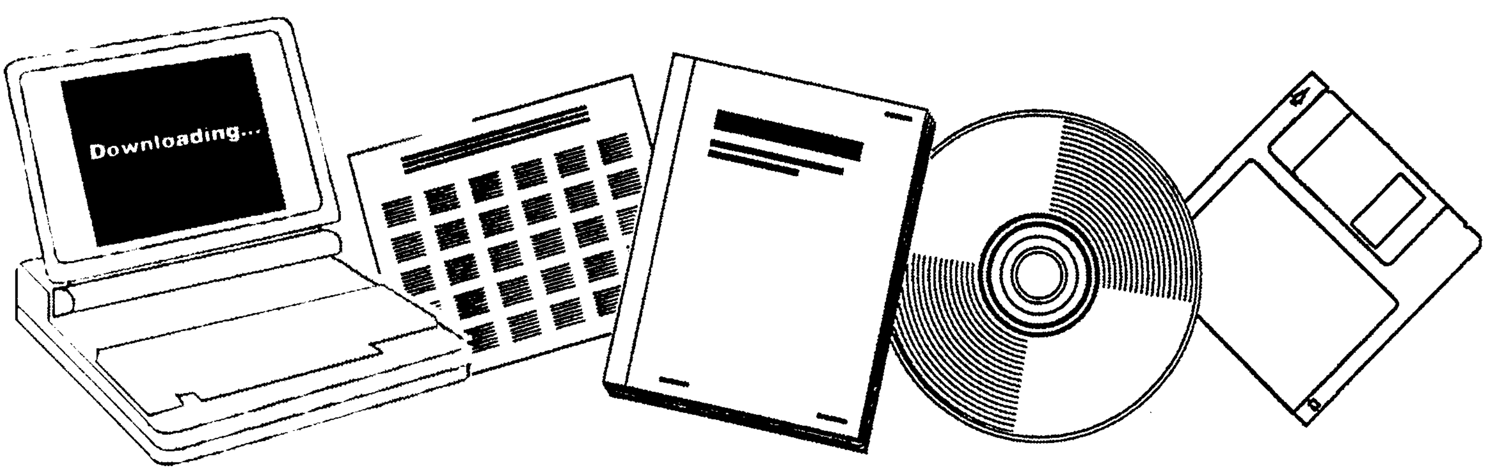
PRELIMINARY DESIGN SERVICES COAL CONVERSION DEMONSTRATION PLANTS. RESEARCH AND DEVELOPMENT REPORT NO. 114. ANNUAL REPORT, JANUARY--DECEMBER 1976

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

MAR 1977



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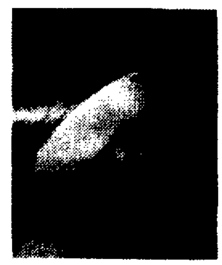

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PRELIMINARY DESIGN SERVICES COAL CONVERSION DEMONSTRATION PLANTS

RESEARCH AND DEVELOPMENT REPORT NO. 114
ANNUAL REPORT
FOR THE PERIOD: JANUARY-DECEMBER 1976

Prepared by:

THE RALPH M. PARSONS COMPANY
100 West Walnut Street
Pasadena, California 91124

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

March 1977

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 1976

Prepared by:

The Ralph M. Parsons Company
100 West Walnut Street
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Energy Research and Development Administration
Washington, D.C. 20545

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

April 1976

ANNUAL REPORT

PRELIMINARY DESIGN SERVICES

THE RALPH M. PARSONS COMPANY

SUMMARY

I. OBJECTIVES

To assist ERDA-Fossil Energy (ERDA-FE) in development of viable commercial coal conversion plants to provide the U.S. with acceptable future energy options for utilization of coal. A key element in achieving this objective is development of preliminary designs that preview design/operating characteristics and projected economics of commercial-scale multi-product coal conversion complexes, including captive coal mines and power plants, using the best data and design techniques available. Also to define additional data and equipment requirements to assure reliable performance of the commercial plants.

II. IMPORTANCE TO FOSSIL ENERGY TECHNOLOGY

The primary impact is to provide a cohesive preliminary definition of the expected characteristics and economics of future commercial coal conversion complexes prepared by Parsons, a major engineering-construction firm.

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 process plant with the coal mine and power plant, operating requirements, and projected economics including the sensitivity of profitability to key economic parameters such as capital investment, operating costs, and raw materials consumption. The project provides:

1. The basis for analysis of capital cost, operating cost, and reliability factor effects on future coal conversion facilities

2. Definition of specific data and information required from the pilot plants to assure successful commercial plant design/operation

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

4. The quantitative economic basis for selection of preferred process alternates

III. PRESENT WORK AND ACCOMPLISHMENTS

- Accomplishments in 1976 include:

  1. Completion of two major conceptual designs/economic evaluations - Fischer-Tropsch and Oil/Gas designs.

The scope of the design reports was expanded to include detailed projections of product characteristics and marketability. Also, summaries of experimental data used for the design basis plus its correlation/interpretation.

2. Completion of preliminary analyses of process candidates for a Coal-Oil-Gas Refinery (COG) and agreement with ERDA on a design basis for the conceptual plant design.

   This design assignment has been renamed Power-Oil-Gas-Other (POGO).

3. Defined procedures for production of petrochemical feedstocks and chemicals from coal in a coal based petrochemical refinery.

4. Completed 15 papers/presentations in support of the ERDA Coal Conversion Development Program; these are listed in Attachment A located at the end of this section. The range of subjects included:

   a) Plant design
   b) Economics
   c) Environmental factors
   d) Materials selection
   e) Petrochemicals from coal

5. Explored the expanded use of computer-assisted simulation capability to optimize the design/operation of large captive power generation/utility systems in coal conversion complexes.

6. Investigated construction procedures and economics for large field fabricated vessels for coal conversion complexes.

7. Completed designs and economic assessments for two large coal mines of 47,000 and 40,000 tons per day capacity.

Additional information regarding key elements of the year's accomplishments are presented in the following paragraphs of this Summary section and reports for the first three quarters of 1976 plus a detailed report on our fourth quarter activities are appended.

A. Fischer-Tropsch Conceptual Plant

The design/economic evaluation was completed and is being published. A block flow diagram, artist's conceptual drawing, and photograph of a model of the complex are shown in Figures 1, 2, and 3, respectively.

This complex will mine approximately 40,000 tons per day (TPD) of run-of-mine coal and wash and size it to produce 30,000 TPD of feed coal to the process plant, where the coal is converted to about 50,000 barrels per day (BPD) of liquid fuel products and 260 million standard cubic feet (SCF) of SNG. This is a two-line plant using an advanced reactor concept still in the development stage. Predesign studies selected preferred equipment/process procedures for each of the process sections.

Computer-assisted process design, fixed capital investment estimating and profitability prediction permitted analysis of a large number of alternatives based on product cost comparisons. As a result, the projected thermal efficiency of the plant is on the order of 70 percent, which is significantly higher than previous plants using this technology.

The predicted fixed capital investment is approximately $1.5 billion. All economics are expressed in fourth quarter 1975 dollars. Predicted required product selling prices, expressed as dollars per million Btu, based on a 12% discounted cash flow rate of return (DCF), 20-year project life, 9% interest rate and 5.7 year design/construction/startup schedule, are:

FINANCING METHOD

100% Equity	$\frac{\text{Debt}}{\text{Equity}}$ Ratio = 65/35	Break-Even
3.25	2.50	1.45

B. Oil/Gas Conceptual Design

This design/economic evaluation was completed. The process scheme is based on the pseudo-catalytic SRC II mode of processing in which unfiltered liquid effluent from the hydroliquefaction reactor is recycled to the reactor with a resulting increase in ash content, retention time and hydrogen consumption in the reactor to produce products which are primarily gases and liquids at ambient conditions.

A simplified block flow diagram, an artist's conceptual drawing, and a photograph of a plant model are shown in Figures 4, 5 and 6, respectively.

The grass roots complex contains a coal mine to produce approximately 47,000 TPD of run-of-mine coal which is converted to about 36,000 TPD of clean, washed coal feed to the process plant where the coal is contacted with hydrogen at approximately 2,000 psig and 850°F. Product recovery and purification produce approximately 65,000 BPD of liquids consisting of LPG, naphtha and fuel oil plus about 165 million SCFD of SNG.

The predicted fixed capital investment is approximately $1.25 billion dollars. All economics are expressed in fourth quarter 1975 dollars. The predicted average required product selling prices, in dollars per million Btu, to provide a 12% DCF return for a 20-year project operating life, 9% interest rate, and a 56 month design/construction schedule, are:

FINANCING METHOD

100% Equity	$\frac{\text{Debt}}{\text{Equity}}$ Ratio = 65/35	Break-Even
2.35	1.80	1.15

Eight detailed process preference studies were completed in the pre-design analysis stage prior to finalizing the process configuration. These study results contributed to achieving the predicted 75-plus percent complex thermal efficiency. A detailed summary of facilities required to assure compliance with environmental requirements was developed.

C. POGO Design

A design basis for this large multi-product complex was completed. To provide guidance, process and economic comparisons were made of all major classes of coal liquefaction and gasification technologies. This design is now in a directed process design phase and is scheduled for completion in 1977.

D. Multi-Purpose Demonstration Plant Design

The purpose of this facilities complex is to demonstrate the commercial feasibility of a variety of coal conversion processes that show promise in pilot plant operations. This major design task was begun, and analyses of candidate processes/facilities were completed, preparatory to finalizing the design basis report. This design/economic summary is scheduled for completion during 1977.

E. Petrochemicals/Chemicals from Coal

A detailed concept of a coal-to-petrochemicals refinery was completed. A block flow diagram for this complex is shown in Figure 7. The complex would process approximately 65,000 TPD of coal and produce olefins, BTX's, SNG, LPG, fuels and chemicals by the following eleven major process steps:

- Coal Liquefaction by SRC II mode of conversion
- Coal Liquefaction by Fischer-Tropsch conversion
- Coal/coal residue gasification to produce syngas and hydrogen
- Hydrocracking of coal liquids
- Naphtha Desulfurization
- Naphtha Reforming
- Aromatics Extraction
- Hydrodealkylation
- Ethylene production
- Hydrogenation of Fischer-Tropsch liquids
- Methanation

F. Supporting Activities

1. Equipment Development

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

b. Status: Major activity was in advanced large pressure vessel design/erection, liquid/solid separation, gas/solid separation, solids feed to gasifiers, 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 selected for the designs Parsons has in progress. Four papers were presented and published in this field.

3. Environmental Factors

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

   b. Status: Analysis and design of facilities required to assure environmental acceptability has now been completed for four coal conversion complexes. Papers have been presented and/or published describing three of these complexes, with the fourth paper scheduled for early 1977.

The bases for defining performance of environmental control requirements for coal conversion facilities are being documented and contact maintained with the proper authorities as new standards are considered.

COAL CONVERSION

PUBLICATIONS AND PRESENTATIONS

1. O'Hara, J. B., Harding, T., Howell, R. D., and Papso, J. E., "Industrial Energy Usage Patterns," Presented at the American Institute of Plant Engineers (AIPE) Symposium, Seattle, Wash., February 26, 1976.

2. O'Hara, J. B., and Teeple, R. V., "Preliminary Economic Analysis: Oil and Power by COED-Based Coal Conversion," Presented at the American Chemical Society (ACS) Symposium, New York, N. Y., April 8, 1976.

3. O'Hara, J. B., Lochmann, W. J., and Jentz, N. E. , "Coal Liquefaction: Materials Systems Design," Presented at American Society for Metals (ASM) Symposium, Pittsburgh, Pa., April 26, 1976.

4. O'Hara, J. B., "Coal Conversion Development: An Overview," Presented at Engineering Institute of Canada (EIC) Conference, Calgary, Alberta, May 12, 1976.

5. O'Hara, J. B., Becker, E. D., Jentz, N. E., and Harding, T., "Potential for Petrochemical Feedstocks and Chemicals from Coal," Presented at the 82nd National Meeting of the American Institute of Chemical Engineers (AIChE), Atlantic City, N. J., August 31, 1976.

6. O'Hara, J. B., Hervey, G. H., Fass, S. M., and Mills, E. A., "Oil/Gas Plant Design Criteria," CEP Capsule, Chemical Engineering Progress, Vol. 72, No. 8, August 1976, Pages 78-79.

7. O'Hara, J. B., Bela, A., Jentz, N. E., and Khaderi, S. K., "Fischer-Tropsch Plant Design Criteria," CEP Capsule, Chemical Engineering Progress, Vol. 72, No. 8, August 1976, Pages 65-67.

8. Lochmann, W. J., "The Materials Problems in Coal Gasification and Liquefaction," Presented at a Symposium of the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME), Niagara Falls, New York, September 22, 1976.

9. Raisbeck, W. C., "Materials, Needs, Opportunities and Problems," Presented at an ERDA/EPRI/AGA-sponsored conference on Materials for Coal Conversion and Utilization, Washington, D.C., September 30, 1976.

10. "Fossil Energy Program Report, 1975-1976," Energy Research and Development Administration, Pages 74-79.

11. O'Hara, J. B., "Coal Liquefaction," Presented at the 3rd International Symposium of the European Federation of Chemical Engineers, Antwerp, Belgium, October 20, 1976.

12. O'Hara, J. B., "Coal Liquefaction," Published proceedings of the 3rd International Symposium of the European Federation of Chemical Engineers, Antwerp, Belgium, October 20, 1976, Pages 43-51.

13. O'Hara, J. B., Loran, B. I., Hervey, G. H., Fass, S. M., "Environmental Factors for Oil/Gas Coal Conversion Technology," Presented at the 69th Annual Meeting of the American Institute of Chemical Engineers (AIChE), Chicago, Ill., December 1, 1976.

14. O'Hara, J. B., "Coal Liquefaction - State-of-the-Art," Hydrocarbon Processing, November 1976, Pages 221-226.

15. O'Hara, J. B., Lochmann, W. J., Jentz, N. E., "Material Considerations in Coal Liquefaction," Metal Progress, November 1976, Pages 33-37. This article was accepted for publication in Chemical Engineering.

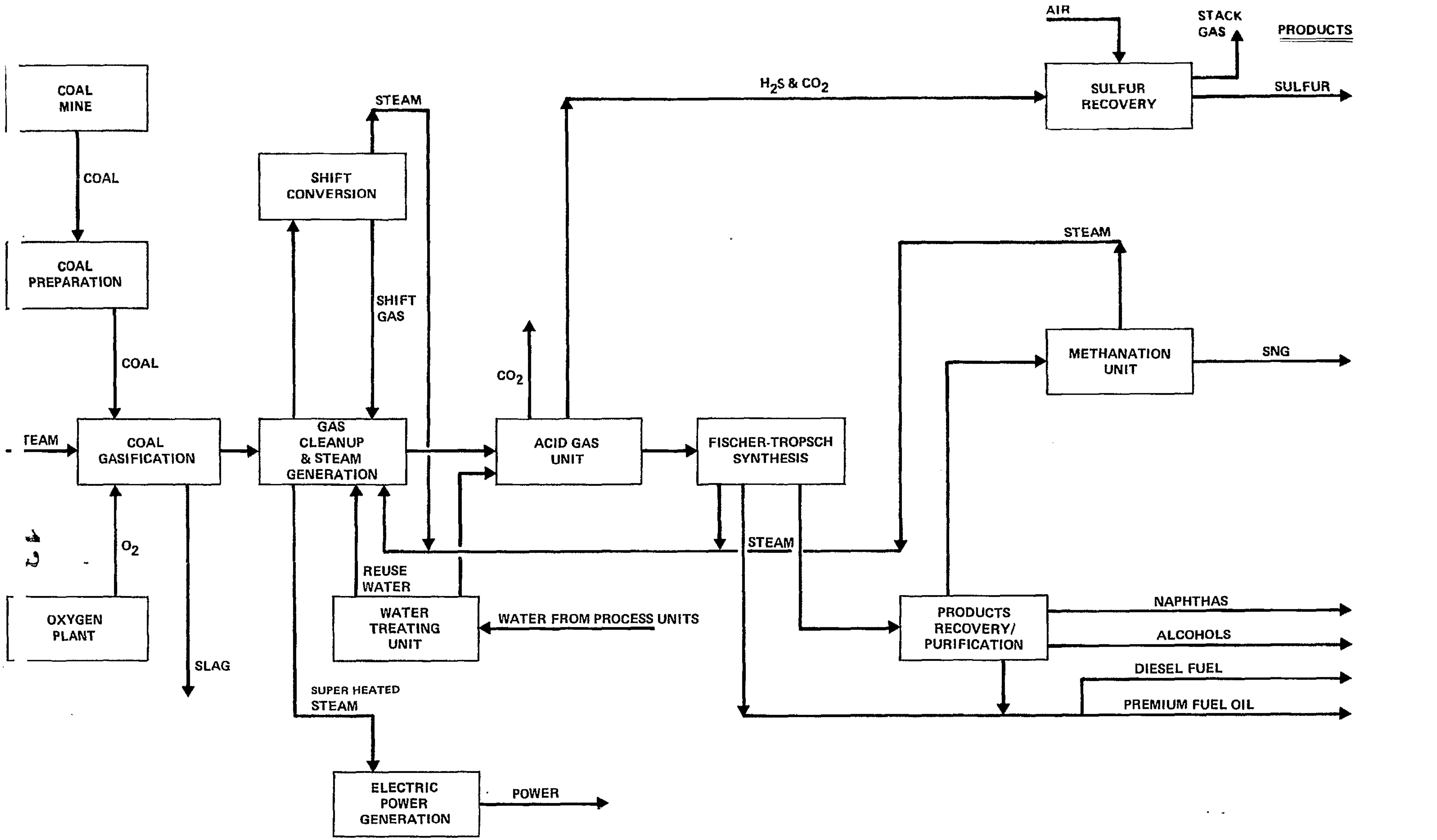

Figure 1 - Fischer-Tropsch Simplified Block Flow Diagram

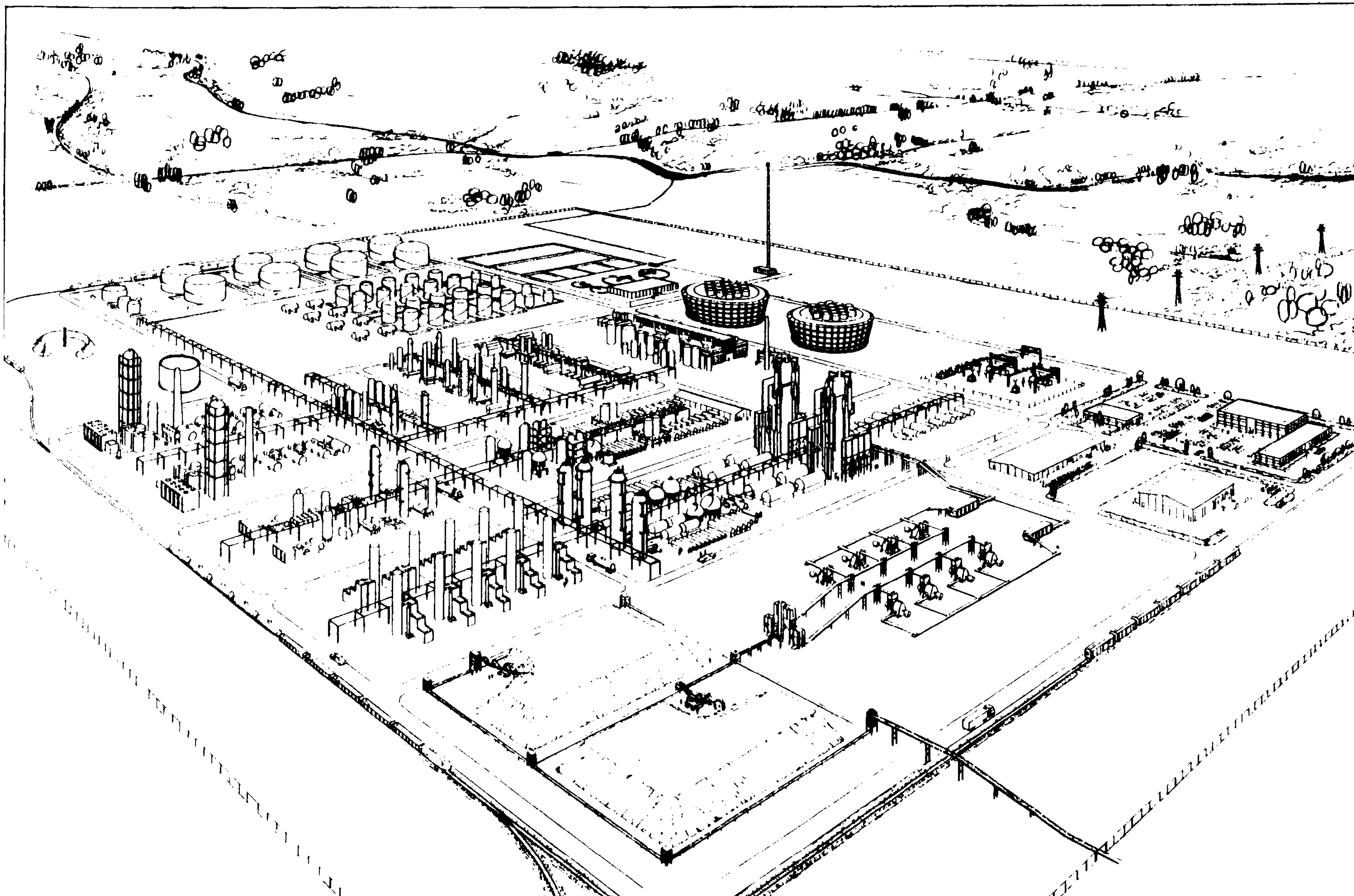

Figure 2 - Artist's Concept, Fischer-Tropsch Plant

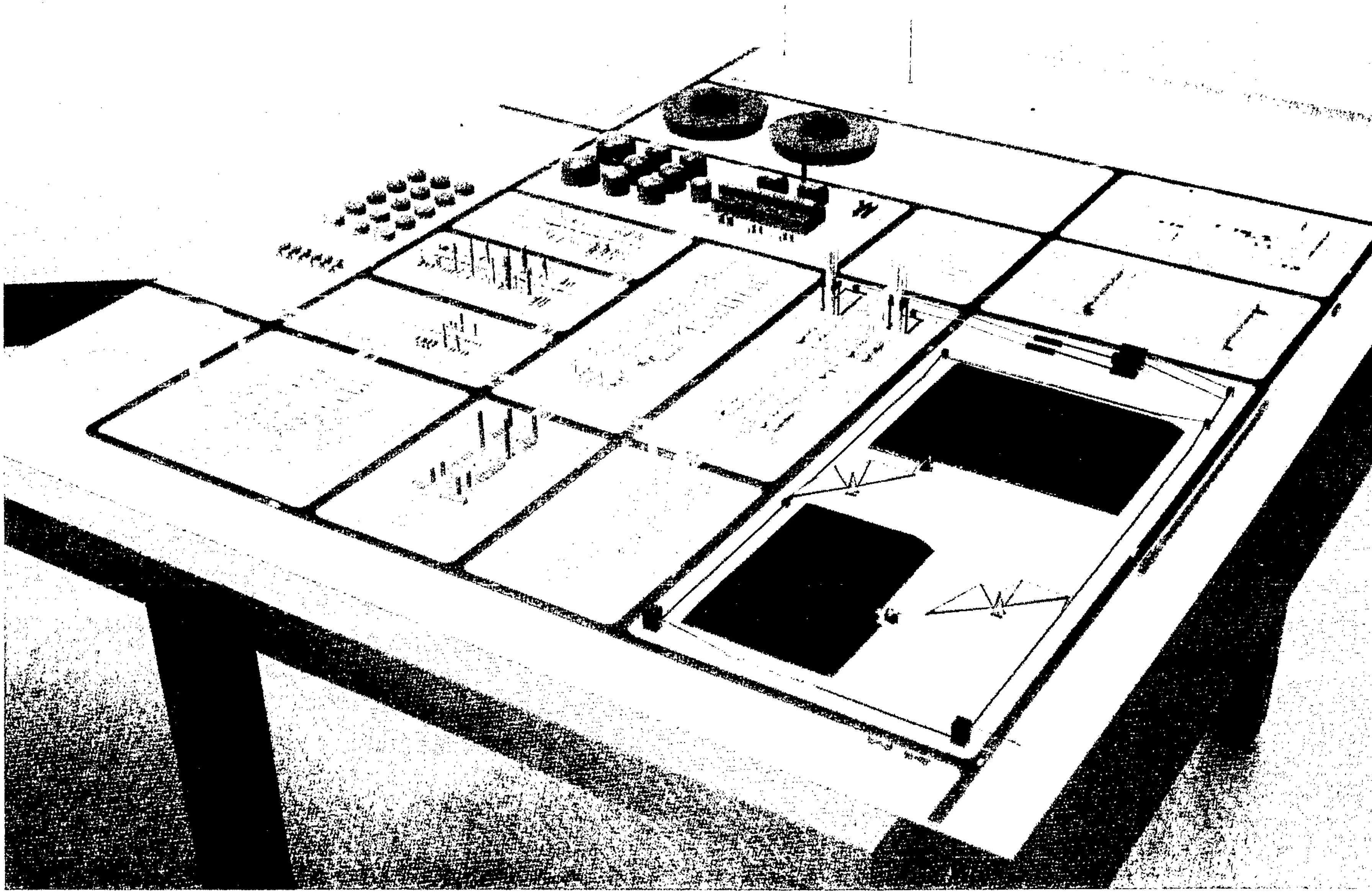

Figure 3 - Fischer-Tropsch Model

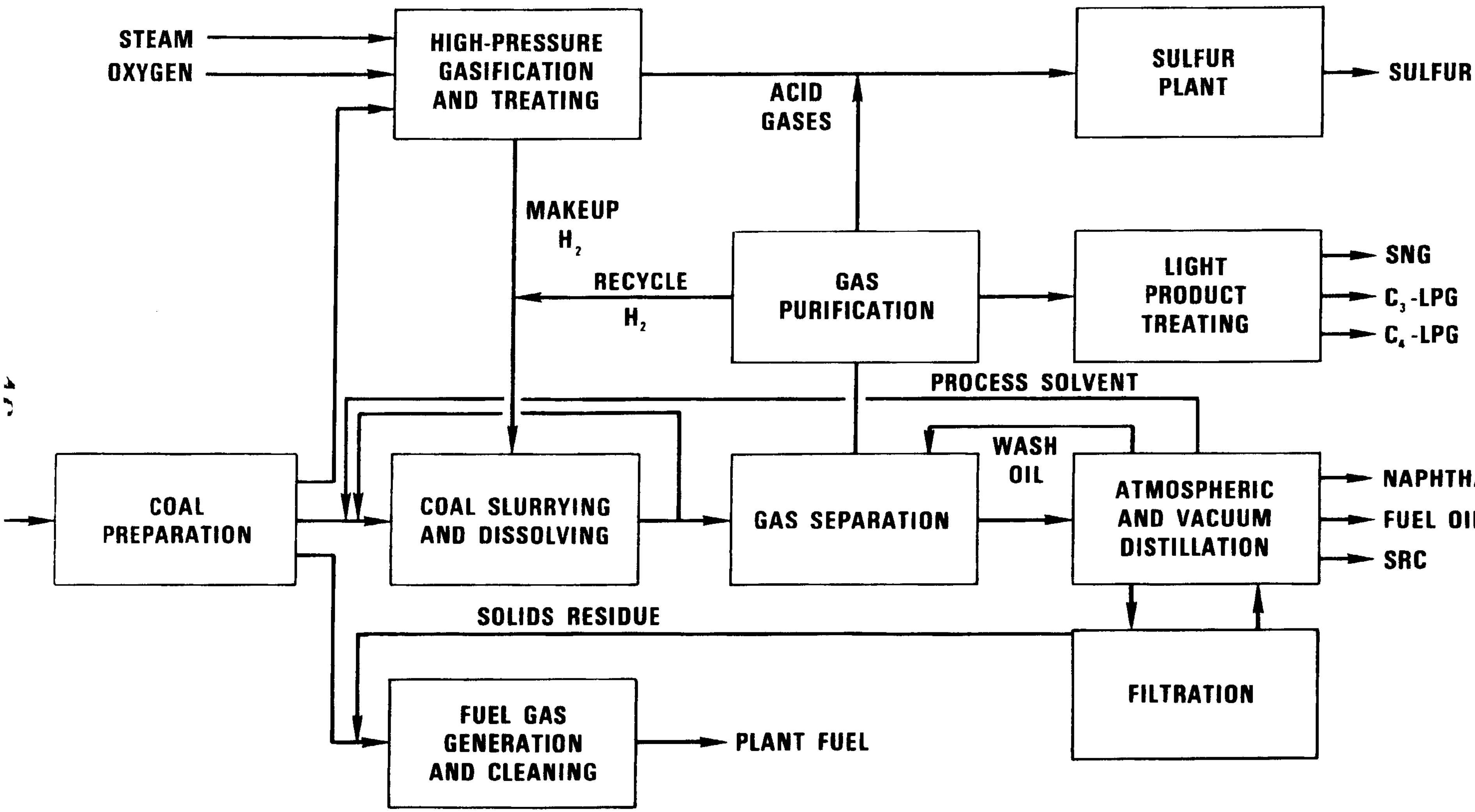

Figure 4 - Oil/Gas Plant
Simplified Block Flow Diagram

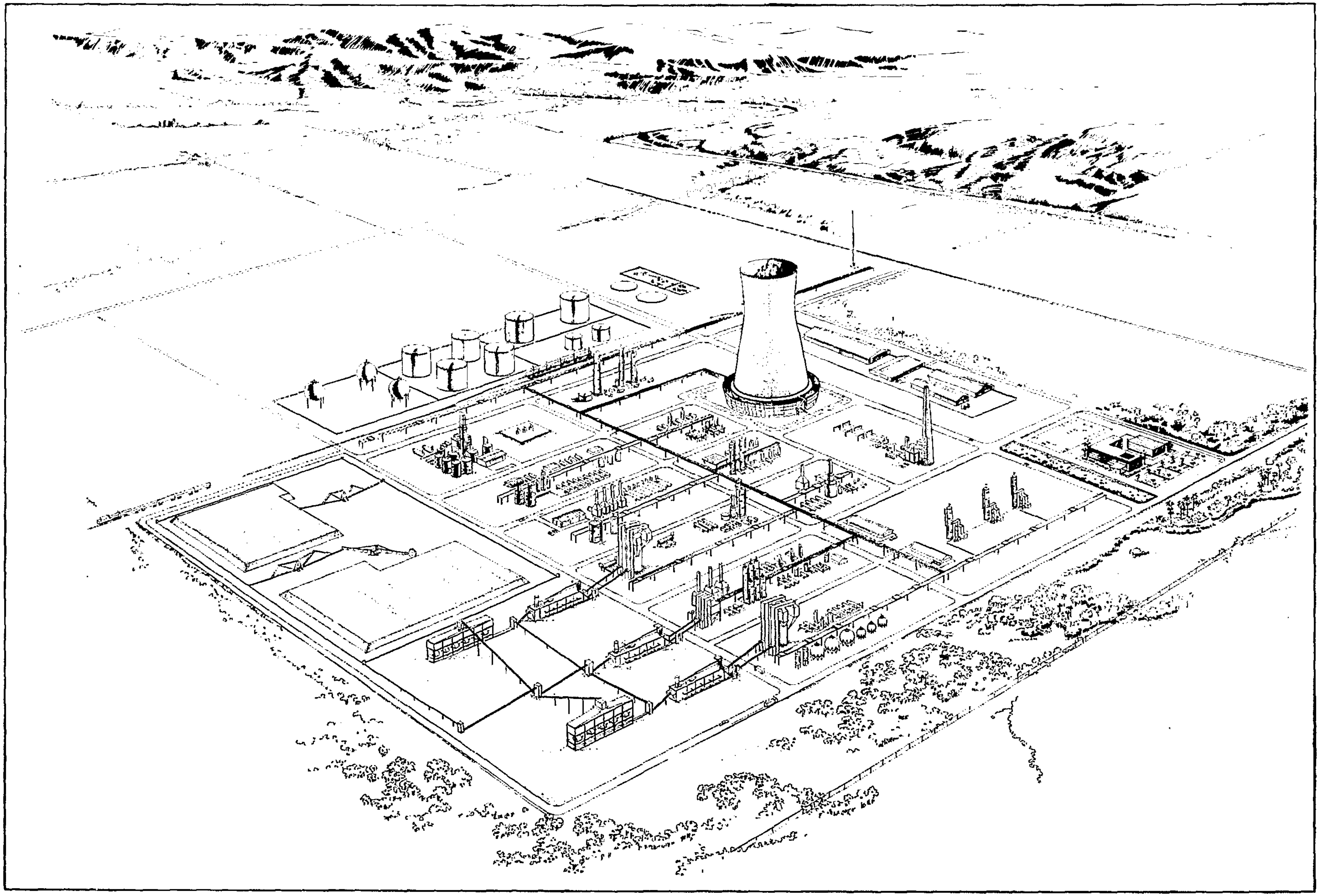

Figure 5 - Artist's Concept, Oil/Gas Plant

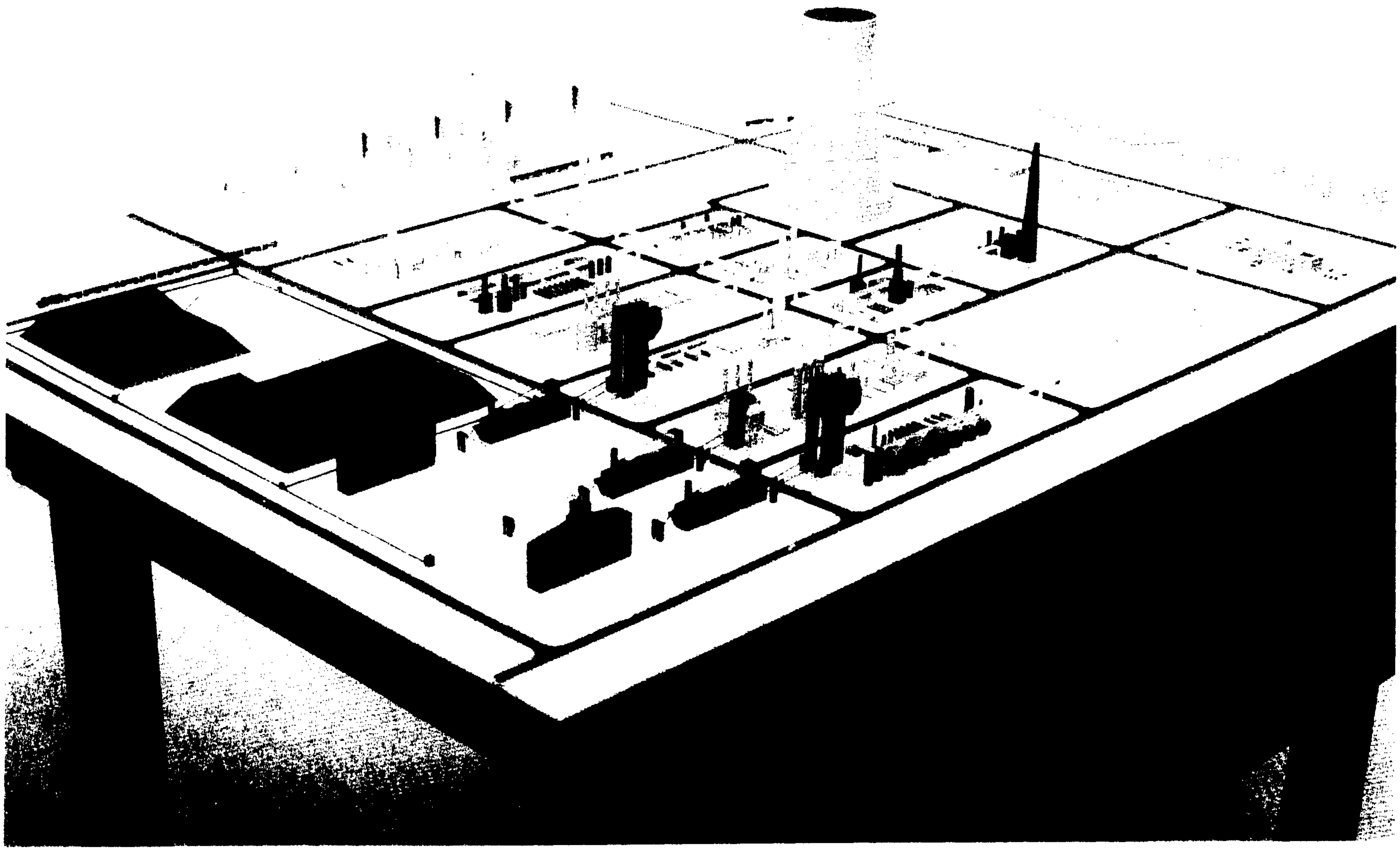

Figure 6 - Oil/Gas Model

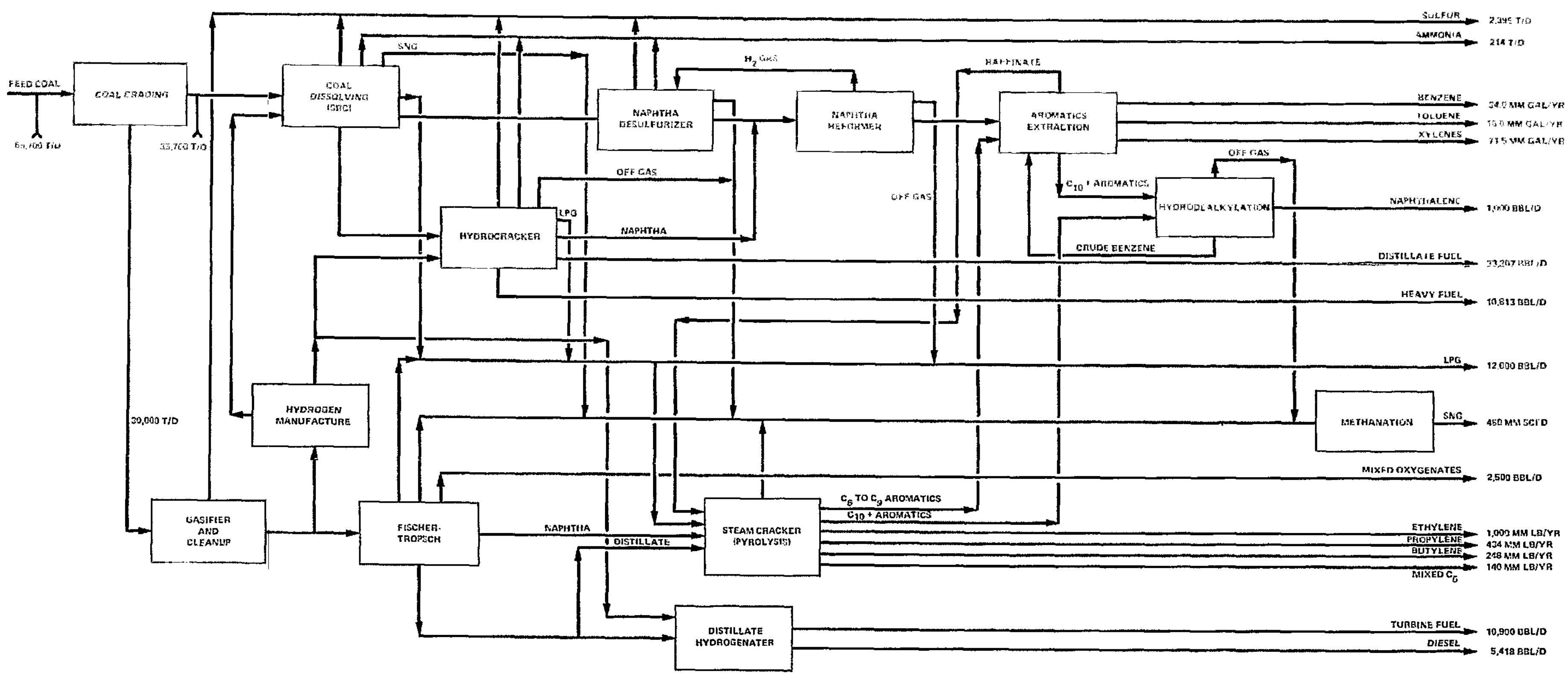

Figure 7 - Coal-to-Petrochemicals Plant Block Flow Diagram

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PRELIMINARY DESIGN SERVICES

RESEARCH AND DEVELOPMENT REPORT NO. 114

QUARTERLY REPORT

For the Period January - March 1976

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

April 1976

FIRST QUARTERLY REPORT

PRELIMINARY DESIGN SERVICES

THE RALPH M. PARSONS COMPANY

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 (COG) refinery to produce clean liquids, gas, and electrical power.
- A facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes that show promise during pilot plant operations.

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

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, was completed in 1975.

During the past quarter we completed the design of the coal preparation and grinding units for the Fischer-Tropsch complex and advanced the same tasks for the oil/gas complex, including estimates of capital cost and operating expenses. We prepared preliminary reports for these units for use in the ERDA R&D reports which will describe the two designs.

We completed the major portions of the Oil/Gas Plant process design, flow diagrams, heat, material, and energy balances and equipment specifications. We prepared a layout for the complex. Fixed capital cost estimates are underway. We started to assemble material for an economic evaluation of the complex.

We completed the major portion of the Fischer-Tropsch plant process design, flow diagrams, heat, material, and energy balances, and equipment specifications. We generated a layout for the complex. Capital cost estimates for the process units have been initiated.

We continued evaluation of coal liquefaction processes for the COG plant design. This includes technical and economic analyses of candidate processes, preparation of block flow diagrams, material balances, yields and preliminary cost estimates for selected processes.

Efforts to obtain test results for liquid/solids separation and coal feeding devices by means of expellers or extruders, are under way. We obtained conceptual configurations, capital cost and power requirement estimates for ground coal compression screw feeders from equipment manufacturers.

We continue activities concerning selection of materials of construction for process units and environmental factor support efforts.

III. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. 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 100,000 tons per day are being considered.

2. Activity This Quarter.

We completed the conceptual design and economic evaluation of the 40,000-ton-per-day coal mine and major parts of the related coal preparation plant as feed facilities to be used for the Fischer-Tropsch design. We completed the design of the 50,000-ton-per-day coal mine to serve the Oil/Gas complex and advanced the design of the coal preparation facilities.

B. 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. Dissolver: We completed the material and energy balance, equipment sizing and specifications. We completed the process flow diagram and equipment process specifications. We started equipment engineering specifications.

b. Dissolver Acid Gas Removal: We completed the process flow diagrams, material balance and process inputs for equipment specifications. We started equipment engineering specification.

c. Fractionation: We completed the column heat and material balance and the equipment sizing calculations. We completed the process flow diagram and the process input for equipment specifications. We completed detailed engineering specifications and started estimation of equipment costs.

d. Naphtha Hydrotreating and Methanation: We completed process process flow diagrams, material balances and equipment sizing and process inputs. We started equipment engineering specifications and completed them for the methanation section. We completed equipment cost estimates for this section.

e. Gas Treating: We completed process flow diagrams, material balance calculations and process input for equipment specification. We started equipment engineering specifications.

f. Sour Water Treater: We completed process flow diagrams, material and energy balances and process input for equipment specifications. We completed equipment engineering specification and equipment cost estimates.

g. Sulfur Plant: We completed the utility requirement calculations, flow diagram, and product quality statement, as well as the capital cost estimates for both process and fuel gas sulfur recovery.

h. Catalyst and Chemicals: We started to list chemicals and catalyst requirements for the complex. We began a review of all material and energy balances to assure their internal agreement as well as agreement between the separate plant units.

C. Fischer-Tropsch Plant Design

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. Gasifier: We completed final process flow diagrams and process input to equipment specification. We completed engineering specification of equipment and started equipment cost estimates.

   b. Fischer-Tropsch Synthesis: A consultant reviewed the reactor design and we are evaluating his conclusions. We completed process input for all other equipment specifications and started preparation of the engineering specifications.

   c. Liquid Products Fractionation: We completed the process flow diagram and process input for equipment specifications. We completed engineering specifications of the equipment and started equipment cost estimates.

   d. Water Reclamation Unit: We advanced the process equipment specifications and data sheets.

   e. Oxygen and Sulfur Recovery Plants: We prepared design specifications and capital cost estimates for the oxygen plant, and for sulfur recovery facilities. We completed the process design and process inputs for the gasifier unit.

D. COG Plant Design

1. Objective.

To develop a preliminary design of a coal processing plant that will produce both liquid and gaseous fuels as principal products. The process 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. We continued to develop costs for individual process units for evaluation extimates.

      1. We completed this work for a complex using SRC-type liquefaction with hydrogen feed to the dissolver and nonslurry recycle.

      2. H-Coal-based complex.

      3. Synthoil-based complex.

      4. Hydrogen donor solvent-based complex.

      5. COED-based complex.

      We further generated block flow diagrams with material and energy balances; also factored capital cost estimates and preliminary economic evaluations for these complexes as well as for three other SRC-based cases studied during the last quarter of 1975.

b. We advanced comparative process evaluation studies as they apply to the COG design purposes.

1. Oil/Gas Plant complex.
2. Fischer-Tropsch Plant complex.
3. Hydrocarbonization complex.

E. Equipment Development

1. Objective.

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. Gas/Solids Separation: We received additional information on dry and wet electrostatic precipitators design for vacuum service, as well as high-pressure units.

b. Liquid/Solids Separation: We are working with the V. D. Anderson Company to establish a test program for the recovery of solvent from filter cake. We further collaborated with the Votator Division of Chemetron for turbo-film vacuum evaporator unit tests for the same material.

c. <u>Solids Feed to Gasifier</u>: We have collaborated with the Fuller Company on preparations for testing ground coal compression screw feeding against 150 psi.

F. <u>Materials of Construction</u>

1. Objectives.

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

2. Activity This Quarter.

We developed materials of construction diagram and specifications for the Oil/Gas and Fischer-Tropsch complexes.

G. <u>Environmental Considerations</u>

1. Objectives.

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. Activity This Quarter.

a. We studied environmental regulations in states where coal conversion facilities could be located and investigated requirements for carbon monoxide emission controls. We investigated water pollution effects of coal ash in preparation for an experimental program.

b. We visited the SRC facility at Fort Lewis, Washington and reviewed their environmental facilities and procedures.

c. We reviewed the Fischer-Tropsch Plant design and provided inputs to avoid deleterious environmental plant emissions. We further investigated the products of the complex to ascertain that their use will be ecologically acceptable.

H. General

1. During the quarter we presented an invited paper titled "Industrial Energy Usage Patterns" before the American Institute of Plant Engineers (AIPE) Symposium on February 26, 1976 in Seattle, Washington.

2. We met with representatives of ERDA in Pasadena on March 28 and 29, 1976 to review the project status.

3. We met with a team from the Oak Ridge National Laboratory in Pasadena on March 1, 1976 to consult on equipment design and development problems in coal conversion.

IV. WORK FORECAST FOR THE NEXT QUARTER, APRIL 1 THROUGH JUNE 30, 1976

A. Coal Mining/Coal Preparation

We will complete design and cost estimation work for the Oil/Gas plant coal preparation units.

B. Oil/Gas Plant Design

We will complete the utility balance and process flow diagrams and equipment sizes for the remainder of the complex. We will complete the capital cost estimate and operating cost estimates for the plant as well as the economic evaluation. We will complete the review draft of the final report.

C. Fischer-Tropsch Plant Design

We will complete the utility balance and all process design work for the facility. We will complete capital and operating cost estimates as well as the economic evaluation. We will complete the review draft of the final report.

D. COG Plant Design

We will prepare a brief text and preliminary economics for determining process design basis. We will advance a design basis for COG plant design. We will prepare a status report on all liquefaction processes currently under evaluation.

E. Equipment Development

We will make contacts to obtain all available information regarding the ERDA program development results for ground coal compression screw feeders and develop judgmental estimates for power requirements and of capital costs.

F. Materials of Construction

We will complete material selection services to the engineering specification of equipment for the Oil/Gas and Fischer-Tropsch designs.

G. Environmental Consideration

We will review all waste disposal processes planned for use in the Oil/Gas and Fischer-Tropsch projects. We will obtain one or more proposals for a slag/ash leaching study from competent analytical laboratories; this information is required to assure acceptable disposal of slag/ash from the coal conversion complexes.

H. General

We will present the following invited papers:

1. "Preliminary Economic Analysis: Oil and Power by COED-Based Conversion" to the American Chemical Society Symposium on Comparative Economics of Synfuels in New York on April 8, 1976.

2. "Coal Liquefaction; Materials Systems Design" for presentation to the American Society for Metals, in Pittsburgh, Pennsylvania on April 26, 1976.

3. "Coal Conversion Development - An Overview" before the Engineering Institute of Canada (EIC) Conference on May 12, 1976 in Calgary, Alberta.

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100 West Walnut Street
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For:

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

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

September 1976

SECOND QUARTERLY REPORT

PRELIMINARY DESIGN SERVICES

THE RALPH M. PARSONS COMPANY

I. OBJECTIVE AND SCOPE OF WORK

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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

A brief review of the status of the major active design efforts is given below, followed by a more detailed reporting on the progress of individual tasks.

During the past quarter we completed the process design work and fixed capital cost estimates for the Oil/Gas and Fischer-Tropsch plants. We also advanced the profitability analyses for these two plants. Additional adjustments to the thermal efficiency of the Fischer-Tropsch plant were completed which resulted in a corrected figure of 69.7 percent.

Preliminary Design bases for COG-type plant concepts were prepared and we made progress on the preparation of a status summary of our work on liquefaction processes and economics. A draft report of a design basis, including a block flow diagram for the most likely combination of operations is being prepared. Work on the Multipurpose Demonstration Facility is underway. We initiated requests for commercial methanol process and economic information. We started preparation of a simplified plant design; the purpose of this design is to evaluate information received from methanol plant licensors.

We obtained additional information on the subject of liquid/solids separation and coal feeding devices. Test information available to us indicates the potential that capital cost of cleaning gas can be substantially reduced. We continue to receive conceptual configurations, capital cost and power requirement estimates for ground coal compression screw feeders from equipment manufacturers.

We have selected appropriate materials of construction for process units in the Oil/Gas and Fischer-Tropsch designs and are in the process of developing the environmental factor analyses.

Outlined below is a brief summary by assigned task.

A. Coal Mining/Coal Preparation

We completed design and capital cost estimates for the Oil/Gas plant coal preparation units. We completed and reviewed the report describing the design and economic information for mining and coal preparation facilities to serve the Oil/Gas and Fischer-Tropsch plants.

B. Oil/Gas Plant Design

We completed the utility balance, process flow diagrams, and equipment sizes for the complex. We completed the fixed capital cost estimate and operating cost estimates for the plant, and worked on the profitability analysis. We completed rough drafts of portions of the R&D report.

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

We completed the utility balance and all process design work for the facility. We completed capital and operating cost estimates and made progress on development of the economic evaluation. We completed a rough draft of the R&D report.

D. <u>COG Plant Design</u>

We prepared a brief text and preliminary economic guidance for determining the preferred process design basis. We made progress on development of a design basis. We prepared a status draft report covering all liquefaction processes currently under evaluation.

E. <u>Equipment Development</u>

We made contacts to obtain available information regarding results generated in the ERDA program for ground coal compression screw feeders development. Information included estimates for power requirements and capital costs.

F. <u>Materials of Construction</u>

We completed material selection services for engineering specification of equipment for the Oil/Gas and Fischer-Tropsch designs.

G. <u>Environmental Considerations</u>

We reviewed the waste treatment processes planned for use in the Oil/Gas and Fischer-Tropsch projects. We obtained proposals for a slag/ash leaching study from competent analytical laboratories; this study is desirable to assure acceptable disposal of a slag/ash from the coal conversion complexes.

H. General

We presented the following invited papers:

1. "Preliminary Economic Analysis: Oil and Power by COED-Based Conversion" -- to the American Chemical Society Symposium on Comparative Economics of Synfuels, in New York on April 8, 1976.

2. "Coal Liquefaction; Materials Systems Design" -- for presentation to the American Society for Metals, in Pittsburgh, Pennsylvania on April 26, 1976.

3. "Coal Conversion Development - An Overview" -- before the Engineering Institute of Canada (EIC) Conference on May 12, 1976, in Calgary, Alberta.

We participated in a Technical Data Book Advisory Committee Meeting on Coal Conversion Systems in Chicago, Illinois, on May 27, 1976.

III. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. 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 100,000 tons per day are being considered.

2. Activity This Quarter

We completed all designs, fixed capital investment estimates, and operating and maintenance cost estimates for the Oil/Gas plant and Fischer-Tropsch mining and coal preparation facilities. We completed and reviewed the drafts of the final report sections.

3. Activity Forecast Next Quarter

We will advance work on a report covering mine development in at least one additional geographic area.

B. Oil/Gas Plant Design

1. Objectives

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

2. Activity This Quarter

a. We completed flow diagrams for all process units.

b. We completed all required details of equipment engineering specifications.

c. We completed the capital cost estimates for the complex.

d. Utility Balance: We reviewed plant electrical and steam requirements with utility specialists to minimize fuel and cooling water requirements.

e. Raw Water Treating: We completed the detailed process design of the raw water treating unit.

f. Fuel Gas Gasifier: We completed modifications for a gasifier design to reduce the capital and operating cost. The revised unit operates at 55 psia thus producing fuel gas at 37 psia after cooling and cleanup. This eliminates fuel gas compressors and reduces the number of gasifiers from two to one.

g. We advanced the profitability analysis and the preparation of the R&D design report.

3. Result of These Activities

The completed process design of the plant complex includes a captive coal mine with capacity to produce approximately 15.5 million TPY for 20 years. Units are included which will clean, wash, size, grind, and dry the coal and feed it to the process units.

The complex is designed as a self-contained unit. All necessary facilities for production of oxygen, hydrogen, and all required utilities are included in the design as well as treatment and disposal of solid, liquid, and gas waste streams. The design is based on a site location capable of providing the necessary quantity of water for process requirements, utilities makeup, and for potable and sanitary water.

The core of the coal conversion plant is the dissolvers. They convert the coal suspended in internally generated solvent in the presence of hydrogen to gases and liquids with an undissolved coal residue and ash constituting 18.9 percent of the moisture-free coal feed. The solids are filtered and dried to maximize liquid recovery. The liquids are fractionated to remove filter wash oil, product fuel oil, a naptha-range liquid and a gas stream. Column bottoms are split to provide a portion of the dissolver feed solvent, and filter feed slurry. The filtrate, in turn, is split to provide the remainder of the dissolver feed solvent, and product liquid.

Hydrogen is required for the dissolving process. It is produced in a high pressure gasifier fed with coal, steam and oxygen. The product gas is rich in carbon monoxide. The ratio of this component to hydrogen is improved in a sour shift unit. The hydrogen sulfide is removed and the sweet gas is mixed with additional hydrogen obtained by cryogenic separation. This gas mixture is used as feed to the dissolvers.

Gases evolving from the dissolvers and from the fractionation are treated to remove their hydrogen sulfide contents. The clean gas is split in a cryogenic unit into methane-rich gas, hydrogen-rich gas and heavier fractions. A portion of the hydrogen-rich gas steam is treated to methanate the remaining carbon monoxide. The resultant 95 percent pure hydrogen steam is used to hydrogenate the napthas produced in liquefaction.

The heavier fractions produced in the cryogenic separation are fractionated into product butane, propane, methane, and naphtha which is sent to the previously mentioned hydrogenation unit.

The methane-rich product of the cryogenic unit is purified by methanation to produce substitute natural gas product.

All hydrogen sulfide streams mentioned above are treated to obtain product sulfur and environmentally acceptable clean tail gas.

The solid products of the dissolver step are gasified in a low pressure air-blown unit to produce fuel gas required for generation of plant utilities. Coal is added to this gasifier to make up the necessary amount of in-plant fuel. The resultant low-Btu gas is treated to remove hydrogen sulfide, making additional product sulfur. The purified gas is used in the plant furnaces. It is also used in the utility plant to produce the steam and electricity required for the operation of the complex.

The throughput of the plant is based on 35,650 TPD of 2 percent moisture coal. This corresponds to approximately 47,000 TPD of ROM coal. This throughput will produce the following approximate output rates:

Fuel Oil (approximately equivalent to No. 6 Fuel Oil)	56,000 BPD
Naphtha	10,000 BPD
LPG (C_3 and C_4)	10,000 BPD

SNG	165,000 MM SCFD
Elemental Sulfur	1,300 STPD
Anhydrous Ammonia	90 STPD

The simultaneous production of coal from five mine faces and the mixing of this coal in the breakers and storage will produce a coal of relatively uniform composition; it is concluded that the product slate will also be reasonably uniform.

4. Activity Forecast Next Quarter

We will complete the economic analysis of the oil/gas complex and incorporate it into the R&D report. We will submit a draft of the report to ERDA for review and prepare to publish the report in its final form.

C. Fischer-Tropsch Plant Design

1. Objectives.

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

a. We completed preparation of equipment engineering specifications.

b. We completed the capital cost estimates for all process units.

c. We completed flow diagrams, equipment and engineering specifications for the utilities and steam power generating facilities and started their capital cost estimate.

d. Raw Water Treating: We completed flow diagrams, engineering and equipment specifications. We started the preparation of capital cost estimates.

e. We completed the comparisons of gasifiers and Fischer-Tropsch reactor types for inclusion in the design report.

f. We reviewed the Fischer-Tropsch reactor design incorporating revised catalyst requirements per information from ERDA-PERC. We further investigated cost reduction possibilities for the reactors.

g. We completed the preparation of a start-up and shut-down procedure for inclusion in the design report.

h. We advanced the profitability analysis and the preparation of a rough draft R&D report.

3. Results of These Activities.

The products of this complex are produced in a two-train plant and have a collective total heating value of 516 billion Btu per day. The design includes a captive coal mine, coal handling, crushing, beneficiation, grinding and drying facilities, and all process plants, utility production, and ancillary units to convert this coal by steam-oxygen gasification to synthesis gas for manufacture of 50 percent liquid hydrocarbons and 50 percent SNG on a Btu basis. Oxygenates and alcohols are produced as a mixed product. Elemental sulfur is a by-product and coal ash is a solid waste material.

The SNG is produced as 1050 Btu per SCF HHV gas at pipeline pressure. The liquid products are LPG, naphtha, diesel oil, premium fuel oil and oxygenates. Oxygenates are comprised primarily of mixed alcohols with ketones and aldehydes.

The design allows a range of coal and carbonaceous charge stocks. Coal handling and preparation equipment is sized for peak rates of 25 percent over average required in order to assure necessary performance at times of lower grade coal production. Flexibility for sulfur and ash content provides for expected range of analyses which might be expected over a 20-year operating life, using coal typically mined in the Eastern Region of the U.S. Interior Coal Province.

The complex is designed with four coal mine faces operating simultaneously, each producing 10,000 TPD. The coal is processed through a coal preparation plant to produce approximately 30,000 TPD of clean, washed and dried coal feed.

The process efficiency of this design is achieved by:

a. Use of a two-stage entrained slagging type gasifier.

b. Use of ERDA-developed flame-sprayed catalyst techniques. The reactors for catalytic reaction are logical extensions of pilot plant designs and a design development peculiar to this report.

c. Generation of 1200 psig steam from the heat of catalytic reactions.

d. Utilization of recovered heat by high efficiency power plant turbo-generators.

e. Extension of the Fischer-Tropsch technology using scale-ups of technology and equipment developments.

The data investigated during design development included iron catalyst in bed and sprayed-on-plate forms for the Fischer-Tropsch synthesis and Raney nickel catalyst for methanation. The sprayed-catalyst-on-plates method was used as developed at Bruceton. The shift reactor is designed with this same technique.

The efficient recovery of the majority of the reaction heat as steam at 1200 psig, and the subsequent superheating of the steam with hot synthesis gas to 950°F, allows use of central power plant steam turbine-driven generators. This steam is converted to electrical power at a 41.5 percent efficiency. Excess process steam produced in the plant at 500 psig, 135 psig and 55 psig is used as bleed steam with electrical power extracted. The boiler feed water is preheated by process heat and bleed steam to provide the stipulated efficiency.

The pressure used by the gasification and Fischer-Tropsch synthesis is 400 psig in the Fischer-Tropsch reactor as was used in most ERDA data runs. At this pressure, experience indicates that carbon formation encountered at lower pressures is avoided. If the Fischer-Tropsch synthesis were carried out at 1000 psig, the overall plant efficiency might improve.

4. Activity Forecast Next Quarter.

We will complete the economic analysis of the Fischer-Tropsch complex and incorporate it into the R&D report. We will submit a draft of the report to ERDA for review and prepare to publish the report in its final form.

D. COG Plant Design

1. Objectives.

To develop a preliminary design of a coal processing plant which 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.

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 for the Quarter.

a. We advanced a summary of the comparison of liquefaction processes studied to date. The comparisons include the process and yield characteristics, utility requirements, capital and operating costs. The summary also includes a status report on development efforts.

b. We completed the preparation of preliminary block flow diagrams of candidate COG complex combinations.

c. We met with ERDA representatives on May 6, and June 8 to establish basic design concepts for a COG-type plant. A meeting was planned in July to finalize the design basis.

d. We initiated a study to determine the best use for char considering possible production of hydrogen, SNG, Fischer-Tropsch feed gas, and power.

e. We prepared a draft of a design basis, including a block flow diagram for a recommended preferred combination of operations, and a material balance.

f. We initiated a study to determine what type of pyrolysis could be incorporated in the plant design. We are investigating flash, hydropyrolysis and the dry catalytic pyrolysis processes. We completed a literature search to obtain additional information on direct flash pyrolysis.

g. We initiated a study to establish the pressure level at which char can be economically gasified with oxygen and below which char should be gasified with air. The study is restricted to fuel gas production.

3. Results of These Activities.

The above activities are in the process of development; final conclusions await their completion.

4. Activity Forecast Next Quarter.

We will complete the status report covering the utilization of various coal liquefaction processes for COG. We will finalize a recommended design basis and transmit this to ERDA. We will start the detailed design of the complex when authorized to do so by ERDA.

E. Multipurpose Demonstration Facility

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. These designs shall be based on the concept that the operating units shall be constructed as module additions over a period of years. The completed facility shall include modules of facilities which can be common to two or more other processes, as well as allowances for future modification and/ or replacement of various pieces of equipment to meet new requirements.

2. Activity This Quarter.

a. We developed a list of licensors and an approved form letter to solicit submittal of methanol plant technical and economic information from commercial plant licensors.

b. We reviewed the preferred steps to convert coal-derived liquids to marketable products such as gasoline. We initiated a study to determine the critical factors affecting the coal charge rate for the facility.

c. We prepared preliminary designs, planning type estimates, and approximate gas values for a low pressure, two-stage, air-blown gasifier. This gasifier will gasify about 200 tons of Eastern bituminous coal per hour to produce a gas of about 160 Btu/SCF of heating value.

This gasifier would operate at about 40 psig and will produce about 160 billion Btu/day of calorific heat content in this gas. This type of unit could be used to supply gas for industrial heating and power boilers.

3. Activity Forecast Next Quarter.

We will continue to advance the preparation of a design basis for this task.

F. Equipment Development

1. Objectives.

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

2. Activity This Quarter.

a. Gas/Solids Separation: We received additional information on cyclone sizing and efficiencies. We continued to work with electrostatic precipitator manufacturers.

b. Solids Feed to Gasifier: We continued to work with vendors on developments of ground coal compression screw feeders.

c. Valves: We met with valve manufacturers and discussed the adaptability of their products to coal conversion applications.

3. Activity Forecast Next Quarter.

We will continue collaboration with equipment manufacturers and monitor progress of their developments. We will propose development programs to ERDA where deemed practical.

G. Materials of Construction

1. Objectives.

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

2. Activity This Quarter.

a. We presented a paper entitled "Coal Liquefaction: Materials Systems Design" to the American Society of Metals Conference on Materials in Coal Conversion Systems. The meeting was held in Pittsburgh, Pennsylvania on April 26, 1976.

b. We supported the Oil/Gas and Fischer-Tropsch design efforts by supplying materials of construction specifications.

3. Activity Forecast Next Quarter.

We will continue to support design efforts by supplying materials of construction specifications.

H. Environmental Considerations

1. Objectives.

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.

3. Activity Forecast Next Quarter.

We will continue collaboration with equipment manufacturers and monitor progress of their developments. We will propose development programs to ERDA where deemed practical.

G. Materials of Construction

1. Objectives.

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

2. Activity This Quarter.

a. We presented a paper entitled "Coal Liquefaction: Materials Systems Design" to the American Society of Metals Conference on Materials in Coal Conversion Systems. The meeting was held in Pittsburgh, Pennsylvania on April 26, 1976.

b. We supported the Oil/Gas and Fischer-Tropsch design efforts by supplying materials of construction specifications.

3. Activity Forecast Next Quarter.

We will continue to support design efforts by supplying materials of construction specifications.

H. Environmental Considerations

1. Objectives.

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. Activity for the Quarter.

a. We completed the design report section on Environmental Factors for the Fischer-Tropsch plant design study. This includes details of treatment of gaseous and liquid effluent streams generated by the complex. The disposal of solid wastes and noise control procedures were described. We also considered possible deleterious action of products, the possible release to the environment of heavy metals and trace elements, and pertinent mine area restoration procedures.

b. We reviewed the Oil/Gas plant design to study pertinent environmental factors. These include treatment of gaseous and liquid effluent streams generated by the complex, disposal of solid wastes, and noise control procedures. We are also considering possible deleterious action of products, the possible release to the environment of heavy metals and trace elements, and pertinent mine area restoration procedures.

3. Activity Forecast Next Quarter.

We will finalize the input to both Oil/Gas and Fischer-Tropsch complex design reports.

I. General

We participated in a Technical Data Book Advisory Committee Meeting on Coal Conversion Systems in Chicago, Illinois on May 27, 1976.

K. Publications

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 papers:

a. Invited paper titled "Preliminary Economic Analysis: Oil and Power by COED-Based Conversion" to the American Chemical Society Symposium on Comparative Economics of Synfuel in New York on April 8, 1976.

b. Invited paper titled "Coal Liquefaction: Material System Design" for presentation before the American Society of Metals (ASM), Systems and Design Symposium, in Pittsburgh, Pennsylvania, on April 26, 1976.

c. An invited paper titled "Coal Conversion Development: An Overview" to the Engineering Institute of Canada, Petrochemicals West, Third Annual Western Regional Conference, Calgary, Alberta, on May 12, 1976.

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PRELIMINARY DESIGN SERVICES

RESEARCH AND DEVELOPMENT REPORT NO. 114

QUARTERLY REPORT

For the Period July - September 1976

Prepared by:

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For:

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

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

November 1976

THIRD QUARTERLY REPORT

PRELIMINARY DESIGN SERVICES

THE RALPH M. PARSONS COMPANY

I. OBJECTIVE AND SCOPE OF WORK

The objective 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 coal processing plant to produce power, oil, gas, and other products (POGO).
- A facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes that show promise during pilot plant operations.

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 consideration of environmental factors.

II. SUMMARY OF PROGRESS TO DATE

A brief review of the status of the major active design efforts is given below, followed by a more detailed reporting on the progress of individual tasks.

During the past quarter we transmitted to ERDA draft copies of the final R&D reports describing the designs/economic evaluations for the Fischer-Tropsch and Oil/Gas plants. A document containing a proposed design basis for the COG design was transmitted to ERDA who directed that this task effort hereafter be referred to as POGO, an acronym for Power, Oil, Gas, and Other. We reached agreement with ERDA regarding primary elements of the POGO design basis. POGO designs will be developed for the following areas of the U.S.:

- Eastern Region of the Interior Coal Province
- Southern Appalachia
- Rocky Mountain Province

We obtained geological information from state agencies on coal availability in Southern Appalachian and Rocky Mountain Provinces for mining up to 100,000 tons per day.

We continued to refine the Oil/Gas and Fischer-Tropsch R&D draft reports in response to comments received from ERDA. We completed the profitability analysis for these tasks.

We obtained additional information on the subject of liquid/solids and gas/solid separation and coal feeding devices. We obtained information that ionizer units can agglomerate fines in gas streams with a resulting increase in downstream cyclone efficiency.

We completed the study of the environmental factors pertaining to the Oil/Gas plant.

A brief summary of results by assigned task follows.

<u>Coal Mining/Coal Preparation</u>

We continued to assemble geological information and started to prepare reports on coal reserves required for 100,000 T/D mine operations in the Southern Appalachia and Rocky Mountain areas. We concluded that it will take a number of coal mines to supply this operation in the Southern Appalachia area.

Potential exists in the Rocky Mountain Province to develop single captive mines producing 100,000 tons per day of coal.

Oil/Gas Plant Design

We completed the profitability analysis and continued work on the R&D report. We transmitted a draft copy to ERDA and reviewed it with them. As a result of this review, we worked to expand the reports at ERDA's request to include:

- A detailed section describing the marketability and characteristics of the products.
- A summary of the experimental data base used for the design.
- A description of the gasifier effluent waste heat boiler design.

Fischer-Tropsch Plant Design

We continued preparation of the R&D report including revision to the power generation facilities to optimize cooling tower operation. We transmitted a draft copy to ERDA and reviewed it with them. Following the review, we began work to expand the report to include the same three sections described above under the "Oil/Gas" design.

POGO Plant Design

We completed a draft of the Design Basis Recommendation Report and transmitted it to ERDA. ERDA accepted our recommended design basis with some modification. It was agreed that the heaviest hydroliquefaction stream would be upgraded to a higher value consumer product. At the direction of ERDA, we also began revision of the report in preparation for issue as an interim ERDA R&D report.

We completed case definitions and specifications for engineering development and pricing for a number of process alternate studies. We completed preliminary alternate economic assessments for options to upgrade heavy coal liquids to higher value consumer products. We will transmit the results to ERDA for review and decision. The decision on this point will provide the final element of the design basis.

We established tentative current market price structures for coal liquefaction products saleable in fuels, chemical and petrochemical markets.

Multipurpose Demonstration Facility

We received economic data, including capital cost, utilities requirements, etc. for a medium pressure (approximately 1,500 psig) methanol plant. We are analyzing these data. We developed operating cost data for the Fischer-Tropsch process based on a 50-50 liquid/SNG product slate.

We worked to develop a recommended design basis for transmittal to ERDA.

Equipment Development

We continued contacts to obtain information regarding results generated in the ERDA program for development of ground coal compression screw feeders which are specified for use in our Oil/Gas and Fischer-Tropsch designs; also for gas/solids separation equipment. Information obtained on solid coal screw feeders included estimates of power requirements and capital costs.

Materials of Construction

We continue to support design efforts by supplying materials of construction specifications.

Environmental Considerations

We completed the study of the environmental factors pertaining to the Oil/Gas plant. This study will be included in the R&D report. We will also prepare a paper describing the key results of this study and present it at the AIChE meeting to be held in Chicago on November 30 - December 2, 1976.

We also completed the investigation of cyanides and their role in the coal conversion process.

General

We presented the following invited papers:

1. "Potentials for Petrochemical Feedstocks and Chemicals from Coal" presented to the AIChE Symposium on "Chemicals

from Coal - New Frontiers," at Atlantic City, New Jersey on August 31, 1976. Chemical Engineering Progress will publish this paper which presents a process plan, material balance, and market penetration information for a scheme to produce a billion pounds per year of ethylene plus large volumes of other petrochemicals from coal.

2. "The Materials Problems in Coal Gasification and Liquefaction Systems" presented at the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) Conference on Materials Requirements for Unconventional Energy Systems to be held September 19-23, 1976 at Niagara Falls, New York.

We participated in the following meetings:

1. Ingersoll-Rand's State of the Art Presentation to ERDA on coal conversion equipment applications in Washington, D.C. on September 9, 1976. Particular emphasis in this meeting was devoted to gas compressors, expanders, and coal slurry pumps.

2. United Technologies Research Center in Pasadena to discuss the potentials of applying their computer-assisted simulation capability to analysis and optimization of power generation/utilities system in coal conversion complexes.

3. T. Y. Lin International to discuss the potential for the use of pre-stressed concrete vessels in coal conversion plants. T. Y. Lin agreed to supply further information on the potential of this technique.

III. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. 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 100,000 tons per day are being considered.

2. Activity This Quarter

a. We obtained geological information from state agencies on coal availability in Southern Appalachian and Rocky Mountain Provinces. We continued to assemble the most current geological information and planning data for the conceptual development of coal mines in these regions.

We concluded from information obtained that coal will have to be obtained from a number of mines to supply 100,000 tons per day of ROM coal production for the lower Appalachia area.

b. We continued to investigate efficient coal preparation methods.

3. Results of These Activities

We have preliminarily concluded that a "water only" jigging and multi-stage cyclone system for reduction of ash content in conversion plant coal feed is adequate and preferable to a heavy media system. Two clean coal cuts can be produced: two-thirds of the total coal with an ash content of about 6.5 percent and one-third in a range of 8 to 8.5 percent.

4. Activity Forecast Next Quarter

a. We will continue development of mine designs for the three areas required for the POGO design.

b. We will continue to develop and confirm coal preparation plant designs with the aim of optimum practical separation of high from low ash/sulfur coal.

B. Oil/Gas Plant Design

1. Objectives

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

2. <u>Activity This Quarter</u>

We submitted a draft of major elements of the R&D report to ERDA. We refined the report and maintained contact with ERDA in order to finalize it for publication. We transmitted updated economic projections to ERDA on August 27, 1976.

3. <u>Result of These Activities</u>

   a. We received ERDA's comments on our R&D report draft and revised it accordingly.

   b. We completed the energy and the utility summaries.

   c. We completed updated profitability analyses of the complex.

   d. We produced a model of the plant.

4. <u>Activity Forecast Next Quarter</u>

We are expanding the R&D report to include:

   a. Marketability of the products plus a detailed summary of product characteristics.

   b. Experimental data used for the design.

   c. A description of the gasifier effluent waste heat boiler design.

C. Fischer-Tropsch Plant Design

1. Objectives

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

a. We transmitted a draft copy of the R&D report to ERDA and reviewed it with them. We maintained contact with ERDA to finalize the report for publication.

b. We completed the utility summary to conform to optimum cooling tower operations.

c. We completed the economics section of the design report, including preparation of the final operations and maintenance manpower tables.

d. At ERDA's request, we worked to expand the R&D report to include:

1. Marketability of products plus a detailed summary of product characteristics; see Section III-C-3-d for further detail.

2. A summary of experimental data used to design the Fischer-Tropsch shift and methanation reactors.

3. A description of the gasifier effluent waste heat boiler designs.

3. Result of These Activities

a. The R&D report is nearing completion with a target to obtain release for publication during the next quarter.

b. It was determined that natural draft cooling towers were unsuitable for the small cooling water temperature differential. Mechanical draft cross flow cooling towers were included in the design.

c. We determined the total personnel requirements for the total complex to be approximately 2,100:

Administrative Personnel	343
Operating Personnel	978
Maintenance Personnel	764

d. "Marketability Considerations" was added to the Product section of the R&D report. Details of the investigations and comparisons of certain product properties with corresponding petroleum product specifications are included. A synopsis of this analysis follows:

SNG: Meets properties requirements for sale as substitute natural gas; has a HHV of 1035 Btu/SCF; is produced at pipeline pressure.

Butanes: Can be marketed as LPG and as ethylene plant feedstock.

Naphtha, light and heavy: Aromatics content would be near zero. Octane numbers are low. Since they consist largely of straight chain saturated hydrocarbons with nil sulfur content, they would be preferred petrochemical feed stocks.

As an alternate, they would be suitable as feedstock for gasoline manufacture, requiring further processing and reforming.

Diesel Oil: This product is a superior diesel engine fuel with nil sulfur content and high Cetane number. It meets all ASTM D975 No. 1-D Diesel Fuel Oil specifications and all ASTM D396 No. 1 Fuel Oil specifications.

Fuel Oil: This product meets all ASTM D2880 No. 3-GT specifications for Gas Turbine Fuel Oil in addition to containing nil sulfur and nil nitrogen.

e. The Data Base section of the report was expanded to include experimental results and data on which the flame sprayed catalyst synthesis reactor designs were based. This will be incorporated as a major report section in the R&D report. It includes detailed descriptions of experimental procedures and data on individual runs.

f. Gasifier effluent waste heat boiler design: Details of the design of the heat exchangers used as steam superheaters and steam generators recovering heat from the gasifier synthesis gas were prepared and added to the R&D report.

These exchangers are vertical shell and tube units with the gas-char mixture flowing downward through two-inch tubes. The tubes are 321 stainless steel selected because of its toughness. Their thickness is equivalent to schedule 80 pipe. The tube inlets are protected against abrasion by ceramic ferrules. Velocities through the tubes are those customarily used in pneumatic conveying systems.

The Syngas coolers are patterned after similar units operated at similar pressures as petroleum fluid cracker regenerator gas outlet coolers and fluid catalyst line exchangers. They are also similar to boilers cooling Syngas and ash in a coal-based ammonia plant located in South Africa.

4. Activity Forecast Next Quarter

a. We will complete the final draft of the R&D report and transmit it to ERDA with the objective to obtain approval to publish it.

D. POGO Plant Design

1. Objectives

To develop a preliminary design of a coal processing plant which 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.

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 This Quarter

a. We completed the Design Basis Recommendation document and transmitted it to ERDA. It includes the following:

1. Block Flow Diagrams for Candidate POGO process configurations.

2. Preliminary Technical/Economic Assessment.

3. Process Comparison Study.

4. Short List Comparison (4 alternative configurations).

5. Recommended Design Basis; key coal conversion steps are flash pyrolysis and hydroliquefaction.

b. We received agreement from ERDA on major points of the design basis. At ERDA's request, we defined procedures to upgrade the heaviest liquid product to higher valued consumer products.

c. At ERDA's direction, we will prepare the design basis document in a form suitable for publication as an R&D report. To accomplish this, we initiated a final check of documents included in the report.

d. We started a preliminary study to determine the advantages and economics of adding a Fischer-Tropsch section to the selected POGO configuration.

e. We made progress on a study to set the maximum economical pressure level for gasification of char with air.

f. We completed a preliminary study of pyrolysis processes. Three basic types of pyrolysis processes were considered: flash, hydropyrolysis, and catalytic "fast" pyrolysis.

g. We prepared a case study for integration of process furnaces and gas turbine operations.

h. We prepared economics comparisons for four POGO configurations.

5. Results of These Activities

We completed alternate economic assessments for the revised design to include upgrading the heaviest liquid product. A preliminary technical description and economics of base Case IV were then transmitted to ERDA for review.

Economic comparisons are based upon the following cases:

Case IVB: The base pyrolysis hydroliquefaction case plus gasification of heavy oil.

Case IVC: Case IVB, adding coal feed to pyrolysis to provide sufficient extra char to feed a 250 billion Btu/day Fischer-Tropsch train.

Case IVD: The base case, but coking the heavy oil.

Case IVE: Case IVD, adding coal feed as in Case IVC for a 250 billion Btu/day Fischer-Tropsch train.

The evaluation procedure was as follows:

1. Establish a block flow diagram, including all units required for plant operation.

2. Establish a process material balance, using a hydroliquefaction unit of the same size as that used in in the Oil/Gas plant, and, where required, a Fischer-Tropsch train equivalent to one train of our U.S.A. FischerTropsch plant. Size other units to supply hydrogen needs for the plant and to treat all products to salable condition. Calculate utility requirements based on fuel gas needs at 15 percent of the heating value of coal fed to the process units.

3. Adjust the fixed capital estimate for all cases to 75,000 TPD coal feed by use of a 0.7 exponent capacity factor.

4. Calculate fuel selling price required to produce a 12 percent discounted cash flow return, based both on an average heating value basis and also probable product market values.

5. On the basis of the above evaluation Case IVD (coking of heavy oil) was recommended as being economically attractive, considering conservative product pricing. ERDA accepted our recommendation.

We obtained analyses of candidate alternate coals as required for the design basis of this task.

4. Activity Forecast Next Quarter

a. The product slate for Case IVD will be specified and detailed design activities started.

b. The coal mine design for all three locations will be started.

c. Coal preparation units design is expected to be completed for the two eastern locations. None is contemplated for the western location.

E. Multipurpose Demonstration Facility

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. These designs shall be based on the concept that the operating units shall be constructed as module additions over a period of years. The completed facility shall include modules of facilities which can be common to two or more other processes, as well as allowances for future modification and/or replacement of various pieces of equipment to meet new requirements.

2. Activity This Quarter

a. We developed a very preliminary design and economics for a conceptual commercial methanol plant from coal. We worked to refine the design and economic estimates.

b. We advanced the comparison of methanol processes for production of coal based methyl fuel.

c. We studied a high pressure (5,000 psig) methanol plant design.

d. We completed a preliminary single-stage gasifier design basis to produce gas with minimum methane and nitrogen as required for methanol plant feed.

e. We reviewed Cresap designs to establish their suitability for inclusion into the multipurpose scheme.

3. Results of These Activities

The preliminary designs/economics were used as a basis to begin preparation of a recommended design basis.

4. Activity Forecast Next Quarter

The studies started during this quarter will be refined during the next quarter. A size determination study for the facility will be started.

F. Equipment Development

1. Objectives

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

2. Activity This Quarter

a. Gas/Solids Separation: We received additional information on cyclone sizing and efficiencies. We continued to work with electrostatic precipitator manufacturers.

b. Solids Feed to Gasifier: We continued to work with vendors on developments of ground coal compression screw feeders.

c. Valves: We met with valve manufacturers and discussed the adaptability of their products to coal conversion applications.

3. Activity Forecast Next Quarter

We will continue collaboration with equipment manufacturers and monitor progress of their developments. We will propose development programs to ERDA where deemed practical.

G. Materials of Construction

1. Objective

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

2. Activity This Quarter

a. We presented a paper entitled "The Materials Problems in Coal Gasification and Liquefaction Systems" to the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME) Conference on Materials Requirements for Unconventional Energy Systems on September 19-23, 1976 at Niagara Falls, New York.

b. We supported the Oil/Gas and Fischer-Tropsch design efforts by supplying materials of construction specifications.

H. Environmental Considerations

1. Objectives

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. <u>Activity This Quarter</u>

a. We assembled a report on "Environmental Factors Related to the Surface Mining of Coal." This report considers mining techniques which facilitate the task of land reclamation, federal and state regulations concerning the surface mining of coal, prevention of water pollution, land reclamation procedures, and representative costs.

b. We reviewed the conceptual design of the Fischer-Tropsch and the Oil/Gas plants to define the proportion of capital and operating expenses which is allocated to environmental control facilities. For the Oil/Gas plant, ten plant units contribute to environmental control and the fixed capital investment for environmental units amounts to approximatel 12.5 percent of the total fixed capital. This is the same order of magnitude as required for a grass roots petroleum refinery.

c. We will investigate the role of cyanides in coal conversion processes. The following subjects will be phases; reactions and equilibria with other chemical species; detoxification of gaseous phases; liquid effluent cleanup.

3. Activity Forecast Next Quarter

We will continue the environmental work along the two main directions followed so far, namely (1) investigation of environmental factors related to coal conversion and identification of environmentally sensitive areas or operational aspects where additional study is required, (2) design monitoring to insure that the Parsons conceptual commercial designs are environmentally acceptable and in compliance with present and projected environmental requirements.

In the first area, we will further investigate the fate of trace elements during coal conversion in view of recent information collected by the Institute for Gas Technology at the Hygas Pilot Plant. We will also further the study of formation of cyanides during gasification or liquefaction of coal and their detoxification during effluent treatment.

We will review the preliminary design work for the POGO Plant and the Multipurpose Demonstration Facility; specific environmental areas requiring consideration will be analyzed and discussed with the design engineers.

FE-1775-9
UC-89

PRELIMINARY DESIGN SERVICES

RESEARCH AND DEVELOPMENT REPORT NO. 114

QUARTERLY REPORT

For the Period: October - December 1976

Prepared by:

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

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

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

April 1976

FOURTH QUARTERLY REPORT

PRELIMINARY DESIGN SERVICES

THE RALPH M. PARSONS COMPANY

I. OBJECTIVE AND SCOPE OF WORK

The objective is to develop preliminary designs and economic evaluations for a number of types 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 coal processing plant to produce power, oil, gas, and other products (POGO).
- A facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes that show promise during pilot plant operations.

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, construction materials development, and environmental factors.

II. SUMMARY OF PROGRESS TO DATE

A brief review of the status of the major active design efforts is given below, followed by a more detailed reporting on the progress of individual tasks.

During the past quarter we expanded and made refinements to R&D reports for the Fischer-Tropsch and Oil/Gas plants. We worked to expand the Oil/Gas plant R&D report to include:

- Experimental data bases for the design.
- Design and operation of the effluent waste heat boiler design.
- Product marketability.

We expanded the catalytic reactor design section of the Fischer-Tropsch plant R&D report.

We established basic material balances on the POGO plant design for the pyrolysis, the high pressure gasifier, the hydroliquefier, fractionation, and distillate desulfurization units and prepared a preliminary material balance for the thermal cracker and the delayed coker.

We continued development of conceptual designs for coal mining facilities in Southern Appalachia and Rocky Mountain Provinces in support of the POGO design. This included continued evaluation of geological information from state agencies on coal availability in Southern Appalachian and Rocky Mountain Provinces for mines with capacity to 100,000 tons of coal per day.

We obtained additional information on the subject of gas/solids separation and coal feeding devices. We obtained information on ionizer units that claim improved collection efficiencies while allowing higher throughput velocities.

We initiated an environmental study on the relative impact of a coal conversion facility of the POGO type on the quality of air for their geographical regions.

A brief summary of results by assigned task follows.

A. <u>Coal Mining/Coal Preparation</u>

We started scale-up of the wet jigging, multi-stage cyclone coal preparation plant to an optimum module size; this is part of our evaluation of various methods of coal preparation.

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

We continued our work to finalize the R&D report. At ERDA's direction, we are expanding this report to include the marketability of products and design and operation of the gasifier waste heat boiler.

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

We continued preparation of the R&D report including expanded coverage of areas requested by ERDA. This included sections on product marketability, experimental basis for the Fischer-Tropsch reactor design, and design characteristics of waste heat boilers.

We completed the experimental and process design basis for the synthesis, methanation and shift reactor systems section.

D. <u>POGO Plant Design</u>

We defined the projected product slate for the preferred plant configuration (Case IVD) and initiated detailed process design activities. We completed the preliminary overall material balance and block flow diagram.

E. <u>Multi-Process Demonstration Facility</u>

We reviewed the objectives of the Multi-Process Demonstration Facility with ERDA representatives and established specific activities for this task. We prepared recommended design criteria and initiated a work breakdown structure which can be performed within the financial restraints of our contract.

F. Equipment Development

We continued to obtain information on Gas/Solids separation equipment and valves.

G. Materials of Construction

We continued to provide material selection services for various tasks.

H. Environmental Considerations

We continued our investigation of sensitive environmental areas of coal conversion where definite answers are available concerning the formation of possible pollutants and their partitioning among the various effluent streams generated. We initiated the study of the relative impact of a coal conversion facility of POGO-type on the air quality.

I. General

1. We are carefully reviewing the potential for use of computer assisted simulation capability in the analysis and optimization of power generation/utilities systems in coal conversion complexes.

2. We presented an invited paper on the subject of "Coal Liquefaction" to the Third International Symposium on Large Chemical Plants Design and Operation on October 21, 1976 at Antwerp, Belgium. The symposium was sponsored by the European Confederation of Chemical Engineers.

3. We participated in an advisory committee meeting for the IGT Technical Data Book program. This meeting was held in Chicago, Illinois on October 21.

4. We attended the 8th Synthetic Pipeline Gas Symposium sponsored by AGA/ERDA/IGU on October 18-20, 1976 in Chicago.

5. We transmitted additional information to the Corps of Engineers relative to Fischer-Tropsch and Oil/Gas Plant Design estimates.

6. We submitted an abstract of our paper titled "Potential Markets for Emerging Energy Technologies" to be presented to the August 1977 National Meeting of AIChE. This is to be a part of the Second Pacific Engineering Conference.

7. We presented an invited paper on the subject of "Materials, Needs, Opportunities, and Problems" at an ERDA/EPRI/AGA-sponsored conference on Materials for Coal Conversion and Utilization on September 30 and October 1, 1976 in Washington, D.C.

8. We presented an invited paper entitled "Environmental Factors for Oil/Gas Coal Conversion Technology" to the 69th Annual Meeting of the American Institute of Chemical Engineers in Chicago on December 1, 1976.

III. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. Coal Mining/Coal Preparation

1. Objective

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 100,000 tons per day are being considered.

2. Activity This Quarter

a. We continued to assemble geological information on coal reserves required for large mining operations in the Southern Appalachian and Rocky Mountain Provinces.

We started the preparation of reports describing the expected capacities of these coal mines.

b. We continued to investigate alternative coal preparation methods including heavy media separation and wet jigging, screening, and multi-stage hydroclone operations.

3. Results of These Activities

a. Southern Appalachian Coal Resources. The study of the mining potential for 100,000 TPD of coal in the Southern Appalachian Region generated the following preliminary conclusions.

In 1975, 22 million tons of coal were mined in Alabama; 50 percent of this was strip mined. We understand that practically all the strip mineable coal is in the Warrior Field. Underground recoverable reserves approximate 850,000,000 tons in this field.

For the first 5 years coal may be obtained in the Warrior coal field area from a combination of underground and strip mine sources in the ratio of 1.2 to 1, respectively. After that, all coal would be obtained from underground mines.

This is based on a geological assessment that present obtainable strippable reserves amount to 90,000,000 tons. We are assuming that half of this can be available to POGO. "Strippable Resource" coal is not considered as available coal, since this is mostly thin seam coal, uneconomical to mine, and therefore impractical for planning purposes.

The following tabulation quantitatively outlines the ROM coal supply plan:

Years 1 through 5:	Tons/Day	Tons/Year	Total Tons
From underground mines	33,000	11,000,000	55,000,000
From strip mines	27,000	9,000,000	45,000,000
Subtotal	60,000	20,000,000	100,000,000
Years 6 through 20:			
From underground mines	60,000	20,000,000	300,000,000
			400,000,000

b. Western Coal Resources. The study of the mining potential for 100,000 TPD of coal in the Rocky Mountain Coal Province led to the conclusion that one mine with several faces working simultaneously can be developed for the required capacity.

c. Coal Preparation. Our studies of heavy media vis-a-vis wet jigging combined with multi-stage liquid cyclones and wet screening led to the preliminary conclusion that the wet jigging procedure is preferable for processing the Appalachian and Illinois ROM coal into high and low ash fractions. This method was therefore selected for the POGO coal preparation design. Further details are shown in the report on the POGO design, Paragraph III D-3-b.

Note that Western coal will require less refined preparation methods.

4. Activity Forecast Next Quarter

We will start design work for strip and underground mines in the Southern Appalachian area. Work will continue on coal preparation facilities for Southern Appalachian and Western coals.

B. Oil/Gas Plant Design

1. Objectives

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

2. Activity This Quarter

We worked to expand the R&D report to include:

a. Experimental data bases for the design.

b. Marketability of the products.

c. Design and operation of the gasifier waste heat boiler.

3. Results of These Activities

a. Experimental Data Base. The design was based primarily on five SRC-II material balance runs performed at the Tacoma Pilot Plant in August 1975, SR-1 through -5[1], plus supporting SRC-11 data from a process development unit (PDU). The following procedure was used to develop the design yield structure:

- Adjust SR-3, 4, 5 yields to 100 percent.

- Average the yields from SR-3, 4, 5.

- Adjust the heteroatom balance to give 15 percent nitrogen removal, 35 percent oxygen removal and 67 percent sulfur removal. These heteroatom removals and reaction conditions are consistent with the objective of producing a fuel oil product containing 0.5 weight percent sulfur, maximum.

  Basis: Nitrogen appears only in ammonia, sulfur in hydrogen sulfide and oxygen in carbon dioxide and water.

- Using the Oil/Gas feed coal analysis, perform an elemental balance for the adjusted yields, based on use of the liquid elemental analyses published for SRC-I yields.[2]

The results of the above procedure are shown in Table B-1, which gives the complete yield structure and elemental analyses of all products.

Tacoma laboratory distillation results[3] were used to construct distillation and specific gravity curves for the products; these are shown in Figures B-1 and B-2. All other properties of product streams were generated by standard Ralph M. Parsons Company proprietary correlations.[4]

All available data were considered in preparing the design basis. The resulting material and elemental balances are a composite projection of expected results. Based on information available, these balances are expected to conform to the yields and product distribution to be achieved with SRC-II.

Other hydroliquefaction design factors are:

o Solvent/Coal (S/C) ratio. Solvent is defined here as the total weight of the recycle stream, including both liquids and solids.

  Initial SRC-II pilot plant tests, runs SR-1 through -5, used S/C ratios in the range of 4-6, which is too high. SRC-1 operates satisfactorily with S/C of 1.5 - 2.0. Judgment led to selection of a design basis of S/C = 3. This judgment was later confirmed when the process developer recommended solvent to coal ratio in the range of 1.5 to 2.5[5]

  Reduction of S/C to 1.5 results in reduction of fixed capital investment of about 6 percent, and required product selling price of about 5 percent.

o Temperature, Hydrogen Partial Pressure and Hydrogen Circulation Rate. The conditions listed below were selected to produce a fuel oil product with 0.5 weight percent sulfur, maximum. The selection was based on data analysis plus discussions with process development personnel from the Pittsburg & Midway Coal Mining Company.

To summarize, the following design conditions were used:

Solvent/Coal Weight Ratio	3:1 (2/3 slurry, 1/3 filtrate)
Temperature	850°F outlet of dissolver 700°F outlet of preheater
Hydrogen Partial Pressure	1900 psig (at preheater entrance)
Hydrogen Circulation Rate	2 times consumption

- Process Gasification. High pressure steam-oxygen gasification of coal was used to produce a hydrogen-rich synthesis gas to supply hydrogen for dissolving and naphtha hydrotreating. The gasifier is an entrained, slagging, two-stage design, based on information published by the Bituminous Coal Research, Inc. during the ERDA-sponsored Bi-Gas Development program.[6] This gasifier also produces a significant quantity of methane which is recovered in a cryogenic separation unit and produces salable SNG.

  Gasifier conditions were selected to convert 20 percent of the carbon in the feed coal to methane.

Heat and material balance calculations for conditions to accomplish this in the gasifier followed closely the procedures recommended by BCR, Inc.[7]

- Fuel Gas Generation. The fuel gas required for process furnaces and power plant boilers is generated in a low pressure, air-blown, two-stage, slagging gasifier. This gasifier was designed to operate at a pressure of 45 psia in order to move the gas through the downstream H_2S removal system and to the points of use. Calculations for this gasifier are similar to for the process gasifier.

- Product Post-treatment. Light oil produced in the SRC process is hydrotreated to produce naptha-range material suitable for gasoline production. Hydrotreater conditions and yields were based on a previously published design for hydrotreating of coal-derived light liquids.[8] Product contains 1 ppm of sulfur and 5 ppm of nitrogen.

b. Projected Marketability. The adaptability of the higher boiling liquid Oil/Gas plant fuel products to current U.S. usage patterns remains to be demonstrated by functional product testing. They are valuable fuel products which have some characteristics which differ slightly from similar products made by crude oil refining. A likely future event is that coal conversion product characteristics will be reconciled with crude oil-based products, possibly by modification of liquid fuel-consuming equipment.

- Marketability Considerations. The products are generally similar to petroleum products presently marketed in the U.S. There are, however, some property differences between coal and crude oil derived products.

  Comments regarding marketability are presented for the following products:

  - SNG
  - Propane and Butane LPG
  - Naphtha
  - Fuel Oil
  - Sulfur
  - Ammonia

- SNG (Substitute Natural Gas). This product would be sold as pipeline gas for either industrial or residential use.

- Propane and Butane LPG. This product would be marketable through normal LPG market channels for

industrial, agricultural and residential uses.
Other potential markets are:

- Ethylene feedstock

  The butane could be marketed to refiners as a gasoline vapor pressure control additive for northern winter markets.

- o <u>Naphtha.</u> The primary value of this feedstock is as a reformer feed blending component.

  The SRC-derived naphtha has a high naphthene content making it suitable for upgrading to lead-free precurser for gasoline through reforming. Hetroatom content is low. It should be marketable through conventional channels.

- o <u>Fuel Oil.</u> This heavy fuel oil should be marketable to utilities.

  Its sulfur content is sufficiently low to allow sale in most areas of the U.S. Also, its viscosity, pour point, flash point and ash content meet Number 6 Residual Fuel Oil specifications.

  A functional product testing program for a related product, solid SRC, is in progress using a 22 megawatt boiler installation. The results of this program should provide information regarding such factors as excess air requirements and preferred burner design. This information should be used to provide further insight into marketability of the Oil/Gas fuel oil.

The compatability of Oil/Gas fuel oil with petroleum-derived fuel oil is being studied and the results of those studies will determine the ability to blend the two products in consumer storage tanks/handling system.

c. Product Characteristics

The following projected characteristics for the products were developed.

o Substitute Natural Gas (SNG). Projected SNG composition and characteristics are:

Composition, vol %, dry basis	
Methane	84.27
Ethane	8.61
Propane	1.69
Nitrogen	3.34
Hydrogen	1.54
Carbon monoxide	.09
Carbon dioxide	.46
	100.00

Higher heating value, Btu/SCF 1050

American Gas Association Interchangeability Indices for the Oil/Gas SNG are given in Table B-1 where they are compared with several types of base load gas.

Characteristics	Value	Test Reference
Hydrocarbon Dew Point, °F	-36 @ 1000 psia	ASTM D1142-58
Water Dew Point, °F	10 @ 1000 psia	ASTM D1142-58
Wobbe Number	1350	(calculated)
Weaver Flame Speed	14.6	(calculated)

(Note: Heat content and dew points can be adjusted to meet consumer specification.)

o Propane and Butane LPG

Composition, mole %	Propane LPG	Butane LPG	Test Reference
Ethane	3.05	--	
Propane	96.08	23.93	
Butane	.89	75.11	
Pentane and higher	--	.96	
Sulfur	nil	nil	ASTM D1266
Specific Gravity, 60°F, liquid	.503	.568	ASTM D1657 or 2598
Vapor Pressure @ 100°F, psig psig	210	70	ASTM D1267 or 2598
Butane and heavier, % ma% max	2.5	--	ASTM D2163
Pentanes and heavier, % max	--	2.0	ASTM D2163
Moisture Content	pass	pass	NGPSA standard test
Corrosion, copper strip	No. 1	No. 1	ASTM D1853

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o <u>Naphtha</u>

The naphtha is a hydrotreated, stabilized light cut of coal-derived liquid products. Its projected characteristics are:

Characteristic	Value	Test Reference
Gravity, °API	50.0	ASTM D287
Distillation		
Vol. % — °F		
IBP — 155		
10 — 210		
30 — 270		
50 — 300		
70 — 320		
90 — 345		
EP — 380		
Viscosity, CS	1.7 @ 100°F	ASTM D445
Sulfur, ppm	1 (max)	ASTM D1266
Nitrogen, ppm	5 (max)	ASTM D3228
Higher Heating Value, Btu/lb	19,900	ASTM D2382
UOP Characterization Factor	11.8	
Composition - General:	Naphthenes-high Aromatic-high	PONA analysis

o Fuel Oil

Fuel Oil is comprised of blending the remainder of the net liquefaction products; projected properties are:

Characteristic	Value	Test Reference
Gravity, °API	-8.2	ASTM D287
Distillation		ASTM D1160 (calculated)

Vol. %	°F
10	460
30	660
50	875
70	1110
90	1450

Characteristic	Value	Test Reference
Viscosity, SSF	45 @ 112°F	ASTM D445
Sulfur, wt %	0.4	ASTM D129
Nitrogen, wt %	1.2	ASTM D3228
Ash, wt % max.	0.1	ASTM D482
Pour Point, °F	50	ASTM D97
Higher Heating Value, Btu/lb	17,200	ASTM D2382
Flash Point, °F	Above 150	ASTM D93
Conradson carbon	25 (est.)	ASTM D189
UOP Characterization Factor	10.1	

- <u>Ammonia</u>

  Ammonia is separated from process waste water by a proprietary process. Predicted characteristics are:

Ammonia content	99.99 wt %
Color	colorless
Water	100 ppm max.
Oils	2 ppm
Carbon dioxide	3 ppm
Hydrogen sulfide	non-detectable
Chlorine	2 ppm
Iron carbonyl	3 ppm
Non-condensables	0.1 cc/g

- <u>Sulfur</u>

  Sulfur is produced in several conventional-type units, which typically give the following product analyses:

Sulfur	99.8 wt % min.
Ash	0.05 wt % max.
Color	bright yellow (combined products)

d. Syngas Heat Recovery.

High pressure synthesis gas, containing approximately 20 weight percent entrained char, flows from the top of the high pressure process gasifier at 1700°F and 1000 psig through lined ducts, and then through the tube side of three critical service heat exchangers in series. The first is a single shell steam superheater, with Incoloy 800 Grade 2 tubes. The second, a single shell gas/oxygen exchanger, has an inlet gas temperature of 1500°F and 321 stainless steel tubes. The third, a two-shell steam boiler, also with 321 stainless steel tubes, operates with an inlet gas temperature of 1470°F.

These heat exchangers are vertical, shell and tube single pass units. Gas with entrained char flow is from top to bottom of each exchanger. In order to minimize tube abrasion, the tube inlets are fitted with abrasion resistant ceramic ferrules to protect the turbulent entry area. The tube materials of construction are selected on the basis of proven suitability at the specific set of operating conditions.

These syngas coolers are patterned after units in petroleum fluid cracker regenerator gas outlet coolers and fluid catalyst line exchangers. These exchangers are also similar to the high pressure tubular boilers cooling ash-laden syngas under similar conditions in a coal-based ammonia plant.

The low Btu syngas flows from the top of the Fuel Gas Gasifier through the char cyclone at a temperature of approximately 1800°F. Air/Fuel Gas Exchangers No. 1 (3 shells), and No. 2 (2 shells), receive the fuel gas at 1800°F and 780°F, respectively, serving to preheat the combustion air to the fuel gasifier to above 1200°F. Between these two air/fuel exchangers a two-shell 1200 psi Steam Generator, receives the hot fuel gas discharging from No. 1 Air/Fuel Gas Exchanger at 1400°F. These heat exchangers are designed for critical service using proven practice in the petroleum industry.

The Air/Fuel Gas Exchangers are of the special fixed tube-sheet type similar to that used for high temperature gas services in steam-methane and naphtha reforming plants. The process gases are in countercurrent flow with a single-pass tube side configuration. The inlet channel and tube sheet is lined with a low iron, low silica insulating castable refractory designed to maintain the metal temperatures within the allowable stress limits. A shell side expansion joint is provided to allow for the thermal differential expansion between the tubes and the shell.

The 1200 psi high pressure Steam Generators are of the fixed tube sheet modified fired tube natural thermosyphon design. The process gas flows through the tube side which is of single-pass configuration. The conical inlet and outlet gas channels, together with the one-pass tube layout, provides a geometry which minimizes impact erosion and gas pressure energy loss. The shell side (water side) of the generators is serviced by strategically placed downcomers and risers arranged to provide a well distributed flow of steam and water throughout the bundle. The downcomers and risers are served by an external steam drum which is placed at sufficient elevation to provide a minimum of 15 to 1 water-to-steam ratio in the risers. The external steam drum will serve one or more boilers and is complete with the necessary internals required to provide the specified steam purity.

Fuel Gas/150 psi steam generators (2 shells), are of the same general design as the high pressure units except that economics of either an external or integral steam drum will be considered in the final design of these units.

Dependable performance is considered assured from these Fuel Gas cooling and heat recovery units considering the use of similar designs in the petroleum refining industry.

4. Activity Forecast Next Quarter

a. We will submit the R&D report to ERDA for publication approval and will publish the report.

b. The suitcase model will be shipped to ERDA.

C. Fischer-Tropsch Plant Design

1. Objectives

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

a. We completed a draft of the synthesis gas heat recovery equipment section for insertion in the R&D report.

b. We expanded the product section of the R&D report to include an analysis and definition of probable market outlets for each of the products from the Fischer-Tropsch plant.

c. We expanded the R&D report to include a section which summarizes experimental data used to develop the design basis for the Fischer-Tropsch synthesis, water gas shift and methanation reactor systems.

d. We developed an expected yield structure for reformate produced from Fischer-Tropsch naphtha. We considered and listed other means available to convert Fischer-Tropsch production to gasoline. We briefly evaluated the steps which would be required to extend the scope of the project to include gasoline manufacture from Fischer-Tropsch liquids.

e. We revised the product descriptions section of the R&D report to include oxygenate removal from Fischer-Tropsch liquid product by water wash. We included nonacid oxygenates in the product descriptions since they should remain with the hydrocarbon phase of the process.

f. We responded to a number of technical and economic questions asked by ERDA regarding the design. We then reviewed the R&D report with the objective to expand coverage of these areas.

g. We completed the experimental and process design basis for the synthesis, methanation and shift reactor systems section and the R&D report was rearranged accordingly.

h. We completed a suitcase model of the Fischer-Tropsch plant.

i. We submitted a revised draft of the R&D report to ERDA for review and authorization for publication.

3. <u>Result of These Activities</u>

a. <u>Details of Syngas Heat Recovery</u>. Syngas flows from the top of the gasifier through parallel, abrasion-resistant, ceramic-lined ducts into vertical straight-tube heat exchangers.

The gas contains approximately 30 wt% entrained char or 0.125 pound solids/acfm entering the heat exchangers at 1700°F, and 0.2 pound solids/acfm leaving the heat exchanger at 950°F. This is considered a light solids loading by pneumatic conveying standards. Velocities downward through these heat exchanger tubes are approximately 75 fps, which is within the design range for pneumatic conveying systems. Accordingly, abrasion of the heat exchange tubes is expected to be within commercial experience limits.

A suitable expansion joint will be provided for each heat exchanger commensurate with each unit's service. The exchangers will be a modified floating-heat design to allow for the differential thermal expansion between the shells and the tubes.

In order to minimize tube abrasion, the tube inlets are fitted with abrasion-resistant ceramic ferrules. Thus, the turbulent entry area of the tubes will be protected. Stainless steel No. 321 with 1/16 inin corrosion allowance, equivalent to Schedule 80 pipe, was selected as the tube material because of its toughness. This material is deemed satisfactory for service up to 1,500°F. Maximum tube temperature is expected to be 1,300°F. The heat exchanger inlets and outlets are lined with ceramic for shell abrasion resistance in these areas.

The syngas coolers are patterned after known 450 psig units used in petroleum fluid cracker regenerator gas outlet coolers and fluid catalyst line exchangers. These exchangers are also similar to the 750 psig tubular boilers cooling syngas and ash under similar conditions in a coal-based ammonia plant.

The parallel streams of 950°F gas, with entrained char, leave the heat exchangers at the bottom and enter individual sets of two-stage cyclones (four sets in all). Connecting ducts are refractory lined, as short as possible, with a minimum of bends. All bends are long sweep and designed with solids retention areas where impingement occurs onto the solids so that direct impingement on duct walls is minimized.

d. Naphtha Utilization and Marketability. The following details of naphtha yield structure and its conversion to gasoline were developed.

The primary value of light and heavy naphtha products as produced in the Fischer-Tropsch complex would be as ethylene feedstocks. Their composition, consisting primarily of straight-chain saturated and monounsaturated hydrocarbons with nil sulfur and near-nil aromatics content provides economic advantages for these purposes. The products differ from normal petroleum naphthas in that they have nil aromatic content and low octane numbers. Therefore their use in the gasoline pool would require further processing. Representative processing procedures to produce higher octane gasoline from F-T liquids have been described. Using a processing procedure consisting of catalytic polymerization of propylene and butylenes plus catalytic reforming of the naphtha, alcohol, and 3 cc tetraethyl lead addition, resulted in research octane numbers of the order of 92. When alkylation of contained butane is included in the processing sequence, the resulting leaded research octane of the product gasoline pool was on the order of 96.

The proposed alternate of marketing them as chemical feedstocks would release petroleum-based naphthas for conventional processing to gasoline and other products.

e. Oxygenate Production. The following details of water extracted oxygenates were developed. They are a mixture of alcohols with a small amount of ketones.

Composition	Vols. %, dry basis
Acetone	3.2
Methyl ethyl ketone	0.7
Methanol	6.0
Ethanol	67.6
Propanol	18.0
Butanol	2.4
Amyl alcohol	1.1
Higher alcohols and other oxygenates	1.0
	100.0

Product Characteristics

Higher Heating Value

dry	13,160 Btu/lb average
as produced	12,505 Btu/lb average
Specific gravity	0.79
Water content	5.0 wt% max.

4. Activity Forecast Next Quarter

   a. Detailed design calculations for the synthesis reactors will be summarized and added to the R&D report appendix.

   b. The suitcase model will be shipped to ERDA.

   c. The R&D report will be published following receipt of acceptance by ERDA.

D. POGO Plant Design

1. Objectives

To develop a preliminary design of a coal processing plant which 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.

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 This Quarter

a. We established a basis for a coal pretreatment facility design to produce optimum coal feeds for the various coal-using sections of the complex.

b. We prepared an outline of a proposed test program required to back up the pyrolysis unit design to be used in the POGO plant design.

The recommended test program includes factorial experiments to determine maximum liquid yield and detailed experiments to establish optimum operating conditions. The execution of this program will improve the valiity of the pyrolysis section design.

c. We prepared an outline of the experimental work required on the SRC process for the POGO plant design. We established a process design basis for an SRC II unit using Illinois No. 6 coal. Experimental data are required for the Alabama and Wyoming coals to be used for this plant design. In the absence of such data, the design will be based on extrapolation techniques which have been proposed.

d. We prepared a comparison of the offsites specifications and costs for estimates with another plant of similar nature. This comparison will be used as reference for designs/economic evaluations to be developed.

e. We recommended selection of the Case IV alternate for the POGO plant design and worked to develop the design basis. The complex will include hydroliquefaction, flash pyrolysis, and gasifier plants. It will produce SNG, LPG, Naphthas, Fuel Oils and high quality crystalline coke. A low Btu fuel gas and power generation plant, utilizing combined cycle operating principles, will produce required plant power and a nominal 1,000 MW of electricity for sale.

f. We completed the preliminary block flow diagram.

g. We initiated the development of flow diagrams, material balances and heat balances for the key coal conversion units.

h. We established the process, engineering design, and overall project schedule.

i. We established basic material balances for the flash pyrolysis, the high pressure gasifier, the hydroliquefier, fractionation, and distillate desulfurization units. We further prepared a preliminary material balance for the thermal cracker and the delayed coker. This preparatory work is necessary before an overall material balance can be established. As gas balances are established, minor revisions will be made to the basic balances listed above.

j. We developed preliminary estimates of utilities requirements and temperature levels of heat recovery as preparation for establishing the basis for integration of the process and power sections.

k. We worked to finalize the POGO Design Basis report for publication. We are adding a summary of the estimated economics of Coalcon to this report.

l. We reviewed hydropyrolysis as an alternative to the flash pyrolysis step. The extrapolation of available low pressure flash pyrolysis data to the 500 psig intermediate pressure is deemed practical. We concluded that the flash pyrolysis route is preferred, due to favorable hydrogen balance and economic factors.

3. Results of These Activities

a. The design of process flow sheets with material balances of individual process units is proceeding.

b. Coal Pretreatment. A coal pretreatment facility was developed for Illinois No. 6 feed coal. The grading procedure segregates the run-of-mine coal containing 10 to 20 percent ash into three fractions.

- A 6.5 wt% ash fraction to be used as hydroliquefaction and pyrolysis section feeds.

- o An 8 wt% ash fraction to be used as fuel gas generation unit feed.
- o A variable rock and ash fraction for return to the mine as backfill.

The analyses for the two process unit feed fractions were estimated as follows:

Proximate Analysis (Composition wt%)	Pyrolyzer/Hydro-liquefier Feed (60% of Total Coal)	Fuel Gas Gasifier Feed (40% of Total Feed)
Moisture	2.7	2.7
Ash	6.3	7.8
Volatile Matter	38.9	38.2
Fixed Carbon	52.1	51.3
	100.0	100.0

Ultimate Analysis Composition Wt.%	Pyrolyzer/ Reactor Feed (60% of Total Coal)	Fuel Gas Gasifier Feed (50% of Total Feed)
Carbon	71.5	70.4
Hydrogen	4.9	4.8
Nitrogen	1.4	1.3
Sulfur	3.9	3.9
Oxygen	9.3	9.1
Moisture	2.7	2.7
Ash	6.5	7.8
	100.0	100.0
Gross Heating Value, Btu/lb	12,886 12,886	12,694

440

c. Offsite Costs. The offsites cost comparison, expressed as a percentage of the total constructed plant cost was developed with the following results:

Oil/Gas Plant	22%
Fischer-Tropsch Plant	19%
Fossil Resource Conversion Plant	20%
POGO Complex preliminary assumption	20%

d. Block Flow Diagram. A preliminary block flow diagram was developed and is shown in Figure D-1.

e. Project Schedule. The process, engineering design, and report preparation schedule is shown in Figure D-2. Completion of the project through final publication of the R&D report is scheduled for the end of 1977.

f. Pyrolysis Process Comparison. Our review of hydropyrolysis as an alternative to the flash pyrolysis step included comparisons of the POGO flash pyrolysis step with the Coalcon intermediate pressure hydropyrolysis process and high pressure hydropyrolysis. Table D-1 gives a preliminary comparison of investments and operating costs indicating cost advantages for the flash pyrolysis process.

4. Activity Forecast Next Quarter

We will continue work on the process units' flow sheets with equipment sizing and material balances.

The coal preparation unit flow sheet will be completed.

E. Multi-Process Demonstration Facility

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 operations. These designs shall be based on the concept that the operating units shall be constructed as module additions over a period of years. The completed facility shall include modules of facilities which can be common to two or more other processes, as well as allowances for future modification and/or replacement of various pieces of equipment to meet new requirements.

2. Activity This Quarter

a. We reviewed the objectives of the Demonstration Facility with ERDA representatives and established guidelines for the design as a development phased over an undetermined period of time.

b. We developed recommended design objectives and design criteria for the work. We initiated the work breakdown structure which can be performed within the financial restraints of our contract.

c. We continued to study methanol plant designs.

3. Results of These Activities

a. Development of Multi-Process Complex. We proposed a three-phase development of the Multi-Process Facility with the following major steps:

(1) Phase 1

- o An air-blown gasifier
- o An oxygen-blown gasifier
- o A combined cycle power plant

(2) Phase 2

- o A shift reactor for hydrogen production
- o Acid gas removal
- o Fischer-Tropsch Unit

(3) Phase 3

- o Liquefaction by SRC, or donor solvent, or rapid hydrogenation
- o SNG, methanol, ammonia production
- o Liquid product processing

With any of this, the coal preparation, the utilities and environmental parts will be supplied as needed.

This program was discussed with ERDA and is under advisement. Further refinement of the program is under way.

b. Design Objectives. The following objectives were developed and discussed with ERDA.

(1) To demonstrate the performance and commercial feasibility of a number of potentially viable coal conversion processes/process steps.

(2) To provide data in sufficient quality and quantity to design a commercial plant. This includes data on process, equipment and environmental factors, among others.

(3) To provide a firm basis for prediction of the economics of commercial scale facilities adequate to generate financial support.

(4) To produce adequate product to support functional product testing and assure product sales.

c. Design Criteria. The following design criteria were developed and discussed with ERDA:

(1) Capacity: large enough to permit scale-up to commercial scale plants.

(2) Flexibility to:

- Test a number of processes/process steps.
- Test a number of coals as feedstock.

(3) Ability to add demonstration scale test facilities for additional potentially viable processes as they are defined in the future.

(4) Adequate raw material, intermediate and product storage to provide the required flexibility.

(5) A high degree of instrumentation plus supporting development laboratory and small scale test units to support an extensive test and evaluation program.

(6) Design process units for high process and thermal efficiency . The total complex operation may or may not be highly efficient.

(7) Environmental control facilities adequate to meet regulatory standards and provide data input for preparation of environmental inpact statements.

(8) Allow capability to test alternate equipment types and measure equipment reliability.

(9) All utilities to be self-contained.

(10) Use modular construction where appropriate.

d. Methanol Production Studies. Our studies of various Methanol production studies led to the following preliminary results:

(1) Catalyst Manufacturers. Girdler and CCI were contacted to obtain basic information for catalyst volume determination, and supply and cost data.

Girdler offer the Lurgi low temperature catalyst, but are unable to provide any information due to licensing problems. CCI have offered the high temperature catalyst in the past, but they have not sold any for years. They no longer promote methanol catalysts, and consider themselves "out of the methanol business."

We are seeking a license for ICI low temperature catalyst technology, but have not yet obtained it. No information can be obtained from ICI until a license is given.

(2) Plant Contractors. Davy-Powergas and Vulcan Cincinnati were contacted to obtain plant construction and operating costs, together with any technical data that they could make available.

Davy-Powergas has supplied plant costs for a 150 TPD and a 2000 TPD unit, together with a useful publication on the ICI Low Pressure Process. They stated that the study for a 5000 TPD plant (maximum size often quoted) consisted essentially of two 2500 TPD units.

On the basis of this information, a preliminary estimate indicates that a SNG/Methanol complex equivalent to the SNG/Fischer-Tropsch study would have an average fuel cost approximately 11 percent gfeater than that for the Fischer-Tropsch route.

Vulcan Cincinnati's reply to our request arrived too late to be analyzed during the report period.

(3) Literature. Published information on Methanol Plants/Economics was reviewed.

This published information provides typical reactor catalyst requirements for the high pressure and the ICI 50 ATM and 100 ATM plants. Operating pressures and temperatures were obtained for all processes.

4. Activity Forecast Next Quarter

The studies started this quarter will be refined during the next quarter. We will complete the description of job scope and objectives for this task. We will prepare and submit for approval a schedule and scope for the project consistent with the contract requirements.

F. Equipment Development

1. Objective

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

2. Activity This Quarter

a. Gas/Solids Separation: We discussed removal of particulates by a moving gravel bed with Combustion Power Company. We will review the capability of their new commercial unit stated to operate at temperatures up to 800°F. We obtained preliminary information describing the Hydro-Precipetrol marketed by Fluid Ionic Systems, a Division of Dart Industries, Inc. We believe this unit is similar to the Ionizer. It seems to be an advanced type of electrostatic precipitator with improved collection efficiencies allowing higher throughput velocities.

b. Valves: We found a commercial pressure letdown valve which appears worthy of further investigation. This is a stacked disc, labyrinth passage-type valve manufactured by Control Components, Inc., Irvine, Calif.

G. Materials of Construction

1. Objective

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

2. Activity This Quarter

a. We continued to support design efforts by supplying materials of construction specifications.

b. We received an invitation from ERDA to participate in a Steering Committee Meeting to form a coordinating body for stress corrosion cracking as part of the Metals Properties Council (MPC) program.

c. We met with personnel from the Lawrence Livermore Laboratory, in Pasadena, California on November 12, 1976 to discuss the potential for a materials of construction study program.

3. Activity Next Quarter

a. We will continue to support design efforts by supplying materials of construction specifications.

b. We will present a paper titled "Corrosion Engineering - Design Interface for Coal Conversion," to the Annual Meeting of Corrosion Engineers - Symposium on "Corrosion in the Coal Conversion Industry" at San Francisco, California on March 15, 1977.

H. Environmental Considerations

1. Objectives

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. Activity This Quarter

a. We continued the investigation of the fate of trace elements during coal conversion. We included recent information released by the California Institute of Technology as well as other sources regarding the volatilization and condensation of the separate elements during coal combustion operations.

b. We completed preparation of an invited paper on "Environmental Factors for Oil/Gas Coal Conversion Technology" which was presented at the session on Environmental Control Technology for Synthetic Fuel Processes of the AIChE 69th Annual Meeting in Chicago, Illinois on December 1, 1976.

This represents the third paper that we have written on the subject of environmental factors for coal conversion complexes.

c. We investigated, at the request of ERDA, the position of synthetic fuels with respect to EPA regulations on registration of fuels and fuel additivies; also the possible socioeconomic impact of a large scale coal conversion plant.

The fuels registration regulations are mainly concerned with air emissions resulting from the use of a fuel and with potential public health effects of fuels. We concluded that gaseous synthetic fuels from coal are comparable to natural gas and should therefore obtain immediate registration. Liquid synthetic fuels contain approximately the same amount of nitrogen as the original coal, and would generate approximately the same amount of nitrogen oxides on combustion. Concerning potential health effects, liquid synthetic fuels are expected to contain coal tar chemicals which are known carcinogens for laboratory animals; these compounds, however, are also present in residual oils from petroleum, currently used as fuels. It is therefore expected that coal-derived liquid fuels would also be candidates for registration.

A considerable socioeconomic impact would be generated by the construction and operation of a coal conversion plant and associated coal mine. Preliminary planning and accurate investigations of community feelings will lead to a minimum socioeconomic disruption. Planning can also minimize the impacts of the influx of construction workers and assure a smooth transition from temporary to permanent facilities.

d. We initiated the study of the relative impact of a coal conversion facility of POGO type on the air quality of the three geographical regions considered for the POGO site, namely eastern region of the Interior Province, Southern Appalachia, and Rocky Mountain Province. A conceptual dispersion modeling of the plant will be carried out using the PTMAX computer program received from the Environmental Protection Agency (National Environmental Research Center, Research Triangle Park, North Carolina).

3. <u>Results of These Activities</u>

a. We projected that our preliminary design of a commercial scale Fischer-Tropsch plant should meet applicable federal and state standards for gaseous and liquid effluents.

b. We projected that our preliminary design of a commercial scale Oil/Gas plant should meet applicable federal and state standards for gaseous and liquid effluents.

c. During the environmental review of the conceptual commercial designs developed we identified five areas where additional experimental data were required and definite answers remained to be developed, namely:

- o Fate of trace elements present in coal.
- o Formation and destruction of metal carbonyls.
- o Cyanide formation, partitioning among effluent streams, and final decomposition.
- o Formation of coal-tar carcinogens and biohazards involved.
- o Possibility of leaching of heavy metals from land filled or buried slagged ash and fly ash.

Preliminary conclusiiions were reached from pilot plant data, comparison with related operations, and application of chemical and engineering principles. In one instance (leaching of heavy metals from fly ash) we recommended a research p!rrogram using slagged ash from coal conversion pilot plants.

d. We concluded that the gaseous and liquid synthetic fuels produced would exhibit environmental effects comparable to the effects of fuels presently in use; they would also therefore be candidates for registration by EPA.

4. Activity Forecast Next Quarter

We will continue the environmental work along the two main directions followed so far, namely (1) investigation of environmental factors related to coal conversion and identification of environmentally sensitive areas or operational aspects where additional study is required, (2) design monitoring to insure that the Parsons conceptual commercial designs are environmentally acceptable and in compliance with present and projected environmental requirements.

We will continue to review the preliminary design work for the POGO Plant and the Multipurpose Demonstration Facility; specific environmental areas requiring consideration will be analyzed and discussed with the design engineers.

We will continue the air quality study mentioned above. Other environmental areas specific to coal conversion designs, such as partitioning of cyanides and leaching of slagged ash, will be further considered.

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Table B-1 - Design Dissolver Balance

	C	H	N	S	O	Ash	Total
Input, lb							
MF Coal	69.07	4.74	1.32	3.78	8.96	12.13	100.00
H_2		4.70					4.70
Total	69.07	9.44	1.32	3.78	8.96	12.13	104.70
Output, lb							
C_1	3.52	1.18					4.70
C_2	2.34	0.59					2.93
C_3	3.17	0.70					3.87
C_4	1.56	0.32					1.88
CO_2	0.29				0.77		1.06
H_2S		0.16		2.49			2.65
NH_3		0.04	0.20				0.24
H_2O		0.30			2.37		2.67
Light oil	5.13	0.93	0.02	0.02	0.40		6.50
Wash solvent	5.99	0.80	0.05	0.02	0.48		7.34
Process solvent	12.72	1.40	0.17	0.05	0.91		15.25
	31.82	2.72	0.59	0.16	1.41		36.70
Mineral residue	2.53	0.30	0.29	1.04	2.62	12.13	18.91
Total	69.07	9.44	1.32	3.78	8.96	12.13	104.70

Table B-1 (Contd)

Compositions						
	MF Coal	Light Oil IBP-400°F	Wash Solvent 400 to 500°F	Process Solvent 500 to 950°F	SRC 950°F+	Mineral Residue
C	69.07	78.92	81.61	83.41	86.70	13.38
H	4.74	14.31	10.90	9.18	7.41	1.59
N	1.32	0.31	0.68	1.11	1.61	1.53
S	3.78	0.31	0.27	0.33	0.44	5.50
O	8.96	6.15	6.54	5.97	3.84	13.86
Ash	12.13	–	–	–	–	64.14
	100.00	100.00	100.00	100.00	100.00	100.00
HHV, Btu/lb	12,444	19,890	18,134	17,376	16,926	2,080
Heat of Reaction - 209.7 Btu/lb MF coal (exothermic).						

Table B-2 - Comparison of Commercial SNG and Projected Oil/Gas SNG Characteristics

	SNG Limits of Interchangeability for Various Base Load Natural Gases (a)						Oil/Gas SNG
AGA Indexes[a]	High Heating Value Natural Gas		High Methane Natural Gas		High Inert Natural Gas		
	Preferable	Objectionable	Preferable	Objectionable	Preferable	Objectionable	
Lifting Index	Under 1.0	Above 1.12	Under 1.0	Above 1.06	Under 1.0	Above 1.03	1.01[b]
Flash-Back Index	Under 1.18	Above 1.2	Under 1.18	Above 1.2	Under 1.18	Above 1.2	1.05
Yellow Tip Index	Above 1.0	Under 0.7	Above 1.0	Under 0.8	Above 1.0	Under 0.9	0.95

[a] "Interchangeability of Other Fuel Gases with Natural Gas," AGA Research Bulletin No. 36.

[b] The Lifting Index can be lowered by increasing the SNG hydrogen content.

Table C-1 - Comparison of Commercial SNG and Projected Fischer-Tropsch SNG Characteristics

	SNG Limits of Interchangeability for Various Base-Load Natural Gases (a)						Fischer-Tropsch SNG
AGA Indexes[a]	High Heating Value Natural Gas		High Methane Natural Gas		High Inert Natural Gas		
	Preferable	Objectionable	Preferable	Objectionable	Preferable	Objectionable	
Lifting Index	Under 1.0	Above 1.12	Under 1.0	Above 1.06	Under 1.0	Above 1.03	1.091[b]
Flash-Back Index	Under 1.18	Above 1.2	Under 1.18	Above 1.2	Under 1.18	Above 1.2	1.048
Yellow Tip Index	Above 1.0	Under 0.7	Above 1.0	Under 0.8	Above 1.0	Under 0.9	0.942

[a] "Interchangeability of Other Fuel Gases with Natural Gas," AGA Research Bulletin No. 36.

[b] The Lifting Index can be lowered by increasing the SNG hydrogen content.

Table C-2 - Comparison of Commercial Butane Specifications with Projected Fischer-Tropsch Butane Characteristics

Characteristic	Commercial Butane Specification ASTM D1835	Projected F-T Butane Characteristics
Vapor pressure at 100°F, psig max.	70	37
Volatile residue:		
evaporated temperature, 95%, max. °F	36	31
pentane and heavier, % max.	2.0	1.6
Residual matter:		
residue on evaporation, 100 ml, max.	0.05	0.05
oil stain observation	pass[a]	pass
Specific gravity at 60/60 F	[b]	
Corrosion, copper strip, max.	No. 1	No. 1
Sulfur, grains/100 ft^3 max.	15	None
Free water content	None	None

[a] An acceptable product shall not yield a persistent oil ring when 0.3 ml of solvent residue mixture is added to a filter paper in 0.1 ml increments and examined in daylight after 2 min. as described in Method D2158.

[b] Although not a specification requirement, the specific gravity must be determined for other purposes and should be reported.

Table C-3 - Comparison of Diesel Fuel and Fuel Oil Specifications with Projected Fischer-Tropsch Diesel Fuel Oil Characteristics

Item	Diesel Fuel Specification	Fuel Oil Specification	Projected F-T Diesel Fuel Characteristics
Grade	No. 1-D ASTM D975	No. 1 ASTM D396	
Flash Point, °F PMCC ASTM D93	100 min. or legal	100 min. or legal	100
Pour Point, °F	(a)	(b)	plus 10°F
Water and Sediment Volume, % Max.	Trace	Trace	Trace
Carbon Residue on 10% Residuum, % Max.	0.15	0.15	Trace
Ash, Wt. % Max.	0.01	None Stated	0.01
Distillation Temp. °F 10% Point, Max. 90% Point, Max.	 None Stated 550	 420 550	 327 539
Viscosity at 100°F CS Min. Max.	 1.4 2.5	 1.4 2.2	1.4
Sulfur, Wt. % Max.	0.50 or legal	0.5 or legal	nil
Copper Strip Corrosion, Max.	No. 3	No. 3	No. 1
Cetane Number, Min	40	None Stated	60+
Gravity, API Min.	None Stated	35	57.4

(a) For cold weather operation, the pour point should be specified 10°F (5.6°C) below the ambient temperature at which the engine is to be operated except where fuel oil heating facilities are provided.

(b) Lower or higher pour points may be specified whenever required by conditions of storage or use. When pour point less than 0°F is specified, the minimum viscosity shall be 1.8 centistokes (32.0 seconds Saybolt Universal) and the minimum 90% point shall be waived.

Table C-4 - Comparison of Fuel Oil and Gas Turbine Fuel Oil Specifications with Projected Fischer-Tropsch Fuel Oil Characteristics

Item	Fuel Oil Specifications	Gas Turbine Fuel Oil Specifications	Projected F-T Fuel Oil Characteristics
Grade	No. 5 (Light) ASTM D396	No. 3-GT ASTM D2880	
Flash Point °F, Min. PMCC ASTM D93	130 or legal	130 or legal	200
Pour Point °F, Max.	--	None Stated	150
Water and Sediment, Vol. % Max.	1.0	1.0	1.0
Ash, Wt.% Max.	0.10	0.03	Trace
Distillation, 90% Temp. °F			875
Min.	--	None Stated	
Max.	--	None Stated	
Saybolt Viscosity, SSU at 100°F			155
Min.	150	45	
Max.	300	None Stated	
Gravity °API, Min.	--	None Stated	41
Vanadium, ppm (wt) Max.	--	2	0
Na + K, ppm (wt), Max.	--	5	0.01
Calcium, ppm (wt), Max.	--	10	0
Lead, ppm (wt), Max.	--	5	0
Mg/V wt ratio	--	None Stated	--
Sulfur, wt %	Legal	None Stated	0

Table C-5 - Example Experimental Results
Flame Sprayed Catalyst (FSC) Fischer-Tropsch Runns

Item	Experiment No. HGR 33		Experiment No. HGR 34	
Catalyst type	Coated Plates	Coated Plates	Coated Plates	Coated Plates
Fresh gas space velocity, vol/vol/hr	600	1000	1000	2000
Fresh feed rate, scfh	165	275	275	550
Recycle ratio: Total recycle ÷ fresh feed, vol/vol	52	15.9	20.4	14.4
Reactor pressure, psig	400	400	400	400
Catalyst temperature, °F				
Average	516	617	608	617
Differential	36	90	72	90
H_2 conversion, %	73.4	90.9	90.1	83
CO conversion, %	80.6	98.8	98.2	94.4
H_2 + CO conversion, %	76.4	94.4	93.4	87.5
Overall weight balance, %	93.6	90.8	87.8	96.6
Hydrocarbons recovered, lb/1,000 scf fresh gas	7.4	9.5	10.3	11.6
Hydrocarbons recovered, wt%				
$C_1 + C_2$	59.7	36.5	33.9	29.5
C_3	6.6	14.1	13.3	12.8
Gasoline (C_3 = <400°F)	31.8	43.7	48.5	53.0
Diesel fuel (400 to 600°F)	1.9	5.0	4.0	3.8
Fuel oil (600 to 842°F)	0	0.4	0.2	0.5
Wax (>842°F)	0	0.3	0.1	0.4

Table C-6,1 - Example Experimental Results
Steel Lathe Turnings Catalyst (SLTC) Fischer-Tropsch Runs

Item	Experiment 26 Period C
Catalyst type	SLTC
Synthesis, hours	416 - 488
Reactor conditions:	
Fresh feed rate, scfh	1,214
Space velocity, vol/vol/hr	607
Reactor pressure, psig	405
Recycle to fresh feed ratios:	
Total	27
Hot	25.5
Cold	1.5
CO_2 scrubbed	1.5
Reactor temperature, °F	
In gas	552
Out gas	610
Increment	58
Average catalyst temperature, °F	586
Maximum catalyst temperature, °F	622
Catalyst pressure drop, inches of H_2O/foot	6
H_2:CO ratio, fresh gas	1.45
Results:	
CO_2 free contraction, %	74.6
H_2 conversion, %	73.7
CO conversion, %	88.7
H_2 + CO conversion, %	79.8
H_2: CO ratio:	
Recycle gas	3.35
Usage	1.21
Water vapor in recycle gas, vol %	7.0
Heating value of tail gas,[(a)] Btu/ft^3	536
Tail gas composition, vol %:[(b)]	
H_2	55.2
CO	16.5
N_2	1.2
CO_2	9.6

Table C-6,2 (Contd)

Item	Experiment 26 Period C
Tail gas composition, vol %:[b]	
C_1	9.8
$C_2^=$	0.7
C_2	2.3
$C_3^=$	0.3
C_3	1.0
$C_4^=$	0.6
C_4	1.8
$C_5^=$	0.2
C_5	0.8
$C_6^=$	0
C_6	0
Yield, g/m^3 (H_2 + CO) converted:	
C_1	24
$C_2^=$	3
C_2	12
$C_3^=$	2
C_3	7
$C_4^=$	6
C_4	18
$C_5^=$	2
C_5	9
$C_6^=$	0
C_6	0
Oil	0.97
Aqueous	130
C_1 - C_3OH[c]	8
Other oxygenates[c]	3
Water	119
CO_2	307
Hydrocarbon recovery, g/m^3	191
Theoretical recovery, g/m^3	201
Hydrocarbon recovery, wt %	
C_1 + C_2	19.4
C_3	3.5
Gasoline (C_3 = <400°F)	59.0
Diesel oil (400 to 600°F)	9.1
Fuel oil (600 to 842°F)	6.2
Wax (<842°F)	2.8

[a]Cubic foot corrected to 60°F and 30 inches of mercury (dry).

[b]Dry basis.

[c]Calculated as hydrocarbons.

Table C-7 - Example Experimental Results
Flame Sprayed Catalyst on Tube Wall Reactor (TWR) Fischer-Tropsch Runs

Item	Experiment Number FT-TW-1		
Fresh gas, $\frac{\text{vol. gas, ft}^3\text{ (stp)/hr}}{\text{Ft}^2\text{ catalyst surface}}$	30	30	30
Fresh gas feed rate, scfh	4.37	4.37	4.37
H_2:CO ratio in feed gas	3:1	3:1	3:1
Reactor pressure, psig	300	650	1,000
Catalyst temperature, average, °F/°C	615.2/324	602.6/317	609.9/318
H_2 conversion,%	40.32	43.67	45.12
CO conversion, %	78.30	78.46	76.21
H_2 + CO conversion, %	49.38	52.02	52.70
Heating value tail gas Btu/ft^3			
With CO_2	383	383	418
Without CO_2	419		453
Overall weight balance, %	93.96	97.05	95.72
Hydrocarbons recovery, lb/1,000 scf fresh gas[(a)]	4.148	5.139	5.714
Theoretical hydrocarbons, g/m^3(H_2 + CO) conversion	188.65	184.13	166.98
Recovery, %	71.33	82.76	108.09
Hydrocarbon recovery, wt%			
C_1 + C_2	71.26	67.01	69.56
C_3	17.70	19.92	11.75
Gasoline ($C_3^=$ + <400°F)[(a)]	9.18	12.14	18.32
Diesel fuel (400 to 600°F)	1.60	.83	.32
Fuel oil (600 to 842°F)	.25	.10	.06
Wax (>842°F)	0.0	0.00	0.00

Item	Period					
	1st	2nd	1st	2nd	1st	2nd
Aqueous layer, g/m^3(H_2 + CO) conversion						
C_1 - C_4OH	3.16	4.34	7.70	17.14	30.34	42.33
Other oxygenates	.19	.13	.13	.18	0.0	0.0
H_2O	126.7	124.9	140.6	135.2	125.6	113.7
Percent CO in tail gas	8.09		8.0		8.3	

(a) Includes alcohols and oxygenates.

Table C-8 - Comparison of Example FSC, SLTC, and TWR Fischer-Tropsch Experimental Results

Item	FSC Experiment HGR 34		SLTC Experiment 26 C	TWR Experiment	
Fresh gas, $\frac{\text{vol gas, ft}^3\text{ (stp)/hr}}{\text{ft}^2\text{ catalyst surface}}$	8.85	17.7	(a)	30	
Fresh gas feed rate, scfh	275	550	1214	4.37	
H_2:CO ratio in feed gas	1.4:1	1.4:1	1:45	3:1	
Reactor pressure, psig	400	400	405	300	
Catalyst temp. average °F/°C	608/320	617/325	586/308	615.2/324	
H_2 conversion, %	90.1	83	73.7	40.32	
CO conversion, %	98.2	94.4	88.7	78.30	
H_2 + CO conversion, %	93.4	87.5	79.8	49.38	
Heating value tail gas Btu/ft^3					
With CO_2	930	785	536	383	
Without CO_2	1000	852	593	419	
Overall weight balance, %	87.8	96.6	---	93.96	
Hydrocarbons recovery, lb/1,000 scf fresh gas[b]	10.3	11.6	9.5	4.15	
Theoretical hydrocarbons,					
g/m^3 (H_2 + CO) conversion	190.28	197.0	201	188.65	
Recovery %	119.53	97.39	95	71.33	
Hydrocarbon recovery, wt%					
C_1 + C_2	38.00	32.71	19.4	71.26	
C_3	13.58	12.07	3.5	17.70	
Gasoline (C_3= + <400°F)[b]	48.11	50.01	59.0	9.18	
Diesel fuel (400 to 600°F)	4.46	4.27	9.1	1.60	
Fuel oil (600 to 842°F)	.18	.52	6.2	.25	
Wax (>842°F)	.11	.42	2.8	0.0	
				Period	
				1st	2nd
Aqueous layer, g/m^3(H_2 + CO) conversion					
C_1 - C_4OH	4.34	6.11	8[c]	3.16	4.34
Other oxygenates	.32	.36	3	.19	.13
H_2O	97.54	108.32	130	126.7	124.9
Percent CO in tail gas	4.21	9.67	16.5	8.09	

(a) Lathe turning bed reactor with hot gas recycle. Total recycle to feed ratio of 27 to 1, 607 scfh/cf catalyst.

(b) Includes alcohols and other oxygenates.

(c) C_1 - C_3OH.

Table C-9 - Catalyst Activity (A_s) and "J" Factor Comparisons

Experiment No.	Catalyst Type	Range of Activity Factor A_s	"J" Factor Cu Ft Gas/ft^2 Catalyst Area
5871/7	Steel Lathe Turnings	0.08 to 0.20	1.0 to 1.5
5871/8	Steel Lathe Turnings	0.10 to 0.54	0.5 to 3.5
5871/9	Steel Lathe Turnings	0.10 to 0.34	0.5 to 2.5
5871/15	Steel Lathe Turnings	0.18 to 0.30	0.63 to 2.5
5871/16	Steel Lathe Turnings	0.20 to 0.66	0.63 to 2.5
5871/17	Steel Lathe Turnings	0.12 to 0.20	2.5 to 3.75
6126/26	Steel Lathe Turnings	0.12 to 0.20	1.5 to 2.0
HGR 33	Flame Sprayed Plates	1.1 to 1.7	5.3 to 8.85
HGR 34	Flame Sprayed Plates	1.2 to 1.6	8.85 to 17.7
TW - 1	Flame Sprayed Tube Wall	0.9 to 0.93	30
Conceptual Plant Flame Sprayed Fintube		0.9	10

Table C-10 - Conceptual Fischer-Tropsch Reactor Design
Compared with PERC Experimental Data

Item	Experiment HGR 34		SLTC Experiment 26 C	TWR Experiment FT-TW-1	Conceptual Design Basis
"J," scfh/sf catalyst surface	8.85	17.7	1.5	30	10.0
H_2:CO ratio in feed	1.41	1.41	1.45	3	1.45
Recycle ratio	20.4	14.4	27.0	-	1.5
(CO + H_2) conversion %	93.4	87.5	80.0	52.0	80.0
Total Reaction Heat Calculated Btu/sf/hr	583.0	1092.0	84.0	1100.0	563.0

Table C-11 - Example Experimental Data
Methanation Runs
Experiment HGR 15

Item	Period Number						
	2	33	34	41	42	44	45
Catalyst type	The primary reactor was packed with flame sprayed Raney nickel-coated plate grids. The second reactor was packed with a precipitated nickel catalyst. Results for the primary reactor operation only are given.						
Hours on stream	91	955	979	1147	1171	1219	1243
Fresh gas:							
Rate, scfh	810	821	820	822	823	617	411
H_2, vol pct	75.1	75.3	74.6	75.1	75.3	74.7	75.5
CO, vol pct	24.5	23.8	24.5	24.5	24.2	24.2	23.7
CO_2, vol pct	0.1	0.1	0.1	0.2	0.1	0.2	0.2
N_2, vol pct	0.3	0.7	0.7	0.2	0.3	0.8	0.5
CH_4, vol pct	0	0.1	0.1	0	0.1	0.1	0.1
H_2:CO	3.1	3.2	3.0	3.1	3.1	3.1	3.2
Exposure vel., scfh/ft^2	17.8	18.0	18.0	18.0	18.0	13.5	9.0
Space vel., hr^{-1}	1990	1986	2013	2015	2017	1512	1008
Mixed feed gas (wet):							
Rate, scfh	12000	9750	7600	8700	10150	6780	4470
H_2, vol pct	8.5	13.5	14.0	13.4	13.7	13.0	12.5
CO, vol pct	1.7	2.5	3.0	3.0	2.7	2.8	2.4
CO_2, vol pct	1.0	0.5	0.5	0.7	0.7	0.6	0.5
N_2, vol pct	3.5	0.9	0.8	1.1	0.8	0.9	0.3
CH_4, vol pct	79.2	78.0	77.7	77.6	77.5	78.4	79.9
H_2O, vol pct	6.1	4.6	4.0	4.2	4.6	4.3	4.4
H_2:CO	5.1	5.4	4.7	4.5	4.9	4.6	5.1
Inlet superficial vel., f/s	6.4	5.2	4.0	4.6	5.4	3.6	2.4
Inlet Reynolds No.	5660	4400	3440	3920	4580	3960	2040
Exposure vel., scfh/ft^2	263	214	166	190	222	149	98
Space vel., hr^{-1}	29400	23900	18600	21250	24900	16620	10950
Vol total recycle/vol fresh gas	14.0	11.1	8.5	0.0	11.6	10.2	10.1
Vol cold recycle/vol fresh gas	2.5	3.0	3.0	3.0	3.0	3.0	3.1
Temperatures:							
Gas inlet, °F	576	574	576	574	572	572	576
Maximum catalyst, °F	743	752	793	797	752	750	752
Pressure, psig	300	300	300	300	300	300	300
Product gas:							
Rate, scfh	206.0	212.3	208.6	210.9	211.7	156.4	103.8
H_2, vol pct	4.0	8.2	6.9	7.2	8.6	7.1	6.4
CO, vol pct	.03	0.6	0.4	0.7	0.9	0.7	0.3
CO_2, vol pct	1.17	0.5	0.6	0.8	0.8	0.6	0.5
N_2, vol pct	3.9	1.0	0.9	1.2	0.9	1.0	0.3
CH_4, vol pct	90.7	89.5	91.0	89.9	88.6	90.4	92.3
H_2O, vol pct	0.2	0.2	0.2	0.2	0.2	0.2	0.2
H_2:CO	133.0	13.7	16.9	9.6	9.3	10.4	21.4
Conversion:							
H_2, pct fresh feed	98.7	97.6	98.0	98.0	97.6	98.3	98.8
CO, pct fresh feed	100	99.5	99.7	99.4	99.2	99.5	99.8
(H_2+ CO), pct fresh feed	99.0	98.1	98.4	98.3	97.9	98.6	99.0
H_2, pct mixed feed	58.4	45.6	56.3	52.0	43.4	51.2	54.4
CO, pct mixed feed	98.4	78.8	88.0	77.6	70.0	78.3	89.1
(H_2+ CO), pct mixed feed	65.0	50.8	61.8	56.7	47.9	56.0	60.1
Usage ratio, H_2:CO	3.0	3.1	3.0	3.0	3.0	3.0	3.1
Heating value, Btu/scf	934	937	947	937	931	943	959
Carbon recovery, pct	95.0	100	96.7	97.0	97.3	96.0	96.3

Table C-12, 1 - Experimental Data
Methanation Experiment 23 C

Item		Experiment 23 Period C
Catalyst Type	Primary Reactor:	Steel Turnings
	Second Reactor:	Granular Raney Ni
Synthesis, hours		475-571
Primary reactor conditions:		
Fresh feed rate, scfh		1,412
Space velocity, vol/vol/hr		706
Reactor pressure, psig		398
Recycle to fresh feed ratios:		
Total		27
Hot		25
Cold		2
Reactor temperature, °F:		
In gas		570
Out gas		628
Increment		58
Average catalyst temperature, °F		603
Maximum catalyst temperature, °F		653
Catalyst pressure drop, in. of H_2O/ft		6
Water vapor in recycle gas, vol %		7.6
H_2O:CO ratio,		
Fresh gas		2.85
Recycle gas		31.7
Second reactor conditions:		
Fresh feed rate, scfh (from primary reactor)		419
Space velocity, vol/vol/hr		9,100
Space velocity (based on fresh feed), vol/vol/hr		26,000
Recycle to fresh feed ratio		7
Reactor temperature, °F		
In gas		556
Out gas		662
Average catalyst temperature, °F		608
Maximum catalyst temperature, °F		662
Water vapor in recycle gas, vol %		2.9
Overall results:		
Reactors in service		2
CO_2-free contraction, %		76.1
H_2 conversion, %		99.3

Table C-12, 2 (Contd)

Item	Experiment 23 Period C
Overall results: (contd)	
CO conversion, %	99.9
H_2 + CO conversion, %	99.5
H_2:CO ratio, usage	2.83
Heating value of tail gas,[a] Btu/ft^3	985
Tail gas composition, vol %:[b]	
H_2	2.1
CO	0.1
N_2	1.1
CO_2	1.3
C_1	94.3
$C_2^=$	0
C_2	0.7
$C_3^=$	0.1
C_3	0.3
$C_4^=$	0
C_4	0
$C_5^=$	0
C_5	0
Feed gas, ft^3 tail gas 0 ft^3	4.13
Tail gas[c] ft^3 tail gas 0 ft^3	342
Yield, 9/m^3 (H_2 + CO) converted:	
C_1	163
$C_2^=$	0
C_2	2
$C_3^=$	0
C_3	2
$C_4^=$	0
C_4	0
$C_5^=$	0
C_5	0
Oil	4
Aqueous	192
C_1 - C_3OH[d]	11
Other oxygenates[d]	0
Water	181
CO_2	6
Hydrocarbon recovery, g/m^3	171
Theoretical recovery, g/m^3	181

[a] Cubic feet corrected to 60°F and 30 inches of mercury (dry).

[b] Dry basis.

[c] Corrected to °C and 760 mm of mercury.

[d] Calculated as hydrocarbons.

Table C-13 - Comparison of Granular and Spray Coated Plate Catalyst Systems

	Granular Catalyst Exp. 7	Sprayed Plates Catalyst		
		PERC Exp. HGR 15 (91 hours)	PERC Exp. HGR 15 (1171 hours)	F-T Conceptual Design Fin Tube Reactor
Number of stages	1	1	1	1
Stage Number	1	1	1	1
Pressure, psig	598	300	300	382
Temperature out, °F	662	743	752	600
Temperature in, °F	556	576	572	571
Temperature, avg., °F	609	660	662	586
Overall				
CO Methanated, %	95.46	100	99.2	98.98
CO_2 Methanated, %	88.08	-197.6	-105.8	-1.9
CO Methanated, %	95.46	100	99.2	98.98
T_e-T_{out},[b] °F	+116	-184	+234	+185
CO_2 Methanated	88.08	197.6	-105.8	-1.9
T_e-T_{out},[b] °F	+97	+41	+160	+135
S_V, scfh/cf[a]	9,100	1,900 (J=17.6)	2,017 (J=17.9)	(J=15.0)
Product (Dry) Mol %				
H_2	2.1	4.0	8.6	4.89
CO	0.1	0.0	0.90	0.10
CO_2	1.3	1.2	0.80	1.82
CH_4	94.5	90.80	88.8	85.52
N_2	1.1	3.9	0.9	6.99
C_2+	1.1	0.1	1.0	0.68
Feed (Dry) Mol %				
CO	1.54	24.5	24.2	16.97
CO_2	7.65	0.1	0.1	.83
H_2	49.04	75.1	75.3	57.25
C_1	30.65	0.0	0.1	18.22
N_2	0.78	0.3	0.3	3.4
C_2+	10.36	0.0	0.0	3.33

(a) Based on fresh feed gas

(b) T_e is equilibrium temperature corresponding to gas composition and pressure.

Table D-1 - Pyrolysis Process Comparison

Item	Flash Pyrolysis	Coalcon	High Pressure Hydropyrolysis
	$ MM	$ MM	$ MM
Investment			
Pyrolysis Unit	14.9	17.9	37.5
Land @ 1.76% P.U.	.3	.3	.7
Working Capital @ 3.83% P.U.	.6	.7	1.4
Total	15.8	18.9	39.6
	$ MM/Yr.	$ MM/Yr.	$ MM/Yr.
Required Income after tax (10% ROI)	1.6	1.9	4.0
Tax	1.7	2.1	4.3
Required Income before tax	3.3	4.0	8.3
Expenses			
Utilities	14.3	18.5	46.0
Hydrogen @ $0.50/MSCF	--	25.5	40.3
Coal @ $14.00/T	50.7	53.5	40.7
Total	65.0	97.4	127.0
Depreciation	1.2	1.4	2.9
Income			
Gross Required Income	69.5	102.8	138.2
Char Credit @ $5/T	6.2	6.2	5.2
Required gas + liquid credit	63.3	96.6	133.0
Gas + liquid cost $/MM Btu	1.49	1.70	1.95
Ratio	1.0 (base)	1.14	1.31

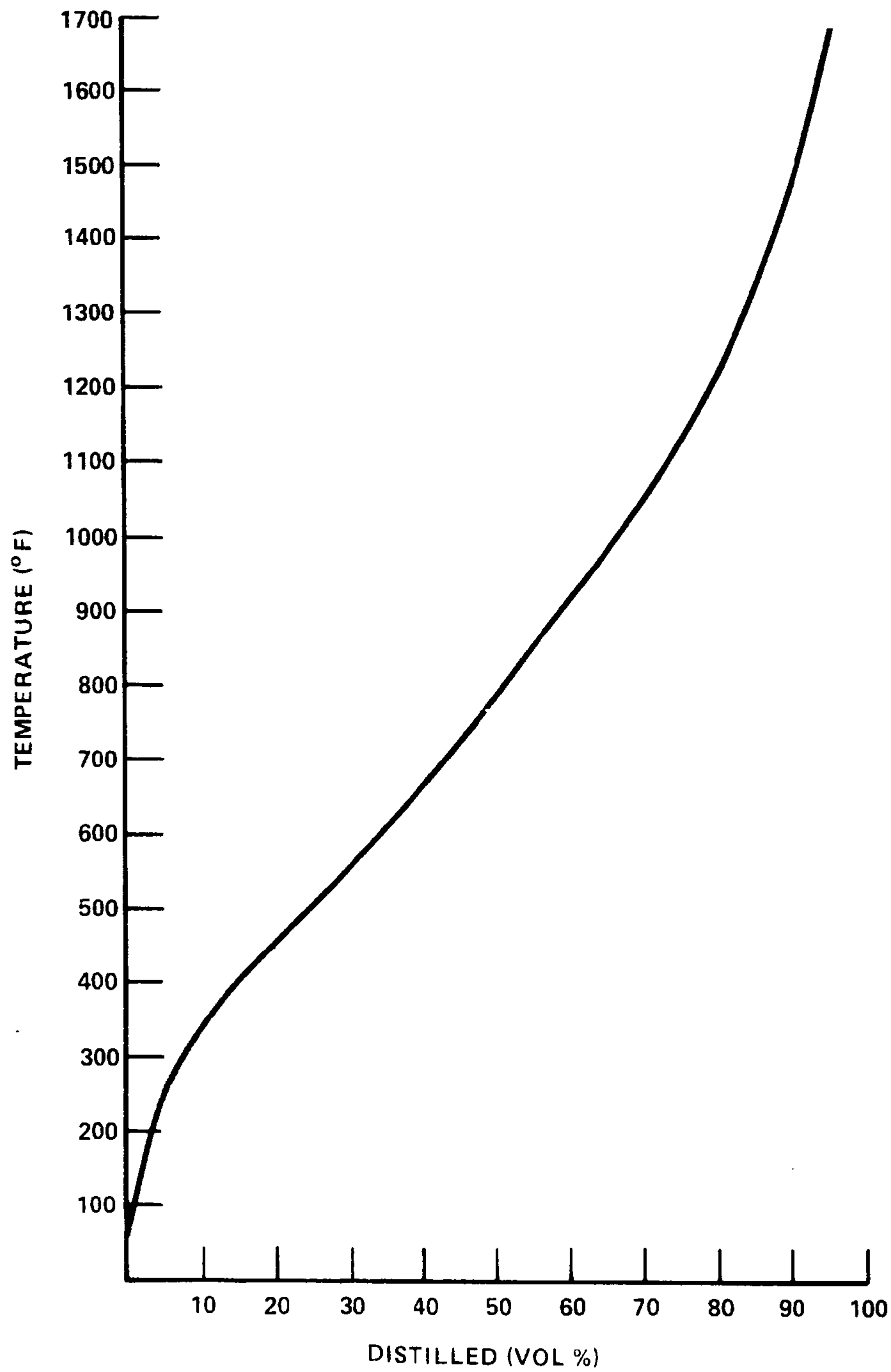

Figure B-1 - Dissolver Product
True Boiling Point Curve

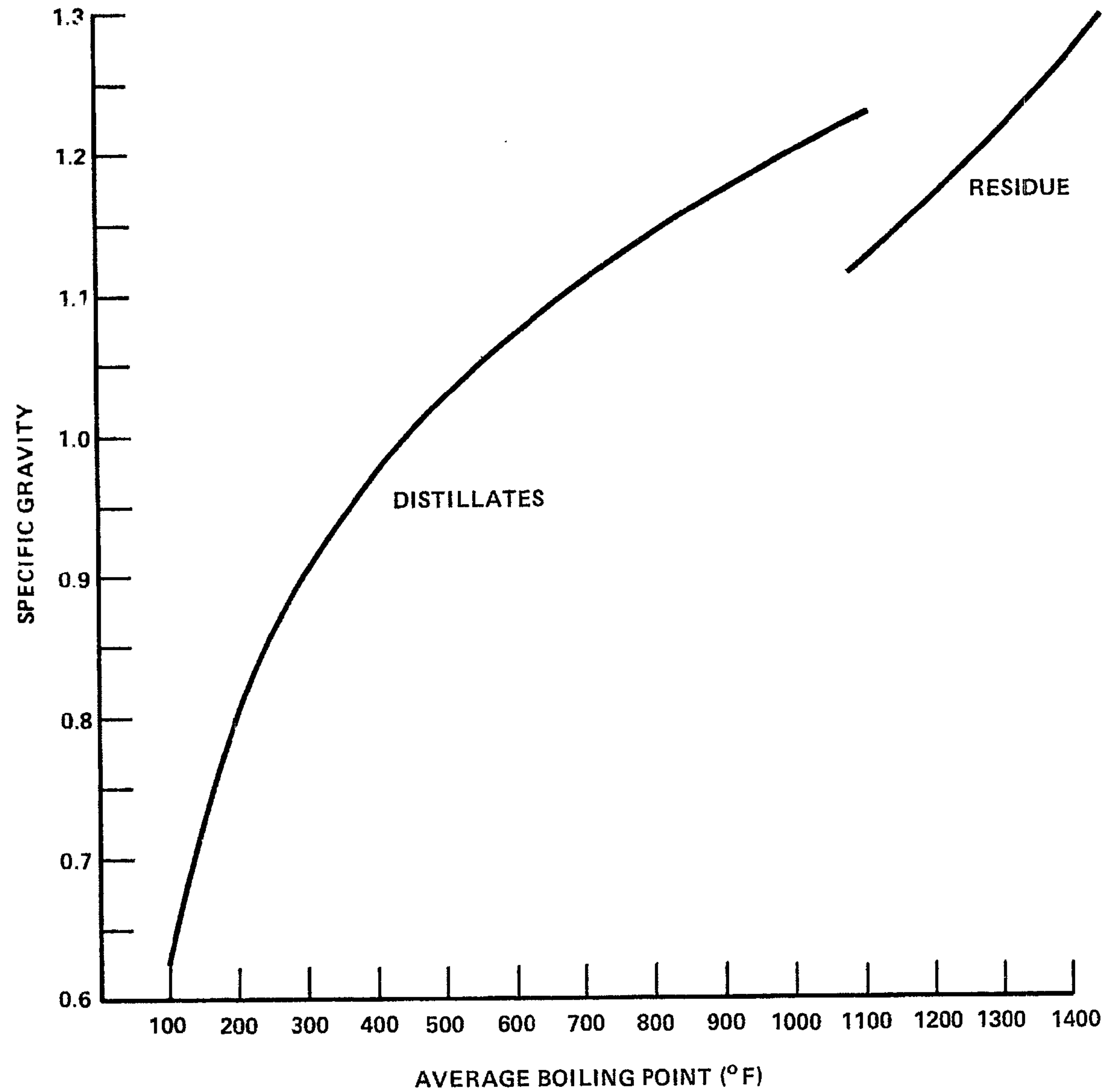

Figure B-2 - Dissolver Product
Specific Gravity vs. Boiling Point

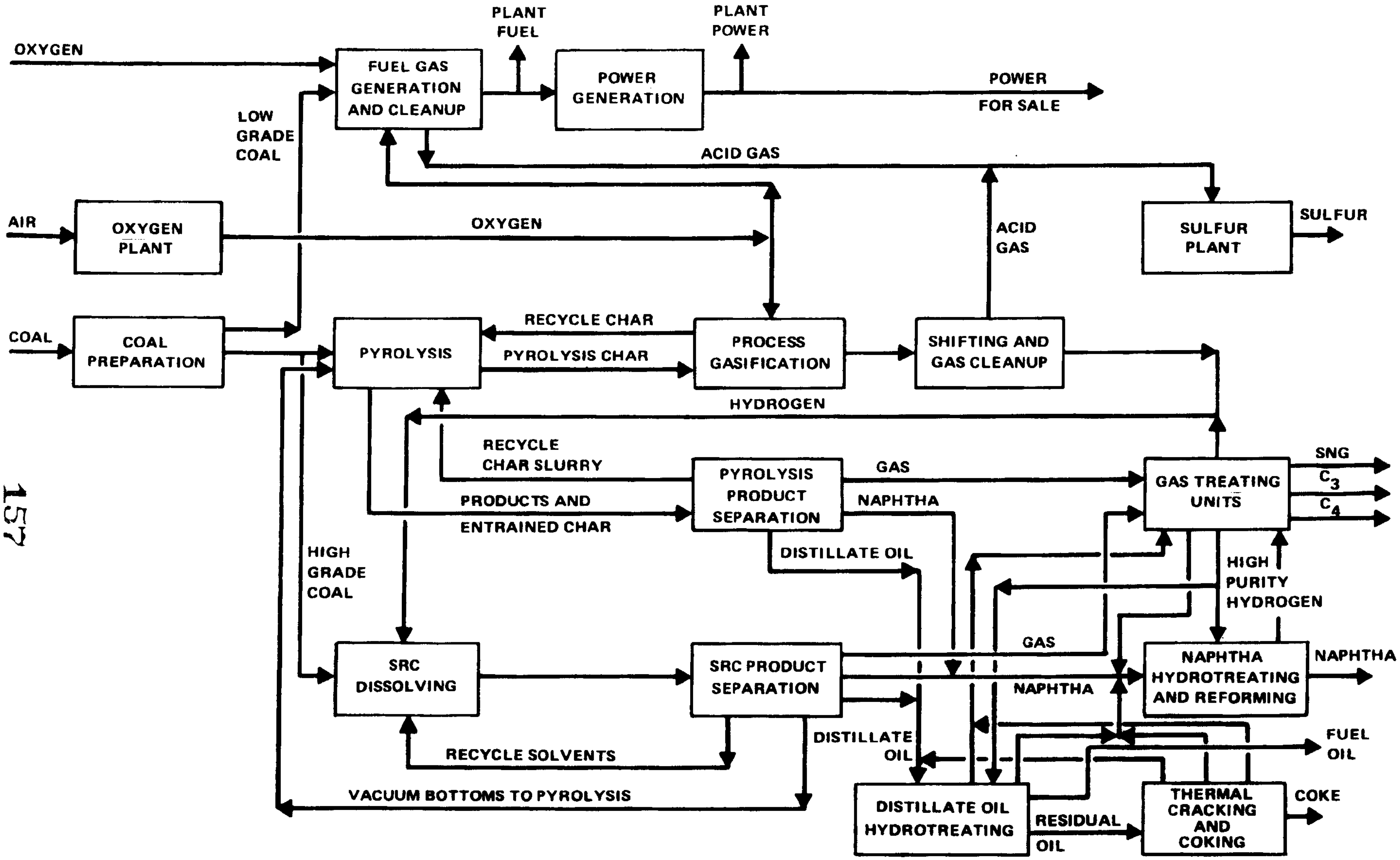

Figure D-1 - Project POGO Coal Conversion Complex
Block Flow Diagram

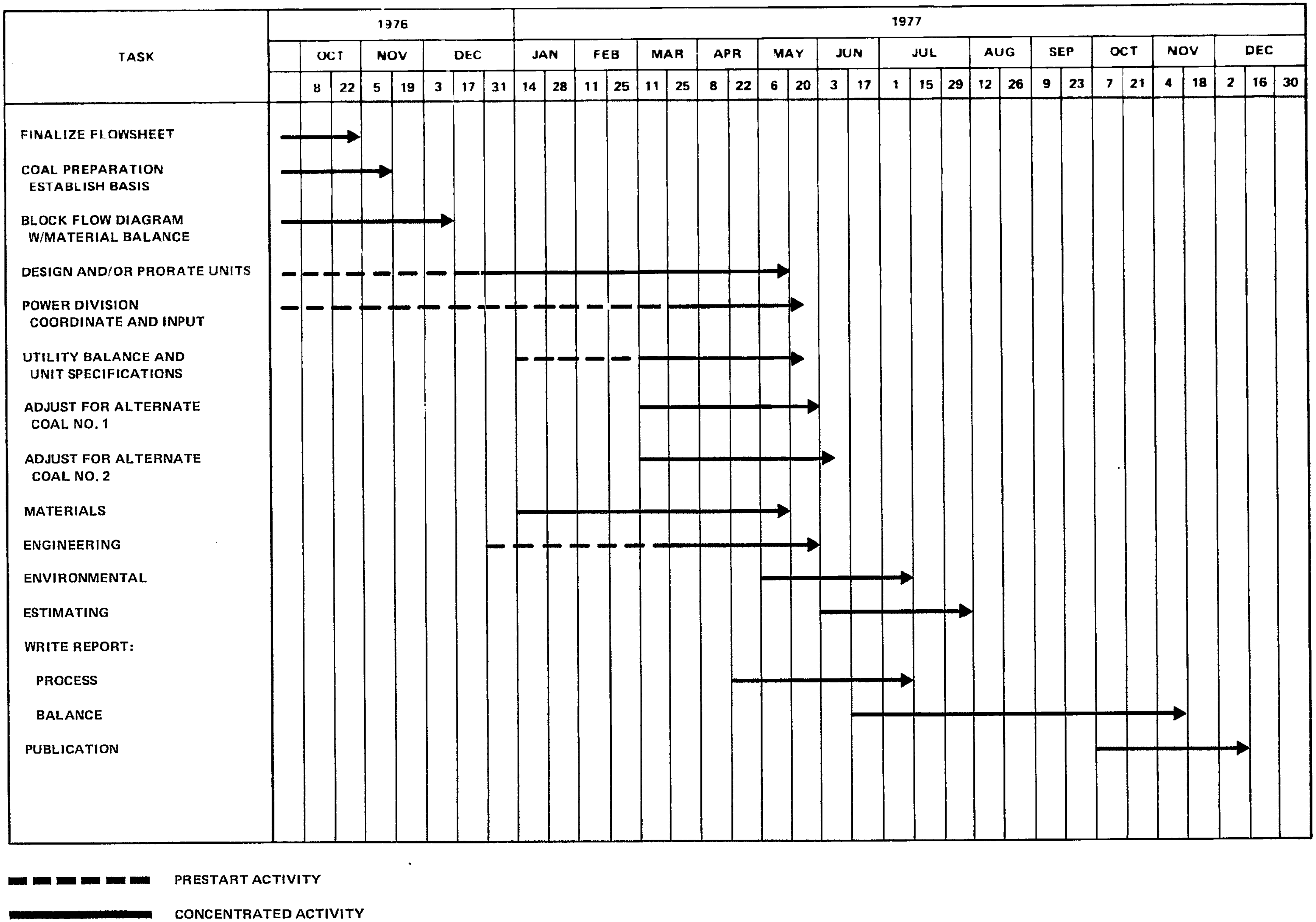

Figure D-2 - POGO Project Schedule

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161 (703) 605-6000