MASTER

**Fossil Energy Program
Progress Report for September 1978**

L. E. McNeese

OAK RIDGE NATIONAL LABORATORY
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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy \$6.00; Microfiche \$3.00

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Contract No. W-7405-eng-26

FOSSIL ENERGY PROGRAM
PROGRESS REPORT FOR SEPTEMBER 1978

L. E. McNeese

Date Published - November 1978

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FOSSIL ENERGY PROGRAM REPORT FOR SEPTEMBER 1978

ABSTRACT

This report - the fiftieth of a series - is a compendium of monthly progress reports for the ORNL research and development programs that are in support of the increased utilization of coal and other fossil fuel alternatives to oil and gas as sources of clean energy. The projects reported this month include those for coal conversion progress development, material engineering, alkali metal vapor topping cycles, a coal equipment test program, an AFB coal combustor for cogeneration (CCC), engineering and support studies, process and program assistance, environmental assessment studies, magnetic beneficiation, and AFBC demonstration plant.

1. Summary

L. E. McNeese

Highlights of our progress in September are as follows:

Coal Conversion Development - Preparation is in progress of a completion report documenting and analyzing the complete results of the hydrocarbonization research project. Shakedown operation of the coal liquids flow system has been initiated, and initial calibration tests have been performed on the pipeline viscometer. Review of design and operating information on coal slurry preheaters has been completed in preparation for commencement of experimental studies of slurry rheology, flow dynamics, and heat transfer performance in the flow system. Exploratory studies aimed at new liquefaction techniques have been focused; effort on two less attractive avenues has been curtailed in favor of increased emphasis on uncatalyzed coal liquefaction in phenolic media. Fabrication is in progress on the portable monitors for spotting contamination by polynuclear aromatics on work area surfaces. Behavior of overburden core samples under in situ gasification conditions is being investigated. Claystone samples from the Hoe Creek field site have been tested during this month.

Materials Engineering - We are continuing to test the fracture toughness of 2 1/4 Cr-1 Mo steel heat treated to simulate the properties of thick sections suitable for the construction of large gasifier vessels. Final experiments on nondestructive examination of steel coated with CoCrAlY were concluded. Experiments to determine whether submerged-arc cladding fluxes can be recycled showed that nickel depletion occurs and that fluxes should not be recycled without special precautions. Examination of heat exchanger tubes exposed for 3000 h in the Fluidyne AFBC is

in progress. Analyses of failed parts and corrosion coupons from solvent refined coal plants are in progress. Specimens and experimental apparatus are being procured for both the liquefaction stress corrosion and ZnCl_2 liquefaction process experimental activities. Steelmakers capable of producing 20-to-30 ton heats of the advanced 9 Cr-Mo steel are being contacted, preparatory to the purchase of a large heat.

Alkali Metal Vapor Topping Cycles - Analysis of samples from the outside surface of the boiler tubes indicated that ferric oxide was present on the lower portion of the tubes, and spinel-type oxide was present on the upper portion. Solid material removed from the plugged valves was analyzed and identified as potassium cyanide. The first draft of the potassium test final report has been completed.

Coal Equipment Test Program - Definition of the inert gas/compressed air subsystem of the Coal Feeder Test Facility was completed. Cost information was received for the pneumatic conveying system and requested for the simulated reactor vessel. Questionnaires were forwarded to manufacturers of coal pulverizing and thermal drying equipment as part of the coal handling equipment survey. Questionnaires were also prepared to survey the equipment required to break up the slag formed in coal gasification reactors. The Bechtel subcontract in support of the coal handling equipment survey has been started, and a meeting was held with Bechtel to discuss the preparation of conceptual design flowsheets for the coal handling/preparation and ash/slag removal equipment. A briefing concerning the preliminary Dynamic Equipment Program Plan was prepared and approved by DOE Fossil Fuel personnel for presentation to their management in October.

Atmospheric Fluidized Bed Coal Combustor for Cogeneration - The draft of the request for proposal for the CCC program has been reviewed by DOE-FE. The RFP will be revised in accordance with their comments. The final 1500-hr run in the corrosion test at Fluidyne has been completed, bringing the total exposure time on several tubes to 4500 hr.

Engineering Studies and Technical Support - The Lehigh University DSS/2 program has now been converted to double precision and implementation on the ORNL IBM-360 system is in progress. Fourteen example problems supplied by Lehigh are being used to test the conversion. Preparation of the final article for Research Digest (examining Fischer-Tropsch synthesis) is now complete and publication awaits only DOE review and approval. The final report describing a detailed investigation of the present state-of-the-art of hot gas cleanup processes is now being published (A Survey of Processes for High Temperature - High Pressure Gas Purification, ORNL/TM-6178). The study concluded that reliable, commercially available, and economically competitive hot gas cleanup systems for conditioning raw gasifier product gases to turbine use levels will not be available for some time.

Process and Program Analysis - The final report, Low Btu Coal Gasification Processes, ORNL/ENG/TM-13, has been prepared for review and approval. The two volumes of the report detail a survey of low Btu coal gasification processes and a detailed examination of selected processes, giving both technical and economic parameters of interest. The evaluation of an in situ facility for production of gasoline (via methanol and the Mobil-M process) is nearly complete and a draft report has been prepared for review and comments: Evaluation of an In Situ Coal Gasification Facility for Producing M-Gasoline via Methanol, ORNL-5439.

In the Fossil Energy Environmental Project, leaching studies were initiated on ash/slag from the Texaco Gasifier in Montebello, California. Vacuum bottoms from the Tacoma SRC-II pilot plant were the feed materials to the gasifier. Technical assistance was provided to DOE/FE on three demonstration plants: Grace; SRC-I; and SRC-II. Work continued on the atmospheric fluidized bed combustion assessment. Two major documents were finalized and published.

Magnetic Beneficiation - Inhouse and contract tests indicate that commercial crushing and air classification experiments can prepare coal for dry magnetic separation. Size fractions down to 10 μ have been prepared and processed in the high-gradient magnetic separator. Preliminary results from the first series of HGMS tests in the gravity feed mode are encouraging.

2. COAL CONVERSION DEVELOPMENT

H. D. Cochran, Jr.

Coal conversion development activities are carried out in the Chemical Technology Division. This section discusses five projects conducted for the Division of Fossil Fuel Processing -- Hydrocarbonization Research, Physical Properties of Coal Liquids, Coal Slurry Preheaters, New Liquefaction Techniques, and In-Plant Environmental Monitors -- and one project conducted for the Division of Fossil Fuel Extraction -- Experimental Engineering Support for In-Situ Gasification Processes.

2.1 Hydrocarbonization Research

E. L. Youngblood, J. Beams, and M. R. Gibson

Work accomplished. The bench-scale hydrocarbonization system has been cleaned and samples have been taken following run HC-28 which was made last month to study rapid hydropyrolysis of Wyodak coal. Off-gas data and some of the samples from run HC-28 have been analyzed but we do not yet have all of the information needed to determine oil yield and material balances.

Inspection of the scrubber after run HC-28 showed that a considerable amount of char had been entrained in the reactor off-gas as expected based on the cyclone efficiency measurements made before the run. The char carry-over damaged the scrubber pump seals but otherwise did not cause any appreciable difficulty. The coal feeder valve and other components appeared to be in good condition.

Since this is the last scheduled run for the bench-scale hydrocarbonization system the vessels, traps, filters and other components are being cleaned and put in standby. The hydrogen supply line to the system has been disconnected to eliminate the possibility of leakage during shutdown. The gas supplies, gas chromatograph, and combustible gas monitors will be used by the Coal Liquids Flow System that is currently being installed in the same facility.

The composition of the off-gas during run HC-28 is given in Table 2.1. A comparison of the off-gas composition from run HC-28 with that from run HC-12 and HC-21 is given in Table 2.2. In run HC-12 a draft tube was used to provide recirculation of the fluidized-bed while HC-21 used a uniformly fluidized-bed with no draft tube. All three runs used Wyodak coal as feed and were made at 300 psig hydrogen pressure. The main differences in the runs were in the type of fluidized-bed used and small differences in temperature. The gas

Table 2.1. HC-28 effluent gas composition at steady state--
300 psig, 1065°F at 0700 on 8/17/78

Component	Effluent flow rate (scfm)	Composition (%)	H ₂ and N ₂ -free composition (%)
CH ₄	0.422	1.88	57.7
C ₂	0.094	0.42	12.9
C ₃	0.020	0.09	2.7
CO	0.167	0.75	22.9
CO ₂	0.028	0.13	3.8
H ₂ S ^a	--	--	--
H ₂	21.636	96.51	--
N ₂	0.052	0.23	--

^aCalibration of the gas chromatograph for H₂S was not satisfactory.

Table 2.2.. Comparison of effluent gas compositions
from runs HC-12, HC-21 and HC-28

Experiment	HC-12	HC-21	HC-28
Temperature °F	1025	1035	1065
Carbon yield % ^a	14.3	13.9	18.8
Bed configuration	Recirculating fluidized-bed	Uniformly fluidized-bed	Rapid hydropyrolysis
Component %			
CH ₄	50.4	49.8	57.7
C ₂	13.3	11.8	12.9
C ₃	4.1	4.4	2.7
CO	22.6	22.9	22.9
CO ₂	9.0	10.5	3.8
H ₂ S	0.6	0.6	b

^aCarbon in gas as percentage of carbon fed.

^bCalibration for H₂S was not satisfactory.

compositions from the three runs are very similar with the exception that the methane concentration is higher and the carbon dioxide concentration lower in run HC-28. The overall gas yield was also somewhat higher for run HC-28. These differences may be due to the higher operating temperature used in HC-28 as well as to the type of fluidized-bed used.

The composition of char from the char receiver after runs HC-12, HC-21 and HC-28 are compared in Table 2.3. The compositions are similar with material from run HC-28 containing somewhat less volatile matter.

Work forecast. Material balances and yields will be determined for run HC-28 as analytical data become available. Work will continue on a completion report for the project.

2.2 Physical Properties of Coal Liquids

G. E. Oswald

Physical properties (viscosity, density, thermal conductivity, and heat capacity) of both coal-solvent slurries and solids-free, coal-derived liquids will be measured at typical processing conditions, up to 4500 psig hydrogen pressure and 1000°F in a bench-scale, continuous flow system. The system includes a slurry preheater section and a hydrogenation reactor to simulate processing conditions prior to physical property measurement. Immediately after physical property measurement, the test fluids will be quenched and sampled for chemical characterization. Physical properties will be correlated with chemical characteristics of the test liquid.

Work accomplished. The Coal Liquids Flow System is undergoing operational checkout; during September, shakedown operation of the system was initiated. Light mineral oil was pumped through the liquid preheater section and pipeline viscometer. Since this was an initial operational test, no heat was applied to the preheater section and pressure was near atmospheric. Pressure drop across the viscometer was recorded for flow rates up to 4 liter/hr. The liquid feed pump and process instrumentation performed well.

The following tasks were accomplished: hydrogen compressor installation, control panel checkout and installation; equipment rack installation and pneumatic signal interconnection to control panel, data logging computer installation and system generation.

Work forecast. Electrical interconnection of the control panel and equipment racks will be completed. Instrumentation for the automatic shutdown system and system safety monitoring will be installed.

Table 2.3. Composition of char from char receiver
after run HC-12, HC-21 and HC-28

Experiment	HC-12	HC-21	HC-28
Temperature °F	1025	1035	1065
Component %			
Moisture	<0.1	0.95	<0.01
Ash	11.8	12.1	13.6
Volatile matter (maf)	10.2	12.8	8.1
Carbon (maf)	92.3	92.8	93.7
Hydrogen (maf)	3.6	4.2	3.4
Nitrogen (maf)	1.1	1.2	1.0
Sulfur (maf)	0.26	0.20	0.6

Shakedown operation of the hydrogen compressor will be initiated. To characterize operation of the pipeline viscometer, it will be used to make measurements on liquids of known viscosity.

2.3 Coal Slurry Preheaters

J. R. Thurgood

The objective of the preheater study is to investigate the rheological and heat transfer characteristics of coal-solvent slurries as they are heated in a liquefaction preheater. During the reporting period, the technical literature review was completed, initial flow visualization tests were conducted in preheater mockup unit, and construction and installation of the preheater test section along with the coal liquids flow facility were continued.

2.3.1 Literature review

The review of technical information, task 1 of the project, has been completed. A summary of the literature reviewed will now be presented; further updating of pertinent information will continue and will be reported as determined necessary. The literature review dealt with several areas of interest (1) preheater technology, (2) measurement of viscosity, (3) analytical characterization of the coal/solvent slurry, and (4) the multiphase flow in the preheater.

Information reviewed on preheater technology considered past experience in preheater design, operation, and problem areas, and the current efforts being conducted in preheater studies. Experience with coal slurry preheaters in the German liquefaction plants during World War II, is perhaps best summarized in articles by Wu and Storch,¹ Laughrey et al.,² and Kimmel et al.³ The German preheaters were usually gas-fired units consisting of several cells, each of which contained several vertical tube passes connected by U-bends. These tubes were subject to bursting and corrosion and were frequently replaced. The coal slurries run in these preheaters contained a high weight fraction of solids (as much as 49%) and often difficulties were encountered with plugging. The German experience was utilized mostly in the design of the Coal Hydrogenation Plant at Louisiana, Missouri which was operated from 1952 to 1956.^{2,3}

An overall summary of current preheater technology and the problems associated with preheater operation is presented by Kimmel et al.³ Also provided in this summary are brief descriptions of the preheaters used in the various processes and pilot plants currently in operation. Most of these were reviewed in detail; a summary of the processes and the pertinent references obtained is given in Table 2.4 as are a few descriptive comments concerning the preheaters. Information on the Synthoil process preheater was not reviewed because the preheater is a

Table 2.4. Summary of preheater information

Project	References	Preheater		Comments
		Diameter, in.	Length, ft	
CONSOL CFS	3, 4	0.8	790	Oil-fired
Exxon EDS	5-7	0.3	150	Heat by fluidized sand-bath, sectionalized preheater
		0.5	100	
H-Coal	8, 9	1.0	300	Gas-fired
SRC I Wilsonville	10-13	1.25	600	Oil-fired
SRC II Merriam	14, 15	0.2	18	Heated by fluidized sand bath
Tacoma	16-18	2.75	1700	Gas-fired

packed-bed unit unlike the preheater being considered for the project. Also, little information was obtained on the Gulf Research and Development pilot plant at Harmerville, Pennsylvania because details concerning it have been proprietary until just recently. The summary of preheater experience given by Kimmel et al.³ is indicative of what is presented in most of the references of Table 2.4. They suggest that the following are critical areas in preheater design and need to be studied further: (1) coking rates and coking temperatures, (2) rheological characteristics of coal slurry, (3) hydrogenation mechanisms in the preheater, and (4) allowable velocity rates which relate to tube erosion, pressure drop, and the flow of the coal/oil/hydrogen stream. All of the preheaters are either oil or gas fired with the exception of the Exxon unit. Fire-side corrosion does not seem to be a major problem nor do the materials of preheater construction.^{19,20}

Two studies are in progress to study two of the critical areas mentioned. A preheater study was initiated in October of 1977 at Sandia Laboratories to investigate, among other items, the effects of space velocity-residence time in the preheater on coal slurry reaction.²¹⁻²³ The second project is concerned with coking and the critical fouling parameters of preheater operation; this project is being conducted by Gulf Research and Development Company.^{24,25}

Several studies have been made of coal/solvent slurry viscosity; however, few have been conducted at actual preheater conditions of high temperature and pressure. Pittsburgh and Midway Coal Mining Company reports viscosity measurements on preheater slurries which indicate non-Newtonian flow in the higher temperature regions of the preheater.²⁶ Exxon Research and Engineering Company presents viscosity data for temperatures below 220°C which show Newtonian flow,⁵ and indicate dilatant flow behavior at higher temperatures.⁶ Recently Amoco initiated a limited study to determine the viscosity of an H-Coal liquid at reactor pressure and temperature.^{27,28} Viscosity data on coal-SRC mixtures is reported by Battelle Laboratory.²⁹

Inasmuch as the intent of this project is to rheologically characterize the slurry at preheater conditions, several means of measuring viscosity at high temperature (4500 psi and 1000°F) were investigated. Vibratory viscometry methods are reported by Oppliger et al.³⁰ and by Fitzgerald and Matusik.³¹ Indications are that such instruments will not operate at the desired conditions. Battelle Laboratories report the design use of a falling cylinder viscometer which will operate at high temperature and pressure.³² Huff et al.³³ describe the use of a pipeline viscometer which could be used at high pressure and temperature; Skelland³⁴ and Bovier and Aziz³⁵ provide details of how such a viscometer is used to rheologically characterize a fluid.

A brief review was made to provide information on the analytical characterization of coal slurries and liquids. Detailed summaries of the analytical methods used are given by Schweighardt,³⁶ de Rosset et al.,³⁷ and Thomas and Noles.³⁸

The final area reviewed was that of the flow regime occurring in the preheater. Because of the uncharacterized slurry rheology, variable preheater diameters, and slurry flow rates, the determination of preheater flow regime has not definitely been made. To date, preheaters have been designed and are being designed for the demonstration plants by use of two-phase flow correlations which were empirically determined for Newtonian flow systems.³⁹⁻⁴² An indication of the size and cost of equipment in such plants may be obtained from a design study of commercial scale preheaters by Fein and Parekh.⁴³ Han et al.⁴⁴ indicates their potential use in preheater design and scale-up. While use of such correlations is helpful, this area remains one in which further research and investigation are definitely needed.

2.3.2 Experimental work

Construction and installation of the preheater test section in conjunction with the coal liquids flow facility is nearing completion. Piping for the preheater, pipeline viscometer, and slurry feed pump is complete. The equipment rack on which the preheater and viscometer are mounted was installed in Building 2528 of the laboratory, and inter-connection of the equipment to the control panel, hydrogen compressor, house air, etc. are now being made. Checkout tests of the various equipment items and of the system operation have begun and will continue in parallel with the completion of the facility installation.

Flow visualization tests were initiated with the preheater mockup unit. The unit is constructed of 14 feet of 0.125 in. I.D. Teflon[®] tubing arranged in four horizontal runs. A Milroyal[®] positive displacement pump (1 gal/hr capacity) is used to feed a glycerol-water solution into the system. Nitrogen is metered in through a calibrated rotameter. The initial tests were made with a glycerol-water solution which has a viscosity of 52.5 cp. Visual observation of 1.2 l/hr glycerol to 11.8 l/hr N₂ flow indicates slug flow in the system. Liquid holdup (defined as the in-situ liquid volume fraction in the tubing) was measured by trapping the liquid and gas in the tubing and then measuring the volume of trapped liquid. Tests run at the stated flow conditions result in an average liquid holdup of 0.64; the input liquid volume fraction is 0.09. This indicates a substantial holdup to be occurring with the viscous solution.

2.3.3 Work forecast

Work scheduled during the next month includes (1) completion of the electrical and pneumatic interconnection of the system, (2) continuation of system checkout, (3) initiation of viscosity

tests with the pipeline viscometer, and (4) continuation of tests with the mockup unit using lower viscosity solutions.

2.4 New Liquefaction Techniques

J. W. Larsen and H. D. Cochran, Jr.

Significant progress has been made in our investigations of the depolymerization reaction, and our efforts are now being concentrated on this reaction. Suprisingly, polyhydroxy benzenes have never been used in this reaction. Results for a dihydroxy and a trihydroxy phenol are shown in Table 2.5. Apparently the more reactive polyhydroxy phenols are better able to cross link the coal and are incorporated more readily than phenol itself. Use of these at low levels might be interesting.

Table 2.5. Depolymerization of Wyodak coal with polyhydroxy phenols^a

Phenol	Run time (hr)	Run temperature (°C)	Wt. increase (%)	Pyridine extractability (%)
Phenol	24	150	99.6	95.7
1,4-dihydroxy-benzene	24	165-195	268	56
1,3,5-trihydroxy-benzene	24	220-250	NA ^b	NA ^b

^aIn all cases, 12.5 g of p-Toluenesulfonic Acid was added as a catalyst.

^bA solid was produced.

A number of experiments have been carried out without the acid catalyst. The results are reported in Table 2.6. The most important conclusion to be drawn from the data in Table 2.6 is that the direct reaction between phenol and coal occurs and produces soluble products. This will simplify enormously any process based on this reaction. Some very preliminary conclusions can be drawn from the data in Table 2.6.

Table 2.6. Reaction between coals and phenol without acid catalyst

Run No.	Coal (wt. g)	Phenol (wt. g)	Wt. increase (%)	Pyridine ^b extractability (%)	Run temperature °C	Run ^a time (min)
8	Wyodak (2.63)	14.6	45	46	425	11.5
10	Wyodak (2.63)	14.6	30	7	425	6
13	Wyodak (2.61)	14.6	7	32	455	5.2
12	Wyodak (0.21)	14.6	15	57	425	10.3
9	Bruceton (2.61)	14.6	31	33	425	10.0
	None	14.6	--	10C ^c	425	10.0

^aIncludes heat-up time, approximately 30 sec.

^bParent coal is 8% pyridine extractable.

^cNo solid produced.

Of interest are the effects of time, temperature, and phenol/coal ratio on the incorporation of phenol and the extractability of the product. We desire to minimize phenol uptake and maximize pyridine extractability. A comparison of runs 8 and 10 shows the effect of reaction time. The 11.5 min run has increased phenol uptake and increased extractability, however, the latter increases faster than the former. Optimum time will be 11.5 min or longer. Runs 10 and 13 allow an examination of the effect of temperature. Increasing the temperature decreases phenol incorporation and increases product extractability. Higher temperatures will be examined. Finally, using runs 8 and 12 the effect of changing the phenol/coal ratio can be examined. Increasing this ratio decreases the phenol uptake while slightly increasing the extractability. Apparently it is advantageous to operate at high phenol/coal ratios. These preliminary conclusions are based on limited data and are very tentative. They are being checked.

No experimental inquiries into the nature of the coal-phenol direct reaction have yet been made. Our best guess is that the reaction involves pyrolytic fragmentation of the coal followed by reaction of the radical fragments with the phenol. The most probable process is homolytic aromatic substitution.

A number of interesting observations have been made on the acid catalyzed depolymerization, the most significant relating to the molecular weight distribution of the products when the reaction is run at high temperatures. The relevant data are contained in Table 2.7-2.10. The reaction is completed very quickly at these high temperatures. Using μ -styrogel columns which had been calibrated with depolymerized Bruceton coal samples of known molecular weight,⁴⁵ the molecular weight distribution of the products was determined.⁴⁶ The most significant fact is the low molecular weight of the products compared to those from this same reaction at lower temperatures. Larsen and Choudburg⁴⁵ have shown that much of the product from this reaction with Bruceton coal at 185°C is high molecular weight and colloidal material. At the higher temperature, most of the product has a molecular weight below 1000. It will be much easier to handle and react the lower molecular weight products formed in the high temperature reaction.

2.5 In-Plant Environmental Monitors

D. D. Schuresko and G. Jones, Jr.

Experimental work with the prototype fluorescence spotter continued during September. In particular, it was shown that high concentrations of phenol (150-50,000 ppm) in PNA containing solutions do not interfere with PNA determination when the PNA fluorescence is excited near 350 nm and detected above 420 nm (solutions contained 10 ppm of perylene in cyclohexane). This result is noteworthy since large amounts of phenolic compounds are present in coal conversion streams.

Table 2.7. Acid catalyzed depolymerization of coals^a

Run No.	Coal (Wt. g)	g p-TSOH ^b	Run time (min)	Run temperature (°C)	Wt. increases (%)	Pyridine extractability (%)
1	Bruceton (17)	13	270	425	74	37
5	Bruceton (2.6)	1.9	2.8	425	23	42
6	Bruceton (2.6)	1.9	10	425	57	60
3	Wyodak (2.6)	1.9	5.3	425	36	59
4	Wyodak (2.6)	1.9	12	425	77	63

^aIn all cases except for Run No. 1, 14.6 g of phenol was used. Run No. 1, 100 g of phenol was used.

^bp-Toluenesulfonic Acid.

Table 2.8. Molecular weight distribution of the products
from Run No. 1

Fraction No.	Wt. (%)	Molecular Wt.
1	0.8	>4000
2	0.6	>4000
3	1.0	>4000
4	4.8	>3000
5	10.0	2900
6	12.9	900
7	17.6	530
8	19.1	340
9	17.7	290
10	3.0	220
11	8.0	180
12	4.1	170

Table 2.9. Molecular weight distribution of the products
from Run No. 3

Fraction No.	Wt. (%)	Molecular Wt.
1	0.59	>3000
2	2.84	>3000
3	6.39	>3000
4	9.33	>2500
5	11.46	2900
6	12.44	900
7	14.55	530
8	15.71	330
9	14.04	290
10	8.92	220
11	3.71	180

Table 2.10. Molecular weight distribution of the products
from Run No. 4

Fraction No.	Wt. (%)	Molecular Wt.
1	0.9	>3000
2	1.16	>3000
3	3.92	>3000
4	10.50	>2500
5	14.78	2900
6	12.55	900
7	18.48	530
8	18.48	330
9	10.73	290
10	6.59	220
11	2.72	180

The fluorescence of solutions of COED syncrude oil, which has been partially characterized by the Analytical Chemistry Division at ORNL, was measured with the prototype spotter. For comparison, synthetic solutions containing the PNA's which had been identified in syncrude were also studied. It was found that the fluorescence of the synthetic solutions was roughly 12-14% of the fluorescence of the syncrude samples, which indicates that syncrude contains considerably more PNA material than has been identified to date.

2.6 Experimental Engineering Support of In Situ Gasification Processes

P. R. Westmoreland, L. S. Dickerson, and B. R. Rodgers

Experiments and analyses continued during this reporting period to increase the understanding of physical processes and reactions in underground coal gasification (UCG). Preliminary results are reported for a recent block pyrolysis experiment using lignite, and data from lignite experiments using inert-gas purge are reviewed and compared. Results are also reported from physical property tests on overburden from in situ coal gasification sites.

The research program on coal block pyrolysis supports both the modeling and field development of in situ (or underground) coal gasification. Block pyrolysis data are valuable for modeling of in situ coal gasification because earlier data described only the pyrolysis of powder samples. By contrast, large masses of coal react during UCG, either as large blocks or as a seam cross-section. For both in situ cases, internal heat and mass transfer resistances become more important, and product yields can change significantly.

In experiments which began at ORNL in 1975, 6-in.-diam (15-cm) right circular cylinders of lignite, subbituminous coal, and bituminous coal have been pyrolyzed by heating the blocks at 0.3-14 C°/min (surface temperature) from ambient temperature to maximum temperatures of 500-1000°C. Using an inert (argon) or reducing (hydrogen) purge gas at atmospheric pressure, gas- and vapor-phase reaction products are continuously swept from the reactor. Water, oils, and tars are collected in a water-cooled condenser and by filters, and the remaining noncondensable gases are metered and periodically sampled. In many of the experiments, block temperature profiles have been measured by internal thermocouples. These tests are designed to support modeling of the field UCG experiments by Laramie Energy Technology Center (LETC), Lawrence Livermore Laboratory (LLL), and Morgantown Energy Technology Center (METC).

2.6.1 Review of recent lignite experiments

Blocks of Texas lignite from the Wilcox formation have been pyrolyzed in experiments conducted since March at experimental conditions of 0.3, 3, or 10 C°/min to 600, 800, or 1000°C in inert (A) or H₂ purge gas. One experiment used a predried block to eliminate the effect of water content. Conditions for each of these experiments, including BP2-55 (conducted during this reporting period), are summarized in Table 2.11. (Preliminary gas evolution data for experiment BP2-55 are summarized in Table 2.12).

Product yields from lignite experiments using inert-gas purge are presented here (Table 2.13) for evaluation and comparison. Yields from experiments using H₂ purge were reviewed previously,⁴⁷ and a detailed comparison of all lignite experiments will be presented later. The experiments discussed here are useful since they include the purely thermal decomposition ("pure pyrolysis") measured in powder pyrolysis tests along with the side reactions involving the products. These latter reactions, which result from internal heat transfer and mass transfer resistances, are purposely eliminated in powder pyrolysis but are important in the "pyrolysis" of bulk coal in situ. By using inert rather than reactive purge gas, these product-product reactions may be isolated from product-purge gas reactions.

Product yields are compared in Table 2.14 to evaluate the effects of coal moisture content, surface heating rate, and maximum temperatures. As for yields from H₂-purged experiments,⁴⁷ yields of maf char are calculated by subtracting ash content of the coal block; net condensibles yield is calculated by subtracting original water content of the coal block; and all yields are calculated per kg of maf coal. Predominant effects of the three variables are:

Water content - Self-gasification of the char block apparently occurs as steam generated inside the block consumes char at the hotter surface of the block. Comparison of yields from a predried block and a naturally wet block (37% moisture) support this hypothesis, since char and condensibles are consumed in the wet-block experiment while gas yield increases.

Surface heating rate - Effects of self-gasification are evident again. Equilibrium calculations⁴⁷ indicate the steam gasification reaction will proceed forward at temperatures above 670°C. Thus, no self-gasification would occur at 0.3 C°/min (only slight internal temperature gradients) since the entire block dried long before the surface reached 670°C. By contrast, steep gradients from the surface to the drying front at 3 and 10 C°/min would cause steam to pass through 670-plus °C char, consumed steam and char to produce more H₂ and CO.

Table 2.11. Summary of experimental conditions for pyrolysis experiments using lignite blocks

Run number	Date of run	Heating rate (C°/min)	Maximum temperature (°C)	Purge gas		Coal block ^a			
				Gas	Flow rate (Std. liter/min)	Dimensions (cm)		Weight	
						Height	Diameter	(kg)	(kg maf)
BP2-46	3/31/78	3	800	H ₂	2.87	15.9	13.5	3.609	1.957
BP2-47	4/21/78	3	1000	H ₂	2.90	17.5	15.1	3.921	2.126
BP2-48	5/4/78	3	600	H ₂	2.828	16.8	14.9	3.743	2.030
BP2-49	5/15/78	0.3	800	H ₂	2.993	19.4	15.1	4.319	2.342
BP2-50	5/26/78	9	800	H ₂	2.775	18.4	14.6	3.927	2.129
BP2-51	6/12/78	0.3	800	A	3.056	17.9	14.6	4.085	2.215
BP2-52	6/26/78	3	800 ^b	A	3.428	20.2	14.9	4.555	2.470
BP2-53	7/12/78	10	800	A	3.016	20.3	14.9	4.558	2.471
BP2-54	8/4/78	3	800	A	3.022	18.9	15.1	4.342	2.354
BP2-55	8/30/78	3	1000	A	2.921	19.8	14.9	4.497	2.438

^aExperiments have used lignite from the Calvert Bluff formation of the Wilcox group, Sandow Mine (Milam County, Texas).

^bBlock predried to 140°C before 3°C/min heating was begun.

Table 2.12. Summary of preliminary gas evolution data from experiment BP2-55
(block pyrolysis of lignite to 1000°C at 3°C/min, Ar purge gas)

	Total	H ₂	CH ₄	C ₂ 's	C ₃ 's	CO	CO ₂	H ₂ S
Gas evolution								
Volumetric (std. liters)	1625.28	888.9	141.22	14.66	3.22	400.14	170.60	6.58
Normalized (std. l/kg maf coal)	666.64	364.6	57.92	6.01	1.32	164.13	69.98	2.70
Mass (g)	1051.81	79.96	101.08	19.36	6.24	500.13	335.0	10.01
Normalized (g/kg maf)	430.82	32.20	41.46	7.94	2.56	205.14	137.42	4.10
Average composition of evolved gas (Vol %)		58.89	9.52	0.99	0.22	26.96	11.52	0.44
Elemental composition (g)								
Carbon	402.45							
Hydrogen	110.67							
Sulfur	9.42							
Oxygen	529.3							
Gas higher heating value (MJ)	25.24							
(Btu)	23940							
(Btu/scf)	387.6							
Gas efficiency (Btu in gas/Btu in coal)	34.7%							

Table 2.13. Distribution of product yields from block pyrolysis
of lignite in inert purge gas

Experiment	Reactor heating rate (C°/min)	Maximum temperature (°C)	Coal block		Products (g)		
			(g)	(g maf)	Char	Condensibles	Gas
BP2-51	0.3	800	4085	2215	1619	1767.8	576.5
BP2-52 ^a	3	800	4555	2470	1825	1697 ^b	630.5
BP2-53	10	800	4558	2471	1427 ^c	1519.3	994.9
BP2-54	3	800	4342	2354	1694	1569.3	802.1
BP2-55	3	1000	4497	2438	1576	1606.9	1051.8

^aBlock predried to 132°C.

^bIncludes water from predrying of the block.

^cChar block partially burned because of extreme pyrophoricity; char yield does not include an estimated 340 g char consumed.

Table 2.14. Comparison of normalized product yields
from block pyrolysis of lignite in inert purge gas

Comparison	Experiment	Reactor heating rate (°C/min)	Maximum temperature (°C)	Product yields (g/kg maf coal)			Gas yield (std.) liters/kg maf coal)
				Char (less coal ash content)	Net condensibles (less coal moisture content)	Gas	
Effect of surface heating rate (steepness of internal temperature gradients)	BP2-52	0.3	800	568	115.7	260.3	312.1
	BP2-54	3	800	557	-15.8 ^c	340.7	471.8
	BP2-53	10	800	-- ^b	-67.7 ^c	402.6	557.9
Effect of coal moisture (predried <u>vs.</u> wet block)	BP2-52 ^a	3	800	576	4.6	255.3	387.1
	BP2-54	3	800	557	-15.8 ^c	340.7	471.8
Effect of maximum temperature	BP2-54	3	800	557	-15.8 ^c	340.7	471.8
	BP2-55	3	1000	484	-23.4 ^c	431.4	666.6

^aBlock predried by heating to 132°C.

^bChar block partially burned.

^cIndicates consumption of coal moisture by reactions with gas or char.

Maximum temperature - As in powder pyrolysis, decomposition of char directly to gas is the main effect of temperature above 800°C.

2.6.2 Property measurements for overburden

The block pyrolysis reactor and other equipment are being used to measure the following properties of overburden and underburden:

(1) physical properties such as thermal diffusivity and density, (2) friability or collapse upon drying or heating, and (3) gas yields from thermal decomposition of the rock. Background for the work and first experiments are described here.

Physical and chemical properties of overburden and underburden (the strata overlying and underlying a coal seam) are important parameters for modeling and control of UCG. For example, heat is lost from the in situ reaction zone through its walls - overburden, underburden, and unreacted coal - so knowledge of thermal properties is important. Secondly, subsidence of overburden into the reaction zone can disrupt shallower strata, overlying aquifers, and the process itself. Finally, organic and inorganic compounds can be decomposed by the heat, contributing to gas yield.

Different types of sedimentary strata are associated with coal seams; for example, shale, claystone, siltstone, sandstone, and limestone. For UCG, impermeable strata such as shale, claystone, and siltstone are necessary to seal against leakage of product gas from the underground "reactor." Strata immediately surrounding the coal at the three UCG sites of LETC, LLL, and METC are compared in Table 2.15. Cores from each site will be tested.

Initial experiments OB-1 and OB-2 were conducted during this reporting period using a cored section of claystone from LLL's Felix No. 1 overburden at Hoe Creek. Cylindrical cores (typically 6.4-cm-diam and 14-cm-long) are instrumented with chromel-alumel thermocouples, as coal blocks are for block pyrolysis; precise positions of the thermocouples are determined from x-rays. Off-gases and internal temperatures are monitored during the experiment, with sudden equalization of internal temperatures chosen as the indicator for block collapse. In experiment OB-1, the carefully-preserved, moist claystone was slowly heated at 0.3 C°/min to 800°C, and in experiment OB-2 the core from the previous experiment was reheated at 3 C°/min to a maximum temperature of 1000°C.

No collapse of this claystone occurred at 27-1000°C; rather, the rock was strengthened (like a fired ceramic). During OB-1, evolution of CO₂ began when surface temperature reached approximately 350°C, and evolution of some H₂, CO, CH₄, and C₂ gases began at 635-685°C. Evolution of these gases continued during experiment OB-2 from 800°C to the maximum temperature of 1000°C. Yields and thermal data will be reported later.

Table 2.15. Comparison of strata at three underground coal gasification sites.
Strata in order of increasing depth

Classification	LETC field site at Hanna, WY (Ref. 48)		LLL field site at Hoe Creek, WY (Ref. 49)		METC field site at Pricetown, WV (Ref. 48)	
	Strata	Thickness (m)	Strata	Thickness (m)	Strata	Thickness (m)
			Siltstone-clay-stone with some shale and sandstone	6-12		
			Felix No. 1 coal seam	3		
Overburden (underburden for Felix No. 1 seam)	Shale	4.6	Siltstone-clay-stone with some shale and sandstone	4.3-5.5	Shale, limestone, mudstone, sandstone	-
Coal used in underground gasification	Hanna No. 1 coal seam	9.1	Felix No. 2 coal seam	7.6	Coal rider	0.5
		-			Carbonaceous shale	0.2
					Pittsburgh seam coal	2.0
Underburden	Shale	1.2	Claystone-shale	3		

2.6.3 Future plans

Experiments in the block pyrolysis reactor will continue to be used for measuring physical properties of overburden and of coal. A test series will begin in which lignite, subbituminous coal, and bituminous coal blocks will be pyrolyzed in a simulated UCG product gas. Results of the lignite series will be reviewed and graphical correlations will be developed.

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3. MATERIALS ENGINEERING

R. T. King

The materials engineering and associated technology reported here are in support of activities directed by Materials Engineering Research, Division of Systems Engineering, Fossil Energy. Other related work not funded directly by this division of DOE/FE is included also.

3.1 Pressure Vessel and Piping Materials

W. J. Stelzman, R. O. Williams, and D. A. Canonico

We are continuing to determine the static fracture toughness (K_{Icd}) of 2 1/4 Cr-1 Mo steel using precracked Charpy specimens. The K_{Icd} testing of specimens from bars which were fast-cooled (3K/s) or slow-cooled (0.3K/s) from 972°C or 1038°C in the DATA TRAK facility followed by a temper or a temper, 40-h stress relief, has been essentially completed. Also completed is the K_{Icd} testing of specimens from bars which were fast- or slow-cooled from 972°C followed by a temper, 40-h stress relief and a 1000-h aging at 343°C. Additional bars are being heat treated to provide K_{Icd} data for, material fast- or slow-cooled from both austenitizing temperatures followed by a temper, 120-h stress relief and Charpy impact, tensile and K_{Icd} data for material tempered stress relieved for 40-h and aged for 1000 h.

It is known that the increased resistance to hydrogen attack for alloy steels arises from the reduced carbon activity as a result of the formation of stable carbides. Further, it is realized that the activity is time and history dependent because of nonequilibrium within the steels. This investigation would be expedited if the carbon activity could be directly measured. This possibility was cursorily investigated by attempting to form methane in a sample surrounded by a hydrogen atmosphere. We were not successful; at the temperatures of interest the kinetics for the reaction are too low to permit the activity determination.

3.2 Inspection Techniques for Wear- and Process-Resistant Coatings

R. W. McClung and G. W. Scott

This will be the last monthly report for this project because of its termination September 30, 1978. Any additional technical data will appear in topical reports now in preparation.

3.2.1 Eddy Current Testing (G. W. Scott)

All parts of the through transmission computer program for eddy current examination of multilayer specimens are now operating properly and trial runs were made for comparison with experimental data at 100 kHz and 1 MHz. The instrument experienced a partial failure and produced unusable data at 1 MHz. The measurements will be repeated at 50 kHz and 500 kHz and compared with a new computer run. These data will be adequate to complete this segment of the project.

3.3 Fossil Energy Welding and Cladding Program

D. P. Edmonds, J. J. Woodhouse, and J. D. Hudson

During this reporting period we have investigated the recycling of alloyed submerged-arc fluxes for cladding with type 320 Cb stainless steel. Recycled fluxes were used to produce clad deposits on 2 1/4 Cr-1 Mo steels. Side bend testing of these clads showed that the clad metal was very brittle. Subsequent chemical analysis of the deposits showed the nickel content was below 10%. Therefore, care should be used in recycling alloyed fluxes when submerged-arc cladding ferritic steels with type 320 Cb stainless steels. In addition, a preliminary draft of a report summarizing work to date on this program has been prepared.

3.4 Fireside Corrosion of Atmospheric-Fluidized Bed Combustor Tubes

T. G. Godfrey and J. H. DeVan

The 3000-h extension of the original 1500-h test of heat exchanger materials in the Fluidyne AFBC was successfully concluded on October 3. Observations by Fluidyne personnel of the tube matrix upon removal of the combustor wall indicate an overall satisfactory appearance with the high-temperature tubes partially covered with multi-colored sulfate deposits and the low temperature tubes, black and featureless. The 20 tubes will be photographed, sealed in plastic bags with dessicant, and returned to ORNL for detailed examination.

The alloy/time matrix for the Fluidyne test is shown in Fig. 3.1 for the 4500-h high-temperature CCC materials and for the 3000-h steam generator materials. Examination of samples through the 3000-h state is partially complete. Major tasks remaining are measurements of tube wall thicknesses and electron microprobe analyses of near-surface regions.

Low-Temperature Tubes — The general appearance of the 500-h composite low-temperature tubes and preliminary metallographic results were described in a previous report.

We have completed our preliminary examination of the tubes exposed for the 1000-h time segments. As shown in Table 3.1, oxide scale thickness increased on both the type 304 and 2 1/4 Cr-1 Mo alloys with time. The fireside scale thickness variation on the 2 1/4 Cr-1 Mo steel was significantly greater than the airside variation, as indicated by the larger calculated standard deviation of the averages. This resulted from partial spallation of the relatively thick scale on the fireside either during operation or upon final cooling. The fireside and airside scales on the stainless steel samples were relatively thin and uniform. Neither alloy displayed significant intergranular corrosion.

Table 3.1 Oxide Scale Thicknesses on Alloy Tubes after 500 and 1000 h Exposure in AFBC at 510–570°C (950–1060°F)

	Scale Thickness (μm)					
	Fireside			Airside		
	Avg ^a	Std Dev ^b	Max ^c	Avg	Std Dev	Max
2 1/4 Cr-1 Mo						
500 h	29.9	10.1	71.4	29.9	7.5	50.2
1000 h	65.2	32.7	181.9	37.4	8.1	70.0
304 Stainless Steel						
500 h	6.8	2.5	20.6	8.4	6.4	29.2
1000 h	8.7	3.4	21.0	11.2	5.1	27.3

^aAverage of maximum features from multiple observations on multiple samples.

^bPooled standard deviation.

^cSingle largest feature observed.

High-Temperature Tubes — Examination of the high-temperature tubes removed during the course of the 3000-h test is not complete at this time.

Fig. 3.1 Test Matrix for Exposure of Heat Exchanger Tubes in the Fluidyne Atmospheric Fluidized-Bed Combustor

3.5 Failure Analysis and Prevention

R. T. King

3.5.1 Examination of Corrosion Coupons from Solvent Refined Coal Plants (R. T. King)

Official metallographic examination of a set of corrosion coupons from the Ft. Lewis, Washington, Solvent Refined Coal plant is in progress. Modification of the microprobe analyzer to allow determination of light elements (particularly oxygen) was completed so that the nature of the scales on these and other samples can be determined.

3.5.2 Analysis of Level Control Valve Seat from the Ft. Lewis, Washington, Solvent Refined Coal Pilot Plant (V. B. Baylor)

A cracked valve seat from the level control valve for the recycle condensate separator at the Ft. Lewis SRC Pilot Plant was received for evaluation. After metallographic examination including scanning electron microscopy, the failure of the valve trim was attributed to brittle cleavage, probably due to the presence of residual stresses as a result of fabrication in combination with the sour gas environment. Hardness readings confirmed that the 17-4 PH martensitic stainless steel had been aged at too low a temperature, resulting in reduced impact strength and notch ductility. Stress corrosion cracking may not have occurred had the trim been properly heat treated. A final report in the form of an ORNL/TM is being reviewed and will be released shortly.

3.6 Materials for ZnCl_2 Liquefaction Process Program

J. R. Keiser and V. B. Baylor

Ceramics manufacturers are being contacted to determine whether anyone can provide the loop capable of containing the simulated ZnCl_2 regeneration system environment. Materials which will be tested for their resistance to corrosion have been ordered and are being received. These materials include selected superalloys such as Inconel 671, MA 956, Haynes 188, and Udimet 720 and various refractories, yet to be chosen. The corrosion laboratory is being rearranged to accommodate the testing arrangement for this program as well as the equipment for the stress corrosion cracking program.

3.7 Stress Corrosion Cracking in Liquefaction Plants Program

V. B. Baylor and J. R. Keiser

Plates of material for making specimens are being received. Of those materials already on hand, some plates are being welded, while already-welded plates are being machined into specimens. Material to make racks on which to hang the U-Bend specimens in the plants is being machined. Equipment for complementary laboratory testing has been ordered.

The shutdown for the Ft. Lewis, Washington, SRC plant was scheduled for October 13. Since racks must be inserted during shutdown, the selection of alloys to be tested during this run was necessarily restricted to those materials on hand. The number of racks we are allowed to insert is also very limited. We hope to make a second run later in the program in order to obtain more pilot plant data.

Since corrosion remains a particular problem in the Ft. Lewis SRC Plant, it was decided to test corrosion coupons in the laboratory in conjunction with the stress corrosion cracking specimens. We plan to coordinate this effort with Gulf Research, which is responsible for the in-plant corrosion testing already taking place.

3.8 Development of Advanced 9 Cr-Mo Structural Steel

R. J. Beaver and R. T. King

Two AOD heats of the advanced 9 Cr-Mo steel have been melted as a part of the Reactor Research and Technology Division's scaleup work, prior to ordering a 20-to-30 ton heat to be funded by the Fossil Energy Division of DOE. A final agreement between DOE and TVA to permit exposure of the new steel in TVA commercial power boilers is essentially ready for signing. Steelmakers are being contacted for initial reviews of the draft specification for the 20-to-30 ton heat.

4. ALKALI METAL VAPOR TOPPING CYCLES

R. S. Holcomb

4.1 Gas-Fired Potassium Boiler

R. S. Holcomb, D. B. Lloyd, and R. H. Guymon

4.1.1 Contract objective

To design, construct, and test a full-scale potassium boiler tube bundle and burner module on water and then potassium to determine performance and operating characteristics.

4.1.2 Status summary

1. Samples taken from the two regions of different color on the surface of the boiler tubes were examined, and the samples from above the color change were found to be a spinel-type oxide and ferric oxide below the color change.

2. Solid material removed from the plugged valves was analyzed and identified as potassium cyanide.

3. The first draft of the potassium test final report has been completed.

4.1.3 Technical progress

It was noted in last month's report that there was a change in color of the oxide coat on the boiler tubes at about the elevation of the top of the shroud between the inner and outer rows of tubes. Samples taken from the surface of the tubes at four elevations indicate a spinel-type oxide above the color change and ferric oxide below. Spinel oxides are normally associated with higher temperatures.

Since at the final shutdown line 102 and HV 103A or B were still plugged, these were cut out of the system and vacuum distilled to remove the potassium. Visual examination indicated a dark-colored material in the inlet of the valves. When this was mechanically removed, a white material was found mixed with it.

Samples of this material were identified by x-ray diffraction as being potassium cyanide. Chemical analysis indicated 28% potassium, 15% carbon, and 17% nitrogen in the white material, and 17 1/2% carbon and 18% nitrogen in the black material. Both samples had about 400 ppm chromium, cesium, and copper; about 700 ppm iron, and about 2,500 ppm silicon.

The first draft of the final report for the potassium test has been completed.

5. COAL EQUIPMENT TEST PROGRAM

J. M. Holmes and R. E. MacPherson

Work under the Coal Equipment Test Program (CETP) is currently divided into three sections:

- Coal Feeder Test Program
- Survey of Industrial Capability for Coal Handling Equipment
- Fossil Fuel Dynamic Equipment Program Plan

5.1 Coal Feeder Test Program

B. T. Thompson, A. R. Sadlowe, M. Schaffer, M. H. Culver

5.1.1 Coal Feeder Test Facility

Work continued on the preparation of a feasibility study (Task 1.0) for a 5-ton/hour capacity facility to test one or more of the dry coal feeders being developed by DOE contractors. Various alternatives are being considered and cost estimates will be furnished.

Work completed this month included:

1. Definition of the inert gas/compressed air subsystem (Area 600) of the coal feeder test facility using information provided by M. H. Culver of Engineering Analysis.
2. Acquisition of prices for pneumatic conveying systems that transport coal in the feed and recycle areas.
3. Requests for price quotations from manufacturers on the simulated reactor vessel (EP 200).

Work planned includes:

1. Approvals of subsystem drawings that have been completed.
2. Completion of plot plans and elevation drawings for the facility.

5.1.2 Utilities for Coal Feeder Test Facility - M. H. Culver

A final report was published that summarizes the nitrogen and compressed air requirements and shows the system necessary to supply these gases for a 5-ton/hour coal feeder test facility. Low pressure (100 psig) nitrogen is used to inert the test facility and prevent potential explosion hazards. High pressure (1500 psig) nitrogen is needed to pressurize the coal receivers. Compressed air is used in pneumatic conveying systems. The proposed system design includes maximum recycle of vented nitrogen and was selected after reviewing alternate designs.

Equipment sizes, capital costs and operating costs are shown in the final report.

5.2 Survey of Industrial Capability for Coal Handling Equipment

F. C. Zapp, O. W. Thomas, M. D. Silverman

Final questionnaires were prepared for both coal pulverizing and thermal drying equipment. Two copies of each questionnaire were sent to all known U.S. manufacturers of these types of equipment, and a personal phone contact was made with each firm to ensure that the questionnaires were received.

A questionnaire was also prepared for grinders, delumpers, and other crushing equipment used for breaking up slag from coal gasification reactors. This questionnaire was mailed during September. All three questionnaires were reviewed with Bechtel National, Inc. personnel during a recent meeting. The meeting was held primarily to discuss a subcontract with Bechtel for preparation of conceptual system design flow sheets and selection specifications for coal handling/preparation and ash/slag removal equipment.

A meeting was held with T. K. Lau of DOE-Washington to review project progress. A project summary, including time and manpower schedules, was prepared at his request.

5.3 Fossil Fuel Dynamic Equipment Program Plan

At the request of DOE, a briefing of the preliminary Dynamic Equipment Program Plan was prepared for presentation to Fossil Fuel Processing management. The briefing, which was developed in cooperation with TRW Energy Systems and Fossil Fuel Processing personnel, included:

- Program scope, strategy, and rationale.
- Interfaces with other DOE equipment programs.
- Details of the Program and an example of our findings to date.
- A discussion of the program implementation.
- Recommendations for continuation and funding of the program.

DOE Fossil Fuel personnel reviewed and approved the briefing for presentation to their management early in October.

6. ATMOSPHERIC FLUIDIZED BED COAL COMBUSTOR FOR COGENERATION (AFB CCC)

R. S. Holcomb

6.1 Objective

The Coal Combustor for Cogeneration (CCC) Program is directed at the development of a fluidized bed coal combustion system heating air inside tubes to provide high temperature clean air to drive a gas turbine to generate electricity. The heat in the air leaving the turbine exhaust would be recovered to supply industrial process heat. The gas turbine is very well suited for cogeneration since the ratio of thermal to electrical energy is about 3 to 1 for the gas turbine cycle as compared to a ratio of about 5 to 1 for a back-pressure steam turbine, and the exhaust heat from the gas turbine is available at a higher temperature. The scope of the program includes the study of industrial cogeneration plants in the size range from 5 to 50 MW(e), and the construction and testing of a 0.3 MW(e) technology test unit.

6.2 Status Summary

The draft of the request for proposal for the CCC program has been reviewed by DOE-FE and Mitre Corporation, and their comments and revisions were discussed in a meeting held at the Mitre Corporation in McLean, Virginia, on October 4. The meeting was attended by Walt Saunders of DOE, Jack Branam and Dr. Rao of Mitre, and J. E. Jones and R. S. Holcomb of ORNL. All of the elements of the RFP were acceptable to DOE and no substantial changes in the content were requested. A number of revisions in organization, and changes and additions in wording were requested.

The RFP will be revised in accordance with these comments as soon as possible and sent to DOE-FE for review and approval.

6.3 Supplemental Studies

The final 1500-hr run in the corrosion test at Fluidyne was completed on October 3. This brings the total exposure time of several tubes in the test array to 4500 hr. No failures have occurred for specimen tubes of 304, 310, 316 stainless steel and Incoloy in this period of time. The tubes have been removed from the furnace and will be sent to ORNL for metallographic examination.

7. ENGINEERING STUDIES AND TECHNICAL SUPPORT

R. W. Glass

Engineering studies and technical support are provided primarily for the DOE/FE Division of Fossil Fuel Processing. The effort includes: the development of analytical tools for use in the evaluation of processes and equipment; the technical and economic evaluation and comparison of coal conversion processes and subprocesses on a uniform basis; surveys of the need for coal conversion equipment and the capability of industry to provide such equipment; and studies of the magnitude and control of coal conversion plant emissions.

7.1 Process Modeling

R. Salmon, O. L. Culberson, and D. M. Lister

7.1.1 Contract Objective

The objective is to assist DOE/FE in its plan for computer analysis and computer support for coal conversion studies. This includes assistance to Purdue and Lehigh Universities in the development of computer programs for this plan. Physical property data are being collected and computerized primarily by Purdue and will be used in support of programs prepared by both universities. Purdue's general design program will aim at material and energy balances, equipment size and costing, plant capacity, and general economics. Lehigh's dynamic simulation programs will address plant design primarily from the standpoint of process performance during transient operations, but can also be used for steady-state conditions. A single flowsheet will be selected to assess the operability and complementary utility of both design programs.

7.1.2 Status Summary

The DSS/2 program was converted to double precision and the fourteen example problems supplied by Lehigh were run on the double precision version. Differences in the results are now being analyzed.

The methanator model is in the process of being converted to double precision. This is about 80% complete.

All of the subroutines of the Purdue mass balance program have been established as a load module in a library data file. Attempts were made to execute the Purdue-supplied examples but difficulties were experienced during the input process. This was traced to the presence of DO loops ending in IF statements. The source code was corrected to eliminate these, recompiled, and the load module library was reestablished. We are now ready to try the test problems again.

An example flowsheet was developed to test the Purdue physical properties package, but difficulties were experienced with the input data. An effort is being made to resolve these with Purdue.

7.2 Coal Liquefaction Advanced Research Digest

F. M. O'Hara, Jr. and R. W. Glass

7.2.1 Contract Objective

The objective is to provide continuing technical assistance to DOE/FE by preparing digest reviews of current or potential subjects relating to coal conversion technology.

7.2.2 Status Summary

Writing of the final article (Fischer-Tropsch) for the second issue has been finished, and the draft has undergone internal technical and editorial reviews. A copy of the draft has been forwarded to DOE/FE for review.

Comments from contractor reviewers (Gulf Mineral Resources and Conoco) were received for the other two articles (SRC-II and CSF, respectively) for this issue. Their suggestions have been reviewed, and the manuscripts have been revised. Both articles have been submitted to the Technical Publications Department for final typesetting and page makeup.

Report literature searches for information concerning two articles for the third issue of the Digest were begun. The two articles, The Kinetics of Coal Hydrogenation and The Mechanisms of Coal Liquefaction, together with a third article, Characterization of Coal-Derived Liquids, will constitute the third issue.

7.3 Survey of Industrial Coal Conversion Equipment Capabilities

W. R. Williams, T. M. Andress, W. F. Boudreau, W. A. Bush,
W. R. Gambill, D. W. Hatcher, J. R. Horton,
J. P. Meyer, W. R. Reed, C. B. Tolliver

7.3.1 Contract Objective

The objective of this project is to conduct surveys of industrial equipment capabilities that will identify the present capability of industry to supply the equipment needed. The project will also determine research and development needs, including lead time requirements, for producing equipment of advanced design for the various unit operations of critical importance to the Division of Fossil Fuel Processing.

7.3.2 Status Summary

Final draft reports covering FY 1979 activities are being prepared. At the end of September, the report on mechanical connectors and expansion joints was in final review, and the report on equipment operating experience, prices, and development programs was near completion. Drafts of these reports should go to Washington, D.C. in early October. The report on letdown valves has been delayed approximately 2 months.

The SAS computer code is being used to analyze pump and compressor price data. David Holden, a Goodyear employee awaiting clearance, has been responsible for setting up the code for this purpose and executing it. Results are expected in early October.

The MIT School of Chemical Engineering Practice completed a study of "Auxiliary Power Recovery from Coal Gasification Processes." They found that cleanup and expansion of the gas from 1650°F was the most economical of three alternatives studies. Results may be summarized as follows.

<u>Operating Conditions</u>		Export Electricity	Power Recovery Unit	
Cleanup	Expander Inlet		Installed Cost	SNG Cost
1650°F	1650°F	306 MW	\$300 x 10 ⁶	\$4.80/MM Btu
1100	1100	276	293	4.82
300	1650	300	361	4.94

T. K. Lau, DOE Project Manager for the survey, visited ORNL on September 18-19 to discuss project status. An executive summary giving an overview of the survey activities during the past 2 years is to be prepared. The possibility of a workshop to promote open discussion and exchange of information on equipment problems and solutions is to be investigated. A paper for publication in an engineering periodical is also planned.

7.4 Flash Hydropyrolysis

S. P. N. Singh

7.4.1 Contract Objective

The objectives are to perform a preliminary technical and economic assessment of the Cities Service and the Schroeder-Spencer Chemical Company flash hydropyrolysis processes and to determine if a more detailed engineering evaluation is justified.

7.4.2 Status Summary

The final report for this study, titled Scoping Study on Two Flash Hydropyrolysis Processes (ORNL/TM-6265), was issued on August 11, 1978. The study concluded that a more detailed engineering evaluation of such processes is justified after a firm data base has been established.

7.5 Hot Gas Purification Processes

J. P. Meyer and M. S. Edwards

7.5.1 Contract Objective

The objective of this project is to investigate the present state-of-the-art hot gas cleanup processes. The application of most interest is the removal of contaminants from coal-derived fuel gas prior to firing combined cycle turbines.

7.5.2 Status Summary

The final report, ORNL/TM-6178, A Survey of Processes for High Temperature - High Pressure Gas Purification, is now in publication. The following preliminary summary remarks for the work are presented.

In order to ensure the optimum operating efficiency of a combined-cycle electric power generating system, it is necessary to provide gas treatment processes capable of operating at high temperatures ($> 1000^{\circ}\text{F}$) and high pressures [> 10 atm (absolute)]. These systems will be required to condition the inlet stream to the gas turbine to suitable levels of gas purity (removal of particulate matter, sulfur, nitrogen, and alkali metal compounds) to be compatible with both environmental and machine constraints. In this work, a survey of the available and developmental processes for the removal of these various contaminant materials has been conducted. Based on the data obtained in this study from a variety of sources, an analysis has been performed to evaluate the performance of a number of potential cleanup processes in view of the overall system needs. Results of this study indicate that commercially available, reliable, and economically competitive hot-gas cleanup systems (for the removal of H_2S , particulate matter, alkali, and nitrogen compounds) capable of conditioning raw product gas to the levels required for turbine use will not be available for some time.

7.6 State-of-the-Art Review of Heat Recovery Processes

W. R. Gambill and W. R. Reed

The final report describing results of this evaluation, ORNL/TM-6222, has been issued. An important conclusion of the study was that there is a clear need for more physical property data, improved heat-transfer correlations for multiphase streams, and more information about rates of fouling, corrosion, and erosion.

7.7 Assessment of a Moving Bed System for Cleanup of Raw Gasifier Gas

R. W. Glass, W. R. Gambill, and R. H. Lamb*

A study has been conducted of the feasibility of passing hot, raw gasifier gas from a coal conversion process through a proposed, regenerable moving bed of particles for removal of sulfur and particulates from the gas. The final draft report, Evaluation of a Moving Bed System for Hot Gas Cleanup, ORNL/TM-6223, has been issued and included a recommendation that an experimental moving bed system be constructed for development of presently unavailable design data.

7.8 Technical/Economic Assessment of Hydrogen Production by the Steam/Molten Iron Process

R. W. Glass and L. Seglin*

7.8.1 Contract Objective

The objective is to determine if there is sufficient incentive to develop the subject process for production of hydrogen from coal. The project considers specifically the comparison of the subject process (a molten-iron/steam concept) to the more conventional concepts employed in the Koppers-Totzek and Bi-Gas processes. All three processes are considered as part of an overall integrated SRC-II system. Process flowsheets, system costs, and product distributions will be described for each case and comparative economics developed. A development program for bringing the molten-iron process to the state of commercial availability will be addressed.

7.8.2 Status Summary

The final project report, Preliminary Evaluation of a Conceptual Molten Iron Gasification Process for the Production of Hydrogen, ORNL/Sub-78/13518/1, has been issued which compares the subject process with more conventional concepts. Within study constraints, there appeared to be little, if any, economic advantage offered by further development of this technology.

*Consultant.

7.9 A Study of Effluent Control Technologies for Hydrocarbon and Carbon Monoxide Emissions from Coal Conversion Plants

J. F. Fisher and G. R. Peterson

7.9.1 Contract Objective

The objective of this project is to provide a technical and economic comparison of processes available for the control of gaseous hydrocarbon (HC) and carbon monoxide (CO) emissions. Control of sulfur emissions is not considered in the present scope of study. The Lurgi gasification process is considered as the reference emission source, and comparisons of control technologies consider incineration as the reference control system. This project is supported and directed by the DOE Division of Environmental Control Technology.

7.9.2 Status Summary

Control of Hydrocarbon and Carbon Monoxide Emissions in the Tail Gases from Coal Gasification Facilities, ORNL/TM-6229, is the final report of this project and was issued in August. Incineration in a coal-fired boiler and catalytic incineration were found to be the most promising processes of those reviewed.

7.10 Environmental Controls for Low-Btu Gasification

S. P. N. Singh, M. S. Edwards, J. F. Fisher,
G. R. Peterson, and R. Salmon

7.10.1 Contract Objective

The objective of this project is to evaluate the various environmental control processes that might be used in connection with low-Btu gasification facilities and to determine the economic tradeoffs for various processes and levels of control.

The project is divided into two phases: Phase I consists of Tasks 1 through 5 of the work statement, and covers the preparation of a detailed work plan and the selection of gasification and environmental control processes for use in the study. Phase II consists of Tasks 6 through 8 in the work statement, and covers the collection and analysis of technical and economic data on the various environmental control processes and the preparation and analysis of flowsheets showing overall systems of environmental control processes used with various gasifiers.

7.10.2 Status Summary

Preparation of the draft report on Task 8 of the study is well underway with approximately 75% of the report complete. Estimates of the capital cost, labor, and utility requirements for the eight alternate wastewater treatment schemes have been developed. These estimates will be incorporated in the economic evaluations of the overall coal gasification complexes. A draft copy of the report will be available shortly for internal review purposes.

7.11 Support of the Office of Initial Operations (OIO)

B. Niemann, J. F. Fisher, H. F. Hartman,
and W. R. Reed

7.11.1 Contract Objective

The objectives of this project are: (1) to perform rapid reaction reviews and analyses of documents provided by DOE on Coal Conversion Demonstration Plant projects with appropriate follow-up as requested; (2) to produce design checklists and conduct requested evaluations in the DOE/FE/OIO's areas of responsibility which include considerations of start-up, safety, environmental pollution, maintainability, and reliability; and (3) to develop guidelines for the preparation of safety, operation, and maintenance manuals.

7.11.2 Status Summary

No requests for document reviews have been received this month.

8. PROCESS AND PROGRAM ANALYSIS

R. W. Glass

Process and program analysis studies are being conducted for the DOE Fossil Energy Engineering Economics and Standards Section of the Division of Program Control and Support. This effort includes research studies on most of the coal conversion and utilization processes. The program objective is to provide on a consistent basis, technical and economic evaluations of competing processes and systems for coal conversion and utilization.

8.1 Low Btu Coal Gasification

H. F. Hartman and J. P. Belk

8.1.1 Contract Objective

The objectives of this study are to survey the low Btu coal gasification processes, select the most promising processes, and provide technical and economic information on the competing processes.

8.1.2 Status Summary

A copy of the mats of the final report, Low Btu Coal Gasification Processes (ORNL/ENG/TM-13), is being circulated for ORNL review and approval. Comments on the report distribution list were received and used to revise the list. Volume 1 of the report, "Summary, Screening, and Comparisons," was reviewed by the senior author; Volume 2, "Selected Process Descriptions," is being reviewed. Future work on the final report includes minor revisions, printing, and distribution. These activities will occur after the report is approved.

8.2 In Situ Coal Gasification

M. S. Edwards and W. C. Ulrich

8.2.1 Contract Objective

The objective of this program is to provide technical and economic evaluations of candidate processes for the conversion of coal in situ to fluid products presently of interest. During FY 1977, technical and economic evaluations of the linked vertical well process applied to subbituminous coal were addressed. Three alternative end product configurations were considered - electricity, SNG, and syngas. In FY 1978, an evaluation is being conducted of an in situ facility for producing gasoline from methanol via the Mobil-M process.

8.2.2 Status Summary

The draft report Evaluation of an In Situ Coal Gasification Facility for Producing M-Gasoline via Methanol, ORNL-5439, has been completed. The report contains:

- a. Descriptions of process designs, including design assumptions and flow diagrams, developed for producing approximately 15,000 barrels per day of gasoline via methanol from in situ coal gasification.
- b. Results of an economic analysis showing the product price of gasoline as a function of coal cost, rate of return on investment, and other technical and economic parameters.
- c. Supporting data such as mass and utility balances, major equipment lists, capital and operating cost estimates, construction schedule, etc.

Copies of the draft report are being sent to the program manager in DOE, John Vlahakis, and are also being circulated to interested parties in ORNL and elsewhere for review and comments.

The final estimates of M-gasoline product prices under various technical and economic assumptions are shown in Table 8.1 for a coal cost of \$5/ton (in place) and annual after-tax rate of return on equity of 15%. These prices reflect the final capital and operating costs estimated by Davy Powergas, Inc. for the methanol synthesis plant. Davy Powergas estimated \$61 million capital cost for the methanol plant and initial catalyst charge, including freight, duty, taxes, fees, and so forth. An additional \$1.5 million was suggested to allow for adequate sparing in the methanol plant.

8.2.3 Open Items

Publication of the FY-1977 in situ work, Process Designs and Economic Evaluations for the Linked Vertical Well In Situ Coal Gasification Process (ORNL-5341) is pending further discussion with DOE/FE.

Table 8.1. Summary of M-gasoline product price

Case No.	Variations for sensitivity analyses	M-gasoline product price	
		(\$/gal)	\$/bbl)
	Base case, with coal cost = \$5/ton and 15% ROE	0.91	38.25
2	No parent corporation tax credit	0.98	41.14
3	No investment tax credit	0.96	40.31
4	100% equity	1.34	56.19
5	30/70 debt/equity ratio	1.14	47.74
6	10% annual interest rate on debt	0.93	39.00
7	8% annual interest rate on debt	0.89	37.51
8	+10% operating costs (constant and proportional)	0.94	39.43
9	Mobil-M catalyst = \$10/lb	0.92	38.63
10	Drilling, casing, and logging = \$75/ft	0.92	38.68
11	Raw water = \$0.50/1000 gal	0.91	38.10
12	+10% capital cost	0.97	40.73
13	Working capital = 9% of depreciable capital	0.92	38.77
14	C ₃ LPG product price = \$5/10 ⁶ Btu	0.90	37.99
15	C ₄ LPG product price = \$6/10 ⁶ Btu	0.94	39.39
16	No sulfur credit	0.91	38.37
17	Plant factor = 80% for entire 20-year lifetime	0.99	41.77
18	Plant factor = 75% in first operating year, 90% for remaining 19 years	0.92	38.69
19	Increase to 7 field trains => design throughput of 18,000 BPD	0.81	33.85
20	Field production average of 5.5 trains, 16,500 BPD	0.85	35.69

8.3 Coal Beneficiation

S. P. N. Singh and G. R. Peterson

8.3.1 Contract Objective

The objective of this study is to provide technical and economic evaluations of currently used and potential coal beneficiation processes. Project efforts culminated in a draft final report titled Survey and Evaluation of Current and Potential Coal Beneficiation Processes (ORNL/TM-5953) which was completed in October and forwarded to DOE for review and comments. The report summarizes the technical evaluations of currently used and several novel coal beneficiation techniques.

8.3.2 Status Summary

Reviewers comments have been included in a final report for this study which is presently receiving minor revisions and editing prior to publication.

8.4 Gas Cleanup Studies

M. S. Edwards

8.4.1 Contract Objective

The objective of the gas cleanup study is to collect information on the technology and economics of processes for the removal of impurities (principally hydrogen sulfide) from fuel gas streams. High- and low-temperature cleanup processes will be reviewed.

8.4.2 Status Summary

A review of seven methods for removal of impurities (primarily H₂S) from fuel gas streams has been completed and the final report is awaiting publication: H₂S-Removal Processes for Low-Btu Coal Gas (ORNL/TM-6077). The processes chosen for evaluation represent each of seven separate categories of treatment methods and were selected from over 50 candidate processes described in the literature.

8.5 HYGAS Modeling

J. P. Meyer, G. C. Frazier, J. W. Wells, and J. P. Belk

8.5.1 Contract Objective

The objective of this project is to develop a computer model of the HYGAS gasifier.

8.5.2 Status Summary

A draft final report (less Appendices) has been prepared and is being circulated internally for review. The Appendices, which include a documented listing of the Fortran source program and graphical results from both the IGT fluidized bed model and the completely backmixed single bed model, are in preparation.

After these internal comments are received, they will be incorporated into a final draft version which will be forwarded to DOE for review.

In addition to soliciting comments from DOE, the following individuals have been asked to review the report:

Dr. C. Y. Wen
Department of Chemical Engineering
West Virginia University
Morgantown, West Virginia

Dr. George Quentin
EPRI
3412 Hillview Avenue
Palo Alto, California

Dr. Robert Koucky
Combustion Engineering
1000 Propsect Hill Road
Windsor, Connecticut

These individuals are experts in the field of gasification modeling and their comments will materially add to the value of the final report.

8.6 Liquefaction

R. W. Glass

8.6.1 Contract Objective

The objective of this project is to provide technical and economic evaluation of coal conversion liquefaction processes. Ralph M. Parsons Company is working under subcontract on the project with J. B. O'Hara as Project Manager. Major tasks included in the subcontract are: (1) a Survey of Liquefaction Processes, and (2) a Detailed Review of High Potential Liquefaction Processes.

8.6.2 Status Summary

Draft final reports for the liquefaction study have been completed and forwarded for DOE/FE and ORNL review:

1. Liquefaction Technology Assessment Final Report (Draft), ORNL/Sub-7186, The Ralph M. Parsons Company.
2. Coalcon Process Review, R&D Interim Report No. 3 (Draft), ORNL/Sub-7186-16, The Ralph M. Parsons Company.

Review and distribution makeup are in progress; resolution of comments has entailed more than originally anticipated. It appears that an extension and modification of the existing subcontract may be necessary to allow DOE/ORNL time to coordinate more fully on their review of the final report.

8.7 High Btu Gas

R. W. Glass

8.7.1 Contract Objective

This subprogram is being analyzed under subcontract by the Scientific Design Company, Incorporated (SD) with A. S. West as Project Manager. The present work is divided into three phases as follows:

1. The objective of Phase I is to provide technical and economic evaluations of competing processes, concepts and systems for the production of high Btu gas from coal.
2. The objective of Phase II is to monitor and analyze data from the HYGAS Pilot Plant.
3. The objective of Phase III is to perform a technical and economical evaluation of the Battelle Agglomerating Ash Burner Process for the production of medium Btu fuel gas, synthesis gas and hydrogen from coal.

8.7.2 Status Summary

Test No. 74 was completed at the pilot plant. SD engineers have issued a test report and the following is a summary of that report:

Test No. 74 started at 0430 hours on August 6, 1978 became self-sustained at 1510 hours on August 9, 1978 and was voluntarily terminated without clinkering after 504 hours of self-sustained operation at 1500 hours on August 30, 1978. The recent practice of operating the Gasifier at reduced pressure (500 psig) was continued during Test No. 74. IGT operates the Gasifier at 500 psig to artificially increase the superficial gas velocity so as to demonstrate their claim that clinkering can be prevented at high temperatures by velocities greater than 1.2 ft/sec. Unfortunately this objective was negated by the further objective of keeping the bed below 1750°F, at which temperature clinkering would not be expected even at very low velocities. Double screened char was fed at values approaching 4000 lb/hr. The objective minimum steam/oxygen ratio of 6.7 was always exceeded, except during the final six days of the run when several extended periods at 750 lb/hr oxygen feed were achieved.

Operations were interrupted several times by the usual mechanical problems in solids handling and purification, however, serious consequences were avoided. Good operator attention ensured prompt reduction of oxygen whenever char feed had to be reduced. Temperature excursions were almost eliminated with 1780°F being the highest SOG temperature recorded.

A serious bed stability problem was encountered which may have been a consequence of fines accumulation during the unusually long period of operation. Correction was generally accomplished by blowing down the beds.

Conversions are not yet confirmed, but quick ash analyses indicate that the objective of 80% may have been realized during some periods of steady operation.

The steam/oxygen sparger cones were removed prior to Test No. 74 because IGT believes that they suppress the mixing of the solids from the bed into the gas jet.

ORNL received the final SD draft report for the Battelle Agglomerating Ash Burner Process for Medium-Btu Application. Review of the report is in progress.

8.8 Comparative Cost Estimates of Five Coal Utilization Processes

R. W. Glass

8.8.1 Contract Objective

The objective of this study is to determine consistent investment costs for four different coal utilization processes plus a conventional coal-fired power plant. The study will consider a high sulfur bituminous coal, such as an Illinois No. 6 used for a 500 MW power plant. Of the four coal conversion processes, two will consider scrubbing sulfur from the flue gases, the third will consider atmospheric fluidized bed combustion with simultaneous entrapment of sulfur by injection of lime, and the fourth will consider a coal beneficiation process coupled with flue gas scrubbing. This study is being conducted under subcontract by Chem. Systems, Inc., with L. H. Weiss as Project Manager.

8.8.2 Status Summary

Final comments for the project completion report have been transmitted to Chem. Systems, Inc. and the final report is expected to be ready for issue within a few days.

8.9 Direct Combustion

E. C. Fox and T. D. Anderson

8.9.1 Contract Objectives

The purpose of this study program is to assist DOE/FE in their effort to develop a national strategy to increase the near-term use of coal through direct combustion; the applications of interest in this study are the small-to-moderate industrial user and the large residential/commercial user. The following objectives will be accomplished:

1. Identify and quantify the important factors restricting the use of coal in the sectors of interest.
2. Evaluate potential technological and institutional solutions to the problems identified in (1) above.
3. Make recommendations to DOE/FE relative to the most promising approaches to increasing the near-term use of coal.

8.9.2 Status Summary

Material not received in time for present draft submission.

8.10 Advanced Power Conversion Systems

J. E. Jones Jr. and A. P. Fraas^a

8.10.1 Contract objective

The objectives of this project are to review selected major advanced power conversion systems and to assess these systems with respect to their basic R&D status.

8.10.2 Status summary

A total of eleven systems or components of systems were evaluated. Draft reports covering all of these topics, an overall summary report, and an executive summary report have been completed and are undergoing final review.

^aConsultant

9. FOSSIL ENERGY ENVIRONMENTAL PROJECT

C. R. Boston

The Fossil Energy Environmental Project provides the Division of Coal Conversion with program assistance in the performance of environmental assessment functions related to the expansion of fossil energy conversion technologies, performs assigned technical assistance tasks, and conducts programmatic environmental investigations that are critical to the early realization of advanced fossil energy technologies.

9.1 Stored Solids Study

W. J. Boegly, Jr.

Ash from the Texaco Gasifier in Montebello, California, was received late in the month. This material was produced by gasifying vacuum bottoms from the SRC-II pilot plant in Tacoma, Washington. Kentucky Number 9 was the feed coal. Leaching studies have been initiated on this material. This waste has been given the highest priority of the wastes currently on hand. Contacts with the Cogas developers continues in an attempt to determine the reasons for the variation in pH of the aqueous slurries of the solid material received by ORNL. This should be resolved early in October and the soil/ash leaching column tests will then be initiated. Four barrels of Pittsburgh No. 8 coal have been shipped by METC to ORNL. This will be the feed coal for the CONOCO demonstration plant. Two of the drums contain sized coal, and the other two are run-of-mine coal.

A paper was presented on "Solid Waste Management" at the Symposium on Potential Health and Environmental Effects of Synthetic Fossil Fuel Technologies, on September 26 at Gatlinburg, Tennessee. A summary report on the Stored Solids Study was prepared to inform DOE/FE management of the current status of the study.

9.2 Technical Assistance

S. G. DeCicco

9.2.1 Interaction with demonstration plant contractors - S. G. DeCicco

SRC-1 - In fulfillment of a DOE-ORO request stemming from the August 4, 1978, environmental meeting for the SRC-I project, we received a review copy of the Environmental Impact Assessment (EIA) for the 2000 tpd design on August 16. The purpose of the review

was to determine whether sections of the EIA could be used for the EIS on the 6000 tpd design. On August 31, ORNL comments were routed to ORO. The staff's review of the EIA determined that: 1) chapter two, baseline characterization of the site, may be applicable to the 6000 tpd EIS; 2) the frequency and timing of the field monitoring program reported in the document is inadequate to satisfy the EIS needs; 3) a site visit is essential to put the scope and quality of the EIA into perspective, and 4) any additional data collected subsequent to September, 1977, should also be reviewed as part of this decision. During the month of September, plans were made for a visit to the proposed site near Newman, Kentucky.

SRC-II - During the month of September, plans were made for a visit to the SRC-II site near Morgantown, West Virginia, now scheduled for October 3.

ICGG - No activity this month. The project is moving toward DOE's high-Btu demonstration program decision date of about November 1st. Either ICGG or CONOCO will proceed toward demonstration. The final ER for ICGG is now scheduled for January 1, 1979.

CONOCO - No activity this month. The final ER is now scheduled for May, 1979. The CONOCO field monitoring program is nearing completion.

MLGW - On August 27, 1978, we received a copy of the report, "Coal Handling and Preparation/Ash Handling" from Foster-Wheeler and MLGW. There was no activity during September; however, we learned of several developments in the project. Due to technical problems the U-gas pilot plant was not able to produce process data needed for the demonstration plant design. This set-back delayed preparation of the final ER, now scheduled for September, 1979. (Decision date, December, 1979). In addition, the state and federal EPA, and Memphis/Shelby County Health Department have informed MLGW that the air quality monitoring program, being used by Energy Impact Associates, is adequate for agency requirements. The applicability of field monitoring data from extant monitoring facilities for MLGW's baseline characterization is now being evaluated.

Grace-Ebasco - On September 18, we received the "Plan of Study Addendum" from W. R. Grace. The addendum is a response to all comments received on their earlier monitoring program after site visits by the reviewers. Comments will be discussed in a forthcoming meeting (yet to be scheduled) with DOE, Grace, ORNL, and Ebasco/Envirosphere. Completion of the final ER for the Grace/Ebasco demonstration project is now scheduled for June, 1979, and the decision date is December, 1979.

9.3 Atmospheric Fluidized Bed Combustion Assessment

S. G. DeCicco

During the month of September, a visit was made to Babcox & Wilcox's research facility in Alliance, Ohio, which houses a 6 foot x 6 foot fluidized bed pilot plant. Later in the month additional sections of the document dealing with the environmental assessment of solid waste disposal were submitted for review.

9.4 Environmental Analysis of Pipeline Gas Demonstration Plants

This document was given final reviews and was revised in response to comments. Final editing was completed and the analysis was published as ORNL/TM-6235.

10. MAGNETIC BENEFICIATION OF DRY PULVERIZED COAL

E. C. Hise

10.1 Objective

The objective of this project is to develop and demonstrate a novel process for coal beneficiation by magnetic separation of pyrites and ash from dry pulverized coal.

10.2 Status Summary

Both the in-house and contract tests of crushing and air classification indicate that conventional commercial equipment can crush coal to a size consist suited to dry magnetic separation and very sharply classify that consist into fractions as needed. The size distribution from two contract grinds of a Kentucky No. 9 coal, shown in Table 1, is typical of the crushing tests and illustrates the results.

Table 1

Particle size range	Grind	
	A	B
-24 + 100 mesh	78.5%	22.8%
-100 + 200 mesh	12.2	45.2
-200 + 325 mesh	5.2	18.8
-325 mesh + 10 μ	2.0	5.1
<10 μ	2.1	8.1

The -325 mesh + 10- μ fraction flows freely, processes well in the HGMS, and appears as discrete particles with no agglomeration when viewed with the scanning electron microscope. A particle size analysis (Coulter Counter) of the -325 mesh + 10- μ fraction shows 2% below 10 μ and 2% above 50 μ , while an analysis of the <10- μ fraction shows the peak to be between 10 and 15 μ , with 45% below 10 μ and 15% greater than 15 μ .

The first series of magnetic separation tests at Sala Magnetics is essentially complete. We elected to perform first the mode of gravity feed with low-velocity air transport. This mode is the most attractive economically because it has the potential for the highest throughput rate with the lowest air circulation rate, but it is least likely to succeed

because the coal has the lowest turbulence and residence time in the matrix. The following tests will be upward pneumatic transport and then fluidization in the matrix with varying residence time.

Rapid total sulfur analyses of the feeds and products were made to monitor the test series. Complete analyses and material balances will follow. Since the pyritic and organic sulfur contents of the feeds have not yet been quantified, the success of the separations can be judged only qualitatively. The Lower Freeport coal in the size fractions of 100-200 mesh, 200-325 mesh, and 325 mesh-10 μ all showed a sulfur reduction from about 1.9% in the feed to about 1.0% in the product. The Kentucky No. 9 100-200 mesh and 200-325 mesh showed a sulfur reduction from about 3.5% in the feed to about 2.8% in the product, while the 325 mesh-10 μ showed no significant sulfur reduction. These are better separations for this mode than reported by previous investigators and are considered encouraging.

A program of exploratory tests of the magnetic separability of certain trace elements from coal has been initiated.

A sample of the "cyclone ash" from a B&W fluidized bed boiler was magnetically separated into what appeared to be the two sharply cut fractions of carbon and limestone. A sample of the "bed ash" was magnetically separated into two different-appearing fractions. Chemical analysis will be required to identify the difference. A program to pursue the applications of magnetic separation to both carbon recovery and unspent bed recovery is urged.

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