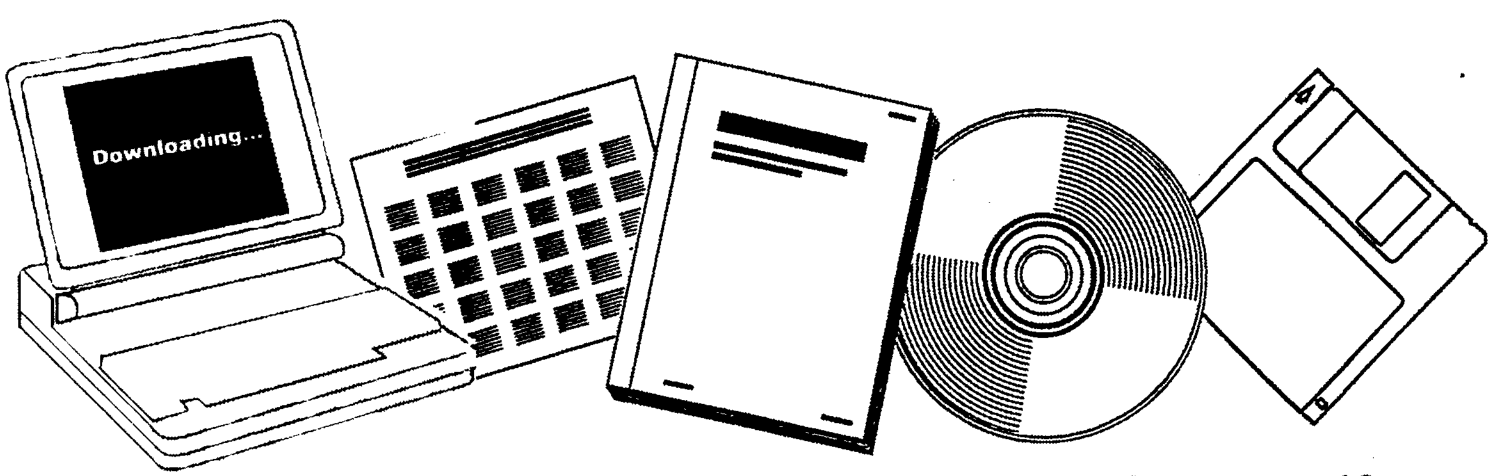
COAL DEMONSTRATION PLANTS. QUARTERLY REPORT, JANUARY--MARCH 1976

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

1976



Office of Fossil Energy
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QUARTERLY REPORT

January–March 1976
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COAL DEMONSTRATION PLANTS

QUARTERLY REPORT

JANUARY–MARCH 1976

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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-scale 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 1980s. These plants will be wholly integrated, self-sufficient in terms of heat generation, and dependent only on feedstocks 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.

During the first quarter of 1976, work on the ***Clean Boiler Fuel Demonstration Plant*** focused on detailed process design for basic engineering packages. Performance specifications, equipment lists, process flow diagrams, and design point heat and mass balances were completed for five sections of the plant, and work on other sections is continuing. The risks and costs of replacing the Koppers-Totzek gasifier with a Texaco gasifier are being evaluated. The possibility of combining the acid-gas removal systems of the gas processing and hydrogen production sections of the plant to use one cold methanol wash system is also being studied. Facility support included completion of construction and pressure testing of the Tonawanda minitest facility. Illinois No. 6 coal has been dried, ground, and screened for testing at this facility, and coal feed tests have been planned to demonstrate the feasibility of feeding 30 pounds of coal per hour in dense-phase transport with the fluidized feeder. At the deagglomeration facility at South Charleston, West Virginia, eight runs were made using hydrogen as process gas. The tests showed that the highly agglomerating Pittsburgh coal does not cake or agglomerate when diluted 4 to 1 with Wyodak coal or char; caking problems are observed with more concentrated mixtures. Computer processing activities included completing a computer program for calculating reactor thermal balances and computing hydrocarbonization heat of reaction at 77° F, generating a data book on thermodynamic and physical properties, and determining the effects of such factors as preoxidation and variations in coal composition and process yields on the process and equipment performance requirements. Coal grinding tests were started, the degree of agglomeration and devolatilization that occurs when coal is heated is being studied, a lock hopper valve test facility is being designed, and process wastewater from the deagglomeration facility is being characterized. Other test programs approved by ERDA this quarter involve coal heating, reactor heat balance, coal cyclone development, and acid-gas removal.

The Phase I report on the ***Development of Coal Feeders for Coal Gasification Operations*** was completed, reviewed by ERDA, and approved for publication. Work on Phase II continued. Preliminary layouts were completed for the coal plug and positive displacement laboratory-scale feeders. Assembly of the coal plug, centrifugal, and positive displacement feeders was completed, and components of these feeders are being tested. The dynamic sealing potential of a twin-screw feed concept is being tested on a limited basis. The layout for the basic coal flow feeder test loop was completed.

As part of the Phase I effort in the ***Development of a Continuous Dry Coal Screw Feeder***, a rotary-valve piston feeder for feeding coal to high-pressure gasifiers was conceived, and its operating cost established. Operating cost analyses comparing existing and conceptual coal feed systems were refined. A comparative evaluation of coal feed systems, based on established technical and economic criteria, indicated that the piston feeder and screw feeder concepts seem to offer advantages over existing methods of feeding coal. A report documenting the Phase I effort was completed and submitted to ERDA for review. In Phase II, construction of the test facility for the dry coal screw feeders was started. The Negri-Bossi V-12 screw feeder has been received, and alternate screws for the feeder are being fabricated. Preparations for initial test operations with the unit continued throughout the quarter. The IMPCO screw feeder was ordered, work on the preliminary designs and engineering of the test system was started, and requirements for the coal receiver for the system were determined.

The final report on Phase I of the ***Coal Feeder Development Program*** was completed and approved by ERDA. The feed systems selected for further study in Phase II are: fluid-dynamic lock, kinetic extruder, ball conveyor, and ejector. Eight tasks were established for the Phase II effort, and schedules were revised to accelerate hardware design and procurement. An annular jet ejector configuration was selected for initial investigation. Preliminary experiments with dense-phase flow of gas-solid mixtures suggested the possibility of developing a reliable, fast response flow meter for dense-phase coal flow, based on measurement of pressure drop across a portion of the coal feed tube; additional tests are planned. Work on the ejector concept focused on design, procurement, and fabrication of parts. Two types of ball conveyor tests were planned: static and dynamic. As part of the supporting analysis effort, the theoretical model of the ejector mixing section was reformulated; the first test rotor for the kinetic extruder was designed; and the standpipe ball conveyor model was developed, coded, and debugged. Work on the model of the fluid-dynamic lock was subcontracted. Other activities included design of the rotor drive system for the kinetic extruder and fluid-dynamic lock; preparation of layouts for the test loop facility; and review of plans, designs, and facility layouts.

Engineering and Technical Support to ERDA during the first quarter of 1976 focused on assisting with the clean boiler fuel demonstration plant program. This work included preparing a detailed cost estimate for the revised scope of work and reviewing RFPs for survey, soil, and topographic work. Among the engineering activities on the clean boiler fuel demonstration plant were reviews of detailed design packages, configuration management plan, and reliability and quality assurance plan. Preparation of a draft project management plan for the synthetic pipeline gas demonstration plant continued; preliminary evaluations of technical, economic assessment, and work breakdown proposals for this plant were completed and cost estimates prepared. Planning activities related to the fuel gas demonstration plant included participation in meetings pertaining to the RFP, model contract, and scope of work.

Technical Assistance Services to ERDA involved continued work on the conceptual designs of the Solvent-Refined Coal oil/gas, Fischer-Tropsch, and Coal-Oil-Gas (COG) plants. Capital cost estimates are being developed. The design of the 40,000-ton-per-day coal mine was completed and adapted to meet the approximately 50,000-ton-per-day requirements of the oil/gas complex. The conceptual design of the related coal preparation facilities for the Fischer-Tropsch plant was also completed, and a two-stage gasifier was selected for the complex. Coal liquefaction processes for the COG plant are being evaluated. Equipment development for gas-solid and liquid-solid separation and for solids feed to the gasifier continued. Process flow diagrams of the Fischer-Tropsch and oil/gas plants were evaluated for conformance to ecological requirements, water pollution effects of coal ash were investigated, and carbon monoxide emission control requirements were investigated. Several organizations were visited to review their environmental or laboratory facilities and capabilities.

I. CLEAN BOILER FUEL DEMONSTRATION PLANT

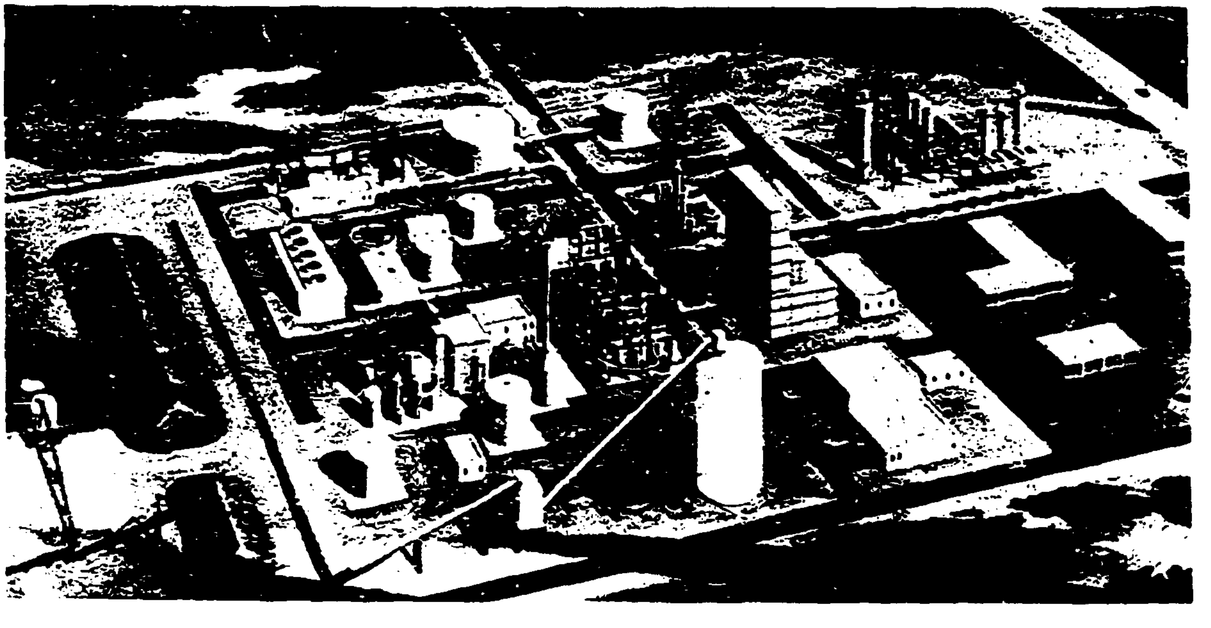
COALCON COMPANY

NEW YORK, NEW YORK

Contract No. E(49-18)-1736 Total Funding: $237,222,300

INTRODUCTION

Under ERDA's sponsorship, a demonstration plant for producing clean boiler fuels from high-sulfur coal is to be designed, constructed, and operated by Coalcon Company, an affiliate of Union Carbide and Chemical Construction Company. The plant must be fully integrated from the receipt of coal to delivery of a finished product, including cleanup of all waste streams and recovery of all potential by-products. Coalcon is organizing financial support for the program among private companies and public agencies. This consortium will provide 50 percent cost sharing of the plant construction, evaluation,



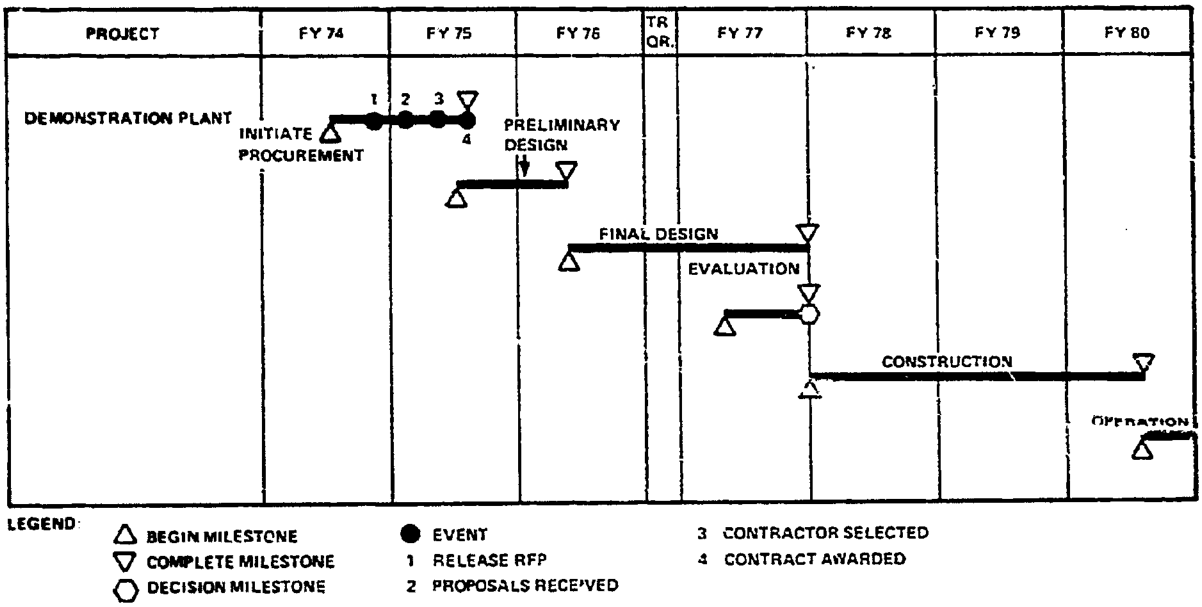


Figure I-1. CLEAN BOILER FUEL PROGRAM SCHEDULE

and operation. The government is funding design and engineering of the plant.

The overall objective of this contract is to design, construct, and operate this demonstration plant to verify the commercial economics, technical scale-up potential, and physical and chemical feasibility of a process for producing clean boiler fuel in a commercial-size, wholly integrated plant. The demonstration plant is to convert 2,600 tons a day of high-sulfur coal to 3,900 barrels per day of clean liquid fuel and 22 million cubic feet per day of high-Btu pipeline-quality gas. These products are to be evaluated for compatibility with existing power plant and boiler designs.

The project is being conducted in four phases. Phase I, preliminary commercial plant process design and engineering, involves (1) identification of characteristics and requirements for a plant for demonstrating, with minimum risk, the economic feasibility of future commercial plants (minimizing plant end-product costs is the major criterion) and (2) preparation of detailed process designs and a preliminary plant design for the demonstration plant. Phase II includes detailed demonstration plant design, engineering, and planning and preparation of detailed specifications, drawings, and a construction bid package. Phase III, the construction phase, includes site preparation, equipment purchase, construction, field erection, and plant acceptance and checkout. In Phase IV, the plant will be operated to produce synthetic products and to obtain data for evaluating the potential of this process for full-scale commercial development and production. Figure I-1 shows the schedule for this project.

PROCESS DESCRIPTION

The process selected by Coalcon for producing clean boiler fuel in the demonstration plant is Union Carbide's method for hydrocarbonization, which produces both liquid fuel and high-Btu pipeline-quality substitute natural gas. In this process (see Figure I-2) coal is crushed, dried, and preheated to 650° F in a stream of hot flue gas. The hot coal is separated from the flue gas by a cyclone separator and is admitted to the high-pressure processing system by means of lock hoppers. A hydrogen stream carries the coal into the hydrocarbonization reactor, where the coal mixes with additional hydrogen at high temperature and pressure. The hydrogen is supplied by a char gasification system. Hydrocarbonization consists of a combination of coal devolatilization and hydrogenation of the various constituents of the volatile matter. The partially converted coal remains as char.

The remainder of the system includes purification and separation of the components into various useful or waste fractions. Immediately after hydrocarbonization, the product gases are separated from the entrained char in a cyclone separator. The fractionator removes the heavy oil and a light oil fraction (mostly decane, toluene, and trimethyl benzene); ammonia is recovered from the gas stream by a wash system and is sold for fertilizer; hydrogen sulfide, carbon dioxide, and trace hydrocarbons are removed by an acid-gas removal system. As a final step, the gas is passed through a cryogenic system; a liquefied petroleum gas type fuel is removed from the gas stream, as is a hydrogen-rich fraction for recycling to the hydrocarbonization reactor. The remaining product is synthesis gas, primarily carbon monoxide and hydrogen, which is sent to a methanation reactor for enrichment to high-Btu pipeline-quality gas.

HISTORY OF THE PROJECT

Work under this contract began in January 1975. Tests in support of this program are being conducted at 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 determined; ultimate analysis of coal, char, and liquid products is being determined; and the major groups (phenols, bases, acids, etc.) in the liquid product are being determined. The in-house laboratories are performing proximate analysis of coal; determining the bulk and particle densities

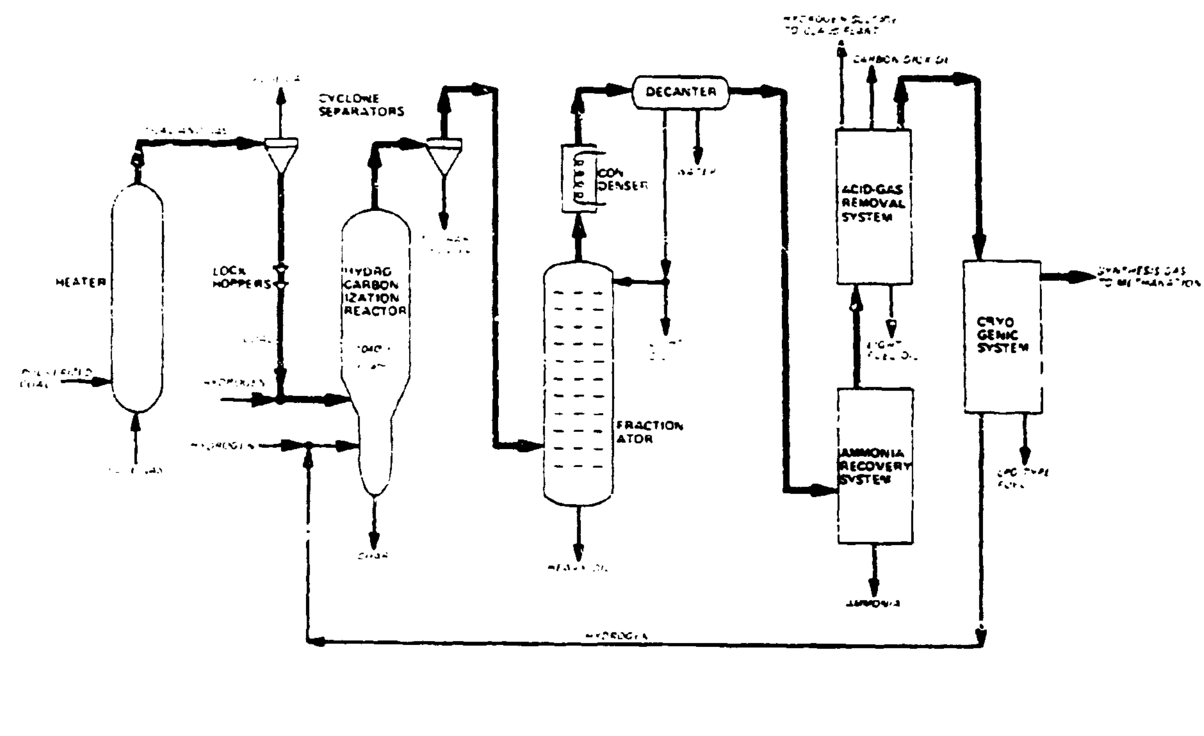


Figure I-2. HYDROCARBONIZATION PROCESS SCHEMATIC and size distributions of coal and char; calculating the simulated boiling-point distributions of products using data obtained from gas chromatography; determining the heating value of coal, char, and liquid products; analyzing gas products for major and minor components; and analyzing liquid products for major 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 mainly 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, flexibility, and reliability. By the end of 1975, design and engineering for the commercial plant were about completed. 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 operating on 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, based on economic, technical, and environmental studies. To support the demonstration plant design effort, tests were planned to resolve design problems.

Emphasis at the various test facilities was on designing, fabricating, and installing necessary equipment. By the end of the year, the minitest facility was nearly completed. The deagglomeration facility was completed, 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 JANUARY-MARCH 1976

Commercial Plant Design and Engineering

Process flow diagram revisions have been completed, with material balance summaries included for all sections.

Demonstration Plant Design and Engineering

The preliminary design basis for the demonstration plant is being updated based on information obtained from engineering studies, support development programs, and design activities. The preliminary system process design was developed from a design point that represented the available average composition data for Illinois No. 6 coal (the primary coal to be used in the test program) and projected reactor yield data. The base case design heat and mass balance, revised to incorporate data from subsystem design and development activities, provided a model that was expanded to include the range of applicability of the data.

Characterization of the Illinois No. 6 (Herrin), western Kentucky No. 11, and Pittsburgh seam No. 8 coal feedstocks was completed.

Detail process design for engineering packages has begun. Performance specifications, equipment lists, and process flow diagrams were issued for the coal handling, preparation, pressurization, and heating sections.

Engineering efforts for the primary processing sections of the plant focused on completing the design point heat and mass balances for hydrocarbonization, gas cooling and hydrocarbon separation, ammonia recovery, acid-gas removal, cryogenic hydrogen purification, methanation, and hydrogen production. These balances were revised during the quarter to incorporate ammonia rejection through decanter wastewater, a slight performance modification in the methanation section, and other minor changes.

Work on coal pressurization included documenting requirements for this section, and results and recommendations for the design of a simple two-lock-hopper system with single equalization; investigating the commercial availability of high-pressure filters and cyclones and high-pressure blowers for dusty gas; and developing a mathematical model of a lean-phase, entrained-bed coal heating tower and a preoxidation tower. Adsorption data for nitrogen in powdered coal were also measured. Up to 2 percent nitrogen adsorption in the coal powder is expected at coal heater and preoxidizer operating conditions. Because the presence of nitrogen could be a problem, a study was started to determine the most effective method for desorbing nitrogen from coal before reactor injection.

Work on developing a reactor design and process flow sheets for the hydrocarbon... ation unit involves evaluating:

- Fast injection based on prior experience and fluid coker reactor configuration.
- Fast injection into a turbulent bed to achieve desired char recirculation and internal dispersion.
- External hot char recirculation with coal injection into a recirculation loop.
- Preoxidation to operate with any of the above configurations.

Range of applicability studies currently in progress will provide the information required for performance specifications of both the hydrocarbonization and the cryogenic hydrogen purification units.

The design for gas cooling and hydrocarbon separation is being reviewed. In the fractionator design effort, difficulties associated with high-pressure operation (near critical) and thermal effects were experienced. Therefore, a revised design is being investigated.

Preparation of a preliminary specification on ammonia recovery was started, and arrangements are being made to subcontract the basic engineering package. The "Phosam-W" process will be used to extract ammonia from the decanter wastewater. (The decanter wastewater will contain 99.5 percent of the ammonia released by the hydrocarbonization reaction.) The acid-gas removal concept has been revised in favor of simultaneously studying sulfinol and cold methanol wash systems. A process specification issued for a cold methanol wash system covers an integrated system to take care of both the hydrocarbonizer circuit and the char gasifier products. Methanation and water-gas shift equilibrium computations were incorporated into the overall process model. Performance specifications and the process flow diagram for the methanation unit were reviewed with ERDA, revised, and reissued.

Specifications and requests for bids are being generated for the char burning and steam generation system. Coalcon intends to procure the entire basic process engineering as well as detailed engineering and equipment supply for this system. A performance specification is being prepared for subcontracting the Claus sulfur removal and recovery system, and a work package to provide total design of the Aqua Claus system was negotiated.

Char cooling process specifications based on quenching the char with organically contaminated process wastewater and using the evolved steam in the char gasifier were nearly completed. Since the approach involves using dirty steam in the char gasifier, the feasibility of using this system depends upon the gasifier selected. Using this method would allow Coalcon to eliminate the Phenosolvan, Phosam, fluidized-bed char cooling, and UNOX wastewater treatment units. This approach would simplify wastewater treatment requirements. Until the proposed system can be carefully evaluated, however, design of the wastewater treatment system is proceeding on the basis of handling organically contaminated water.

Process flow diagrams for gasification, gas compression, carbon monoxide conversion, and acid-gas removal in the hydrogen production system were updated. To assure reliability and availability of the total facility, initial work was predicated on a Koppers-Totzek gasifier. Recent information about the Koppers-Totzek gasifier, however, compared to a Texaco gasifier indicates that the latter is best for Coalcon's needs. Therefore, Coalcon currently is evaluating the risks and costs associated with the change from a Koppers-Totzek gasifier to a Texaco gasifier. To minimize the overall impact of a decision to switch to the Texaco gasifier, Coalcon is designing a Selexol system (required for the Texaco approach) as well as the Sulfinol system for acid-gas removal. Simultaneously, Coalcon is investigating the possibility of combining the acid-gas removal systems of the gas processing and hydrogen production sections into one cold methanol wash acid-gas removal system for the plant. A preliminary material balance for the Selexol unit has been completed.

Discussions were held with vendors to develop information on lead times of equipment for the water treatment system. Preparations are under way to obtain an engineering consultant for the water treatment system because of the unique water requirements of the clean boiler fuel program. A composite river water analysis was developed from historical river data.

Review of the preliminary performance specification for the cooling water system indicated that a 10° F approach between cooling water temperature and wet bulb temperature should be compared economically with an 8° F approach. The economic study was completed, resulting in a decision by Coalcon to use the 8° F approach, which provides a cooling water temperature of 85° F. In designing the direct-contact aftercooler for the oxygen plant, Coalcon decided not to use demineralized water as the cooling medium.

The preliminary summary covering the feed streams of the demonstration plant wastewater treatment unit is being evaluated. The results are being compared with analyses of wastewater samples from the deagglomeration facility to develop performance specification requirements. Meetings are being held with the Illinois EPA to determine effluent requirements for the wastewater treatment plant. Existing and proposed standards for wastewater treatment are being reviewed. Coalcon is considering the use of a phenol removal system in the process area of the demonstration plant and a tertiary purification step for final treatment of hydrocarbon-laden wastewater; a literature search for various methods of treating phenol-laden waste streams is in progress.

Facility Support

Minitest Facility

Construction of the minitest facility was completed and instruments were calibrated. Pressure testing of the facility was also completed, and the hot lines and vessels are being insulated.

The Illinois No. 6 coal feedstock for the test program was dried, ground, and screened, and a 4.5-ton supply of Wyodak coal was ordered. Tests have been planned to demonstrate the feasibility of feeding 30 pounds of coal per hour in dense-phase transport with the fluidized feeder. Coal feed rate will be calibrated against pressure drop across the coal feed line. The tests will be performed at preheater temperatures of 70° F and 660° F for pressure drops of 4.4, 7.8, and 11.2 atm at a hydrogen flow rate of 0.3 foot per second and char hopper pressure of 35 atm. For the tests, coal in the feed hopper is fluidized by hydrogen, then transported by additional hydrogen through the preheater to a char hopper. (Normally, coal is fed to the reactor, but for ease of operation in these tests, a char hopper replaces the reactor.) The weight of the coal in the feed hopper is measured by three load cells to determine coal feed rate. Pressure drop is defined as the difference between the hydrogen pressure in the feeder and that in the char hopper.

Deagglomeration Test Facility

Using hydrogen as process gas, eight runs (Run 19 through Run 26) were conducted in the deagglomeration facility to determine the amount of noncaking material that must be premixed with the feed coal to prevent agglomeration in the reactor. Runs 19, 20, and 21 were completed using one part Pittsburgh seam No. 8 coal diluted with two or four parts Wyodak coal. The results demonstrated that a 4-to-1 dilution of the highly agglomerating Pittsburgh coal with Wyodak coal can be processed successfully.

During a 5-hour run in February, about 60 pounds of Wyodak char was produced for an extended run using a 4-to-1 ratio of Wyodak char to Pittsburgh coal. The first attempt at the prolonged run, Run 22, lasted 90 minutes, terminating when the coal conveying line split and released hydrogen into the test cell. When attempts to complete Run 22 were plagued with coal feed stoppages, the inner diameter of the coal feed line was increased from 0.082 to 0.127 inch to alleviate the problem.

Run 23 was conducted successfully for 6 hours, feeding 187 pounds of the 4-to-1 char-to-coal mixture at a rate of 31.9 pounds per hour, with no apparent caking or agglomeration. A stabilized bed composition was achieved during the test. Several brief feed interruptions occurred that may have been caused by minute pressure fluctuations combined with the effect of a low fines content of the feed mix, but they did not cause operational upsets. Of the char recovered from the receiver. 55.3 percent was greater than 60 mesh, whereas none of the original feed char was greater than 60 mesh. The reactor walls and thermowalls were completely free of coke buildup.

Three additional runs (Run 25 using a 3-to-1 ratio of Wyodak char to Pittsburgh coal, and Runs 24 and 26 using a 2-to-1 char-to-coal ratio) experienced coking and agglomerating problems caused by insufficient dilution of the agglomerating Pittsburgh No. 8 coal with inert material.

Other Technical Support

Computer Processing

The computer program for calculating reactor thermal balances and computing hydrocarbonization heat of reaction at 77° F was completed and checked out. The demonstration plant is to be designed with a capability for heating reactor feeds to provide a thermal balance, even if an excess heat input (similar to that observed for a simulated pilot plant run this quarter) is required.

A data book on thermodynamic and physical properties was generated by computer. The book covers pressure and temperature ranges of interest for the 32 compounds used for simulating the process system. This computer data book will be used for modeling thermal calculations of the hydrocarbonization, gas cooling and hydrocarbon separation, ammonia recovery, acid-gas removal, cryogenic hydrogen purification, methanation, and hydrogen production sections of the plant.

A parametric study is being conducted using the computer process model to determine the effects of such factors as preoxidation and variations in coal composition and process yields on the process and equipment performance requirements. The results will be used to generate process specifications that include the required performance rangeability for all plant sections involved.

Coal Grinding

ERDA authorized Coalcon to start a coal grinding test program. A sample of Illinois No. 6 coal, obtained from Peabody Coal Company and consisting of run-of-mine coal and washed coal, was shipped to Williams Patented Crusher Company, St. Louis, Missouri. The coal is being tested to characterize the grinding conditions required to prevent the production of more than 10 percent –325 mesh coal. Tests made with a roll mill pulverizer appeared to produce more fines than expected. In an attempt to control particle size distribution, further tests were made using a hammer mill pulverizer. Results of the tests are being evaluated.

Agglomeration and Devolatilization of Coal

The degree of agglomeration and devolatilization that occurs when coal is heated and held or transported at elevated temperatures is being determined. Initial emphasis is on establishing the agglomeration tendencies of coal in the feed vessels and of coal fines in the holding vessels, cyclones, and piping. Tests were designed to provide specific data such as weight loss of coal; the amount of carbon monoxide, carbon dioxide, ammonia, sulfur dioxide, and hydrocarbons in the effluent; and the degree of agglomeration based on screen analysis and visual observation. Oxidized and unoxidized samples of each of three different types of coal are to be tested at five different temperatures ranging from 570° F to 750° F and pressures of 2 and 35 atm for 1, 2, 5, 10, and 20 minutes in hydrogen and nitrogen atmospheres.

Coal Heating

A coal heating test program was approved by ERDA this quarter. Coalcon currently is negotiating to subcontract the work. The test is to cover all process parameters believed to influence heat transfer fouling in a tube heat exchanger handling a hot gas that contains fine coal solids.

Reactor Heat Balance

Coalcon received verbal authorization from ERDA to proceed with a reactor heat balance test program. The work on this program was subcontracted to the Institute of Gas Technology (IGT). The computer program designed to compute the heat of hydrocarbonization of Illinois No. 6 coal will be used to process the experimental data and heat of combustion data that IGT is generating from Illinois No. 6 coal and char.

Lock Hopper Valve Development

Preliminary design of a valve test facility is under way. The present concept features several test legs in parallel, pressurization of individual test articles, heating of individual test articles to demonstration plant temperatures, and dense-phase fluidized recycle of the test medium. Preliminary design data will include physical size of the test rig, services required, operating cost estimates, and test cycle time. Functional valve specifications for the coal feed and char let-down lock hopper system have been sent to valve suppliers.

Wastewater Treatment

As part of the wastewater treatment test program, laboratory studies are being conducted to determine how easily the water can be treated. Characterization of wastewater samples taken from the deagglomeration facility is nearing completion.

Program Management

A proposed plot plan for the New Athens site was prepared, illustrating the probable location of the demonstration plant, the future expansion to a commercial facility, the ash pond for the demonstration plant, and the rights-of-way for the access road and rail line. The ash pond, designed to serve demonstration plant operations for 10 years, was designated on the plant layout with provisions for expansion, and the amount of overflow from the ash pond was estimated. Approval of proposed road and rail access to the plant is being sought from railroad and local authorities.

Work on property acquisition is continuing. The preliminary overall plant size was established, indicating that additional land is required at the demonstration plant site. Peabody Coal Company is to provide an additional drawing that will show maximum western and southern limits available for the plant. The real estate report has been submitted to ERDA.

Demonstration plant cost estimates are being prepared. Initial drafts of the configuration management plan were prepared. With a revised program plan identified, Coalcon has developed a data management system consistent with chemical industry practices to obtain and store vendor information that will be generated after procurement of equipment and systems. This vendor information is critical to the design of the facility and will be stored in the data control center that has been established for total control and retrieval of data and documents.

Formal subcontracts were processed for environmental analysis and soil investigation and for a topographic survey of the plant site. Existing and proposed standards that apply to coke and power plants were reviewed, and suggestions for clarification of Illinois standards were made. The EPA was contacted to obtain information on proposed levels of ammonia, carbonyl sulfide, and carbon disulfide. An environmental protection strategy statement was formulated and is being reviewed. Files of pertinent regulations are being developed.

Product Assurance

Coalcon expanded the reliability and quality assurance program plan to establish a product assurance program plan. Schedules and manpower loadings were revised to accommodate program revisions. Product assurance personnel established and updated the availability apportionment requirements for each section of the demonstration plant; subdivided the apportionment for the hydrogen production system because of the separate specification and procurement required for the char gasifier, carbon monoxide shift, carbon dioxide removal, and hydrogen compression units; and requested information concerning equipment reliability and maintainability from potential contractors of the various sections.

Among other activities, Coalcon reviewed performance specifications and process flow diagrams for the demonstration plant and investigated the reliability and quality of Koppers-Totzek and alternative hydrogen generation processes. Participation in the development of the design concept for the char burning and steam generation system included consideration of alternate configurations for furnaces and boilers. Vendors of char- and coal-burning furnaces are being contacted for information related to on-stream availability. Vendors were also contacted for information on the suitability of materials for heating hydrogen at about 42 to 49 atm; a study was completed that recommended the use of Incoloy 802 at operating temperatures up to 1,600° F.

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

INTRODUCTION

Coal feeders for coal gasification plants are to be developed through the pilot plant stage by Foster-Miller Associates, Inc., under ERDA sponsorship. The project recognizes that the coal feed is one element common to all gasification processes. However, no system available now 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 1/8 inch and less, from an atmospheric-pressure hopper into a gasifier, where pressure may be as high as 100 atm.

Feed methods being used in pilot and demonstration plants depend on the coal size and gasifier pressure. Low-pressure units use lock hoppers (which must be operated at low temperatures) with batch feeding of the coal. Slurry-feed techniques used in high-pressure gasifiers need energy to vaporize the liquid used to transport the coal. Both 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 costs.

PROGRAM DESCRIPTION

The project to develop coal feeders, started during May 1975, has three phases; it is to be completed by May 1977. By the end of 1975, the initial phase of this project, coal feeder concept study, was about completed. This effort included the preparation of a list of coal feeder requirements and an evaluation of existing feeders. The results show that there is no suitable dry coal feeder available that can operate with a gasifier pressure of over 20 atm. However, based on literature, patent reviews, and consultations with manufacturers, four feeder concepts coal plug feeder, centrifugal feeder, positive displacement feeder, and conveyor feeder—were selected for further study in the second phase of this project.

In Phase II, started late in 1975, critical components of the feeders selected in Phase I are being tested in the laboratory. The four different laboratory-scale feeders will be built, then tested for about 2 months. These tests will be conducted to determine how accurately the equipment controls the flow of coal, and whether it maintains stability, seals effectively against the gasifier pressure, operates economically in terms of equipment life and power requirements, and delivers coal having the desired characteristics to the gasifier. Data from laboratory research will be used to design feeders compatible with existing and projected pilot plant operations. The report on feeder evaluation, developed in Phase I, will be updated to include feeder performance, application range, projected capital and operational costs, and development risk. Recommendations will be made to ERDA for further development of promising feeder concepts.

During Phase III, feeder concepts that have a strong probability of being feasible on a commercial scale will be designed, built, installed, and operated in current or projected pilot plants, as directed by ERDA; feed rates will range from 3 to 5 tons an hour. The final report of this phase will contain design specifications, assembly and detailed drawings and procedures, installation and functional test procedures, and operation and maintenance manuals.

A fourth phase (not part of this contract), using the results of pilot plant testing, will likely include the development, design, fabrication, and delivery to ERDA of coal feeders compatible with demonstration plants. Feed rates in this phase should be 50 tons or more an hour.

PROGRESS DURING JANUARY-MARCH 1976

Coal Feeder Concept Study

The Phase I program effort was concluded with completion of the Phase I report. The report, which includes detailed descriptions of candidate feeder concepts, was reviewed by ERDA during the quarter and approved for publication.

Laboratory-Scale Coal Feeder Development

Preliminary layouts of the laboratory-scale coal plug and positive displacement feeders were completed. Component testing is proceeding on the coal plug feeder, centrifugal feeder, and positive displacement feeder concepts.

Assembly of the component test rig for the coal plug feeder was completed this quarter. The results of initial tests to quantify the performance of a compacted coal plug as a pressure seal were encouraging. Leakage rates for coal plugs formed and fed against backpressures exceeding 68 atm were substantially less than vent losses from a dual lock hopper system. Additional objectives of the coal plug feeder tests are to minimize the power requirements of a plug feeder and optimize coal feeder passage geometry.

Component testing of the coal plug has included feeding of coal compacted to 1,020 atm against a backpressure of about 70 atm. Attempts to lower the high compaction pressures of the straight section feeder have been limited by friction forces that raise the pressure required to move the plug. Therefore, expanding taper feeder sections are being tested; these tapered sections decrease the friction forces that must be overcome in plug feeding and, simultaneously, provide a check-valve effect to prevent backward movement (blow-out) of the coal plug. To date, coal at a compaction pressure of 545 to 681 atm has been fed against a 35-atm backpressure in tests with the tapered sections. Feeding also has been accomplished at backpressures up to about 70 atm, but stability problems were encountered.

Assembly of the zero pressure differential centrifugal feeder model was completed. The design of the model was modified to accommodate feed against small pressure differentials (to about 2 atm). This model will be used to investigate coal flow from a supply point to the feeder eye, transition flow from the feeder eye into the feeder sprues, and coal flow in the feeder sprues. In preliminary testing, the unit fed uniformly but output was less than theoretical predictions. After evaluation of test data indicated the coal flow was choked at the sprue inlet, sprue shapes were revised. Further testing showed that a bi-stable feeder flow condition exists: a high-rate streaming flow condition in which the feeder sprue is only partially filled and a lower flow rate that is choked at the sprue outlet. The latter flow condition is necessary for successful performance of a pressure feeder. Changes in feeder design necessary to ensure that the feeder always operates in the choked outlet mode were identified.

A Megatech glass engine was procured and modified so that it would operate as a positive displacement feeder. Assembly of the positive displacement feeder model was completed, and the peripheral equipment necessary for testing the unit was designed and partially fabricated. The unit, operating without peripherals, has conveyed hand-fed coal.

Limited testing was conducted to evaluate the dynamic sealing potential of a twin-screw feeder concept. Results to date have not been encouraging.

The components, drawings, and background data for a cold feeder test loop, designed by Petrocarb, Inc., for a previous feeder development program at Bituminous Coal Research, Inc. (BCR), were received in January. Foster-Miller personnel met with BCR personnel to obtain detailed information on the BCR feeder test loop. As a result, the time required to make the test loop operational probably will be shortened substantially.

The basic layout for the feeder test loop was completed. The layout and a parts list were submitted to ERDA for approval to procure equipment. Detail design of Foster-Miller modifications to the BCR test loop is continuing, and bids are being sought. The basic test loop is a batch system that will allow feeder operation for 10 to 15 minutes; the next stage of development will include additions to provide for continuous feeder operation at rates up to 5 tons per hour.

A study is being conducted to determine if technology within the briquetting industry is relevant to the Foster-Miller coal plug feeder development effort. Efforts to date have revealed no significant potential for technology transfer.

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

INTRODUCTION

A continuous dry coal screw feeder is being developed for compatibility with existing and projected pilot plant operations by Ingersoll-Rand Research, Inc., under the auspices of ERDA. Ultimately, Ingersoll-Rand is to recommend coal feed injector equipment that will be compatible with projected demonstration plant requirements. The engineering and economic feasibility of the candidate coal feed injector will be evaluated throughout the development. A successful continuous dry coal feeder could be used widely in, for instance, gasification plants that produce high-Btu pipeline-quality gas or low-Btu gas that would supply combined-cycle electric power generation stations, and in gasifiers used to supply hydrogen for coal liquefaction plants.

PROGRAM DESCRIPTION

Tests by Ingersoll-Rand indicated that it would be feasible to use a screw feeder in commercial coal gasification and liquefaction plants in place of pressurized lock hoppers and slurry systems. Under its contract with ERDA, started in July 1975, Ingersoll-Rand is conducting a three-phase development program to refine and scale up a screw feeder to be compatible with a demonstration plant. Basically, the feeder being developed is a modified injection molding machine, operating like an extruder.

Work on Phase I, coal feeder concept study, during 1975 included a determination of coal feeder requirements imposed by several coal gasification processes being considered for future commercial operation and the establishment of optimum conditions for a coal feeder system. A survey of manufacturers showed that no commercial equipment now available is suitable to use for coal delivery at the high pressures and temperatures of future gasification systems. As a result of a limited patent search, however, two concepts involving the use of piston feeders were found; these might be adaptable to the delivery of coal to gasifiers. Conceptual designs of two adaptations of piston feeders were prepared during 1975.

To compare the systems being evaluated, technical and economic criteria were established. A comparison of the operating costs of existing coal feed techniques (lock hopper and slurry pump) with those of the dry coal screw feeder and piston feeders indicated that the latter was an acceptable technique for coal delivery to high-pressure gasifiers.

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In Phase II, critical components of the equipment selected in Phase I are being tested, and two laboratory-scale, coal feeder prototypes—one using a Negri-Bossi V-12 injection molding machine and the other using an IMPCO 1500 machine—are being designed, fabricated, and tested. Among the characteristics to be studied are feeder stability and controllability, seal effectiveness, coal metering accuracy, life expectancy of critical components, mechanical power requirements, and methods for reducing the feed coal to a size compatible with process requirements. The data resulting from laboratory tests will be used to design feeders compatible with existing and projected pilot plant operations. Recommendations will be made to ERDA for further development of promising screw feeder concepts.

Phase III will involve the installation and operation of the IMPCO screw feeder in a pilot plant selected by ERDA. Feed rates during this phase will range from 0.5 to 5 tons an hour. A report will also be written, and will include design specifications, installation drawings for the selected pilot plant, assembly procedure, installation and functional test procedures, and an operation and maintenance manual. Feeder performance in the pilot plant tests will be judged, based on the test data, and a final report will be prepared; this report will include an engineering design of equipment sized for a demonstration plant.

A fourth phase (not part of this contract), using the results of pilot plant testing, will probably include the development, design, fabrication, and delivery to ERDA of coal feeders compatible with demonstration plant requirements. Feed rates in this phase will be 50 tons or more an hour.

PROGRESS DURING JANUARY-MARCH 1976

Coal Feeder Concept Study

During the first quarter of 1976, a third new concept for coal feed to high-pressure gasifiers—a rotary-valve piston feeder—was identified. (Two concepts were identified and described in the previous quarter: a single-acting piston feeder and a double-acting piston feeder.) The rotary-valve piston feeder uses a hollow cylinder, situated in a cylindrical body, which is perforated at one end to admit coal to be delivered. The cylinder is restrained from axial motion and is caused to rotate on its axis by a rotary actuator to fill and deliver coal alternately. Coal falls by gravity from a hopper and through the perforated wall into the zone bounded by the walls and end of the hollow cylinder and the face of the piston positioned within the hollow cylinder. Gasifier pressure is sealed by stationary seals around the ports to prevent blowback through the hopper. To deliver coal, the cylinder is rotated 180 degrees. Following delivery, hydraulic pressure translates the piston into the cavity previously charged with coal to expel the pressurized gas back into the gasifier without loss. The cycle is completed by simultaneous retraction of the piston and rotation of the hollow cylinder back to the fill position. Power is required for rotation of the cylinder and linear actuation of the piston.

The operating cost for the rotary-valve piston feeder was established. The comparative operating cost analyses performed previously for existing feed systems and the several new concepts were refined and the method of analysis was expanded. The operating costs indicate that the piston feeder is an attractive technique for coal delivery to high-pressure gasifiers.

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 qualitatively and quantitatively, when possible, with new feed system concepts (the single-acting, double-acting, and rotary-valve piston feeders and a screw feeder). 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 shows advantages over existing methods. A proposal is to be submitted for further evaluation of the piston feeder concepts.

A report documenting the efforts and results of the Phase I program was completed and submitted to ERDA for review.

Laboratory-Scale Coal Feeder Development

Architectural, mechanical, and electrical drawings and specifications were completed for construction of the test facility for the IMPCO and Negri-Bossi dry coal screw feeders within an existing Quonset building at Ingersoll-Rand. With ERDA's approval, construction began in March and is proceeding as scheduled, with completion expected in April 1976.

A functional test of the Negri-Bossi V-12 screw feeder was conducted satisfactorily at Ingersoll-Rand's Plastic Machinery Division in Nashua, New Hampshire, before it was shipped to Ingersoll-Rand's New Jersey facility. The layout that will be used for studying modifications, alternate design approaches, etc., was completed.

Preparations for the initial test operations continued. Equipment such as the solenoids, check valves, regulator, methane monitor, muffler, pressure gauges, piping, and hoses were mounted on the instrumentation panel. Operation of each test component was verified. The pressure vessel capacity was increased by 50 percent. The sieve shaker operation was checked out and high-volatile coal received from West Virginia was sized up to 32 mesh; arrangements are being made to procure and size different types of coal. Manufacturing drawings of alternate screw designs were completed, and fabrication was started.

The IMPCO screw feeder and all long-lead-time items such as the explosion-proof motor have been ordered. The necessary modification in the hydraulic and electrical engineering area is 80 percent completed, including safety requirements for operation in a coal dust environment. Mechanical engineering work has begun.

Preliminary design and engineering of the IMPCO screw feeder test system were started. Problem areas, such as the coal receiver, coal disposal, and safety during testing, were identified, and various alternatives are being considered to solve the problems. Definition of preliminary requirements for the coal receiver included:

- A coal flow rate of 1 to 5 tons per hour.
- A pressure rating of about 100 atm.
- Use of nitrogen as the pressurization gas.
- Adaptation to the injection assembly of the IMPCO screw feeder.
- Seals at the receiver/screw discharge interface that are capable of withstanding temperatures as high as 500° F.
- A discharge port capable of opening quickly for removal of pumped coal.
- A capability for retractability from the injection assembly for inspection and service.

A primary consideration in the design of the coal receiver is the establishment of a method for removing pumped coal with minimal pressurization gas loss and downtime. Several concepts are being examined with emphasis on reliability, complexity, design and engineering effort required, and initial and operating costs.

IV. COAL FEEDER DEVELOPMENT PROGRAM

LOCKHEED MISSILES AND SPACE COMPANY, INC.
SUNNYVALE, CALIFORNIA

Contract No. E(49-18)-1792 Total Funding: $108,186

INTRODUCTION

Lockheed Missiles and Space Company, Inc., a subsidiary of Lockheed Aircraft Corporation, is conducting a coal feeder development program under ERDA's auspices. There is a need for this effort because lock hopper or slurry concepts for coal feeding are inadequate with respect to pressurization power losses, efficiency, maintenance, service life, feed rates, and capital investment requirements. Because 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 for all processes using pulverized dry coal at reactor pressures up to 100 atm must be developed.

PROGRAM DESCRIPTION

Work under this program to develop improved methods for continuously feeding dry, pulverized coal into pressurized coal conversion reactors began in July 1975. The program is divided into three phases. The initial phase, the coal feeder concept study, was nearly completed by the end of 1975. Seven major types of solids handling systems were identified through a literature survey and patent search. Four systems were considered to be reasonable candidates for further development: fluid-dynamic lock, kinetic extruder, ejector, and ball conveyor. These systems apparently offer potential technical advantages over lock hoppers and slurry systems and are economically competitive. The fundamental problem areas of these four candidate systems were assessed, and techniques were defined for studying and resolving these problems in Phase II of this program.

Initiation of Phase II, laboratory-scale feeder development, was authorized in December 1975. In Phase II, Lockheed will conduct laboratory tests of critical components of the equipment selected in Phase I. Target specifications for the design are feed rates of 0.5 to 1 ton an hour, pressures of 6.8 to 100 atm, feedstock sizes of fine to 1/8 inch, and temperatures as determined in Phase I. In addition, coal feeder prototypes will be designed, fabricated, and tested for stability and controllability, seal effectiveness, coal metering accuracy, life expectancy of critical components, mechanical power requirements, and characteristics of the prepared coal. Data resulting from testing will be used to design feeders compatible with existing and planned pilot plant operations. Recommendations will be made to ERDA for further development of promising feeder concepts.

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During Phase III, feeder concepts having a strong probability of being commercially feasible will be designed, fabricated, and operated in existing and projected pilot plants. Feed rates for these feeders probably will be 3 to 5 tons an 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 engineering design of equipment for a demonstration plant will be prepared.

A fourth phase (not part of this contract), using the results of pilot plant testing, is envisioned to include development, design, fabrication, and delivery to ERDA of coal feeders compatible with demonstration plants. Feed rates in this phase likely will be 50 tons or more an hour.

PROGRESS DURING JANUARY-MARCH 1976

Coal Feeder Concept Study

The Phase I final report was completed, reviewed by ERDA, and approved for release.

Laboratory-Scale Coal Feeder Development

Four coal feeder systems are being studied in Phase II: fluid-dynamic lock, kinetic extruder, ball conveyor, and ejector. (Lockheed had indicated previously that an injector, rather than an ejector, would be studied. Further analysis of the injector late in the fourth quarter of 1975 indicated, however, that it was not a reasonable candidate because of its high energy requirements.)

To establish a firm basis for the design of the coal feed systems for use in commercial plants, Phase II 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.

Schedules for the Phase II program were revised to accelerate hardware design and procurement so the test program can begin in August rather than October 1976.

Lockheed selected a design for an ejector that should transfer coal from atmospheric pressure to a reservoir at about 2.5 atm, at a maximum rate of about 720 pounds per hour. The analysis predicts that a primary air supply of about 380 pounds per hour at 5 atm is required to drive the ejector at maximum efficiency. To simplify the coal-air entrance geometry, an annular jet ejector configuration was selected for initial investigation. The laboratory test hardware is being designed.

Preliminary experiments with dense-phase flow of gas-solid mixtures were done during the quarter to assist planning for additional laboratory hardware and tests and to provide an initial correlation with literature results. Dense-phase flow from a bed (with an internal diameter of 3.77 inches) of sodium chloride fluidized with air was established through a flexible neoprene tube (22.5 by 0.128 inches) by pressurizing the fluidized bed slightly to establish a pressure difference across the feed tube. A funnel-shaped flare on the feed tube inlet was used to decouple the feed tube inlet from the bubble phase in the fluidized bed. A steady salt flow rate of about 50 pounds per hour was achieved with a feed tube pressure difference of about 1.24 atm. The feed rate changed very little during large variations in bed height and fluidizing gas velocity. The experimental data, coupled with conclusions reached by other investigations, suggest the possibility of developing a reliable, fast-response flow meter for dense-phase coal flow based on measurement of pressure drop across a portion of the coal feed tube. Additional tests are planned to:

- Calibrate the dense-phase feed and transfer system, obtaining data such as flow rates of solids and gases as a function of pressure drop across the feed tube, bed height, fluidizing gas flow rate, solid-particle-size distribution, and gauge pressure drop.

- Determine ejector performance with gas-gas single-phase operation.
- Determine ejector performance with gas-solid two-phase operation.

Detailed designs of components were completed for laboratory investigation of dense-phase pneumatic transport of pulverized coal and the ejector or jet-pump concept for dry coal pressure feeding. Hardware is being procured. Installation of equipment for solids transport studies was completed, and check-out runs with inert solids were started. Fabrication of machined parts for the ejector mixing and diffuser section is behind schedule.

Two types of ball conveyor tests are planned:

- Static tests designed to observe the flow of gases through a column of packed spheres and coal to determine the coal-bed characteristics. The variables to be investigated are coal-bed packing density, diametral clearance, and pressure drop across the bed.
- Dynamic tests designed to observe the behavior of the column while moving at the expected velocity. Coal-bed properties, diametral clearance, and column velocity are to be investigated. The force on the piston will be determined to permit calculation of frictional forces.

Fabrication and procurement of parts for the ball conveyor laboratory equipment are nearly completed. Assembly of the test setup is also nearing completion. Instrumentation for both the static and the dynamic tests has been completed, and the first tests with coal are scheduled for April 1976.

Supporting analysis efforts involved work on all four feeder system concepts:

- The theoretical model of the ejector mixing section was reformulated to eliminate an arbitrary temperature ratio selection problem.
- The first test rotor for the kinetic extruder was designed. Contacts with workers active in the field of particle flow dynamics have not yielded information beyond that already considered in development of the existing kinetic extruder flow model.
- Development, coding, and debugging of the standpipe ball conveyor model were completed. Basic inputs to the model are number of balls, sizes and clearances, ball speed, gasifier pressures, temperature, coal porosity and permeability, gas properties, and fraction of flow area betwcen each bed that is blown (channeled). Model runs made to date indicate that, if channeling occurs, flow through the channels accounts for 90 to 99.5 percent of the net gas leakage. If the standpipe pressure gradient is approximately uniform as required, gas leakage is fairly significant. To minimize leakage, a distribution with a small pressure drop near the top of the pipe is needed; controlled gas flow can provide this small pressure drop.
- Work on the model of the fluid-dynamic lock has been subcontracted. The effort involves development of a mathematical model to describe two-phase flow through a bladeless radial flow compressor.

Design work during the quarter focused on the rotor drive system for both the kinetic extruder and the fluid-dynamic lock. The design will be released on a component basis so that material procurement and manufacturing can be started.

The test loop facility will be located in Building 150 of the Lockheed plant in Sunnyvale, California. Layouts were prepared for equipment location and preliminary sizing. Tank support structures are being designed. Plans for instrumentation to record test data are being formulated. The bid package for the pressure vessels was released to qualified vendors.

Manufacturers of critical components such as seals, bearings, and valves were contacted to determine availability of equipment. Consideration is being given to using existing components, if applicable; for example, an existing air turbine capable of delivering 35 horsepower at 20,000 rpm could power initial tests of the fluid-dynamic lock and the kinetic extruder.

Product assurance and safety efforts were devoted to review of plans, designs, and facility layouts. A preliminary analysis of hazards was prepared to establish safe test setups and operational procedures. The ball conveyor test equipment and proposed operating procedures were also reviewed.

V. ENGINEERING AND TECHNICAL SUPPORT

HUNTSVILLE DIVISION
U.S. ARMY CORPS OF ENGINEERS
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 Corps of Engineers is providing ERDA with engineering and technical support related to demonstration plant design and construction and to the procurement of equipment with long lead times. This support, begun in mid-1974, involves the services of the Army's engineering forces to provide technical services for facility design, construction, and related support as requested by ERDA. Demonstration plant assistance requests are made in the form of task assignment letters describing the scope of services desired. The task letter defines the specific function requested, enumerates the contract responsibilities, indicates the proposed location of the project, defines the funding limitations, and designates the individual or office responsible for furnishing any requested ERDA inputs, directions, or approvals. ERDA is billed by the responsible field operating agency for actual expenses incurred monthly.

PROGRAM DESCRIPTION

Under the current task letter, the Corps of Engineers is supporting ERDA in advance planning for several demonstration plants and preliminary engineering for the clean boiler fuel demonstration plant (see Section I). The scope of services requested is:

Advance Planning

- Help prepare requests for proposals (RFP) for new demonstration plants.
- Take part in reviewing and evaluating proposals received in response to the RFPs.
- Perform special studies, such as specific concept designs, relating to design and construction on a task basis.

Preliminary Engineering

- Review and/or prepare design criteria.

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

The Corps of Engineers was also asked to procure long-lead-time items for the Coalcon clean boiler fuel demonstration plant. The Huntsville Division was designated as the field operating agency responsible for these tasks.

PROGRESS DURING JANUARY-MARCH 1976

Planning

A detailed cost estimate was prepared for the revised scope of work for the clean boiler fuel demonstration plant, which is to convert 2,500 tons of high-sulfur coal per day to clean liquid boiler fuel and to high-Btu pipeline-quality gas using the Union Carbide hydrocarbonization process. The Corps of Engineers also participated in a review of the estimate with ERDA. RFPs for survey, soil, and topographic work for the Coalcon plant were also reviewed.

Activities related to the synthetic pipeline gas demonstration plant that will convert high-sulfur coal to clean high-Btu pipeline-quality gas included helping ERDA prepare a project management plan describing ERDA management of the program and relationships of ERDA, other government agencies, and the contractor(s). Preliminary evaluations of technical proposals for the synthetic pipeline gas demonstration plant were completed by the technical advisory committee, questions were prepared and sent to the offerors, and oral presentations by the offerors were held. Preliminary evaluations of economic assessment and work breakdown proposals were completed. Cost estimates for each proposal were prepared and submitted to ERDA.

The Corps of Engineers participated in a final meeting to review and incorporate comments into the final draft of the RFP and model contract for a fuel gas demonstration plant that will convert high-sulfur coal or lignite into a clean low-Btu fuel gas. Other activities during the quarter included participation in a preproposal meeting at ERDA and in a meeting at Mound Laboratory, Miamisburg, Ohio, to review the scope of the effort and establish operational facilities for the project.

Engineering

The Corps of Engineers, ERDA, and Coalcon met to review the completed design packages for the clean boiler fuel demonstration plant. Package content was defined and schedules established. ERDA and Coalcon responded favorably to the level of review of detailed design proposed by the Corps of Engineers. During the quarter, review conferences on process flow sheets for five process systems were conducted. Also, the Corps of Engineers reviewed the Coalcon configuration management plan and reliability and quality assurance plan, participated in the Coalcon quarterly review, and participated in a task force meeting on environmental impact statements.

VI. TECHNICAL ASSISTANCE SERVICES

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

Contract No. E(49-18)-1775 Total Funding: $2,990,892

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 solid fuels from coal. Under this program, started 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 construction problems, in-

cluding 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 main tasks: develop conceptual designs and economic evaluations of commercial plants, and do 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. The COED design was completed by the end of 1975, and designs of the oil/gas, Fischer-Tropsch, and COG plants were well under way. The design, equipment specifications, and capital cost estimate of a 40,000-ton-per-day mine were also completed during 1975.

Parsons, at its own expense, is developing a computerized process simulation program that can estimate 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 fuel production, are being considered, along with the associated units for power generation and waste treatment. Another evaluation consists of a study of materials for equipment to determine what is preferred for use in coal conversion processes. Parsons is also determining what facilities are 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 for ERDA.

PROGRESS DURING JANUARY-MARCH 1976

Conceptual Designs of Commercial Plants

Work to change the design of the SRC-based oil/gas plant to include a 2-to-1 oil-to-gas ratio continued. A 50,000-ton-per-day coal mine was designed to supply the oil/gas complex, and the capital costs were estimated; design of the related coal preparation facilities continued. All basic process designs, process flow diagrams, and process input for equipment sizing and specifications for the complex were completed. Some changes incorporated were the use of vacuum filters in the dissolver design, the addition of a third shift reactor to the shift unit to control the ratio of hydrogen to carbon monoxide, and the addition of a second side stripper to the distillation unit so that the unit now is capable of producing naphtha, light fuel oil, wash oil, and bottoms (boiling above 400° F). Parsons selected a liquid phase methanation process, completed design calculations for the methanator, completed a preliminary overall utility balance, and initiated the final review of all unit material balances. Preparation of a list of catalyst and chemical requirements for the complex, estimation of capital costs, and selection of construction materials is continuing.

Material and energy balances and a preliminary utility balance for the Fischer-Tropsch plant were completed. The design, specifications, and capital and operating cost estimates for the 40,000-ton-per-day coal mine and related coal preparation facilities for the Fischer-Tropsch complex were completed, in addition to the process flow diagrams, equipment specifications, and capital cost estimates for the coal storage, grinding, and drying units. Capital cost estimates for the process units were started. A quantitative economic comparison of the capital and operating costs of single-stage and two-stage gasifiers indicated a potentially lower product cost for the latter; therefore, the two-stage gasifier was chosen for the Fischer-Tropsch plant design. Construction materials for the plant are being selected. A draft was prepared that describes the products expected from the plant and lists the properties and market specification for each product.

The comparative evaluation of coal liquefaction processes for the COG plant continued. The scope and objectives of the program are being defined. Cost, yield, and utility data are being developed for the H-Coal and Synthoil processes and for four SRC processes. Block flow diagrams, material balance calculations, some equipment specifications, and factored cost estimates for selected processes were prepared.

Technical Evaluations

Equipment development continued this quarter. Conceptual configurations and capital cost and power requirement estimates for ground coal compression screw feeders were obtained from equipment manufacturers; preparations for tests at 11 atm were started.

Additional information was received on the gas venturi scrubbers for the Fischer-Tropsch process and on the dry and wet electrostatic precipitators designed for vacuum service. Parsons requested that a rotary pressure filter cake sample, without solvent, from the SRC pilot plant be submitted for expeller tests and that samples of filter cake with solvent be submitted for turba-film vacuum evaporator tests.

Other activities included evaluation of process flow diagrams of the Fischer-Tropsch and oil/gas plants for conformance to ecological requirements, investigation of water pollution effects of coal ash, and investigation of requirements for carbon monoxide emission controls in states where coal conversion facilities could be located. The SRC plant in Fort Lewis, Washington, was visited to review its environmental facilities and procedures. Parsons visited several organizations to evaluate their facilities and capabilities for investigating the engineering properties of materials for coal conversion.

GLOSSARY

The intent of this glossary is to give a general definition of terminology as used in this report. A glossary is considered desirable because of the diverse origin of the technology and broad spectrum of potential readers. For more precise and detailed definitions, the reader is referred to *The Annual Book of ASTM Standards* published by the American Society for Testing Materials (ASTM), *Chemical Engineers' Handbook* by R. H. Perry and C. H. Chilton, and *A Dictionary of Mining, Mineral, and Related Terms* published in 1968 by the U.S. Department of the Interior.

Å – Angstrom unit, a unit of length equal to 10^{-10} meters or 10^{-4} microns, generally used as the unit for describing interatomic distances, as an example, the carbon atoms in diamond are 1.5 Å apart.

absorption – the dissolution of a gas in a liquid.

acceptors – calcined carbonates that absorb carbon dioxide evolved during gasification, exothermically.

acid-gas removal – a section of a gas plant where hydrogen sulfide and carbon dioxide are removed from the 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 physical and chemical adherence of a gas to the surface of a solid.

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

anode carbon – carbon of high purity, usually crystallized to graphite form, widely used in Leclanche cells, in rods for alumina refining, in electric arcs and nuclear reactors.

anthracite coal – any coal containing 86 to 98 percent fixed carbon, on a dry, mineral-matter-free basis.

aromatic hydrocarbon – an unsaturated cyclic hydrocarbon containing one or more six-carbon rings.

ash – theoretically, the inorganic salts contained in coal; practically, the residue from the combustion of dried coal that has been burned at 1,380° F.

autoclave – a vessel, constructed of thick-walled steel (alloy steel or nickel alloys), for carrying out chemical reactions under pressure and at high temperatures.

bench-scale unit – a small-scale laboratory unit for testing process concepts and operating criteria 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 noncoking coals.

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

blow down – the removal of liquids from a process vessel by the application of pressure

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, toluene is methyl-benzene, xylene is dimethyl benzene

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

calcine – to heat a solid to a high temperature to cause the decomposition of hydrates and carbonates.

carbon fiber – very fine filaments about 8 microns in diameter which are used in composite materials, being bound with resins.

carbonization – the destructive distillation of coal in the absence of air accompanied by the formation of char (coke), liquid (tar), and gaseous products.

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 to separate solids from liquids, e.g., undissolved residue from coal solution in the SRC process.

char – the solid residue from coal after the removal of moisture and volatile matter, i.e., essentially ash plus fixed carbon.

Claus process – a process for recovering elemental sulfur from hydrogen sulfide gas, utilizing a brick-work kiln, at high temperatures with oxygen reacting with the hydrogen sulfide to yield dry sulfur and steam.

closed cycle – a thermodynamic power cycle in which the working fluid is recycled.

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coal — a natural solid material consisting of amorphous elemental carbon with various amounts of organic and inorganic compounds.

coke — a solid consisting primarily of amorphous carbon having certain properties of strength, cell structure, and minimum impurities, and manufactured by the thermal decomposition of petroleum residues and certain types of coal.

coke breeze — coke particles smaller than 1/2 inch in size.

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

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

combustor — a vessel in which combustion of gaseous products from a fuel takes place by the chemical union of oxygen with the gas.

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 — gas produced in a gasifier containing a wide range of impurities, also known as offgas.

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 draining naturally occurring methane from coal seams.

delayed coking — a process whereby coal is subjected to a long period of carbonization at moderate temperatures to form metallurgical coke.

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

demonstration plant — a plant whose design is based on data derived from pilot-scale testing, of sufficient capacity to demonstrate the large-scale feasibility of a process.

depolymerization — the change of a large molecule (e.g., coal polymers) into simpler molecules (e.g., aromatics, BTX), usually accompanied by the substitution of hydrogen for oxygen.

destructive distillation — the distillation of coal or other solids accompanied by their decomposition, destructive distillation of coal yields coke, tar, ammonia, gas, etc.

desulfurization — the removal of sulfur from hydrocarbonaceous substances by chemical reactions. Various processes are Claus, Appleby-Frodingham, C.S.I.R.O., ferric chloride leaching, Kennecott.

devolatilization — the removal of a proportion of the volatile matter from medium- and high-volatile coals to prevent subsequent caking.

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

distillation — a process of evaporation and recondensation used for separating liquids into various fractions according to their boiling points or boiling ranges.

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

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

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

economizer — a heat exchanger for recovering heat from flue gases and using it to heat feedwater or combustion air.

effluent gas — gas issuing from a gasifier or combustor.

electrode carbon — see anode carbon.

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

endothermic — a process in which heat is absorbed.

enthalpy — a form of thermal energy defined as the sum of the internal energy of a system plus the product of the system's volume and pressure.

entrained bed — a bed in which solid particles are suspended in a moving fluid and are progressively carried over in the effluent stream.

entrained flow — see entrained bed.

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

exothermic — a process in which heat is liberated.

extraction — a process for dissolving certain constituents of a mixture by means of a liquid with solvent properties for selected components only.

extraction-hydrogenation — extraction carried out in the presence of hydrogen either as a gas or derived by transfer from hydrogen donor solvents.

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

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, diatomite.

Fischer assay — an assay for the determination of oil (tar) yields from coal or oil shale; conducted in a retort under an inert atmosphere with a gradual increase in temperature.

Fischer-Tropsch catalyst — iron and cobalt catalysts developed by Fischer and Tropsch for the catalytic synthesis of liquid fuels from coal-derived synthesis gas.

fixed bed — solid particles in intimate contact with fluid passing through them, but too slowly to cause fluidization.

fixed carbon — theoretically, the carbon content of coal which exists in the elemental state; practically, the difference between 100 percent and the sum of ash, moisture, and volatile matter percentages.

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

flue gas — gas issuing from a combustor, either exhausted to atmosphere or expanded through a gas turbine.

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) — solid particles transported by a high-velocity fluid stream with little or no solid interaction.

fluidized bed — a bed through which a fluid is passed with a velocity high enough for the solid particles to separate and become freely supported in the fluid.

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; an effective separation can only be achieved by the use of fractionating columns attached to the still; also called fractional distillation.

freeboard — the space in a fluidized-bed reaction 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.

Freidel Crafts catalyst — the catalyst employed in the synthesis of benzene hydrocarbons by the action of alkyl halides on aromatics in the presence of anhydrous aluminum chloride.

fuel cell — a galvanic cell in which the oxidation of a fuel (e.g., coal) is utilized to produce electricity.

fuel gas — low heating value product generally utilized on-site for power generation or industrial use.

gasification of coal — the conversion of solid coal into a gaseous form by any of a variety of chemical processes.

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

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

high heating value (HHV) — the heat liberated during a combustion process in which the product water vapor is condensed to a liquid.

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

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

hydrocyclone — 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.

hydrogasification — gasification that involves the addition of hydrogen to the products of primary gasification to optimize formation of methane.

hydrogenation — chemical reactions involving the addition of hydrogen, present as a gas, 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 evolution of liquid products of lower boiling range which are then taken up by the solvent.

hydrotreating — a process involving the reaction of hydrogen with hydrocarbon mixtures for the removal of such impurities as oxygen, nitrogen, and sulfur.

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

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

industrial gas — see fuel gas.

inerts — macerals in coal not readily changed by the action of solvents in the solvent extraction of coal, e.g., fusinite.

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

intermediate-Btu gas — synthesis gas product with an HHV between 250 and 500 Btu per standard cubic foot, consisting mainly of carbon monoxide and hydrogen.

lignite — a low rank of coal between peat and subbituminous.

limestone — a sedimentary rock composed mostly of calcium carbonate ($CaCO_3$) and possibly some magnesium carbonate ($MgCO_3$).

liquefaction — conversion of a solid to a liquid; with coal this invariably involves hydrogenation to depolymerize the coal molecules to simpler molecules.

liquefied petroleum gas (LPG) — those hydrocarbons that have a vapor pressure (at 70° F) slightly above atmospheric (such as propane 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 of 150 to 350 Btu per cubic foot, when made from coal, water, and air. it contains varying quantities of carbon monoxide, carbon dioxide, nitrogen, hydrogen, and methane.

MAF — moisture- and ash-free; a term that relates to the organic fraction in coal. "moisture- and mineral-matter free" is equivalent.

methanation — the production of methane (CH_4) from a mixture of carbon monoxide and hydrogen.

micron — a unit of length equal to one millionth of a meter.

natural gas — naturally occurring gas extracted from sedimentary structures consisting mainly of methane and having an HHV to 1,050 Btu per standard cubic foot.

noncoking — 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.

perfect gas — see ideal gas.

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 group directly attached to the benzene ring. They give the reactions of alcohols, forming esters, ethers, and thiocompounds, phenols are more reactive than the benzene hydrocarbons; derived from coal tar.

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 process.

pipeline gas — a methane-rich gas that conforms to certain standards and having an HHV between 950 and 1,050 Btu per standard cubic foot. Standards include minimum water content, minimum inert gases, minimum hydrogen and carbon monoxide content and compressed to 1,000 psig.

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 laboratory-sized system used to study the effects of process variables on performance.

proximate analysis — analysis of coal based on the percentages of moisture, volatile matter, fixed carbon, and ash.

purification — removal of the wide range of impurities present in gases from coal gasification to yield purity gas. See Rectisol process

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

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

Raney nickel catalyst — nickel sponge used as a catalyst in the hydrogenation of organic materials and the methanation of synthesis gas to methane.

raw gas — see crude gas.

reactivity — susceptibility to chemical change, in coal conversion, the reactivity of the coal for conversion to liquid products is a function of the MAF volatile matter content and the petrographic composition of the coal.

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, hydrogen sulfide, and carbon dioxide are removed from the gas stream by the methanol at temperatures below 0°C.

reducing gas — used as a reducing agent in redox reactions, e.g., hydrogen, superheated steam.

reforming processes — a group of proprietary processes in which low-grade or low molecular weight hydrocarbons are catalytically reformed 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.

refractory — a material capable of withstanding extremely high temperatures and having relatively low thermal conductivities.

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

saturated hydrocarbon — a hydrocarbon in which all bonds are single covalent bonds and none are double or triple bonds.

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

semi-water gas — a mixture of carbon monoxide, carbon dioxide, hydrogen, and nitrogen obtained by passing an air-stream mixture through an incandescent bed of coke; HHV 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 wash plant. The ratio of hydrogen to carbon monoxide in the product gas can be changed at will.

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

slag – a molten mixture of various metallic oxides and salts.

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, or whose physical state is the same as that of the solution.

solvent extraction – selective transfer of desired 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 – the volume of a fluid (usually measured at standard conditions) passing through a unit volume in a unit time; units are in reciprocal time.

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 moist mineral-matter-free basis.

substitute natural gas (SNG) – a synthetic gas 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 or coal extracts, which is similar to petroleum crude.

synthesis gas – a mixture of hydrogen and carbon monoxide which can be reacted to synthesize a hydrocarbon.

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.

turned down – the reduction of reactor flow rates to a fluidized-bed reaction vessel.

ultimate analysis – the analysis of coal based on the percentages of chemical elements.

volatile matter – those constituents of coal, exclusive of moisture, that are liberated from a sample when heated to 1,750° F (for 7 minutes) in the absence of oxygen.

water gas – gas produced by the reaction of carbon and steam to provide 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: $CO + H_2O = H_2 + CO_2$.

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

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