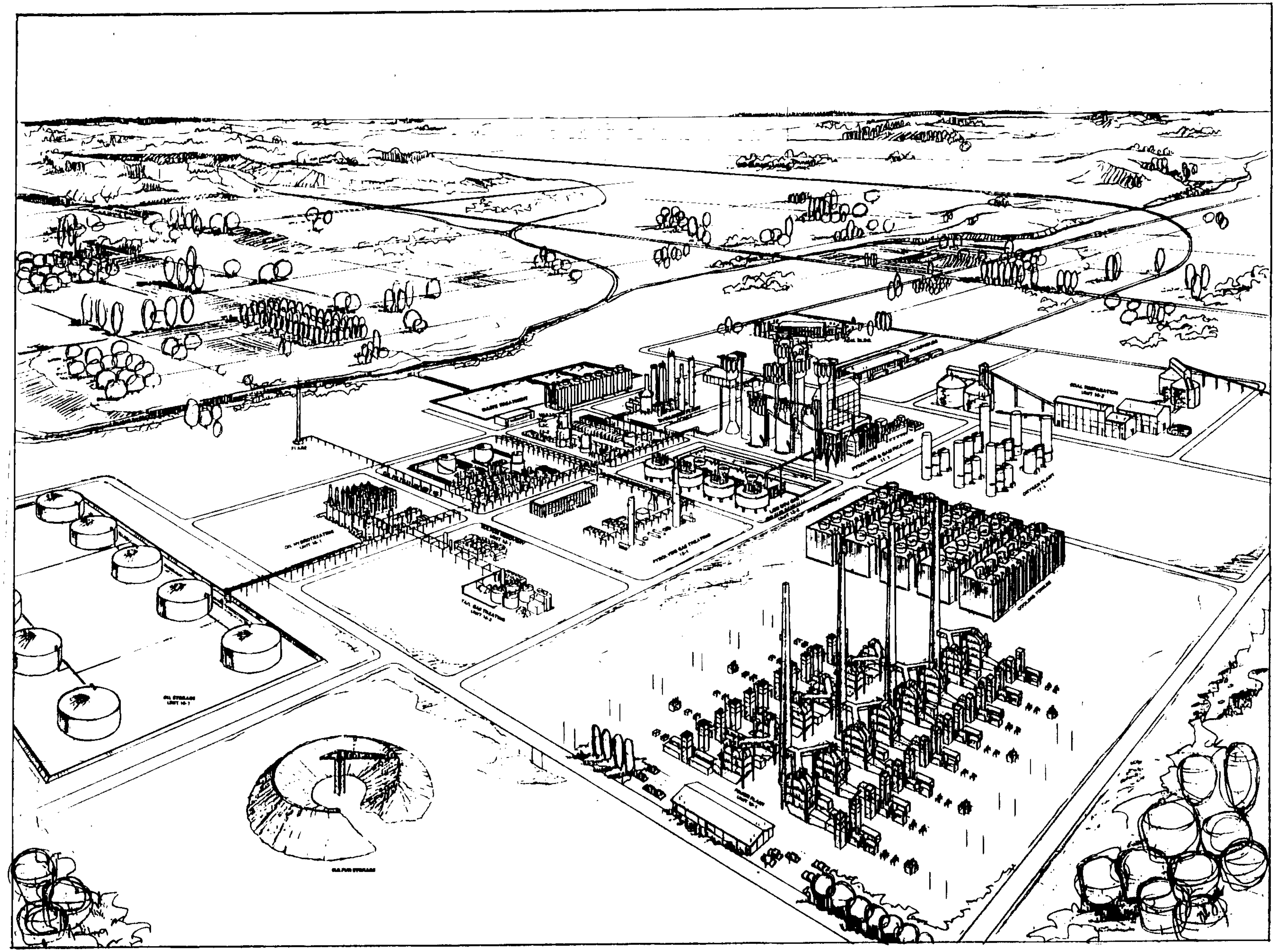

Figure 1 - COED Conceptual Commercial Plant

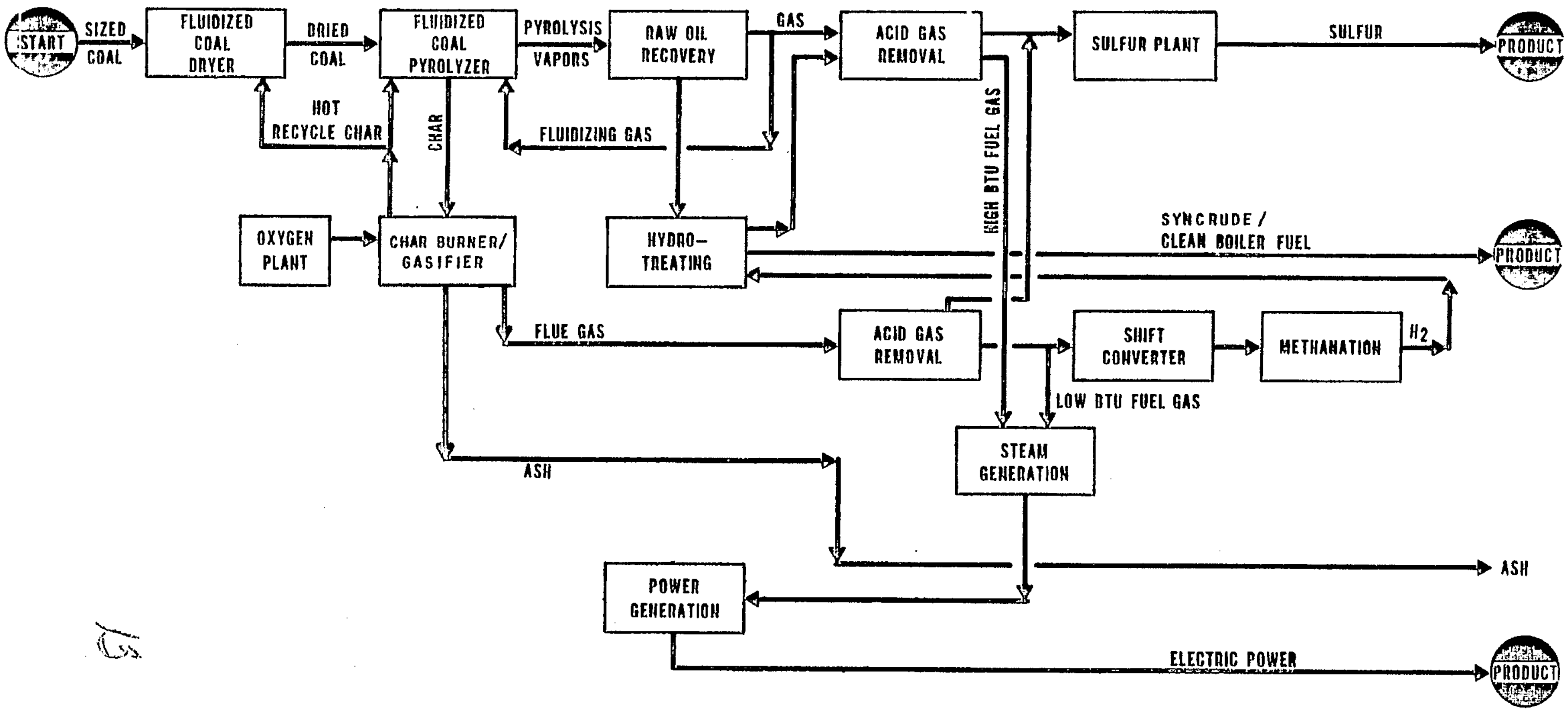

Figure 2 - COED Process
Simplified Block Flow Diagram

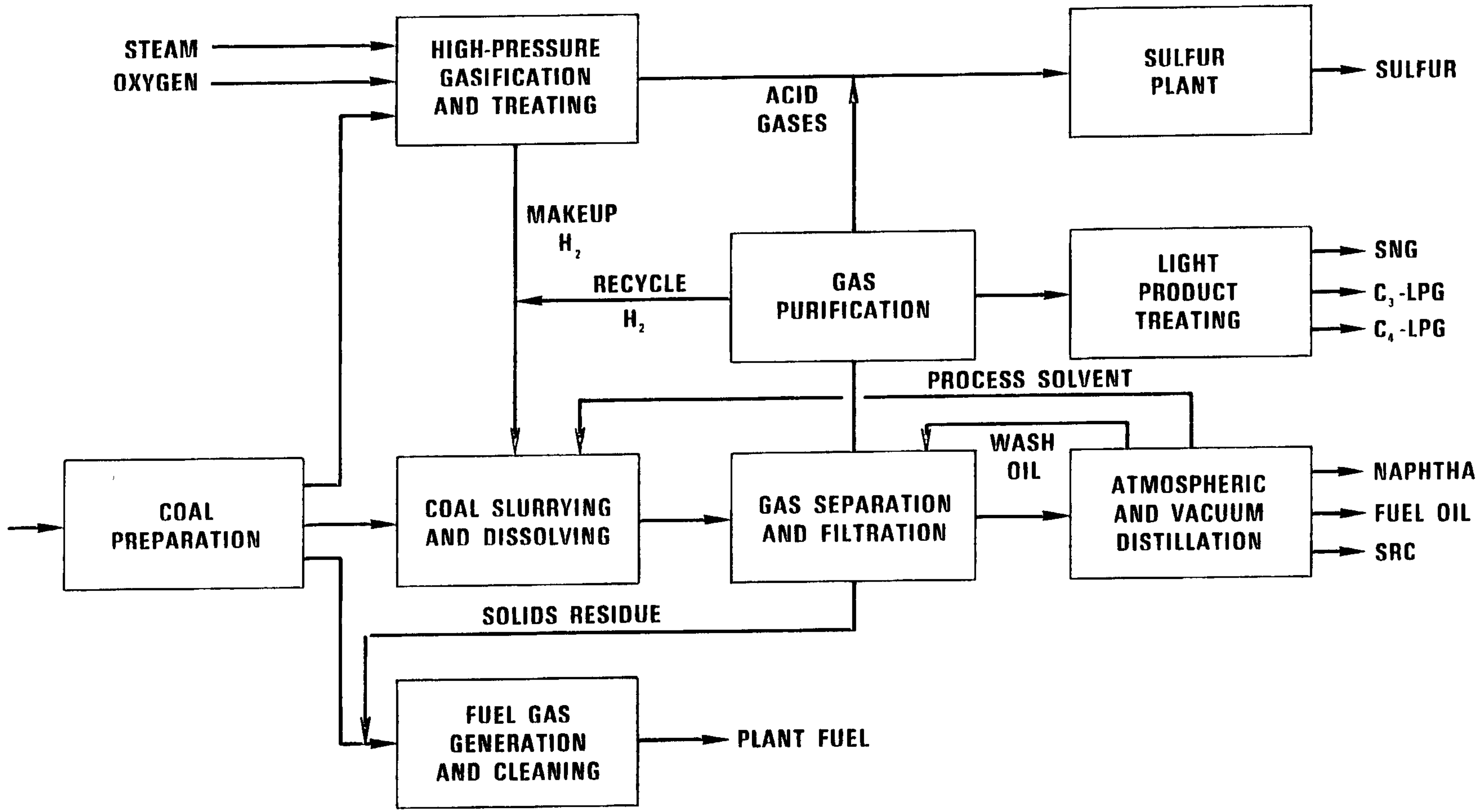

Figure 3 - Oil/Gas Plant
Simplified Block Flow Diagram

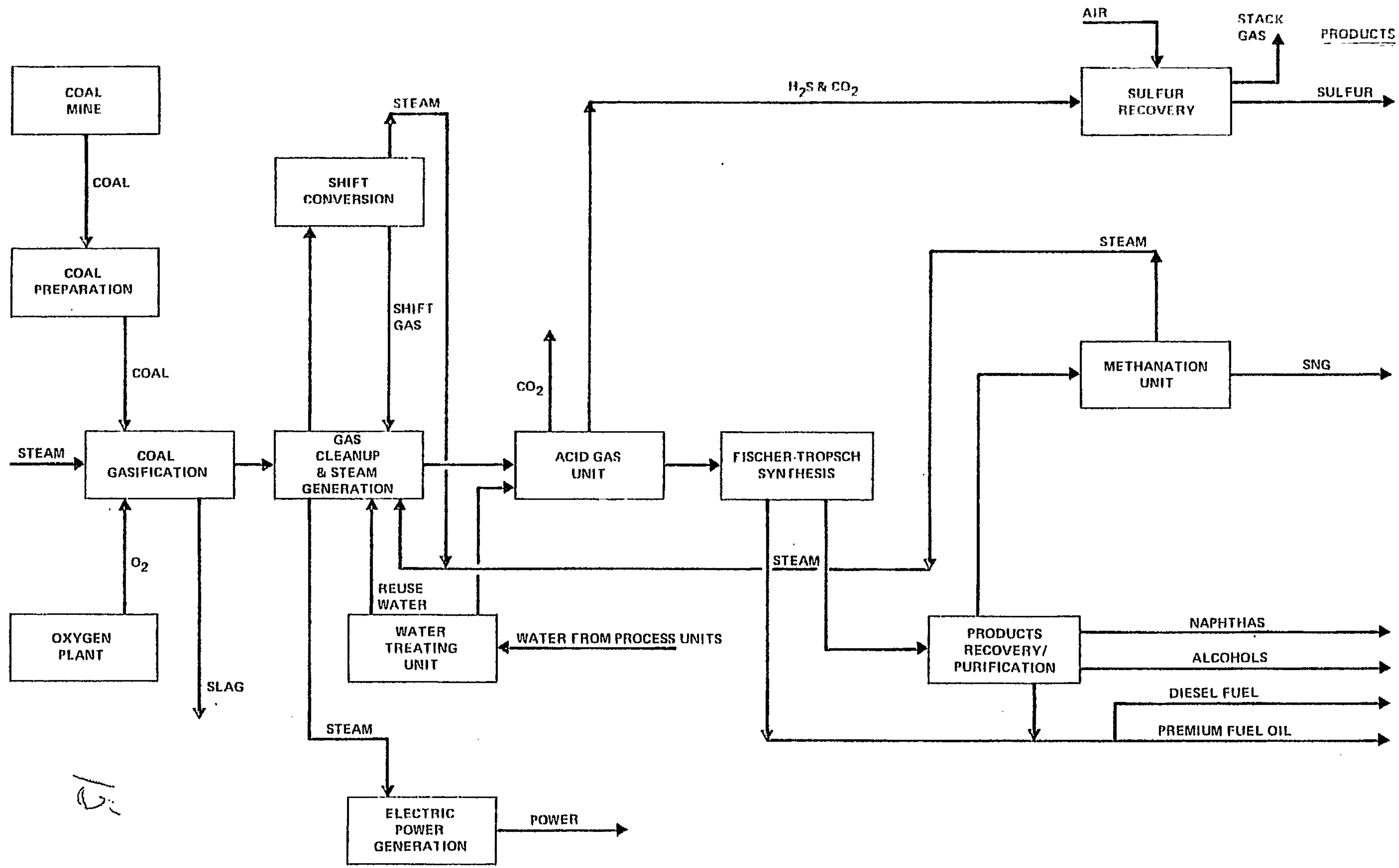

Figure 4 - Fischer-Tropsch Simplified Block Flow Diagram

The Ralph M. Parsons Company
ENGINEERS • CONSTRUCTORS / PASADENA, CALIFORNIA 91124

May 8, 1975

Energy Research and Development
Administration
Fossil Energy
2100 M Street, N. W.
Washington, D. C. 20545

ATTENTION of Mr. Neal P. Cochran
Assistant Director - Demonstration Plants

SUBJECT Contract No. E(49-18)-1775
Quarterly Report of Work Performed
Period January 1 through March 31, 1975
Parsons Job No. 5435
Letter No. PN-17

Gentlemen:

This report summarizes pertinent progress for our separate task assignments during the subject period.

I. ACTIVITY SUMMARY.

A. COED Conceptual Commercial Plant Design

1. Objective.

The overall objective is to develop a conceptual design and cost estimate for a commercial-size plant and to define additional data required from pilot plant operation or other sources.

2. Activity this Quarter.

Revisions remain to be made to the draft prior to finalization. A suitcase-size model of the plant is in final stages of completion.

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B. Coal Mining and Preparation

1. Objective.

To develop conceptual designs and economic evaluations for mines in the following five geographic areas: Interior Province (eastern region), Appalachia, Feather River (western area), Four Corners, and Utah. Mining plans and cost estimates for facilities to supply feed to conceptual plant designs including COED, SRC, Fischer-Tropsch, Cresap, and others are to be developed. Mines with capacities to 100,000 tons per day will be considered.

2. Activity this Quarter.

We studied the characteristics of the separate coal supply sources.

C. Oil/Gas Plant Design

1. Objective.

To develop a preliminary design and economic evaluation for a commercial Oil/Gas Plant to produce synthetic liquid fuels and SNG from coal.

2. Activity this Quarter.

We developed a schedule, manpower requirements, job procedure, basic design criteria, and design basis ready for final review. Preferred procedures for syngas generation, filter cake washing and drying, and the use of power recovery turbines were studied. The concept of slurry recycle was investigated. Material balances for these various options are in process.

D. Fischer-Tropsch Commercial Plant Design

1. Objective.

To develop a preliminary design and economic evaluation for a commercial Fischer-Tropsch plant to produce liquid fuel and SNG.

b. "Potentials for Synthetic Fuels from Coal by the Fischer-Tropsch Process" before the 79th National AIChE Meeting held in Houston on March 18, 1975.

c. We prepared a paper entitled: "Coal Conversion - An Overview" for presentation before the Energy Symposium sponsored by the Los Angeles Council of Engineers and Scientists in Los Angeles on April 3, 1975.

d. We participated in the hearings concerning the ERDA appropriations before the Subcommittee on Energy Research and Water REsources of the U.S. Senate Committee on Interior and Insular Affairs; this was held in Washington, D.C. on March 3, 1975.

We attended a restricted invitation briefing on the subject "Chemicals from Coal" sponsored by the National Science Foundation.

We met with key personnel of the Institute for Gas Technology in support of their preparation of a Coal Conversion Data Book. We made plans to assist them in their work.

II. WORK FORECAST FOR THE NEXT QUARTER, APRIL 1 THROUGH JUNE 30, 1975.

A. <u>COED Conceptual Commercial Plant Design</u>

Complete the review and editing of the report. Issue the completed report for publication. Complete suitcase-size model of plant complex.

B. <u>Oil/Gas Plant Design</u>

Complete comparative process studies and their economic evaluation. Start design of the commercial-size plant.

C. <u>Fischer-Tropsch Plant Design</u>

Issue the Design Basis, block flow diagram, and continue individual unit process selections on the basis of construction costs and economic studies.

I. Environmental Requirements Program

1. Objective.

To define those environmental control facilities required to assure the operation within applicable environmental requirements.

2. Activity this Quarter.

We reviewed the general approach required for the overall program. We started preparation of an invited paper entitled "Gaseous Environmental Factors in Coal Pyrolysis Plant Design" for presentation at the Joint Power Generating Conference sponsored by the American Society of Mechanical Engineers in Portland, Oregon, October 1-3, 1975.

J. General

1. Objective.

To provide general support activities to ERDA as directed and to present appropriate reports and papers.

2. Activity this Quarter.

We met on February 5-6, 1975 in Pasadena with representatives of ERDA to review plans and status for our work. We reviewed an overall program schedule with them. This document was subsequently revised to conform with accelerated ERDA requirements.

We prepared and transmitted, by our Letter No. P-247, a preliminary list of vessels and columns to serve as a basis for cost comparison between field and shop fabrication.

We presented the following papers:

a. "Survey of Coal Liquefaction Products Including Suitability as Petrochemical Feedstocks" before the 79th National AIChE Meeting held in Houston on March 18, 1975.

2. Activity this Quarter.

We requested proposals from various in-house engineering disciplines and from the process engineers regarding equipment problems previously encountered and foreseen. We met with representatives of The Ducon Company of Mineola, New York, who made a presentation of gas/solids separation equipment.

G. Controls Development Program

1. Objective.

To develop functional and preliminary specifications for control apparatus required for candidate processes and upon agreement by ERDA to discuss development programs with industry. To recommend to ERDA the issue of RFP's for development programs where appropriate.

2. Activity this Quarter.

We requested proposals from the in-house controls engineers and from the process engineers regarding the subject of control problems previously encountered and foreseen. We met with representatives of Compressor Controls Corp. of Des Moines, Iowa, who presented their electronic compressor control system which we are presently evaluating.

H. Materials of Construction Assessment

1. Objective.

To participate in the investigatory work in progress in order to define the preferred materials of construction for equipment and construction in coal conversion projects.

2. Activity this Quarter.

We reviewed the materials of construction shown on the equipment list for the Demonstration Plant, OCR R&D Report No. 82, Interim Report No. 1 and updated same. We collaborated with the Illinois Institute of Technology Research Institute, Metals Properties Council, particularly in the field of high-temperature gaseous corrosion. We visited the Fort Lewis SRC Pilot Plant and consulted with Plant Management on their corrosion and erosion problems.

2. Activity this Quarter.

We developed a schedule and manpower control documents ready for final review. We reviewed prior Bureau of Mines' work and visited the Bruceton facility to obtain further detailed information. We also studied the Kellogg synthesis system as well as SASOL reports. We worked on the development of the design basis.

E. COG Plant Design

1. Objective.

To develop a preliminary design of a coal processing plant which will produce both oil and gaseous fuels as principal products. The processes employed in this plant design will result from an economic selection from the candidate coal conversion processes available.

To develop a model capable of calculating material and heat balances for units of a variety of coal conversion processes using computer capability and to estimate the overall utility balance of the complex.

2. Activity this Quarter.

We started studies of various candidate processes for this plant. In order to arrive at valid comparisons, we began preliminary designs for all processes using Illinois No. 6 seam coal as feed. We continued development of a computer model able to produce heat and material balances, as well as yields for these processes and adapted a computer program used for the SRC process to apply it to a catalytic conversion process.

F. Equipment Development Program

1. Objective.

To develop functional and preliminary specifications for equipment required for candidate processes and upon agreement by ERDA to discuss development programs with industry. To recommend to ERDA the issue of RFP's (Request for Proposals) for development programs where appropriate.

D. COG Plant Design

Continue study of candidate processes and evaluate their cost and economic values.

E. Coal Mining and Preparation

Begin preliminary work to supply the feed coal necessary to support the coal conversion designs.

F. Equipment Development Program

Continue to pinpoint equipment items requiring development programs. Oil/Solids and Gas/Solids separation and gasifier design will be among the targets as well as pressure recovery turbines.

G. Controls Development Program

Continue to pinpoint control problems requiring development programs. Pressure letdown valves in slurry service will be further investigated.

H. Materials of Construction Assessment

Issue equipment list for Demonstration Plant with updated materials of construction. Continue collaboration with Illinois Institute of Technology Research Institute and work with National Association of Corrosion Engineers on problems relative to coal conversion plants.

I. General

Prepare study reports and papers as requested by ERDA.

Very truly yours,

THE RALPH M. PARSONS COMPANY

J. B. O'Hara
Project Manager

JBO:GHH:bk

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The Ralph M. Parsons Company

ENGINEERS • CONSTRUCTORS / PASADENA, CALIFORNIA 91124

August 1, 1975

Energy Research and Development
Administration
Fossil Energy
2100 M Street, N. W.
Washington, D. C. 20545

ATTENTION of Mr. Neal P. Cochran
Assistant Director - Demonstration Plants

SUBJECT Contract No. E(49-18)-1775
Quarterly Report of Work Performed
Period April 1 through June 30, 1975
Parsons Job No. 5435
Letter No. PN-51

Gentlemen:

This report summarizes pertinent progress for our separate task assignments during the subject period.

I. ACTIVITY SUMMARY.

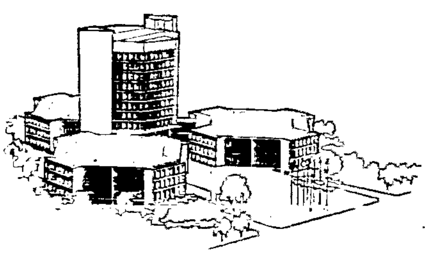
A. COED Conceptual Commercial Plant Design

1. Objective.

The overall objective is to develop a conceptual design and cost estimate for a commercial-size plant and to define additional data required from pilot plant operation or other sources.

2. Activity this Quarter.

We transmitted the technical section of the final R&D Report to ERDA by our letter PN-30 dated May 30, 1975, for review and comments. A suitcase size model of the complex was completed and transmitted to ERDA. A report of the Institute for Gas Technology analyzing COED char gasification was received and reviewed.



The preparation of a parametric economic analysis of the complex was essentially completed.

B. Coal Mining and Preparation

1. Objective.

To develop conceptual designs and economic evaluations for mines in the following five geographic areas: Interior Province (eastern region), Appalachia, Feather River (western area), Four Corners, and Utah. Mining plans and cost estimates for facilities to supply feed to conceptual plant designs including COED, SRC, Fischer-Tropsch, Cresap, and others are to be developed. Mines with capacities to 100,000 tons per day will be considered.

2. Activity this Quarter.

We studied the characteristics of the separate coal supply sources.

C. Oil/Gas Plant Design

1. Objective.

To develop a preliminary design and economic evaluation for a commercial Oil/Gas Plant to produce synthetic liquid fuels and SNG from coal.

2. Activity this Quarter.

We completed process flow diagrams, material balances and equipment specifications for filter cake washing and drying and hydrogen vis-a-vis syngas as dissolver feed. We completed capital cost estimates for a reduced dissolver residence time case and for utilization of pressure letdown turbines. We developed criteria for NH_3-H_2S separation and for various levels of SNG production involving cryogenic separation processes and submitted them to candidate process licensors for process and capital cost estimate development. We started development of process data for use of sour shift applied to the syngas dissolver feed case. We started design development and consultation with manufacturers concerning high pressure gasifiers.

D. Fischer-Tropsch Commercial Plant Design

1. Objective.

To develop a preliminary design and economic evaluation for a commercial Fischer-Tropsch plant to produce liquid fuel and SNG.

2. Activity this Quarter.

We prepared a bibliography for the Fischer-Tropsch process and prepared a preliminary design basis. We studied Fischer-Tropsch feed gasifier designs and analyzed gas/solids separation criteria and methods.

We investigated candidate configurations of Fischer-Tropsch reactors and developed a preliminary block flow diagram for the total complex.

E. COG Plant Design

1. Objective.

To develop a preliminary design of a coal processing plant which will produce both oil and gaseous fuels as principal products. The processes employed in this plant design will result from an economic selection from the candidate coal conversion processes available.

To develop a model capable of calculating material and heat balances for units of a variety of coal conversion processes using computer capability and to estimate the overall utility balance of the complex.

2. Activity this Quarter.

We continued to incorporate various liquefaction and gasification concepts into the computer process model. We developed process design specifications for an air blown gasifier to produce low BTU fuel for in-plant use.

F. Equipment Development Program

1. Objective.

To define the equipment and control system development programs required to assure reliability and viability of coal conversion processes being developed. To recommend appropriate developmental programs to ERDA - Fossil Energy Division.

2. Activity this Quarter.

We contacted equipment manufacturers to obtain technical and cost information for candidate systems pertaining to high pressure gasifier dry coal feed devices, liquid/solids and gas/solids separation, and filter cake drying. We received responses to these inquiries and are in the process of cost and economic evaluation as well as analysis of their process suitability.

G. Materials of Construction Assessment

1. Objective.

To define the preferred materials of construction for use in coal conversion projects.

2. Activity this Quarter.

We continued collaboration with the Illinois Institute of Technology Research Institute Metals Properties Council in their four phases of study of corrosion-erosion in the field of coal conversion. We continued monitoring the Fort Lewis SRC Pilot Plant materials application problems. We issued an equipment list with updated materials of construction for the Demonstration Plant (R&D Report No. 82) by our letter PN-18 dated April 29, 1975.

H. Environmental Requirements Program

1. Objective.

To define those environmental control facilities required to assure the operation within applicable environmental requirements.

2. Activity this Quarter.

We completed an invited paper entitled "Gaseous Environmental Factors in Coal Pyrolysis Plant Design" for presentation at the joint power generating conference sponsored by the Americal Society of Mechanical Engineers in Portland, Oregon on October 1 to 3, 1975. We incorporated the results of this work in the COED plant design.

I. General

1. Objective.

To provide general support activities to ERDA as directed and to present appropriate reports and papers.

2. Activity this Quarter.

We met on April 8, 1975 in Pasadena with a representative of ERDA to review the status of the work and project control procedures.

We presented an invited paper titled "Coal Conversion - An Overview" before the Energy Symposium sponsored by the Los Angeles Council of Engineers and Scientists on April 3, 1975.

We completed preparation of an invited paper titled "Gaseous Environmental Factors in Coal Pyrolysis" for the Joint Power Generating Conference sponsored by the American Society of Mechanical Engineers in October.

We presented an invited paper titled "Commercial Coal Conversion Plant Design-Translation from Pilot to Commercial-Scale Plants" before the Clean Fuels from Coal Symposium II sponsored by IGT in Chicago on June 26, 1975.

We accepted an invitation to present two papers before the 68th National AIChE meeting to be held in Los Angeles in November 1975. The titles are "Oil/Gas Plant Design Criteria" and "Fischer-Tropsch Plant Design Criteria".

II. WORK FORECAST FOR THE NEXT QUARTER, JULY 1 THROUGH SEPTEMBER 30

A. COED Conceptual Commercial Plant Design

Issue the completed report.

B. Oil/Gas Plant Design

Complete analysis, estimates and economic evaluation of process alternates and prepare a design basis. Complete process flow diagrams and process equipment specification and start engineering of the commercial scale complex.

C. Fischer-Tropsch Plant Design

Complete analysis, estimates and economic evaluation of process alternates. Complete block flow diagram and unit process flow diagrams, as well as equipment sizing and data sheets ready for detail engineering. Complete a design basis and begin design and engineering. Prepare a design basis and begin design effort.

D. COG Plant Design

Continue study of candidate processes and evaluate their cost and economic values.

E. Coal Mining and Preparation

Continue preliminary work to supply the feed coal necessary to support the coal conversion designs.

F. Equipment Development Program

Continue to pinpoint equipment items requiring development programs. Continue development of liquid/solids and gas solids separation systems, dry coal and/or char gasifier feed systems, filter cake drying equipment and various types of gasifiers.

G. Controls Development Program

Continue to pinpoint control problems requiring development.

H. Materials of Construction Assessment

Continue collaboration with Illinois Institute of Technology Research Institute and work with National Association of Corrosion Engineers on problems relative to coal conversion plants.

I. General

Prepare study reports and papers as requested by ERDA, including two papers for the November 1975 EIChE Meeting titled "Oil/Gas Plant Design Criteria" and "Fischer-Tropsch Plant Design Criteria."

Very truly yours,

THE RALPH M. PARSONS COMPANY

J. B. O'Hara
Project Manager

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FE-1775-2
UC-89

PRELIMINARY DESIGN SERVICES

RESEARCH AND DEVELOPMENT REPORT NO. 114

INTERIM REPORT NO. 2

For the Period: July-September 1975

Prepared by:

The Ralph M. Parsons Company
100 W. Walnut Street
Pasadena, California 91124

For:

Energy Research and Development Administration
Washington, D.C. 20545

Under Contract No. E(49-18)-1775

November 1975

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The data and conclusions presented in this report are essentially those of the Contractor and are not necessarily endorsed by Fossil Energy, Energy Research and Development Administration.

I. OBJECTIVE AND SCOPE OF WORK

The objective of the work is to develop preliminary designs and economic evaluations for a number of coal conversion plants. The following designs are included in the scope of work:

- A conceptual commercial plant for a Coal-Oil-Energy-Development (COED) plant.
- An Oil/Gas plant to produce liquid fuels plus substitute natural gas (SNG).
- A commercial-scale Fischer-Tropsch plant with motor fuel and SNG as the main products.
- A commercial-scale plant for the production of solvent-refined coal (SRC).
- A Coal Oil Gas Refinery (COG) to produce clean liquids, gas and electrical power generating capacity.
- A facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes that show promise during pilot plant operations.

  The following facilities will be considered; conversion of coal to:

  (1) Low to high Btu fuel gas.

  (2) Methanol/motor fuel by Fischer-Tropsch process.

  (3) Clean liquid fuels by alternate liquefaction processes.

In addition, supporting efforts will be provided to the above activities. These efforts include planning and progress monitoring, equipment development, and environmental factors.

II. SUMMARY OF PROGRESS TO DATE

Some portions of the work on Contract No. E(49-18)-1775, were initiated under Contract No. 14-32-0001-1234 which was awarded by the Office of Coal Research, Department of the Interior in 1972. OCR R&D Report No. 82, Interim Report No. 1, "Demonstration Plant, Preliminary Design/Economic Evaluation, Clean Boiler Fuels From Coal," and a significant part of the COED design were completed under Contract-1234. Also a number of technical Evaluation Contractor Services have been, and are being supplied to ERDA-FE.

In addition, two preliminary assessments of the Fischer-Tropsch Synthesis process for production of liquid fuels and substitute natural gas were completed and reported.

The work effort for Contract E(49-18)-1775 is divided into twelve tasks. These tasks and their schedules are shown in Figure 1 - Overall Program 34

B. Coal Mining/Coal Preparation

1. Objectives:

a. Initially to develop a conceptual design and economic evaluation for facilities to (1) mine a minimum of 35,000 TPD of Illinois No. 6 seam coal, and (2) prepare it in a form suitable for use as feed to various coal conversion process plants. The initial mine conceptual design will be used for the COED project.

b. The long-range objective is development of conceptual designs and economic evaluations for mines in four additional geographic areas. These include the Appalachian area, the Feather River (Western) area, the Four Corners area, and the Utah deposits. Mine costs will be developed to supply feed to the various conceptual plant designs including those based on SRC, Cresap-Development processes, COG, and others that may be defined in the course of the program. Mines with capacities up to 100,000 TPD will be considered.

2. Activity This Quarter:

We continued to assemble information regarding reserves and mining characteristics for the various coal sources to be used in our work as described under the objectives.

We completed a major portion of the conceptual design for a 40,000-TPD coal mine for use in the Fischer-Tropsch plant complex. The mine location is in the Eastern Interior Coal Region.

3. Activity Forecast Next Quarter:

Complete the design and fixed capital estimate for the 40,000 TPD coal mines for the Fischer-Tropsch plant and Oil/Gas complexes.

C. Oil/Gas Plant Design

1. Objectives:

To develop a preliminary design and economic evaluation for a commercial Oil/Gas plant to produce synthetic liquid fuels and SNG from coal. To define the maximum practical capacity single-train plant using the process.

2. Activity This Quarter:

A preliminary block flow diagram incorporating the currently available results of the process alternative studies described below

Schedule. A brief synopsis of the status of the major active design efforts is given below, followed by a more detailed reporting on progress for the separate tasks.

The first task, to complete the conceptual design of the COED process and issue the final report, has been completed. Multiple copies of the report were transmitted to ERDA by our letter PN-74 dated October 3, 1975. The Oil/Gas plant design is underway; a number of studies that compare the technical and economic performance of various process operations have been completed. The results of these studies have been incorporated into the process design that has been reviewed with ERDA. The remaining studies are well underway, and will be completed during the coming quarter.

The Fischer-Tropsch plant design is also well underway. The design basis and process block diagrams have been reviewed with ERDA personnel. The detailed design of equipment is underway.

Work on the COG design is underway. Computer simulation capability is being used to assist in defining the capabilities of a number of liquefaction technologies.

Activities continue on the metallurgical support, equipment development, and environmental factor efforts.

III. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. COED Conceptual Commercial Plant

1. Objectives:

   To develop a conceptual design and cost estimate for a commercial-size plant.

2. Activity This Quarter:

   Forty copies of the final report describing the conceptual design investment and economic evaluation was transmitted to ERDA on October 3, 1975. This is ERDA R&D Report No. 114 Interim Report No. 1 "Commercial Complex, Conceptual Design/Economic Analysis, Oil and Power by COED Based Coal Conversion."

   The economic section of the report includes a complete parametric economic analysis. Review comments received from ERDA were incorporated into the final report.

3. Activity Forecast Next Quarter:

   Transmit additional copies of R&D Report No. 114 Interim Report No. 1 to ERDA.

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was prepared and discussed with ERDA personnel. Modifications to this process design will be made as the results of the continuing studies indicate appropriate need.

Work proceeded on development of preliminary material balances to allow sizing of equipment for the separate plant units to begin.

We continued work to finalize the design basis. Predesign studies to select the elements of a preferred design consist of economic and technical comparisons of a number of process alternatives. These alternatives include:

a. Hydrogen vs Syngas: Process designs and equipment data were developed for use in preparing capital cost estimates for the two alternate feeds to the dissolvers. The capital cost comparison for the two alternate feeds is being estimated.

b. Filter Cake Washing and Drying: Process designs and equipment data were developed for preparation of capital cost estimates for this process alternative. The estimation of the capital cost effect of this process alternative is in progress.

c. Dissolver Design Basis: Data from the Tacoma SRC Pilot Plant progress reports was used to determine a preliminary basis for dissolver calculations. These reports gave us details of yields, approximate stream properties, and elemental analysis of all streams; the elemental balance data was rationalized for consistency.

   A preliminary evaluation of the economic impact of dissolver residence time indicated that reduction of the dissolver nominal residence time from 1 hour to 15 minutes would be economically attractive. The annual revenue requirements for a 10,000-TPD coal feed plant would be reduced by approximately $2 million at a 12% discounted cash flow rate of return (DCF).

d. Power Recovery Turbines: A preliminary economic evaluation of this equipment alternative shows that the power savings that make use of power recovery turbines are economically attractive.

e. NH_3 - H_2S Separation: The addition of this unit changes the sulfur removal plant design basis. A revised process stream specification was prepared for these sulfur plant requirements, heat and material balances were prepared and capital cost estimates are being developed.

   A technical and economic comparison has been made of the commercial separation processes. Preliminary estimates were received from the vendors of each of these processes. 37

f. High Pressure Gasification: We are working on the material and energy balance for a 1000-psig gasifier responding specifically to the Oil/Gas Plant requirements. Design of the gasifier, shift and acid gas removal units has begun.

g. SNG Production: We continued to assemble material required to estimate the effects of various levels of SNG production.

The SNG production potential from the Oil/Gas Plant was analyzed and two cases were selected for current consideration: (1) cryogenic extraction of methane plus LPG and purification of LPGs as products, and (2) cryogenic extraction of methane and LPG followed by steam reforming of LPG to produce additional methane. The design results for these two cases were summarized and are being used as the basis for estimating the economic impacts.

h. Sour Shift: We completed work on process calculations, equipment data sheets, specifications, and process flowsheets for this process alternative. The engineering disciplines are developing equipment data for use in capital cost estimates.

i. Alternative H_2S Removal Processes: A technical and economic comparison of the three processes has been completed and the results are being summarized. Two of the processes used physical absorption solvents. The work included development of performance specifications, and of material and utility balances.

j. Omit Slurry Recycle: A design basis was established for this study so that the coal conversion simulator program originally developed under the COG task assignment could be used for process and economic evaluation.

Material balance calculations were completed for this study. In order to allow selection of the desired option for the design basis, a preliminary estimate of equipment and operating cost differences was made. The economics for the two options - slurry and nonslurry recycle - appeared nearly equal, and the nonslurry case was chosen to permit use of the available pilot plant data.

k. Solids Separation-Coking: A study of coking has been completed and the results are being summarized. A preliminary estimate of the magnitude of plant changes required to incorporate coking and the resulting products was made to evaluate its potential.

l. Solids Separation-Vacuum Flash: Material balance calculations were completed for the vacuum flash treating of dissolver effluent to carry out solids/liquid separation. We analyzed studies previously performed on vacuum flashing of SRC product.

3. Activity Forecast Next Quarter:

   The prime thrust will be the preparation of the final plant design.

   Process information for completed predesign studies will continue to be supplied to the engineering disciplines and to estimating. Work will continue to complete additional optimization studies as time allows. The economic impact of process alternatives will be evaluated.

D. <u>Fischer-Tropsch Plant Design</u>

1. Objectives:

   To develop a preliminary commercial plant design and economic evaluation for a plant using Fischer-Tropsch technology to produce pipeline gas and motor fuel.

2. Activity This Quarter:

   a. <u>Design Basis</u>: A preliminary design basis has been prepared. The Btu value of the total plant products was set at 500 billion Btu per day, the plant will consist of two trains of 250 billion Btu per day each. The design basis was reviewed with ERDA representatives during a progress review meeting held September 16 and 17.

   b. <u>Process Block Flow Diagram</u>: A preliminary process block flow diagram has been completed, this diagram was reviewed with ERDA representatives.

   c. <u>Plant Visit</u>: Parsons and ERDA personnel visited the SASOL plant located at Sasolburg, Republic of South Africa. Information obtained will be used as background for Fischer-Tropsch studies.

   d. <u>Gasifiers</u>: The development of the design for large-scale gasifiers suitable for production of feed gas for the Fischer-Tropsch synthesis continued.

   e. <u>Gas-Solids Separation</u>: The study of alternative means for removal of solid particulates from the hot, pressurized gas stream leaving the gasifier was continued. Contacts were made with vendors to determine the suitability of their equipment.

f. Acid Gas Removal: Criteria were developed for the purity of the feed gas to the Fischer-Tropsch synthesis units. Process specifications were prepared for acid gas removal and compared with published information on the subject for SASOL plant. These specifications were issued to potential process licensors for their proposals. We reviewed with them their concern on the removal of the acid gases to the required low concentration level.

g. Fischer-Tropsch Reactor: Work was continued on the detailed conceptual design of the reactor as applied to the USA Fischer-Tropsch plant. A patent disclosure has been prepared on the details of this reactor design.

h. Coal Feed System: We developed a lock hopper feed system for coal injection into the gasifier. Preliminary capital investment estimates were obtained on this feed system.

i. Gasification System: We continued our efforts to develop a gasification system suitable for a United States Fischer-Tropsch design. This involves the specific steps of (1) how to remove solids particulates, (2) whether or not the shift conversion should operate on sour (H_2S-containing) gases, (3) the extent and method of cooling the gasifier product gases, and (4) how much steam is required to accomplish the necessary gas and carbon reactions. Since our requirements are not to make high purity hydrogen, the last question has a serious impact on economics and plant operation as it affects the plant steam requirements.

j. Overall Process Flow Diagram: We prepared a preliminary overall process flow diagram. This will be used in preparation of equipment lists and assigning equipment numbers.

k. Process Flow Diagram: Preliminary process flow diagrams for units 12-Process Gasification, 13-Gas Cleaning, 15-Shift Conversion, 16-Fischer-Tropsch Synthesis, 17-Methanation, 18-Liquid Product Recovery, and 19-Chemical Recovery were prepared.

3. Activities Forecast for Next Quarter:

The mine, coal preparation, and process design will be completed with flowsheets and capital cost estimates during the next quarter. Services, utilities, and waste treatment facilities design and estimations will begin and be well underway next quarter.

E. Preliminary Design Commercial SRC-Type Plant

1. Objective:

Prepare a preliminary design for a commercial-scale plant for the production of Solvent-Refined Coal (SRC). Information developed from actual pilot plant operations will be furnished by the Government and is to be utilized in the plant design.

2. Activity This Quarter:

None; scheduled to begin in October 1976.

3. Activities Forecast for Next Quarter:

Continue to monitor progress of the Tacoma SRC pilot plant.

F. COG Plant Design

1. Objectives:

To develop a preliminary design of a coal processing plant that will produce both liquid and gaseous fuels as principal products. The processes employed in this plant design shall be the result of an economic selection from the candidate coal conversion processes available.

To develop a model capable of calculating material and heat balances for a number of coal conversion processes using computer capabilities and to estimate the overall utility balance of the complex.

2. Activity This Quarter:

a. Computer Simulation: We have developed the computer process model to the point where it is now operational. We are using it to evaluate various COG candidate processes, while at the same time expanding and adapting the program as the applications are being developed. The program is also being modified for use in other design task assignments such as Oil/Gas, and Fischer-Tropsch.

b. Gasifier: We completed process specifications for a large-scale air-blown entrained-type coal gasifier to supply in-plant fuel gas requirements. We started engineering design of this unit.

c. Process Screening: Our efforts in preparing screening estimates continued. It appears that more detailed information than now available is required to enable us to make even this type of estimate for evaluation of the Consolidation Coal Company process. We have taken steps to obtain this

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information. A request has been made to receive current reports for H-Coal development.

3. Activity Forecast Next Quarter:

During the next quarter we plan to continue screening process assessments and estimates. The in-plant fuel gasifier design will be completed. We will prepare preliminary reports for process selections.

G. <u>Preliminary Designs for Complex to Demonstrate the Feasibility of a Variety of Coal Conversion Processes</u>

1. Objectives:

To develop preliminary designs for a facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes that show promise during pilot plant scale operations. This task will consider:

(1) Low to high Btu fuel gas.

(2) Methane/motor fuel by Fischer-Tropsch process.

(3) Clean liquid fuels by alternate gasification processes.

2. Activity Last Quarter:

None; this task scheduled to begin January 1976.

3. Activity Forecast for Next Quarter:

None planned.

H. <u>Commercial Plant Scale Models</u>

1. Objective:

To make scale models of commercial plants as described in activities A through F.

2. Activity This Quarter:

A scale model of the COED-based complex has been supplied to ERDA.

3. Activity Forecast Next Quarter:

None.

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I. Equipment Development

1. Objectives:

To define the equipment and control system development program required to assure reliability and viability of coal conversion processes being developed. To recommend appropriate developmental programs to ERDA - Fossil Energy Division.

2. Activity This Quarter:

a. Liquid/Solids Separation: The V.D. Anderson Company of Chicago requested and received a sample of SRC dissolver product for laboratory testing of their screw expeller as a means of separating SRC product from the solids. Testing of the sample is presently underway.

We continued to work on the development of various separation processes with other candidate equipment manufacturers. Samples of nonwoven fine stainless steel fiber filter media were obtained from the Hydraulic Research Inc. This material may hold promise as a direct high temperature filter medium for rotary drum pressure filters. The samples were sent for testing to Goslin-Birmingham.

b. Gas/Solids Separation: We continued contacts with manufacturers of cyclones, wet electrostatic precipitators, sintered metal fiber filters, and granular bed filters to develop data on the applicability, cost, and economic operation parameters of this equipment based on cost information received from manufacturers of such equipment. This information will be used in process design development.

c. Solids Feed to Gasifiers: We investigated the current status of developmental efforts in the field of extrusion coal feed devices. We contacted vendors and development organizations engaged in development work concerning extrusion coal feeding. Their test data were discussed. The vendors stated their belief that the coal particles that are cemented together due to compression will disintegrate to the original granular size upon entry to the gasifier due to gas velocity and the expansion of entrapped moisture in the coal.

We discussed laboratory experimental work on extrusion coal feeding with the Research Director of the V.D. Anderson Company. This firm is designing and assembling a pressurized test installation for use in extrusion coal feeding test work.

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d. Filter Cake Drying: We continued contacts with various manufacturers to develop diverse approaches to the problems of filter cake drying. We received preliminary capital cost information from two kiln manufacturers. We are also reviewing information on other drying methods such as flash drying and wiped film dryers.

e. Valves: We received information regarding the Gemco segmental ball valve. The Gemco standard product is designed for intermediate temperature and low-pressure service. Modifications of this design for heavier duty service appears possible.

3. Activity Forecast Next Quarter:

We anticipate obtaining results from the V.D. Anderson Company's laboratory testing of liquid/solids separation and on extruder coal feeding.

The coal liquefaction slurry filtration tests and filter cake oil and solvent recovery equipment investigations and cost proposals should be completed.

Investigations will be continued in the areas of gas-solids separation and solids feeding techniques.

J. Materials of Construction Assessment

1. Objectives:

To define the preferred materials of construction for use in coal conversion projects.

2. Activity this Quarter:

a. Metals Property Council: We attended a meeting at the Illinois Institute of Technology Research Institute on July 10. We reviewed the status of the Phase I (High Temperature Laboratory Corrosion Test) and made comments concerning the materials to be evaluated. We further reviewed the Phase II (Pilot Plant Corrosion Tests) Summary report and collaborated in the revisions thereto.

We attended a meeting of the Phase V Committee on Engineering Properties of Metals that was held in Los Angeles, California on September 30. We helped to prepare a draft proposal for mechanical testing of candidate alloys suggested by the Phase V Committee.

b. NACE Technical Practices Committee (T-12A): We met with the chairman of committee T-12 of the National Association of Corrosion Engineers to discuss the agenda for an initial committee meeting to be held at the annual Association meeting in Houston in March 1976. The meeting is planning a two-day program addressing problems of materials selection for coal conversion plants.

c. Pilot Plant Activities: A letter report was transmitted to Project Lignite and ERDA personnel concerning metallurgical investigation of defects and corrosion of the expansion loop between Dissolvers R-1A and R-1B of Project Lignite at the University of North Dakota Pilot Plant.

The design and materials of High Pressure Separators S-1 and S-2 and Dissolvers R-1A and R-1B were also evaluated.

3. Work Forecast For Next Quarter:

We will continue our participation in the ongoing programs of the Metals Property Council and the NACE activities.

K. Environmental Considerations

1. Objectives:

To define environmental factors and required facilities for proposed coal conversion complexes and to define product quality standards to meet environmental regulations for product users.

2. Activity Last Quarter:

We summarized federal and state statutes and regulations concerning coal conversion plants and ancillary facilities.

3. Activity Forecast Next Quarter:

Continue to advise and define environmental requirements as they affect each process. Review the Oil/Gas and Fischer-Tropsch designs as they are developed in order to ensure that environmental control facilities are incorporated.

L. General

1. Objectives:

To plan and define work efforts. Define short-term project objectives and priorities. Prepare recommendations to ERDA on actions to be taken.

2. Activity This Quarter:

a. Review Meeting: A progress review meeting was held at The Ralph M. Parsons Company offices in Pasadena on September 15 to 17 with ERDA representatives. 45

b. Papers: We prepared two invited papers presented to the 68th National AIChE meeting held in Los Angeles on November 19, 1975. The titles of these papers were "Oil/Gas Design Plant Criteria" and "Fischer-Tropsch Plant Design Criteria."

We presented an invited paper titled "Gaseous Environmental Factors in Coal Pyrolysis Plant Design" at the Joint Power Generation Conference held in Portland, Oregon on September 29 to October 2, 1975.

3. Activities Forecast Next Quarter:

a. Continue program surveillance and planning.
b. Present papers to organizations as described under 2b above.
c. Perform such miscellaneous services as requested by ERDA.

V. CONCLUSIONS

The design basis for the Fischer-Tropsch plant has been selected. Design efforts are now well underway.

The Oil/Gas plant design has commenced. Most of the required process studies have been completed. The detailed engineering design effort is now being emphasized.

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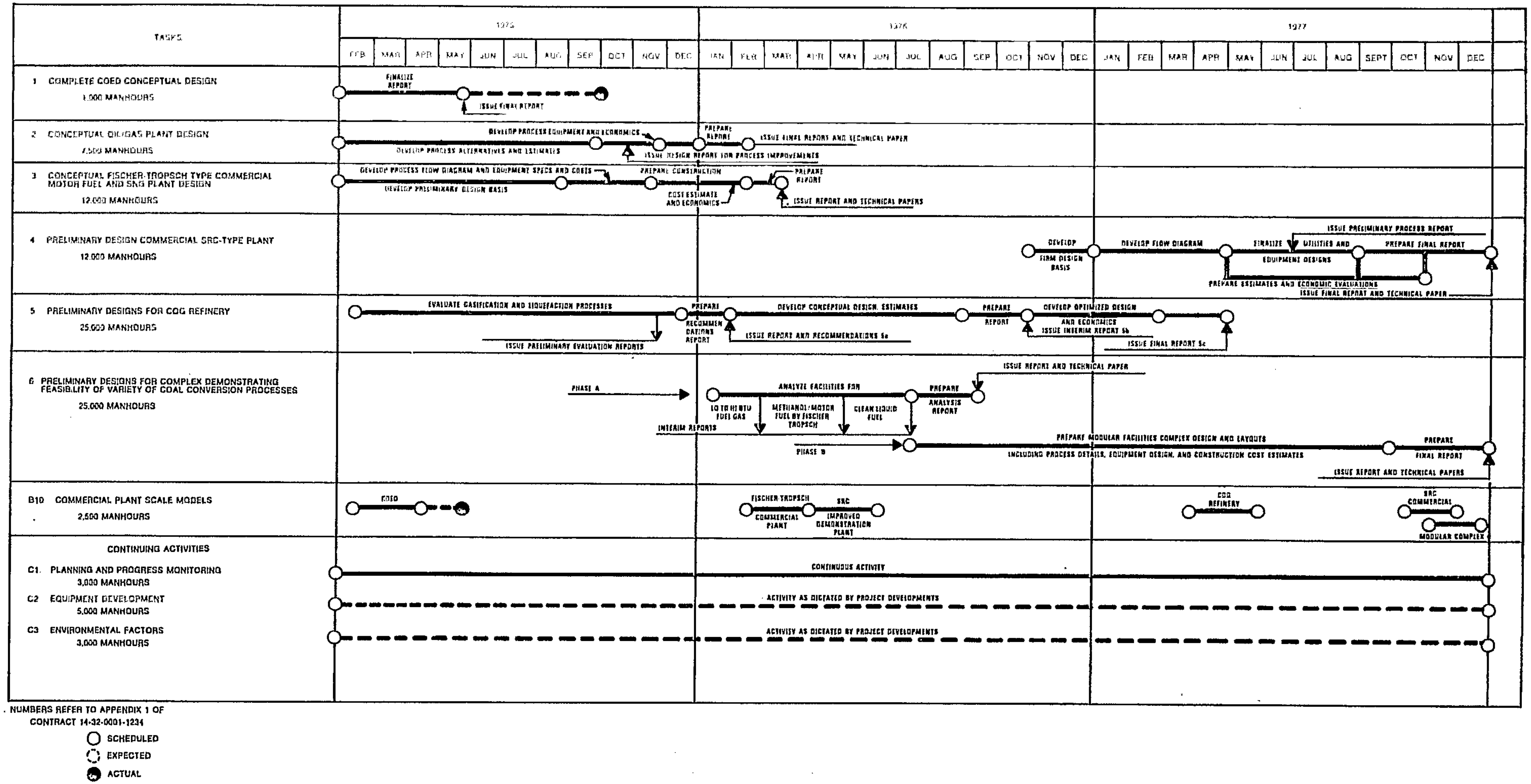

Overall Program Schedule
OCR Projects
Parsons Job No. 5435

FE-1775-3
UC-89

PRELIMINARY DESIGN SERVICES

RESEARCH AND DEVELOPMENT REPORT NO. 114

QUARTERLY REPORT

For the Period: October - December 1975

Prepared by:

The Ralph M. Parsons Company
100 W. Walnut Street
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For:

Energy Research and Development Administration
Washington, D.C. 20545

Under Contract No. E(49-18)-1775

March 1976

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The facilities will be considered for conversion of coal to:

1. Low- to high-Btu fuel gas

2. Methanol/motor fuel by Fischer-Tropsch process

3. Clean liquid fuels by alternate liquefaction processes

In addition, supporting efforts will be provided to the above activities. These efforts include planning and progress monitoring, equipment development, and environmental factors.

II. SUMMARY OF PROGRESS TO DATE

Published designs include OCR R&D Report No. 82, Interim Report No. 1, "Demonstration Plant, Preliminary Design/Economic Evaluation, Clean Boiler Fuels From Coal," and ERDA R&D Report No. 114, Interim Report No. 1, titled "Commercial Complex, Conceptual Design/Economic Analysis, Oil and Power by COED-Based Coal Conversion."

In addition, two preliminary assessments of the Fischer-Tropsch Synthesis process for production of liquid fuels and substitute natural gas were completed and reported.

The work effort for Contract E(49-18)-1775 is divided into six primary and four supporting tasks. These tasks and their schedules are shown in Figure 1 - Overall Program Schedule included at the end of this report. A brief synopsis of the status of the major active design efforts is given below, followed by a more detailed reporting on progress for the separate tasks.

The first task, to complete the conceptual design of the COED process and issue the final report, has been completed. The last required copies of the report were transmitted to ERDA by our letter PN-87 dated November 11, 1975.

The oil/gas plant design is underway. All planned studies that compare the technical and economic performance of various process alternates have been completed. The results of these studies have been incorporated into the process design.

We reviewed the oil/gas design basis for the complex without slurry recycle, which will produce an oil-to-gas ratio of approximately 6.25 to 1 (Btu basis) and with slurry recycle, which can produce a ratio of about 2 to 1. We concluded that the oil-to-gas ratio of about 2 to 1 would have more commercial interest and proposed to ERDA that this design basis be adopted. ERDA accepted our proposal and the changes (including slurry recycle as dissolver feed) were initiated.

The Fischer-Tropsch plant design is also well underway. The design basis and process block flow diagrams have been reviewed with ERDA personnel. The detailed design of process flow diagrams, material balances, and equipment specifications is approximately 50% complete.

Work on the COG design is underway. Computer simulation capability is being used to assist in defining the capabilities of a number of liquefaction technologies. Capital cost estimates for several candidate process have been completed as well as three block flow diagrams.

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Activities continue on the materials selection, metallurgical, equipment development, and environmental factor support efforts.

III. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. COED Conceptual Commercial Plant

1. Objectives

The objectives are to develop a conceptual design and cost estimate for a commercial-size plant.

2. Activity this Quarter

We transmitted 365 copies of the final report, describing the conceptual design, and economic evaluation, to ERDA on November 4, 1975 per our letter PN-87 dated November 11, 1975. The report is titled "Commercial Complex: Conceptual Design/ Economic Analysis; Oil and Power by COED Based Coal Conversion; ERDA R&D Report No. 114 - Interim Report No. 1." This completes our assignment on the COED design.

B. Coal Mining/Coal Preparation

1. Objectives

A long-range objective is to conceptually design and evaluate, as feed facilities to conversion plants, coal mine and preparation facilities for five assigned geographic areas where conversion facilities are being studied. Capacities up to 100 MTPD are being considered.

2. Activity this Quarter

We completed a design for an integrated strip mine to produce 40 MTPD of Run-of-Mine (ROM) coal, or 14 MMTPY for 350 operating days per year. We also completed a preliminary capital cost estimate and an operating cost estimate for this unit. Work is progressing on a coal preparation plant to treat this coal. These units are intended to serve the Fischer-Tropsch Plant Design.

3. Results of These Activities

General Mine Plan: A preliminary mining plan was developed and is presented in Figure 2 included at the end of this report. The mine is divided into four separate mining units, each unit producing 10 MTPD.

4. Activity Forecast Next Quarter

We will complete the design of the coal preparation and grinding units for both Fischer-Tropsch (40 MTPD ROM) and oil/gas (53 MTPD ROM) complexes, including estimates of capital cost and operating expenses. We will prepare report sections for these units for use in the ERDA R&D report that will describe the two designs.

C. Oil/Gas Plant

1. Objectives

The objectives are to develop a preliminary design and economic evaluation for a commercial oil/gas plant to produce

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synthetic fuels and SNG from coal, and to define the maximum practical capacity single-train plant using the process.

2. Activity this Quarter

We completed the design, fixed capital cost, estimating, and economic analysis of the process alternates to be considered as improvements to the demonstration plant design. We presented the results of the studies in a paper titled "Oil/Gas Plant Design Criteria" to the 68th Annual Meeting of the AIChE in Los Angeles on November 19, 1975.

In the early part of December we recommended that the design criteria for the oil/gas ratio on a Btu basis be changed from approximately 6 to 1 to 2 to 1. The reason was the belief that the 2 to 1 ratio will have greater commercial interest. ERDA accepted our recommendations. The necessary design changes due to this revision were immediately begun. This revision will delay the task completion by approximately 1 month as shown on the attached Figure 1 schedule included at the end of this report.

3. Results of the Activities

   a. Fixed Capital Cost Estimate Updating. We updated the fixed capital cost estimate for the Demonstration Plant design published as R&D Report No. 82 - Interim Report No. 1 to a mid-1975 basis partly by using computer-assisted methods and partly by escalating the original estimates. The total constructed cost published in R&D Report No. 82, including home office costs and sales tax, was $226 MM based on mid-1973 costs, while the comparable revised mid-1975 estimated constructed cost was $311 MM.

The updated estimate was used as a basis for certain elements of the fixed capital investment portions of the studies discussed below. Updated economics for the R&D No. 82 complex are shown in Table 1 included at the end of this report and result in a required product selling price of $3.20/MMBtu.

Eight process preference studies were completed. The objective was to evaluate a number of process alternates to determine a preferred design configuration. In general, an economic comparison was made, usually in the form of a differential in required product selling price between the alternates, expressed in dollars per Btu of product. The basis of these evaluations is shown in Appendix 1: "Basis of Economic Evaluations". A summary of the results of these studies follows.

b. Process Preference Studies

(1) Additional SNG Production by Light Ends Reforming.

Since the aim of this design effort is a complex that will provide significant quantities of substitute natural gas (SNG), we investigated various alternates to the basic R&D Report No. 82 plant design to increase the percentage of SNG produced.

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Five different methods of producing SNG were briefly investigated. This screening work showed that three of the methods were of marginal nature or that the cost would be sufficiently high as to eliminate them as candidate process alternates. For reference, the R&D Report No. 82 design used these off-gases as inplant fuel after acid gas removal and is used as an economic base point.

The remaining cases examined in detail are the following:

Case A. Production of SNG and LPG from the complex off-gases while the plant fuel requirements will be met from a low-Btu gasifier especially provided for the purpose. Figure 3 included at the end of this report shows the block flow diagram required for this case.

Case B. The off-gases are treated to produce only SNG; i.e., the LPG components are reformed and methanated to utilize them as SNG. Figure 4 shows the block flow diagram used to obtain this result.

Table 2, included at the end of this report, summarizes the economic results for the three cases. The economic comparison shows a reduction of approximately 3% of required selling price for the co-production of both LPG and SNG as salable products. Even though these savings are within the accuracy of the estimate we will use the lower cost alternate for the design due to its simpler configuration.

(2) Hydrogen Vis-a-Vis Syngas as Dissolver Feed. R&D Report No. 82 used syngas produced in a gasifier as hydroliquefaction agent in the dissolvers. The gas produced in the dissolver section was used as inplant boiler fuel. This off-gas is rich in carbon monoxide and relatively poor in hydrogen.

To meet the objective of producing significant quantities of SNG, we investigated the use of hydrogen-rich gas as liquefaction agent. This increases the concentration of hydrogen in the dissolver off-gases, which facilitates the separation of the hydrogen from the carbon monozide in a cryogenic separation unit.

Figure No. 5 shows a block flow diagram containing the units required to produce and use the hydrogen-rich gas. The total constructed cost of these facilities compared to similar facilities in the R&D Report No. 82 plant present a 5.6% increase in total plant fixed capital investments. Table 3 shows the economic comparison of the two cases including the influence of operating costs, catalyst and chemical cost, and coal consumption. This shows that the use of syngas requires a slightly lower product selling price (approximately 3%) as compared to the use of hydrogen. 58

Considering the range of accuracy of the estimate, the choice of the hydroliquefaction agent therefore becomes elective and subject to process and operations considerations.

(3) Use of Recycle Slurry Vis-a-Vis Filtrate as Coal Slurry Agent. The R&D Report No. 82 design was based on using unfiltered dissolver product as the vehicle for slurrying the coal feed. This can be termed the slurry recycle method.

The hydrogen consumption for the case where clear filtrate is used to slurry the feed coal can be in the range of 2 wt % of the feed coal, while the slurry recycle mode can increase the hydrogen uptake to the range of 3 wt %. As a result of this increased hydrogen consumption, the product slate will tend to produce liquid fuels.

For the purposes of this comparison, the potential increase of the SNG production was not considered. The product slate was restricted to liquid products and all gases evolved are used in the plant as fuel. The difference of energy available as product is 1.8×10^9 Btu/d, which amounts to 1% of the total Btu value generated in the plant. This difference is well within the accuracy of the calculation of the total heat available. We therefore concluded that the energy efficiencies for the 59 two modes of operation are essentially equivalent and that the choice of slurry or nonslurry recycle depends primarily upon the overall product slate desired for the complex.

Future work should consider the differential product cost in \$/MM Btu resulting from the two alternate operational modes.

(4) Reduction of Dissolver Residence Time. Experimental runs in the Tacoma SRC Pilot Plant showed that high coal conversions can be obtained at relatively low liquid residence time in the dissolvers. We therefore studied the economic impact of reducing the nominal liquid space time in the dissolvers from 60 to 30 minutes. The installed cost of the affected equipment for the R&D Report No. 82 design as escalated to 1975 was \$41 MM. The cost for the same equipment, considering the reduced dissolver residence time, was \$32 MM. The required annual revenue is reduced by \$2.8 MM/yr or approximately 1.7% of the total base required annual revenue (see Table 1). It was therefore decided to incorporate the reduced dissolver residence time in the design basis.

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(5) Acid Gas Removal. The R&D Report No. 82 design used a chemical absorption process to separate the hydrogen sulfide from the gas stream to produce an ecologically acceptable fuel gas. Considering the greater quantities to be treated for the oil/gas design, we also investigated several physical solvent processes used for the same purpose. We obtained a quotation from two potential licensors of physical solvent separation processes and found that the capital investment for both these processes is approximately $1.8 MM lower for a 10,000-TPD coal feed plant than the chemical absorption process.

Considering catalyst usage, utilities, and other economic factors, as shown in Table 4, we found that the use of a physical solvent process reduces the annual revenue requirements. It was therefore decided to use a physical solvent process for hydrogen sulfide removal in the oil/gas plant design.

(6) Sour Vis-a-Vis Sweet Shift. A shift operation is required to increase the ratio of hydrogen to carbon monoxide in the gasifier gas product to make it

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suitable for production of high-purity hydrogen to be used in the dissolvers. The reaction used is:

$$CO + H_2O \rightarrow H_2 + CO_2$$

We studied the use of sour shift vs. sweet shift to determine which of the two processes is the more economical for the Oil/Gas Plant design. Figure 6 shows the two process configurations.

In the sweet shift configuration, gasifier product gas is cooled to 100°F for treating in an acid gas removal unit. Nearly all of the water present in the gas is condensed. Following acid gas removal, the gas is reheated to shift temperature (650-700°F) and steam is added. After the shift reaction, the gases are cooled again prior to removal of the carbon dioxide produced in shifting. Product gas is then available for use.

In the sour shift configuration, gasifier off-gas is fed directly at 700°F to the shift unit with additional steam feed to adjust the steam feed to dry gas ratio. The shift product gas is then cooled for acid gas removal and process use.

The total acid gas removal burden is the same in both shift schemes. Sour shift offers the advantage of

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eliminating two sets of heat exchangers and one acid gas removal unit. Furthermore, it reduces the steam requirements by not condensing steam ahead of the shift unit. However, the sour shift unit must use a greater quantity of a more expensive catalyst. In addition, steam requirements in the sour shift unit are greater than in the sweet shift unit as a result of the presence of carbon dioxide in the feed. A single unit is used in the sour shift case where two smaller units are used in the sweet shift case.

Fixed capital investment and operating costs for the two cases were estimated. Results indicate that the use of a sour shift procedure should reduce the fixed capital investment by approximately $2.2 MM. Expected utility requirement reductions for sour vis-a-vis sweet are:

- Fuel gas: 763 MMBtu/yr
- Steam: 1,228.3 MMlb/yr
- Power: 36 MkWh/yr (increase)

Table No. 5 is a summary of the economic factors that show that the use of the sour shift procedure will reduce the required annual revenue by more than $6 MM per year, equivalent to about 4% of the total

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required annual revenue. It was therefore decided to incorporate the sour shift procedure in the oil/gas plant basis.

(7) Filter Cake Solvent Recovery. In the R&D Report No. 82 design, the wet filter cake, with projected 50 wt % solids and 50 wt % liquids, was sent directly to the gasifier with a resultant conversion of solvents or wash oils adhering to the filter cake to syngas. This was considered as one of the alternates for this study. As a potential improvement, we studied an alternate consisting of drying the filter cake and thus recovering the liquids adhering to the cake. The cake would then be transported to the gasifier and injected therein in the form of a water slurry. Block flow diagram Figure No. 7 shows the major components of the system.

For the alternate case a second side-stripper was added to the main fractionator to recover a kerosene-range filter wash oil. This cut is light enough to be easily removed from the filter cake in a dryer but not so light as to vaporize in the filter and fail to wash off the adhering liquids. This wash oil is sent to the filter to wash through the filter cake and displace adhering filtrate. A volume of wash oil equal to twice the volume of the adhering liquid was

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used and it was predicted that 97 wt % of the original adhering liquid would be displaced. The resultant wet filter cake is projected to be 50 wt % solids and 50% liquids. Since the filtrate includes a large portion of the wash oil and additional recovered filtrate, the main fractionator and attendant equipment were sized to accommodate the larger flows.

Wet filter cake is dried in rotary dryers with a circulating stream of heated gas used to provide heat and to remove vapors from the dryer. The wash oil is recovered as a liquid and the dried filter cake is mixed with water and raw coal and is fed to the gasifier. Table No. 6 shows the material and utility balance for the two alternate cases studied.

The addition of filter cake washing and drying increases the total capital investment cost of the plant by approximately \$12 MM and the required annual revenue is also increased by about \$12 MM as shown in Table 7. The output of the complex is increased by approximately 37×10^9 Btu/d. The required selling price of the products is reduced by \$0.435/MMBtu, a reduction of approximately 13%. We therefore plan to use this concept in the oil/gas design.

(8) Use of Power Recovery Turbines. The "Clean Boiler Fuels from Coal" design contains several streams that have to be reduced from a high to a low pressure. We studied the possibility of utilizing this pressure drop to drive power-recovery turbines that in turn would drive appropriate rotating equipment. We eliminated streams that were either of insufficient pressure drop or insufficient flow quantity to warrant the investment in the power-recovery turbines. Approximately 90% of the pressure drop of the streams of sufficient size and pressure drop was utilized for the pressure recovery turbine leaving approximately 10% of the pressure drop for control purposes. This also reduces the duty requirements of the pressure letdown valves.

The analysis indicates that the economic impact of the use of power recovery turbines is small. The reduction in required selling price is less than $\frac{1}{2}$%. However, the technical advantage of reducing the duty imposed upon the pressure-reducing valves is deemed sufficient to utilize the power recovery turbines where applicable in the oil/gas plant design.

4. Activity Forecast Next Quarter

We will complete the process design, flow diagrams, heat, material, and energy balances for the complex. We will prepare equipment specifications. We will generate a layout for the complex and prepare a fixed capital cost estimate. We will start the economic evaluation of the complex.

We will prepare and review a draft of the technical portion of the R&D report to describe the design.

D. Fischer-Tropsch Plant Design

1. Objectives

The objectives are to develop a conceptual commercial plant design and economic evaluation for a plant using Fischer-Tropsch technology to produce pipeline gas and motor fuel.

2. Activity this Quarter

We advanced the process design of the complex. We particularly addressed the reactor train section and studied the utilization of reactors incorporating sprayed catalyst on finned tubes on the shell side with steam being generated in the tubes so as to remove the heat created by the highly exothermic reaction and thereby reducing overall utility requirements. We further advanced the process design of the gasifier train, acid gas removal unit, and waste water reclamation unit. We studied the relative merits of single-stage vis-a-vis two-stage gasifiers and decided to use the latter. We made comparative

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studies of alternate gas removal processes and decided to use a physical absorption process. We continued development of material and energy balances, flow diagrams, and equipment specifications.

3. Results of the Activities

   a. Catalytic Reactors. The ERDA Pittsburgh Energy Research Center (PERC) located in Bruceton, PA, (formerly Bureau of Mines) has conducted tests extending over a period of more than 5 years, addressing the operation of exothermic reactors utilizing catalyst sprayed onto base metal surfaces. The results of these tests were sufficiently successful to lead us to the conclusion to utilize their application to Fischer-Tropsch synthesis, water gas shift, and methanation reactions.

   Traditionally, reactors are of the packed tube, fixed bed, fluidized bed, or entrained catalyst type. Due to the highly exothermic nature of the reaction, heat removal is required from the gas stream or from the catalyst surface. Fluid and entrained catalyst systems require equipment to remove entrained catalyst from the effluent gas stream. Fixed-bed systems use gas recycle rates as high as 27 to 1 (ratio recycle to feed) to control the reactor heat and packed tube systems require a ratio of approximately 2.5 to 1.

   Reactors utilizing external fin tubes with sprayed catalyst on the fin surface were designed. The tube side serves as

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a means to produce steam, thus extracting the heat of reaction. This reduces the gas recycle to a 1.5 to 1 ratio of recycle to feed. Activated iron oxide is the Fischer-Tropsch synthesis catalyst. Sulfur-resistant watergas shift catalyst is used for shift conversion and Raney nickel is used for methanation.

Figure No. 8 is a block flow diagram for Fischer-Tropsch synthesis reactor trains in two typical configurations, one for a catalyst packed tube and the other for the sprayed catalyst installation. A comparison of preliminary guesstimates of fixed capital costs and economic results are shown in Table No. 8. Based on the cost savings shown in this table, we decided to use the sprayed catalyst design approach for the Fischer-Tropsch complex.

b. <u>Comparison of Basic Gasifier Types.</u> We studied costs and process merits of fixed bed gasifiers with moving grates, as well as fluid bed and entrained two-stage gasifiers for the production of Fischer-Tropsch syngas.

The entrained type two-stage gasifier operates with a shorter coal retention time, thus requiring the smallest size per unit of throughput. Due to the high gasification temperature, byproduct tar and phenols pose the least problems in this design.

As shown in the enclosed Table 9, the estimated fixed capital investment and coal consumption are lowest for the 69 entrained two-stage gasifier, more than offsetting a higher oxygen consumption. This gasifier design was therefore chosen as basis of design for the complex.

c. Comparison of Entrained Gasifier Types. We investigated the relative merits of single-stage vis-a-vis two-stage entrained gasifiers with oxygen feed to serve as source for Fischer-Tropsch synthesis gas. Figures No. 9 and 10 show the general configuration of these two types of gasifiers and Figures No. 11 and 12 show the required ancillary equipment.

The single-stage unit is less costly to build and simpler to operate, due in part to the small amount of char recycle. However, we expect a high rate of char loss in the overhead stream and a higher rate of coal and oxygen consumption per unit of output than that required for the two-stage unit.

Table No. 10 shows that predicted higher thermal efficiency and lower utilities consumption (oxygen) more than offsets the lower capital cost of the single-stage unit. We therefore will use the two-stage entrained gasifier as the basis for the design for the Fischer-Tropsch complex.

4. Activity Forecast Next Quarter

We will complete the process design, flow diagrams, heat, material, and energy balances for the complex. We will prepare equipment specifications. We will generate a layout for the complex and prepare a fixed capital cost estimate. We will start the economic evaluation of the complex. We will prepare

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and review the draft of the technical portion of the R&D report that will describe the design.

E. COG Plant Design

1. Objectives

The first objective is to develop a preliminary design of a coal processing plant that will produce liquid and gaseous fuels as principal products. The processes employed in this plant design shall be the result of an economic selection from the candidate coal conversion processes available.

The second objective is to develop a model capable of calculating material and heat balances for a number of coal conversion processes using computer capability and to estimate the overall utility balance of the complex.

2. Activity in this Quarter

We continued development and utilization of the computer simulation program addressing hydroliquefaction, catalytic liquefaction, and donor solvent-type processes. We continued the process and capital cost evaluation of candidate processes.

The basic yields for each process were obtained from published data; the reliability of these data varies widely. The data for each process were tabulated in a form suitable for easy comparison.

Subsequently, we adjusted the product yields obtained for a particular coal to the yields to be expected if the process was using Illinois No. 6 coal. We then completed the yield analysis for each candidate process by computer simulation. We based the comparative product yields and economic analyses for each candidate process on the following parameters:

Coal source	Illinois No. 6
Feed to dissolver	25 MTPD coal
Feed to gasifier	100% coal as required to produce necessary quantity of H_2
SNG	1 MBtu/SCF HHV
	2% H_2 and 0.1% CO max
Filter cake product	5% liquid content

Dry filter cake and additional coal as required are used for generation of low-Btu fuel gas supplying all fuel requirements of the complex, including electric generating facilities.

We advanced the design of an air-blown low-pressure single-stage gasifier for production of inplant low-Btu fuel gas. We developed a flow sheet for this gasifier, including the required ancillaries.

3. Results of the Activities

a. Hydroliquefaction. We made preliminary studies of eight different modes of operation of hydroliquefaction complexes and studied in depth four of these process as follows.

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(1) Hydrogen consumption at 2 wt % of feed coal, MAF basis, with high-purity hydrogen dissolver feed gas source

(2) Same hydrogen consumption with syngas as dissolver feed gas source

(3) Hydrogen consumption at 3.3 wt % of feed coal, MAF basis, with high-purity hydrogen dissolver feed gas

(4) Same hydrogen consumption with syngas as hydrogen dissolver feed gas source

The 3.3 wt % hydrogen consumption case is obtained by operating with slurry recycle as used in the "Clean Boiler Fuels from Coal" demonstration plant design (R&D Report No. 82). Calculations were completed for Items (2), (3), and (4). Figures 13, 14, and 15 are block flow diagrams illustrating the yields of the complex for these three cases.

b. Catalytic Hydroliquefaction Conversion. We analyzed the latest published pilot plant data generated by Hydrocarbon Research, Inc., and correlated them with data from the report "Project H-Coal" published by the American Oil Company. We are using process conditions as indicated by

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the process developer and have made preliminary computer simulation runs.

c. Catalytic Hydroliquefaction (Synthoil). We analyzed published pilot plant data included in a report on run FB-30 as obtained from the Bureau of Mines. We have made preliminary computer simulation runs based on developer process conditions.

d. Donor Solvent Liquefaction. We analyzed the pilot plant data for this process, which were based on West Virginia coal feed and calculated yields for the various plant units on this basis. We are in the process of converting these data to yields expected from Illinois No. 6 coal feed.

e. Plant Fuel Gasifier. A flow diagram and material balance as well as an air-blown gasifier design were prepared for a low-Btu gasifier and gas cleaning facility. Figure 16 shows the flow diagram for this unit. One or several of these units will be used as required for the various candidate processes. A capital cost estimate for the unit is underway.

4. Activity Forecast Next Quarter

We will complete the process evaluation of the eight basic processes considered for the complex and will complete and issue a preliminary study report including process information, capital cost estimates, and economic analyses covering at least six of these candidate processes.

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F. Equipment Development

1. Objective

The objectives are to define the equipment and control system development programs required to ensure reliability of coal conversion processes being developed and to recommend appropriate developmental programs to ERDA-FE.

2. Activities this Quarter

a. Liquid/Solids Separation. We continued our search for improvement or elimination of filters. The use of expellers and vacuum film evaporators, and improvements to filter media were considered. We started discussions concerning the applicability of vacuum filters.

b. Gas/Solids Separation. We explored further the ultimate removal of fine particles from streams issuing from cyclones. We addressed particularly the use of scrubbers and wet and dry electrostatic precipitators with emphasis on units capable of operating at pressures up to 475 psig.

c. Filter Cake Solvent Recovery. We investigated various approaches to the problem of the recovery of liquids from filter cake. Kilns, wiped film evaporators, and various types of heated screw conveyors or similar apparatus were considered. We discussed the results of tests of the "Torus Disc" dryer at the Tacoma pilot plant with the manufacturer.

d. Solids Feed to Gasifiers. We continued to explore the field of equipment that might present potential use as solids feed device for medium- and high-pressure gasifiers in lieu of lock hopper systems. Specifically, work is underway to establish the potential of expellers and extruders for this purpose.

e. Valves. We continued contacts with industry in our search for valves suitable for coal slurry and solids-carrying gas stream.

3. Results of the Activities

a. Liquid/Solids Separation

(1) Expeller. The V. D. Anderson Company of Cleveland, Ohio tested their basic expeller to separate dissolver product from the Tacoma pilot plant into its solid and liquid components. These tests proved unsuccessful. However, the equipment still shows promise for separating wash solvent from filter cake and samples for such testing were requested.

(2) Disc/Conveyor-type Dryer. The Berwind Corporation Torus Disc dryer was tested at the Tacoma pilot plant to separate wash solvent from the filter cake. The test results were not encouraging due to caking of the filter cake solids on the heated discs and due to unsatisfactory forward movement of the dried minerals/ash mixture to the outlet. Berwind Corporation feels

that a 3 to 1 admixture of dried filter cake to the fresh filter cake feed using controlled recirculation will solve the caking problem. They further feel that increase in size of the devices causing the forward movement will improve the flow through the dryer. The Berwind Corporation is in the process of planning for manufacture of an improved unit to be used for testing at the pilot plant.

b. Gas/Solids Separation. We collaborated with a number of manufacturers of gas/solids separation equipment to define equipment to be used to remove practically all solids from the feed gas stream to the Fischer-Tropsch unit. The result of these consultations resulted in providing a combination in sequence of the following equipment:

- Two-stage cyclones
- Hot electrostatic pressure-type precipitator
- Venturi scrubber
- Wet electrostatic precipitator

The result of this process is a clean syngas with less than 0.001 grains of solids per 100 standard cubic feet.

c. Solid Feed to Gasifiers. We investigated the potential of extruder-type feeders to accept ground coal at

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atmospheric conditions and feed it into high-pressure gasifier feed streams. The V. D. Anderson Company of Cleveland, Ohio is planning a test facility to obtain test results for pressures up to 1,000 psig.

d. Valves and Pressure Letdown Devices. We contacted a number of manufacturers engaged in this field. Some of these manufacturers are willing to collaborate in the testing of their devices for specific sets of operating conditions in actual pilot plant work.

4. Activity Forecast Next Quarter

We will continue efforts to obtain test results for liquids/solids separation and coal feeding devices by means of expellers or extruders.

We will attempt to simplify the equipment required for gas/solids separation.

G. Materials of Construction Assessment

1. Objectives

The objective is to define the preferred materials of construction for use in coal conversion projects.

2. Activity this Quarter

We continued participation in the work of the Metals Property Council (MPC) at the Illinois Institute of Technology Research Institute. These activities were rather low key during the quarter.

We established material-of-construction requirements for various complexes being designed under this contract.

3. Results of the Activity

Through our attendance at MPC Phase III, Aqueous Corrosion, we helped in changing the emphasis of the program from an empirical approach to determining the effect on the corrosion of candidate materials by chemical factors occurring in various areas of coal conversion processes.

4. Activity Forecast Next Quarter

We will complete the materials of construction specification for the oil/gas and Fischer-Tropsch plant designs.

We will continue our support of the ongoing activities of the Metals Property Council as appropriate.

H. Environmental Considerations

1. Objectives

The objectives are to define environmental factors for proposed coal conversion complexes, to define facilities required for the coal conversion complexes to meet environmental standards, and to define product quality standards to meet environmental regulations for product users.

2. Activities this Quarter

We continued the study of various coal conversion effluent streams emitted by the units presently under design. We

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assessed their ecological effect and developed means of rendering them environmentally acceptable.

We addressed the problem of rendering vent gas emissions of acid gas treatment processes ecologically acceptable and studied the treatment techniques for conversion of Fischer-Tropsch water effluent to make it reusable in the process. We further studied the ecological problems of coal mining and coal preparation.

3. Results of these Activities

   a. Coal Drying. We defined a method to dry crushed coal by using steam as a heating medium instead of using a coal-fired dryer. This avoids ecologically unacceptable dryer stack emissions.

   b. Fischer-Tropsch Process Water Reuse. We developed a system to convert the major part of the process water effluent into boiler feed water, thus reducing the amount of liquid plant effluents.

4. Activities Forecast Next Quarter

We will concentrate on providing necessary measures to make all effluents of the oil/gas and Fischer-Tropsch plant designs ecologically acceptable. We will also monitor the products emanating from these plants to ensure that their use is ecologically suitable and meets required rules and standards.

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I. <u>Publications</u>

1. Objectives

In the course of the development of the designs, our objectives will be to prepare and present invited papers before various technical bodies to communicate the status of Parsons efforts and knowledge to the scientific and industrial community.

2. Activities this Quarter

We presented the following report and papers:

(1) Report titled "Commercial Complex, Conceptual Design/ Economic Analysis; Oil and Power by COED based Coal Conversion;" R&D Report No. 114 - Interim Report No. 1, plus transmittal of all required copies.

(2) Invited paper titled "Oil/Gas Plant Design Criteria" before the 68th Annual Meeting of the American Institute of Chemical Engineers in Los Angeles, California on November 19, 1976.

(3) Invited paper titled "Fischer-Tropsch Plant Design Criteria" before the 68th Annual Meeting of the American Institute of Chemical Engineers in Los Angeles, California on November 19, 1976.

(4) Invited paper titled "Gaseous Environmental Factors in Coal Pyrolysis Plant Design" before the ASME/IEEE Joint Power Generation Conference in Portland, Oregon on

October 1, 1975. The paper was published by the American Society of Mechanical Engineers as Publication No. 75-PWR-3.

3. Activities Forecast Next Quarter

We will present the following:

(1) Invited paper before the American Institute of Plant Engineers (AIPE) Symposium titled "Industrial Energy Usage Patterns" in February 1976 in Seattle, Washington.

(2) Capsule versions of the papers presented earlier, titled "Oil/Gas Plant Design Criteria" and "Fischer-Tropsch Plant Design Criteria," for publication in the Chemical Engineering Progress Magazine.

(3) Invited paper titled "Coal Liquefaction: Materials System Design" to be presented before the American Society of Metals (ASM), Systems and Design Symposium in April 1976 in Pittsburgh, Pennsylvania.

(4) Invited paper titled "Preliminary Analysis: Oil and Power by COED Based Coal Conversion" to be presented before the American Chemical Society (ACS), Industrial Engineering Chemicals Division in April 1976 in New York City, N.Y.

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J. Technical Meetings

1. Objectives

The objectives were to advance interchange of communications with others engaged in the field of coal conversion, especially members of government, academia, and industry, and further, to enhance Parsons expertise and acquaint others with Parsons contributions to the forward movement of the field by personal contacts.

2. Attendance

We attended the following technical meetings and symposia:

(1) ASME/IEEE Joint Power Generation Conference from September 28 to October 2, 1975 in Portland, Oregon.

(2) AGA/ERDA Pipeline Gas Symposium from October 27 to 29, 1975 in Chicago, Illinois.

(3) 68th Annual AIChE Meeting from November 16 to 20, 1975 in Los Angeles, California.

(4) Meeting sponsored by EPA Environmental Research Laboratories on the subject: "Environmental Aspects of Coal Conversion Technology II" from December 15 to 18, 1975 in Hollywood, Florida.

3. Activities Forecast Next Quarter

We will attend the American Institute of Plant Engineers (AIPE) Symposium on February 26, 1976 in Seattle, Washington.

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APPENDIX 1

BASIS OF ECONOMIC EVALUATIONS

The plant produces 157,000 MMBtu/d. The 320 T/d of byproduct sulfur is credited at $30/T. Plant operating rate is 330 d/yr. Startup costs are estimated at $20 MM. One-hundred-percent equity financing is used.

Working capital is based on the following:

- 3-day coal inventory
- 30-day inventory of finished product
- 4% major equipment for spare parts inventory
- 30-day accounts receivable
- 30-day budget for current expenses
- 30-day credit for accounts payable

Consumption of coal is 10 MTPD at $12/T. Total operators, including supervision, are 271 at an average hourly wage rate of $6. As a result, the annual cost of operating labor is $3.4 MM/yr. Payroll burden is 35% of total labor; plant overhead is 60% of operating and maintenance labor, including payroll burden. Utility costs are internally generated. The G&A overhead is computed at 1.5% of manufacturing costs.

Maintenance is calculated at 4% of fixed-capital investment except where otherwise stated: 40% is applied to labor and 60% to materials. Property tax and insurance is 2.75% of fixed capital investment. Straight-line method of

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calculating depreciation is used. The useful life for depreciation purposes is 20 years. Working capital is obtained from equity.

The discounted cash flow rate of return (DCF) on equity is 12% after 52% combined federal and state income taxes.

The required annual revenue is presented in the form of equivalent uniform annual costs (EUAC). This method may be used to compare nonuniform time series of money disbursements and receipts at a given discount value. The present value of each nonuniform disbursement is calculated and then restated in terms of an equivalent uniform annual series. This is a convenient means of showing a single representative cost item when using the DCF method.

Although in the base case all utilities were produced internally, for case comparison purposes it was necessary to assign utility cost values. The following were used:

- Fuel at $3.20/MMBtu
- Steam at $3.20/Mlb (Oil/Gas Plant)
  $2.00/Mlb (Fischer-Tropsch Plant) (See Note)
- Power at $30/MWh
- Water at $0.10/Mgal

Note: Due to the fact that the steam for the Fischer-Tropsch complex is generated in the various exothermic reactors without expenditure for fuel gas and boiler plant investment, an average cost of $2.00/Mlb was assigned for the preliminary comparisons of process alternates.

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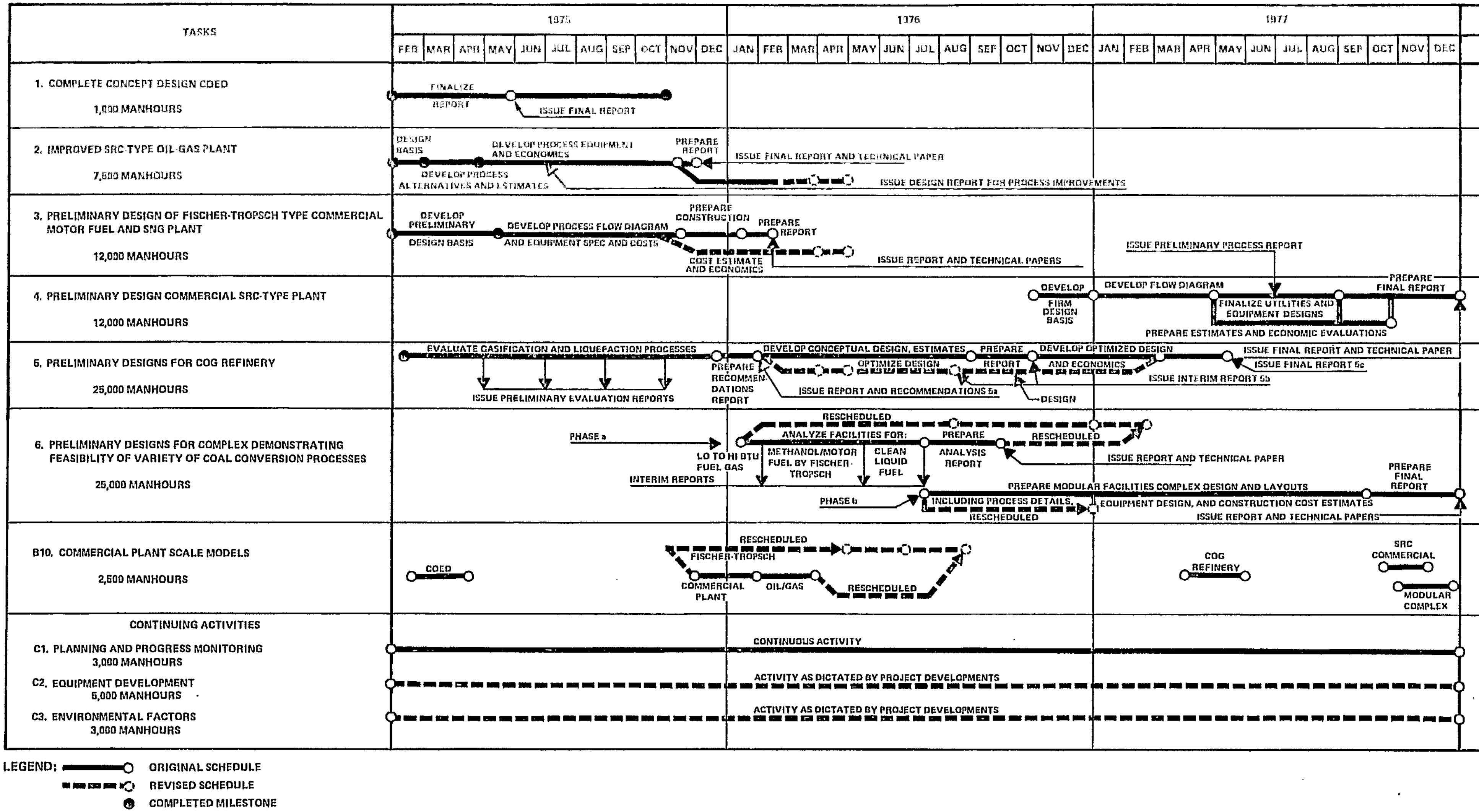

Figure 1 - Overall Program Schedule
ERDA Contract E(49-18)-1775
Parsons Job No. 5435
Issue 3/1/76

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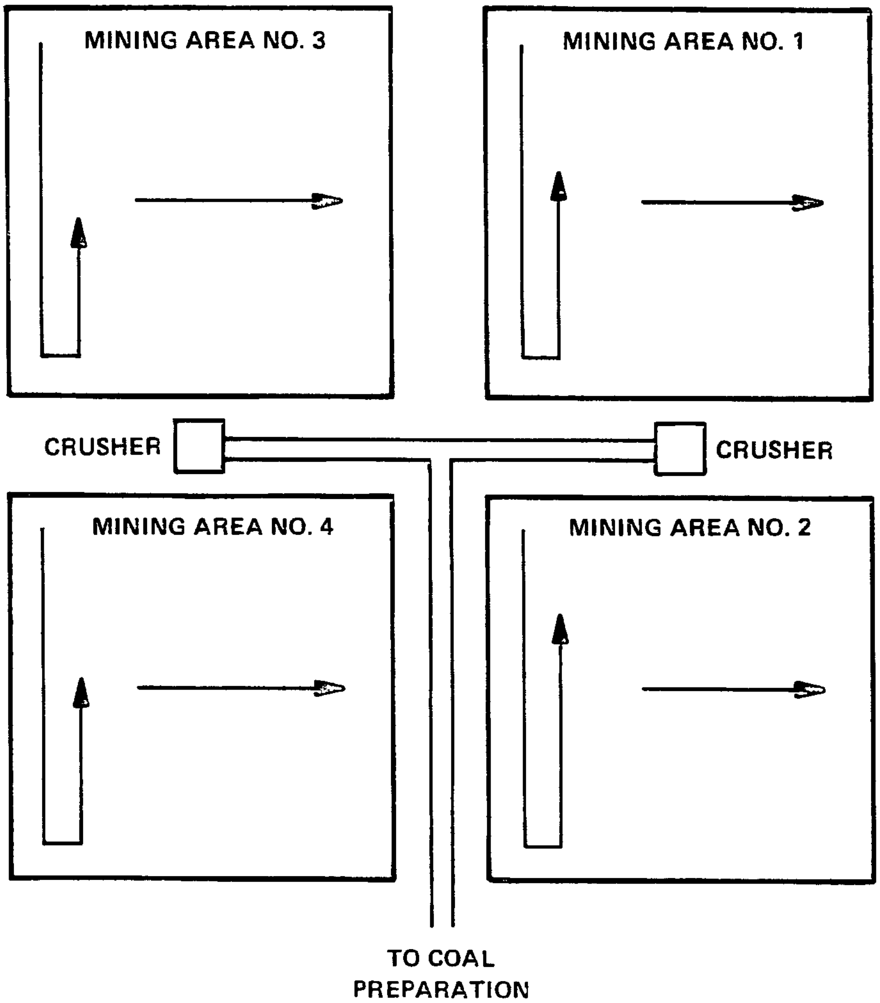


Figure 2 - Mining Plan
Coal Mining/Coal Preparation

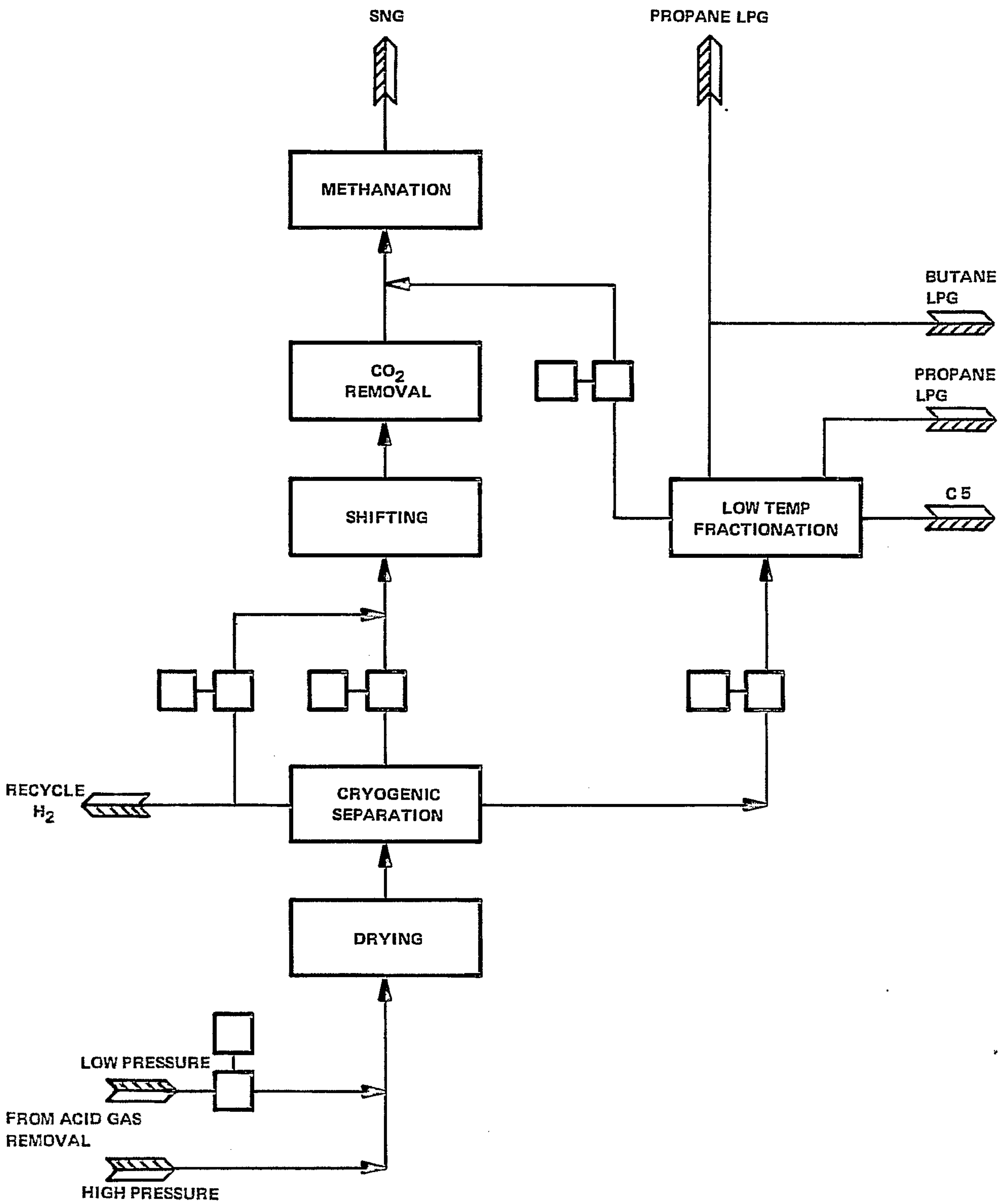


Figure 3 - SRC Process
SNG and LPG Production Schematic Diagram
Oil/Gas Plant

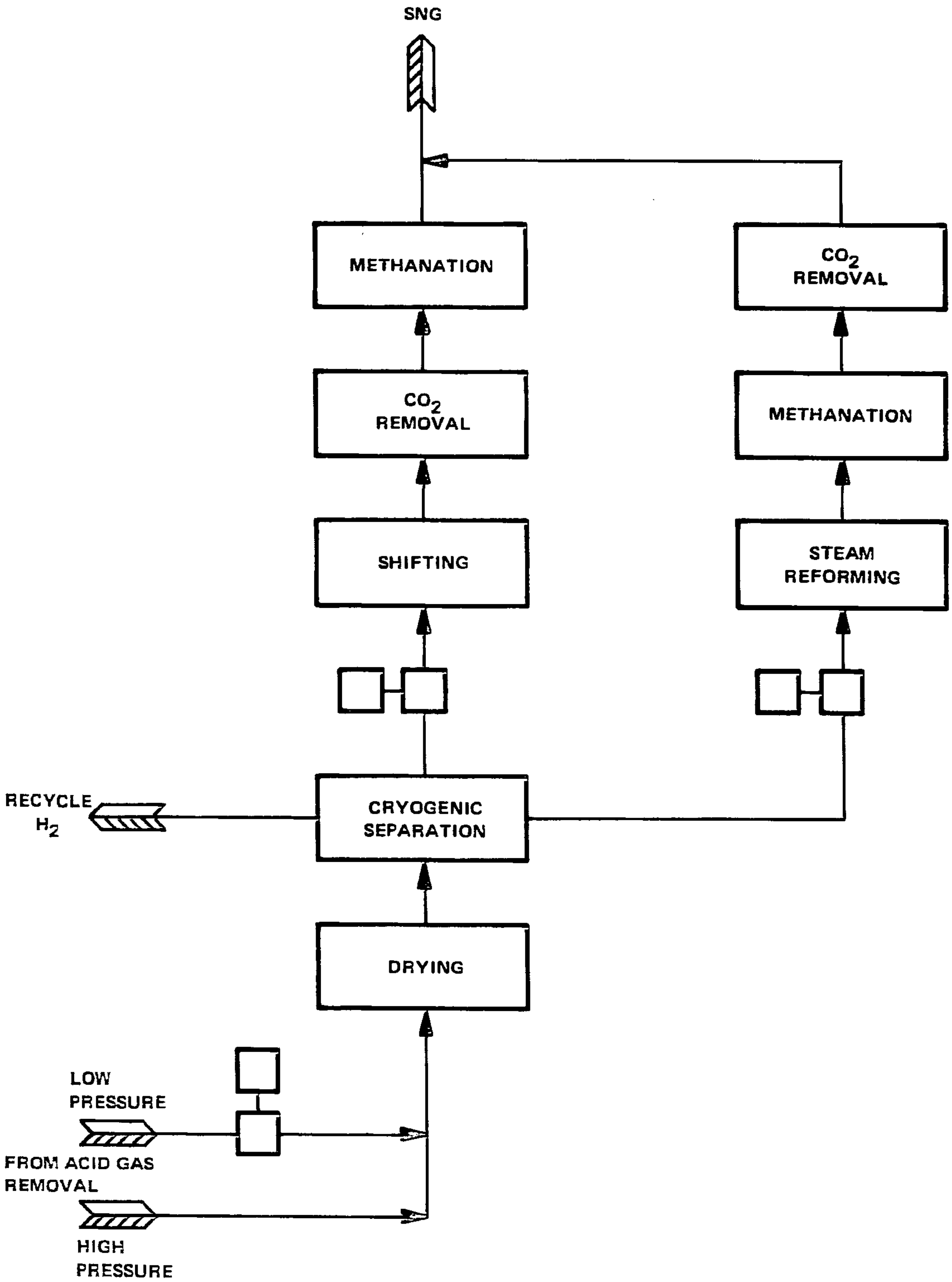


Figure 4 - SRC Process
SNG Production (No LPG Product) Schematic Diagram
Oil/Gas Plant

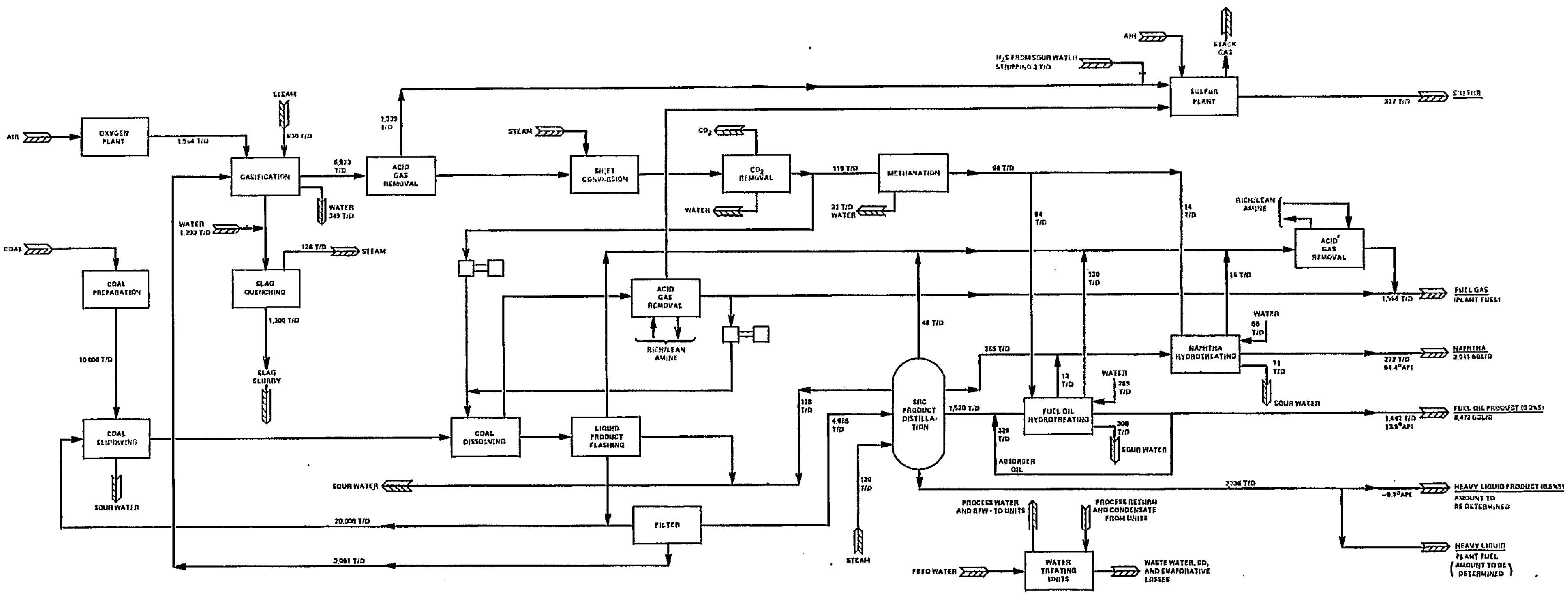


Figure 5 - SRC Process
H_2 Dissolver Feed
Oil/Gas Plant

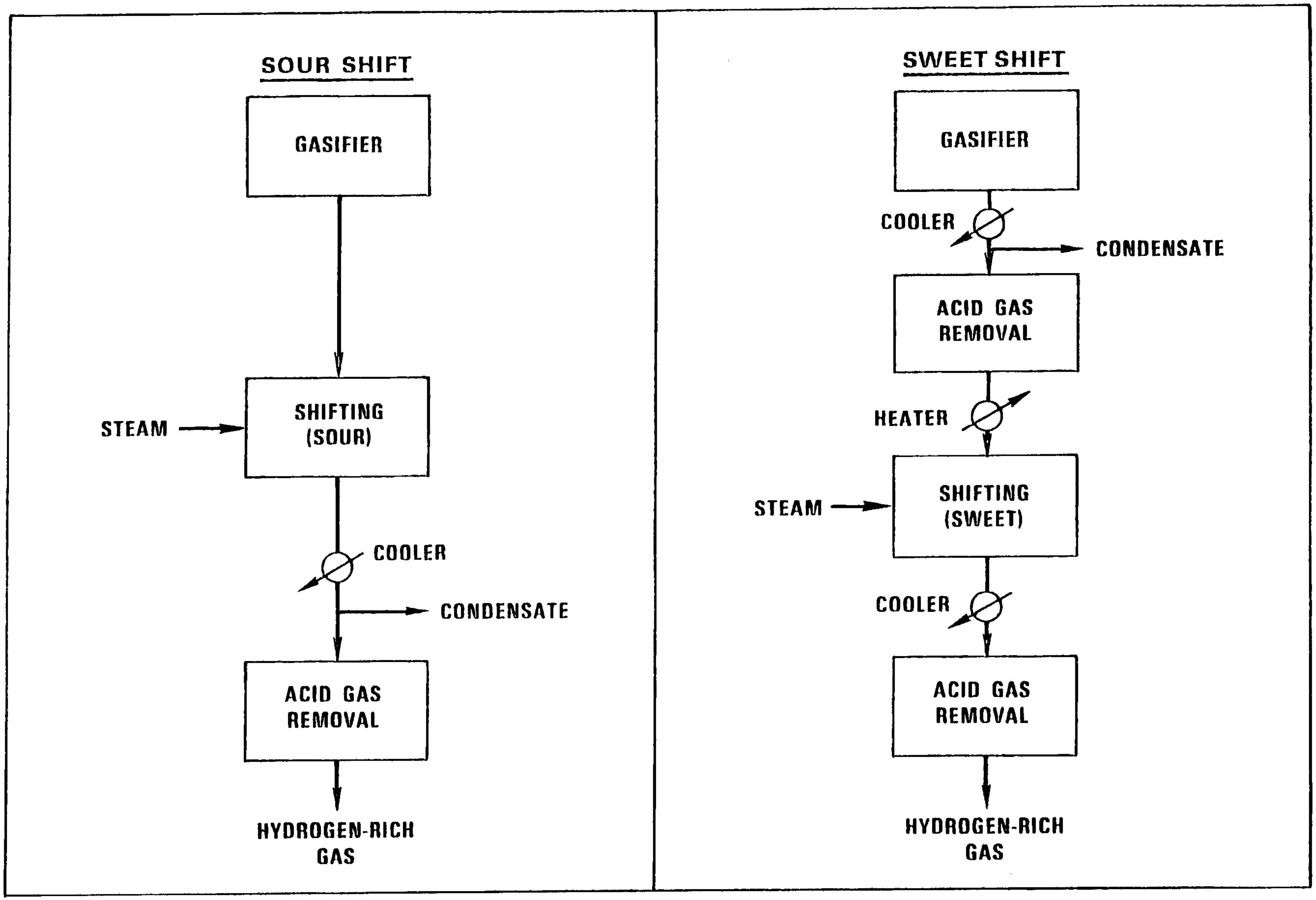


Figure 6 - SRC Process
Sour Vis-a-Vis Sweet Shift, Process Configuration
Oil/Gas Plant

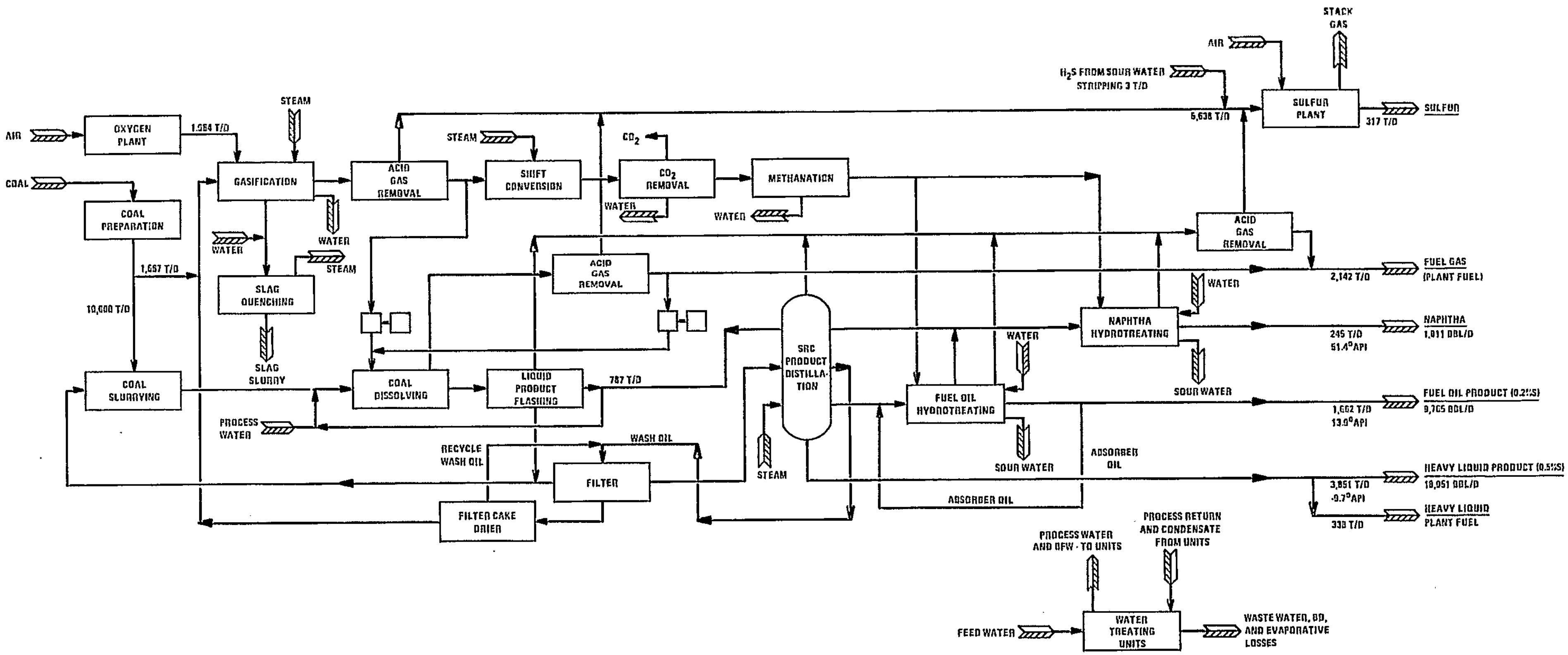
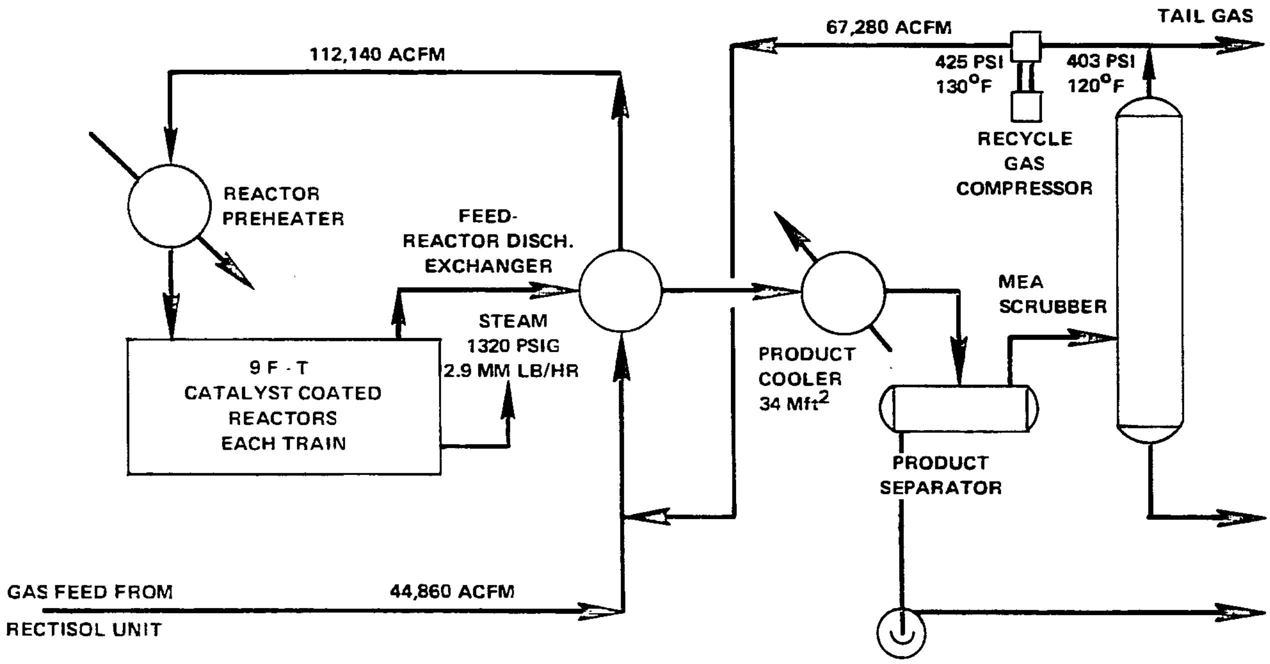
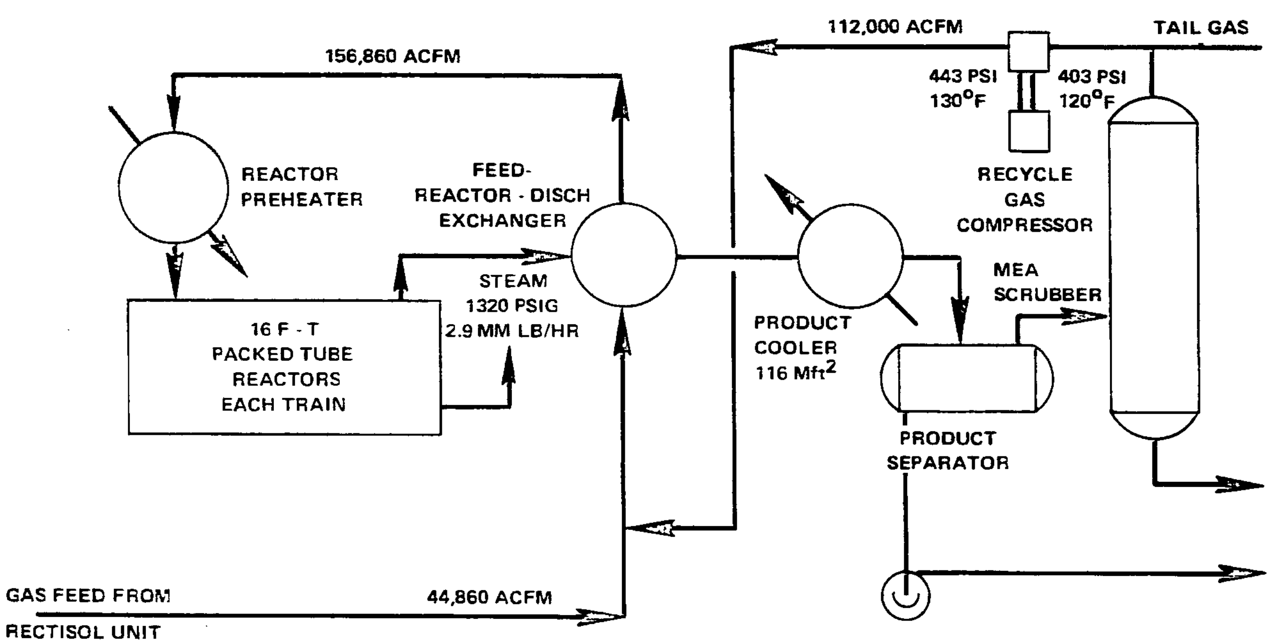


Figure 7 - SRC Process
Filter Cake Drying Preliminary Block Flow Diagram
Oil/Gas Plant



Fischer-Tropsch Synthesis
Coated Fin Tube System



Fischer-Tropsch Synthesis
Packed Tube System

Figure 8 - Alternative Fischer-Tropsch Reactor Trains
Fischer-Tropsch Plant

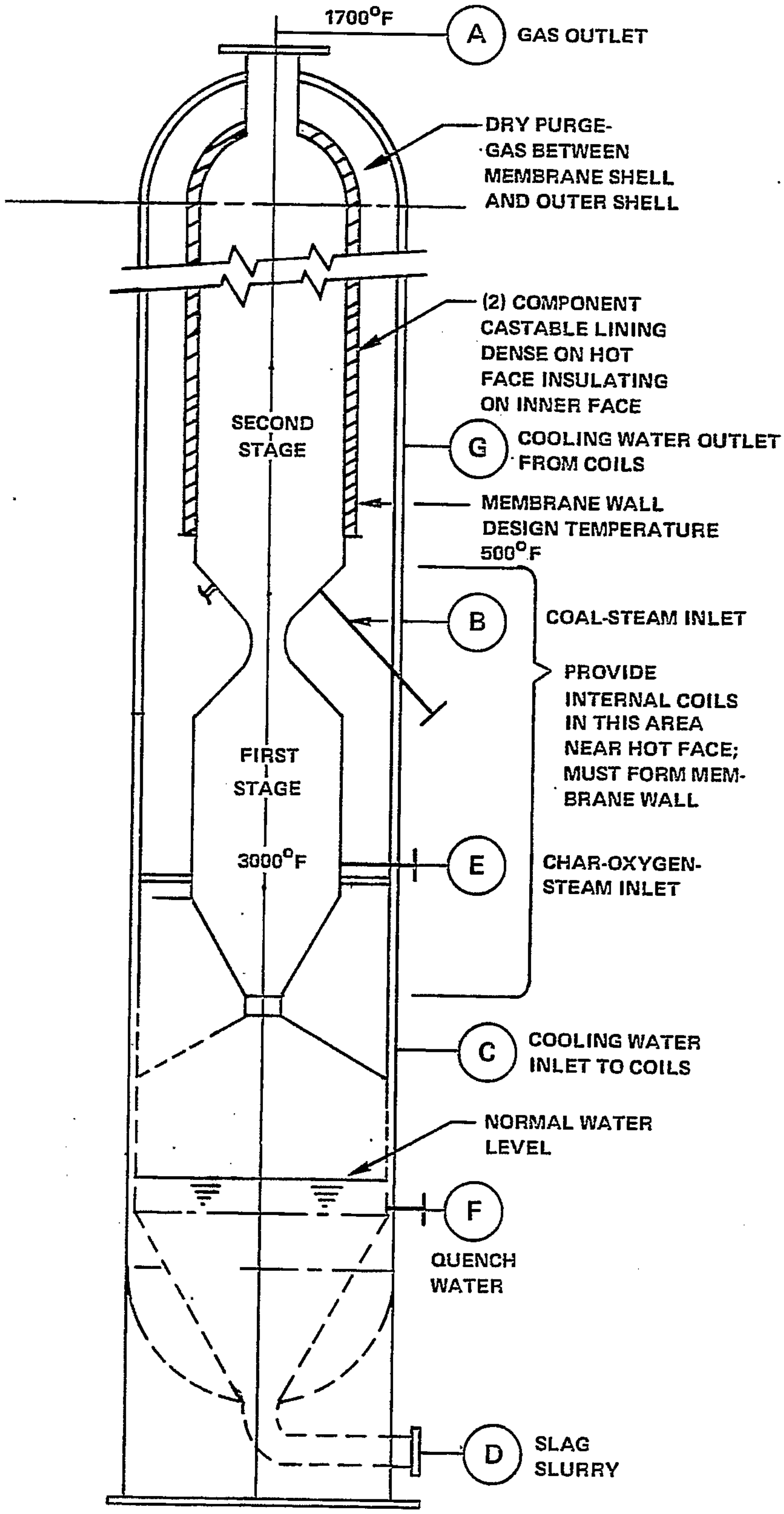


Figure 9 - Two-Stage Gasifier Design Concept
Fischer-Tropsch Plant

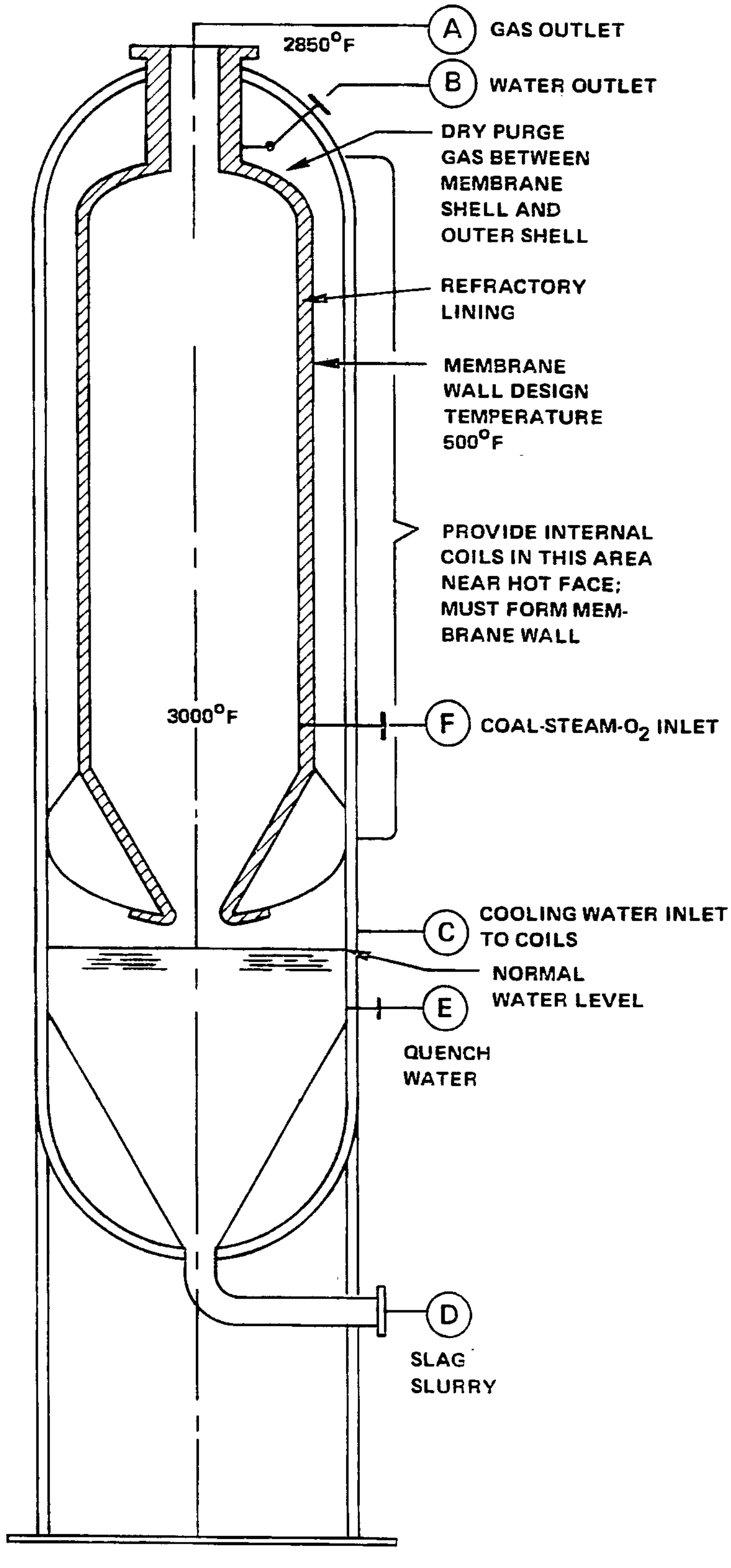


Figure 10 - Single-Stage Gasifier Design Concept
Fischer-Tropsch Plant

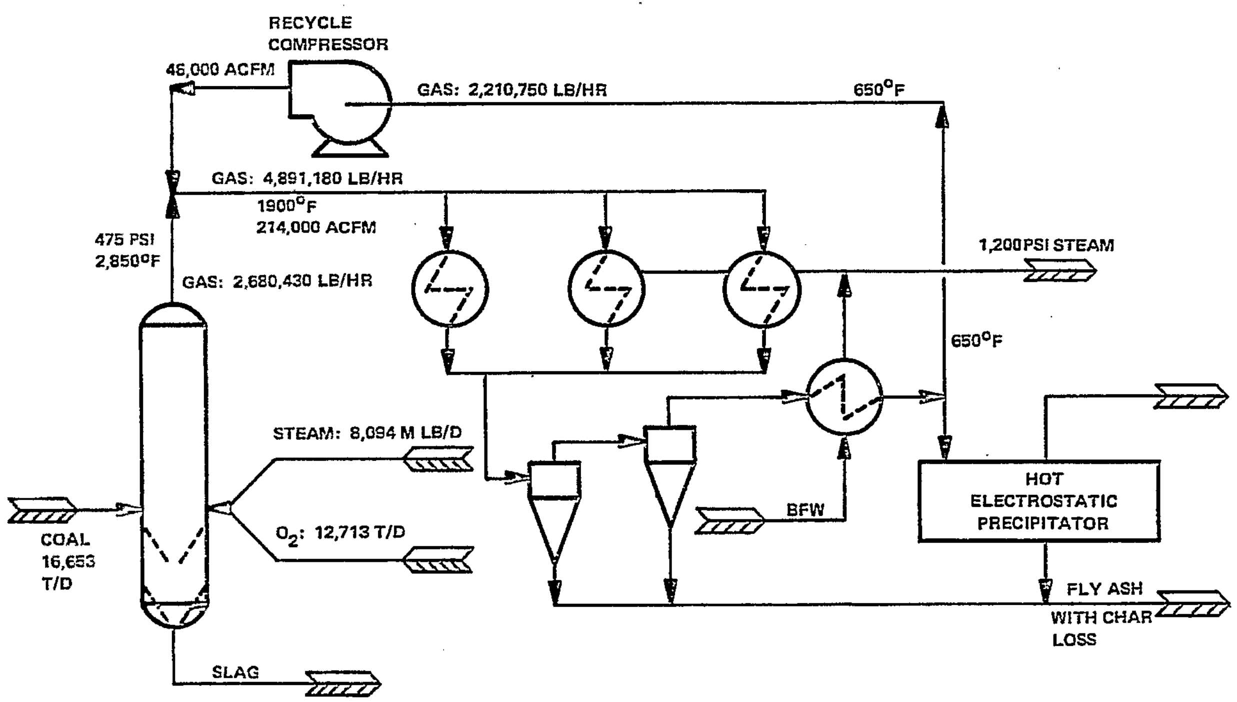


Figure 11 - Single-Stage Entrainment Gasifier Flow Diagram (One of Two Trains)
Fischer-Tropsch Plant

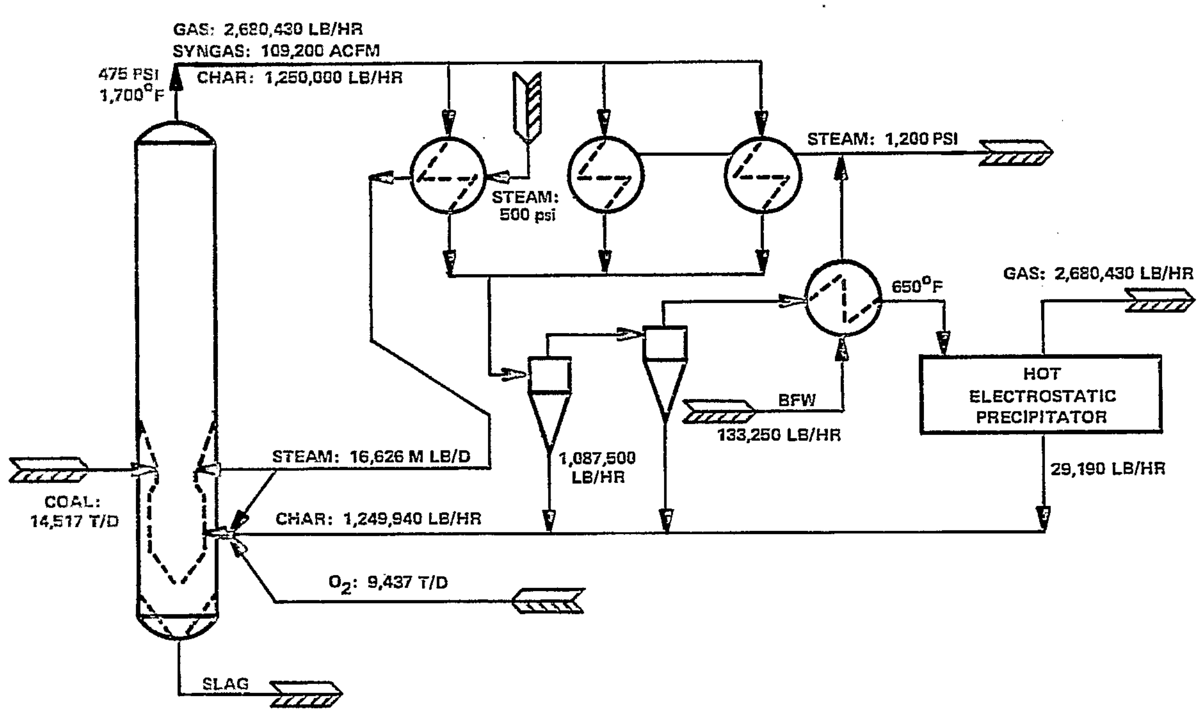


Figure 12 - Two Stage Entrainment Gasifier Flow Diagram (One of Two Trains)
Fischer-Tropsch Plant

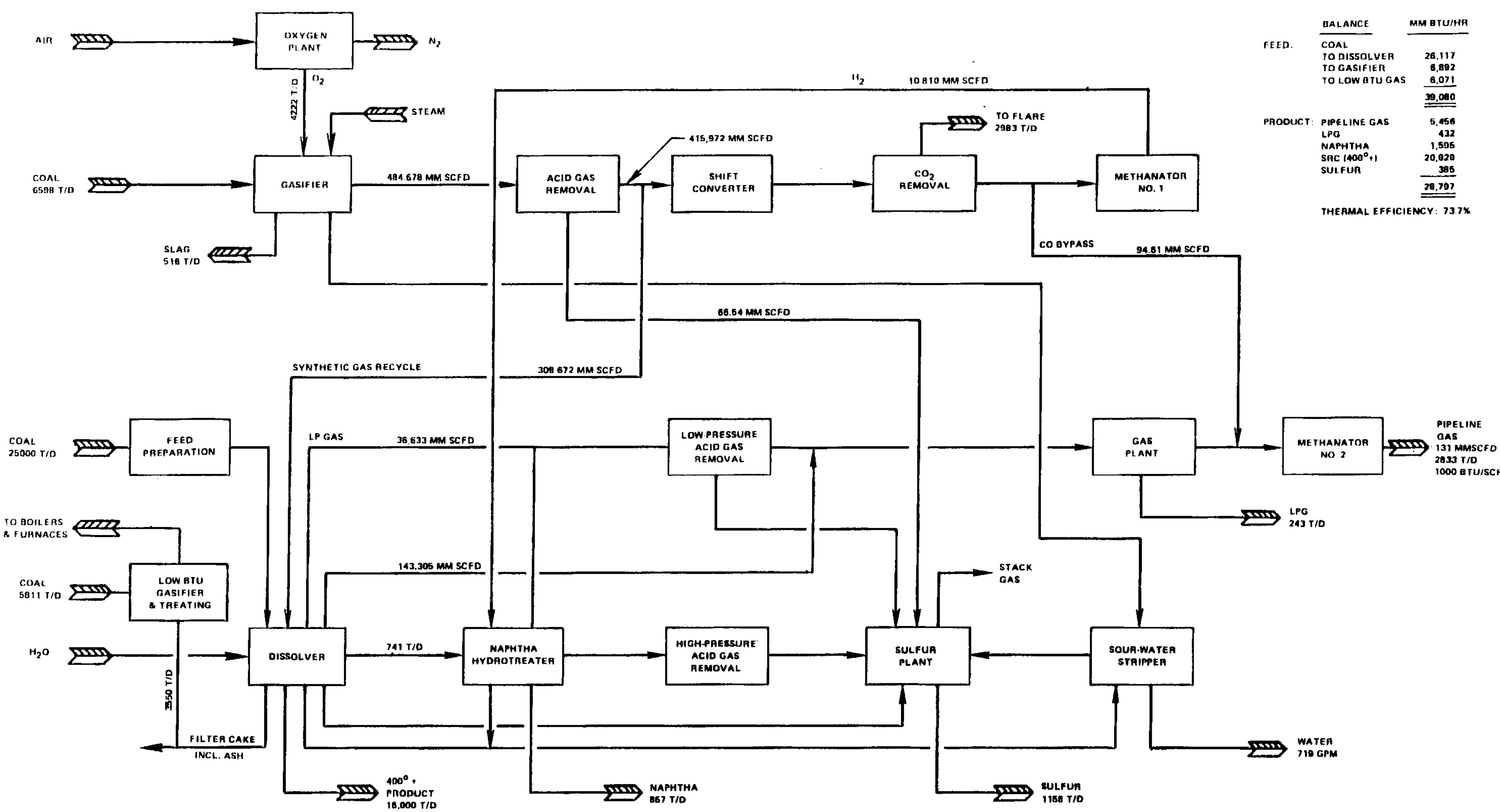


Figure 13 - SRC Process: 2% H_2 Uptake
Syngas and Distillate Feed to Dissolver
COG Plant

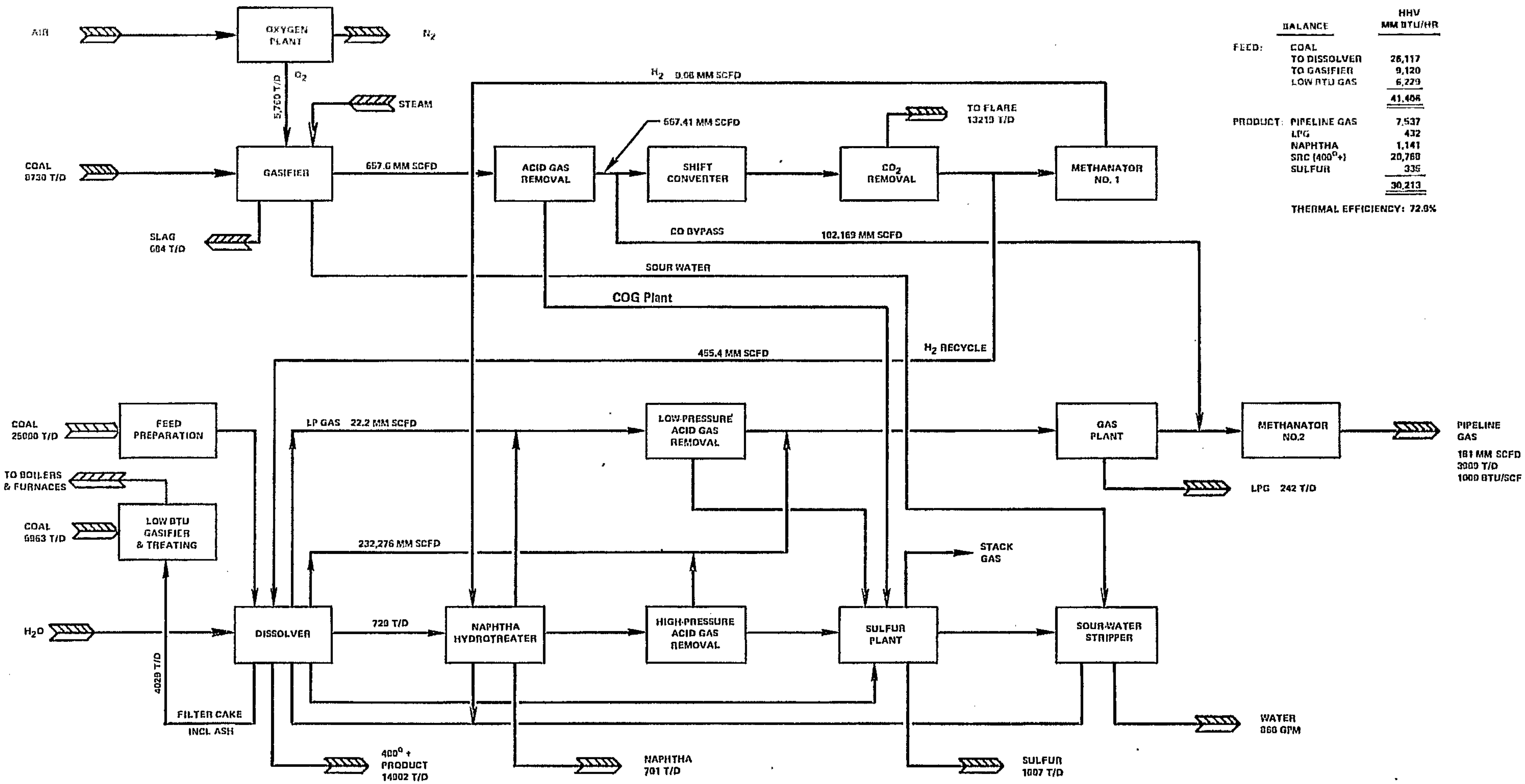
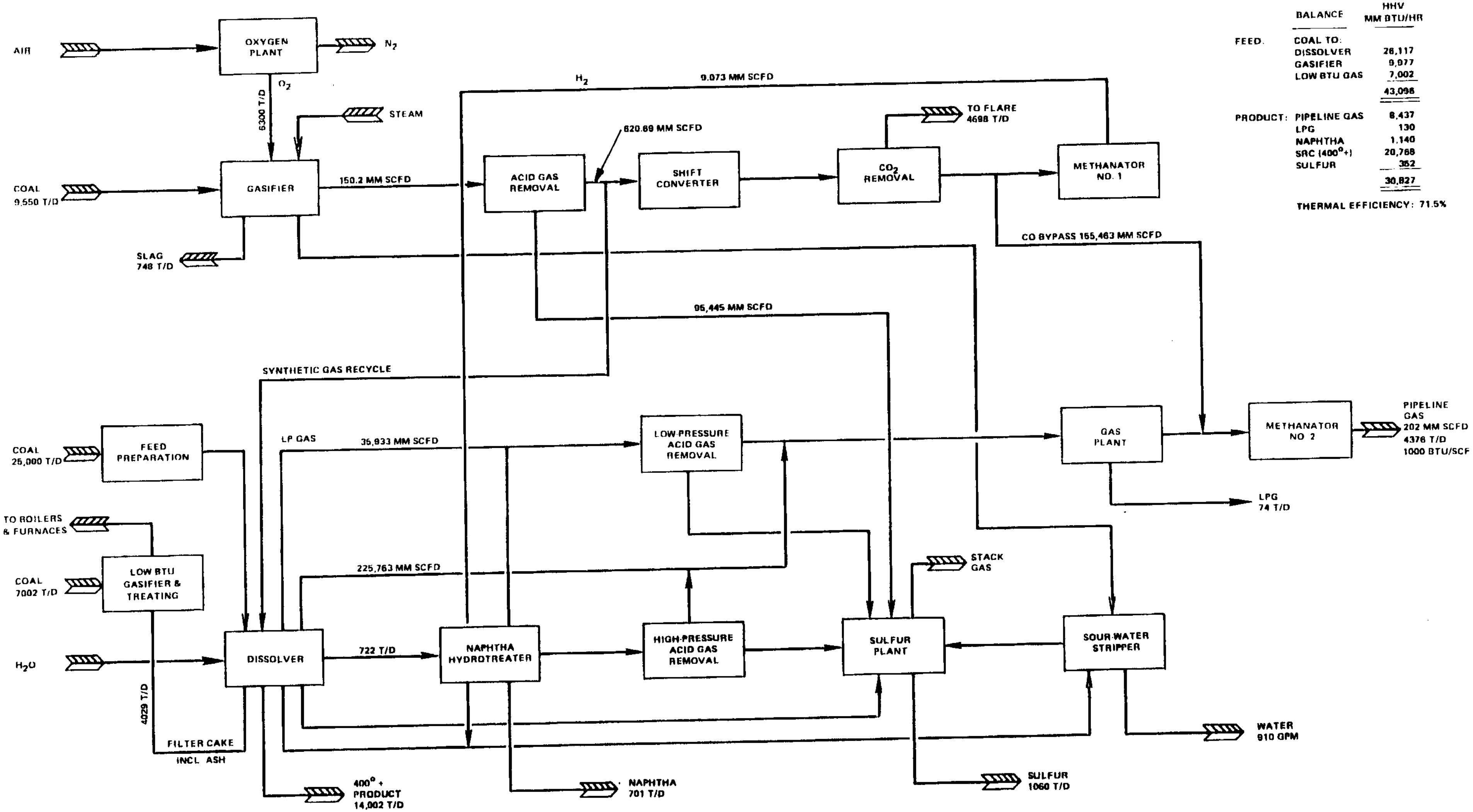


Figure 14 - SRC Process: 3.3% H_2 Uptake
H_2 and Slurry Feed to Dissolver
COG Plant



	BALANCE	HHV MM BTU/HR
FEED.	COAL TO:	
	DISSOLVER	26,117
	GASIFIER	9,077
	LOW BTU GAS	7,002
		43,096
PRODUCT:	PIPELINE GAS	8,437
	LPG	130
	NAPHTHA	1,140
	SRC (400°+)	20,768
	SULFUR	352
		30,827

THERMAL EFFICIENCY: 71.5%

Figure 15 - SRC Process: 3.3% H_2 Uptake
Syngas and Slurry Feed to Dissolver
COG Plant

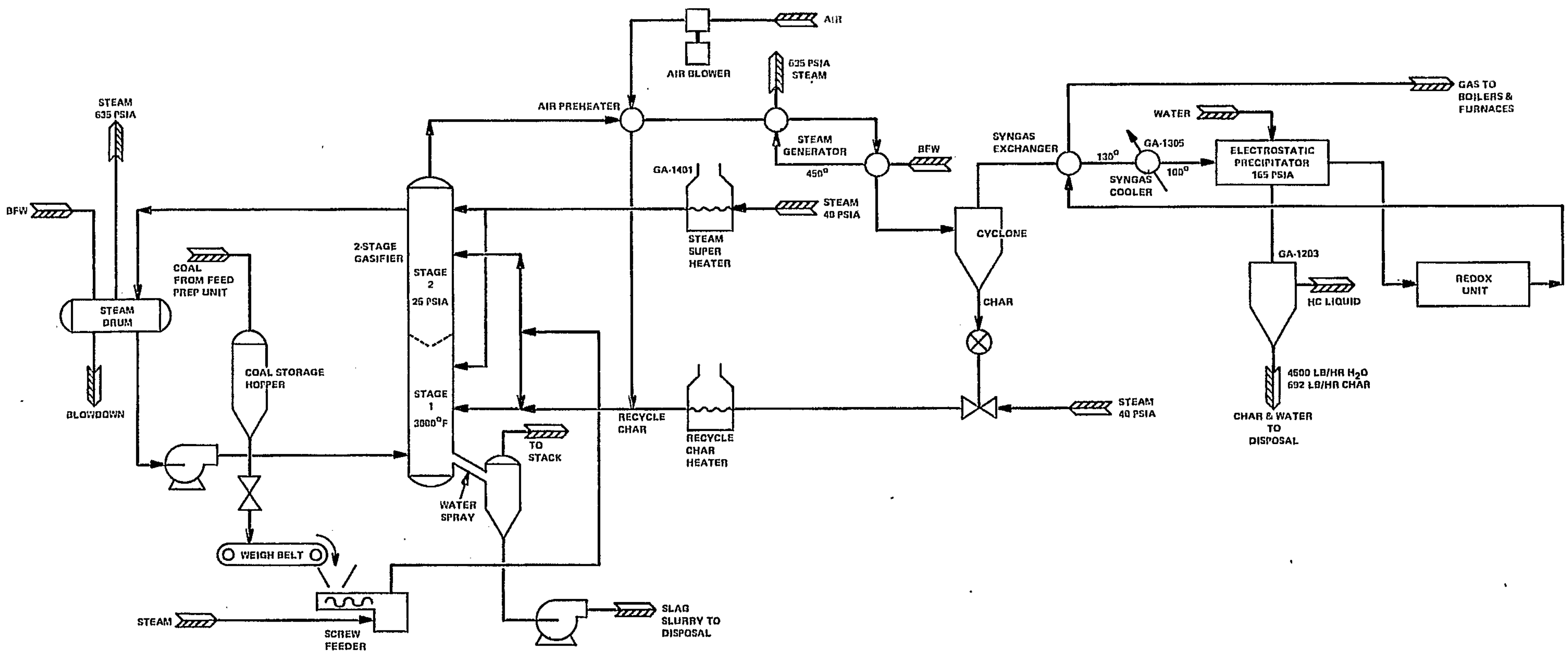


Figure 16 - Low Btu Gasifier Flow Diagram
COG Plant

Table 1 - Demonstration Plant Estimate
Economics Update
EUAC at 12% DCF
Oil/Gas Plant

Costs	$MM/yr
Coal	39.6
Catalysts and Chemicals	4.4
Operating Labor	3.4
Maintenance Labor	3.7
Payroll Burden	2.5
Plant Overhead	5.7
Maintenance Materials	7.5
Utilities	
Property Tax and Insurance	8.6
G&A Overhead	1.1
Total	76.5
Income Tax	39.4
Investment	
Fixed Capital Investment Burden	48.3
Initial Catalysts and Chemicals	0.3
Startup Costs	2.4
Total	51.0
Working Capital	2.1
Credit for Sulfur	(3.2)
Required revenue	
$MM/yr	165.8
$/MMBtu	3.20

Table 2 - Additional SNG Production
EUAC at 12% DCF
Oil/Gas Plant

	Updated Demonstration Plant		Case A (LPG+SNG)		Case B (SNG Only)	
		$MM/yr		$MM/yr		$MM/yr
Costs						
Coal	10,000 TPSD	39.6	10,000 TPSD	39.6	10,000 TPSD	39.6
Catalysts and Chemicals		4.4		4.7		5.0
Operating Labor		3.4		3.4		3.4
Maintenance Labor		3.7		3.8		3.9
Payroll Burden		2.5		2.5		2.7
Plant Overhead		5.7		5.8		6.3
Maintenance Materials		7.5		7.8		7.8
Utilities		Incl		Incl		Incl
Property Tax and Insurance		8.6		8.9		9.0
G&A Overhead		1.1		1.2		1.2
Total		76.5		77.7		78.9
Income Tax		39.4		41.0		41.3
Investment, $MM						
Fixed Capital	311	48.3	323	50.2	326	50.7
Initial Catalysts and Chemicals		0.3	2.591	0.3	2.541	0.3
Startup Costs	20	2.4	20	2.4	20	2.4
Total		51.0		52.9		53.4
Working Capital	20	2.1		2.1		2.1
Credit for Sulfur	320 T	(3.2)		(3.2)		(3.2)
Total Required Revenue		165.8		170.5		172.5
Production, MMBtu/d	156,720		126,828		124,350	
Required Selling Price $/MMBtu		3.20		4.07		4.2

Table 3 - Syngas vs. Hydrogen as Dissolver Feed
Case A (LPG+SNG)
EUAC at 12% DCF
Oil/Gas Plant

	Hydrogen		Syngas	
		$MM/yr		$MM/yr
Costs				
Coal	10,000 TPSD	39.6	10,825 TPSD	42.9
Catalysts and Chemicals		4.7		4.5
Operating Labor		3.4		3.4
Maintenance Labor		3.8		4.0
Payroll Burden		2.5		2.6
Plant Overhead		5.8		6.0
Maintenance Materials		7.8		8.2
Utilities		Incl		Incl
Property Tax and Insurance		8.9		9.4
G&A Overhead		1.2		1.2
Total		77.7		82.2
Income Tax		41.0		43.1
Investment, $MM				
Fixed Capital	323	50.2	341.3	53.1
Initial Catalysts and Chemicals	2.6	0.3	1.6	0.2
Startup Costs	20	2.4	20	2.4
Total		52.9		55.7
Working Capital	20	2.1	21	2.2
Credit for Sulfur	320	(3.2)	320	(3.2)
Required Revenue		170.5		180.0
Production, MMBtu/d	127,800		138,000	
Required Selling Price, $/MMBtu		4.1		3.96
Syngas Case		3.96		
Savings with Syngas		$ 0.14		

Table 4 - Alternate H_2S Removal Processes
EUAC to Achieve a 12% DCF After
Tax Return on Investment
Oil/Gas Plant

	Units	Unit Cost	Physical Solvent Process No. 1 Quantity per Year	Physical Solvent Process No. 1 EUAC $MM/yr	Physical Solvent Process No. 2 Quantity	Physical Solvent Process No. 2 EUAC $MM/yr	Chemical Absorption Quantity	Chemical Absorption EUAC $MM/yr
Catalysts and Chemicals								
Methanol	Mlb	$65.00			198	0.013		
Benfield Solution								0.004
Utilities								
Steam	Mlb	$ 3.20		-		-	573,400	1.835
Cooling Water	Mgal	$ 0.10	475,200	0.048	370,000	0.037	-	-
Power	kW	$ 0.03	19,100,000	0.57	6,400	0.192	1,300	0.037
Nitrogen $9/T	MSCF	$ 0.33	3.564×10^6	1.188				
Total				1.810		0.229		1.372
Capital Associated								
Fixed Capital Investment	$MM		2.1	0.281	2.36	0.316	3.9	0.523
Working Capital	$MM		0.43	0.046		0.017	0.99	0.104
Maintenance Labor				0.025		0.028		0.046
Payroll Burden				0.009		0.010		0.016
Maintenance Material				0.051		0.057		0.094
Plant Overhead				0.020		0.023		0.037
Property Tax and Insurance				0.058		0.065		0.107
Total				0.490		0.516		0.972
G&A Overhead				0.029		0.006		0.068
Income Tax				0.240		0.233		0.467
Total				2.569		0.997		3.383
Less Chemical Absorption Cost				3.383		3.383		
Savings				0.814		2.386		

Table 5 - Comparison of Sweet and Sour Shift Economics
Savings in EUAC with 12% DCF
Oil/Gas Plant

Utilities		EUAC Savings $ Millions/yr
Fuel Gas	762,700 MMBtu/yr at 3.20/MMBtu	2.440
Power	36,000,000 kW/yr at $0.025/kWh	(1.080)
Steam	1,228,300 Mlb/yr at $3.20	3.930
Total		5.290
Capital Associated		
Fixed Capital Investment - $2.23 MM		0.347
Working Capital		0.065
Maintenance Material		0.054
Maintenance Labor		0.026
Payroll Burden		0.009
Plant Overhead		0.021
Property Tax and Insurance		0.061
G&A Overhead		0.050
Income Tax		0.325
Total Savings		$6.248
Sour Shift Savings in $/MMBtu based on 157,000 MMBtu/d		$0.121

Table 6 - Filter Cake Washing, Material and Utility Balance
Oil/Gas Plant

	Without Filter[a] Cake Washing	With Filter Cake Washing
Coal Feed		
To Dissolvers	10,000 T/d	10,000 T/d
To Gasifier	-	1,667 T/d
Plant Products (after supplying plant fuel)		
Naphtha	270 T/d 2,000 B/d 10,600 MMBtu/d	245 T/d 1,800 B/d 9,600 MMBtu/d
Fuel Oil	1,440 T/d 8,500 B/d 48,800 MMBtu/d	1,660 T/d 9,800 B/d 56,300 MMBtu/d
Heavy Liquid	2,915 T/d 14,300 B/d 96,000 MMBty/d	3,850 T/d 19,000 B/d 126,800 MMBtu/d
Plant Fuel Required		
Fuel Gas	2,140 T/d	2,140 T/d
Heavy Liquid	120 T/d	340 T/d

[a]Refer to R&D Report No. 82

Table 7 - Filter Cake Solvent Recovery, Economic Evaluation
EUAC at 12% DCF - Oil/Gas Plant

	EUAC $Million/Yr	EUAC $/MMBtu
Raw Material Coal at $12.00/T	6.600	
Capital Associated Costs		
Fixed Capital Investment ($11.93 million)	1.854	
Working Capital	0.122	
Maintenance (at 8% of FCI)		
Labor	0.283	
Payroll Burden	0.099	
Plant Overhead	0.229	
Materials	0.573	
Property Tax & Insurance	0.328	
	3.488	
G&A Overhead	0.086	
Income Tax	1.495	
Total Additional Revenue Required	$11.670	
Base Case at 156,700 MMBtu/d	$165.844	3.207
With Solvent Recovery 194,000 MMBtu/d	$177.514	2.773
Savings in $/MMBtu		$0.434

Table 8 - Economic Comparison - Fischer-Tropsch Reactors
Difference in Operating Cost Between Packed Catalyst
Tube Reactors (Base Case) and Finned Tube
Reactors With Catalyst on Fins
Fischer-Tropsch Plant

Costs	EUAC Savings $MM/yr	EUAC $/MMBtu
Steam Consumed	2.5	0.015
Maintenance	3.6	0.022
Taxes and Insurance	2.5	0.015
Catalyst Replacement	3.2	0.020
Plant Overhead	0.8	0.005
G&A Overhead	0.2	0.001
Total Costs	12.8	0.078
Income Tax	8.4	0.051
Fixed Capital Investment	11.9	0.072
Working Capital	0.3	0.002
Steam Produced (Credit)	16.5	0.100
	$49.9	$0.303

Table 9 - Comparison of Entrainment Gasifier with Fixed and Fluidized Bed Types
Fischer-Tropsch Plant

	Cost/Unit	Units	Fixed Bed			Fluid Bed			Entrained		
			Units/Sd	$MM/yr	$/MMBtu	Units/SD	$MM/yr	$/MMBtu	Units/SD	$MM/yr	$/MMBtu
Raw Materials											
Coal	$15/T	MT	15.8	78.3	0.95	15.7	77.9	0.94	15.0	74.2	0.90
Oxygen	$10/T	MT	7.6	25.2	0.31	4.2	13.9	0.17	9.4	31.1	0.38
Steam	$ 2/MLB	MMLB	43.9	28.9	0.35	29.3	19.3	0.23	(24.0)	(15.8)	(0.19)
Credit for Tar and Oil	$10/BBL	BBL	5.7	(28.1)	(0.34)	2.9	(14.4)	(0.17)	0	None	None
Maintenance	5% of FCI										
Materials				6.3	0.08		3.7	0.04		3.5	0.04
Labor				3.1	0.04		1.8	0.02		1.8	0.02
Payroll Burden				1.1	0.01		0.6	0.01		0.6	0.01
Plant Overhead					0.03		1.5	0.02		1.4	0.02
Property Tax and Insurance				5.8	0.07		3.4	0.04		3.3	0.04
G&A Overhead				2.3	0.03		1.9	0.02		1.5	0.02
Total Costs				125.4	1.53		10.6	1.32		101.6	1.24
Fixed Capital Investments			$MM 210	28.1	0.34	$MM 122.8	16.4	0.20	$MM 118.3	15.8	0.19
Working Capital				3.9	0.05		3.2	0.04		2.8	0.03
Taxes											
Income Tax	52%			20.5	0.25		13.1	0.16		12.2	0.15
Investment Tax Credit	10%			(2.5)	(0.03)		(1.5)	(0.02)		(1.4)	(0.02)
Subtotal				175.4	2.13		140.8	1.71		131.0	1.59
Less Cost of Entrainment Case				131.0	1.59		131.0	1.59			
Savings				$44.4	0.54		$9.8	0.12			

Table 10 - Economic Comparison - Fischer-Tropsch Entrainment Gasifiers - Two-Stage vs. One-Stage - Two Trains Fischer-Tropsch Plant

	Quantity				Savings	
	Two-Stage	One-Stage	Difference	Cost/Unit	EUAC $MM/yr	$/MMBtu
Raw Materials						
Coal, MTPSD	29.0	33.3	4.3	$15/T	21.146	0.128
Oxygen, MTPSD	18.9	25.4	6.5	$10/T	21.622	0.131
Steam, MMlb/SD	33.3	16.2	17.1	$ 2/Mlb	-11.262	-0.068
Compressor Turbine Steam, Mlb/SD		1,361	1,361	$ 2/Mlb	0.898	0.005
Maintenance				5% of FCI		
Material					-0.160	
Labor					-0.079	
Payroll Burden					-0.027	
Plant Overhead					-0.064	
					0.330	-0.002
G&A Overhead					-0.323	-0.002
Property Taxes and Insurance					-0.147	-0.001
Fixed Capital Investment						
Basic Gasifier in million $	6.150	1.300				
Char Recycle Auxiliaries	2.000					
Recycle Compressor		1.500				
	8.150	2.800	5.350		-0.716	0.004
Working Capital					-0.420	0.003
Income Tax					-0.872	
Investment Tax Credit					+0.064	
Total Tax						0.005
Credit for Steam Produced, Mlb/SD		-15,712	15,712	$2/Mlb	-10.370	-0.063
Savings of two-stage over one-stage gasifier					$19.287	$0.117

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