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DEMONSTRATION STRAIGHTS PLANTS

U.S. DEPARTMENT OF ENERGY
Division of Coal Conversion

QUARTERLY REPORT

October-December 1978
DOE/ET-0069/4
Publication Date: September 1979

COAL

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COAL DEMONSTRATION PLANTS

QUARTERLY REPORT OCTOBER-DECEMBER 1978

U.S. DEPARTMENT OF ENERGY
Division of Coal Conversion
Washington, D.C. 20545

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FOREWORD

The technical reviews contained in this document were prepared by Cameron Engineers, Inc., Denver, Colorado, based on information supplied by DOE and its various contractors. The reviews, as they appear herein, have been authorized for publication by representatives of DOE. Cameron Engineers, Inc. assumes responsibility for the accuracy of the reviews but not for the accuracy of the information provided by either DOE or its contractors.

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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 Division of Coal Conversion — U.S. Department of Energy (DOE) 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 in areas of gasification, liquefaction, and direct combustion will satisfy an urgent need for a particular type of fuel. 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.

The Department of Energy's demonstration plant program was started in 1974 by one of the Department of Energy'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, DOE is sponsoring the development of a series of demonstration plants, each of which will be a smaller version of commercial plants envisioned for the 1980's. These plants will be wholly integrated, self-sufficient in terms of heat generation, and dependent only on feedstock of coal, water, and air.

Under the DOE program, contracts for designing, constructing, 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 operating phases being co-funded, 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 Department of Energy just recently contracted with the Pittsburgh and Midway Coal Mining Company and Southern Company Services, Inc. for two separate contracts for the preparation of a demonstration plant design and cost estimate for Solvent-Refined Coal (SRC). Pittsburgh and Midway is responsible for developing the SRC-II, liquid solvent refined coal while Southern Company Services, Inc. will develop SRC-I, solid solvent refined coal.

The Illinois Coal Gasification Group (ICGG) was selected to design, construct, and operate a *Pipeline Gas Demonstration Plant* with the objectives of demonstrating the commercial feasibility and economic attractiveness of a chemical process for conversion of high sulfur coal to clean pipeline gas. The primary process licensor is the COGAS Development Company, and the architect/engineering firm is the Dravo Corp., Synfuels Division. Much of the work continued at a slowed pace due primarily to a DOE suspension of work order still in effect. The Conceptual Commercial Plant Design Report and several site characterization studies were completed and submitted to the DOE.

Continental Oil Company will design a *Pipeline Gas Demonstration Plant* which may lead to cost shared construction and operation of the plant that would commercially supplement the natural gas supply to an industrial and residential area of Ohio. During the quarter, various tasks in Phase I continued to be slowed down at the request of DOE, pending the outcome of the technical support program at Westfield. In October, a report was submitted to the DOE summarizing the results of the Westfield support program. It is anticipated that after a competitive evaluation either the ICGG or the Conoco project will be discontinued.

Memphis Light, Gas, and Water, a municipal utility, was awarded a contract by the DOE to design an advanced *Fuel Gas Industrial Demonstration Plant* to convert coal into fuel gas for industrial use utilizing the U-Gas process developed by the Institute of Gas Technology. Work is beginning to accelerate after the cancellation of several stop work orders by the DOE. Pilot plant testing has continued and four runs have been completed. Portions of the task I final report describing the commercial plant design and economic analysis have been submitted to the DOE.

A *Fuel Gas Industrial Demonstration Plant* program is the responsibility of W.R. Grace & Company. The program is aimed at producing a substitute for natural gas for the production of ammonia. Principal areas of investigation during the quarter involved the further definition of the commercial plant design parameters through a variety of process trade-off studies. Other activities included continued work on the demonstration plant design and on-site activities for the purposes of site confirmation and environmental report preparation.

A program for the *Development of Coal Feeders for Coal Gasification Operations* using second generation systems for pressurized coal conversion processing is being conducted by Foster-Miller Associates, Inc. Performance testing of

the linear pocket feeder (LPF) continues with over 234 hours of testing. The major problem has been the durability of the conveyor joints. The design, fabrication and assembly of the 500 psig centrifugal feeder has been completed. Testing with start in January.

Ingersoll-Rand Research, Inc. continued their *Development of a Continuous Dry Coal Screw Feeder*. The screw feeder was performance tested to substantiate the flowrate at various back pressures and to determine the sealing characteristics of the pump. A breaker was developed to breakup the extrudate from the feeder. Seal development continued on the Coal Piston Feeder.

Lockheed Missiles and Space Company, Inc. is responsible for a *Coal Feeder Development Program*. The Model 3 Kinetic Extruder was received and assembly was well under way by the end of the year. Component and design testing continued. It was also substantiated that gas injection is an effective way to compensate for fluctuating coal properties and to throttle the flow rate of coal.

Preliminary Design Services by the Ralph M. Parsons Company continued to be directed toward the conceptual designs of commercial plants. The preparation of the R&D report on prestressed concrete pressure vessels continued during the quarter.

The objective of the *Lockhopper Valve Development Program* being conducted by Consolidated Controls is to design, manufacture, test and evaluate eight and 12-inch refractory type valves that would be compatible with operating conditions found in numerous coal gasification plants. Four valves have been completely assembled to date, one for each of the operating conditions defined. Four other valves are in the design stages. A problem with the gate design and fabrication has been the only major setback encountered thus far.

Fairchild Stratos Division is responsible for *Valve Development for Coal Gasification Plants*. Design and engineering of four valves for the various operating conditions are well underway. The valves are expected to be completed in mid-1979. Development testing has continued throughout the quarter.

Kennedy Van Saun has essentially completed a *Coal Grinding Equipment Development* program to produce reliable coal grinding equipment for the controlled grinding and preparation of feed coal for demonstration and commercial size plants.

Jet Propulsion Laboratory has a contract for *Coal Pump Development and Technical Support* to DOE in evaluating new feeder technology. Extruder development continued throughout the quarter. An Applications Research Laboratory is being set up to test a Davis Standard high pressure 1.5 inch extruder. Negotiations were initiated to use the 2.5 inch coal pump on the Rockwell Hydrogasifier at the Morgantown Energy Technology Center.

Argonne National Laboratory is developing *Instrumentation and Process Control for Fossil Demonstration Plants*.

Water Purification Associates has the contract for the *Development of Conceptual Designs for Water Treatment in Demonstration Plants* in order to develop and determine water technologies for various coal conversion demonstration plants to minimize water use. Conceptual designs for the integrated water treatment plants have been completed for all sizes of coal conversion demonstration plants. The first draft of the Final Report has been submitted to the DOE.

The Conceptual Design of a Coal-to-Methanol Commercial Plant is the responsibility of Badger Plants. Work continued on the design of the methanol-to-gasoline plant, and the overall coal-to-gasoline plant. In addition, a number of economic analysis studies were conducted throughout the quarter.

Procon, Inc. was selected to design a *High-Btu Pipeline Gas, HYGAS Conceptual Basis* commercial plant based on Illinois No. 6 coal. Reports completing the Commercial Plant design effort were underway at the end of the quarter. Work had begun on the Demonstration Plant design in May.

I. SOLVENT-REFINED COAL (SRC) PROCESS DEMONSTRATION PLANT

THE PITTSBURGH & MIDWAY COAL MINING
COMPANY
SOUTHERN COMPANY SERVICES, INC.

Contract No.: ET-78-C-01-3055 —
ET-78-C-01-3045

Contract Funding: \$3,200,000 (each contract)
(100% DOE)

INTRODUCTION

In July 1978, DOE contracted with the Pittsburgh & Midway Coal Mining Company for the preparation of a Demonstration Plant Design and Cost Estimate for a Liquid Product Solvent Refined Coal (SRC-II) Process Facility, identified as the SRC-II Demonstration Project, leading to the final design, construction, and operation of the SRC-II facility. Also in July 1978, DOE contracted with Southern Company Services, Inc. for the demonstration of the Solid Product Solvent Refined Coal Process. Both plants would process an average of 6,000 tons-per-day into clean fuels primarily for use as utility boiler fuels.

A four-phase program is envisioned for each process. Phase Zero, the Initial Effort, is part of the four-phase program which consists of the following work items:

- Phase Zero — the initial report, consists of seven tasks:
 1. Preliminary Demonstration Plant Design and Cost Estimate
 2. Long Lead Procurement Planning
 3. Market Analysis
 4. Program Management
 5. Plan and Cost Estimate for Phases I, II, and III
 6. Cost Sharing Plan
 7. Environmental Analysis
- Phase I — Detail/Final Design

- Phase II — Procurement and Construction
- Phase III — Operation and Evaluation of First Module Plant

Figure I-1 provides the schedule for the development of the project.

PROCESS DESCRIPTION

In the original SRC mode (SRC-I) the product is a solid fuel at ambient conditions, and serves as a direct clean fuel substitute for high-sulfur coal. In a modification of the process (SRC-II mode), using slurry recycle instead of distilled process solvent and increased severity of reaction conditions, a distilled liquid product results. The SRC-II mode product can be used directly as boiler fuel or, with further hydrogenation, as a refinery feed for conversion to conventional fuels.

Schematic process flow diagrams of the SRC-I and SRC-II processes are shown in Figures I-2 and I-3, respectively. For operation in the SRC-I mode the coal is pulverized and mixed with coal-derived distillate solvent. The slurry, after addition of hydrogen, passes through a fired preheater and into a dissolver which operates at a pressure of 1,500 to 2,000 psig and a temperature of about 850° F. Under these conditions, about 90 percent of the carbonaceous material in the coal is dissolved. The coal is depolymerized and hydrogenated as well as hydro-

ACTIVITY	FISCAL YEAR							
	1978	1979	1980	1981	1982	1983	1984	1985
PHASE 0 PRELIMINARY DESIGN	△	▽						
PHASE 1 DETAILED DESIGN		△	▽					
PHASE 2 CONSTRUCTION			△	▽				
PHASE 3 OPERATION AND EVALUATION						△	▽	

Figure I-1. SRC-I & II DEMONSTRATION PLANT PROGRAM SCHEDULE

Figure I-2. SRC-I PROCESS SCHEMATIC

Figure I-3. SRC-II PROCESS SCHEMATIC

cracked, resulting in a decrease in molecular weight of hydrocarbon product ranging from methane upward. Much of the sulfur is removed by formation of hydrogen sulfide.

From the dissolver, the mixture flows to a separator for removal of gas from the slurry of undissolved solids and coal solution. Raw gas is sent to hydrogen recovery and desulfurization units. Recovered hydrogen is combined with fresh makeup and recycled to the process. Hydrogen gases are recovered and hydrogen sulfide is converted to elemental sulfur.

After separation of gases, the slurry of undissolved solids and coal solution leaving the dissolver is routed to filtration or other de-ashing processes for separation of solids, after which the product is recovered by fractionation.

In the modified or SRC-II process mode, part of the slurry from the dissolver is recycled as solvent for the pulverized coal feed instead of the 480° F+ boiling range distillate used for the SRC-I mode. As a result of increased severity of reaction conditions, hydrogen reaction is greater and a major part of the coal is converted to a liquid-distillate product. The quantity of unconverted coal and vacuum residue is controlled so as to be in balance with the requirements. This permits the use of distillation for the solid-liquid separation step, since all product is in the distillate boiling range.

HISTORY OF THE PROJECT

The SRC project was begun in 1962 when Spencer Chemical Company was awarded a research contract by the Office of Coal Research (OCR, subsequently a part of ERDA, now DOE) to study the technical feasibility of a coal de-ashing process (now called the SRC process). In 1965, the process was successfully demonstrated in a 50-pound-per-hour continuous-flow unit, completing the work on the contract. During the term of the contract, Gulf Oil Corporation acquired Spencer Chemical Company. After reorganization, the contract was assigned to the research department of P&M.

To develop the SRC process further, a contract was awarded to P&M to design, construct, and operate a pilot plant capable of processing 50 tons of coal per day. In 1969, Stearns-Roger Corporation completed the design for the pilot plant, but funds to begin construction were not available until late 1971. In June 1972, OCR extended its contract with P&M to construct and operate the pilot plant. Rust Engineering Company began constructing the pilot plant in July 1972 at Ft. Lewis, Washington, near Tacoma.

The pilot plant began operation in October 1974 for process studies. Production of 3,000 tons of solid product for full scale combustion tests in a utility boiler were completed in 1976. Pilot plant modifications for

operation in the SRC-II mode were completed in 1977. The modified pilot plant produced over 5,000 barrels of distillate fuel oil for combustion testing in a utility boiler in the fall of 1978. Pilot plant operations are continuing in support of both SRC-I and SRC-II demonstration plants.

In March 1972, the Southern Company System and the Edison Electric Institute jointly began a pilot scale study of key steps in the SRC process. Southern Company Services, Inc., representing the Southern Company System provides project management. In April 1973, the Electric Power Research Institute assumed the functions formerly performed by Edison Electric Institute. The United States Energy Research and Development

Administration, now the Department of Energy, began co-sponsorship of the Wilsonville operation in 1976.

The six ton-per-day SRC pilot plant at Wilsonville, Alabama, was designed, constructed and is being operated in the SRC-I solid fuel mode by Catalytic, Inc. Operation began in January 1974 and one subbituminous and six bituminous coals have been tested. This installation provides a flexible test unit for screening coals and investigation of various process improvement options to supplement the Fort Lewis pilot plant.

Contracts for the preparation of a demonstration plant design and cost estimate for the SRC-I and SRC-II Process Facility became effective in July 1978.

II. PIPELINE GAS DEMONSTRATION PLANT

ILLINOIS COAL GASIFICATION GROUP
CHICAGO, ILLINOIS

Plant Site:	Perry County, Illinois
Contract No.:	EF-77-C-01-2012
Total Funding:	\$293,215,609
Phase I:	\$ 22,691,309 *(96% DOE/4% ICGG & CDC)
Phase II:	\$199,386,300 *(50% DOE/50% ICGG)
Phase III:	\$ 71,138,000 *(50% DOE/50% ICGG)

INTRODUCTION

The Illinois Coal Gasification Group (ICGG) consisting of a joint venture on the part of the subsidiaries of the Northern Illinois Coal Gas Co., Peoples Gas Light & Coke Co., Central Illinois Light Co., Inc., Central Illinois Public Service Co., and North Shore Gas Co. was selected by DOE to design, construct, and operate a pipeline gas demonstration plant with the objectives of demonstrating the commercial feasibility and economic attractiveness of a chemical process for conversion of high sulfur coal to clean pipeline gas. The primary process licensors (pyrolysis, gasification and liquid product recovery) is the COGAS Development Company, and the architect/engineering firm is the Dravo Corp., Chemical Process Division.

This comprehensive program includes a number of specific objectives which are to:

- Confirm design criteria, demonstrate technology and obtain experience which will yield those characteristics required to establish and/or define plant investment and operating costs for future clean pipeline gas commercial production plants.

*1975 Dollar Estimate (contract Value). Phase I cost and schedule changes are now being negotiated. Phase II and Phase III will be renegotiated prior to the initiation of these phases.

- Project plant investment, operating and end-product costs for full-scale commercial production plants.
- Provide technology, performance, reliability and maintenance characteristics which will permit the design of a full-scale clean pipeline gas commercial production facility.
- Investigate the general applicability and limits of the selected process and plant design for a variety of coal types.
- Determine scaling parameters (with respect to the commercial production of the primary product) and sizing of major process components, such as those for gasification, hydrogenation, etc.
- Provide finished marketable clean pipeline gas in quantities sufficient for end-use evaluations.
- Determine the general characteristics, composition and quality of the end-product(s).
- Assess and/or evaluate characteristics and suitability of the product in actual representative end-use applications.
- Establish guidelines for by-product use and/or disposal.
- Obtain data which will permit design of an environmentally acceptable commercial plant.
- Establish the design compatibility with Occupational Safety and Health Administration (OSHA) requirements.

PROGRAM PLAN

The overall effort on the program has been divided into three distinct phases, these are:

- Phase I — Development and Engineering — 22 months*
- Stage 1 conceptual design
- Stage 2 final engineering design

*Extension to 42 months has been proposed by ICGG, and is now being negotiated as part of the Cost and Schedule Change Proposal negotiations (Sept. 1979).

- Phase II — Demonstration plant construction — 34 months*
- Phase III — Demonstration plant test, evaluation and operation — 42 months*.

The following is a brief description, by phase, of the total program*.

Phase I Development and Engineering Stage 1 — Conceptual Design

A conceptual design for a Commercial Plant using second generation gasification technology has been prepared. This design is based on the maximum use of proven, commercially-available components and equipment. The capital and operating cost estimates, as well as the economic analysis, consider various process trade-off and design studies. Based on a favorable economic evaluation of the conceptual design for a Commercial Plant, a conceptual process design for a Demonstration Plant is being developed. A site evaluation study and an environmental analysis, as well as preliminary plans for resources (coal, water, etc.) and water pipeline right-of-way acquisition, will be prepared. A recommendation for a Demonstration Plant will be submitted to DOE at the end of Stage 1.

Stage 2 — Engineering Design

During Stage 2, bid packages, construction plans and an economic

reassessment will be prepared. In addition to the possible procurement of long lead time equipment, plans for procuring raw materials, permits, and easements will be finalized.

*Phases II and III terms subject to negotiation.

Phase II

Demonstration Plant Construction

Phase II encompasses the actual "filled" design* and construction of the Demonstration Plant. The contractor will finalize the site acquisition and agreements related to feedstocks, product transportation, by-products sale, wastes, permits, licenses, easements and rights-of-way. After competitive bidding, the construction subcontract(s) will be awarded. The contractor will be responsible for procurement of equipment and facilities, preparation of the site, inspection of the work, and construction management.

Operation, training and maintenance manuals required for the start-up, testing and operation during Phase III will be developed. Training programs will be implemented with the specific objective of developing the necessary skills required for the operation and maintenance of the Demonstration Plant. The training program will emphasize both the safety features and the hazards of the equipment. A final economic reassessment of the investment and the operating costs of both the Demonstration Plant and a Commercial Plant will be performed.

Updated "as-built" drawings will be submitted to DOE. After the approval by DOE of a check-out and acceptance plan, necessary mechanical testing of the plant will be performed prior to start-up.

*Final design including detailed pipeline layout based on vendor prints: "as built" drawings.

A plant shakedown test plan will be submitted to DOE for approval before the plant components are tested. A detailed report summarizing the six months of testing will be submitted to DOE. Two months are planned for establishing the operating conditions and operating variables for the primary coal type, after which the plant will be operated for twelve months to demonstrate the long term operating characteristics of the plant. At the conclusion of the testing of the primary coal type, DOE may direct the contractor to test one or both of the alternate coals for a period of six months each. At the end of Phase III, DOE has the option to extend the period of performance for a period not to exceed eighteen months in accordance with terms and conditions mutually agreed upon by the contractor and DOE.

As a result of the experience gained from constructing and operating the Demonstration Plant, the contractor will conduct process trade-off studies and an economic re-analysis for the optimization of the design, construction and operation of a commercial plant.

The program schedule is given in Figure II-1.

PROCESS DESCRIPTION

Technology to be used by the contractor includes the COGAS coal gasification concept, licensed by COGAS Development Company partnership comprised of the FMC Corporation, Consolidated Gas Supply Co., Panhandle Eastern Pipe Line Co., and the Tennessee Gas Pipeline Co. The concept for pyrolysis and gasification (shown in Figure II-2) consists of three sub-units: multi-stage fluid bed pyrolyzers (adopted from the COED Process), a fluid bed gasifier, and a slagging char fines combustor.

The multi-stage fluid bed pyrolyzers are vertical cylindrical steel vessels. For most coals three pyrolysis stages are used. Coal is transported to the first stage using a suitable carrier gas. Temperature of pyrolysis increases from the first stage through the third stage. Coal is fluidized and pyrolyzed in the first stage by a portion of gas from the third stage. The char from the first stage flows to the second stage, where it is fluidized and pyrolyzed by the remainder of the gases from the third stage. In the third stage, the char is fluidized and pyrolyzed by a portion of hot synthesis gas. Char from the third stage then feeds the gasifier, where the synthesis gas is produced. Gas from the first two pyrolysis stages, i.e. the pyrolysis gas, is water scrubbed and quenched to condense out most of the condensibles and water. It is then compressed and sent to the purification section for acid gas removal.

The char fed into the gasifier is fluidized by steam injected at the bottom of the gasifier. The hot char is more reactive than coal and reacts to produce synthesis gas by the following endothermic reaction:

Figure II-1. ICGG PROJECT SCHEDULE

Figure II-2. COED PYROLYSIS/GASIFICATION PROCESS SCHEMATIC

The heat for this endothermic reaction is obtained by circulating a hot char stream through the combustor lift tube into the gasifier (See Figure II-3). As the hot char mixes with the char to be gasified, in the gasifier, it provides the heat for the endothermic reaction mentioned above. Char from the gasifier lift tube is recycled to the combustor for reheating. Char fines in the char steam and those collected in synthesis gas and flue gas cyclones are burned in the combustor to produce hot flue gas and molten slag. The molten slag flows out of the bottom of the combustor into a slag quench tank where circulating water quenches the slag to a solid form. It is then settled and sent to disposal.

The hot flue gas from the combustor rises through the lift tube and heats the entrained circulating char. The char stream is separated from the flue gas at the top of the lift tube. The char is then fed to the gasifier. The flue gas, after passing through cyclones, is cooled in a waste heat boiler to produce high pressure superheated steam which is expanded through power recovery turbines. The flue gas is then used in coal driers to dry and preheat the feed coal.

gasifier are eliminated by passing the gas through cyclones. A portion of the gas is sent to the third stage pyrolyzer to provide the heat for pyrolysis. The remainder of the gas is cooled in two waste heat boilers to produce high pressure superheated and low pressure saturated steam. The other processing steps are as shown in the overall process block diagram (Figure II-4). Liquid products are condensed from the pyrolysis gases and the heavier liquids are hydrotreated. The synthesis gas is processed as shown to produce pipeline gas.

PROGRESS DURING OCTOBER-DECEMBER 1978

Work has continued throughout the year on the following Tasks previously opened in Phase I, Stage I of the Pipeline Gas Demonstration Plant Program:

Task I	— Conceptual Design and Evaluation of Commercial Plant
Task II	— Demonstration Plant Process Design
Task III	— Site Evaluation and Selection

Figure II-3. CHAR/GASIFIER COMBUSTION SYSTEM

- Task IV — Demonstration Plant Environmental Analysis
- Task V — Materials and Licenses
- Task IX — Technical Support
- Task XI — Project Management

During this past quarter, the following Task I and Task III Major Contract Deliverables were received by DOE:

- Conceptual Commercial Plant Design Report
- Climatological and Meteorological Report

- Preliminary Foundation Investigation and Soil Analysis Report
- Site Survey Report
- Site Transportation Study Report
- Site Water Resources Report
- Site Environmental Survey Report

With the submittal of the Conceptual Commercial Plant Design Report to DOE on September 28, 1978, ICGG has completed the Task I Work Effort.

Work in Tasks II, III, IV, V, IX and XI has progressed,

All other work activity under the contract is still officially suspended in accordance with DOE the Suspension of Work Order, XXXII.

III. PIPELINE GAS DEMONSTRATION PLANT

CONOCO, INC.

STAMFORD, CONNECTICUT

Plant Site: Noble County, Ohio
Contract No.: EF-77-C-01-2542
Total Funding: \$371,590,000
\$198,790,000
(U.S. Government)
\$172,800,000 (Industry)

INTRODUCTION

The Conoco project is part of the DOE high-Btu gasification program, which will develop new and improved second generation gasification technology necessary to build commercial scale plants for processes that convert coal to Substitute Natural Gas (SNG) of pipeline quality. The project will utilize the slagging British Gas Lurgi gasification process and will employ Foster Wheeler Energy Corp. as the architect-engineering firm.

Other than Conoco, who is the managing operator for the plant, the participants include: Consolidated Gas Supply Corporation; Natural Gas Pipeline Company of America; Texas Gas Transmission Company; Texas Eastern Gas Transmission Company; Trans Continental Gas Pipeline Corporation; Panhandle Eastern Pipeline Company; Sun Gas Company; EPRI; and Gulf Mineral Resources Company. Although most of the above companies do not distribute gas in Ohio; they are contributing to the program for possible future application of the technology in their distribution areas.

As with the other demonstration plants, the project will be conducted in three phases. Phase I will consist of commercial plant conceptual design and demonstration plant detailed design. Phase II will involve three major

tasks which are demonstration plant final design, initiation of long lead procurement, and demo plant construction. Phase III, the end result of the project, will be shakedown and operation of the plant. The project schedule is shown in Figure III-1.

PROCESS DESCRIPTION

The technology chosen to be demonstrated in this project is the British Gas Slagging Lurgi process. This process (shown in Figure III-2) is a modification of the existing Lurgi (dry ash) process which has been commercially operated for over 35 years. Modifications are being made to accept caking coals and operate at higher temperature over slagged ash bottoms. The slagging process reduces the carbon content of the molten ash stream and thereby increases the conversion of coal to gas. The process also produces less tar, phenol, and heavy hydrocarbons than the older commercial Lurgi process units; however, high boiling carcinogenic hydrocarbons will be recycled to the gasifier to be destroyed by gasification to produce a higher yield of gas than competing processes.

Gases leaving the gasifiers are cooled by quenching with a gas liquor (recycled water) spray. The H_2/CO ratio

Figure III-2. CONOCO HIGH-BTU PIPELINE GAS "A" PROCESS SCHEMATIC

Figure III-1. CONOCO PROJECT SCHEDULE

as required for downstream methanation is adjusted by shift conversion. A major portion of the crude gas passes through the converter while the remainder bypasses the converter. In the purification step, naphtha, oil and water are separated by condensation, while hydrogen sulfide and carbon dioxide are removed by the Rectisol process. In the methanation step, methane is formed from carbon monoxide and hydrogen over a fixed-bed nickel catalyst. The conversion to methane produces a gas similar in heat content to natural gas for pipeline distribution.

In the gas liquor separator, coal fines, tar and tar oil are removed from water. The fines with tar and oil are recycled to extinction in the gasifiers. The Phenosolvan process extracts phenols from the water. Ammonia is removed from the gas by the CLL process to produce aqueous ammonia. An air separation plant will produce oxygen which is a necessary part of the process in making pipeline quality gas.

In addition to tar precipitation, oil separation, and phenol extraction processes, the plant will include all the service sections required, such as steam production, water purification, air separation plant, incineration, and waste treatment, as well as product loading, tankage, and buildings.

As currently planned, the plant will have a feed rate of 3,783 tons of coal per day producing 58.9 million standard cubic feet per day of 950 Btu/SCF pipeline gas. Although a demonstration plant, the product will commercially supplement the natural gas supply to an industrial and residential area of Ohio.

HISTORY OF THE PROJECT

This project for the design, construction, and operation of a Demonstration Plant capable of converting bituminous coal into pipeline quality gas was initiated in mid-1977. The process design of the gasification section and some of the downstream processing units are completed. A 1,200 acre tract in Marion and Center townships in Noble County, Ohio was proposed for the location of the demonstration plant.

Fifteen runs of a technical support program carried out

by British Gas Corporation at its Westfield Development Center have been completed. Data from this program will be used to design the downstream gas processing units for the plant.

On January 6, 1978, DOE requested that work on Task II be deferred for the present, and work on Tasks III, IV, and V be continued at a reduced rate. Work on Task VI which was stopped in September, 1977, was not restarted. Work on the remaining tasks, particularly Task I and Task IX, continued as planned. Plans are being made to reprogram and restart the project.

PROGRESS DURING OCTOBER-DECEMBER 1978

Work on Phase I started on July 1, 1977, and was originally scheduled to be completed on April 30, 1979. DOE, however, subsequently deferred all engineering design work on the Demonstration Plant and stipulated that other work activities be continued at a reduced pace. This slowdown continued during the current reporting period. Work in the main during this period was limited to collection of site data (Task III), collection of environmental data (Task IV), and a reassessment of the basis of design for the Demonstration Plant (Task VI).

On July 21, 1978, DOE announced that the Government would conduct a formal, competitive evaluation of the two pipeline gas demonstration projects, namely, Continental Oil Company's project and a project managed by the Illinois Coal Gasification Group (ICGG). Both contractors were informed that the evaluation process would likely result in the termination of one of these projects for the convenience of the Government. The Department of Energy had not announced the results of the evaluation by December 31, 1978.

During October, report FE/2542-13 entitled, "Phase I: The Pipeline Gas Demonstration Plant — Technical Support Program Report," was submitted to DOE. The report covers the 15 pilot plant runs required under the Westfield agreements with British Gas Corporation. It contains all of the data obtained under the technical support program carried out at the Westfield Development Centre in Scotland.

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IV. FUEL GAS INDUSTRIAL DEMONSTRATION PLANT — "A"

MEMPHIS LIGHT, GAS, AND WATER
MEMPHIS, TENNESSEE

Plant Site:	Memphis Tennessee
Contract No.:	ET-77-C-01-2582
Total Funding:	\$283,000,000
Phase I:	\$12,000,000 (100% DOE)
Phase II:	\$185,000,000 (\$154,000,000 DOE*, \$31,000,000 MLGW)
Phase III:	(\$86,000,000, \$3,000,000 DOE*, \$83,000,000 MLGW)

INTRODUCTION

Memphis Light, Gas, and Water, a municipal utility, was awarded a contract by the DOE to design a demonstration plant to convert coal into fuel gas for industrial use. Under the terms of the contract, Memphis Light, Gas, and Water will prepare a conceptual design of a 50 MMBTU/day demonstration facility which would utilize the U-Gas process developed by the Institute of Gas Technology with DOE funding. If the DOE and Memphis decide to proceed with the project following the conceptual design phase, the plant would be built on city owned property adjacent to the Frank C. Pidgeon Industrial Park on the Mississippi River. Fuel Gas produced at the Plant would be distributed by a relatively short (less than 15 miles) pipeline to industries on President's Island and new industries locating in Pidgeon Park. The medium Btu fuel gas produced by the facility would have a heat content of approximately 280 Btu's per cubic foot, converted from 2800 tons-per-day of high sulfur coal. Approximately 175 million cubic feet (an equivalent of 50 million Btu's) of fuel gas would be produced daily.

*These numbers reflect current dollars, contingency, government support, and front end government funding.

As with the other major demonstration projects, this program will be carried out in three phases. These will be accomplished as follows:

- Phase I — Program Development and conceptual design.
 - Task I — Conceptual design and evaluation of commercial plant.
 - Task II — Demonstration plant process design.
 - Task III — Demonstration plant process and mechanical design package.
 - Task IV — Site evaluation and selection.
 - Task V — Demonstration plant environmental analysis.
 - Task VI — Materials and licenses.
 - Task VII — Construction and operation planning.
 - Task VIII — Economic assessment.
 - Task IX — Technical support.
 - Task X — Long lead items.
 - Task XI — Program management.
- Phase II — Demonstration plant final design procurement and construction.
- Phase III — Demonstration plant operation.

The program schedule is shown in Figure IV-1.

ACTIVITY	FISCAL YEAR									
	77	78	79	80	81	82	83	84	85	86
PHASE I CONCEPTUAL DESIGN		△		▽						
PHASE II ● DETAILED DESIGN ● LONG LEAD PROCUREMENT ● CONSTRUCTION				△	△	△	▽			
PHASE III SHAKEDOWN & OPERATION						△	△	▽		

Figure IV-1. MEMPHIS FUEL GAS DEMONSTRATION PLANT PROJECT SCHEDULE

Figure IV-2. MEMPHIS LIGHT, GAS & WATER DIVISION
MEDIUM BTU FUEL GAS INDUSTRIAL "A" PROCESS SCHEMATIC

DEMONSTRATION PLANT PROCESS DESCRIPTION

The demonstration plant process will be based on the U-Gas process. The U-Gas fluidized-bed gasifier is of vertical cylindrical construction with external cyclones for returning elutriated fines to the bed. A sloped grid at the bottom, containing one or more inverted cones, serves as the oxygen and steam distributor and the agglomerated ash outlet.

The U-Gas process is shown schematically in Figure IV-2. Raw coal is crushed to 1/4 × 0 inch size. The feed may contain up to 10 percent - 200 mesh material as generated in the crushing step. Non-caking, subbituminous coals or lignite can be fed directly to the gasifier from the crusher. Caking coals (Eastern bituminous, for example) may have to be pretreated by contact with oxygen and steam in a fluidized bed operating at gasifier pressure at 700° to 800° F. An oxidized outer layer forms on the coal particles, and this prevents agglomeration and possible blockage in the gasifier. However, experimental data to date indicate this step may be eliminated.

Coal fed to a gasifier is gasified with a mixture of oxygen and steam in a single stage fluidized bed. The residence time of the coal is about 45 minutes to an hour. Fluidizing velocity is in the order of 2 to 4 feet per second.

The key to operation of a U-Gas gasifier is the agglomeration and separation of the low carbon content ash from the bed. The U-Gas gasifier concept accomplishes this while maintaining a bed of approximately 45% ash. This is accomplished by proper design and operation of the grid, the fines return system, and the agglomerate removal section in the bottom of the gasifier. The grid is sloped toward one or more inverted cones contained in the grid. Part of the fluidizing steam and oxygen flow through nozzles in the grid, while the remaining fluidizing gas flows upward at high velocity through a discharge at the cone apex. The ratio of steam to oxygen in the fluidizing gas fed to the cone is chosen so that the resulting submerged jet in the cone is hotter than its surroundings. The concept of agglomeration of coal presently being pursued suggests that the temperature of the material in the jet is maintained near the softening point of the ash particles for the specific coal being gasified. Ash particles preferentially stick together, and the agglomerates grow until they are heavy enough to move downward counter to the force of the gas stream in the apex of the cone and, thus, fall out of the fluidized bed.

One design suggests that fines elutriated from the fluid bed are separated from the product gas by two cyclones in series. Fines removed by the first cyclones are returned to the bed by a standleg. Fines removed by the external cyclone are entrained in the inlet oxygen/steam to the gasifier where they are instantly gasified.

The hot product gas, after fines removal in the two cyclones, is cooled via waste-heat recovery and the result is a medium-Btu fuel.

HISTORY OF THE PROJECT

Work on the contract began in late 1977. A Plan of interfacing Schedule and Test Work for Pilot Plant was prepared and submitted to DOE. The plan outlines the

interface agreements between this program and DOE Contract Ex-76-C-01-2336, Operation of the Atmospheric Ash-Agglomerating Gasifier (AAG). The plan described the schedule of operation and test work for use of the AAG in this project. On January 1, 1978, the AAG pilot plant was officially transferred by DOE to this project. AAG pilot plant runs were conducted thru the first quarter of 1978. A new pilot plant program was developed by DOE and the project team members. It went into effect on September 20, 1978.

PROGRESS DURING OCTOBER-DECEMBER 1978

During the final quarter of 1978, the Task I report was drafted, circulated for comment, then placed in final form for submission to DOE. The Task I final report consists of four volumes, of which Volumes II and III are issued. Volumes I and IV will follow in January, 1979.

Volume titles of the Task I report are:

- Volume I — Executive Summary
- Volume II — Commercial Plant Design
- Volume III — Economic Analysis
- Volume IV — Demonstration Plant Recommendations

DOE's Stop Work order covering Task II of Phase I was cancelled in part, effective November 15, 1978. During November and December, process studies were started in order to allow Phase I completion by December 1979. As with Task II, Tasks III and IV were also released, in part, from DOE's Stop Work order. A limited amount of work is in progress on Task V, Demo Plant Environmental Analysis.

Completion of Phase I by December, 1979 will be dependent mainly on acquisition of Pilot Plant data. Pilot Plant operations continued during this quarter with four pilot plant runs being made. Some success was achieved in obtaining an ash balanced condition for several days with ash agglomeration with washed Kentucky coal feed. This was the objective of the first three months of the approved program.

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V. FUEL GAS INDUSTRIAL DEMONSTRATION PLANT — "B"

W.R. GRACE & CO.
AGRICULTURAL CHEMICALS GROUP
MEMPHIS, TENNESSEE

Plant Site:	Baskett, Kentucky
Contract No.:	ET-77-C-01-2577
Total Funding:	\$510,000,000
Phase I:	\$12,000,000 (100% DOE)
Phase II:	\$376,000,000 (\$284,000,000 DOE*, \$92,000,000 WRG)
Phase III:	\$122,000,000 (\$4,000,000 DOE*, \$118,000,000 WRG)

INTRODUCTION

W.R. Grace & Co. has been chosen by the Department of Energy for design, construction, and operation of a demonstration plant for conversion of coal to synthesis gas for use in ammonia production. This program is aimed at producing a synthesis gas that is a direct substitute for natural gas in ammonia production, thereby freeing this scarce natural resource for higher priority use. The overall objective of the program is the construction of an integrated facility that will convert 1,700 tons-per-day of coal into 1,200 tons-per-day of ammonia and yield 60 tons-per-day of sulfur as a by-product. Ebasco Services, Inc. is the architect and engineering firm and construction manager for the project.

As now planned, the project will be carried out in three phases. Phase I will be 100 percent funded by government with Phase II and III being 50-50 cost sharing with industry and government.

*These numbers reflect current dollars, contingency, government support, and front end government funding.

The adjacent ammonia plant will be funded 100% by W.R. Grace at a cost of about \$40 million. A provision is also in the contract for W.R. Grace to ultimately buy back and have complete ownership of the entire facility.

Phase I involves eight major tasks which include:

- Conceptual design and evaluation of a commercial plant
- Demonstration plant conceptual design
- Current estimate of Phases II & III
- Site evaluation and selection
- Demonstration plant environmental analysis
- Demonstration plant construction and operation plan
- Economic reassessment of commercial & demonstration plant design
- Technical support, including pilot plant operations

The purpose of the preliminary commercial plant design is to obtain a detailed process design based on maximum use of proven, commercially available components and equipment on which to base detailed cost estimates. The end use of this design will be to evaluate the economic and technical feasibility for commercial plants and to recommend changes to the overall commercial

plant concept. The demonstration plant design will be based on a system that will integrate commercially available components and equipment. This effort will include preparation of process flow charts and schematics for the plant, and for each major process train and subsystem. Major process and utility piping, electrical networks, process operating conditions, and mass and heat balances, will be a part of the effort.

The conceptual demonstration plant design will establish the basis for designing the actual demonstration plant. The conceptual design will include estimated operating life of the plant, selection of the plant size, and

development of the preliminary heat and material balances for the plant using the coal selected.

Phase II work will involve the preparation of the complete plant design, including drawings, specifications, and definitive cost estimates. A bid package will be prepared and the physical plant will be constructed. Phase III, the ultimate objective of the project, will be the operation of the plant. Experience gained during this period will be used to determine the technical and economic performance and assess the project with regard to the scale-up of the operation to larger commercial plants. The project schedule is given in Figure V-1.

Figure V-1. W.R. GRACE PROJECT SCHEDULE

PROCESS DESCRIPTION

The Texaco Coal Gasification Process (TCGP) was chosen for use in the project. The process has been demonstrated on heavy oils and light feedstocks and is considered a second generation technology. The proposed plant will operate on Kentucky number 9 coal feedstock which is ground to 70 percent minus 200-mesh and then slurried in water to 50-60 percent solids for high pressure pumping and atomized injection into the gasifier. The slurry and pure oxygen enter at the top of the gasifier. In the presence of steam derived from the water of the coal slurry feed, they react to produce hot gases and molten slag, which are quenched in the lower section of the generator. The cooled gases leave the generator saturated with steam. The slag is removed through a lock hopper system to recover and recycle unconverted carbon.

The raw gas from the gas generator is rich in CO which reacts with water to produce H₂ and CO₂. The CO₂ and any hydrogen sulfide (H₂S) produced are absorbed in refrigerated methanol (Rectisol process) to remove them

from the gas stream. The clean gas is scrubbed in liquid nitrogen which removes any residual CO, methane or argon. Adding the liquid nitrogen also produces the product gas, which is feedstock for the ammonia synthesis step.

The ammonia synthesis reaction in the proposed design is conducted at 3000 pounds-per-square-inch. The gas from the ammonia converter is cooled by heat exchange and refrigeration to condense the ammonia. The generalized process flow diagram is shown in Figure V-2.

HISTORY OF THE PROJECT

The project was initiated in mid-1977, and actual engineering work on the conceptual commercial plant design phase was begun in the third quarter of the year.

During 1978, work focused on the further definition of commercial plant design parameters.

NOTE: AREA INDICATED BY HATCHED LINES NOT COST-SHARED WITH DOE

Figure V-2. W.R. GRACE AMMONIA PROCESS SCHEMATIC

PROGRESS DURING OCTOBER-DECEMBER 1978

While the bulk of effort during the quarter continued to be directed toward Commercial Plant design activities, significant acceleration of the development of Demonstration Plant documentation also occurred. Other reported activities included finalization of various trade-off studies (TOS), continuation of environmental and site confirmation related activities and operation of Texaco's coal gasification pilot plant at Montebello, California.

Specific activities of a technical nature accomplished during this quarter included:

- TOS-I, Gasifier Operating Pressure — The TOS-I final report had been delivered to DOE last May. The results of the TOS-I report have now been incorporated in design activities on both the Commercial and Demonstration Plants.
- TOS-II, Gas Purification Alternatives — After comparing cost advantages of the Rectisol and Selexol acid gas removal systems, The Rectisol system was favored. The final report will be issued next quarter.
- TOS-III, Method of Coal Preparation — Due to an inability to specify either a wet or a dry coal grinding system, it was determined that tests should be run to determine grinding system capabilities.

- TOS-IV, Air Quality Control System Alternatives — The TOS-IV final report has been submitted, and the recommended Wellman-Lord flue gas desulfurization system has now been incorporated for design purposes.
- TOS-V, Cooling Tower Optimization — This was also submitted to DOE and the recommended system has now been incorporated in plant designs.
- TOS-VI, By-Product Sales Analysis — It was determined that the work should be subdivided into two distinct areas. Therefore, work has progressed on the development of a first volume addressing the question of elemental sulfur versus sulfuric acid production as a by-product and a second volume concerned with the potential sale/use of carbon dioxide and slag by-products. A preliminary draft of the first volume was submitted to Grace on December 28, 1978. The recommendation contained therein consisted of a combination sulfur recovery/processing unit which would allow recovery of sulfur in the form of either elemental sulfur or sulfuric acid.
- TOS-VII, Equipment Arrangement Studies — Contract was modified to eliminate this TOS.

A major milestone was achieved with the successful operation of Texaco's Montebello pilot plant with the design coal at design pressure. Additional testing is scheduled for the coming quarter.

Activities continued in the areas of environmental and site confirmation. Both an Air Quality Monitoring Program and additional sampling and analysis for polycyclic aromatic hydrocarbons (PAH) and trace metals have been incorporated into the Phase I Statement of Work.

Other activities included continuation of revisions to the Plan for Obtaining Approval, Permits and Licenses from Agencies and the initiation of efforts on both the Phase II and III Current Working Estimate and the Construction and Operation Plan.

VI. DEVELOPMENT OF COAL FEEDERS FOR COAL GASIFICATION OPERATIONS

FOSTER-MILLER ASSOCIATES, INC.

WALTHAM, MASSACHUSETTS

Contract No.: EX-76-C-01-1793

Total Funding: \$2,729,149
(100% DOE)

INTRODUCTION

Under the sponsorship of DOE, coal feeders for use in all coal gasification plants are to be developed through the pilot plant stage by Foster-Miller Associates, Inc. The project recognizes the coal feeder as one element common to all processes and that no currently available system can handle the quantities of coal, about 1,000 tons per hour, that will be used in commercial processes. These processes require the injection of coal from an atmospheric-pressure hopper into a reactor whose operating pressure may be as high as 1,500 psi.

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

PROGRAM DESCRIPTION

The project to develop coal feeders was initiated in May 1975. It consists of three phases, with Phases I and II to be

completed by December 1977. In Phase I, Foster-Miller visited and studied gasification plants and consulted with DOE personnel and consultants to prepare a list of coal feeder requirements for DOE approval. Foster-Miller then prepared a report based on information concerning existing equipment and new conceptual designs. The report included a list of candidate equipment and an evaluation of that equipment.

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

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

A fourth phase, not part of this contract, design of demonstration scale feeders, will use the results of pilot

plant testing. It is projected to include the development, design, fabrication, and delivery to DOE of coal feeders compatible with demonstration plant requirements. Feed rates in this phase are anticipated to be 50 tons-per-hour and greater

PROJECT ACCOMPLISHMENTS

Foster-Miller Associates completed the Phase I program effort in March 1976, with the release of the Phase I report. The results from the evaluation of coal feeder requirements and existing feeders revealed that no suitable dry coal feeders were available that could operate at gasifier pressures above 300 psi. As part of this initial effort, literature searches, patent reviews, and consultations with manufacturers were made to determine what particular concepts should be studied in Phase II.

Based upon the results of the Phase I effort, four feeder concepts were selected and approved for the Phase II development. These concepts included:

- A centrifugal solids feeder
- A fluidized piston feeder
- A linear pocket feeder
- A compacted coal plug feeder

The Phase II program effort is essentially the hardware evaluation of the concepts developed in Phase I. In conducting this phase, two scaling steps have been carried out. Bench scale models of all four concepts were designed, built and tested. Following this work, pilot plant scale prototypes of three of the four concepts were designed and built and are being tested.

The bench scale centrifugal feeder model was used to perform coal flow studies and to determine if the required outlet limited (full sprue) flow mode could be achieved. This flow condition is necessary if the device is to be capable of sealing against pressure. For the piston feeder development, a glass model of the feeder was built and tested to study possible development problems. A full scale, two flight, sealing section model for the linear pocket feeder was developed to test leakage rates and drive forces. For the plug feeder, a small bench scale apparatus was tested to determine leakage, plus stability, driving forces, compaction forces required, etc. At the conclusion of the bench scale testing, essentially all four concepts were deemed to be technically feasible. However, because of funding limitations, the plug feeder concept development was suspended.

Upon completion of the bench scale testing program, the development of prototype pilot plant scale feeders was undertaken for the three remaining concepts.

A prototype centrifugal feeder unit was designed and built for feed rates of up to one ton-per-hour at pressure differentials to 200 psi. The unit has a 24-inch diameter feeder head. Testing of the prototype centrifugal feeder was initiated in mid-November of 1976.

A prototype fluidized piston feeder was designed and built and has been under test since March of 1977. The feeder has a four-inch bore and an adjustable stroke length up to eight inches. In testing the piston feeder, prototype problems were encountered with the intake and exhaust valves. The other components of the feeder operated reliably.

The design, fabrication, and assembly of a prototype linear pocket feeder designed for a feed rate of up to five tons-per-hour at 500 psig was also completed.

Phase III effort was initiated in October 1977. The selected feeder concepts for the Phase III effort are the Foster-Miller linear pocket and centrifugal feeders. The feeder concepts will be designed and built to pilot plant scale specifications. The feeders will be subjected to a performance test program on an expanded coal feeder test loop constructed for this task. Conceptual designs for the feeder systems will be prepared for pilot and/or demonstration scale applications.

PROGRESS DURING OCTOBER-DECEMBER 1978

Linear Pocket Feeder (LPF) Durability Testing

The LPF has been operated for a total of 234 hours. The critical sealing tube and sealing rings have 204 and 151 hours respectively and have exhibited no measurable wear. The only durability problem with the feeder to date has been excessive wear of the conveyor joints.

During October the feeder was shut down to replace the clevis and rod bushings, the joint pins and the stainless steel rollers on the conveyor. New materials when they were received did not meet the design specifications and after installation, the tungsten carbide bushings fractured after 16 hours of operation. The broken bushings were removed and bearing steel drilling bushings were ordered to effect a short term solution. The LPF should be operational again in January, 1979. Carbide bushings made to specifications and an alternative pin material are currently on order and should be received later in the year. These should solve the conveyor joint problems permanently. A test program has been set up to verify this and to determine if there are any other "long term" solutions.

Centrifugal Feeder Development

Support testing of the 200 psig centrifugal feeder prototype has been suspended so that more effort can be directed to the 500 psig prototype development. Design, fabrication, and assembly of the 500 psig unit were completed and testing was initiated. Coal feed testing will begin in January 1979.

Test Loop Development

The 5-ton capacity hatch test loop was completed during the month of October. The facility is presently being used for the testing of the 500 psig centrifugal feeder prototype. Present plans are to install the LPF on the enlarged feeder test facility in early 1979.

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VII. DEVELOPMENT OF A CONTINUOUS DRY SCREW COAL FEEDER

INGERSOLL-RAND RESEARCH, INC.
PRINCETON, NEW JERSEY

Contract No.: EX-76-C-01-1794
Total Funding: \$2,642,445
(100% DOE)

INTRODUCTION

The overall objective of this program is to develop pilot plant size coal feeder devices that can be scaled up for feeding large quantities of coal into pressurized, commercial scale reactors. The program is comprised of three basic elements:

- Development of a Dry Coal Screw Feeder
- Development of a Dry Coal Piston Feeder
- Feasibility of Spraying and Feeding Fully Plasticized Coal

This development work is of importance to the fossil energy program since current methods (lock hopper and slurry) of feeding coal to high pressure gasification processes are undesirable due to economic and technical considerations.

The feeders are to be developed through the pilot plant stage, with the engineering and economic viability evaluated throughout the development process. The end result of the research will be a recommendation by Ingersoll-Rand of coal feed injector equipment that will be compatible with projected demonstration plant requirements. The equipment could be used in both high- and low-Btu gasification plants and also in coal liquefaction systems.

PROGRAM DESCRIPTION

Coal Screw Feeder

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

Phase I of the program involved the establishment of the coal feeder requirements imposed by the various processes being considered for commercial scale coal conversion operations. Literature searches, consultations with DOE personnel and consultants, studies of plant operations, etc. were used to obtain information on the feeder requirements.

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

characteristics to be investigated are:

- Feeder stability and degree of control
- Seal effectiveness
- Coal metering accuracy
- Life expectancy of critical components
- Mechanical power requirements
- Methods for reducing the feed coal size to meet process requirements.

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

During Phase III, an IMPCO screw feeder will be installed and operated in a pilot development unit selected by DOE. Feed rates will be in the range of 1.5 to 5.0 tons-per-hour. A report will be prepared that will include design specifications, installation drawings, assembly procedures, installation and functional test guides, and operation and maintenance manuals. The performance of the feeder in the pilot plant tests will be assessed based on the test data. A final report will be prepared which will include the design of equipment sized for a demonstration plant.

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

Coal Piston Feeder

Activities on piston feeder concepts were initiated in late 1977 in a three-phase program, leading to a pilot plant demonstration of a selected piston feeder configuration.

Phase I of the piston feeder development program involved Concepts Evaluation. Phase II involves Laboratory Development of Selected Piston Concepts, and Phase III will be the installation and operation of the piston feeder in a selected pilot plant.

Feasibility of Spraying and Feeding Fully Plasticized Coal

In this effort the feasibility of delivering fully plasticized coal in spray form and in an acceptable particle size range against atmospheric and elevated back pressures was to be established with the Negri Bossi V-12 screw feeder.

PROJECT ACCOMPLISHMENTS

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

Coal Piston Feeder

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

The Phase I evaluation has been completed. A single-acting feeder, functionally similar to the original concept, has been selected for further development as a pilot plant feeder. This configuration is considered to be an excellent design to demonstrate that coal feeding by a piston type feeder is a viable approach.

The double-acting feeder was rejected primarily because of its relative complexity while the rotary feeder was rejected because of substantial seal, bearing, coal inlet and coal outlet design problems.

The piston seals, inlet and discharge port configurations and the coal transport cylinder material are critical to the successful development of the piston feeder.

Several seal configurations have been defined which offer promise of meeting all seal requirements. Initial tests on a three-inch diameter K-30M ring seal have shown very low leakage rates under simulated feeder operating conditions. However, test time accumulated to date on this seal concept is insufficient to predict seal life.

Experimental work with simulated inlet ports has indicated that good flow and filling characteristics can be obtained. Volumetric fill in excess of 90 percent has been demonstrated. An experimental discharge port has been configured that permits free fall of coal particles pushed out of the coal transport cylinder bore by the coal piston. Experimental work indicates that moist (12 percent) coal can be handled by the inlet and outlet ports under design.

Candidate materials of construction for the coal transport cylinder liner have been identified. These

materials offer promise for meeting the requirements of seal compatibility and wear resistance. An initial choice of Xaloy has been made.

Alternate piston feeder configurations have been conceived which appear to offer significant advantages over the present concept with respect to sealing, loading and unloading.

Coal Screw Feeder

Testing began with the 1.5" diameter screw feeder (NB-V-12) in mid-1976. Coal has been successfully pumped under steady-state conditions against elevated back pressure in three operating modes:

- Extrusion mode, with external heat
- Injection mode, with external heat
- Injection mode, without external heat

A 5-1/2" diameter screw feeder (IMCO 1500) was designed and fabricated. Its coal feed rate ranged from one to five tons per hour against 1,500 psig back pressure. At a low feed rate of 300 pounds-per-hour, coal has been pumped against a back pressure of 300 psig.

The design and testing activities of the 5-1/2" diameter coal screw feeder (IMPCO #1500) was continued in 1978. The injection mode of operation, without external heat addition, was found to offer the most promise with respect to power consumption, coal delivery rate and ease of operation.

Stable, controllable operation of the feeder at a coal delivery flow rate in excess of 2,800 pounds-per-hour and sealing capability against a gas back pressure up to 900 psig have been demonstrated. In addition, tests were performed with various coal-pitch mixtures and significant reductions in power consumption were observed.

In 1978, major development effort was directed towards meeting the Morgantown Energy Technology Center's (stirred fixed bed) coal gasifier pilot plant requirements. Emphasis was placed on providing maximum coal output through the feeder in the injection mode without external heat and minimizing the associated power consumption. Breaker studies were also initiated to meet the size requirements for this gasifier.

Spraying Fully Plasticized Coal

The plasticized coal delivery program was initiated in July 1977. This approach utilizes the tendency of many bituminous coals to exhibit plasticity at elevated temperatures.

The final report, "Feasibility of Spraying Fully Plasticized Coal," was published in mid-1978, concluding this part of the feeder development program. The final report concludes that the technical feasibility of spraying fully plasticized coal and feeding it into gas at elevated back pressure has been successfully demonstrated in the injection mode of operation with the 1.5" diameter screw feeder.

PROGRESS DURING OCTOBER-DECEMBER 1978

Coal Screw Feeder

Early in the quarter, steady state operations were achieved feeding 1554 lb/hr coal against a 300 psig back pressure. Later in the quarter, the screw feeder was operated against 900 psig back pressure without any gas leakage. Testing at higher pressures was not attempted because of the limited pressure available from bottled nitrogen. Static tests were also conducted at 500 psig for over 30 minutes to demonstrate the long-term sealing capability of the coal plug (with a binder). The success of these tests indicates that the coal plug can be used as a safety device to prevent gas blow back in the event of a feeder malfunction.

Extrudate Break-Up Development

Six breaker types were investigated using simulated coal plugs and eventually using actual plug samples produced in the 5.5 inch diameter screw feeder. Based upon observations to date, a new breaker design was developed and tested. This breaker proved to be the most promising. It uses a recessed cone surrounded by 4 to 8 equally spaced wedges. The relative positioning of the different elements of the breaker is important to the size consist of the product. Variations of this design have produced acceptable lump size (minus 2") with the quantity of fines reduced to 9%. A maximum flow rate of 2250 lb/hr was achieved during a demonstration test for METC. It was concluded that the breaker for the METC pilot plant will be based on this design. A design layout will be prepared and reviewed by METC during the first quarter of 1979.

Coal Piston Feeder

The seal development program continued. A new type of seal has evolved which combines the features of the buffered seal and a seal that provides for substantial wear.

This new seal, the Parker Polypale Seal, The Fluorocarbon Omni and the new K-30M "thick, two way seal" have all been tested in the 3" seal tester.

In December, the 3" seal tester was modified to examine the pressure equalization phase of the feeder cycle. Testing is now underway without coal at a back pressure of 500 psig and a buffer pressure of 600 psig. After 327 pressure equalization cycles, the condition of

the seals appears very good, and the dynamic leakage rate at 600 psig for a 9" diameter seal is estimated to be 0.07 SCFM. If the test results without coal are satisfactory, coal will then be added to simulate feeder conditions.

The pilot-plant-scale feeder and its test system procurement and installation activities are progressing satisfactorily.

VIII. COAL FEEDER DEVELOPMENT PROGRAM

LOCKHEED MISSILES AND SPACE COMPANY,
INC.

SUNNYVALE, CALIFORNIA

Contract No.: EX-76-C-01-1792

Total Funding: \$2,591,640
(100% DOE)

INTRODUCTION

Lockheed Missiles and Space Company, Inc., a subsidiary of Lockheed Aircraft Corporation, is conducting a coal feeder development program under the auspices of DOE. A need exists for this development effort because current lock hopper or slurry concepts for coal feeding are inadequate. The feeder system is a critical component of a coal conversion plant, affecting equipment and maintenance costs, plant efficiency, and down time. An improved coal feeder that is applicable to all processes using dry pulverized coal at reactor pressures up to 1,500 psi must be developed.

PROGRAM DESCRIPTION

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

The examination included:

- Screening potential candidates
- Investigating existing equipment

- Synthesizing feeder system designs
- Assessing problem areas
- Defining laboratory evaluation techniques
- Preparing a final report

Phase II studies, which were completed in July 1977, involved tests on four coal feeder systems. These include a fluid dynamic lock, kinetic extruder, ball conveyor, and an ejector. To establish a firm basis for the design of the coal feed systems for use in commercial plants, testing efforts for this phase will include:

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

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

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

PROJECT ACCOMPLISHMENTS

Lockheed completed Phase I of the contract and issued the Phase I report in December 1975. Literature and patent searches were conducted which established fundamental principles used in the design of the feeder. Operating requirements were established via field trips to various coal conversion installations in the U.S. As a result of these efforts, various candidate concepts were selected for further evaluation and were segregated into low pressure and high pressure usage. Cost data were subsequently generated to compare the equipment and operating costs of each of the feed systems. From these studies, four feeder concepts emerged as the most promising for further laboratory testing. The four systems selected for Phase II investigation were:

- Ejector, based on the use of jet pumps.
- Kinetic Extruder, a system based on the use of centrifugal force to reduce the permeability of the compacted coal to prevent net back flow of gases.
- Ball Conveyor, using large metal balls loosely fitted into a standpipe and conveying coal in the interspace, designed to overcome net gas leakage by the downward motion of the column and the static pressure by the weight of the column. The return leg uses a liquid seal to prevent gas flow.
- Fluid Dynamic Lock, a system based on the use of bladeless, disk type compressor.

The Phase II report preparation was carried out throughout both July and August. Lockheed felt that the Phase II program resulted in design procedures which permit confident evaluation of the four feeder systems considered for coal conversion plant application. Because of the variety of coal feed stocks, feed rates, and pressure levels considered and the variety of proposed conversion processes, it is not possible to select one feeder system as superior. A tradeoff must be conducted to select the proper candidate for a specific use.

As a result of the work carried out in Phases I and II, the kinetic extruder was selected for further development during Phase III. In the kinetic extruder, coal at atmospheric pressure is fed to the center of a spinning rotor having multiple radial sprues. Centrifugal force compacts the pulverized coal and forms a low permeability plug. The plug moves with a velocity that prevents backflow of gases from the high-pressure discharge zone.

At the beginning of Phase III, extensive design studies were performed to identify components of the kinetic extruder which had an important impact on performance. In accordance with the development plan, these components were optimized and subject to extensive testing in a coal feeder test loop or to detailed analytical evaluation, as was the case for the bearings and seals.

The improved components were incorporated in the design of kinetic extruder, Model 3. The major accomplishments during the experimental activities include:

- Demonstration of one-ton-per-hour delivery rate at 400 psi back pressure (the maximum obtainable within the present test-site capability).
- Total test time exceeding 30 hours while feeding coal against pressure at the one ton-per-hour rate.

Based on these activities, the feasibility of building commercial size equipment for feeding coal at 1,500 psi has been established.

During 1978, emphasis will be on efficient means to vary the output rate of the kinetic extruder. This will include means to cope with variations in feed stock.

PROGRESS DURING OCTOBER-DECEMBER 1978

The Model 3 kinetic extruder was received early in the quarter, and the horizontal drive shaft assembly was received in December. Testing was carried out throughout the period to verify the design principles employed for

Phase II of the contract, was completed in July 1977.

this new model. Operation of the kinetic extruder in the horizontal mode provides the feeder geometry selected for commercial applications. The Model 3 kinetic extruder has a 28 inch rotor and a capacity of approximately 1 ton/hr. During the quarter, an effort was initiated to determine the subsystem requirements and costs for the installation and operation of both a 7 and a 50-ton/hr feeder system.

Initial tests on the new controllable sprue rotor have confirmed that the new rectangular shaped sprue entrance configuration eliminates plugging. This new design eliminates the free space between sprue entrances where coal can collect and agglomerate causing plugging when the feeder is shut down. Tests were run where the coal flow was stopped 10 times in succession without plugging. All other sprue components were evaluated during the quarter and the design principles employed for the Model 3 rotor were fully validated.

The use of gas injection was also evaluated during the quarter as a method to compensate for variation in the coal permeability and for throttling the coal flow rate. Testing verified that the sprue gas pressure at the injection point was easily controllable by means of the injection gas flow. This demonstrates the feasibility of using gas injection to "fine tune" the sprue pressure distribution to adjust for short term variations in feed-stock permeability. Using sprue gas injection, the coal throughput rate could be adjusted between 0.5 and 1.5 tons/hr while maintaining a constant delivery pressure. The upper limit of 1.5 tons/hr is imposed by the coal feed pipe capacity; the lower limit is dictated by the control orifice size.

A number of other tests were conducted during the quarter; these included:

- Wear Testing — A number of conical control orifices made from hardened steel, Ni cast and, TZM alloy were tested under actual operating

conditions for approximately 20 hours. Preliminary inspection showed minor evidence of wear, with Ni cast appearing to have the best overall performance. Because of the wear patterns, flat button orifices will also be considered in these applications.

- Water Injection Tests — Two test runs have been made wherein water has been injected into the kinetic extruder rotor while feeding coal to simulate the effects of a weeping water seal and bearing configuration. Different rotors, water flows, and points of water injection were used in the two tests. Water injection was initiated while the feeder was operating at delivery pressure (200 psig). Within a minute or two all the control orifices plugged. This finding supports the decision to use contact-type face seals in the commercial size coal feeders.
- Flow Simulator — The horizontal shaft flow simulator have been completely assembled and is ready for testing.
- Seal and Bearing Study — The design report on the bearing and seal design study for the straddle-mount 7-and 50-ton/hr coal feeder has been released by the subcontractor, Mechanical Laboratory, Inc., and is being reviewed.
- Feed Stock Temperature Tests — In commercial applications, the Kinetic Extruder may be supplied by a feed stock of an elevated temperature (~ 200°F) due to upstream drying operations. To establish the flowability of the coal is not adversely affected by higher temperature, flowability tests have been conducted using heated coal samples. A slight decrease in flowability is evident in going from room temperature to 150°F. However, no further change occurs until the 450°F level is reached. At this temperature, the coal was smoking considerably and higher-temperature tests were not run. These tests indicate that no problems should be encountered at temperatures below 350°F, which is the operating limit imposed on the coal feeder.

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IX. PRELIMINARY DESIGN SERVICES

THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA

Contract No.: EX-76-C-01-1775
Total Funding: \$3,280,154
(100% DOE)

INTRODUCTION

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

- Preparing conceptual designs and economic evaluations for commercial plants.
- Evaluating pilot plant performance and other experimental programs.
- 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 materials problems associated with the design of large plants and equipment.
- Identification of problems in sizing, safety factors, and instrumentation of equipment, which must be resolved before equipment is specified for manufacture.

- Identification of equipment design problems, and development of programs for solution of those problems.
- Identification of construction problems, including availability of materials, type of land base, and area required for construction, that must be solved before large equipment can be fabricated in the field.
- Establishment of overall utility requirements. This effort will provide a common economic basis for comparing capital and operating costs of the processes. Ultimately, the commercial design concepts will serve as guides for selecting the best coal processes to be demonstrated in commercial-sized plants.

PROGRAM DESCRIPTION

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

Conceptual designs and economic evaluations of commercial-scale plants are being developed for the Char-Oil Energy Development (COED) process, an oil-gas process based on the Solvent-Refined Coal (SRC) process, the Fischer-Tropsch process, and a combined POGO (Power, Oil, Gas, and Other Products) 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 overall objectives of the individual tasks are given below. The idea behind the Coal Mining/Coal Preparation task is to design and evaluate, as feed facilities to conversion plants, coal mine and preparation facilities for five geographic areas where conversion facilities are being studied. Plant capacities of up to 100,000 tons per day of coal feed are being considered.

Oil/Gas Plant efforts will be to prepare preliminary design and economic evaluation for a commercial plant to produce synthetic fuels and SNG from coal, and to define the maximum practical capacity of a single train plant using the selected process. The purpose of the Fischer-Tropsch plant task will be to develop a conceptual commercial plant design and economics for production of pipeline gas, motor fuel, distillates and other hydrocarbon fractions.

The objectives of the POGO (Power, Oil, Gas, and Other) plant design is to develop a preliminary design of a coal processing plant which will produce power, oil, gas, and other products. The chosen process will be based on economic evaluations of the candidate coal processes available. Other efforts will include the development of a model capable of calculating material and heat balances for a number of coal conversion processes using computer capability and the estimate of the overall utility balance for the complex.

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

Among the technical evaluation activities is the development of functional and preliminary specifications for equipment and control apparatus required in the

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

PROJECT ACCOMPLISHMENTS

The final Oil/Gas Plant Design report was completed in February 1977. The Fischer-Tropsch Plant Design Report was published in March. Work was initiated in April 1977 on the design of the Multi-Process Demonstration Plant and on designs of Prestressed Concrete Pressure vessels.

During 1978, work was done on modification to the fluidized-bed gasifier design to make possible the elimination of the oxygen pre-treatment stages. The draft report on the Multi-Process Demonstration Plant was completed and submitted to the DOE.

PROGRESS DURING 1978

During this quarter, the final report (FE-1775-18) on the Multi-Process Demonstration Plant was completed. The projects' Annual Report (FE-1775-18) was also completed and submitted to DOE for publication, and the Contract Final Report (FE-1775-21) was in draft form. These reports complete all technical assignments and contractual obligations for this contract.

X. LOCK HOPPER VALVE DEVELOPMENT

CONSOLIDATED CONTROLS
EL SEGUNDO, CALIFORNIA

Contract No.: EX-76-C-01-2355

Contract Funding: \$2,574,669

INTRODUCTION

The objective of this lock hopper valve development contract is to design, manufacture, test and evaluate 8- and 12-inch valves that would be compatible with operating conditions found in numerous coal gasification plants. This program was initiated in June, 1976. The development of such valves will be required to assure the efficient, continuous and safe operation of coal conversion processes in future plants.

PROGRAM DESCRIPTION

The specific objectives of the project are threefold:

- To provide reliable data sufficient to permit the confident design of solids handling valves compatible with existing and projected pilot plant operations.
- To produce reliable coal valves suitable for commercialization.
- To provide for the orderly transfer of the demonstrated technology to private industry.

The project will be conducted in three phases. Phase I, preliminary design, will evaluate the proposed design based on engineering analysis. A review of and determination of the availability of special hardware and test

procedures will be conducted. Phase II, prototype design and pretest, will involve the fabrication and testing of 8-inch prototype valves. In addition, analysis of test results will be conducted in order to identify areas where modifications may be necessary in the final prototype design. Twelve-inch valves (based on Phase II test results) will be fabricated and tested in a pilot plant during Phase III. A review and evaluation of the test results will be made and a report published concerning the test data. The overall objective of this program is to design, develop, fabricate, and test scale model prototypes of each of four types of valves to be used in a coal gasification system. The valve types are identified as follows:

Type I	— Valves for Feed System
Type II	— Valves for Use Between Injector Hopper and Gasifier
Type III	— Valves for Char and Ash Removal System
Type IV	— Valves for Slurry Dis- charge System

ACCOMPLISHMENTS TO DATE

Of the four types of lock hopper valves in the 8-inch class, the Type III was chosen for preliminary design studies and prototype development since it had the most stringent requirements. This valve will incorporate high

alumina ceramic and commercial refractory parts for higher reliability and longer life because of their higher resistance to corrosion and erosion over metal parts.

An extensive material survey and evaluation was conducted by Consolidated Controls to select a refractory material or materials, other than for their insulating qualities, that would retain a high degree of structural integrity as finished components when used at elevated temperatures and pressures under the highly erosive and corrosive environments. Other prerequisites are permanence in dimensional stability, non-spalling and non-fracturing from temperature fluctuations, low permeability and ease of fabrication.

Though published reports have been completed encompassing the above criteria, the testing and evaluation still continue to date.

High alumina ceramic components are used where strength greater than that offered by any other refractory material is required. These components include such items as the seats, the sealing disc in the gate, stop rings, and most noticeably, the ceramic spring.

The designs were completed for all four valve types, and the manufacture of each of the valves began.

PROGRESS DURING 1978

The first Type III valve was completely assembled using a Ceramic Refractory Composite Gate with a Ceramabond surface. The following tests were performed:

- Proof Pressure Test (2400 psi)
- External Leakage Test (1600 psi)
- Internal Leakage Test (1600 psi Inlet to Outlet and Outlet to Inlet)

Some leaks were discovered during the tests. These were due primarily to poor seating of the seals and cracking of the seal material during the tests. The other Type III valve interior will be recast with new refractory to obtain the correct seal alignment.

The first Type I, II and IV valves have been completely assembled with a stainless steel gate. Acceptance testing has disclosed no problems as yet. A second set of Type I, II and IV valves are approximately 50% assembled.

The gate design has been the major problem encountered during the program. Because of casting and manufacturing problems during curing, a number of alternate materials are being investigated and made into prototype gates for testing. Many of these new gates will be delivered in February and then will be machined for assembly and testing. Stainless steel gates were also ordered for the valve Types I, II and IV. These gates were designed with a Tungsten Carbide coating which should be adequate for the temperature and pressure requirements of Type I, II & IV service, but may not offer the corrosion and erosion resistance of ceramic, which remains the preferred material.

The following reports were revised or published during the period:

- FE-2355-9, Revision B, Refractory Material Test and Evaluation Procedure, was revised and enlarged to include testing and materials currently being evaluated.
- FE-2355-12, Rev. C, Component Development Test Procedure, was revised and enlarged to include testing performed since the last revision.
- FE-2355-21, Rev. A, Component Test Report, was revised and enlarged to include testing performed since the last report.
- FE-2355-28, Assembly Procedure, Type I, II, and IV, was issued.
- FE-2355-29, Assembly Procedure, Type III, was issued.

XI. VALVE DEVELOPMENT FOR COAL GASIFICATION PLANTS

FAIRCHILD STRATOS DIVISION
MANHATTAN BEACH, CALIFORNIA

Contract No.: EX-76-C-01-2356
Contract Funding: \$2,238,023

INTRODUCTION

The goal of this valve development contract, is to design, develop, test, and evaluate 8-inch and 12-inch solids-handling valves scaleable to 24-inch that would be compatible with operating conditions found in various coal gasification plants. The project was initiated in June 1976. Reliable valves to handle abrasive solids are not now available for pilot plants, and even larger valves will be required to assure the efficient, continuous and safe operation of coal conversion processes in future plants.

Presently available lock hopper valves are not suitable for prolonged troublefree service in the hostile environment encountered in coal gasification service. Through a program of extensive material testing and thermal and structural analysis, a valve design will be developed for this type of service.

PROGRAM DESCRIPTION

Phase I Conceptual Design

During Phase I, different concepts will be evaluated and trade-off studies will be conducted to arrive at the most promising design.

Erosion and corrosion resistant materials will be investigated and tested in order to determine the most promising materials for critical parts, such as seats and bearings. Thermal and structural analyses of the valve components will be conducted. The Phase I effort was scheduled for completion April 1978.

Phase II Prototype Testing

From the experience gained in Phase I, a total of eight 8-inch prototype valves will be designed and manufactured, two each for Type I, II, III and IV service conditions: Feed System (350°F), Injection Hopper (600°F), Ash Removal (2000°F), and Slurry Discharge (600°F), respectively.

These valves will be tested at the Morgantown Energy Technology Center (METC). Failures and shortcomings experienced during this testing program will be analyzed. The design will be modified to incorporate any recommended changes. The Phase II effort was scheduled to start in May 1978 with delivery in May 1979.

Phase III Pilot Valve Testing

After demonstration of the performance of the Phase II valves, eight 12-inch valves will be designed and manufactured for Type I, II, III and IV service

conditions. These valves will be tested in a pilot plant, and experience from operating these valves will be incorporated into a Demonstration Plant Size Design. All findings of the testing programs will be incorporated in a final report.

PROJECT ACCOMPLISHMENTS

Phase I

A trade-off study was conducted to determine the most promising valve design. Candidate seat and bearing materials were tested for abrasion and impact resistance.

A valve design layout was completed and a thermal and structural analysis of the valve was conducted. A prototype valve was manufactured and the assembly was tested at ambient temperature and cycled approximately 1000 times to verify the operation of the actuator mechanism.

Test fixtures for evaluating the seats and bearings were manufactured. Boron carbide seats were tested in this fixture and cycled 500 times at room temperature showing no signs of wear. A borided 502 steel seat was tested and showed signs of wear and was therefore eliminated as a candidate material.

Tungsten carbide coated shafts, Stellite No. 6 and tungsten carbide bearings were tested in the bearing test fixture at simulated operating conditions.

The tungsten carbide coated shaft with tungsten carbide bearings performed for 30,000 cycles at temperatures of 650°F with no visible deterioration. A summary report for the Phase I Conceptual Design and Functional Analysis effort was published in April.

PROGRESS DURING OCTOBER-DECEMBER 1978

Progress on Phase II has continued throughout the year. Phase I carryover work has also continued. Phase II effort is approximately 25% finished, with a scheduled completion in November 1979. The scheduled delivery dates for the four prototype valves (Phase II) are estimated to be:

Type I	May 25, 1979
Type II	April 27, 1979
Type III	June 22, 1979
Type IV	July 20, 1979

The design engineering is 68% complete and detail drawings are 60% completed for the Type II valve.

The transient thermal analysis for all valve types were completed. The results of these analyses indicate that the valves' most conservative designs are based on the thermal gradients resulting from the worst case of steady-state thermal load, as was previously indicated.

A two-dimensional seat purge test model was fabricated and successfully used to evaluate counter vs. parallel seat purge flow rates. Cigar smoke was introduced into the model via an aspirator to visually explore flow patterns. Coal fines were then introduced into the model to evaluate flow pressure differentials and to size the purge flow ring annulus. The best results were obtained when both the counter flow and parallel flow jets were operated concurrently. The combined flows cleared the entire seat area as well as the set.

The first valve body was cast. Surface examination and subsequent preliminary information radiographs indicated a sound body with no repair welding necessary. During rough machining of the body by the foundry, a center line shrinkage was revealed. The cause of the shrinkage was attributed to the casting configuration. It was believed that such a phenomena could severely compromise the body's structural integrity. Therefore, the first body was scrapped. A modification of the casting configuration was developed by FSD and the foundry. Preliminary indications were that major rework to the body pattern would be necessary, and a new body could be poured with only a 3 to 4 week's loss off the original schedule.

The test of an alternate seat and visor combination (compression seat concept) for the Type III valve application, has now been tested in excess of 5600 cycles at sustained temperatures of 950°F and pressures up to 1600 psig. The test was suspended when a large retainer O-ring leakage developed due to loss in sealing compression caused by yielding of Inconel 718 retainer bolts. It was confirmed that the bolts had been mistakenly furnished in the solution annealed condition. Examination of the Silicon Nitride and Boron Carbide inserts revealed both to be in excellent condition. Evaluation of the test results will determine if further testing is warranted. Preliminary conclusions indicate this seat/visor concept is an acceptable candidate for the Type III valve application.

XII. COAL GRINDING EQUIPMENT DEVELOPMENT

KENNEDY VAN SAUN
DANVILLE, PENNSYLVANIA

Contract No.: EX-76-C-01-2475

Contract Funding: \$840,000

INTRODUCTION

Kennedy Van Saun is under contract to DOE to develop and modify coal grinding equipment and procedures to meet the needs of demonstration and commercial coal conversion plants. The efficient conversion of coal to clean synthetic fuels is dependent on achieving and maintaining a continuous and controllable reaction process which is in turn dependent on uniform and optimum size consist of coal feedstock. Current practice is to size grinding equipment without regard for excessive amounts of fines and undersized particles. This project is therefore designed to alleviate the above mentioned deficiencies associated with the coal grinding processes. A coal grinding handbook which can be utilized by process engineers for grinding system selection will be published at the end of this project.

PROGRAM DESCRIPTION

These project objectives, as formulated by DOE are:

- to produce reliable coal grinding equipment for the controlled grinding and preparation of feed coal for demonstration and commercial size plants.
- To provide a controlled size output with a minimum of fines.

The project, initiated in September 1976, is expected to be completed in December 1978. Phase I, the study phase, requires approximately eighteen months to complete. This will involve a study on the state-of-the-art of commercial coal grinding equipment. Further, three to five types of coal will be selected for experimentation. The Pennsylvania State University, under subcontract to Kennedy Van Saun, will perform laboratory analysis to determine the mechanical properties of the coal, the kinetic parameters of comminution, and perform rate testing.

Phase II, is the preparation phase where the selection, design, layout and modification of coal grinding equipment to be used in Phase III will be carried out. The actual grinding experiments with the coal will take place during Phase III. Dry and wet grinding tests (in water and oil) will be made. Phase IV will involve documentation and reporting on the findings during the first 3 phases of the contract. A handbook will be prepared which will describe modifications of equipment and selected grinding procedures, required safety items, and will also include economic analysis comparing various grinding procedures and equipment.

PROJECT ACCOMPLISHMENTS

The testing facility layout for the four grinding systems — dry ball mill, ball and race mill, hammer mill and wet

ball mix — was completed and the dry ball mill grinding system installed. Since the feed material handling system is common to all grinding systems and the product material handling system is common to all dry grinding systems, the other grinding systems are also almost completed.

Five coal samples were selected and delivered to the testing site. The types of coal and delivered tonnages, in order of decreasing Hardgrove Index, are washed Lower Freeport bituminous (108), washed Western Kentucky #9 bituminous (99), unprepared Ohio #9 bituminous (86), unwashed Belle Ayre South subbituminous (80) and washed Pennsylvania anthracite (44).

Numerous manufacturers of coal size reduction devices were contacted and a brief literature search conducted. This information was assembled into a report and a draft copy issued.

The main thrust of the laboratory analysis, being performed by the Pennsylvania State University, is the investigation of the breakage characteristics of the coals in order to assist the testwork at KVS. This work has centered on the grinding of the coals in a ball mill (dry and in water) and a ball and race mill (Hardgrove Machine).

PROGRESS DURING OCTOBER-DECEMBER 1978

As of the end of 1978, the mechanical properties

analyses of the project coals were completed. There was no property which correlated with the grindability of the project coals. The mechanistic models for the three dry grinding systems were derived and are undergoing validation. Two special studies were completed. The first examined the grinding of coal in oil. The second special study involved a comparison between two types of grinding media — The conventional ball and the cylpeb, a type of equidistant rod mill.

Work under the Testing Phase involved the consolidated subtasks — Testing Planning/Modification; Testing; Data Reduction. All of the coal grinding circuits (air swept ball mill; ball and ace mill; hammer mill; wet overflow ball mill) were operated to generate data to validate the mechanistic models. The coals produced during these tests were made available to other DOE projects requesting material. In addition, the grinding facilities were used in support of developing coal grinding process information for several DOE demonstration projects.

Work under the Reporting Phase involved the three subtasks: Economic Analysis; Systems Layout; and the Grinding Handbook. A rough draft of the Economic Analysis Report was issued. Generic P and I drawings for a negative, direct air swept coal grinding circuit with an external classifier; a negative, direct air swept coal grinding circuit with an internal classifier; and a wet coal grinding circuit were made. A working draft of the Handbook entitled "Coal Grinding Technology" was submitted to the DOE.

XIII. COAL PUMP DEVELOPMENT AND TECHNICAL SUPPORT

JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

Interagency
Agreement No.: EF-77-C-01-616
Total Funding: \$2,176,000

INTRODUCTION

In support of the Department of Energy, Division of Coal Conversion, the Jet Propulsion Laboratory (JPL) has been awarded a contract to assist DOE in the development of coal feeder devices and to lend technical support to DOE in evaluating new feeder technology.

The objectives of the contract are two-fold. One concerns the analysis of general coal feeder and related peripheral equipment and technology. The other objective concerns the assessment of the technical feasibility of developing, on a commercial scale, a coal extruder or "coal pump" based on the plastic properties of coal.

The first objective consists of two separate tasks (Task I and III) which are based on engineering analysis and evaluation. Task I, coal feed program support, will provide support to DOE by:

- Analyzing coal-feeding requirements for scale-up coal plants with particular emphasis on pressurized converters.
- Formulating engineering and performance criteria to guide the subsequent selection, development, and commercialization of coal-feeder systems.
- Monitoring the technical progress of the feeder developments: evaluating performance of on-going coal-feeder programs, comparing development progress against the criteria.
- Formulating and recommending program plans for the development of selected feeder systems.

Task III, facilities development requirements study, will be carried out by:

- Identifying equipment deficiencies for demonstration facilities.
- Recommending equipment development actions to DOE.

The second objective (Task II) will be accomplished by establishment of a base engineering experience in the continuous extrusion of coal in the plastic state through use of a modified thermoplastic extruder, and assessment of the feasibility of developing large commercial size coal feeding systems based on this approach. Also, JPL will attempt to acquire the data required to initiate the design of a commercial-size coal extruder.

PROGRESS DURING OCTOBER-DECEMBER 1978

Task I — Coal Feed Program Support

No effort was expended on the Coal/Solids Handling and Feed Systems Program during this quarter since it is not clear if implementation of the Plan, or any parts if it, will be authorized by DOE in FY-79. The Program Plan is currently under review at DOE.

A Process/Feeder Tradeoff Analysis was started in December at the request of DOE. This analysis will

consider all current process requirements including third generation.

The lack of availability of test facilities to test pilot scale coal feeders still remains a problem. Contacts will continue to be made with ORNL and other potential facilities on the requirements for a suitable test facility to test feeders.

Demonstration plant schedules still show that design of these plants will occur prior to the completion of second generation equipment demonstrations. This implies that demonstration plants will contain untried and untested equipment due to utilization of scaled-up existing technology or untested new technology.

Facilities Equipment Development Requirements Study — Task III

During December, revisions to the preliminary draft of the Instrument and Control Program Plan were completed and all materials turned over to the Documentation Section for production of the first draft. Proof copies of this draft are due January 15, 1979.

A number of visits were made to DOE contractors to review the status and progress of their programs. Trip reports were completed for visits made during September and October.

Task II — Coal Pump Development

A status report plus a proposed plan to incorporate the 2.5 in. coal pump on a Rockwell 1/4 TPH Hydrogasifier was presented to program management personnel at the Morgantown Energy Technology Center (METC) and at DOE Headquarters. This plan would provide an excellent opportunity to demonstrate the high pressure capability of the coal pump.

The presentation elicited favorable reaction regarding the potential utilization of the coal pump in their process. This reaction supported our preliminary survey study results which were based entirely on available published reports. A joint effort which would utilize the 2.5 in. extruder on the Rockwell 1/4 TPH hydrogasifier is being pursued.

Extruder Development

A number of changes which were recommended during

a review held in August were made to the 2.5 inch extruder during this quarter. The changes included switching the pulleys on the drive system to halve the screw speed to 100 rpm and to double the available torque, and to obtain shallower depth screws so that flood feed conditions can be reached. The change in the pulleys to decrease the screw feed and increase the torque aided in making the drive system run much smoother.

Three tests were made using the two new shallow channel screws. All three tests were terminated early following formation of a wet plug of coal in the feed section of the screw. Apparently, because of the shallower channel depth, there is less of a passage available for the backstreaming of the condensable volatiles. As a result, more of these volatiles condense on the incoming coal, building up a plug on the screw shaft. This continuous buildup finally blocks all of the incoming coal.

Fabrication of the melt control/check valve was started and the receiver equipment was assembled to permit melt diversion to either of two receivers. Also, one of the extruder barrels was modified to incorporate a vent similar to the vent on the 1.5 in. coal pump. These items will be tested during the next quarter.

Material Characterization

The final report, "Development of Methods of Characterizing Coal in its Plastic State," has been submitted by the Institute for Mining and Minerals Research at the University of Kentucky. A series of tests on the viscosity of Pittsburgh No. 8, Ohio No. 9, Illinois No. 6, and mixtures of Pittsburgh No. 8 and Pocahontas No. 3 coals has been completed.

Applications Research Laboratory

The preparation of the coal pump applications research laboratory for the new, high pressure 1.5 in. extruder is proceeding on schedule. The Davis Standard extruder has been installed and the die and clamping assembly completed. Modifications to the barrel for installation of the vent and to accept the die have been completed. Checkout of the extruder has started. Based on progress to date, it is anticipated that testing of the extruder with coal will begin in February.

During this period, the Centerline Machinery 1.5 in. extruder was run several times. The major test was a 34 hour duration run. During this run, data on power versus backpressure was obtained for Pittsburgh No. 8 coal. Extrudate and vent gas samples were collected for a material balance. Additional runs were conducted to

demonstrate flood feeding and feeding of fines and to investigate power fluctuations during operation.

Analytical Support

A report reviewing a number of processes which may be able to use the plasticating coal pump is in preparation. Publication is expected shortly.

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XIV. INSTRUMENTATION AND PROCESS CONTROL FOR FOSSIL DEMONSTRATION PLANTS

ARGONNE NATIONAL LABORATORY
ARGONNE, ILLINOIS

Contract No.: ANL 189a 49622R2

Contract Funding: \$1,000,000 FY-77

INTRODUCTION

The Department of Energy, Division of Coal Conversion, is funding Argonne National Laboratory efforts in the development of instrumentation and process control for large scale gasification, liquefaction, and direct combustion plants. The object of the program is to insure timely availability from commercial sources of process control instruments needed for these facilities.

PROGRAM DESCRIPTION

This program will develop instruments not currently available but ultimately needed for coal conversion and/or combustion demonstration plants. Several general types of instruments are needed to improve safety and to optimize operation: mixed-phase mass-flow, on-line composition, level of fluidized beds, and temperature (particularly when rapidly fluctuating) in vessels and on vessel walls. These instrument systems are required for process monitoring and control in each phase of the plant operation: initial startup and operation, operational reliability improvement, and process efficiency optimization.

The development program will involve continuing information exchange and cooperation with commercial

instrument suppliers and final plant users through symposium sponsorship, industrial subcontracts, and industrial participants at Argonne National Laboratory (ANL). The program will ultimately transfer the knowledge and designs to instrument suppliers for instrument production. Using unique test facilities constructed during the program, instrument testing and calibration will continue after the development of the instruments.

The program will be carried out under five major tasks. Task I, update and State-of-the-Art Report, will involve incorporating the latest information on process needs and developments in commercial instrumentation into the recent ANL study of instrumentation for fossil demonstration plants and will provide an information base for future efforts. Task II, develop mixed phase mass flow instruments, represents the heart of the overall hardware development program. This task includes development at ANL and in industry of several promising techniques for measuring the flow of solids in fluids. It includes the design and fabrication of mixed solids/fluids loops for instrument development, testing, evaluation, and calibration. Task III, develop other on-line instruments, includes on-line composition analysis, level measurement, and temperature monitoring. Task IV, perform process control analysis, will give guidance on instrument performance requirements in support of the hardware development tasks. Task V, organize instrumentation and control symposia, is an important part of the information exchange aspect of the overall program.

PROGRAM ACCOMPLISHMENTS

- Visits to pilot plants and identification of specific points in the system where instrument needs exist and where instrument tests are planned.
- Issue initial state-of-art study on instrumentation needs for coal conversion plants (ANL-76-4).
- Initiate construction of solids/ gas flow test facility (S/GFTF).
- Feasibility-Study for acoustic/ultrasonic flow measurement in solid/liquid streams.

Operations of the Solids/Gas Flow Test Facility (S/GFTF) in all eight operational states was reached in 1978 after extensive shakedown tests, including tests of safety and emergency shutdown interlocks. The Spectron particle counter was installed and successfully tested. This test revealed the need to have control of dust particles concentration over a much wider range, particularly at low concentration. Special attention has been given to flow systems having large variations in the density of materials in different states (solid, liquid, or gas). A slurry-liquid test loop will provide experimental confirmation of such calculations in addition to providing a loop for testing mass-flow instrumentation.

The data from the HYGAS experiment were analyzed and indicate that an acoustic/ultrasonic flowmeter is feasible. The noise background level is small when compared with the transmitted signal through the toluene/coal slurry. The attenuation through the slurry was higher than the predicted theoretical values but within the design requirements. Based on the HYGAS results and additional laboratory experiments, a design concept for a doppler acoustic flowmeter was tested, and the results indicated feasibility. Also, data from HYGAS pertaining to the active acoustic cross-correlation techniques are being analyzed, and preliminary results indicate that a measurement of velocity through this technique can be made.

Analysis of the capacitive mass-flow data from the HYGAS pilot plant experiments was continued during 1978. Density signal (averaged capacity) increases approximately linearly with char concentration in percent by weight. Density signals were shown to provide possible warning of incipient plugging and/or plugging of slurry feedlines. A study of capacitor potential mapping in regions of non-homogenous dielectrics was initiated using an existing neutron diffusion code.

XV. DEVELOPMENT OF CONCEPTUAL DESIGNS FOR WATER TREATMENT IN DEMONSTRATION PLANTS

WATER PURIFICATION ASSOCIATES

CAMBRIDGE, MASSACHUSETTS

Contract No.: EF-77-C-01-2635

Contract Funding: \$263,000 (100% Transfer Funds
from EPA)

INTRODUCTION

The program objective is to produce six conceptual designs for integrated water treatment plants in coal conversion demonstration plants. The water treatment plant designs will be developed so that disposal of all residuals can be made in an environmentally acceptable manner.

The program will be carried out under the following five major tasks:

- *Process and Site Selection.* Selection of six demonstration coal conversion plant site combinations.
- *Conceptual Designs for Water Treatment Technologies.* Develop designs for building an integrated water treatment plant.
- *Ultimate Disposal of Residuals.* Provide designs to accomplish the following: reduce mass and water to relatively harmless soluble and insoluble organic wastes and inorganic salts; destroy toxic organic wastes; and render insoluble, recover, and segregate non-destructible toxic metal wastes.
- *Integrated Water Treatment Plants.* Selection and explanation of specific designs to create an integrated water treatment plant for coal conversion plants.

- *Development of Test Program.* Develop a test program which incorporates the following: type and size of equipment to be installed; specific measurements to be made and the necessary measurement techniques and equipment; and specific calculations to be made to optimize the next generation of the water treatment section.

PROJECT ACCOMPLISHMENTS

The coal conversion process, coal type, site location, and water source for six coal conversion plants were identified by WPA and approved by DOE. The criteria used for selection included a mix of technology and geographic siting of plants in both the east and west.

PROGRESS DURING OCTOBER-DECEMBER 1978

Conceptual designs for the integrated water treatment plants have been completed for all six coal conversion demonstration plants. A summary of the processes considered in these designs is shown in Table XV-1.

Table XV-1. PROCESS DESIGN SUMMARY

Process Site	HYGAS North Dakota Montana	HYGAS Western Penn. Eastern Kentucky West Virginia	LURGI New Mexico	SRC Western Penn., Eastern Kentucky West Virginia	BIGAS Montana Wyoming	SYNTHANE Illinois
Site	Demonstration 50 x 10 ⁶ scf day	Demonstration 50 x 10 ⁶ scf day	Commercial 250 x 10 ⁶ scf day	Demonstration 2000 tons day	Demonstration 50 x 10 ⁶ scf day	Demonstration 50 x 10 ⁶ scf day
<u>Water Streams (10³ lb hr)*</u>						
Output Waters						
Worst Quality	59	0	130	8	0	119
Next Worst	0	107	950	0	0	0
Not so Bad	0	0	0	16	254	23
Cooling Waters						
Minimum	180	210		290	140	120
Reasonable	290	340	1220	370		220
Probably Wasteful	370	450	(commercial design)	450		
<u>Processes Considered in the Design</u>						
	Oxygen Activated Sludge	Oxygen and Air Activated Sludge	Solvent Extraction	Phenol Removal	Side Stream Softener	Sodium Ion Exchange Softening
	Cooling Tower/ Trickling Filter	Lime Softening	Resin Adsorption	Solvent Extraction	Clarification	Normal Ion Exchange
	Ammonia Stripping	Ammonia Stripping Stripping	Ammonia Separation	Resin Adsorption	Ultrafiltration	Reverse Osmosis
			PHOSAM W Process Stripping	Ammonia Adsorption	Activated Carbon Evaporation	Vapor Compression
			Ammonium Sulfate Process		Ion Exchange	Ammonia Stripping
			Ammonia Distillation		Stripping	Ammonia
<u>Design Status</u>						
Processing Unit Designs	Completed	Completed	Completed	Completed	Completed	Completed
Integrated Plant Design	Completed	Completed	Completed	Completed	Completed	Completed

The draft of the Final Report was completed and mailed to the DOE on December 13, 1978. Water Purification Associates are currently awaiting comments

from the DOE before the final draft is submitted. This final draft is expected to be submitted early in 1979.

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XVI. CONCEPTUAL DESIGN OF A COAL-TO-METHANOL COMMERCIAL PLANT

BADGER PLANTS

CAMBRIDGE, MASSACHUSETTS

Contract No.: EX-76-C-01-2416

Contract Funding: \$2,585,610
(100% DOE)

INTRODUCTION

The goal of this project is to prepare a conceptual design for a coal-to-methanol commercial plant, and to make recommendations for a demonstration plant to produce methanol fuel and other synthetic liquids and their precursors by advanced coal conversion techniques. This effort will include a study of various gasifiers and synthesis processes in order to arrive at optimum process selections and configurations. In addition, it is anticipated that cost estimates and economic evaluations to be derived will aid in technical and economic feasibility analysis.

PROGRAM DESCRIPTION

Badger Plants, under the current contract to DOE which began in July 1976, is conducting a three phase program to define and engineer a conceptual coal-to-methanol plant. The three phases will consist of a preliminary engineering stage, the development of a conceptual design, and analysis and evaluation of the overall design. The Phase I preliminary engineering will involve an evaluation of a full scale commercial production plant process design. This will include identification of the characteristics and requirements for an initial plant of a size suitable for demonstrating the economic utility of future commercial plants. This effort will also include process selection and configuration.

Phase II, development of a conceptual design, will center on preparation of structural specifications and drawings that are fixed to process requirements, process flow diagrams describing the overall material and energy balance, operating conditions and descriptions for each unit process selected.

Phase III is planned to be used for analysis and evaluation of the completed conceptual design. This will include economy of scale evaluation and process trade-off studies.

PROGRAM ACHIEVEMENTS

Design of the coal-to-methanol plant was completed in 1977.

The overall coal conversions schemes of the methanol-to-gasoline plant were developed based on integrating the Mobil M-Gasoline Process into the Methanol-to-Gasoline Complex. Process design work also commenced in 1977 on a second plant configuration which is based on the production of gasoline, by-product LPG, and high-Btu gas.

PROGRESS DURING OCTOBER-DECEMBER 1978

All process flow diagrams and material balances were up dated and revised to provide an overall integrated

design for the Coal-to-Gasoline plant. Three cases were considered in this design: production of gasoline and LPG; production of gasoline, LPG and high-Btu gas; and maximum gasoline production. Textual material has been completed for the basis of design, and process and systems description sections of the final report. Product and by-product yields and specifications were also established for the complete Coal-to-Gasoline plant. Work has also continued throughout the year on plant plans for the facility. The overall area plot plan, the key plan, and the overall equipment layout and elevation diagram have all been completed.

A computer program was used to provide preliminary air pollution modeling. The results of this effort were used to update and revise environmental process flow diagrams for the completely integrated facility. Textual material for the environmental volume of the Final Report was revised and updated to describe all environmental and waste treatment processes for the integrated Coal-to-Gasoline plant. Descriptive texts for the utility systems were also completed during the period.

A number of economic studies were conducted throughout the quarter. These efforts are summarized below:

- Gasoline production economics — Process flow diagrams, material balances, equipment lists and process area utility summaries have been prepared for 1/12, 1/6, 1/3 and 1/2 the base case coal feed rate to the coal-to-gasoline plant. The results of this effort were used to evaluate the economics of scale for the production of gasoline from the base case plant.
- Petrochemicals removal from gasoline — The technical feasibility and market incentives were evaluated to determine the viability of removing various components from gasoline and selling them as petrochemicals.
- Integration with a petroleum refinery — A process study was completed to evaluate the feasibility of integrating the methanol conversion (methanol-to-gasoline) facility with a petroleum refinery.
- Methanol Market Study — The market potential was assessed by conducting an extensive literature search through MIT and Harvard University. A meeting was held with DOE — Resource Applications Personnel to review with the scope of this effort. Work was also initiated on a similar study for the use of by-product sulfur in asphalt-sulfur paving, based on technology developed by Gulf Oil Canada.

XVII. HIGH BTU PIPELINE GAS, HYGAS CONCEPTUAL BASIS

PROCON, INC.
DES PLAINES, ILLINOIS

Contract No.: EF-77-C-01-2618
Total Funding: \$7,540,000 (Design Phase Authorization Only)

INTRODUCTION

Procon, Inc. was selected to design a coal gasification plant to demonstrate the HYGAS process, developed by the Institute of Gas Technology (IGT) and DOE. The contract calls for preparation of conceptual designs of a 250 MMSCFD commercial plant and, based on those designs, demonstration plant designs and the associated economic evaluations. The principal design basis will be Illinois #6 coal with gasifier pressures of 500 psi in one case and 1200 psi in the second case.

Unlike the other demonstration project contracts, this is funded only for Phase I, with detailed design, construction, and operation phases to be determined at a later date. A project schedule is given in Figure XVII-1, which illustrates possible activities for the HYGAS demonstration program should it be pursued on a high priority basis.

PROCESS DESCRIPTION

The process flow diagram for an agglomerating coal (Illinois 6) is shown in Figure XVII-2. In the process, crushed coal from the feed hopper is screened to remove (+) 14 mesh and fed to a pretreater where its agglomerating tendency is reduced by heat from the reaction with a

limited amount of air. The resultant char is slurried with the light by-product oil. A positive displacement pump meters this slurry into the high pressure (500-1200 psi) fluidized bed hydrogasifier. It enters the upper or/drying bed of a stacked series of three beds in the gasifier. As the solids move by gravity down through the reactor's beds, heat is carried up with the gases originating in the lowest bed, where oxygen and steam react exothermically with the residual carbon at about 1,800° F. The temperature of the successive beds is set to maximize the formation of methane in the reactor through reaction of the coal with the hydrogen formed in the lower beds. In theory, sixty-five to seventy percent of the total methane produced is formed in the reactor by the direct reaction of coal with hydrogen.

Ash and residual carbon are removed as dry solids from the bottom bed. Solids are discharged through a control valve to the waste treatment section.

The raw gas, including the vaporized slurry oil, leaves the top of the reactor and passes through a quench section where coal fines, slurry oil, and excess steam are removed. A shift converter adjusts the hydrogen to carbon monoxide ratio for proper methanation feed. The acid gas removal system removes hydrogen sulfide and the bulk of the carbon dioxide present. In the methanation section, hydrogen and carbon monoxide react to form methane and water. The drying section removes the water, leaving pipeline quality gas.

ACTIVITY	FISCAL YEAR							
	77	78	79	80	81	82	83	84
PHASE I CONCEPTUAL DESIGN		△	▽					
PHASE II ● DETAILED DESIGN ● LONG LEAD PROCUREMENT ● CONSTRUCTION			△	▽				
			△	▽				
				△	▽			
PHASE III SHAKEDOWN & OPERATION						△	▽	

Figure XVII-1. HIGH BTU PIPELINE GAS, HYGAS CONCEPTUAL DESIGN PROJECT SCHEDULE

Figure XVII-2. HYGAS CONCEPTUAL DESIGN PROCESS FLOW DIAGRAM

Provisions will be made for the production of by-product H_2SO_4 or elemental sulfur, anhydrous ammonia, phenol, and light oils. Utilities, such as air, service water, cooling water, refrigeration, steam, and power will be provided as required. Waste treatment sections to permit the maximum recycle of water, acceptable disposal of solids, and optimum treatment of gaseous emissions will be included.

The Commercial Plant will provide a nominal 250 million standard cubic feet per day (MM SCFD) of substitute natural gas with a heating value of approximately 980 BTU/SCF. Typically, there might be three gasification trains with an output of about 84 MM SCFD each. This will require 6525 tons per day of coal feed per

train or about 19,600 tons per day for the entire plant, exclusive of any fuel required for steam and/or power generation. In addition, about 1210 tons per day of 98% pure oxygen and 6350 tons per day of steam (about 529,400 pounds per hour) will be required for each reactor. This amounts to a total of about 3640 tons per day of oxygen and 19,050 tons per day of steam (about 1,588,000 pounds per hour) for all reactors in the entire plant. Also, about 1450 tons per day of spent char (75% by weight ash) per reactor will need to be disposed of. Other products will include approximately 138 tons per day of ammonia and 350 long tons-per-day of sulfur, on a total plant basis.

Work began on the Demonstration Plant designs in May, 1978.

PROGRESS DURING OCTOBER-DECEMBER 1978

Clean-up work for the 1200 PSIG Case Commercial Plant design effort is essentially completed. Some initial work has been started on the 500 PSIG Case Commercial Plant estimate effort.

Several units in the 1200 PSIG Case of the Demonstration Plant have undergone process flow diagram revisions. Process flow diagrams were issued for several units for the 500 PSIG Case. Heat & Material Balances

were issued for three units of the 500 PSIG Case and were revised and reissued for several units in both cases. Steam balances for both design cases were issued during the month.

Piping and instrumentation diagrams for units of the 1200 PSIG Case and units of the 500 PSIG are being issued as soon as their development is completed.

Pilot plant verification of the design basis is lacking for the 1200 psi design case and only partially complete for the 500 psi design case. Additional pilot plant runs are scheduled.

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GLOSSARY

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

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

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

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

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

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

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

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

API — American Petroleum Institute.

API gravity — a scale adopted by the API for measuring the density of oils; $^{\circ}\text{API} = \frac{141.5}{\text{Specific gravity, } 60^{\circ}\text{F}/60^{\circ}\text{F}} - 131.5$

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

ash — solid residue remaining after the combustion of coal.

ASTM — American Society for Testing Materials.

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

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

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

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

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

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

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

BTX — benzene, toluene, xylene; aromatic hydrocarbons.

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

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

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

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

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

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

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

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

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

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

coalification — metamorphosis of vegetable debris into coal.

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

coke breeze — the fine screenings from crushed coke usually passing a 1/2 inch or 3/4 inch screen opening.

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

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

combustor — a vessel in which combustion takes place.

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

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

crude gas — impure gas produced in a gasifier.

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

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

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

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

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

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

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

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

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

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

diatomite — See Diatomaceous Earth.

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

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

dolomite — a carbonate of calcium and magnesium having the chemical formula $\text{CaMg}(\text{CO}_3)_2$.

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

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

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

effluent gas — gas given off from a process vessel.

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

endothermic reaction — a process in which heat is absorbed.

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

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

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

exothermic reaction — a process in which heat is liberated.

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

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

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

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

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

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

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

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

Fischer-Tropsch process — method of hydrogenating mixtures of

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

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

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

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

flue gas — gaseous combustion products.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

hydrogen donor solvent — solvent, such as anthracene oil, tetralin (tetrahydronaphthalene), decalin, etc., which transfers hydro-

gen to coal constituents causing depolymerization and consequent conversion to liquid products of lower boiling range which are then dissolved by the solvent.

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

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

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

industrial gas—see fuel gas.

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

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

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

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

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

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

liquefied petroleum gas (LPG)—those hydrocarbons that have a vapor pressure (at 70°F) slightly above atmospheric (such as 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 up to 350 Btu per standard cubic foot.

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

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

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

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

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

methanol—methyl alcohol, CH_3OH .

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

raw gas—see crude gas.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

slurry—a suspension of pulverized solid in a liquid.

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

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

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

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

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

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

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

standard cubic foot (SCF)—the volume of a gas at standard conditions of temperature and pressure. The American Gas Association

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

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

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

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

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

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

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

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

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

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

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

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

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

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

water gas shift—the reaction between water vapor and carbon monoxide to produce hydrogen and carbon dioxide or the reverse: $\text{CO} + \text{H}_2\text{O} \rightleftharpoons \text{H}_2 + \text{CO}_2$.

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