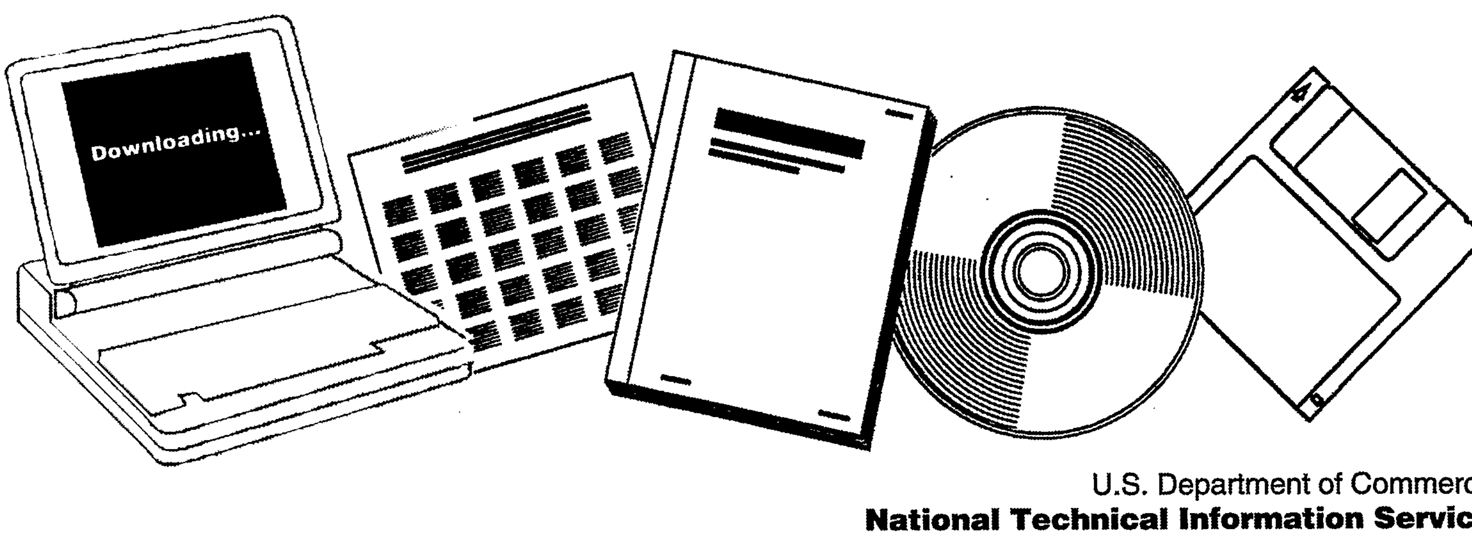
COAL DEMONSTRATION PLANTS. QUARTERLY REPORT, APRIL--JUNE 1976

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION, WASHINGTON, D.C. OFFICE OF FOSSIL ENERGY

1976



Assistant Administrator
for Fossil Energy

Energy Research and
Development Administration

QUARTERLY REPORT

April–June 1976
ERDA 76-95/2

COAL

COAL DEMONSTRATION PLANTS

QUARTERLY REPORT

APRIL - JUNE 1976

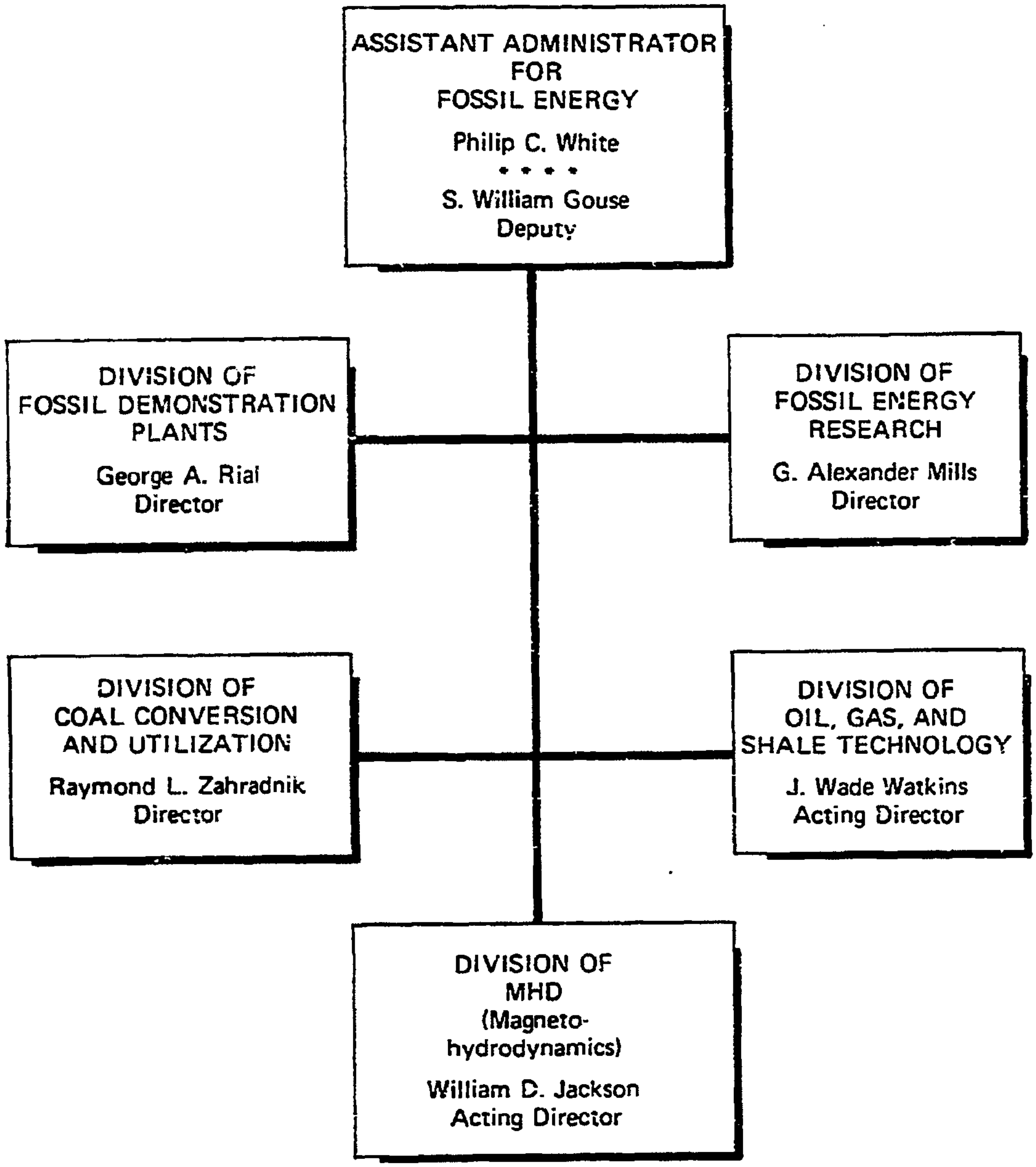
Philip C. White
Assistant Administrator
Office of Fossil Energy

George A. Rial
Director
Division of Fossil Demonstration Plants

Office of Fossil Energy
Energy Research and Development Administration
20 Massachusetts Avenue, N.W.
Washington, D.C. 20545

CONTENTS

BLANK PAGE


ASSISTANT ADMINISTRATOR FOR FOSSIL ENERGY
Philip C. White
S. William Gouse
Deputy
DIVISION OF FOSSIL DEMONSTRATION PLANTS
George A. Rial
Director
DIVISION OF FOSSIL ENERGY RESEARCH
G. Alexander Mills
Director
DIVISION OF COAL CONVERSION AND UTILIZATION
Raymond L. Zahradnik
Director
DIVISION OF OIL, GAS, AND SHALE TECHNOLOGY
J. Wade Watkins
Acting Director
DIVISION OF MHD (Magneto-hydrodynamics)
William D. Jackson
Acting Director

EXECUTIVE SUMMARY

The United States has more energy available in coal than in petroleum, natural gas, oil shale, and tar sands combined. Nationwide energy shortages, together with the availability of abundant coal reserves, make commercial production of synthetic fuels from coal vital to the nation's total supply of clean energy. In response to this need, the Office of Fossil Energy of the Energy Research and Development Administration (ERDA) is conducting a research and development program to provide technology that will permit rapid commercialization of processes for converting coal to gaseous and liquid fuels and for improved direct combustion of coal. These fuels must be suitable for power generation, transportation, storage, and residential and industrial uses.

The technologies selected for development—gasification, liquefaction, and direct combustion—satisfy an urgent need for a particular type of fuel, are potentially feasible both technically and economically (in terms of the costs of research and development and the final product), and will not exceed the air, water, and solid pollution standards established by the Environmental Protection Agency (EPA). The emphasis given each technology varies, depending on such things as technical complexity, development stage (laboratory research, including bench-schale tests and experiments with process development units, and pilot plant design, construction, and operation), variety of uses for the fuel produced, and urgency of the need that the technology is designed to satisfy.

ERDA's demonstration plant program was started in 1974 by one of ERDA's predecessor agencies: the Office of Coal Research, U.S. Department of the Interior. The objective of the program is to establish the technical and financial feasibility of coal conversion technologies proven during pilot plant testing. Demonstration plants will minimize the technical and economic risks of commercialization by providing a near commercial size plant for testing and production. Thus, ERDA is sponsoring the development of a series of demonstration plants, each of which will be a smaller version of commercial plants envisioned for the 1980's. These plants will be wholly integrated, self-sufficient in terms of heat generation, and dependent only on feedstock of coal, water, and air.

Under the ERDA program, contracts for designing, building, and operating the demonstration plants will be awarded through competitive procedures and will be jointly funded. The conceptual design phase will be funded by the government, with the detailed design, procurement, construction, and operation phases being cofunded, 50 percent from industry and 50 percent from the government. The cost involved in building and operating a demonstration plant will probably be between $200 million and $500 million, depending on the size of the plant.

The processes to be demonstrated include the conversion of coal to liquid fuels, high-Btu gaseous pipeline fuels, and low-Btu fuel gas. Other processes will be demonstrated as they become available. ERDA awarded the first contract under this program to Coalcon Company in January 1975. Coalcon is to design, build, and operate a demonstration plant for converting high-sulfur coal to clean boiler fuel. Contracts involving the development of coal feeders were awarded to Foster-Miller Associates, Inc.; Ingersoll-Rand Research, Inc.; and Lockheed Missiles and Space Company, Inc. Engineering and technical support for demonstration plant design and construction and the procurement of equipment with long lead times is being provided by the U.S. Army Corps of Engineers. The Ralph M. Parsons Company is furnishing ERDA such technical assistance services as the development of conceptual designs of commercial plants for producing liquid and solid fuels from coal, and evaluations of pilot plant performance and unit operations for processing coal.

Overall progress on the ***Clean Boiler Fuel Demonstration Plant*** was maintained on schedule. A major new development during the quarter involved the decision to change to the Texaco gasifier from Koppers-Totzek. This switch required a complete new engineering effort in many sections and a rework of the overall plant heat and mass balances. This effort is proceeding well and is not expected to delay the current project schedule. No major problems were encountered during engineering work in the 21 process sections of the plant.

Facility support progressed well during the quarter. Coalcon completed a total of nine calibration runs on the coal feed apparatus at the Tonawanda minitest facility. The de-agglomeration facility activities involved tests that were aimed at determining the best way to feed Illinois No. 6 coal to increase the production rate of char above the 4:1 char-to-coal feed ratio currently being projected. There were 21 runs made during the period with varying amounts of success for each run. Testing was inconclusive and further experiments were planned.

Technical support involved a successful coal grinding/drying test on Illinois No. 6 coal using a ring roll mill crusher. The test confirmed that the mill performance would meet the demonstration plant requirements. Other efforts in this area included successful runs for cyclone design on the Cyclone Development computer program and completion of the reactor heat balance program by the Institute of Gas Technology.

Program management involved completion of the draft environmental analysis report and receipt of the preliminary foundation and soil analysis draft report. The product assurance group continued monitoring all plant engineering items such as equipment data sheets, process flow diagrams and P&ID diagrams.

Development of Coal Feeders for Coal Gasification Operations continued with the successful testing of the zero pressure differential centrifugal feeder. The objectives of achieving particular flow rates for different machine configurations were accomplished during the quarter.

Positive displacement feeder model testing was initiated during the period. Several modifications were made to the device to improve overall performance and allow better operation for testing next quarter. Design work continued on the pressurized centrifugal feeder and on the design of a single cylinder for a multi-cylinder positive displacement feeder. Investigation into coal plug feeder technology available in the briquetting industry was suspended when it was learned that hardware suitable for pressurized coal feed was not available.

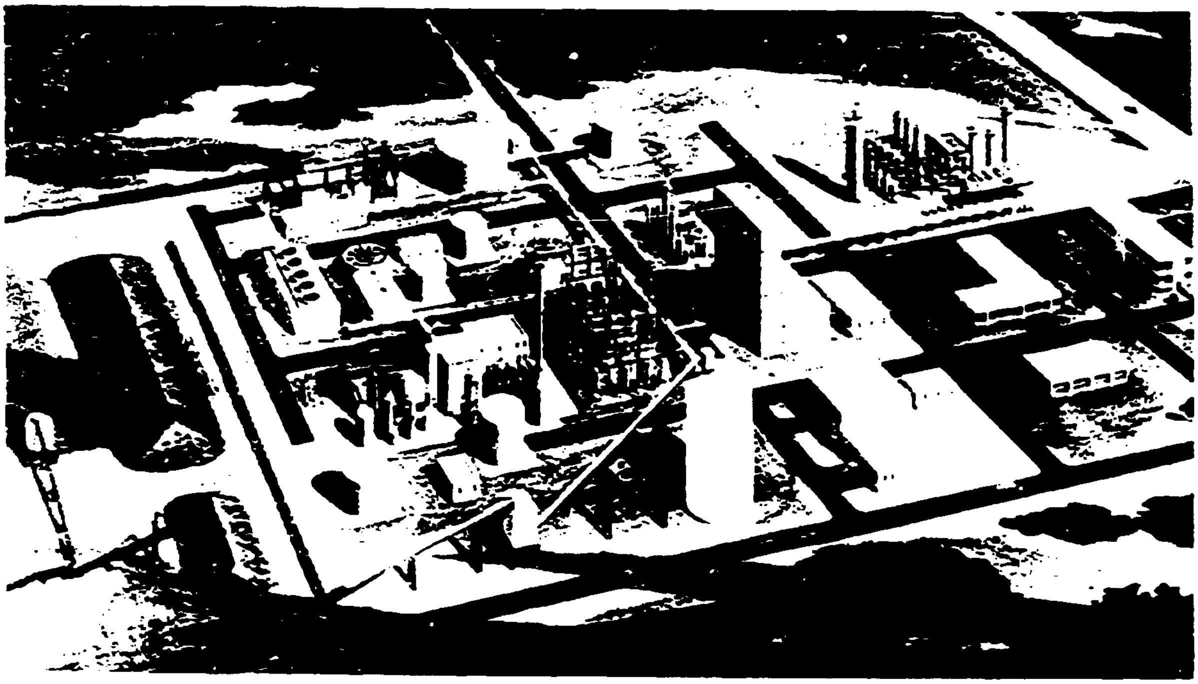
Ingersoll-Rand Research concluded the Phase I effort of the *Development of a Continuous Dry Coal Screw Feeder* program with the issuance of the Phase I report. ERDA reviewed and approved the release of the report. Construction work for the experimental facility continued throughout the quarter. Items completed include general construction and mechanical work. Electrical work was approximately 80% complete. Initial testing of the Negri-Bossi #V-12 machine was conducted during May using high volatile bituminous coal from West Virginia. The test revealed some difficulties and operating characteristics of the machine which will be used for improving results from future coal testing experiments. The development of the IMPCO #1500 feeder continued with the issuance of the modification drawings to the standard IMPCO model. Other development included finalizing the concept for the IMPCO #1500 coal receiver subsystem. The drawings for the subsystem were sent to twelve companies for their cost estimates and comments.

Laboratory testing for the *Coal Feeder Development Program* centered around ejector and ball conveyor operation. Ejector experiments involved dense phase transport of dry pulverized coal. Fifty transfer tests were made with two types of coal and nitrogen gas. Results revealed that transport could be initiated and maintained at relatively low pressures. Ball conveyor testing was to determine if a ball/coal column would still retain mobility when packed tightly enough to be impermeable to gas flow. Experiment results revealed that the column was still mobile when packed firmly enough to react as an effective gas seal. Support activities for the project included work on the theoretical models of the ejector, kinetic extruder, ball conveyor, and the fluid dynamic lock. Design of the rotor drive system and rotor head for the kinetic extruder and fluid dynamic lock comprised the design effort for the quarter. Facility support remained on schedule with orders being placed for pressure vessels, load cells, and valves.

Engineering and Technical Support to ERDA for the Clean Boiler Fuel Demonstration Plant centered on review of completed program work. These items included process flow sheets, product assurance plans, a configuration management plan, and integrated logistics support plan. Other Corps of Engineers activity focused on review and evaluation of technical proposals for the synthetic gas pipeline demonstration plant and preliminary evaluation of proposals for the Fuel Gas Demonstration Plant.

Technical Assistance Services by the Ralph M. Parsons Co. consisted of further effort on conceptual designs of commercial plants. Process design work was done on the oil/gas plant and the Fischer-Tropsch plant. This process work included utility balances, equipment specifications and process flow diagrams. COG plant activity centered on a literature search for pyrolysis data and a compilation of a bibliography of applicable references. Engineering effort in the plant included studies on the alternate uses of char, i.e., hydrogen production, SNG, Fischer-Tropsch, synthesis gas, and power generation. Three studies were initiated during the quarter. These include a look at conversion of coal derived liquids to consumer products, critical factors affecting the change rate of the facility, and characteristics of candidate processes for testing in the facility. Environmental aspects of the Fischer-Tropsch plant were studied and brought together in a report that was completed during the reporting period.

I. CLEAN BOILER FUEL DEMONSTRATION PLANT



COALCON COMPANY, INC.
NEW YORK, NEW YORK

Plant Site: New Athens, Illinois

Contract No.: E(49-18)-1736

Total Funding:	$237,222,300
Phase I:	$ 4,750,000
Phase II:	$ 17,700,000
Phase III:	$142,300,000
Phase IV:	$ 72,472,300

INTRODUCTION

Coalcon Company, Inc., an affiliate of Union Carbide and Chemical Construction Company, will design, construct and operate a demonstration plant for producing clean boiler fuels from high-sulfur coal. The plant will be fully integrated in all phases of processing, from receipt of coal to delivery of a finished product. The design will be geared to be environmentally acceptable by cleanup of all waste streams, and energy efficient by recovery of all by-products. Coalcon is organizing financial support for the program in the form of a consortium of energy and power companies and public agencies that will provide funds for the 50–50 government/industry cost sharing portion of the program. At present, participants involved in the project include:

Atlantic Richfield Company, Ashland Oil, Mobile Research and Development Corp., Dupont, Reynolds Metals, Consolidated Gas, State of Illinois, Northern Natural Gas, Ohio Power, Pacific Gas & Electric, Electric Power Research Institute, and Celanese Corporation.

The overall objective of the project is to verify, through a demonstration size plant, the commercial economics, technical scale-up potential, and the physical and chemical feasibility of a process for producing clean boiler fuel in a commercial-size plant. The plant will be designed to convert 2,600 tons per day of high-sulfur coal into 3,900 barrels per day (BPD) of clean liquid fuel and 22 million standard cubic feet per day (MMSCFD) of high-BTU pipeline-quality gas. These products will be evaluated for compatibility with current power plant and boiler designs.

The project is being conducted in four phases. Phases I and II are funded entirely by ERDA, while Phases III and IV are on a 50–50 cost sharing basis with ERDA and industry.

Phase I involves evaluation of various processes for commercial feasibility, process design of a commercial plant, preliminary plant design, and detailed process design for the demonstration plant. The preliminary process evaluation will be made in an effort to increase the potential for creating a clean boiler fuel industry. Variations to the basic concept will be evaluated to determine their impact for increasing production flexibility, improving cost effectiveness and reducing sulfur content in the primary products. Some of the variables that will be evaluated include:

- Size of plant, degree of modularization
- Coal type, size, mixture, composition, and cost
- Alternative process trains and steps
- Process operating conditions (e.g., temperature, pressure, residence time, thermal efficiency, etc.)
- Product quality and yield.

The purpose of the preliminary commercial plant design is to obtain a detailed process design based on maximum use of proved, commercially available components and equipment on which to base detailed cost estimates. The end use of this design will be to evaluate the economic and technical feasibility for commercial plants and to recommend changes to the overall commercial plant concept. The demonstration plant design will also be based on a system that will integrate commercially available components and equipment. This effort will include process flow charts and schematics for the plant, and for each major process train and subsystem. Major process and utility piping, electrical networks, process operating conditions, and mass and heat balances, will be a part of the effort.

Phase II work will involve the preparation of the complete plant design, including drawings, specifications, and definitive cost estimates. A bid package for the construction of the plant will be prepared from these data. Phase III, demonstration plant construction, will

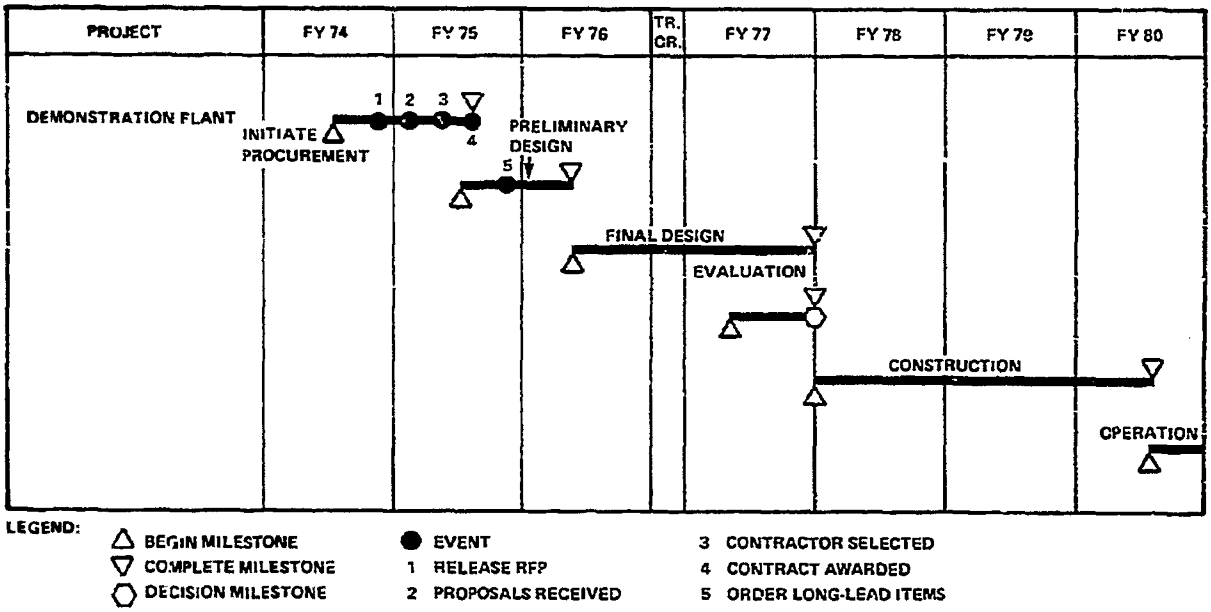


Figure I–1. CLEAN BOILER FUEL PROGRAM SCHEDULE

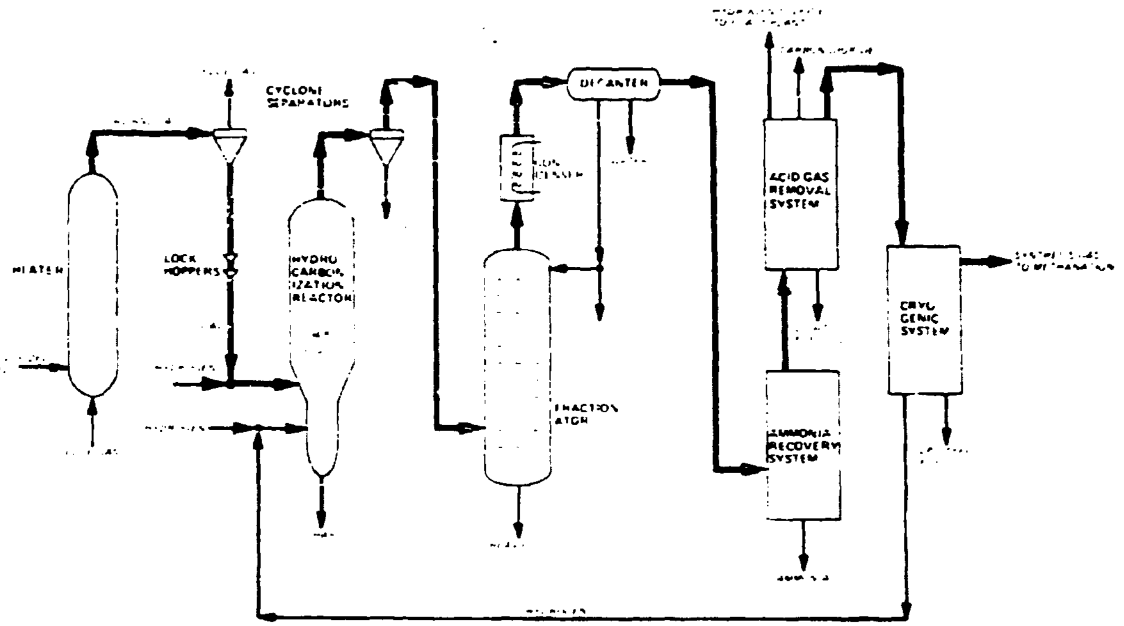


Figure I–2. HYDROCARBONIZATION PROCESS SCHEMATIC

include site preparation, equipment purchases, construction and field erection of process equipment, and plant acceptance and checkout. Phase IV, the ultimate objective of the project, will be the operation of the plant. Experience gained during this period will be used to determine the technical and economic performance and assess the project with regard to the scale-up of the operation to a full scale commercial plant. The clean boiler fuel program schedule is illustrated in Figure I–1.

PROCESS DESCRIPTION

The method selected by Coalcon for producing clean boiler fuel in the demonstration plant is Union Carbide's hydrocarbonization process. The conceptual design of the plant using this process is divided into five main areas: (1) coal preparation, (2) hydrocarbonization reactor, (3) reactor product cooling and liquids separated, (4) gas processing, and (5) hydrogen generation. The process flow diagram is shown in Figure I–2.

Initially, the coal is crushed, milled, and classified, then fed to the coal preheater. The heating scheme involves entraining the coal in a hot, oxygen-free flue gas and separating the solids from the gas in a cyclone. This heating process helps maintain the reactor heat balance and also drives off some volatiles and moisture. After heating to about 617 F, the coal is held in the coal feed hopper before it is pressurized to the operating pressure of the system, approximately 37 atm. The coal is dropped from the lock hoppers into another coal holding vessel. From there, it is gravity fed into an injection vessel where it is fluidized with hydrogen at 1040 F and 51 atm. This mixture enters the hydrocarbonization reactor which operates at 37 atm and 1040 F. The solid residence time in the reactor is approximately 25 minutes. The solids not gasified are removed from the reactor through an agglomerate removal system at the bottom of the reactor. This char is used to manufacture hydrogen and also may be burned to generate steam.

The gas residence time in the bed is approximately 25 seconds. These gases are heavily laden with solids which subsequently are removed by two cyclones. The cleaned gas vapor from the cyclones is sent downstream to the fractionator for cooling and separation. The basic purpose of the fractionator is to split the reactor product into four basic streams:

- Overhead gas (H_2, CO, CO_2, CH_4)
- Light liquid (#2 fuel oil)
- Heavy liquid (#5 or #6 fuel oil)
- Waste water

The heavy oil from the bottom of the fractionator is partially cooled and recycled to a venturi where it mixes with the hot reactor product gas. This mixture is fed to the fractionator and split into a hot heavy fuel oil and a moderately hot (350° F) fractionator overhead stream. The heavy oil product is cooled to about 104° F and pumped to storage. The fractionator overhead is condensed and the liquid/vapor mixture is fed to a decanter where the light fuel oil, overhead gas, and waste water are separated. Some of the light oil is sent to the fractionator as reflux and the remainder is sent to storage as product. The remaining gas is sent through a series of separation and purification systems which include ammonia removal and recovery, acid gas (H_2S, CO_2) removal, and a cryogenic gas processing system. The cryogenic system manufactures LP fuel gas, synthesis gas, and hydrogen-rich stream. The hydrogen stream is recycled back to the hydrocarbonization reactor while the synthesis gas is sent to a methanation reactor for upgrading to high-Btu pipeline gas. The LP fuel gas may be either burned on site or sold.

HISTORY OF THE PROJECT

Work under this contract was initiated in January 1975. Union Carbide's hydrocarbonization process was selected as the process to be demonstrated. Current emphasis is on the demonstration plant design.

Tests in support of this program are being conducted at Coalcon facilities in Tonawanda, New York; South Charleston, West Virginia; Buffalo Testing Laboratories in Buffalo, New York; and in-house laboratories. The Tonawanda minitest facility is directing its work toward confirming kinetics and yield data for agglomerating high-sulfur bituminous coals: Pittsburgh Seam No. 8, Illinois No. 6, and Kentucky No. 11. The South Charleston facility is being used to evaluate alternative methods for deagglomerating high-sulfur bituminous coals in the hydrocarbonization process. At the Buffalo Testing Laboratories, the physical properties, viscosity, density, pour point, heat capacity, etc. of the liquid product, are being analyzed; ultimate analysis is being performed on coal, char, and liquid products, and the major groups in the liquid product (phenols, bases, acids, etc.) are being determined. The in-house laboratories are performing several tasks. These include:

- Performing proximate analyses of coal.
- Determining bulk and particle densities and size distribution of coal.

- Calculating simulated boiling point distribution of products using gas chromatography data.
- Determining heating values of coal, char, and liquid products.
- Analyzing gas products for major and minor components.

Union Carbide's computer process simulation system, PROBE, is also being used to support this project.

During 1975, work on the Clean Boiler Fuel Demonstration Plant involved preliminary process design and engineering of a commercial plant. This effort included a review and evaluation of all hydrocarbonization subsystems to minimize capital investment and maximize subsystem operability and reliability. By the end of 1975, design and engineering for the commercial plant were near completion. A process evaluation report was prepared and submitted to ERDA. This report includes preliminary data on plant design and provides a basis for starting the design of the demonstration plant.

Work toward establishing the definition and design basis for the demonstration plant began late in 1975. The plant will be one-fifth the size of a commercial-scale plant and will be capable of utlizing three different types of coal. Preliminary performance specifications were issued, and work on the overall process design of the demonstration plant, analysis of the three coal types to be tested, and development of process designs of plant subsystems were started. New Athens, Illinois, was selected as the site for the plant. The selection was based on economic, technical and environmental studies.

Emphasis at the test facilities was on designing, fabricating, and installing necessary equipment. By year end, the minitest facility was nearly completed. The deagglomeration facility was finished, and a series of tests was started to determine the minimum amount of noncaking material that must be premixed with the feed coal to prevent agglomeration in the reactor. Other activities involved:

- Computer processing—for example, updating the process simulation system and writing new programs to ease detailed process design, preparing functional specifications, and evaluating subsystem alternatives.
- Procurement.
- Reliability and quality assurance, such as the analysis of the process and equipment risks associated with the demonstration plant and studies of criteria for selecting materials.

PROGRESS DURING APRIL–JUNE 1976

Summary

Overall progress on the demonstration plant design remains on schedule. A major new development during the quarter was a decision to change to the Texaco gasifier from the Koppers-Totzek. This switch required a complete new engineering effort in many sections and a rework of the overall plant heat and mass balances. This effort is proceeding well but is expected to delay the current project schedule. Many minor problems were encountered during engineering work in the 21 sections of the plant.

Facility support fell behind during the quarter. Nine calibration runs were made on the coal feed apparatus at the mini test facility and 21 experimental runs were conducted with respect to char production at the de-agglomeration test facility.

Technical support effort involved a successful coal grinding/drying test on Illinois #6 coal and completion of the reactor heat balance program by IGT. Successful design runs were made with the cyclone development computer program.

Program management involved completion of the draft environmental analysis report and receipt of the preliminary foundation and soil analysis draft report. Unexpected problems were encountered in both areas and solutions are being investigated. The product assurance group continued monitoring all plant engineering items such as equipment data sheets, process flow diagrams and P&ID diagrams.

Demonstration Plant Design and Engineering

Section 1—COAL HANDLING (I)

The basic engineering package for this section was completed and presented to ERDA. A request for quotations for the detailed engineering was initiated and is now 90 percent complete. There were no major problems to report during the quarter.

Section 2—COAL PREPARATION (I)

Studies done during the period on the coal heating loop indicated that coal moisture content must be reduced to 0.3 percent in the coal preparation section. This created a problem in acquiring equipment since coal grinding/flash drying equipment suppliers are reluctant to guarantee performance for less than one percent moisture. Coalcon engineering spent some time investigating ways of providing coal to this section with the 0.3 percent moisture requirement. The new temperature (250° F) and moisture requirements were incorporated in the demonstration plant design.

Evaluations were conducted in May and June with respect to the need for changes in the feed coal particle size distribution to the reactor. Various de-agglomeration tests indicated that micro-agglomeration in the hydrocarbonization reactor causes particle growth to approximately double that of the feed coal. These evaluations should reveal what problems this will create and possible solutions.

Section 3—COAL PRESSURIZATION (I)

The lock-hopper coal pressurization system process design and functional specifications were revised to reflect the quantities of nitrogen expected to be absorbed by the powdered coal at various points in the system. The P&ID diagrams for Section 3 were reviewed by the instrumentation group and subsequently sent to the piping group for a further review.

Section 4—COAL HEATING

A rigorous computer model of an entrained-bed coal heater/preoxidizer/gas quencher was documented during April. The program will be used in the design of this section of the plant. A detailed process specification was issued for the heater preoxidizer/quencher for heating the coal from the grinder/dryer before it enters the reactor. Equipment sizing and selection work, as well as cost estimating were performed for this Section during the Quarter. Work on data sheets, electrical diagrams, and plot plans have been placed on hold pending the outcome of studies for a more optimal process scheme for Sections 3 and 4.

Effort in June centered on conceptual designs of low pressure, high pressure, and dense-phase methods of heating coal. Results from the work led to the selection of the dense-phase system as the most suitable method for coal heating. This system would feed pressurized coal into four lines with the H_2 in dense phase of about 20 pounds per cubic foot. The coal would be heated by Dowtherm condensing on the outside of the lines at 700° F. Process design for this system was initiated.

Section 5—COAL HYDROCARBONIZATION

Results from a conceptual evaluation led to a recommendation that the reactor design resemble a "fluid coker" configuration. Detailed designs were prepared for two variations of the basic reactor configuration. These included high speed injection of coal into low velocity beds and coal injection into recycled hot char. In June, design details for the reactor with four external circulation loops were analyzed. A draft of the performance specifications was prepared and work on a process flow diagram was initiated.

Section 6—GAS COOLING/HEAVY HYDROCARBON SEPARATION

The main activity during the second quarter involved an optimization design of the section to produce the following:

- Heavy oil that is free of light ends, has a flash point greater than 100° F. and has a sulfur content less than 0.5 lb sulfur per million Btu.
- Light oil with lower than atmospheric vapor pressure, low sulfur content, and completely free of four-ring aromatic material.
- Wastewater containing minimum dissolved hydrocarbonaceous material and no four-ring aromatic material.
- Gas that is substantially free of C_5 and heavier material.

The design concepts were simulated on the computer. Coalcon is experiencing difficulty in the design of this section difficult since the concept of removing heavy hydrocarbons is much different from that established in the petroleum industry. Preliminary results indicate that a three-stage pump-around with two theoretical plates above each pump-around section is the most effective in rejecting heavy hydrocarbons. Preliminary process flow diagrams for all three systems were completed.

Sections 7–13

Work involved in Sections 7 through 13 continued at a satisfactory pace. The only major development in these areas was the elimination of Section 7, the gas process/ammonia recovery system. No major problems have occurred. The percentage completion for these various support facilities is as follows:

- *Gas processing-ammonia recovery*—this section was eliminated after Texaco advised that the hydrogen plant was capable of accepting waste water from the fractionation section.
- *Gas processing-acid gas removal*—a cost proposal for basic and detailed engineering was requested from Barnard & Burke.
- *Cryogenic hydrogen purification*—preliminary efforts up to detail design have been completed. Coalcon is awaiting information from Texaco on various items before proceeding with the design.
- *Gas processing-methanation*—the basic engineering package (BEP) for a 24.76 million standard cubic foot per day methanation plant was completed in June and subsequently issued to Barnard & Burke for cost estimates on detailed design.
- *Char burning and steam generation*—a major effort centered on reworking process balances which were changed by a switch in gasifiers from Koppers-Totzek to Texaco. These changes were completed in June. Specifications for two 300,000 pounds per hour, 900 psig steam boilers and the steam plant were 50 percent complete.
- *Sulfur recovery*—requisitions to subcontractors for additional basic and detail engineering design proposals for the Claus plant were reissued. Performance specifications for the Aqua Claus system were 60 percent complete.
- *Char cooling and grinding*—performance specifications are 75 percent complete. Plot plan workup is 60 percent complete and the effort on the P&ID's at the end of the quarter was 75 percent complete.

Section 14—GASIFIER

The decision was made during the quarter to use the Texaco gasifier in place of a Koppers-Totzek. This change required a completely new engineering effort, including new char slurry tests by Texaco to determine slurry composition for normal gasifier operation. Other items included revising the overall energy and material balances, and generating schedules for Texaco support work. The initial issue of performance specifications was completed and a conceptual process flow sheet for the gasifier was prepared.

Sections 15–21

Effort on these support systems continued on schedule with no problems. Status for the end of the period was as follows:

- *Oxygen production*—process specifications for the air separation plant were prepared and issued. The design effort, with changes compensating for the use of the Texaco gasifier have been initiated.
- *Water treatment*—requisition for water treatment consulting services was issued. No further work was performed during the quarter.

- *Cooling water system*—the cooling water balance was revised to cover the Texaco gasifier. The performance specifications were revised and completed and the preliminary layout based on the new water balance was finished.
- *Process, service, and power distribution*—utility data were collected from the various process sections. Four cooling water balances were made to reflect the four possible processing alternatives. An equipment list was prepared. Steam and condensate balances were 40 percent complete.
- *Waste water treatment*—a preliminary design of an integrated waste water treatment plant was completed and cost data for the facility were being assembled as input to the overall demonstration plant cost estimate.
- *Product storage*—the basic engineering package for the system was completed and issued.
- *General facilities*—progress in this area involved preliminary site studies for design of roads and railroads and a preliminary study of the economics of alternate ash disposal methods (truck versus ash pond). Dames & Moore submitted their interim report on soil investigations at the New Athens, Illinois site in early May. General data collection continued.

Facility Support

Mini Test Facility

By the end of April, the facility had been assembled in the configuration required for conducting coal feed experiments. Various auxiliary installations were finished and the total system construction was completed. After minor repairs and problems were resolved, nine calibration runs were made on Illinois #6 coal. The runs were conducted with hydrogen at 250° F and 450° F and no problems were encountered.

De-Agglomeration Facility

Activity centered on experimental runs aimed at determining the best method of feeding Illinois No. 6 coal to produce char. This effort is designed to increase the production rate of char above the 4:1 char-to-coal feed ratio currently being projected. A total of 21 runs were made, but results were inconclusive and further testing was expected to continue.

Other work completed included a draft of the final de-agglomerating report and the cold fluidization studies in the four-inch diameter vessel.

Technical Support

Coal Grinding

Grinding tests were made with Illinois #6 coal at Williams Patented Crusher Co. in St. Louis. It was found that a ring roll mill system will produce the required coal size and also dry the product to less than 1 percent moisture. A report on these findings was issued and reviewed during April and May. The review indicated the need for additional grinding runs. Three additional runs conducted during June at the St. Louis facility confirmed that the mill performance could meet the demonstration plant requirements.

Cyclone Development

Preliminary design runs were made on the Ducon computer program to study the effect of the number of cyclones on overall system performance. The resulting data indicate that one cyclone first stage and one cyclone second stage would meet performance requirements. Entrainment calculations were made using the Union Carbide Entrain program and various entrainment correlations were fitted to the program to enhance computer results.

Reactor Heat Balance

The Institute of Gas Technology (IGT), subcontractor for this program, completed the test runs and analytical data for six runs and three calibration runs. Preliminary results confirm that the heat of hydrocarbonization can be calculated from the solids heat of combustion and the related product slate. IGT is completing a final report for the program.

Lock Hopper Valve Development

Lock hopper valve specifications were sent to 21 valve suppliers. Sixteen responded favorably and meetings with these will be scheduled to discuss valve supply and testing. Work started on the valve test facility design. This design package will accommodate long duration testing (30,000 cycles) of lock hopper valve systems at demonstration plant conditions. At the end of June, the completion status was as follows:

- Mechanical components and piping 42%
- Structural steel, footings and plot plant .. 21%
- Electrical services and lighting 0
- Instrumentation and controls 12%

Waste Water Treatment

Characterization of waste water samples from the de-agglomeration facility was completed. The oxygen activated sludge treatability study on waste water simulating hydrocarbonization waste from the Coalcon plant was also completed. Other activity included work on an activated sludge nitrification system.

Program Management

Work of an environmental nature progressed with completion of a draft environmental analysis report for the Coalcon site. The draft is being reviewed for corrections and changes. Coalcon also received for review a draft from ERDA of a Request For Proposal for a socio-economic assessment of the demonstration plant.

The suitcase model of the Coalcon plant was finished in May and was presented to ERDA for acceptance.

An addendum to the real estate report reflected a new property description that had been developed. Railway and plant access roads were rerouted to reflect provisional understanding with the Peabody Coal Company. The site master plan is expected to be completed soon.

The preliminary foundation and soil analysis draft report was received in May. The draft established the nature of the soil based on borehole logs. These revealed a heterogeneous structure of clay and sandy soils over 25 percent of the site and predominantly sandy soil over the remainder. Laboratory evaluations of the soil will follow and will be included in the final report.

Product Assurance

Activities by the product assurance group included review of equipment data sheets and materials selection, and review of process flow sheets and P&ID drawings. Reviews were also made of procurement documentation and general Coalcon procedures. A product assurance provision for all procurement packages was initiated. Various meetings were held with support groups and visits to support facilities were made to keep abreast of new developments and problems that would affect the product assurance schedule.

II. DEVELOPMENT OF COAL FEEDERS FOR COAL GASIFICATION OPERATIONS

FOSTER-MILLER ASSOCIATES, INC.
WALTHAM, MASSACHUSETTS

Contract No.: E(49-18)-1793
Total Funding: $799,545
(100% ERDA)

INTRODUCTION

Under the sponsorship of ERDA, coal feeders for use in all coal gasification plants are to be developed through the pilot plant stage by Foster-Miller Associates, Inc. The project recognizes the coal feeder as one element common to all gasification processes. However, no currently available system can handle the quantities of coal, about 1,000 tons per hour, that will be used in commercial processes. These processes require the injection of coal, crushed to ⅛-inch and below, from an atmospheric-pressure hopper into a gasifier whose pressure may be as high as 100 atm.

Feed methods currently being used in pilot and demonstration plants depend on the coal size and gasified pressure. Low-pressure units use lock hoppers, which must be operated at low temperature, with batch feeding of the coal. Slurry-feed techniques used in high-pressure gasifiers require energy to vaporize the liquid used to transport the coal. Both of these techniques are inefficient but can be tolerated in small-scale gasifiers. It will, however, be necessary to develop a technique to provide a continuous, high-pressure flow of coal to commercial-scale units at reasonable efficiencies and capital costs.

PROGRAM DESCRIPTION

The project to develop coal feeders was initiated in May 1975. It consists of three phases, all of which are to be completed by May 1977. In Phase I, Foster-Miller will visit and study gasification plants and will consult with ERDA personnel and consultants to prepare a list of coal feeder requirements for ERDA approval. Foster-Miller will then prepare a report based on information concerning existing equipment and new conceptual designs. This report will include a list of candidate equipment and an evaluation of that equipment.

In Phase II, critical components of the equipment selected in Phase I will be tested in the laboratory. Equipment of four different designs will be constructed, and each laboratory-scale feeder will be tested for approximately two months. These tests will be conducted to determine the ability of the equipment to control the flow of coal with accuracy, maintain stability, seal effectively against the gasifier pressure, provide economic operation in terms of equipment life and power requirements, and deliver to the gasifier coal having the desired characteristics. Data from laboratory research will be used to design feeders compatible with existing and projected pilot plant operations.

During Phase III, feeder concepts that have demonstrated a strong possibility of commercial-scale usage will be integrated into current and projected pilot plants as directed by ERDA. Feed rates will be in the range of three to five tons per hour. The final report of this phase will contain design specifications, assembly drawings and procedures, installation and functional test procedures, and operation and maintenance manuals.

A fourth phase, not part of this contract, will use the results of pilot plant testing. It is projected to include the development, design, fabrication, and delivery to ERDA of coal feeders compatible with demonstration plant requirements. Feed rates in this phase are anticipated to be 50 tons per hour and greater.

PROJECT ACCOMPLISHMENTS

Foster-Miller Associates completed the Phase I program effort in March 1976, with the release of the Phase I report. The results from the evaluation of coal feeder requirements and existing feeders revealed that no suitable dry coal feeders were available that could operate at gasifier pressures above 20 atmospheres. As part of this initial effort, literature searches, patent reviews, and consultation with manufacturers were made to determine what particular concepts should be studied in Phase II. Results from these activities led to the selection of four methods:

- Coal plug feeders
- Centrifugal feeders
- Positive displacement feeders
- Conveyor feeder.

Evaluation of these concepts will be carried out during Phase II.

PROGRESS DURING APRIL–JUNE 1976

Laboratory-Scale Coal Feeder Development

Critical Component Testing

Zero pressure differential (ZPD) centrifugal feeder model testing continued in April and May. The required "choked" flow condition in the feeder sprue was achieved by modifying the sprue geometry to restrict the sprue outlet. Flow rates of 300 pounds per hour were achieved with one sprue operating. The flow rate of the model was found to be limited by the transition flow between the feeder standpipe and the feeder sprue, but modifications alleviated this choking of the transition area. Flow rates of 950 pounds per hour were achieved with a single sprue configuration and 1800 pounds per hour with a dual sprue configuration at 600 rpm. At this point, essentially all the objectives of the ZPD feeder testing have been achieved.

The positive displacement feeder model was assembled and debugged in April. Initial testing of the device began in May and continued through June. Testing of the feeder led to a number of modifications which have improved overall performance. These changes included modifying all valves to achieve line contact seating, and modifying porting to improve coal flushing from the cylinder. Further testing of the feeder will continue during the next quarter.

Test Loop Design and Fabrication

Design of the basic cold flow feeder test loop was completed in April, and loop assembly continued throughout the quarter. No significant problems have been encountered and this effort is expected to remain on schedule.

Laboratory Scale Feeder Design and Fabrication

Design of the pressurized centrifugal feeder model continued in May. A layout of the system was completed but various shaft sealing techniques were still being investigated. By the end of June, parts procurement for the feeder had been initiated and all major design features had been established.

Foster-Miller resumed the design of a single cylinder for a multi-cylinder, pilot plant scale, positive displacement feeder. The initial design on the feeder has been modified to include knowledge gained in the model test program. The modifications include:

- A recirculating fluidized feed loop to the inlet of the unit.
- Hydraulic actuation of all pistons and valve functions.
- A two-stage inlet valve which separates the solids and gas sealing functions.

The investigations into the briquetting industry for coal plug feeder technology revealed no hardware suitable for pressurized coal feed is available and this evaluation effort has been suspended.

III. DEVELOPMENT OF A CONTINUOUS DRY COAL SCREW FEEDER

INGERSOLL-RAND RESEARCH, INC.
PRINCETON, NEW JERSEY

Contract No.: E(49–18)–1794
Total Funding: $1,043,719
(100% ERDA)

INTRODUCTION

Development of a continuous dry coal screw feeder is being conducted by Ingersoll-Rand Research, Inc. through ERDA sponsorship. The feeders are to be developed through the pilot plant stage, with the engineering and economic viability evaluated throughout the development process. The end result of the research will be a recommendation by Ingersoll-Rand of coal feed injector equipment that will be compatible with projected demonstration plant requirements. The successful development of a continuous dry coal feeder would have a significant impact on coal processing. The equipment could be used in both high- and low-Btu gasification plants and also in coal liquefaction systems.

PROGRAM DESCRIPTION

Under the current contract with ERDA, started in July 1975, Ingersoll-Rand is conducting a three-phase development program to refine and scale-up a screw feeder that could be used in a demonstration plant. Tests initially conducted by Ingersoll-Rand indicated that screw feeders could be used in full size coal gasification and liquefaction plants in place of pressurized lock hoppers and slurry systems. The feeder currently being developed is a modified injection molding machine, operating like an extruder.

Phase I of the program involves the establishment of the coal feeder requirements imposed by the various processes being considered for commercial scale coal conversion operations. Literature searches, consultations with ERDA personnel and consultants, studies of plant operations, etc. will be used to obtain information on the feeder requirements. Using the information gathered, Ingersoll-Rand is to examine existing equipment and conceptually design new approaches to coal feeders.

In Phase II, critical components of the candidate equipment selected in Phase I will be tested. In addition, two laboratory scale, coal feeder prototypes, a Negri-Bossi V-12 injection molding machine and an IMPCO 1500, will be designed, fabricated, and tested. Among the characteristics to be investigated are:

- Feeder stability and degree of control
- Seal effectiveness
- Coal metering accuracy
- Life expectancy of critical components

- Mechanical power requirements
- Methods for reducing the feed coal size to meet process requirements.

The data resulting from laboratory testing will be used to design feeders for use in existing and projected pilot plant operations. Recommendations will be made to ERDA for further development of promising screw feeder concepts.

During Phase III, IMPCO screw feeder will be installed and operated in a pilot plant selected by ERDA. Feed rates will be in the range of 0.5 to 5.0 tons per hour. A report will be prepared that will include design specifications, installation drawings, assembly procedures, installation and functional test guides, and operation and maintenance manuals. The performance of the feeder in the pilot plant tests will be assessed based on the test data. A final report will be prepared which will include the design of equipment sized for a demonstration plant.

A fourth phase, not part of the current contract, will use the results of pilot testing for development, design fabrication, and delivery to ERDA of coal feeders compatible with demonstration plant requirements. Coal feed rates in this phase will be 50 tons per hour or greater.

PROJECT ACCOMPLISHMENTS

Ingersoll-Rand Research developed, during Phase I, three conceptual designs for coal feeding. These concepts included a single-acting piston feeder, double-acting piston feeder, and a rotary valve piston feeder.

A comparative evaluation of coal feeder systems was completed, using the technical and economic criteria established during the fourth quarter of 1975. Existing coal feed systems, lock hoppers and slurry pumps were compared with new feed system concepts. The evaluation indicated that the piston feeders as a class seem to offer advantages over the lock hopper and slurry pump methods of feeding coal to high-pressure gasifiers. The screw feeder concept, although not as dramatic, also showed advantages over existing methods. A proposal is to be submitted for further evaluation of the piston feeder concepts.

ERDA received the Phase I report in March for review and comment.

PROGRESS DURING APRIL–JUNE 1976

Coal Feeder Concept Study

During April, ERDA reviewed and approved the Phase I report to conclude the Phase I effort.

Laboratory-Scale Coal Feeder Development

Construction work for the experimental test facility progressed satisfactorily during April but slowed in May and June when vendors failed to deliver various items on time. Various steps were taken by Ingersoll-Rand Research to obtain the required items so that test work could be conducted. By the end of June, the general construction and mechanical was complete and the electrical work was approximately 80 percent complete. The ball mill and sieve shaker were installed in the laboratory for use in crushing and sizing coal for future testing.

The Negri-Bossi #V–12 machine and the 800A chiller were installed in May. The initial shakedown tests were conducted with styrene plastic to gain experience with the controls and various operational modes of the machine.

Preliminary tests with coal began in the second week of May and most of the tests were conducted with high volatile bituminous coal from Loveridge Mine, West Virginia. During operation of the NB #V–12, various observations were made, including the following:

- Repeatibility was affected by the strong dependence of coal properties on processing time and temperature.
- Condensation of volatile vapor on the incoming coal caused feeding problems due to bridging in the intake area.
- The venting system for the pressure vessel needs to be modified to reduce the venting time in the event of sealing plug failure.
- Under certain operating conditions, the screw tended to jam due to excessive torque.

During preliminary testing, several parameters were varied. These include:

- Screw speed 0–60 RPM
- Back pressure—0 + 0 1,500 psig
- Barrel heater temperature—100° F + 0 800° F
- Coal temperature (at hopper)—70° F to 250° F
- Moisture level

Table III–1 summarizes the tests conducted during the quarter.

Table III–1—SUMMARY OF TESTS

NB #12V

Types of Coal	Number of Tests Run	Extruded Against Max. Back Pressure of (PSIG)
Pittsburgh Seam		
Loveridge Mine		
8–12 Mesh	11	1,500
12–20 Mesh	15	600
20–30 Mesh	13	1,500
Pittsburgh Seam #8		
8–12 Mesh	2	Atmosphere
Illinois #6		
12–20 Mesh	2	Atmosphere
Wyodak		
Dried & Screened	1	Atmosphere

Ingersoll-Rand continued development of the Impco #1500; the engineering and modification drawings were released to the manufacturer. This effort was necessary because numerous changes needed to be made to the standard Impco production model. IR Research was notified that delivery of the machine would be delayed. As now planned, the Impco #1500 will be delivered by September 15, 1976.

The Impco #1500 coal receiver subsystem concept was finalized. This system was selected from a group of six concepts on the basis of its simplicity, reliability, and low cost. The system will be capable of handling one ton of extruded coal, and this will provide about one hour of machine operation. The pressure vessel would be filled with water to the maximum possible level to minimize nitrogen consumption. The vessel is also designed so that when collecting dry extruded coal for inspection, the entire vessel can be filled with nitrogen. In addition to batch type operation, the system can be modified to operate as a continuous slurry-liquid level system.

The subsystem drawings were completed and sent to twelve companies for cost estimates and comments. Seven responded and one of the seven will be selected to construct the system.

BLANK PAGE

IV. COAL FEEDER DEVELOPMENT PROGRAM

LOCKHEED MISSILES AND SPACE COMPANY, INC.

SUNNYVALE, CALIFORNIA

Contract No.: E(49–18)–1792

Total Funding: $1,000,000

(100% ERDA)

INTRODUCTION

Lockheed Missiles and Space Company, Inc., a subsidiary of Lockheed Aircraft Corporation, is conducting a coal feeder development program under the auspices of ERDA. A need exists for this development effort because current lock hopper or slurry concepts for coal feeding are inadequate. The feeder system is a critical component of a coal conversion plant, affecting equipment and maintenance costs, plant efficiency, and down time. An improved coal feeder that is applicable to all processes using pulverized dry coal at reactor pressures up to 100 atm must be developed.

PROGRAM DESCRIPTION

Work under this three-phase program was initiated in July 1975. Phase I, which was completed in March 1976, involved the selection of candidate coal feed injector concepts based on a detailed examination of the system requirements imposed by the various coal conversion processes.

The examination included:

- Screening potential candidates
- Investigating existing equipment
- Synthesizing feeder system designs
- Assessing problem areas
- Defiining laboratory evaluation techniques
- Preparing a final report

Phase II studies will involve tests on four coal feeder systems. These include a fluid dynamic lock, kinetic extruder, ball conveyor, and an ejector. To establish a firm basis for the design of the coal feed systems for use in commercial plants, testing efforts for this phase will include:

- Laboratory tests, using simple bench-scale equipment, to answer questions pertinent to equipment design.
- Supporting analysis provided by mathematical models developed for optimizing equipment design, projecting operating efficiency, and updating economic data generated during Phase I.
- Design of test equipment.
- Fabrication, including procurement of materials.
- Installation of test equipment followed by testing as outlined in the test plan and data reduction and analysis.
- Documentation.
- Design, procurement, and installation of equipment for the test loop facility.

- Assurance that hardware is manufactured to applicable specifications and that all operations and specifications adhere to safety requirements.

During Phase III, candidate feeder concepts showing promise for commercial scale use will be designed and operated in current and/or projected pilot plants. Feed rates for these feeders are expected to be in the range of three to five tons per hour. As part of this phase, Lockheed will also prepare a report that will include design specifications, assembly and detail drawings, assembly procedures, installation and functional test procedures, and operation and maintenance manuals. The data obtained in the pilot plant tests will be analyzed, and a final report including an engineering design of equipment for a demonstration plant will be prepared.

A fourth phase, not part of this contract, will utilize the results of pilot plant testing, and is projected to include the development, design, fabrication, and delivery to ERDA of coal feeders compatible with demonstration plant requirements. Feed rates in this phase are anticipated to be 50 tons per hour and greater.

PROGRESS DURING APRIL–JUNE 1976

Laboratory Testing

Ejector

During April, the major activity dealt with experiments on dense phase transport of dry pulverized coal. Data were collected to define the coal inlet flow which will result for conditions expected to be generated by operation of the bench scale ejector unit.

The efforts included equipment and instrumentation check-out tests of the bench scale pneumatic transfer apparatus using 30-mesh sand conveyed by air. About 40 transfer tests were made with the sand-air medium. Solids transfer rates of 200 to 400 pounds per hour were achieved through the ¼-inch ID feed line with pressure differentials of from 2.5 to 8 pounds per square inch (psi). The test utilized two feed line lengths, 5.1 and 8.8 feet, and smooth bends at corners where flow direction was changed.

Fifty transfer tests were made using two types of pulverized coal and nitrogen gas. The results were similar to those obtained with the sand-air mixture except that transport could be initiated and maintained at much lower pressures. It was found that flow could be maintained with a pressure differential of less than 1 psi. These experiments were repeated with a different coal to compare the observed results and determine the effect coal properties had on flow characteristics. It was found that similar flow properties were obtained with the second coal, indicating that the type of coal would have little bearing on the transport experiment results.

Various feed line modifications were made to investigate the effect of tees and elbows. This was accomplished by replacing all smooth curves with tee section fittings for all 90 degree tube bends. These modifications caused few changes in flow but increased the differential pressure requirement to about 4 to 5 psi.

Ejector work in May involved installation of the bench scale equipment and check out runs. Pulverized coal was pumped successfully from atmospheric pressure into a receiver tank at 20 psig.

Various equipment problems showed up during the initial runs; however, modifications and replacements remedied all the diagnosed problem areas. A zone fluidization and coal recycle system was designed and operated successfully. This will permit transfer of coal in the high pressure receiver tank into the ejector inlet without opening the system for manual operation.

Coal pressurization tests were conducted on the ejector system in June. Conclusions reached from the tests indicate that the bench scale ejector system is not properly matched for optimum transfer of coal from a reservoir at atmospheric pressure. Additional experiments are planned to confirm this and draw up modification plans. The ejector system is illustrated in Figure IV–1.

Ball Conveyor

Several ball conveyor experiments were conducted during the quarter. The objectives of these experiments were to determine if a ball/coal column still retains its mobility when it is packed tightly enough to be impermeable to gas flow. Lockheed reported that based on their experimentation, the ball conveyor concept is feasible. Specific conclusions reached were:

- The standpipe is an extremely effective gas seal if the coal between the balls is stressed enough so that it cannot expand to allow bubbling or channeling.

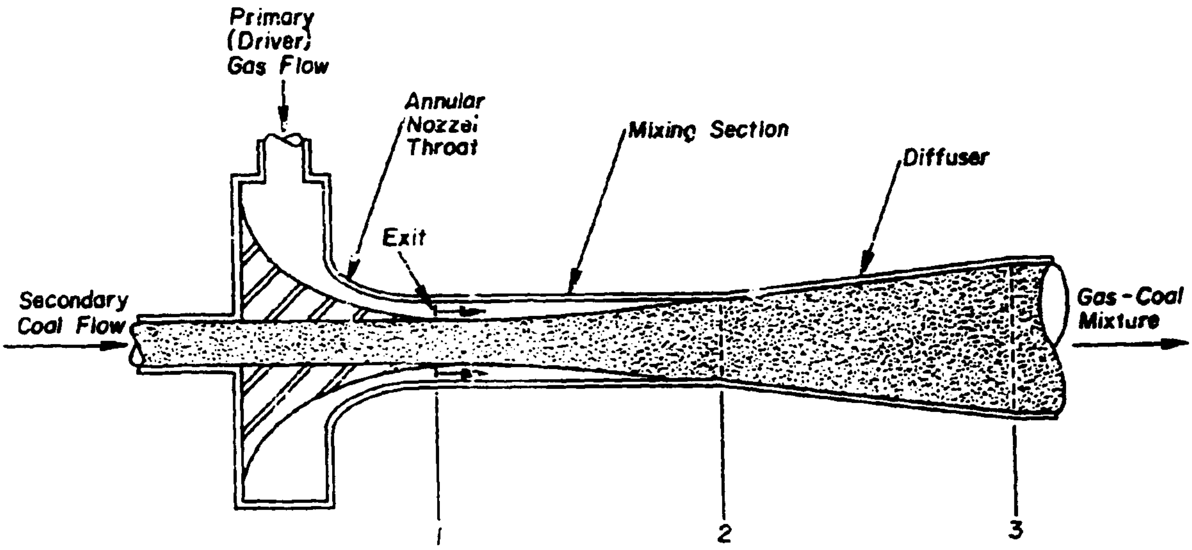


Figure IV-1. EJECTOR COAL FEEDER

- No extremely high fraction efforts occur when the ball cavities are over filled and the balls are not touching.

Another series of tests were made which involved ball motion against gas pressure. A 6-foot ball/coal column, using 5-inch steel balls, was dropped against pressures of approximately 12 psig. The objective was to determine the friction between the pipe and ball column and its dependence on the gas pressure distribution within the column. The test results were extremely favorable for the finely ground coal (70 percent passing 200 mesh), but not as favorable for coarser ground coal. The test results will be used to predict performance of all-up recirculating ball conveyors and to make recommendations for future work. The ball conveyor concept is pictured in Figure IV-2.

Supporting Analysis

Ejector

The ejector mixing section theoretical model has been successfully formulated. Experimental data will be incorporated into the model as they become available. During June, operating performance for the bench scale unit was predicted using this model. Based on a comparison of theoretical results with experimental results, it was recommended that the design of the one tons per hour ejector with the theoretical model be postponed until more experimental results become available.

Kinetic Extruder

The analytical model was used to design the rotor head for the extruder. No further effort is planned for further refinement of this model.

Ball Conveyor

As of end of the quarter, the ball conveyor computer model was operational and performed satisfactorily. Some runs simulating ball conveyor experiments were made and good agreement between theory and experiment was achieved. At present, the model is being used for data reduction and scaleup activities. No further model development is planned.

Fluid Dynamic Lock

The computer model for this system was used to ton per hour feeder stage. It was decided that more data was needed to verify that the model can actually be used for predicting performance of the fluid dynamic lock without making modifying assumptions to describe

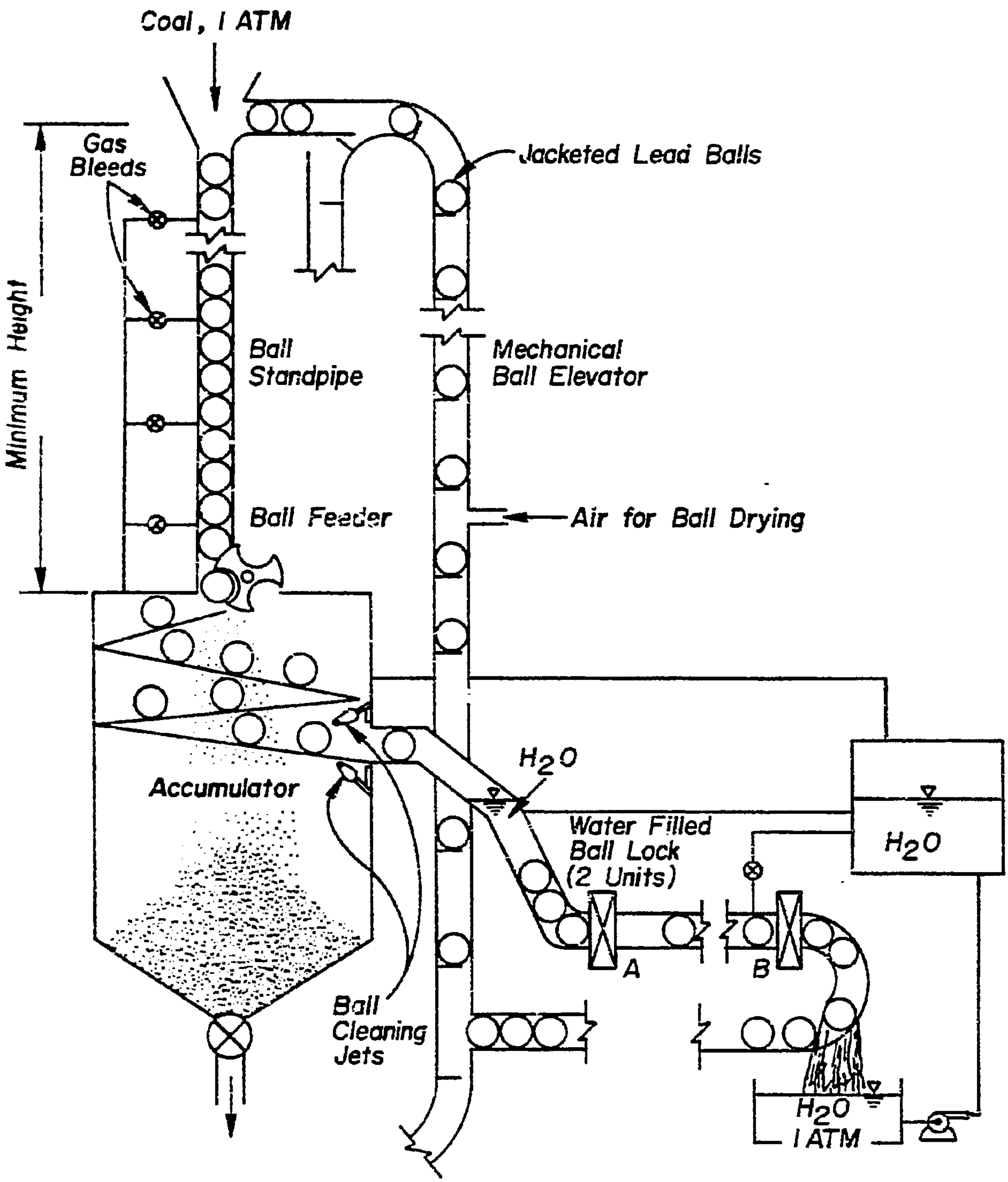


Figure IV-2. BALL CONVEYOR COAL FEEDER

the operation of this device. Further work is planned in this area.

Project Support

The design effort for the quarter involved the rotor drive system and rotor head for the kinetic extruder and the fluid dynamic lock. The test rotor is currently under construction and all parts of the lock to be fabricated by subcontractors have been released for procurement. This effort is on schedule.

Facility support is proceeding as scheduled. Pressure tanks have been designed and an order has been placed for manufacturing. Other orders for manufacture include stands for vessels, load cells, and valves. All deliveries are anticipated to be on schedule.

BLANK PAGE

V. ENGINEERING AND TECHNICAL SUPPORT

U.S. ARMY CORPS OF ENGINEERS,
HUNTSVILLE DIVISION

HUNTSVILLE, ALABAMA

Contract No.: E(49–18)–1759

Funded by Individual Task

INTRODUCTION

Under an interagency agreement between ERDA and the Office of the Chief of Engineers, U.S. Department of the Army, the U.S. Army Corps of Engineers is providing ERDA with engineering and technical support. This contract, initiated in mid-1974, involves the services of the Corps of Engineers engineering forces to provide technical services for demonstration plant design, construction, and related support for such projects and at such locations as requested by ERDA.

Demonstration plant assurance requests are made in the form of task assignment letters describing the scope of services desired. The task letter defines the specific function requested, the proposed location of the project, funding limitations, and designates the individual or office responsible for furnishing any requested ERDA direction. ERDA is billed by the responsible Field Operating Agency for actual expenses incurred.

PROGRAM DESCRIPTION

Under the current task letter, the Corps of Engineers is supporting ERDA in the areas of advance planning for several demonstration plants and preliminary engineering for the Clean Boiler Fuel Demonstration Plant (see Section I). The specific scope of services requested is as follows:

Advance Planning

- Assist in the preparation of request for proposals (RFP) for three demonstration plants.
- Participate in the review and evaluation of proposals received in response to RFP's.
- Perform special studies, e.g., specific concept designs, relating to design and construction on a task basis.

Preliminary Engineering

- Review and/or prepare design criteria.
- Review preliminary engineering designs.
- Review and validate cost estimates and schedules.
- Review and/or assist in development of environmental impact statements.
- Review the results of site investigations and evaluations performed by contractors.
- Provide assistance in the development of reliability and quality assurance plans, configuration management plans, and computer programming for resource management.

The Huntsville Division was designated as the Field Operating Agency responsible for performing these tasks.

PROGRESS DURING APRIL–JUNE 1976

Engineering/Planning

The Corps of Engineers effort on the Coalcon clean boiler fuel plant was primarily involved with review of completed program work. These reviews included contractor program plans with ERDA and Coalcon, conferences on process flow sheets for the one process system, a review conference on the product assurance plan, configuration management plan, and the integrated logistic support plan outline. The Corps also participated in the monthly evironmental impact statement task force meetings.

Activities related to the synthetic pipeline gas demonstration plant centered on the draft project management plan between the Corps of Engineers and ERDA. This plan describes ERDA management of the program and the relationships between ERDA, other government agencies, and the private contractor. The technical proposals for the plant were received and evaluated and the evaluation of the cost/price proposals was initiated. Preparation of data sheets for use in negotiations with contractors was also initiated.

Involvement in the fuel gas demonstration plant included Corps of Engineers representatives assisting in completing the preliminary evaluation of proposals, and developing questions to be submitted to the offerors.

VI. TECHNICAL ASSISTANCE SERVICES

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

Contract No.: E(49–18)–1775
Total Funding: $2,990,892
(100% ERDA)

INTRODUCTION

The Ralph M. Parsons Company is providing technical assistance services to ERDA with the objective of developing and demonstrating practical processes for producing liquid and/or solid fuels from coal. Under this program, initiated in 1972 and updated in 1974, Parsons is:

- Developing conceptual designs and economic evaluations for commercial plants.
- Evaluating pilot plant performance and other experimental operations.
- Evaluating unit operations and processes for possible applications in coal processing, including design and construction of pilot plants.
- Evaluating proposals for new work and for changes in ongoing work.

The development of commercial design concepts and technical evaluations involve:

- Review of chemical, mechanical, and material problems associated with the design of large plants and equipment.
- Identification of problems in sizing, safety factors, and instrumentation of equipment, which must be resolved before equipment is specified for manufacture.
- Identification of equipment design problem areas, and development of programs for solution of those problems.
- Identification of construction problems, including availability of materials, type of land base, and area required for construction, that must be solved before large equipment can be fabricated in the field.
- Establishment of overall utility requirements. This effort will provide a common economic basis for comparing capital and operating costs of the processes. Ultimately, the commercial design concepts will serve as guides for selecting the best coal processes to be demonstrated in commercial-sized plants.

PROGRAM DESCRIPTION

Parsons has two primary tasks: (1) development of conceptual designs and economic evaluations of commercial plants and (2) technical evaluations.

Conceptual designs and economic evaluations of commercial-scale plants are being developed for the Char-Oil Energy Development (COED) process, an oil-gas process based on the Solvent-Refined Coal (SRC) process, the Fischer-Tropsch process, and a combined Coal-Oil-Gas (COG) process. The conceptual designs and economic evaluations are based on engineering data such as process yields, conversion efficiency, plant economics, and environmental analysis from pilot plant operations.

Parsons, at its own expense, is developing a computerized process simulation program capable of estimating fixed capital investment, material and energy (utility) balances, and potential profitability of various coal conversion complexes. The program will be available to this project.

Among the technical evaluations is the development of functional and preliminary specifications for equipment and control apparatus required in the candidate conversion processes. All the components of a plant, from coal handling through production of fuel, are being considered, along with the associated units for power generation and waste treatment. Another technical evaluation activity is the investigation of materials for construction of equipment to determine which are preferred for use in coal conversion processes. Parsons is also defining facilities required to control air, water, and solid waste pollution to assure that plant operations are within applicable state and EPA environmental standards. Finally, Parsons is providing general support activities and preparing reports as apropriate or requested by ERDA.

PROGRESS DURING APRIL–JUNE 1976

Conceptual Designs of Commercial Plants

Design and economic information on coal mining preparation facilities for oil gas and Fischer-Tropsch plants was drafted into a report. RMP completed the process design activity for the oil/gas plant. This design effort included completion of:

- Process flow diagrams for all units.
- Equipment engineering specifications.
- Fixed capital cost estimates for the complex.

Utility balances, the raw water treatment facility and the fuel gas gasifier engineering were also finished during the period. Work on the profitability analysis and preparation of the final R&D report continued.

Fischer-Tropsch plant design was nearly completed by the end of the quarter. Flow diagrams were finished for the utilities system and raw water treatment system. Comparisons of gasifiers and Fischer-Tropsch reactor types for inclusion in the design report were wrapped up and the equipment engineering specifications and fixed capital cost estimates for all process units were also finished. Other Fischer-Tropsch work centered around advancement of the profitability analysis and the preparation of the final R&D report for the task. Adjustments were made to the plant's thermal efficiency figure, which now stands at 69.7 percent.

Effort on the COG plant was applied in many areas. A literature search for pyrolysis data and a bibliography of applicable references were completed. Progress was made on a comparison summary of the liquefaction processes studied by RMP. A draft of the design basis was prepared along with a complete preliminary material balance for the process combination. Work was also done to establish characteristics for alternative configurations of the COG plant. Further studies for the alternative uses of char were investigated, which included hydrogen production, SNG, Fischer-Tropsch, synthesis gas, and power generation.

Other work by RMP included preparation of letters to licensors for solicitation of methanol plant design for the multipurpose demonstration facility, and the initiation of three studies. One study involves research to determine what steps are necessary to convert coal-derived liquids to consumer products. The second one involves studying the critical factors affecting the coal charge rate for the facility, and the third study will establish the characteristics of candidate processes for testing in the facility.

Technical Evaluations

Equipment development of gas/solids separation, solids feed to gasifier, and valves continued through vendor contact and literature searches.

Support in the area of environmental considerations centered on completion of the environmental section of the design report for the Fischer-Tropsch plant. This included details of treatment of gaseous and liquid effluent streams, disposal of solids, and noise abatement. Carcinogenic action of new materials and products was studied along with the possible release of heavy metals and trace elements into the environment.

Evironmental effort in June revolved around a review of the oil/gas plant environmental factors, which will include the same areas as the report made on the Fischer-Tropsch plant.

The first of two technical papers presented during the quarter, "Preliminary Economic Analysis: Oil and

Power by COED-Based Conversion," was presented April 8, 1976 at the New York City American Chemical Society meeting. The second paper, "Coal Liquefaction: Materials System Design," was given April 26 at the American Society of Metals Conference held in Pittsburgh, Pennsylvania.

BLANK PAGE

GLOSSARY

absorption—an imprecise term suggesting the taking up of one substance by another by either a physical process or a chemical combination.

acceptor—calcined carbonate that absorbs carbon dioxide evolved during gasification, liberating heat.

acid gas removal—the process of selectively removing hydrogen sulfide and carbon dioxide from a gas stream.

activated carbon—carbon obtained by carbonization in the absence of air, preferably in a vacuum; has the property of absorbing large quantities of gases, solvent vapors; used also for clarifying liquids.

adiabatic—any process where heat is neither given off nor absorbed.

adsorption—the process by which the surface of a solid or liquid attracts and holds any atom, molecule, or ion from a solution or gas with which it is in contact.

agglomerate—assemblage of ash particles rigidly joined together, as by partial fusion (sintering).

anthracite coal—hard coal containing 86 to 98 percent fixed carbon and small percentages of volatile material and ash.

API—American Petroleum Institute.

API gravity—a scale adopted by the API for measuring the density of oils:

$$^{\circ}API = \frac{141.5}{\text{Specific gravity, } 60^{\circ}F/60^{\circ}F} - 131.5$$

aromatic hydrocarbon—a cyclic hydrocarbon containing one or more six-carbon (benzene) rings.

ash—solid residue remaining after the combustion of coal.

ASTM—American Society for Testing Materials.

autoclave—a vessel, constructed of thick-walled steel, for carrying out chemical reactions under high pressures and temperatures.

bench-scale unit—a small-scale laboratory unit for testing process concepts and operating parameters as a first step in the evaluation of a process.

binder—carbon products, tars, etc., used to impart cohesion to the body to be formed; a coal-extract binder may be used to prepare formed-coke pellets from non-coking coals.

bituminous coal—a broad class of coals containing 46 to 86 percent fixed carbon and 20 to 40 percent volatile matter.

blow down—periodic or continuous removal of water from a boiler to prevent accumulation of solids.

bottoming cycle—the lower temperature thermodynamic power cycle of a combined-cycle system.

Btu—British thermal unit, the quantity of energy required to raise the temperature of one pound of water one degree Fahrenheit.

BTX—benzene, toluene, xylene: aromatic hydrocarbons.

caking—the softening and agglomeration of coal as a result of the application of heat.

calcination—the process of heating a solid to a high temperature to cause the decomposition of hydrates and carbonates.

calorific value—the quantity of heat obtained by the complete combustion of a unit mass of a fuel under prescribed conditions.

carbon fiber—fine filaments of carbon about eight microns in diameter which are used in composite materials, being bound with resins.

carbonization—destructive heating of carbonaceous substances with the production of a solid, porous residue, or coke, and the evolution of a number of volatile products. For coal, there are two principal classes of carbonization, high-temperature coking (about 900° C) and low-temperature carbonization (about 700° C).

catalyst—a substance that accelerates the rate of a chemical reaction without itself undergoing a permanent chemical change.

centrifuge—an apparatus rotating at high speed which utilizes the centrifugal force generated to separate materials of different densities, e.g., undissolved residue from coal solution in the SRC process.

char—the solid residue remaining after the removal of moisture and volatile matter from coal.

Claus process—industrial method of obtaining elemental sulfur through the partial oxidation of gaseous hydrogen sulfide in air followed by catalytic conversion to molten sulfur.

coal—a readily combustible rock containing more than 50 weight percent and more than 70 volume percent of carbonaceous material including inherent moisture, formed from compaction and induration of variously altered plant remains similar to those in peat.

coalification—metamorphosis of vegetable debris into coal.

coke—strong porous residue consisting of carbon and mineral ash formed when bituminous coal is heated in a limited air supply or in the absence of air. Coke may also be formed by thermal decomposition of petroleum residues.

coke breeze—the fine screenings of crushed coke usually passing a ½-inch or ¾-inch screen opening.

combined cycle—two sequential thermodynamic power conversion systems operating at different temperatures.

combustion gas—gas formed by the combustion of coal, e.g., burning.

combustor—a vessel in which combustion takes place.

coupon—a polished metal strip used to measure the rate of corrosion of the metal in a specific gaseous or liquid environment.

cracking—the partial decomposition of high-molecular-weight organic compounds into lower-molecular-weight compounds, generally as a result of high temperatures.

crude gas—impure gas produced in a gasifier.

culm—the waste or slack from anthracite mines or preparation plants consisting of fine coal, coal dust, and dirt.

cyclone separator—essentially a settling chamber to separate solid particles from a gas, in which gravitational acceleration is replaced by centrifugal acceleration.

degasification—a process for removing naturally occurring methane from coal seams.

delayed coking—a process wherein coal is subject to a long period of carbonization at moderate temperatures to form coke.

demineralization—removal of mineral matter (ash) from coal by solvent extraction, usually under hydrogen atmosphere.

depolymerization—the change of a large molecule into simpler molecules usually accompanied by the substitution of hydrogen for oxygen in the molecular structure.

destructive distillation—the distillation of coal accompanied by its thermal decomposition.

desulfurization—the removal of sulfur from hydrocarbonaceous substances by chemical reactions.

devolatilization—the removal of a portion of the volatile matter from medium- and high-volatile coals

diatomaceous earth—a yellow, white, or light-gray, siliceous porous deposit made up of opaline shells of diatoms; used as a filter aid, paint filler, adsorbent, abrasive, and thermal insulator. Also known as kieselguhr.

diatomite—See Diatomaceous Earth.

dissolution—the taking up of a substance by a liquid with the formation of a homogeneous solution.

distillation—a process of vaporizing a liquid and condensing the vapor by cooling; used for separating liquids into various fractions according to their boiling points or boiling ranges.

dolomite—a carbonate of calcium and magnesium having the chemical formula $CaMg(CO_3)_2$.

Dowtherm—trademark for a series of eutectic mixtures of diphenyl oxide and diphenyl used as high-temperature heat-transfer fluids.

ebulleted bed—gas containing a relatively small proportion of suspended solids, bubbles through a higher density fluidized phase with the result that the system takes on the appearance of a boiling liquid.

economizer—heat exchanging mechanism for recovering heat from flue gases.

effluent gas—gas given off from a process vessel.

elutriation—the preferential removal of the small constituents of a mixture of solid particles by a stream of high-velocity gas.

endothermic reaction—a process in which heat is absorbed.

enthalpy change—the increase or decrease in heat content of a substance of system which accompanies its change from one state to another under constant pressure.

entrained bed (flow)—a bed in which solid particles are suspended in a moving fluid and are continuously carried over in the effluent stream.

eutectic—that combination of two or more components which produces the lowest melting temperature.

exothermic reaction—a process in which heat is liberated.

extraction—a method of separation in which a solid or solution is contacted with a liquid solvent (the two being essentially mutually insoluble) to transfer components into the solvent.

extractive coking—similar to delayed coking process, with the emphasis on high tar yields to produce liquids.

filter aid—finely divided solids used to increase efficiency of filtering.

filter cake—the moist residue remaining from the filtration of a slurry to produce a clean filtrate.

filtrate—a liquid free of solid matter after having passed through a filter.

filtration—the separation of solids from liquids by passing the mixture through a suitable medium, e.g., cloth, paper, diatomaceous earth.

Fisher assay—method for determining the tar and light oil yields from coal or oil shale; conducted in a retort under an inert atmosphere with a prescribed increase in temperature to 500° C.

Fischer-Tropsch catalyst—catalysts developed for the catalytic synthesis of liquid fuels from coal-derived synthesis gas; catalysts contain principally iron, cobalt, nickel, or ruthenium.

Fischer-Tropsch process—method of hydrogenerating mixtures of carbon monoxide and hydrogen produced from coal, lignite, or natural gas by means of steam, at 1–10 atmospheres and 360–410° F to yield liquid and gaseous fuels, and a wide spectrum of industrial chemicals.

fixed-bed—stationary solid particles in intimate contact with fluid passing through them.

fixed carbon—the solid residue, other than ash, obtained by destructive distallation; determined by definite prescribed methods.

flash carbonization—a carbonization process characterized by short residence times of coal in the reactor to optimize tar yields.

flue gas—gaseous combustion products.

fluidization (dense phase)—the turbulent motion of solid particles in a fluid stream; the particles are close enough as to interact and give the appearance of a boiling liquid.

fluidization (entrained)—gas-solid contacting process in which a bed of finely divided solid particles is lifted and agitated by a rising stream of gas.

fluidized bed—assemblage of small solid particles maintained in balanced suspension against gravity by the upward motion of a gas.

fly ash—a fine ash from the pulverized coal burned in power station boilers, or entrained ash carried over from a gasifier.

fractionation—distillation process for the separation of the various components of liquid mixtures.

freeboard—the space in a fluidized-bed reactor between the top of the bed and the top of the reactor.

free swelling index—a standard test that indicates the caking characteristics of coal when burned as a fuel.

Friedel-Crafts reaction—a substitution reaction, catalyzed by aluminum chloride in which an alkyl (R-) or acyl (RCO-) group replaces a hydrogen atom of an aromatic nucleus to produce a hydrocarbon or a ketone.

fuel cell—a galvanic cell in which the chemical energy of a conventional fuel is utlized to produce electricity.

fuel gas—low heating value (150–350 Btu/scf) product generally utilized on site for power generation or industrial use.

gasification of coal—the conversion of solid coal into a gaseous form by various chemical reactions with steam.

gasifier—a vessel in which gasification occurs, usually utilizing fluidized-bed, fixed-bed, or entrained-bed units.

heat capacity—quantity of heat required to raise the temperature of one pound of substance one degree Fahrenheit.

high-Btu gas—a gas having a heating value of 900 to 1,000 Btu per standard cubic foot which approaches the value of natural gas.

higher-heating value (HHV)—the heat liberated during a combustion process in which the product water vapor is condensed to a liquid and the heat of condensation is recovered.

hydroclone—a small cyclone extractor for removal of suspended solids from a flowing liquid by means of the centrifugal forces set up when the liquid is made to flow through a tight conical vortex.

hydrocoking—coking of tars, SRC, etc., under hydrogenating conditions to form liquid products.

hydrocracking—the combination of cracking and hydrogenation of organic compounds.

hydrogasification—gasification that involves the direct reaction of fuels with hydrogen to optimize formation of methane.

hydrogenation—chemical reactions involving the addition of gaseous hydrogen to a substance in the presence of a catalyst under high temperatures and pressures.

hydrogen donor solvent—solvent, such as anthracene oil, tetralin (tetrahydronaphthalene), decalin, etc., which transfers hydrogen to coal constituents causing depolymerization and consequent conversion to liquid products of lower boiling range which are then dissolved by the solvent.

hydrotreating—a process to catalytically stabilize petroleum or other liquid hydrocarbon products and/or remove objectionable elements from products or feedstocks by reacting them with hydrogen.

ideal gas—any gas whose equation of state is expressed by the ideal gas law, namely $PV = nRT$ where P is the pressure, V is the volume, R is the gas constant, T is the absolute temperature, and n = number of moles.

ignition temperature—the minimum temperature necessary to initiate self-sustained combustion of a substance.

industrial gas—See Fuel Gas.

inerts—constituents of a coal which decrease its efficiency in use, e.g., mineral matter (ash) and moisture in fuel for combustion.

in situ—in its original place, e.g., underground gasification of a coal seam.

intermediate-Btu gas—synthesis gas product with a higher heating value between 350 and 500 Btu per standard cubic foot.

lignite—brownish-black coal containing 65–72 percent carbon on a mineral-matter-free basis, with a rank between peat and subbituminous coal.

limestone—sedimentary rock containing 50 percent carbonate (CO_3) of lime or magnesia. Chemical formula (for calcite limestone) is $CaCO_3$.

liquefaction—conversion of a solid to a liquid; with coal, this appears to involve the thermal fracture of carbon-carbon and carbon-oxygen bonds, forming free radicals. These radicals abstract hydrogen atoms yielding low molecular weight gaseous and condensed aromatic liquids.

liquefied petroleum gas (LPG)—those hydrocarbons that have a vapor pressure (at 70° F) slightly above atmospheric (such as propone and butane); kept in liquid form under a pressure higher than 1 atm.

lock hopper—a mechanical device that permits the introduction of a solid into an environment of different pressure.

low-Btu gas—a gas having a heating value up to 350 Btu per standard cubic foot.

lower heating value—the heat liberated by a combustion process assuming that none of the water vapor resulting from the process is condensed, so that its latent heat is not available.

MAF—moisture and ash-free; a term that relates to the organic fraction in coal.

mesh—measure of fineness of a screen, e.g., a 400-mesh sieve has 400 openings per linear inch.

methanation—the production of methane (CH_4) from carbon monoxide or dioxide and hydrogen.

methane—CH_4, a colorless, odorless, and tasteless gas, lighter than air; the chief component of natural gas.

methanol—methyl alcohol, CH_3OH.

micron—a unit of length equal to one millionth of a meter; 10^{-6} meter.

moving bed—particlized solids in a process vessel that are circulated (moved) either mechanically or by gravity flow.

natural gas—naturally occurring gas extracted from sedimentary structures consisting mainly of methane and having a higher value of approximately 1,050 Btu per standard cubic foot.

noncoking coal—a coal that does not form coke under normal coking conditions.

olefinic hydrocarbon—a class of unsaturated hydrocarbons containing one or more double bonds and having the general chemical formula C_nH_{2n}.

open cycle—a thermodynamic power cycle in which the working fluid passes through the system only once and is then exhausted to the atmosphere.

peat—an unconsolidated, hydrophilic, yellowish-brown to brownish-black, carbonaceous sediment, formed by accumulation of partially fragmented and decomposed plant remains in swamps and marshes which retains more than 75 percent inherent moisture and less than 12 percent mineral matter in saturated natural deposits.

petrochemicals—those derived from crude oil or natural gas, or their coal-derived substitutes; they include light hydrocarbons such as butylene, ethylene and propylene, the raw materials for the production of plastics by polymerization.

phenols—a group of aromatic compounds having the hydroxyl (OH) group directly attached to the benzene ring.

pilot plant—a chemical process plant containing all the processes of a commercial unit, but on a smaller scale, for the purpose of studying the technical and economic feasibility of the process.

pipeline gas—a methane-rich gas that conforms to certain standards and has a higher heating value between 950 and 1,050 Btu per standard cubic foot.

plenum chamber—an enclosed space through which air is forced for slow distribution through ducts.

precoat—layer of suitable filtering medium, e.g., diatomaceous earth, laid down on a rotary filter cloth prior to operation.

prilling tower—a tower that produces small solid agglomerates by spraying a liquid solution in the top and blowing air up from the bottom.

process development unit—a system used to study the effects of process variables on performance; sized between a bench-scale unit and a pilot plant.

proximate analysis—analysis of coal based on the percentages of moisture, volatile matter, fixed carbon (by difference) and ash, using prescribed methods. Reported on different bases, such as-received (or as-fired), dry, mineral-matter-free (mmf), and dry mineral-matter-free (dmmf).

purification—removal of a wide range of impurities present in gases from coal gasification.

pyrolysis—thermal decomposition of organic compounds in the absence of oxygen.

quenching—cooling by immersion in oil, water bath, or water spray.

Raney nickel catalyst—specially prepared nickel catlyst used in the hydrogenation of organic materials and the methanation of synthesis gas to methane.

raw gas—See Crude Gas.

reactivity—susceptibility to chemical change; for example, in coal liquefaction, the reactivity of the coal for conversion to liquid products is a function of the coal rank, among other things.

reactor—vessel in which coal-conversion reactions take place.

Rectisol process—a process for the purification of coal-gasification gas based on the capability of cold methanol to absorb all gas impurities in a single step; gas naphtha, unsaturated hydrocarbons, sulfur componds, hydrogen cyanide, and carbon dioxide are removed from the gas stream by the methanol at temperatures below 0° C.

reducing gas—a gas which, at high temperatures, lowers the state of oxidation of other chemicals.

reforming processes—a group of proprietary processes in which low-grade or low molecular weight hydrocarbons are catalytically converted to higher grade or higher molecular weight materials; also applies to the endothermic reforming of methane, for the production of hydrogen, by the reaction of methane and steam in the presence of nickel catalysts.

refactory—a material capable of withstanding extremely high temperatures and having a relatively low thermal conductivity.

residence time—time spent by a typical particle in a particular zone.

saturated hydrocarbon—a carbon-hydrogen compound with all carbon bonds filled; that is, there are no double or triple bonds as in olefins and acetylenes.

scrubber—apparatus in which a gas stream is freed of tar, ammonia, and hydrogen sulfide.

seam coal—coal which is intermediate in rank between bituminous coal and anthracite; contains 8 to 22 percent volatile matter and from 91 to 93 percent carbon.

semi-water gas—a mixture of carbon monoxide, carbon dioxide, hydrogen, and nitrogen, obtained by passing an air-steam mixture through a hot bed of coke, having a higher heating value of about 120 Btu per standard cubic foot.

sensible heat—that heat which results in only the elevation of the temperature of a substance with no phase changes.

shift conversion—process for the production of gas with a desired carbon monoxide content from crude gases derived from coal gasification; carbon monoxide-rich gas is saturated with steam and passed through a catalytic reactor where the carbon monoxide reacts with steam to produce hydrogen and carbon dioxide, the latter being subsequently removed in a scrubber employing a suitable sorbent.

sintering—the agglomeration of solids at temperatures below their melting point, usually as a consequence of heat and pressure.

slag—molten coal ash composed primarily of silica, alumina, iron oxides, and calcium and magnesium oxides.

slurry—a suspension of pulverized solid in a liquid.

solvation—the association or combination of molecules of solvent with solute ions or molecules.

solvent—that component of a solution which is present in excess; liquid used to dissolve a substance.

solvent extraction—selective solution of coal constituents from finely divided coal particles into a suitable solvent after intimate mixing, usually at high temperatures and pressures in the presence of hydrogen, with or without a catalyst, followed by phase separation.

solvent refined coal (SRC)—a coal extract derived by solvent extraction; a brittle, vitreous solid (m.p. 300° F to 400° F) containing about 0.1 percent ash and about 10 percent of the sulfur in the original coal feedstock; calorific value is about 16,000 Btu per pound; may be used as a clean fuel for power generation by combustion; utilized for the production of high-grade metallurgical coke, anode carbon, and activated carbon by coking, or hydrogenated to produce synthetic crude oil.

space velocity—volume of a gas (measured at standard temperature and pressure) or liquid passing through a given volume or catalyst in a unit time.

specific gravity—ratio of the weight of any volume of a substance to the weight of an equal volume of water at 4° C.

specific heat—heat capacity of a substance as compared with the heat capacity of an equal weight of water.

standard cubic foot (SCF)—the volume of a gas at standard conditions of temperature and pressure. The American Gas Association uses moisture-free gas at 60° F and 30 inches of mercury (1.0037 atm) as its standard conditions. The pressure standard is not universal in the gas industry: 14.7 psia (1.000 atm) and 14.4 psia (0.980 atm) are also used. The scientific community uses 32° F and 1 atm as standard conditions.

stoichiometry—the definite proportions in which molecules react chemically to form new molecules.

stripping—the removal of the more volatile components from a liquid mixture of compounds.

subbituminous coal—the rank of coal between bituminous and lignite, classified by ASTM as having a range of heating values between 8,300 and 11,000 Btu per pound on a moisture and mineral-matter-free basis.

substitute natural gas (SNG)—a gas produced from coal, oil sands, or oil shale conforming to natural gas standards.

superficial velocity—the linear velocity of a fluid flowing through a bed of solid particles calculated as though the particles were not present.

superheater—a heat exchanger which adds heat to the saturated steam leaving a boiler.

syncrude—synthetic crude oil; oil produced by the hydrogenation of coal, coal extracts, oil sands, or oil shale, which is similar to petroleum crude.

synthesis gas—a mixture of hydrogen and carbon monoxide which can be reacted to yield a hydrocrabon.

tail gas—a gas issuing from a gas-treatment unit which may be recycled to the process or exhausted.

tar (coal)—a dark brown or black, viscous, combustible liquid formed by the destructive distillation of coal.

therm—a unit of heat used as a basis for the sale of natural gas; equal to 100,000 Btu.

topping cycle—the higher temperature thermodynamic power cycle of a combined-cycle system.

turndown ratio—the minimum ratio of actual flowrate to design flowrate at which a process unit can be operated.

ultimate analysis—the determination by prescribed method of carbon and hydrogen in the material as found in the gaseous products of its complete combustion, the determination of sulfur, nitrogen, and ash in the material as a whole and the estimation of oxygen by difference; may be reported on different bases, such as as-received (or as-fired), mineral-matter-free (mmf), and dry mineral-matter-free (dmmf).

Venturi scrubber—a gas cleaning device which involves the injection of water into a stream of dust-laden gas flowing at a high velocity through a contracted portion of a duct, thus transferring the dust particles to the water droplets which are subsequently removed.

volatile matter—those constituents of coal, exclusive of moisture, that are liberated from a sample when heated to 1750° F for seven minutes in the absence of oxygen.

water gas—gas produced by the reaction of carbon (in coal or coke) and steam to yield mixtures of carbon monoxide and hydrogen; similar to synthesis gas.

water gas shift—the reaction between water vapor and carbon monoxide to produce hydrogen and carbon dioxide or the reverse:

$$CO + H_2O \rightleftharpoons H_2 + CO_2$$

working fluid—a gas stream which directly does work, e.g., powering a gas turbine.

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