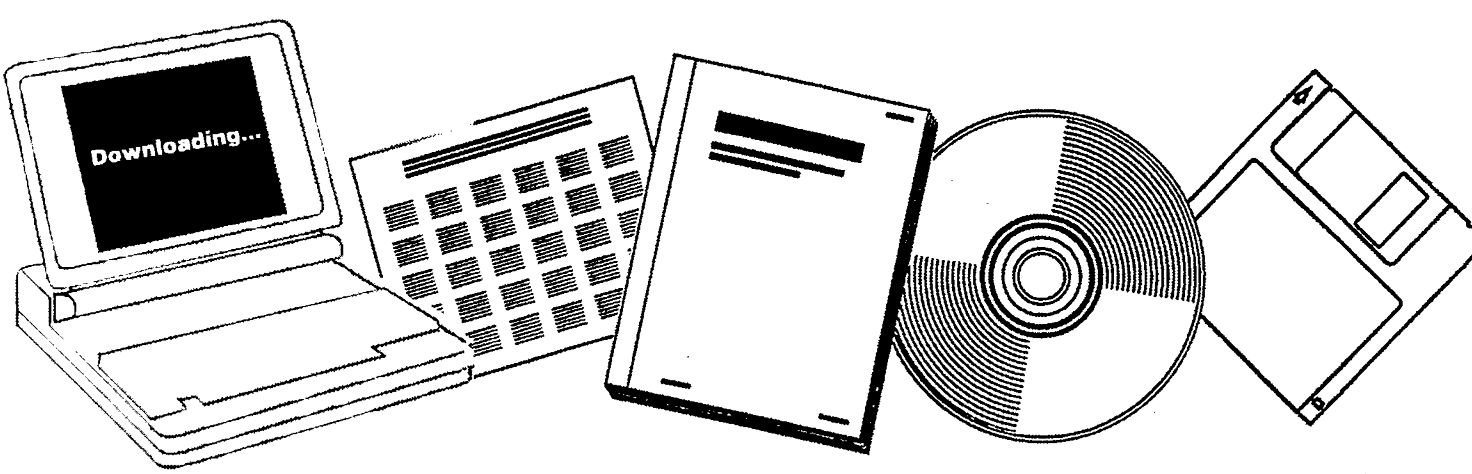
PRELIMINARY DESIGN SERVICES, COAL CONVERSION DEMONSTRATION PLANTS. RESEARCH AND DEVELOPMENT REPORT NO. 114. QUARTERLY REPORT, JANUARY--MARCH 1977

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

MAY 1977



FE-1775-10
Distribution Category UC-89

PRELIMINARY DESIGN SERVICES COAL CONVERSION DEMONSTRATION PLANTS

RESEARCH AND DEVELOPMENT REPORT NO. 114
QUARTERLY REPORT
FOR THE PERIOD: JANUARY - MARCH 1977

Prepared by:

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Under Contract No. E(49-18)-1775
May 1977

Prepared for

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D. C. 20545

FIRST 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 evaluations for a number of types of coal conversion plants. The following designs are included in the scope of work:

(1) Conceptual commercial plant for a coal-oil-energy-development (COED) plant

(2) Oil/Gas plant to produce liquid fuels plus substitute natural gas (SNG)

(3) Commercial-scale Fischer-Tropsch plant with motor fuel and SNG as the main products

(4) Coal conversion plant to produce power, oil, gas, and other products (POGO)

(5) Facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes that show promise during pilot plant operations

  (a) The facilities will be considered for conversion of coal to:

  - Low- to -high-Btu fuel gas
  - Methanol/motor fuel by Fischer-Tropsch process
  - Clean liquid fuels by alternate liquefaction processes

In addition, supporting efforts will be provided for 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.

A. Fischer-Tropsch and Oil/Gas Designs

During the past quarter, we transmitted multiple copies of the final R&D reports for the Fischer-Tropsch and Oil/Gas plants to ERDA. These reports were expanded to include:

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

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

B. POGO Design

We established overall material balances for the POGO plant design. Detailed material balances and process flow diagrams were prepared for seven major process units: dissolving, pyrolysis, process gasifier, naphtha hydrotreating, olefin recovery and polymerization, refrigeration, and shift conversion. Basic material balances have been made for the remaining process units.

Power generation and steam utilization optimization studies were initiated.

Mining plans, conceptual coal mine designs, and coal preparation plant designs were prepared for the Southern Appalachia location. This will be a second site location for POGO plant design.

C. Multi-Process Demonstration Plant Design

A basic block flow diagram and preliminary material balance were prepared for the Multi-Process Demonstration Plant (MPDP); these were transmitted to ERDA for review. This plant will be designed for engineering, construction, and operation in three phases. The first phase is a low-pressure air-blown gasification unit with capacity to process 1,800 tons per day (TPD) of feed coal; also included are the required coal storage and preparation, heat recovery, and desulfurization units. The second phase is an oxygen-blown, medium-pressure gasifier to produce medium-Btu gas for either combined cycle power plant or for use as a synthesis gas (syngas). It would have a capacity to process 3,600 TPD of feed coal. The third phase is a Fischer-Tropsch Unit with liquids separation, methanation, and auxiliary equipment.

D. Supporting Areas

We continued work on development of equipment needs with vendors of valves, solids-gas separation devices, and feeders.

We continued our investigation of sensitive environmental areas of coal conversion where additional information is to be developed. We initiated an air dispersion modeling study applicable to the geographic location planned for the Multi-Process Demonstration Plant.

E. General

We prepared nine invited manuscripts for publication/presentation in the field of coal conversion technology and projected economics.

A brief summary of results by assigned task is presented in the following paragraphs.

1. Coal Mining/Coal Preparation

We completed the design of a typical underground mine unit for the Southern Appalachia location in support of the POGO design. The basic mine unit produces 2 million short tons per year (STPY) of run-of-mine (ROM) coal.

We also completed the designs of a basic strip mine unit for the Southern Appalachia location in support of the POGO design. The unit has an average capacity of 1 million STPY of ROM coal.

We completed the design of the wet-jigging, screening, and multi-stage cyclone coal preparation plant in support of the POGO design for the Eastern Interior Region. This plant will beneficiate high ash content coal to produce a "clean" 7% ash (dry basis) fraction. Pyrites sulfur will also be largely removed by this plant.

2. Oil/Gas Plant Design

We transmitted bound copies of the R&D report to ERDA and also transmitted reproducibles of the report to National Technical Information Service (NTIS) for publication from that source. This report had been expanded to include projections on the marketability of products, design and operation of the gasifier waste heat boiler, and a summary of key experimental data used in design of the prime coal conversion steps.

3. Fischer-Tropsch Plant Design

We transmitted bound copies of the R&D report to ERDA and reproducibles to NTIS. This report was also expanded to include sections on product marketability, the basis for the Fischer-Tropsch reactor design, and design characteristics of waste heat boilers.

Also included were the experimental and process design bases for the synthesis, methanation, and shift reactor system sections.

4. POGO Plant Design

Overall material balances were established for a plant to be located in the Eastern Region of the Interior Coal Province. This plant will use Illinois No. 6 feed coal. Detailed process engineering for the various units is underway; with heat and material balances prepared for the dissolving, pyrolysis, process gasifier, naphtha hydrotreater, olefin refrigeration, and shift conversion units.

Optimization studies were initiated on methods of power generation and steam utilization.

Designs/economic analyses will be developed for three locations. Mining plans, conceptual coal mine designs, and coal preparation plant designs were prepared for the Southern Appalachia location. This was the second of the three planned coal mine/coal preparation designs.

5. Multi-Process Demonstration Facility

We transmitted to ERDA objectives and design criteria for the demonstration plant.

Based on the results of agreements reached with ERDA during discussions, we prepared a block flow diagram showing the process units to be incorporated into each phase. Basically, the facility will be designed for a four-phase construction program. The first phase will include coal handling, an air-blown low-Btu fuel-gas gasifier with a capacity to process 1,800 TPD of coal, H_2S removal, and the necessary support facilities required for an operational unit. The clean product gas would be supplied to an existing power boiler.

The second phase would have additional coal handling and preparation facilities, an oxygen-blown medium-pressure (400-600 psig) gasifier with a process capacity of 3,600 TPD of coal, acid gas removal, a combined cycle power plant, and the necessary support facilities for an operational unit.

The third phase would be a Fischer-Tropsch unit to convert syngas to liquid fuels and SNG.

The fourth phase will provide additional modules for demonstration of other processes. For design purposes, each of these modules would require syngas equivalent to 750 TPD of coal.

6. Equipment Development

We continued to obtain information of gas/solids separation equipment and valves.

7. Materials of Construction

We continued to provide material selection services for various tasks.

8. Environmental Considerations

We initiated a dispersion modeling study concerning the air pollutants which could be released by the Multi-Process Demonstration Facility. Object of the study is to verify compliance with ambient air quality standards after air dispersion. The EPA-developed PTMAX and PTDIS computer programs, providing maximum concentration of pollutants on the ground and contours of equal pollutant concentration from the source (isopleths), are being used for the study. Specific meteorological data pertinent to the geographical area studied will be obtained.

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.

9. General

Several papers were prepared for presentation during the quarter and several papers/book chapters were published. A listing of the publications is presented in the following paragraphs.

(1) We prepared and transmitted an invited chapter on the subject of Fischer-Tropsch Technology to the Encyclopedia of Chemical Processing and Design; probable publication date is February 1978.

(2) We authored a chapter that was published in the Marcel Dekker, Inc. book titles Synthetic Fuels Processing Comparative Economics.

(3) We prepared and transmitted an invited manuscript titled "Potential Markets for Emerging Energy Technologies". This paper is scheduled for presentation at the August 28-31, 1977 Denver AICHE meeting. It compared projected economics for five types of coal conversion facilities with projected economics for production of oil and gas from new wells, LNG, and two types of shale oil production.

(4) We received notification by Chemical Engineering Progress of their intent to publish our paper titled "Potential for Petrochemical Feedstocks and Chemicals from Coal" in the June 1977 issue. This will be based on a paper that was presented at the 82nd National Meeting of AIChE in Atlantic City on August 31, 1976.

(5) We received a request to publish, in the Spanish language, the paper titled "Coal Liquefaction", which was presented to the European Federation of Engineers 3rd International Conference on Large Chemical Plants Design and Operation in Antwerp on October 20, 1976. The invitation is from the Ingenieria Quimica, a Madrid, Spain monthly journal.

(6) We prepared and transmitted an invited paper entitle "Environmental Factors in Fischer-Tropsch Coal Conversion Technology" to the American Institute of Chemical Engineers. The paper has been accepted and will be presented to the Second Pacific Chemical Engineering Congress in Denver, Colorado, August 28-31, 1977.

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 TPD are being considered.

2. Activity This Quarter

The design of a typical underground mine unit for the Southern Appalachia location in support of the POGO design was completed. The basic mine unit produces 2 million STPY of ROM coal.

We completed the design of a basic strip mine unit for the Southern Appalachia location in support of the POGO design. The basic unit has an average capacity of 1 million STPY of ROM coal.

We completed the design of the wet-jigging, screening and multistage cyclone coal preparation plant for the Eastern Interior Region. This plant will beneficiate high ash content coal to produce a clean coal product having an average of 7% ash, dry basis. Pyrites sulfur will also be largely removed by this plant.

3. Activity Forecast Next Quarter

We will finish coal mine design and mining plans for the Rocky Mountain coal province.

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. Multiple copies of the R&D report were printed and transmitted to ERDA. We also transmitted a reproducible copy of the report to NTIS for their use in production of additional volumes. The expanded report included the experimental data basis for the overall design, design and operation of the gasifier effluent waste boiler, and the marketability of products.

3. Results of These Activities

a. Summary

A conceptual design and economic evaluation was completed for a project to design, engineer, construct, startup, and operate an industrial complex to mine high-sulfur coal and convert it to SNG, LPGs, naphtha, and heavy fuel oil. The results are summarized in this section.

The design basis, utilizing information from the SRC process development program, was developed in cooperation with ERDA.

The scope of the industrial complex is a grassroots facility, consisting of a large captive coal mine that produces approximately 47,000 TPD of ROM coal supplying the feed material to a coal preparation plant, which, in turn, supplies approximately 36,000 TPD of clean washed coal to a hydroliquefaction-based coal conversion plant. In the facility, the feed coal is converted to the above-mentioned product slate; byproduct ammonia and sulfur are also produced. Low-Btu, low-sulfur fuel gas is produced as fueld for process furnaces and for use in a close-coupled steam and power generation plant that produces all utilities required for the captive use in the complex.

The complex is conceived to be located in the eastern region of the Interior Coal Province. The facility meets desired location criteria consisting of significant resource of high-sulfur coal with a large utility-industrial market nearby and with ecological restrictions on direct consumption of the indigenous high-sulfur coal.

Process flowsheets and accompanying heat and material balances were prepared, based on a typical coal analysis that is intermediate between the extreme analyses that might be encountered during a 20-year project life. The equipment was sized to handle this typical coal. The design provides for the simultaneous mining of five mine faces and the mixing of the resultant coals in a storage pile to produce a relatively uniform feed coal to the process plant.

Products from the process plant include the following approximate quantities:

- 56,000 BPD of fuel oil; characteristics are projected to be roughly equivalent to low-sulfur bunker C
- 10,000 BPD of naphtha
- 10,000 BPD of LPG (C_3 and C_4)
- 165 MM SCFD of SNG
- 1,300 STPD of sulfur
- 90 STPD of anhydrous ammonia

The estimated fixed capital investment for the complex is \$1.25 billion; all estimates are in fourth-quarter 1975 dollars. The total capital investment is estimated to be \$1.4 billion, which includes the cost of initial raw materials, catalyst and chemicals, allowance for startup and land acquisition, and initial working capital.

The fixed capital investment estimate was independently evaluated by the U.S. Army Engineer Division (USAEDH), Huntsville, Alabama. This work was done under contract to ERDA, Contract No. EX-76-C-01-1759. The USAEDH estimate was approximately 4% lower than Parsons, and they report an indicated overall estimate confidence factor of ±4%

A representative project schedule for design, engineering, construction, and startup is given; a 56-month schedule to mechanical completion is projected, and a probable fund drawdown schedule is presented.

b. Economic Projections

The population of the complex is estimated to be about 2,350. Operation costs are projected to be about \$195 million per year. The required plant revenue for a 12% discoutned cash flow (DCF) rate of return with 65% debt at 9% interest is

$395 million per year. The predicted required product selling price for these financial parameters is $1.80/MM Btu.

Predicted required product selling prices, expressed in dollars per million Btu, for 100% equity financing and a nonprofit (0% DCF) or break-even boundary case in addition to the 65/35 debt/equity case described are:

Financing Method	Selling Price, $
100% equity	2.35
Debt/equity ratio = 65/35	1.80
Break-even	1.15

These values correspond to approximately $10.80/bbl and $14.10/bbl of oil equivalent for the 65/35 debt/equity ratio and 100% equity cases, respectively; values are based on a heating value of 6 million Btu/bbl.

The sensitivities of required selling prices and profitability to key economic parameters are presented. The selling prices are highly capital sensitive.

The design represents an assessment of a proposed configuration and potential economics for this type of technology. It projects a total thermal efficiency of approximately 77%, which means that more than three-quarters of the energy (Btu) contained in the feed coal is converted to low-sulfur fuel products. This efficiency is higher than predicted by earlier designs and is the result of detailed analysis of the efficiency in all major plant units.

The design conceives operation in the mid-1980s and therefore proposes use of certain equipment and techniques that require further development prior to commercial operation. To accomplish this objective, the use of engineering judgment for the scaleup and the selection of the equipment was required. The design also represents an exposition of factors required to integrate the coal conversion plant with a large coal mine and a closely coupled electrical power plant has defined a number of the design and operational options that exist to maximize efficiencies and profitabilities.

The details of the design are contained in the report "Oil/Gas Complex, Conceptual Design/Economic Analysis," ERDA R&D Report No. 114 - Interim Report No. 4.

c. Key Process Steps

An overall process block flow diagram is shown in Figure 1.

The design incorporates the following key process steps:

(1) Coal Liquefaction. Twenty thousand TPD of washed and dried coal will be fed to the hydroliquefaction process dissolvers. The SRC-II mode of operation was used as a basis for the design. This mode uses the recycle of dissolver effluent slurry as part of the coal slurry solvent, thereby permitting a high hydrogen uptake.

The major product of this process mode, after suitable treatment, is a low-sulfur fuel oil.

(2) Process Gasification. The gasifier is an entrained, slagging, two-stage design. This high-pressure steam-oxygen gasification of feed coal will be used to produce methane and a hydrogen-rich syngas product. The raw gasifier product stream will be tested to produce the hydrogen required as feed for the dissolvers and for naphtha hydrogenation. The methane will be recovered as part of the product SNG.

(3) Low-Btu Gasification. The fuel gas required for process furnaces and power plant boilers is generated in a low-pressure, air-blown, slagging, two-stage gasifier. This gasifier will be designed to operate at a pressure of 45 psig in order to move the gas through the downstream H_2S removal system and to the point of use.

(4) Supporting Processes. The complex contains units to remove acid gases consisting primarily of H_2S to elemental sulfur and ecologically acceptable tail gases. Process steps are included to separate the gas streams into SNG, LPG, and hydrogen. Liquid product treatment is provided to produce 0.4 wt% sulfur fuel oil containing a maximum of 0.15 wt% solids plus commercially salable naphtha.

d. Facilities Provided

(1) All effluent streams will be treated to meet environmental standards. Disposal of solid wastes will be integrated with coal mining to provide haulaway and proper disposal. Equipment will be designed to meet OSHA noise level requirements.

(2) Facilities are provided for storage of a 14-day feed coal inventory and a 30-day product storage inventory.

(3) Ancillary facilities adequate to service the industrial complex and its personnel population of approximately 2,350 are included.

The overall material balance is shown in Figure 2. The energy balance is given in Figure 3.

C. Fischer-Tropsch Plant Design

1. Objective

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

Multiple copies of the final R&D Report were produced and transmitted to ERDA during the quarter. The report had been expanded to include design bases and heat transfer mathematical analysis for the expanded surface heat exchanger reactors.

3. Results of These Activities

a. A conceptual design and economic evaluation was completed for a project to design, engineer, procure, construct, startup, and operate an industrial complex which will mine high-sulfur coal and convert it to a nil-sulfur product mix using Fischer-Tropsch technology. The objective was that the complex should be responsive to future U.S. energy requirements and be competitive with alternate energy sources.

This design is intended to aid in defining the potential for large, second-generation coal conversion plants. It incorporates a number of concepts and equipment items that careful analyses indicate have potential advantages and good probability for high performance. A number of these items are based on commercialization of expected favorable results of an in-progress development program and require further work before commercial plants can be designed with confidence. Key developments required and recommendations for continued development are presented. Comments regarding projected plant performance and caveats regarding interpretation of the results are presented.

The Fischer-Tropsch converter design is based on application of flame-sprayed catalyst (FSC) techniques that have been demonstrated experimentally by what is now the Pittsburgh Energy Research Center (PERC) of ERDA. Similar reactor designs were used for the shift and methanation reaction sections. This type of reactor is projected to provide efficient recovery of reaction heat as steam at a pressure of 1,200 pounds per square inch (psi). As a result, all steam required to operate the plant, produce the necessary captive power requirements, and produce excess power for sale is generated in the process section. A fuel-fired utility plant is not required for normal operation. All utilities are internally generate; i.e., feeds to the process plant consist of coal, air, and water.

As conceived, the complex is located in the Eastern Region of the U.S. Interior Coal Province, which includes portions of Illinois, Indiana, and Kentucky. It will mine approximately 40,000 TPD of ROM coal from whick it will produce about 30,000 TPD of clean, sized coal as feed to the Fischer-Tropsch plant. Here the coal will be gasified, the gases purified, and then reacted to produce liquid proudcts plus SNG. The products will be separated and refined ready for sale. Plant products will have an energy value of approximately 525 billion Btu/day, which is about twice the energy value of commercial coal gasification plants planned for construction in the U.S. The plant will consist of two production lines. The plant is designed to meet environmental standards. It should be noted that the design is one of many that can be developed using Fischer-Tropsch technology.

Products from the plant include about 260 MM SCFD of SNG and approximately 50,000 BPD of liquid products. The liquids consist of LPGs, light and heavy naphthas, diesel fuel, fuel oil, and oxygenates (consisting primarily of alcohols). All petroleum liquids produced contain nin-sulfur, nitrogen, and particulate matter and can be referred to as premium fuels.

b. Estimated time needed to design, procure, construct, and start up the facility is 57 months. The estimated fixed capital investment is approximately $1.5 billion; all economics have been based on fourth-quarter 1975 dollars.

The total capital investment required is estimated to be about $1.75 billion. In addition to fixed capital requirements, this total includes the cost of initial raw materials, catalysts and chemicals, working capital, allowance for startup costs, and allowance for land acquisition. The cost of financing during design and construction depends on the method of financing, and was added to the $1.75 billion for the separate project cases reported.

Annual operating costs for the complex are predicted to be about $190 million. Plant population is approximately 2,100 people.

c. Predicted required product selling prices, expressed as dollars per million Btu, for a 12% DCF rate of return and a 20-year project operating life are:

FINANCING METHOD		
100% Equity	Debt/Equity Ratio = 65/35	Break-even
3.25	2.50	1.45

These values correspond to about $14.80 and $19.40 per barrel equivalent for the 65/35 Debt/Equity (D/E) ratio and 100% equity cases, respectively, based on a heating value of 6 million Btu/bbl.

d. Key characteristics of the complex include:

- Large captive coal mine
- Use of high capacity gasifiers; each gasifier vessel projected to produce 250+ million Btu/day of energy products.
- Fischer-Tropsch converter design that permits high throughput and recovery of reaction heat as 1,200 pounds psi steam
- Design for high thermal efficiency. Predicted thermal efficiency is approximately 70%, expressed as Btu of salable products divided by Btu in feed coal, times 100. Predicted efficiency is the result of considerable technical and economic analysis of alternates. Results of these analyses are reported. The products, having nil-sulfur, nitrogen, and particulate matter, represent premium grade fuels from an environmental standpoint. They also have characteristics which make them attractive as potential feed-stocks for high value petrochemical and chemical manufacture.

e. The description of the facility is presented below.

A block flow diagram is shown in Figure 4. The complex includes a captive coal mine with the capacity to produce approximately 15 million TPY for 20 years. Units are included which will clean, wash, crush, and size the coal, and feed it to the process units.

Facilities for the production of oxygen, and all required utilities, are included in the design as well as for the treatment and disposal of solid, liquid, and gaseous effluent streams. The design is based on a site location capable of providing 18,000 acre-feet of water per year for process requirements and utilities makeup. Well water is used for all potable and sanitary water requirements.

The land area required for the life of the project for mining the required coal is estimated to be about 47 square miles; approximately 500 acres should be alloted to the initial plant complex.

The process consists of the reaction of coal with oxygen and steam at elevated temperature and pressure to produce a syngas, purification and adjustment of composition of the gas to form principally hydrocarbon liquids. Unreacted tail gas and methane are further processed to produce SNG.

Approximately one-half of the carbon in the coal is reconstituted into hydrocarbons with greater hydrogen content than the feed coal, heat being supplied primarily by heat of reaction released from the gasifier, water gas shift, Fischer-Tropsch synthesis, and methanation steps. Efficient heat recovery provides all process needs for power and steam plus salable electric power.

The processing complex consist of two trains and contains the following primary units:

- Unit to crush, wash, and prepare the coal for gasifier feed.
- Facilities to dry the coal
- Entrainment type, two-stage slagging gasifier, to primarily produce a mixture of carbon monoxide and hydrogen (synthesis gas)
- Syngas heat recovery and dust removal unit
- Water gas shift reaction unit to increase the hydrogen content of the syngas
- Unit to remove acid gases from the syngas
- Unit to desulfurize the acid gases removed from the syngas
- Fischer-Tropsch synthesis unit to convert syngas to hydrocarbons

- Unit to remove carbon dioxide produced in the Fischer-Tropsch synthesis unit from the recycle gas
- Unit to recover hydrocarbons from the Fischer-Tropsch synthesis tail gas and separate liquid products
- Unit to make SNG by methanation of the Fischer-Tropsch tail gas
- Unit to recover product oxygenates and dispose of organic acid solution
- Unit to recover process water and recycle it to the steam generators
- Unit to convert superheated steam generated in the process to electrical power
- Unit to provide oxygen to the coal gasifier

All effluent streams will be treated to meet environmental standards. Disposal of solid waste will be integrated with coal mining to provide haulaway and proper disposal. Equipment will be designed to meet OSHA noise level requirements.

Adequate ancillary facilities are provided to service this square-mile industrial complex and its personnel population of approximately 2,100.

f. The principal products are listed below:

Product	Characteristics	Production Rate (approximate)
SNG	1,035 Btu/SCF HHV	258,700,000 SCFD
C_4s	37 Psig	3,000 BPD
Naphtha	Nil sulfur, UOP K-12.3	20,000 BPD
Oxygenates	Mixed alcohols	4,000 BPD
Diesel fuel	Nil sulfur, 60-plus cetane	16,000 BPD
Fuel oil	Nil sulfur, low viscosity	5,000 BPD
Sulfur	99.9% sulfur	1,000 STPD
Power for sale	13,800 volts	3,352,000 kWh

g. The overall material balance for the process sections of the complex is depicted in Figure 5. The results project that approximately 12,500 TPD of premium hydrocarbon and oxygenate products will be produced from 30,000 TPD of bituminous coal. The balance is based on miscellaneous internal consumption equal to approximately 1.2 wt% of the total product quantity.

h. The overall energy balance is illustrated in Figure 6. The results indicate that the energy value of products is approximately 525 billion Btu/day, which represents about 70% of the energy contained in the feed coal.

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

We completed underground and strip mine unit designs for the Southern Appalachia location. During the first 5 years of the project, 10 strip mine units and 5 underground mine units will furnish the Southern Appalachia POGO plant. At the end of this period the strip mine operations would be phased out and 5 additional underground mine units placed into operation. The 10 underground units would supply coal requirements for the remaining 15 years of the project life.

We completed the design of the coal beneficiation plant for the Eastern Region of the Interior Coal Province.

We commenced Unit 10: Coal Storage, Grinding, and Drying design for the basic case Eastern Interior Region location.

We finalized the flowsheets and material balances for Units 24: Naphtha Hydrotreating; 28: Olefin Recovery and Polymerization; and 18: Shift Conversion. A sour shift process was designed.

We advanced the design and preliminary flowsheets for the remaining process units:

- 12 - SRC
- 13 - SRC Atmospheric Distillation
- 14 - SRC Vacuum Distillation
- 15 - Pyrolysis
- 18 - Gasification
- 21 - Heavy Liquid Hydrotreating
- 25 - Naphtha Reforming
- 29 - Hydrogen Recovery and Purification

The materials review was completed for Unit 19: Shift Conversion plant.

Optimization studies were initiated by the Power Division on the power generation and stem utilization method.

We continued to work to finalize the POGO design basis report for publication.

3. Activity Forecast Next Quarter

We will complete detailed flowsheets and material balances for the process units.

We will continue work on the mechanical equipment design and specifications.

We will continue environmental reviews and materials of construction reviews.

We will initiate preparation of Fixed Capital Investment estimates.

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

We reviewed the conceptual design of the facility with ERDA representatives.

A program plan was transmitted to ERDA for the Multi-Process Demonstration Plant (MPDP). This plan outlined the concept logic, facilities to be provided, and a proposed plan for engineering, procurement, and construction of the facility. The facility would be build in three phases. The first phase would be an air-blown gasification unit to provide low-Btu gas to an existing power boiler. The second phase provides for moderate-pressure, oxygen-blown coal gasification with a combined cycle power plant. The third phase consists of process units for production of liquid fuels and SNG, using the syngas from Phase 2.

3. Results of These Activities

a. A plan and preliminary design information for a MPDP was prepared. This plan provides for demonstration scale testing of a number of coal gasification and liqefaction process units, plus supporting purification and power generation units. It will provide significant quantities of products for functional product testing and characterization by potential customers, along with information to support future designs of environmentally acceptable commercial scale plants.

b. The conceptual design uses centralized coal preparation, gasification, and purification units to demonstrate a number of processes. It is anticipated that considerable time and funds could be saved by such a plant. Only those units peculiar to a particular process would need to be installed to demonstrate that process. As presently conceived, the plant would be designed and constructed in overlapping phases. The phases are shown in Figure 7. These phases are described in the following paragraphs.

c. The first phase will gasify coal/lignite at low-pressure to provide a clean, sulfur-free, low-Btu gas for boiler firing. It would consist of an air-blown, entrained-type gasifier and associated equipment to gasify 1,800 TPD of coal. This unit would be designed to operate at pressures to 40 psig. The unit would be about 26 feed ID of shell by 75 feet high. Proven design and materials technology elements will be used in the gasifier. The design is patterned after present blast furnace practice. The gasifier will be capable of gasifying any solid carbonaceous fuel: coal, lignite, char, coke, or residue.

Storage for purchased coal, grinding and drying facilities to prepare the coal for process use, gas purification (solids removal), steam generation from process gas cooling, H_2S removal, a sulfur plant, and necessary offsites. The offsites will include such items as boilers, offices and development laboratories, cooling water, and other facilities required to provide an operating facility and support the plant population.

This gasification system will produce clean, sulfur-free, low-Btu gas (about 160 Btu/SCF, water-free basis) for use in an existing nearby power boiler. The output gas will have a total calorific heat of about 1.6 billion Btu/h.

d. The second phase provides a medium pressure (400-600 psig), entrained, oxygen-blown gasifier to provide syngas to a combined cycle power plant; it can be converted to feedstock for process units. It will provide a medium-Btu (300-324) syngas consisting primarily of CO, H_2, CO_2, H_2O, and H_2S to downstream process facilities.

   Included in this phase are the following items:

   - A medium-pressure (400-600 psig), oxygen-blown gasifier. This unit will supply medium-Btu (300-325) syngas consisting primarily of CO, H_2, CO_2, H_2, and H_2S to downstream processing facilities. The unit will be of entrained type and about 10 feet ID of the refractory. The inside shell diameter will be approximately 13 feet. It will have a slag quenching section in the lower section of the gasifier vessel.

     This unit will be sized to provide gas to a combined cycle gas turbine unit, a Fischer-Tropsch synthesis unit, and to one other process module. The feed to this unit will be 3,600 TPD of coal feed.

   - Two additional types of process gasifiers, the specific types to be defined later. The present plan is that the process gasifiers will serve:

     - A combined cycle power generation plant with a capacity of approximately 370 MW.

     - Two process modules. The process modules will each required syngas equivalent to 750 TPD of coal.

   - Necessary additional storage for purchased coal, plus coal grinding and drying facilities to meet the gasifier requirements.

- An oxygen plant to supply oxygen and inert gas requirements for the plant. These units are tentatively sized at 4,500 TPD of oxygen.

- Gas purification facilities to remove solids from the gasifier effluent product stream.

- Steam generation by heat removal from the gasifier product gas.

- Acid gas removal to remove H_2S and CO_2 from the solids-free product gas.

- A combined cycle power system to produce approximately 370 MW of electrical power.

- Necessary additional offistes and utilities to start up and operate the facility. This includes waste treatment facilities.

e. The third phase will provide a Fischer-Tropsch process for conversion of syngas to liquid fuels and SNG. The items to be installed in this phase include:

- Sour shift conversion unit to provide the correct ratio of H_2 to CO for the reactor.

- Acid gas unit to remove CO_2 and H_2S from the gas after shift conversion. The H_2S will be sent to the sulfur plant. Facilities will be provided to further reduce sulfur content to meet purity requirements for feed to the Fischer-Tropsch reactors.

- Fischer-Tropsch synthesis reactor unit. This unit is planned to consist of two 10-foot-diameter by 30-foot-long flame spray coated catalyst extended surface heat exchanger-type reactors. The reactors will be in parallel so that all gas may flow through either unit. Associated pumps, compressors, heat exchangers, and other equipment will be provided. This unit is tentatively rated to process 112 million standard cubic feet per day of syngas to produce 900 BPD of liquid fuels and 90 BPD of chemicals.

- Methanation unit to process the effluent gas from the Fischer-Tropsch unit to produce SNG. This unit will produce 5.7 billion Btu/d of SNG, equivalent to approximately 900 BPD of fuel oil.

- Liquid product separation unit to produce salable products: fuel oil, naphthas, and liquified petroleum gases.
- Chemicals recovery unit to separate the various oxygenated hydrocarbons into salable products.
- Offistes and utilities additions necessary to provide an operational Fischer-Tropsch facility.
- Facilities will be designed to serve a comprehensive testing program. This will include provision for high instrumentation development-type laboratories, a computer system, and product storage capabilities.

Additional process modules will be added in following phases. Details of the later phase development are beyond the scope of the current design assignment.

4. Activity Forecast Next Quarter

We will prepare heat and material balances and flow diagrams for the process units in each phase. We will initiate studies on optimum sizing of the power generation and steam utilities units. Mechanical design of equipment will commence.

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 development programs to ERDA — Fossil Energy Division.

2. Activity This Quarter

Gas/Solids Separation. Air Pollution System, Inc. and Ducon are preparing budget proposals for solids removal equipment in support of the POGO project.

We further investigated the practical efficiency of electrostatic precipitators for removal of char from syngas streams. We confirmed that wet electrostatic precipitators are best suited for this application; and that dry units are also satisfactory, but can be expected to vary in efficiency depending on the specific char's resistivity properties and the operating gas velocity.

G. Materials of Construction

1. Objective

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

2. Activity This Quarter

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

We presented 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, March 15, 1977.

3. Activity Forecast Next Quarter

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

We will attend meetings in San Antonio, Texas, Phase 5, Engineering Properties, of the Metal Properties Council and in Denver, Colorado, on June 1 to discuss a liquefaction metals properties council meeting.

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. The first results obtained from a dispersion modeling study indicate that the emissions from a typical coal conversion plant (such as the Oil/Gas plant) can meet ambient air quality standards after atmospheric dispersion. More detailed results will be available when meteorological records for the New Athens, Illinois, area are received. Object of this study is to verify compliance with ambient air quality standards after air dispersion. The EPA-developed PTMAX and PTDIS computer programs, providing maximum concentration of pollutants on the ground and contours of equal pollutant concentration from the source (isopleths), are being used for the study. Specific meteorological data pertinent to the geographical area studied will be obtained.

A paper entitled "Environmental Factors in Fischer-Tropsch Coal Conversion Technology" has been prepared and transmitted to the Americal Institute of Chemical Engineers. The paper has been accepted for presentation to the Second Pacific Chemical Engineering Congress, Denver, Colorado, August 28-31, 1977.

We attended a workshop on "Exposure to Polynuclear Aromatic Hydrocarbons in Coal Conversion Processes" in Oak Ridge, Tennessee, on March 9-10, 1977. Both medical and safety considerations were presented.

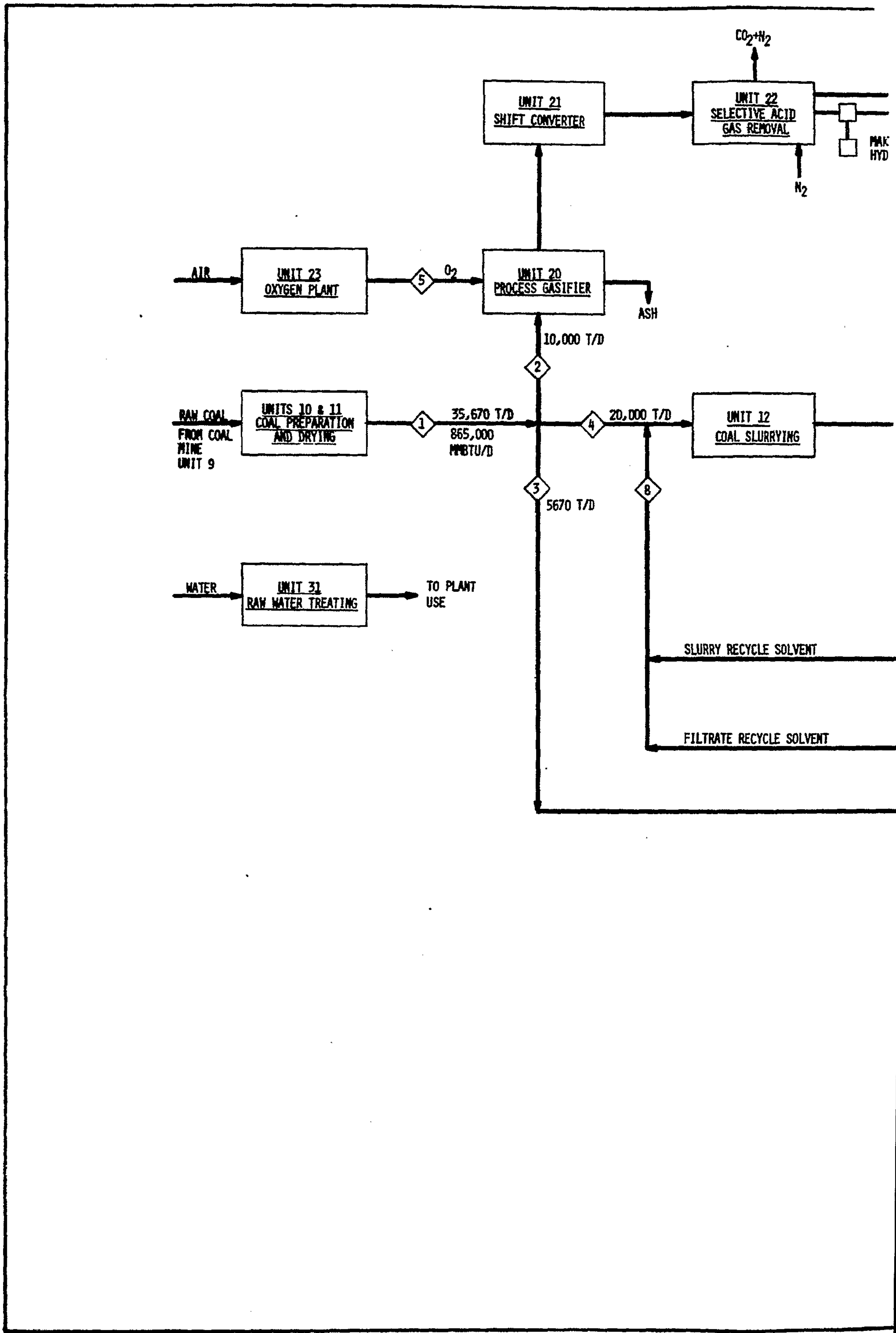
We reviewed the updated "Standards Support and Environmental Impact Statement for Lurgi Coal Gasification Plants," which we received from the EPA Emission Standards and Engineering Division (Research Triangle Park, North Carolina).

3. Activity Forecast Next Quarter

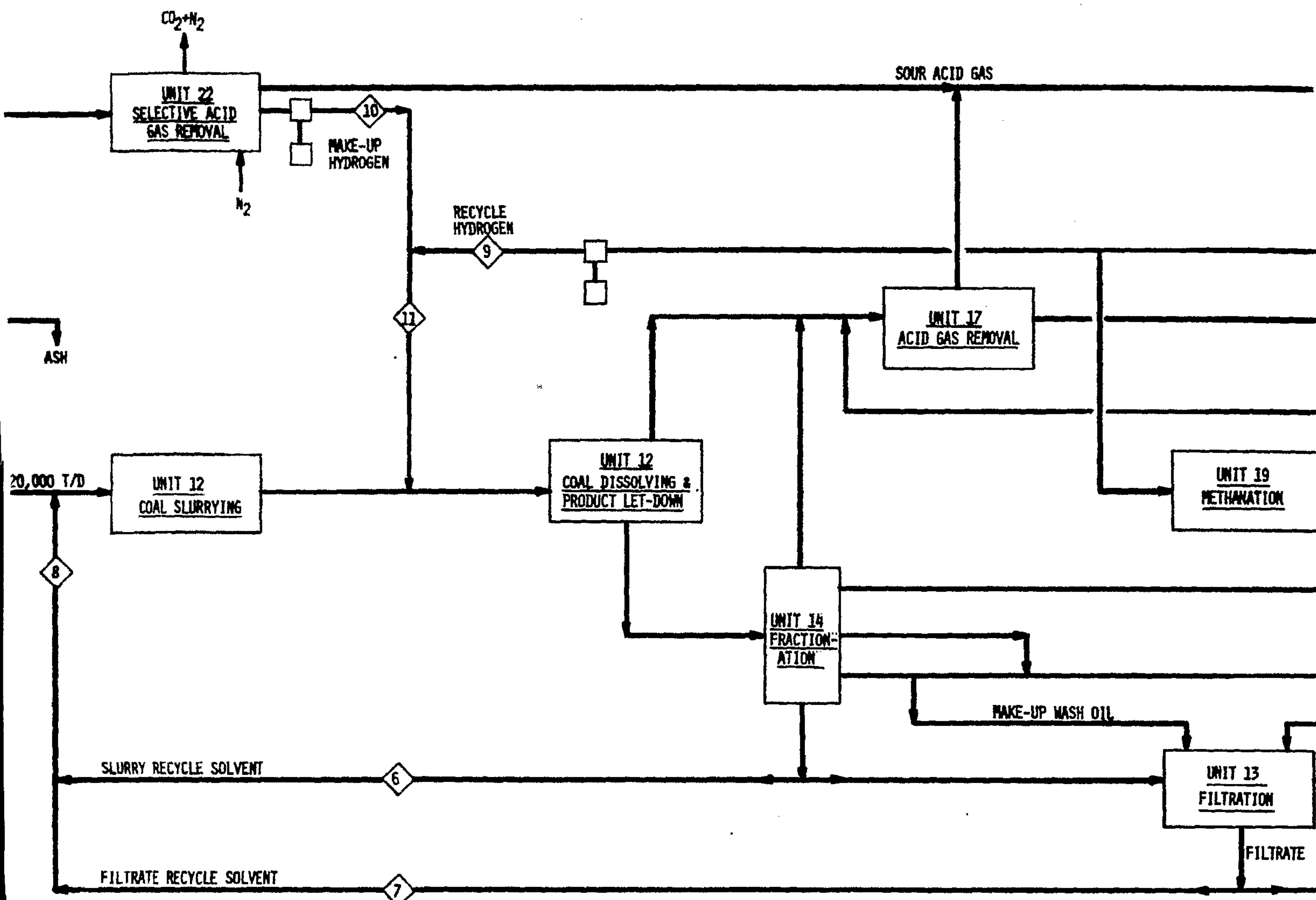
We will continue the environmental work along the two main directions followed so far: (1) investigation of environmental factors related to coal conversion and identification of environmentally sensitive areas or operational aspects where additional study is required, and (2) design monitoring to ensure 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 Multi-Purpose Demonstration Facility. Specific environmental areas requiring consideration will be analyzed and discussed with the design engineers.

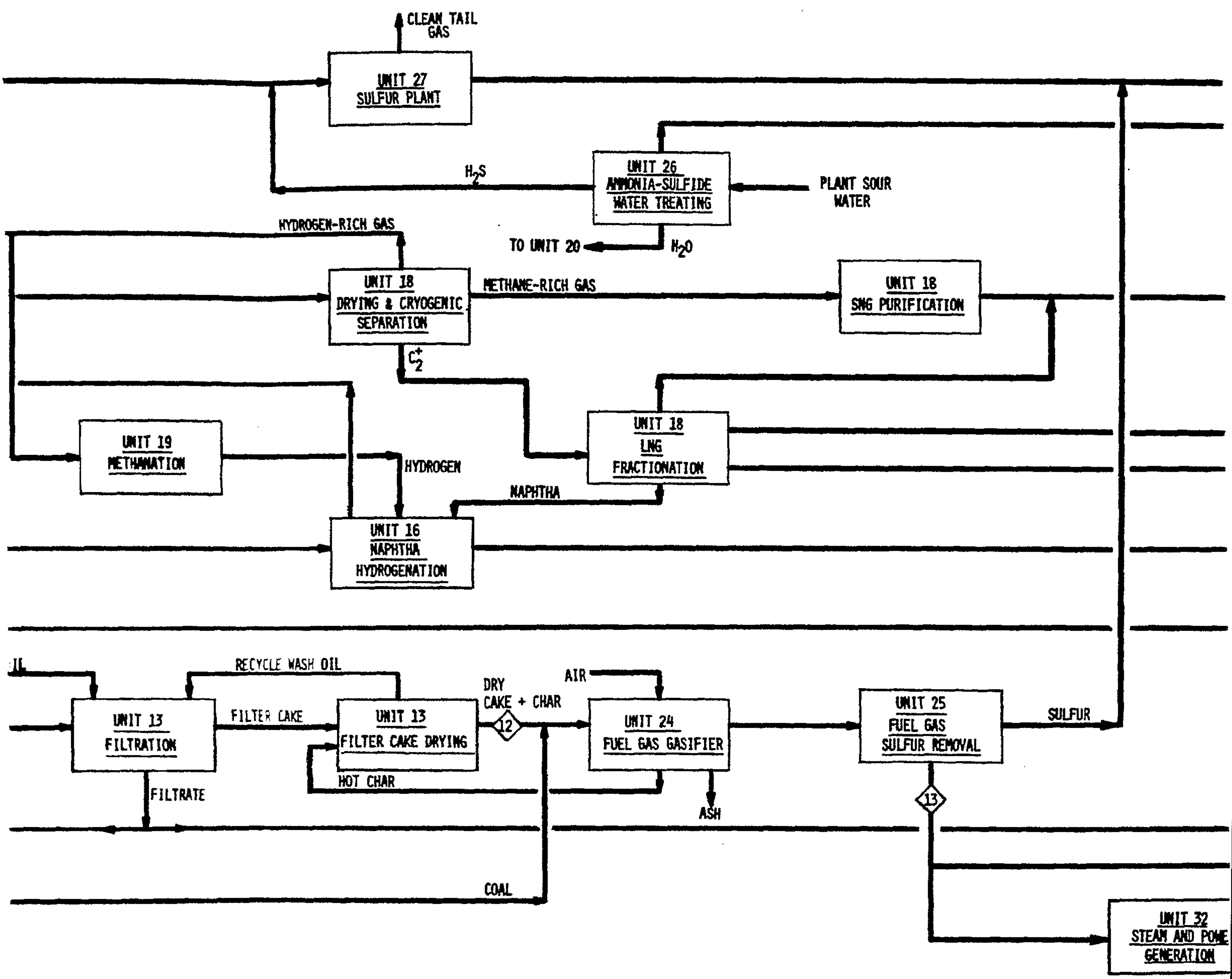
We will continue the air quality study mentioned above. Other environmental areas specific to coal conversion designs, such as partitioning of cyanides and leaching of slagged ash, will be further considered.



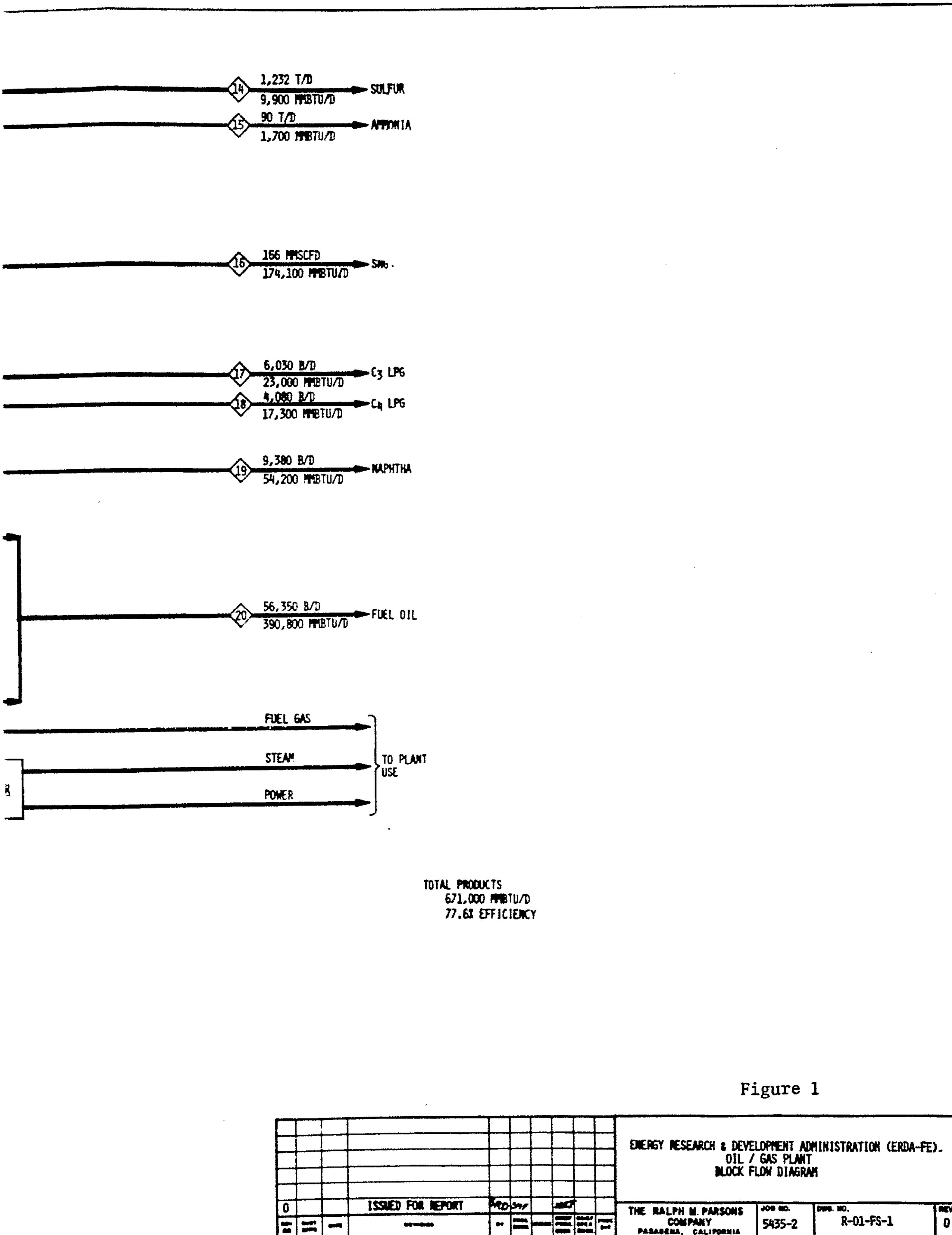
CO2+N2
UNIT 21
SHIFT CONVERTER
UNIT 22
SELECTIVE ACID
GAS REMOVAL
MAK
HYD
N2
AIR
UNIT 23
OXYGEN PLANT
5
O2
UNIT 20
PROCESS GASIFIER
ASH
10,000 T/D
2
RAW COAL
FROM COAL
MINE
UNIT 9
UNITS 10 & 11
COAL PREPARATION
AND DRYING
1
35,670 T/D
865,000
MMBTU/D
4
20,000 T/D
UNIT 12
COAL SLURRYING
3
5670 T/D
8
WATER
UNIT 31
RAW WATER TREATING
TO PLANT
USE
SLURRY RECYCLE SOLVENT
FILTRATE RECYCLE SOLVENT



STREAM NO.	1	2	3	4	5	6	7	8	9	10
STREAM NAME	CLEAN COAL FEED	COAL TO H.P. GASIFIER	COAL TO L.P. GASIFIER	COAL TO DISSOLVING	OXYGEN TO H.P. GASIFIER	SLURRY SOLVENT	FILTRATE SOLVENT	TOTAL SOLVENT	RECYCLE HYDROGEN	M… H…
O_2, T/D	-	-	-	-	4,418.85	-	-	-	-	
H_2	-	-	-	-	-	-	-	-	760.50	1,
N_2	-	-	-	-	78.38	-	-	-	105.91	
CO	-	-	-	-	-	-	-	-	271.32	
CO_2	-	-	-	-	-	-	-	-	-	
NH_3	-	-	-	-	-	-	-	-	-	
H_2S	-	-	-	-	-	-	-	-	-	
H_2O	963.09	270.00	153.09	540.00	-	-	-	-	-	
C_1	-	-	-	-	-	-	-	-	49.27	1,
C_2	-	-	-	-	-	-	-	-	-	
C_3	-	-	-	-	-	-	-	-	-	
nC_4	-	-	-	-	-	-	-	-	-	
IBP-200	-	-	-	-	-	-	-	-	-	
200-400	-	-	-	-	-	-	-	-	-	
400-450	-	-	-	-	-	-	-	-	-	
450-500	-	-	-	-	-	-	-	-	-	
500-650	-	-	-	-	-	152.18	84.89	237.07	-	
650+	-	-	-	-	-	35,701.82	19,915.11	55,616.93	-	
Residue	-	-	-	-	-	1,485.60	-	1,485.60	-	
Ash	4,209.07	1,180.00	669.07	2,360.00	-	2,660.40	-	2,660.40	-	
Coal (MAF)	30,497.96	8,550.00	4,847.96	17,100.00	-	-	-	-	-	
Sulfur	-	-	-	-	-	-	-	-	-	
Total, T/D	35,670.12	10,000.00	5,670.12	20,000.00	4,497.23	40,000.00	20,000.00	60,000.00	1,187.00	3.
MMSCFD	-	-	-	-	107.1	-	-	-	299.3	
BPD	-	-	-	-	-	-	-	-	-	
Heating Value, Billion BTU/D	865.0	242.5	137.5	485.0	-	-	-	-	-	



7 FILTRATE SOLVENT	8 TOTAL SOLVENT	9 RECYCLE HYDROGEN	10 MAKE-UP HYDROGEN	11 TOTAL HYDROGEN	12 DRY CAKE (ONLY)	13 PLANT FUEL GAS	14 SULFUR	15 AMMONIA	16 SNG	17 C_3 LPG	18 C_4 LPG	19 NAPHTHA	20 FUEL OIL
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	760.50	1,069.20	1,829.70	-	331.15	-	-	6.80	-	-	-	-
-	-	105.91	204.70	310.61	-	14,684.08	-	-	204.17	-	-	-	-
-	-	271.32	625.42	896.74	-	8,533.99	-	-	5.71	-	-	-	-
-	-	-	29.23	29.23	-	1,067.58	-	-	43.83	-	-	-	-
-	-	-	-	-	-	-	-	90.10	-	-	-	-	-
-	-	-	11.71	11.71	-	-	-	-	-	-	-	-	-
-	-	-	9.17	9.17	-	408.48	-	-	-	-	-	-	-
-	-	49.27	1,688.71	1,737.98	-	-	-	-	2,951.04	-	-	-	-
-	-	-	-	-	-	-	-	-	565.20	11.05	-	-	-
-	-	-	-	-	-	-	-	-	162.56	514.44	77.82	-	-
-	-	-	-	-	-	-	-	-	-	6.28	322.02	53.83	-
-	-	-	-	-	-	-	-	-	-	-	5.88	101.11	
-	-	-	-	-	-	-	-	-	-	-	-	1,123.49	294.98
-	-	-	-	-	-	-	-	-	-	-	-	-	532.58
-	-	-	-	-	2.89	-	-	-	-	-	-	-	510.11
84.89	237.07	-	-	-	51.59	-	-	-	-	-	-	-	1,511.36
15.11	55,616.93	-	-	-	139.89	-	-	-	-	-	-	-	8,459.93
-	1,485.60	-	-	-	1,318.53	-	-	-	-	-	-	-	-
-	2,660.40	-	-	-	2,465.51	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	1,231.70	-	-	-	-	-	-
00.00	60,000.00	1,187.00	3,636.14	4,825.14	3,957.61	25,105.28	1,231.70	90.10	3,939.31	531.77	405.72	1,278.43	11,308.96
-	-	299.3	506.8	806.1	-	792.92	-	-	165.9	-	-	-	-
-	-	-	-	-	-	-	-	-	-	6,030	4,082	9,379	56,348
-	-	-	-	-	-	114.9	9.9	1.7	174.1	23.0	17.3	54.2	390.8



14
1,232 T/D
9,900 MMBTU/D
SULFUR
15
90 T/D
1,700 MMBTU/D
AMMONIA
16
166 MMSCFD
174,100 MMBTU/D
SNG
17
6,030 B/D
23,000 MMBTU/D
C_3 LPG
18
4,080 B/D
17,300 MMBTU/D
C_4 LPG
19
9,380 B/D
54,200 MMBTU/D
NAPHTHA
20
56,350 B/D
390,800 MMBTU/D
FUEL OIL
FUEL GAS
STEAM
POWER
TO PLANT USE
TOTAL PRODUCTS
671,000 MMBTU/D
77.6% EFFICIENCY
0
ISSUED FOR REPORT
ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION (ERDA-FE)
OIL / GAS PLANT
BLOCK FLOW DIAGRAM
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA
JOB NO.
5435-2
DWG. NO.
R-01-FS-1
REV.
0

Figure 1

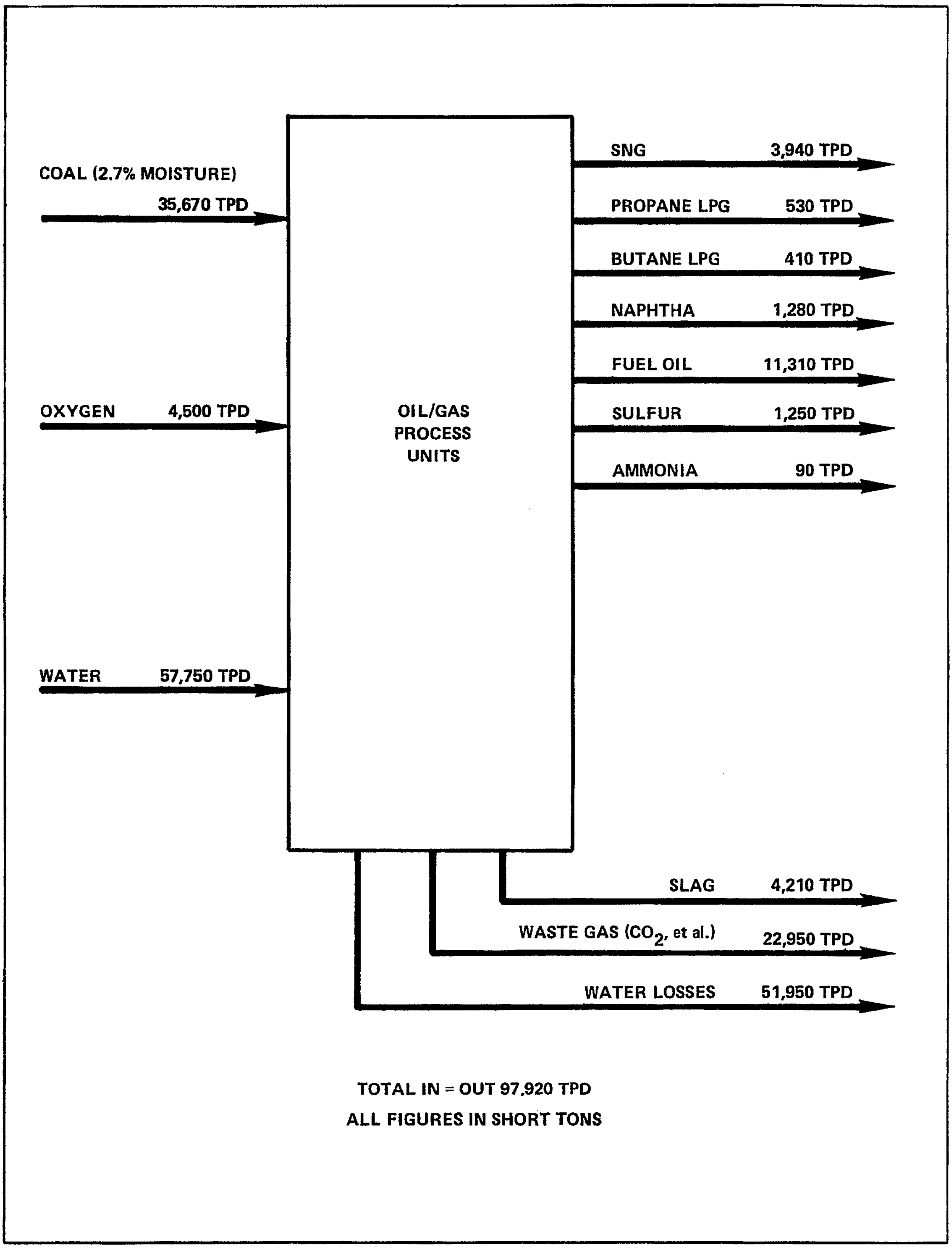


Figure 2 - Overall Material Balance
Oil/Gas Plant

COAL ENERGY DISTRIBUTION		
STREAM	MM BTU/H	% CLEAN COAL
FEEDS		
COAL TO PROCESS	30,310	84.1
COAL TO UTILITIES	5,730	15.9
TOTAL	36,040	100.0
PROCESS COAL YIELDS		
SALEABLE PRODUCTS	27,951	77.6
FILTER CAKE	844	2.3
REACTION HEATS	1,515	4.2
TOTAL	30,310	84.1

UTILITY ENERGY DISTRIBUTION		
STREAM	MM BTU/H	% CLEAN COAL
INPUTS		
COAL	5,730	15.9
FILTER CAKE	844	2.3
STEAM	632	1.8
TOTAL	7,206	20.0
OUTPUTS		
TO MINING AND PREPARATION		
STEAM	458	1.3
POWER	132	0.4
TOTAL	590	1.7
TO OXYGEN PLANT		
STEAM	1,007	2.8
POWER	8	–
TOTAL	1,015	2.8
TO OIL/GAS PLANT		
POWER	601	1.7
FUEL GAS	1,020	2.8
TOTAL	1,621	4.5
LOSSES TO ATMOSPHERE	3,980	11.0
TOTAL	7,206	20.0

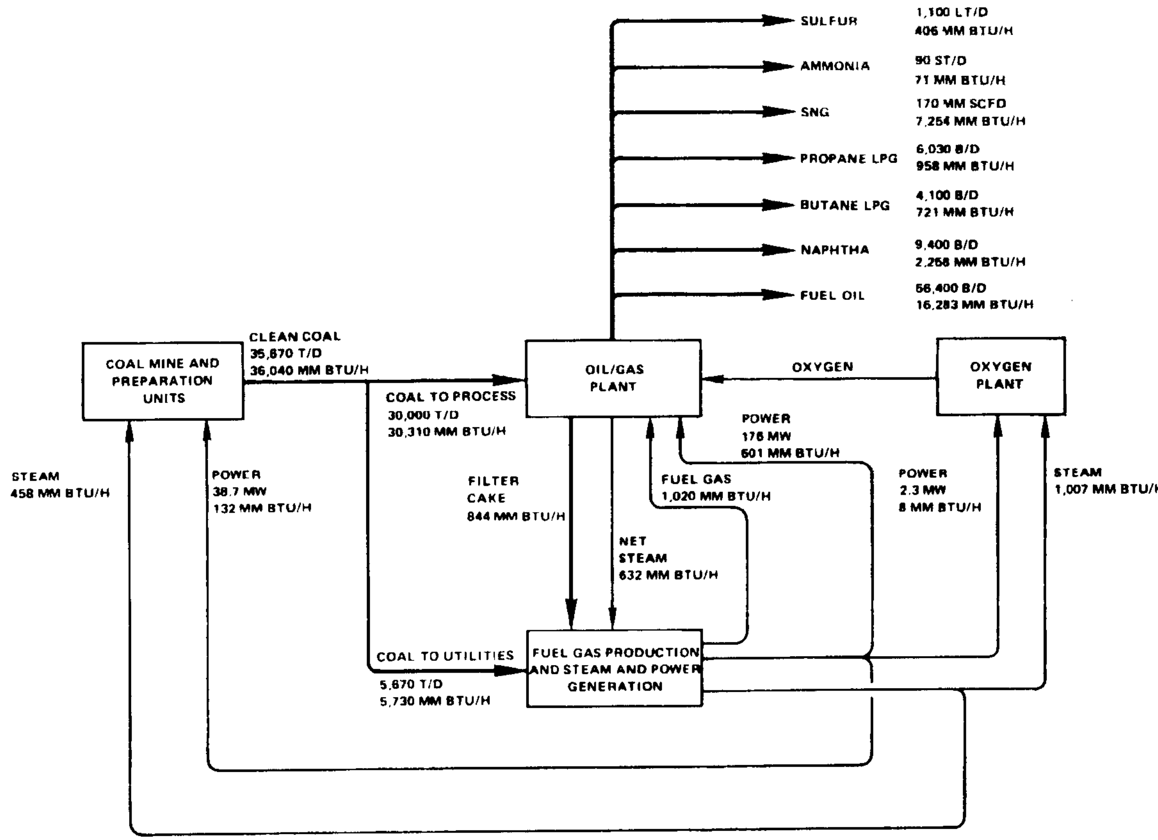
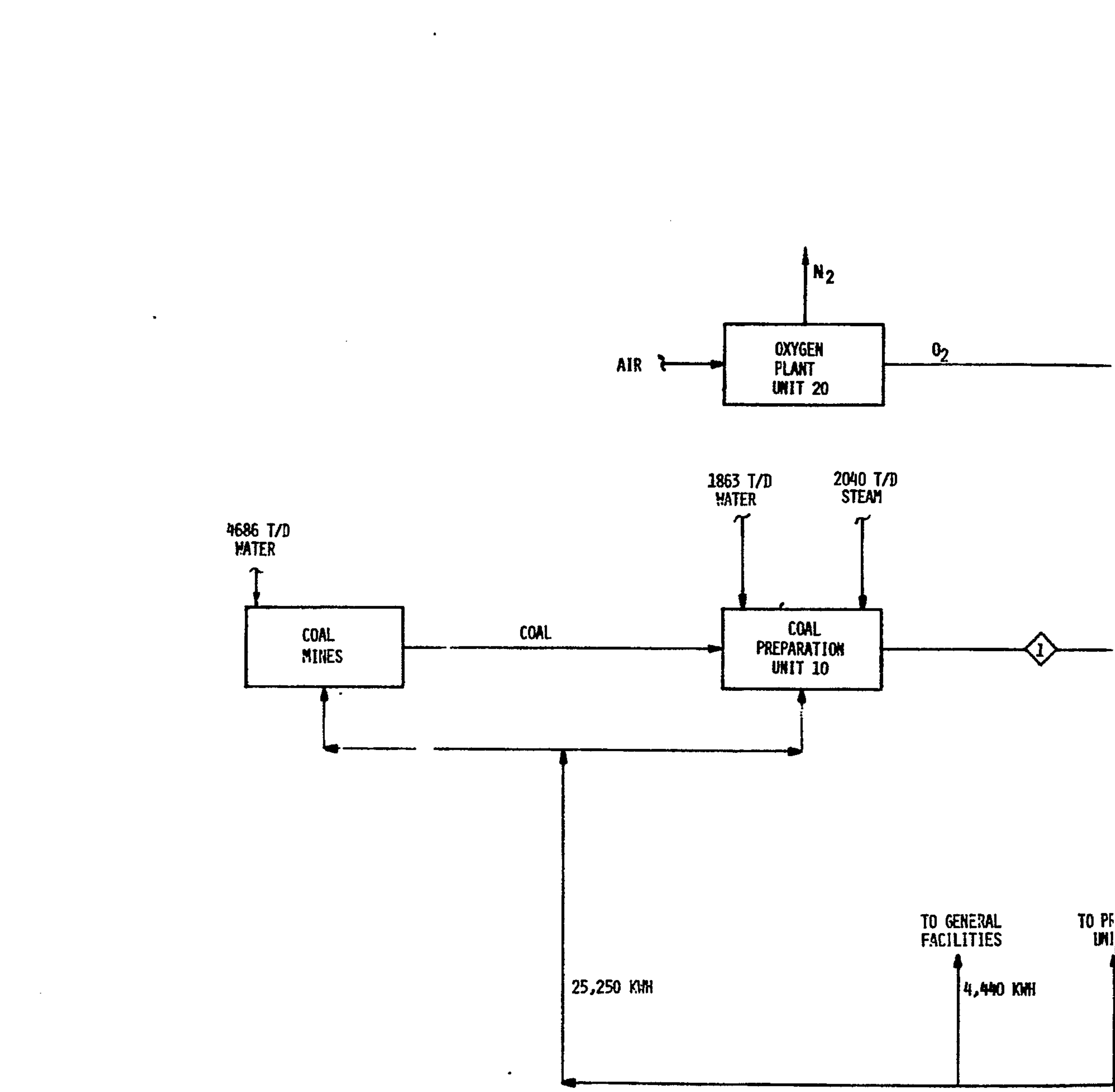
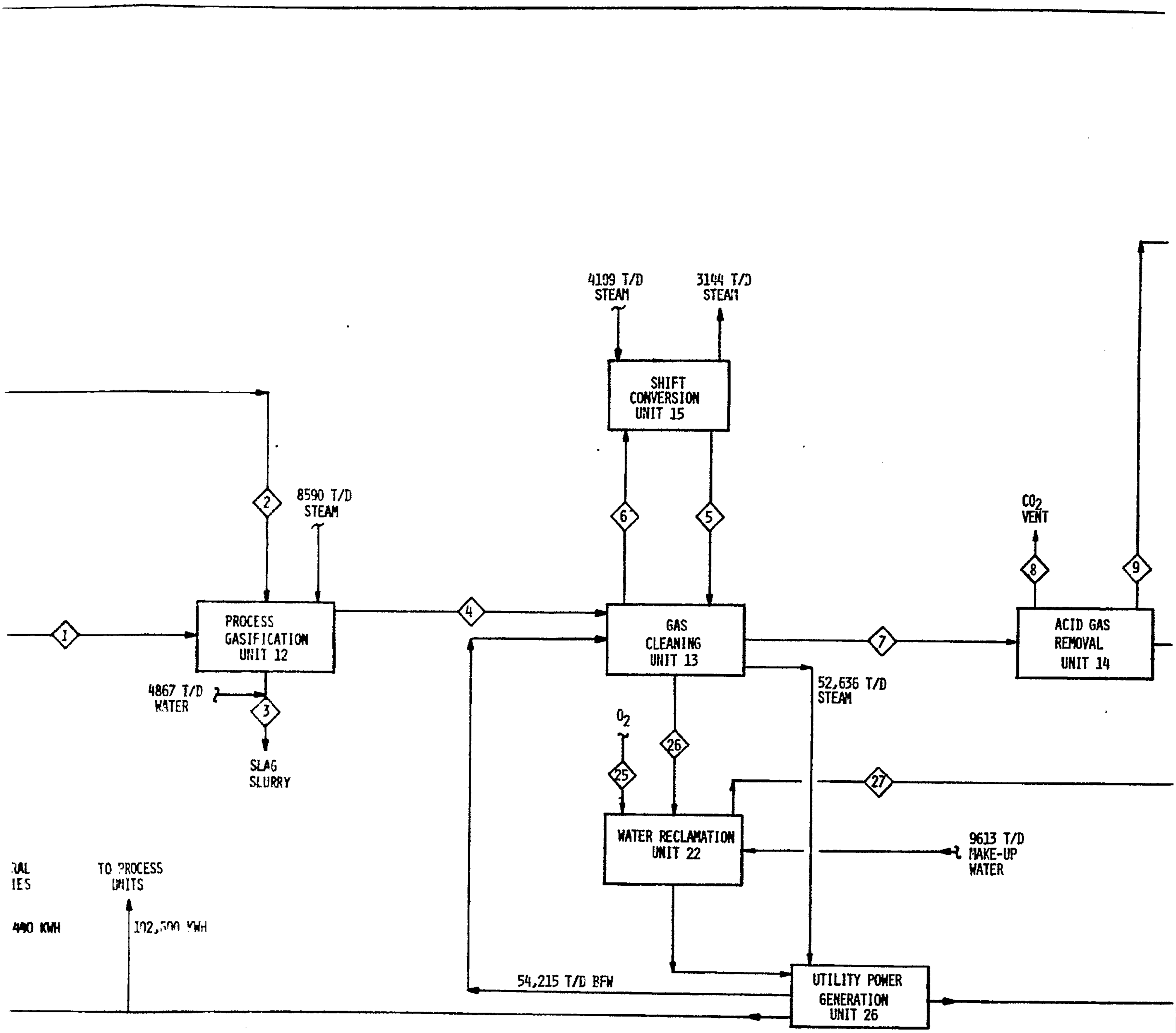


Figure 3 - Energy Balance Oil/Gas Plant

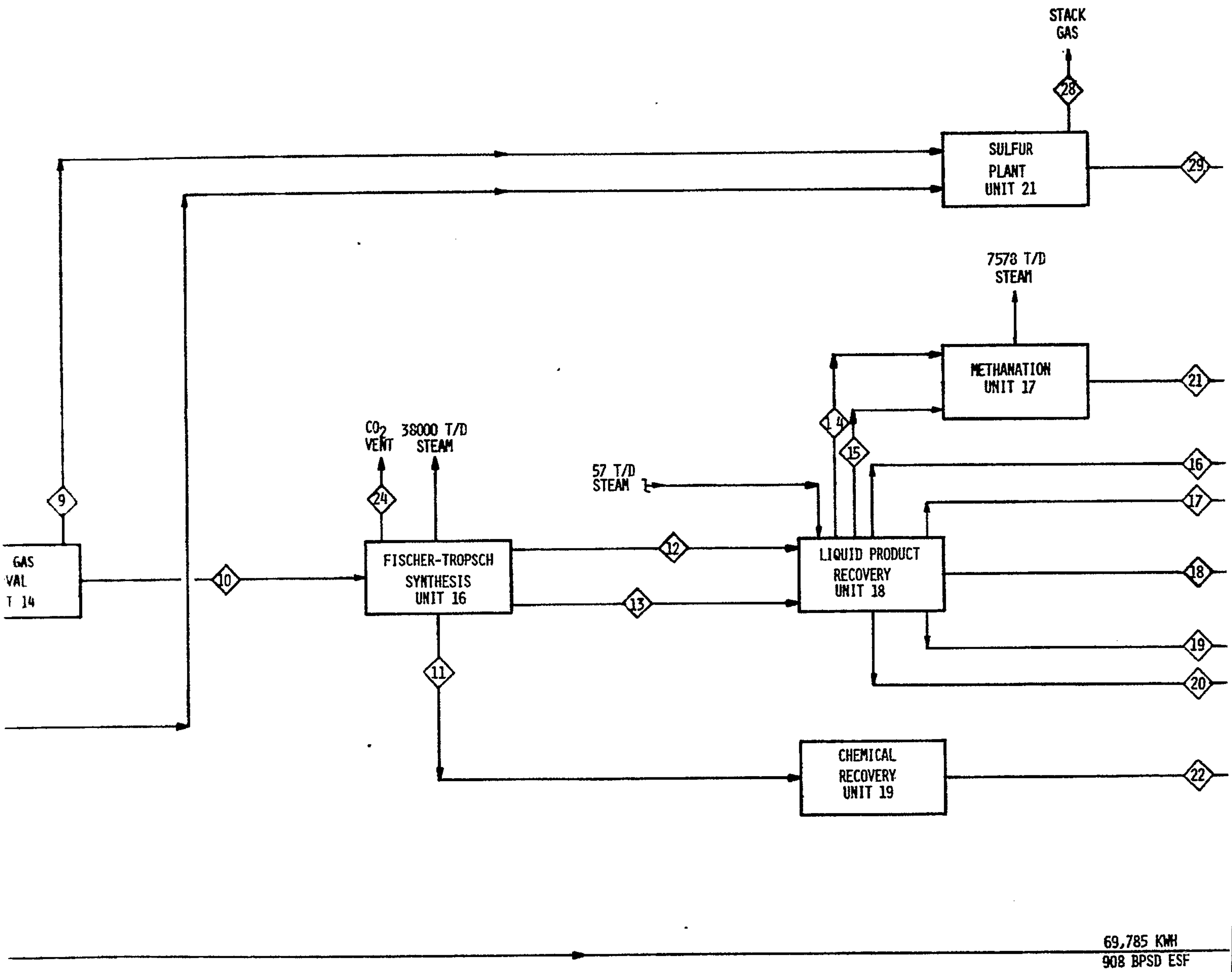


STREAM NO.	1	2	3	4	5	6	7	8
STREAM NAME	COAL FEED	OXYGEN	SLAG SLURRY	RAW SYN GAS	SHIFTED SYN GAS	SYN GAS TO SHIFT	DUST FREE SYN GAS	CO_2 VENT
Flow, T/D								
H_2	-	-	-	1177	697	361	1513	0.24
CO	-	-	-	19172	1213	5886	14499	200 PPMV
CO_2	-	-	-	7052	9506	2165	14393	11480
CH_4	-	-	-	477	146	146	477	7
H_2S	-	-	-	526	162	162	519	5 PPMV
N_2	-	171	-	329	101	101	329	-
O_2	-	9580	-	-	-	-	-	-
H_2O	404	-	4886	3409	2152	1047	108	40
NH_3	-	-	-	4	1.2	1.2	-	-
COS	-	-	-	19	6	6	19	-
SO_2	-	-	-	2	0.8	0.8	2	-
ASH	1070	-	2140	-	-	-	-	-
CHAR	-	-		351	0.6	0.6	-	-
COAL (MAF)	13526	-	-	-	-	-	-	-
TOTAL T/D	15000	9751	7026	32518	13986	9876	31860	11527



	8	9	10
E	CO_2 VENT	ACID GAS	SWEET SYN GAS
3	0.24	-	1512
9	200 PPMV	-	14376
3	11480	2342	570
7	7	-	445
9	5 PPMV	519	0.1 PPMV
9	-	8	321
	-	-	-
8	40	28	41
	-	-	-
9	-	19	-
2	-	2	-
	-	-	-
	-	-	-
	-	-	-
)	11527	2918	17265

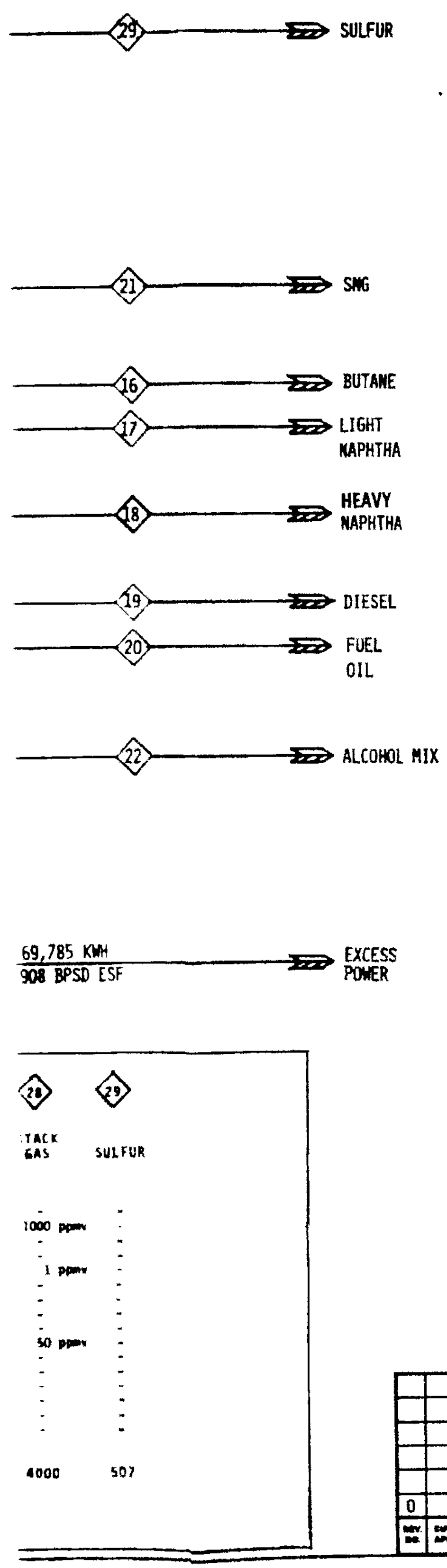
STREAM NO.	11	12	13	14	15	16	17	18
STREAM NAME	ALCOHOL SOLUTION	F-T GAS	F-T LIQUID	C_3/C_4'S	STRIPPED F-T GAS	BUTANE	LIGHT NAPHTHA	HEAVY NAPHTHA
Flow, T/D								
H_2	-	397	0.5	-	398	-	-	-
CO	-	1632	6	-	1638	-	-	-
CO_2	4	138	0.5	13	126	-	-	-
N_2	-	328	1	-	329	-	-	-
H_2O	2408	27	-	-	-	-	-	-
C_1	-	1001	8	4	1005	-	-	-
C_2-	-	65	2	6	60	-	-	-
C_2	-	258	9	42	226	-	-	-
C_3	-	41	4	26	19	-	-	-
C_3	-	141	15	102	53	-	-	-
C_4-	-	105	29	106	1	28	-	-
C_4	-	304	96	252	1	144	3	-
C_5-	-	24	20	1	-	1	43	-
C_5	-	103	97	-	2	2	196	-
LIGHT NAPHTHA	-	95	270	-	8	-	354	3
HEAVY NAPHTHA	-	47	551	-	2	-	17	549
DIESEL	-	7	1103	-	-	-	-	41
FUEL OIL	-	-	332	-	-	-	-	-
ALCOHOLS	271	-	-	-	-	-	-	-
ACID SALTS	41	-	-	-	-	-	-	-
TOTAL T/D	2724	4717	2543	552	3869	174	614	593



18	19	20	21	22
HEAVY NAPHTHA	DIESEL	FUEL OIL	SNG	ALCOHOL MIX
-	-	-	4	-
-	-	-	5	-
-	-	-	106	-
-	-	-	329	-
-	-	-	-	14
-	-	-	2318	-
-	-	-	-	-
-	-	-	77	-
-	-	-	-	-
-	-	-	137	-
-	-	-	-	-
-	-	-	362	-
-	-	-	-	-
-	-	-	1	-
1	-	-	-	-
549	30	-	-	-
41	1028	41	-	-
-	10	321	-	-
-	-	-	-	269
-	-	-	-	-
593	1068	362	3344	283

STREAM NO.	24	25	26	27	28	29
STREAM NAME	CO_2 VENT	OXYGEN	PROCESS WATER	SOUR GAS	STACK GAS	SULFUR
Flow, T/D						
H_2	-	-	-	-	-	-
CO	-	-	-	-	*1000 ppmv	-
CO_2	7282	-	-	-	-	-
CH_4	-	-	10 PPM	-	-	-
H_2S	-	-	4	3.5	1 ppmv	-
N_2	-	-	-	-	-	-
O_2	-	7	-	-	-	-
H_2O	192	-	6125	3	-	-
NH_3	-	-	2	1.5	-	-
COS	-	-	-	-	50 ppmv	-
SO_2	-	-	-	-	-	-
COD	-	-	4	-	-	-
ORGANICS	-	-	1	-	-	-
CHLORIDES	-	-	1	-	-	-
CARBONATES	-	-	5	-	-	-
SOLIDS	-	-	2	-	-	-
TOTAL T/D	7474	7	6144	8	4000	507

*MAXIMUM



NOTES:

1. SIZE AND QUANTITY SHOWN HERE FOR ONE TRAIN OF A TWO TRAIN PLANT, EACH TRAIN CHARGING 15,000 T/D COAL TO THE PROCESS PLANT TO MAKE 262 BILLION BTU/D THERMAL PRODUCT OUTPUT.

Figure 4

REV. NO.	CUST APPR	DATE	REVISION	BY	PROC. ENGR.	CHECK	CHIEF PROC. ENGR.	CHIEF OPER. ENGR.	PROC. DIR.
0			ISSUED FOR REPORT	SS	AMT	AMT			

ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION (ERDA-FE)
U.S.A. FISCHER-TROPSCH PLANT
BLOCK FLOW DIAGRAM

THE RALPH M. PARSONS COMPANY PASADENA, CALIFORNIA	JOB NO. 5435-3	DWG. NO. R-01-FS-1	REV. 0

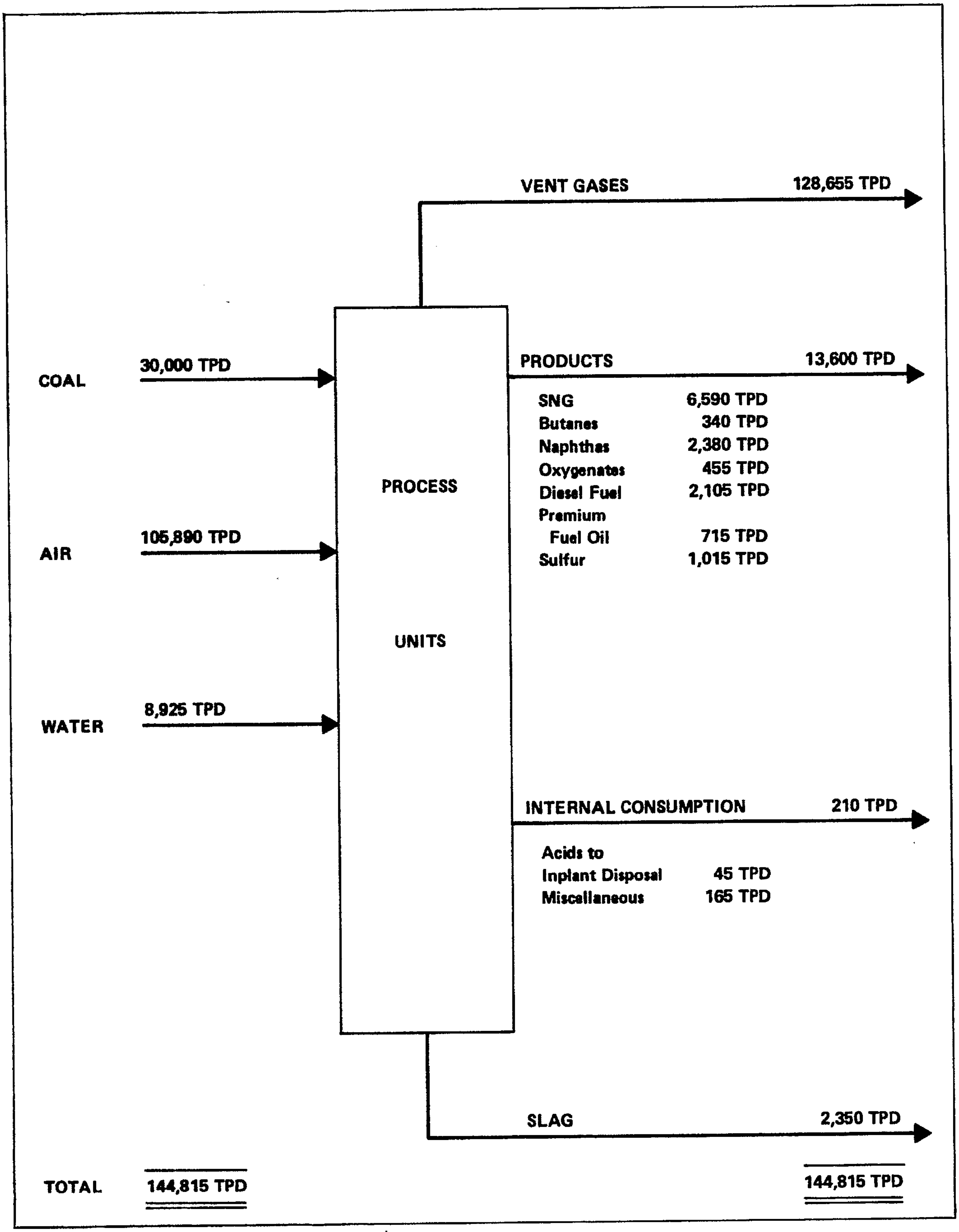
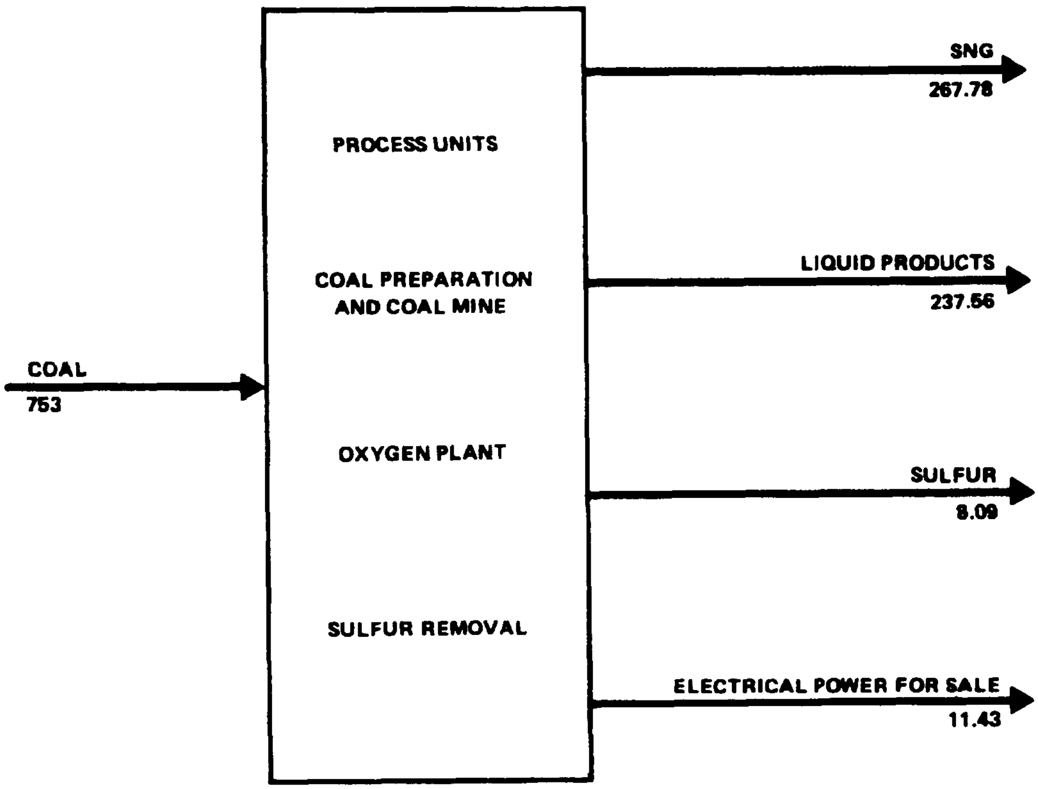


Figure 5 - Overall Material Balance Process Units
Fischer-Tropsch Plant



ALL FIGURES ARE MMM BTU/D, HHV

$$\text{THERMAL EFFICIENCY} = \frac{267.78 + 237.56 + 8.09 + 11.43}{753} = 69.7\%$$

Figure 6 - Thermal Efficiency
Fischer-Tropsch Plant

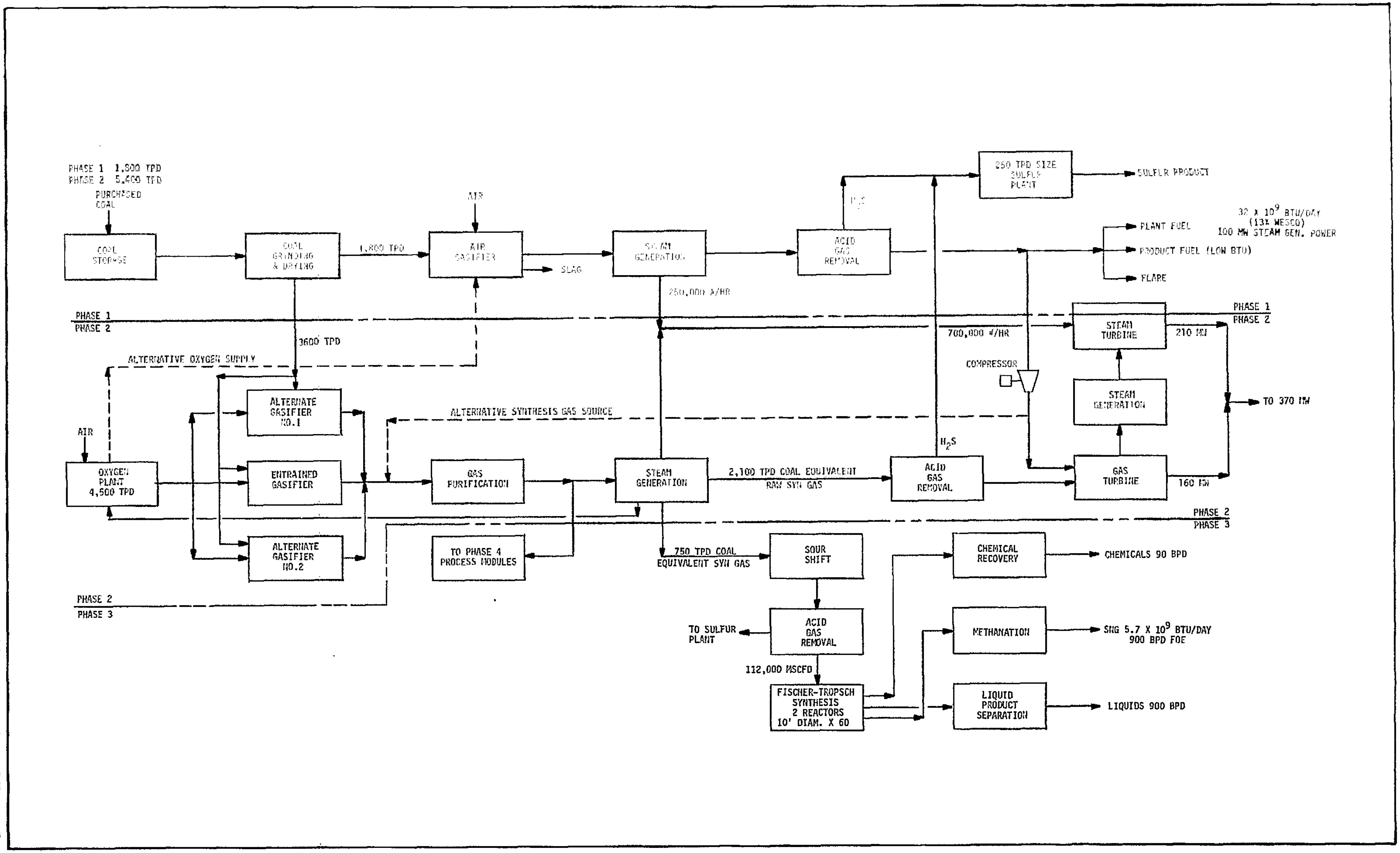


Figure 7 - Preliminary Block Flow Diagram Multi-Process Demonstration Plant

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