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

OAK RIDGE NATIONAL LABORATORY
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FOSSIL ENERGY PROGRAM
PROGRESS REPORT FOR MAY 1978

L. E. McNeese
Program Director

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FOSSIL ENERGY PROGRAM PROGRESS REPORT FOR MAY 1978

ABSTRACT

This report — the forty sixth 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 process development, materials engineering, alkali metal vapor topping cycles, a coal equipment test program, an AFB coal combustor for co-generation (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 May are as follows:

Coal Conversion Development — Results are reported from hydrocarbonization of Illinois No. 6 coal in the bench-scale reactor. An oil yield of 21.0 wt % (maf) was obtained when this coal was pretreated with aqueous CaO and Na_2CO_3 at 80°C and 1 atm. Progress is reported on design of instruments for determining physical properties of coal liquids and on design of the Coal Liquids Flow System and Slurry Preheater Test sections. Results from control experiments on ionic hydrogenation of three coals are presented. One test with a hydride donor showed a two-fold increase in pyridine solubility. The sensitivity of the monitor for polynuclear aromatics on work area surfaces has been enhanced by an order of magnitude as a result of improvement to the optics of the laboratory instrument. Electronic circuitry for the portable prototypes has been designed, fabricated, and tested satisfactorily but will be modified slightly to increase its overload capacity. Three lignite pyrolysis tests were completed in support of the underground coal gasification program. New results from earlier experiments are also reported.

Materials Engineering — All heat treatment for as-quenched, quenched and tempered, and stress relieved samples of 2 1/4 Cr-1 Mo steel is complete and some aging is in progress. Impact testing of material that was slow-cooled (0.3K/sec) from 1038°C and subsequently heat treated has been completed.

The first CoCrAlY tensile specimen was successfully cracked to provide a standard for the work.

Recent work has shown that the nickel content of Type 320Cb cladding is a major factor influencing cracking of deposits made at high deposition rates.

Experimental evaluation of heat exchanger tubes exposed in the Fluidyne atmospheric fluidized bed combustor is continuing.

Failure analysis activities continue to include involvement with the Wilsonville Solvent Refined Coal Plant. The Solvent Refined Coal Plant at Tacoma has confirmed that a set of corrosion coupons is being sent to ORNL by way of Gulf Research in Pittsburgh, Pennsylvania. The final report on the Type 310 stainless steel air distributor plate from the Rivesville, West Virginia atmospheric fluidized bed combustor is being prepared for publication.

Alkali Metal Vapor Topping Cycles — The system was operated at burner power levels up to 2.4×10^6 BTU/hr while venting off gas to drain tank. The pressure control vent valve opened due to high pressure (> 16 psig) at the 2.4×10^6 BTU/hr power level and some potassium was released. Valve plugging problems continue but corrective measures are being taken.

Coal Equipment Test Program — Three pilot-sized test loop facilities have been identified:

- (1) Hot Dirty Gas — Energy Technology Engineering Center,
- (2) Char Circulation — General Atomics, and
- (3) High Pressure and Low Pressure Slurry — CRESAP.

Atmospheric Fluidized Bed Coal Combustor For Cogeneration (AFB CCC) — Information obtained from the Rivesville AFBC Plant along with the design recommendations from the ash handling system vendors are being incorporated into the system specifications. The first 500 hr of the 3000 hr corrosion test has been completed with no tube failures or unusual incidents.

Direct Combustion — The industrial representatives indicated complete agreement on the draft report.

Advanced Power Conversion Systems — 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.

Magnetic Beneficiation of Dry Pulverized Coal — A 4-in. diameter by 40-in. long column has been placed in operation as a fluidized bed to air classify crushed or pulverized coals. The column elutriates the fines with a fair degree of selectivity and the amount of fines removed is a function of the degree of crushing or pulverizing.

Fossil Energy Environmental Project — Work is underway on COGAS process residues and attempts are underway to secure representative SRC wastes. The Environmental Monitoring Handbook was completed. Technical assistance was provided to DOE/FE on four demonstration plants: Grace/Ebasco; Memphis Light, Gas and Water; ICGG; and CONOCO. Work was initiated on the atmospheric fluidized bed combustion assessment.

Process Modeling — The revised physical properties package was received from Purdue and has been compiled and linked into the subroutine library.

Synthesis Fuels Research Digest — Work on the Digest has resumed. Review of articles continues. Future issue articles are under consideration.

Survey of Industrial Coal Conversion Equipment Capabilities — Evaluation of market demand for coal conversion equipment is continuing. Letters to producers concerning equipment price and development costs are being prepared for mailing. Overview comments are given on a trip to IGT facilities on pumps, expanders, expansion joints, mechanical connectors, and heat recovery.

In Situ Coal Gasification — Process flowsheets were completed for all major plant units of the in situ syngas-to-gasoline facility. Material and heat balances for the M-gasoline plant were revised.

Hygas Modeling — Work continues on the areas of devolatilization, the characterization and thermal cracking behavior of coal derived liquids, model definition and thermal cracking behavior, model definition and development of a multiple bed simulation program.

Liquefaction — Information for the H-Coal process has been collected. Fixed capital cost estimates and profitability analyses for the SRC-II, CSF, and H-Coal processes are in progress.

High Btu Gas — Monitoring of the HYGAS Pilot Plant continues.

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 Coal Conversion -- 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 Oil, Gas, Shale, and In-Situ Technology -- Experimental Engineering Support for In-Situ Gasification Processes.

2.1 Hydrocarbonization Research

E. L. Youngblood, J. Beams, and J. C. Rose

Work accomplished. During May modification and testing of the longer reactor vessel was completed. An attempt was made to operate the system using Illinois No. 6 coal (run HC-27); however, caking occurred in the reactor and the run was terminated after processing 5 lbs of coal. The oil yield (21%) and material balance data for run HC-26, which was made using Illinois No. 6 coal treated with CaO and Na₂CO₃, are given in this report.

After modifications were made to the reactor to increase the depth of the fluidized-bed section by 5 ft, the vessel was installed and given a pneumatic pressure test at 350 psig and 1350°F. The test showed that temperature control and leak rate from the system were satisfactory. Additional tests were run in the Lucite mockup of the reactor to determine if adequate char circulation and fluidization would be achieved under conditions that had given satisfactory operation in the shorter reactor. The tests indicated that conditions used in previous runs gave good char circulation and mild fluidization of the downcomer. Vigorous fluidization of the downcomer was difficult to achieve because of bypassing of gas from the distributor plate to the draft tube.

An objective of run HC-27 was to determine if the longer reactor and increased residence time in the reactor would give sufficient devolatilization of coal in the draft tube to eliminate the caking problems at the top of the draft tube that had occurred in previous runs with untreated Illinois No. 6 coal. Operating conditions for the run were similar to those used in runs HC-23, HC-24, and HC-26 with the exception that the bed temperature was approximately 50°F higher at 1110°F. The operating pressure was 300 psig. The total hydrogen flow to the system was 20 scfm with 6 scfm being fed to the draft tube and 14 scfm to the distributor plate. Assuming approximately 80% by-passing of gas from the distributor plate to the draft tube, as observed in mockup studies, the gas residence time in the draft tube was about 0.8 sec.

Before beginning the run, 8.5 kg of char was fed to the reactor as a starter bed. With the starter bed in the reactor and with the hydrogen flow at the desired ratio, temperatures in the downcomer were uniform, indicating good circulation of the char. The transport gas stream was preheated to 370°F. The temperature of material leaving the draft tube was about 1090°F or about 20°F cooler than the bed in the downcomer. Coal feed to the reactor was started at a slow rate of about 3 lbs/hr. Almost immediately after the feed was started, the temperature profile in the reactor changed probably as a result of caking. Thirty minutes after the coal feed was started the transport line plugged, and it was necessary to reduce the system pressure to clear the line. Coal was fed to the reactor during three other periods for a total time of 1 hr and 40 min, during which time a total of 5 lbs of coal were fed; however, operation was erratic, and bed circulation and fluidization were poor during this time; therefore, the run was terminated. The reactor was examined after the run, and caking was found both at the top and bottom of the fluidized-bed section. We have not determined at what location the caking first began to occur. Performances of the system with caking coal could likely be improved by more vigorous fluidization of the downcomer and by improving mixing and the method of introduction of coal at the bottom of the draft tube.

A preliminary material balance and summary of experimental conditions for run HC-26, which used Illinois No. 6 coal pretreated with CaO and Na₂CO₃, are given in Tables 2.1 and 2.2. The oil yield from the run was 21% (based on maf coal). The presence of fine CaO particles in the system complicated the material balance and oil yield calculations since a considerable amount of the CaO passed through the cyclone at the top of the reactor and collected with the oil product in the scrubber. It was necessary to separate the oil from the solids by extraction to determine the composition. Only about 80% of the ash present in the coal and starter bed has been accounted for in the products from the run. The carbon, sulfur, and overall material balance are within the normal limits. The composition of the coal used in HC-26 before and after treatment with CaO and Na₂CO₃ is given in Table 2.3. The results indicate that sulfur was not removed by the pretreatment.

Work forecast. The system will be cleaned and inspected. No attempt will be made to determine oil yields or material balances for run HC-27 because of the short duration. We will begin modification of the system to couple the cyclone directly to the draft tube to permit rapid hydrolysis of Wyodak coal and rapid quenching of the volatile products. The Lucite mockup will be used to test char circulation and the performance of the cyclone at high solids loading.

Table 2.1. Preliminary material balance for Experiment HC-26

Average bed temperature: 1055°F

Total pressure: 300 psig

	Mass (g)	Carbon Fraction	Ash Fraction	Sulfur Fraction	Percent of Carbon fed	Percent of ash fed	Percent of sulfur fed
<u>Input</u>							
(1) Coal	50,517	0.573	0.271	0.031	93.5	98.1	99.1
(2) Char starter bed	2,448	0.818	0.110	0.006	6.5	1.9	0.9
(3) Scrubber water	23,090	0.0	0.0	0.0			
<u>Output</u>							
(4) Char recovered	25,245	0.702	0.289	0.028	57.3	52.3	44.7
(5) Scrubber and cold trap oil phase	9,650	0.432	0.204	0.014	13.5	14.1	8.6
(6) Scrubber aqueous phase	24,390	0.013	0.028	0.034	1.1	4.9	53.3
(7) Charcoal trap light oil	649	0.81	--	0.005	1.7	--	0.2
(8) Solvent residue scrubber	8,516	0.256	0.112	0.009	7.0	6.9	4.7
(9) Solvent residue cold trap	1,246	0.755	0.0139	0.010	3.1	0.1	0.8
(10) Residue in water rinse of scrubber	357	0.486	0.225	0.014	1.4	1.4	0.8
(11) Gases	<u>5,408</u>	0.656	--	0.009	<u>11.5</u>	<u>--</u>	<u>3.1</u>
Overall Balances (Percent)	99.9				96.6	79.7	116.2

Table 2.2. Summary of Experiment HC-26 conditions
and preliminary material balances

Experiment	HC-26
Bed temperature, °F	1055
Reactor pressure, psig	300
Estimated solids residence time in the reactor, min ^a	35
Period at steady state, hr	12.8
Coal feed (Na ₂ CO ₃ -CaO treated Illinois No. 6 coal)	
Moisture content, wt %	2.78
As-received feed rate, lb/hr	8.7
Moisture-and-ash-free rate, lb/hr	6.1
Time of feeding, hr	12.8
Hydrogen flow rates, scfm	
Total hydrogen feed	18.9
Coal transport tube	5.8
Through distributor plate	13.1
H ₂ /coal feed ratio	
lb H ₂ /lb coal (maf)	0.97
scf H ₂ /lb coal (maf)	186
H ₂ consumed	
lb H ₂ /lb coal (maf)	-0.01
Carbon balance (% of carbon fed)	
Char ^b	57.3
Liquids	27.8
Gases	11.5
Overall	96.6
Overall ash balance (% of ash fed)	79.7
Sulfur balance (% of sulfur fed)	
Char ^b	44.7
Liquids	68.4
Gases	3.1
Overall mass balance (% of mass charged)	99.9
Oil yield (wt % of maf coal)	21

^aBased on bed density and coal feed rate.

^bBased on char from char receiver and reactor.

Table 2.3. Analysis of Illinois No. 6 coal before and after treatment with CaO and Na₂CO₃ for run HC-26

	Illinois No. 6 coal (before treatment)	Illinois No. 6 coal (after CaO-Na ₂ CO ₃ treatment)
Moisture	0.2	2.78
Ash	11.0	27.1
Volatile matter	39.7	35.1
C (maf)	77.7	81.7
H (maf)	5.9	5.8
N (maf)	1.4	1.5
Total sulfur (maf)	4.1	4.4
Organic sulfur (maf)	2.9	2.8
Ca	0.6	3.4
Na	0.07	2.6

2.2 Physical Properties of Coal Liquids

G. E. Oswald and H. D. Cochran, Jr.

Communications have been established with personnel associated with the H-Coal and SRC processes to ensure that physical properties data are obtained on process streams of importance and under temperature and pressure conditions so as to be of maximum use to plant operations and related modeling and design efforts. Al Camolli of HRI and Iacovas Vasalos of Amoco have been contacted regarding the H-Coal process, and H. E. Lewis of Catalytic and Joe Naylor of PAMCO have been contacted regarding the SRC process. All persons contacted have expressed a strong interest in physical properties data and have been helpful in arranging for samples to be made available for testing and in coordinating the selection of suitable test conditions.

Progress continued on the instruments for physical properties determinations. The falling-ring viscometer is being fabricated by Norcross and will be available shortly. Mechanical design is near completion on the pulsed hot wire instrument for thermal conductivity measurement; electronics and heat transfer design calculations are also nearly

completed. Mechanical design has been completed for the static head density instrument. The instrument for heat capacity determination is still in preliminary design.

A Lucite model of the static head density meter has been constructed and tested satisfactorily at ambient conditions with glycerol-water mixtures spanning a range of viscosity from 1 to 500 cP and density from 1.00-1.25 g/cm³. Currently under design is a system for controlling the rate of bubble generation at about 2/sec over the range of anticipated operating conditions. As a backup for the static head instrument, a gamma ray attenuation instrument will also be installed. This latter instrument is mechanically simple and reliable but may require calibration for different fluid compositions.

Design difficulties associated with the flow calorimeter for heat capacity determination are associated with measuring and controlling the mass flow rate through the instrument. If these problems cannot be solved satisfactorily, we plan to use the pulsed, hot wire instrument to measure thermal diffusivity. Heat capacity may be determined from the thermal diffusivity if density and thermal conductivity are known.

Design drawings for the physical properties instruments will be included in the next monthly progress report for this project.

2.3 Coal Slurry Preheaters

H. D. Cochran, Jr.

During May design for instrumentation and controls for the Coal Liquids Flow System (CLFS) was completed and installation and wiring of the control panels was begun. The CLFS and control systems were described in a project safety summary which has been submitted for review and approval. Detailed design of the Preheater Test Section is currently under way; fabrication and installation are scheduled to permit shakedown testing during the last quarter of this fiscal year.

Effort is under way to review and report the status of slurry preheater technology as the first task of this project. J. R. Thurgood, who will assume the role of principal engineer for this project in June, is accumulating a data base from project reports and the technical literature. In addition, discussions are planned with design and operating personnel associated with the H-Coal and SRC processes to ensure that the technical data base is complete and up to date. Two recent publications^{1,2} describing a plug formed between the preheater and the dissolver of the Tacoma SRC pilot plant have been studied to gain further insight into the factors which influence formation of semi-coke and plugs in preheater streams. It appears that backflow of mineral matter from the dissolver may contribute to plug formation.

2.4 New Liquefaction Techniques

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

Control experiments have been initiated on the reactions of $\text{BF}_3 \cdot \text{H}_2\text{O}$ with three coals--a North Dakota Lignite and two bituminous coals, Illinois No. 6 and Bruceton. One test with Illinois No. 6 coal included isopropanol as a hydride donor. Preliminary results from these first experiments are presented in Tables 2.4, 2.5, and 2.6. From these early results, particularly with Illinois No. 6 coal, it is clear that $\text{BF}_3 \cdot \text{H}_2\text{O}$, alone, increases the pyridine solubility only slightly, but with the presence of a hydride donor (isopropanol) the pyridine solubility is more than doubled.

Control experiments will be performed with Wyodak subbituminous coal and with Solvent Refined Coal in preparation for the program of experiments aimed at converting coal using ionic hydrogenation through the use of Lewis acids and hydride donors.

2.5 In-Plant Environmental Monitors

D. D. Schuresko and R. G. Phillips^b

Work on this project during April has principally consisted of: (1) modifying and testing the prototype detector head for improved sensitivity, and (2) "bread-boarding" and testing of a prototype synchronous demodulator circuit which will ultimately be incorporated into the spotter electronics units.

The sensitivity of the prototype optics unit has been increased to enable detection of 1 microgram of perylene (located 100 cm distant) with the room lights on, and sub-nanogram amounts of perylene with the room lights off.^c This sensitivity increase is due to substitution of a 1 kHz, wide-aperture tuning fork chopper for the 2 kHz chopper used previously, resulting in a greater than 10-fold increase in the uv illumination intensity. This increased sensitivity is considered to be adequate for all currently envisioned uses of the spotter.

Design, fabrication, and testing of a proto-board synchronous demodulator circuit is nearing completion. This circuit, which consists

^aORNL Chemistry Division and University of Tennessee Department of Chemistry.

^bInstrumentation and Controls Division.

^cThe previous sensitivity was 5 micrograms of perylene (at 70 cm) with fluorescent room lights on and 15 nanograms in the dark.

Table 2.4. Reaction of Illinois No. 6 coal

Type of coal and manner of treatment	Temperature of run	Elemental analysis of sample (%)								Solubility in pyridine (%)	Run time (hr)	Solvent reactants run conditions	Percent increase in weight on run
		carbon	hydrogen	nitrogen	sulfur	boron	fluorine	ash	oxygen				
Illinois No. 6 Unreacted Soluble + insoluble	Does not apply	74.97	4.95	1.64	1.89	2.19	0.02	5.70	8.64	--	NA	NA	NA
Unreacted Soluble	Does not apply	a	a	a	a	a	a	a	a	18.0	NA	NA	NA
1 Reacted (BF ₃ ·H ₂ O Soluble + insoluble	Room temperature	72.83	4.80	1.15	1.73	1.51	3.41	4.69	9.88	--	24	BF ₃ ·H ₂ O(1:1) stirring	No signif- icant change
As above Soluble	Room temperature	a	a	a	a	a	a	a	a	21.5	24	BF ₃ ·H ₂ O(1:1) stirring	No signif- icant change
2 Reacted (BF ₃ ·H ₂ O/isoprop.) Soluble + insoluble	Room temperature	76.21	6.85	1.29	1.57	0.87	3.47	3.11	6.63	--	24	BF ₃ ·H ₂ O(1:1) isoprop. 20% vol, stirring	~ 22%
As above Soluble	Room temperature	a	a	a	a	a	a	a	a	38.4	24	"	

^a Analytical results not yet available.

Table 2.5. Reaction of North Dakota lignite

Type of coal and manner of treatment	Temperature of run	Elemental analysis of sample (%)								Solubility in pyridine (%)	Run time (hr)	Solvent reactants run conditions	Percent increase in mass on run
		carbon	hydrogen	nitrogen	sulfur	boron	fluorine	ash	oxygen				
North Dakota lignite Unreacted Soluble + insoluble	NA	64.21	4.86	0.90	0.87	0.011	0.039	8.48	20.73	--	NA	NA	NA
As above Soluble	NA	a	a	a	a	a	a	a	a	6.8	NA	NA	NA
1 Reacted ($\text{BF}_3 \cdot \text{H}_2\text{O}$) Soluble + insoluble	Room temperature	67.96	5.16	0.91	0.78	0.16	0.88	1.52	22.63	--	24	$\text{BF}_3 \cdot \text{H}_2\text{O}$ (1:1) stirring	No significant increase
As above Soluble	Room temperature	a	a	a	a	a	a	a	a	8.0	24	"	No significant increase

^a Analytical results not yet available.

Table 2.6. Reaction of Bruceton coal

Type of coal and manner of treatment	Temperature or run	Elemental analysis of sample (%)								Solubility in pyridine (%)	Run time (hr)	Solvent reactants run conditions	Percent increase in mass on run
		carbon	hydrogen	nitrogen	sulfur	boron	fluorine	ash	oxygen				
Bruceton Unreacted Soluble + insoluble	NA	78.66	5.01	1.53	1.15	0.001	0.014	4.44	9.20		NA	NA	NA
As above Soluble	NA	a	a	a	a	a	a	a	a	a	NA	NA	NA
1 Reacted ($3F_3 \cdot H_2O$) Soluble + insoluble	Room temperature	76.70	5.20	1.50	0.96	0.09	2.99	4.35	8.21		24	$BF_3 \cdot H_2O$ (1:1) stirring	No significant increase
Soluble	Room temperature	a	a	a	a	a	a	a	a	a	24	"	No significant increase

^aAnalytical results not yet available.

of a current sensitive preamplifier, a band pass filter, and FET switches operated by a phase locked loop which tracks the chopper reference signal, converts the 1 kHz fluorescence component of the detector photocurrent into a DC output voltage. The prototype circuit performs well as far as noise and stability are concerned and needs only minor modifications to increase its overload capacity.

2.6 Experimental Engineering Support of In Situ Gasification Processes

P. R. Westmoreland, L. S. Dickerson, and C. F. Bertsch

Coal block pyrolysis experimentation continued during May, supporting modeling and field development of in situ (underground) gasification (UCC). Block pyrolysis data are needed for modeling of in situ coal gasification because earlier data described only the pyrolysis of powder samples. By contrast, large blocks formed by roof collapse or seam fracturing may react during in situ gasification; possibly a broad seam cross-section may react. Internal heat and mass transfer resistances are more important, and product yields can change significantly.

In experiments which began at ORNL in 1975, 6-in.-diam (16-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 field in situ gasification experiments by Laramie Energy Research Center (LERC), Lawrence Livermore Laboratory (LLL), and Morgantown Energy Research Center (MERC).

Effects of internal heat and mass transfer resistances have been observed in each coal. High water content and the insulating properties of dry coal combined in low-rank coals (lignite and subbituminous coal), create a sharp steam front and steep temperature gradients at heating rates of 3 C°/min. In the low-rank coals, steam-char gasification reactions were observed as steam diffused from the center through the hot char surface. Although water content was low in the bituminous coal, thermal conductivity was low enough to create steep temperature gradients within the block at higher heating rates. These gradients reduced swelling because plasticity of the coal became nonuniform. Because oil and tar yields were decreased with increased external heating rate while water and gas yields increased, steepness of the gradients and mass flow resistance are hypothesized to have caused secondary cracking reactions of the oils and tars.

2.6.1 Recent experiments and data

During May, a series of block pyrolysis experiments using lignite in H_2 was completed. With experiments BP2-48, BP2-49, and BP2-50, lignite hydrolysis was tested for blocks heated to 800°C at 0.3, 3, and 9 C°/min and for blocks heated at 3 C°/min to 600°, 800°, and 1000°C. Experimental conditions for individual experiments are summarized in Table 2.7, and gas evolution data for the past three experiments are listed in Tables 2.8-2.10. Table 2.11 lists proximate and ultimate analyses of the lignite used in this series.

Resolution of temperature measurements has been greatly improved by computer monitoring compared to recorders. Because of this improvement, more precise analysis of thermal behavior is possible. As temperature data from BP2-50 have shown, such resolution helps greatly in measuring the small temperature gradients present within the wet core of the coal.

2.6.2 Product yields from lignite in H_2

In powder pyrolysis, tars and C_2^+ hydrocarbons are typically evolved in a "primary devolatilization" between 350-550°C; H_2 and CH_4 continue to be evolved in "secondary degasification" as temperature increases. Thus, as temperature increases, evolution of condensibles (H_2O and organics) would be completed near 600°C, char yield would continue to decrease, and gas yield would continue to increase. Increased heating rates slightly decrease the yield of volatile matter from powder at a given temperature.³

Preliminary yield data are presented in Table 2.12, which describes product yields from block pyrolysis of lignite in H_2 . As for subbituminous and bituminous coals, the effects of heat and mass transfer resistances are apparent. Yield of condensibles drops sharply both with increased block temperature and with increased heating rate. Based on temperature profiles and analogy to earlier results with subbituminous coal, this drop and the accompanying rise in gas yield likely result from self-gasification of the block surface by coal moisture. At higher heating rates, steep temperature gradients are set up between the wet core and the hot outside layer of char, favoring steam gasification. This effect would be superimposed on the yield structure from pyrolysis reactions. In addition, block pyrolysis data from bituminous coal suggests that secondary cracking of oils and tars may occur in the hot outer layer. Coke deposition from such reactions may account for the slight rise in char yield with increased heating rate.

2.6.3 Yields of water and condensible organics from bituminous coal

Yields of condensibles from experiments with bituminous coal have been resolved into yields of water and of condensible organic compounds (oils and tars). These liquids were collected primarily in the water-cooled condenser, normally forming aqueous and organic phases. After

Table 2.7. Summary of experimental conditions for pyrolysis experiments
using a hydrogen purge gas and lignite blocks

Run number	Date of run	Heating rate (C°/min)	Maximum temperature (°C)	H ₂ cover gas flow rate (Std. liter/min)	Coal block ^a			
					Dimensions (cm)		Weight	
					Height	Diameter	(kg)	(kg maf)
BP2-46	3/31/78	3	800	2.87	15.9	13.5	3.609	1.957
BP2-47	4/12/78	3	1000	2.90	17.5	15.1	3.921	2.126
BP2-48	5/4/78	3	600	2.828	15.8	14.9	3.743	2.030
BP2-49	5/15/78	0.3	800	2.993	19.4	15.1	4.319	2.342
BP2-50	5/26/78	9	800	2.775	13.4	14.6	3.927	2.129

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

Table 2.9. Summary of gas data from experiment BP2-49 (lignite block pyrolysis to 800°C at 0.3 C°/min, H₂ purge gas)

	Total	H ₂	CH ₄	C ₂ 's	C ₃ 's	CO	CO ₂	H ₂ S
Gas in - H ₂ cover gas (std liters)	7902							
Gas out (std liters)	8252							
Net gas from experiment								
Volumetric (std liters)	347.5 ^a	-197.4	319.56	21.21	5.78	98.97	96.21	2.70
Normalized (std liter/kg)	148.4	-84.29	136.45	9.06	2.47	42.26	41.08	1.15
Mass (g)	566.9	-17.76	228.73	28.02	11.20	123.70	188.94	4.10
Normalized (g/kg maf)	242.1	-7.58	97.66	11.96	4.78	52.82	80.67	1.75
Average gas composition (vol %)								
(H ₂ , Ar-free vol %)			91.97	6.10	1.66	28.48	27.69	0.78
Elemental composition of gas (g, net)								
Carbon	254.83							
Hydrogen	135.72							
Sulfur	3.86							
Oxygen	208.04							
Net heat of combustion (HHV in Btu)	12791							
Gas efficiency (Btu in product gas <u>vs</u> Btu in coal and in consumed H ₂)	18.6%							

^aSum of component volumes; difference of gas out less gas in is 350 std liters.

Table 2.8. Summary of preliminary gas evolution data from experiment BP2-48
(block pyrolysis of lignite to 600°C at 3 C°/min, H₂ purge gas)

	Total	H ₂	CH ₄	C ₂ 's	C ₃ 's	CO	CO ₂	H ₂ S
Gas evolution								
Volumetric (std liters)	649.68	191.31	173.71	20.97	5.13	111.99	143.89	2.69
Normalized (g/kg maf)	302.04	94.24	85.57	10.33	2.53	55.17	70.88	1.33
Mass (g)	605.82	17.21	124.33	27.71	9.93	139.98	282.58	4.09
Normalized (g/kg maf)	298.43	8.48	61.25	13.65	4.89	68.96	139.20	2.02
Average composition of evolved gas (vol %)	--	29.45	26.74	3.23	0.79	17.24	22.15	0.41
Elemental composition (g)								
Carbon	260.94							
Hydrogen	57.85							
Sulfur	3.85							
Oxygen	285.42							
Gas higher heating value (MJ)	13.72							
(Btu)	13000							
(Btu/scf)	556.7							
Gas efficiency (Btu in gas/Btu in coal)	22.7%							

Table 2.10. Summary of preliminary gas evolution data from experiment BP2-50
(block pyrolysis of lignite to 800°C at 9 C°/min, H₂ purge gas)

	Total	H ₂	CH ₄	C ₂ 's	C ₃ 's	CO	CO ₂	H ₂ S
Gas evolution								
Volumetric (std. liters)	1052.2	442.4	170.48	25.43	4.72	227.09	178.87	3.21
Normalized (std. l/kg maf coal)	494.1	207.8	80.06	11.94	2.22	106.65	84.00	1.51
Mass (g)	844.6	39.80	122.02	33.59	9.15	283.84	351.28	4.88
Normalized (g/kg maf)	396.7	18.69	57.30	15.77	4.30	133.30	164.97	2.29
Average composition of evolved gas (Vol %)	--	42.04	16.20	2.42	0.45	21.58	17.00	0.30
Elemental composition (g)								
Carbon	343.3							
Hydrogen	83.0							
Sulfur	0.29							
Oxygen	835.1							
Gas higher heating value (MJ)	18.53							
(Btu)	17560							
(Btu/scf)	450.5							
Gas efficiency (Btu in gas/Btu in coal)	29.2%							

Table 2.11. Analyses on Sandow lignite

	ORNL (3 samples)		Edgar et al. ^a (64 samples)		Gomex et al. ^b (sample dried at 149°C)
	Mean	Std. dev.	Mean	Std. dev.	
Proximate analysis					
Moisture (%)	36.95	0.53	35.0	2.9	--
Ash (% moisture-free)	14.0	2.2			16.5
Volatile matter (% maf)	54.7	2.2			52.1
Ultimate analysis (% maf)					
Carbon	73.40	0.40			73.8
Hydrogen	6.15	0.28			5.5
Nitrogen	1.383	0.012			1.5
Sulfur	1.87	0.37			2.4
Oxygen (difference)	17.2	--			16.8
Heating value (Btu/lb maf)	12820	270			12930

^aT. F. Edgar et al., "In Situ Conversion of Texas Lignite to Synthetic Fuels," Semiannual Report to National Science Foundation RANN Division, January 1977.

^bM. Gomez, J. B. Gayle, and A. R. Taylor, Jr., "Heat Content and Specific Heat of Coals and Related Products," Bureau of Mines RI-6077, 1965.

Table 2.12. Preliminary yield data from block pyrolysis of lignite in H₂

Experiment	Reactor heating rate (C°/min)	Maximum block temperature (°C)	Weight of products (g)			Product yield (g/kg maf)		
			Char	Condensibles	Gas	Char	Condensibles	Gas
BP2-49	0.3	800	1539	1997	566.9	657	853	242
BP2-48	3	600	1407	1610	605.8	693	793	298
BP2-46	3	800	1402	1353	862.2	716	691	441
BP2-47	3	1000	1380	1466	924.9	649	690	435
BP2-50	9	800	1620	1308	844.6	761	614	397

decantation, total carbon in the aqueous phase was measured, and water content of the organic phase was measured by azeotropic distillation with benzene.

These yields are summarized and compared in Tables 2.13 and 2.14. Heating rate affects the yields most strongly, although effects of sweep gas composition and of maximum temperature are also apparent.

- Water yields increase and organic yields decrease with heating rate of the bituminous coal blocks for a given sweep gas and maximum temperature. Such an increase is consistent with the mechanism of secondary cracking described earlier in which organic vapors produced by pyrolysis can themselves pyrolyze as they diffuse outward through the hotter block surface. Secondary cracking would be favored when an appreciable temperature gradient exists between the moving zone of primary pyrolysis (350-550°C) and the surface, i.e., at higher heating rates.
- Water yield was not significantly affected by difference in sweep gas composition (inert gas vs H₂), but H₂ seemed to decrease yield of oils and tars slightly. The latter effect was most pronounced in 600°C (maximum) experiments.
- Maximum block temperature had little effect on yield of condensibles in 800°, 900°, or 1000°C experiments. Since primary pyrolysis reactions (source of most condensible products) are complete at temperatures near 600°C, it is plausible that for a given sweep gas composition and heating rate (or temperature gradient), yield of condensibles would not be much affected by higher surface temperatures.

2.6.4 Work forecast

Lignite experiments in an inert sweep gas (Ar) will begin in June as evaluation of previous experiments continues. An abstract on "Effects of Internal Heat and Mass Transfer Resistances on Pyrolysis of Bituminous Coal" has been accepted for presentation at the Fourth Annual Underground Coal Conversion Symposium (July 17-20, 1978), and the paper will be prepared during June.

2.7 References for Section 2

1. L. A. Harris, C. R. Kennedy, and C. S. Yust, "A Study of Solids Formed in a Solvent Refined Coal Pilot Plant," submitted to Fuel.

Table 2.13. Yield of water from block pyrolysis of bituminous coal (g H₂O/kg maf coal)

Maximum temperature (°C)	Purge gas	Reactor heating rate (C°/min)		
		0.3	3	14
600	Ar	28.3	53.1	--
	H ₂	27.9	75.5	--
800	Ar	33.8	66.0	--
	H ₂	53.3	62.9	--
900	Ar	--	--	--
	H ₂	31.1	53.4	62.3
1000	Ar	41.5 ^a	68.5	--
	H ₂	50.5	58.5	--

^a Does not include BP2-23, in which block was predried in Ar.

Table 2.14. Yield of condensible organics from block pyrolysis of bituminous coal (g/kg maf coal)

Maximum temperature (°C)	Purge gas	Reactor heating rate (C°/min)		
		0.3	3	14
600	Ar	158.8	107.4	--
	H ₂	126.5	76.7	--
800	Ar	126.6	90.1	--
	H ₂	121.2	69.2	--
900	Ar	--	--	--
	H ₂	144.1	87.9	68.5
1000	Ar	133.3	86.7	--
	H ₂	123.1	88.8	--

2. L. A. Harris and C. S. Yust, "SEM and EMA Studies of a Solvent Refined Coal Pilot Plant Carbonaceous Plug," submitted to Scanning Electron Microscopy.
3. D. W. Van Krevelen, Coal, Amsterdam: Elsevier Publishing Co., 1961.

3. MATERIALS TECHNOLOGY

R. T. King

The Metals and Ceramics Division is conducting fossil energy technology programs directly supported by the Division of Coal Conversion, Plant Initial Operations/Materials and Components, of DOE and is performing research on related assignments in support of selected programs assigned to other functional divisions at ORNL.

Summary

Work was performed to determine the fracture toughness and tensile properties of thick sections of several steels that are candidates for use in advanced coal conversion systems. All heat treatment for as-quenched, quenched and tempered, and quenched, tempered, and stress relieved samples of 2 1/4 Cr-1 Mo steel is complete and some aging is in progress. Impact testing of material that was slow-cooled (0.3K/sec) from 1038°C and subsequently heat treated has been completed.

The program for developing nondestructive testing methods for wear and process-resistant coatings is now centered on CoCrAlY coatings. After debugging our computer system, we computed the necessary base for comparison of predicted coil response during thickness measurements with experimental eddy current measurements. The first CoCrAlY tensile specimen was successfully cracked to provide a standard for the work.

Recent work has shown that the nickel content of Type 320 Cb cladding is a major factor influencing cracking of deposits made at high deposition rates. Because surface conditions may also affect cracking, the gas metal-arc welding apparatus has been equipped with a trailing gas shield to reduce oxidation. Work to determine whether satisfactory deposits can be made over a wider range of candidate commercial welding parameters with this shield is in progress.

Experimental evaluation of heat exchanger tubes exposed in the FluidDyne atmospheric fluidized bed combustor is continuing. Tubes that were exposed for the first 500 hrs of a 3000 hr test period are now being prepared for metallographic examination.

Failure analysis activities continue to include involvement with the Wilsonville Solvent Refined Coal Plant. We are assisting the plant in developing nondestructive inspection methods for the centrifugally cast dissolver tank. A set of fifty-two corrosion coupons is undergoing metallographic examination, and the set will be made available this summer for a second round of examinations. The Solvent Refined Coal Plant at Tacoma has confirmed that a set of corrosion coupons is being sent to ORNL by way of Gulf Research in Pittsburgh, Pa. The final report on the Type 310 stainless steel air distribution plate from the Rivesville, West

Virginia atmospheric fluidized bed combustor is being prepared for publication.

3.1 Pressure Vessel and Piping Materials

D. A. Canonico and W. J. Stelzman

All of the 2 1/4 Cr-1 Mo specimen bar heat treatments (quenched; quenched and tempered; and quenched, tempered, and stress relieved) have been completed and the 1000 hr at 343°C (650°F) aging has begun. The finished bars are being machined into standard Charpy bars which will be used for either Charpy testing or precracked for static fracture toughness evaluation.

We have completed the Charpy impact testing of the specimens slow cooled (0.3K/sec) from 1038°C (1900°F). The specimens were investigated in the quenched; quenched and tempered; and quenched, tempered and stress relieved conditions. We have also completed Charpy impact testing of specimens slow cooled (0.3K/sec) from 972°C (1700°F) in the quenched only condition. Tensile specimens of material heat treatments corresponding to the aforementioned Charpy tests are ready for testing.

3.2 Inspection Techniques for Wear- and Process-Resistant Coatings

R. W. McClung and G. W. Scott

3.2.1 Eddy Current Testing (G. W. Scott)

Our laboratory computer was reloaded with a revised operating system and compiler. When certain programs were run, including our through-transmission instrument simulator, we found that an integer-to-floating point converter had been removed from the compiler, so that the programs computed incorrect answers. This problem was corrected by minor changes to the affected programs.

We fabricated a pair of well-matched (1.02-mm) radius coils to run the corrected through-transmission simulation for these coils, which will then be used for measurements. We developed a full set of tabulated predictions for comparison with experimental measurements, which covers the following ranges:

- 1) coating thickness, 4 steps, 0.005-0.025 in.
- 2) coating resistivity, 4 steps, 100-400 $\mu \Omega$ -cm.
- 3) coating permeability, 8 steps, 1-60.
- 4) operating frequency, 7 steps, 10-500 kHz.

With this body of tabulated data for interpolation, we expect to be able to determine the unknown resistivity and permeability of the coatings from measurements made with a single-channel modular instrument with selectable frequencies. Measurements will be made at the same frequencies used in the simulation computations.

3.2.2 Surface Inspection Materials (S. D. Snyder)

A tensile-crack specimen, no. 23, with a 0.5 mm (0.020 in.) thick plasma-sprayed CoCrAlY coating on an alloy 800 substrate was cracked under tensile stress at a 16KN (3550 lb) load. One major crack, large enough to be seen visually without magnification, developed across the full width of the specimen throat. The radiograph of this cracked specimen also revealed several smaller cracks. Testing with surface inspection materials is in progress.

3.3 Fossil Energy Welding and Cladding Development Program

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

During this reporting period we have emphasized gas metal-arc (GMA) cladding of 2 1/4 Cr-1 Mo steel with Type 320-Cb stainless steel. A special trailing gas shield has been fabricated and attached to our GMA equipment to decrease oxidation of the clad surface. This shielding device provides an inert atmosphere over a larger area of the surface, thus protecting the solidified clad from the atmosphere until it reaches a lower temperature. This has allowed us to increase the oscillation width of these deposits to 5 cm. The wider oscillations allow flatter bead contours and slightly higher deposition rates. These clads are being made with an intermediate layer of Inconel 82. Appropriate preheat and post weld heat treatments are being performed on these clads. In the trial welds made to date, the use of the trailing shield with the GMA clads has significantly reduced oxidation on the surface of both the Inconel 82 and the Type 320-Cb stainless steel, by visual observations. A series of welds being made now will be analyzed to determine whether crack-free deposits can be made over a wider range of candidate commercial welding parameters than without the shield.

3.4 Fireside Corrosion of Atmospheric-Fluidized Bed-Combustor Tubes

T. G. Godfrey and J. H. DeVan

The first 500-hr portion of the 3000-hr test of heat-exchanger tubing in the AFBC at Fluidyne was concluded on May 23, 1978. During the test, three extended coal-feed interruptions caused a total of 18-1/2 hours of delays and required use of the propane torch bed lightoff procedure to re-establish the test conditions. There were numerous other feed plugs that were cleared quickly enough that the test did not go off-condition. The cause of this problem was traced to a deteriorating rotary airlock valve which leaked an excessive amount of the transport air that is injected below the valve. A new airlock has been installed and it should result in more reliable operation.

Test conditions for this 500-hr segment were essentially the same as for the previous 1500-hr experiment (3 - 3.5% excess oxygen, 300-400 ppm SO₂, 1635 ± 2°F [890 ± 1°C] bed temperature, 2.3 ft/s [0.70 m/s] fluidizing

velocity) except for the slightly higher coal feed rate (52-56 lb/hr) required because of the increase in heat extraction by the four new low-temperature composite tubes. Other than for the coal plugs, the 500-hr test proceeded without incident and all target parameters were met. Preliminary data indicate that the high-temperature tubes operated within the same thermal envelope (T max ~1625°F, 885°C) obtained in the earlier test. Three of the low-temperature tubes were in good thermal agreement with the 2 1/4 Cr-1 Mo maximum at 925-930°F (498-500°C) and the Type 304 stainless steel at 990°F (530°C). The fourth tube (8-B), however, was about 70°F (39°C) hotter, for unknown reasons.

The following tubes were removed from the FBC for detailed examination and the new replacements were installed:

<u>Position</u>	<u>Type</u>	<u>Material</u>	<u>Time, hr</u>	<u>Replaced With</u>
2-C	Hi T	I800	1500	304 SS
8-C	Hi T	361 SS	500	316 SS
3-A	Lo T	2 1/4 Cr-1 Mo/304 SS	500	2 1/4 Cr-1 Mo/304 SS
8-B	LoT	2 1/4 Cr-1 Mo/304 SS	500	2 1/4 Cr-1 Mo/304 SS

On-the-spot examination of these tubes revealed no unusual features. The high-temperature tubes were partially covered with semi-adherent sulfate scale ranging in color from red to olive with a tightly adhering corrosion product beneath the scale that looks like metallic oxides we have observed before. The low temperature composite tubes were a uniform dull black, almost featureless. Metallographic preparation has begun.

The next segment (1000 hr) of the 3000-hr test is scheduled to begin the second week of June after installation of some new instrumentation.

3.5 Failure Analysis

R. T. King

3.5.1 Inspection Assistance to SRC, Wilsonville, Alabama (G. W. Scott)

We received the 0.5 and 1.0 MHz ultrasonic transducers required to inspect the casting material calibration blocks prepared for SRC. We have run our characterization (quality assurance) checks on the transducers. We expect to check the calibration blocks early in June.

3.5.2 Examination of Type 310 Stainless Steel Air Distributor Plates
From 30 MW Rivesville, West Virginia Atmospheric Fluidized Bed
Combustor

A final report covering the subject is in final edited draft form, and will be in press shortly. The results indicate that thermally induced stresses in the plate caused buckling, probably under cyclic conditions. The fracture mode was intergranular, and the observed low ductility may have resulted from the formation of sigma phase at grain boundaries.

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 Objective

Design, construction, and testing of a full-scale potassium boiler tube bundle and burner module using water first and then potassium to determine the performance and operating characteristics.

4.1.2. Plans for Next Month

Modifications will be completed and endurance testing will be resumed.

4.1.3. Technical Progress

The installation of the wire mesh filter in the fill-and-drain line was completed, and the boiler was refilled with potassium. Operational testing was resumed at a burner power of 1.2×10^6 Btu/hr and continued to a power of 2.4×10^6 Btu/hr.

Prior to startup, a cross connection had been made between the argon separator vent and the fill-and-drain line. This allowed argon from the condenser to be vented from the system through the fill-and-drain tank. This method of venting provided an extended surface (i.e., the fill-and-drain line) upon which the residual potassium in the argon could deposit and adequate volume (i.e., the fill-and-drain tank) to contain the potassium carryover. The residual potassium in the drain tank provided the same function as the potassium bubbler previously installed in the condenser vent line.

During the startup operation, the pressure control valve on the drain tank was set to maintain about 3 psig in the drain tank. The pressure control valve in the condenser vent line was set to open at 16 psig to provide additional venting capacity, if needed.

Initial operation at 1.2×10^6 Btu/hr was normal, and the new method of venting operated well. However, there was a marked tendency for the system (boiler-condenser) pressure to exceed the set pressure in the drain tank during those periods when large amounts of argon were being expelled from the system; i.e., initial system boiling and subsequent increases in power level. When the venting rate diminished, the measured pressure difference between the boiler/condenser and the drain tank decreased.

After about two hours of operation at 1.2×10^6 Btu/hr, the burner power was increased to 1.8×10^6 Btu/hr and 10 minutes later to 2.4×10^6 Btu/hr. The system pressure rose quickly, and when it reached 16 psig, the condenser vent valve opened.

A significant quantity of potassium had been deposited in the condenser vent line immediately behind the vent valve and was expelled from the system when the valve opened.

The system was shut down, and the boiler was pressurized to return the potassium to the fill-and-drain tank. After about 15 or 20 lbs had been returned to the tank, the flow ceased, and it was necessary to heat the wire mesh filter, in parallel with the fill-and-drain valves, to complete the transfer. Subsequent efforts to flow through the fill-and-drain valves were futile. In an attempt to determine the cause of the plug, the filter was removed from the system, cleaned with ammonia, and flushed with water. A particle, similar in appearance to those found previously but much larger (~ 0.250 in. long), was found in the catch basin. Numerous other small particles were also found. The filter was cut open for further examination, but nothing else was found.

A filter bypass trap was designed, fabricated, and installed in parallel with the wire mesh filter and the plugged valves. In the future, the system will be filled by passing the potassium through the filter and drained through the bypass trap. Selective heating and cooling of one or the other will serve to make these components act much as a freeze valve.

Operation of the argon vent system appears to require considerable subcooling in the condenser to avoid excessive potassium carryover. This in turn, aggravates the thermal stress problem at the intersection of the condensate return line and the boiler vapor exit line. Therefore, a decision was made to install auxiliary heaters on the condensate return line between the argon separator and the mixing tee outlet. By reheating the condensate return flow, it will be possible to obtain more subcooling in the condenser without exceeding the allowable thermal stresses.

The necessary additional power supplies and control circuits have been designed, fabricated, and connected. The heaters and thermocouples are currently being installed.

During this shutdown period, all of the valves in the heated valve box were disassembled, lubricated with high-temperature lubricant, and reassembled.

The insulation applied to the lower portion of the condenser (as mentioned in last month's report) appears to have been effective in making the outlet temperature of both banks of condenser tubes more nearly the same.

5. COAL EQUIPMENT TEST PROGRAM

J. M. Holmes and R. E. MacPherson

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

- Critical Equipment for Demo Plants
- Coal Feeder Test Program
- Survey of Industrial Capability for Coal Handling Equipment
- Program Plans for Coal Equipment Testing

5.1 Critical Equipment for Demo Plants

Negotiations have been completed with the Illinois Coal Gasification Group (ICGG) and their subcontractors concerning non-disclosure agreements for use by TRW in their CETP study. Individual agreements have been signed by ORNL personnel, and transmittal of the ICGG information is being requested. Negotiations between two of the Memphis Light, Gas and Water Division (MLGW) subcontractors have been completed, and two more must be completed before the information can be released.

Work continued at TRW towards completing their Critical Components Test and Evaluation Program. Activities during the month included:

- Pilot-Sized Test Loop Facilities have been identified as follows:
 - (1) Hot Dirty Gas - Energy Technology Engineering Center (formerly Liquid Metal Engineering Center), operated by Atomics International for DOE. Their Thermal Shock Test Facility can be modified to provide the needed test loop. They are currently performing some engineering and cost estimating and have committed to provide us a letter proposal in early June.
 - (2) Char Circulation - General Atomics can modify current test facilities owned by DOE to provide this test loop. They are currently performing some engineering and cost estimating and have committed to provide us a letter proposal in early June.
 - (3) High Pressure and Low Pressure Slurry - The CRESAP Liquefaction Test Facility appears to have the correct conditions for fulfilling the needs of the two demonstration plants under consideration.
- The first draft of the final report is completed, except for Section 6, Site Selection and Appendix B, Site Information Base. All other sections are in typing or graphics.

5.2 Coal Feeder Test Program

B. T. Thompson

Work this month focused on preparation of the feasibility study (Task 1.0) for a 5-ton per hour capacity coal feeder test facility using one or more of the feeders being developed by DOE contractors. Various alternatives will be considered in the feasibility study and cost information will be provided. A preliminary test loop flow sheet has been completed on the linear pocket feeder; Foster-Miller will provide comments on the proposed flow sheet. Flow sheets are to be prepared on at least one of the other more promising feeder concepts, such as the Foster-Miller centrifugal feeder or the Ingersoll-Rand unheated screw extruder feeder.

5.3 Survey of Industrial Capability for Coal Handling Equipment

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

Meetings were held with representatives of Bechtel Corporation to review their coal mine-coal conversion plant interface evaluation and conceptual design report; preliminary criteria were also discussed for preparation of flow sheets of conceptual designs for coal handling-preparation and ash/slag removal systems in future commercial coal conversion plants. The preliminary flow sheet criteria were revised based on the Bechtel discussions and the recent DOE emphasis on coal liquefaction technology.

A listing of coal handling and preparation equipment, including specifications, is being compiled for use in preparing the questionnaires to be forwarded to industrial equipment and A-E firms. Contact was made with the Pennsylvania State University regarding coal information from their PSU-DOE coal data bank.

5.4 Program Plans for Coal Equipment Testing

R. E. MacPherson, J. M. Holmes, and J. E. Jones Jr.

The Coal/Solids Handling and Feed Systems Program Plan, developed by the Jet Propulsion Laboratory with ORNL participation, was presented to DOE management on May 19, 1978. The plan, which provides for the development and testing of coal/solids handling systems at the pilot scale, was approved, but priority status of the recommended program will be required in order to conform to the budget available for FY 1979.

ORNL has been requested to prepare a plan for the surveillance and testing of coal conversion plant components exclusive of those considered in the Coal/Solids Handling and Feed Systems Program Plan. This would include all the components downstream of the coal feeders except for the ash and slag handling devices. To implement this request, an inquiry has been made to TRW for technical assistance in developing the plan.

ORNL personnel would be utilized to manage the effort and provide consulting services on various component problem areas. An advisory committee will be formed consisting of representatives from industry, the National Laboratories, and Energy Research Centers to provide information and advice on the scope and procedures to be used. A preliminary schedule indicates that the effort will require about four months, which will include four advisory group meetings and result in a draft plan for presentation to DOE management.

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

R. S. Holcomb

6.1 Status Summary

The revisions in the request for proposal and combustor specifications that were requested by DOE-FE on May 2 were made. The package was sent to the Purchasing Division for review and preparation of the legal and contractual parts of the procurement document. The Purchasing Division has prepared the legal section, and a draft of the final procurement package was submitted to ORNL for review the last week of May. It is expected that the request for proposal will be ready for issue early in June.

Good progress is being made on the preparation of the specifications for the ash handling system. Ralph Guymon, Chuck Claffey and Bob Delagrange made a visit to the Rivesville AFBC Plant on May 3 to obtain information and recommendations relative to the ash handling system. The information obtained there along with the design recommendations from the ash handling system vendors are being incorporated into the system specifications.

A third vendor that appears to be well qualified in AFBC ash handling systems has been identified. A visit will be made to this firm and it is expected that they will be requested to submit a proposed design.

6.2 Supplemental Studies

The new quantity of limestone for the coal feeding tests has not been received. But it is expected that it will be delivered early next month.

The first 500 hr of the 3000 hr corrosion test was completed on May 23. There were no tube failures or unusual incidents during the test. Several of the tubes in the test array were among the original tubes installed at the beginning of the previous 1500 hr test program and have now been subjected to a total exposure time of 2000 hr.

Two tubes were removed for metallographic examination: an Incoloy 800 tube with 1500 hr exposure and a 316 stainless steel tube with 500 hr exposure. The surface appearance of both tubes was good and apparently no significant corrosion had occurred. The two tubes were replaced with new ones; one of 304 and one of 316 stainless steel. The corrosion test was resumed on June 7.

7. ENGINEERING STUDIES AND TECHNICAL SUPPORT

R. W. Glass

Engineering studies and technical support are provided primarily for the DOE/FE Division of Coal Conversion. 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 revised physical properties package was received from Purdue and has been compiled and linked into the subroutine library. The test cases supplied by Purdue were run with partial success. Two of the examples ran without difficulty and the results agreed with those given by Purdue. The other five examples failed due to execution incompatibilities between the CDC and IBM systems. These are being corrected.

The Purdue material balance program MBP-2 is being compiled. Of the 64 subroutines, 42 have been compiled successfully. Various compilation errors in the others are being corrected.

The Lehigh subroutine INTEG (part of DSS/2) has been split into 15 subroutines for greater convenience. These have all been compiled successfully. The ORNL-mounted DSS/2 program will be tested using the methanator example developed by Lehigh.

A quarterly project meeting was held at Purdue University on May 23. Schedules and plans for completion of the project were discussed. An effort is being made to develop a coordinated plan for conducting training courses for users of the Purdue and Lehigh programs. It was agreed that short courses conducted by Purdue and Lehigh would be desirable if funding can be arranged.

An outline of a capital cost estimation program using Guthrie's factor method was completed and forwarded to Purdue.

7.2 Synthetic Fuels 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

Following receipt of DOE/FE comments on the CSF and SRC-II articles, the articles have been revised and will be forwarded to DOE/FE for final considerations.

Writing of the Fischer-Tropsch article is nearing completion.

Considerations for future issue articles are complete, and our recommendations will be forwarded to DOE/FE for concurrence.

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 Coal Conversion (CC).

7.3.2 Status Summary

Printing of FY 1977 valve (ORNL/TM-6071) and hot gas cleanup (ORNL/TM-6072) survey reports is to be completed on June 8 and 16, respectively, at which time they will be distributed. The report on heat recovery will not go to printing until mid-June after which time 3 weeks will be required for printing.

Preliminary work for the survey of expansion joint, mechanical connector, and let-down valve industries is complete. Survey forms and mailing lists are final and the mailing to industry will be accomplished by June 1. Nineteen expansion joint manufacturers, 460 mechanical connector manufacturers, and 48 let-down valve manufacturers will be surveyed. During May, a visit was made to Zallea Brothers Expansion Joint Company in Wilmington, DE. Also, W. A. Bush presented the FY 1977 valve survey results and FY 1978 activities at the Spring Meeting of the Valve Manufacturers Association in Cincinnati, OH.

Evaluation of market demand for coal conversion equipment is continuing. Projections of the number of new 250×10^9 Btu/day* coal conversion plants required each year between 1985 and 2000, assuming straight-line growth, vary from an average range of 5.2 to 7.7 to a high range of 10.9 to 14.9. By way of comparison, the equivalent of 9.6 new refineries per year of 250×10^9 Btu/day capacity were completed during the period 1960-1976. In 1971, 26.1 equivalent refineries were completed. Equipment demand will be determined in early June.

Letters to producers concerning equipment price (compressors and expanders) and development costs (expanders) are being prepared for mailing. Letters concerning pump prices are in draft form. Responses

* Assumed equivalent to one 250×10^6 scfd gasification plant or one 40,000 BPD liquefaction plant.

to a request for budgetary pricing of heat transfer equipment considered last year were received from three vendors.

Synthane and Conoco trip reports have been completed. The BIGAS report is being reviewed.

IGT facilities in Chicago, IL (HYGAS and Steam-Iron pilot plants) were visited May 9 and 10. This trip report is now being prepared; some overview comments follow.

1. Pumps. Erosion continues to be a problem in slurry pumps, even when slurry concentrations are approximately 1%, as in a quench water recirculating pump operating with a tip speed of 126 fps. Wilson-Snyder reciprocating pumps are used for pressurizing a 35% char-BTX slurry. Ball valve life in pump check valves is 400 hrs on bituminous and 2500 on lignite and subbituminous coals. Packing and plunger life are coincidental at 1000 to 1500 hrs.

2. Expanders. C. F. Braun and Bechtel have proposed a power recovery train for the Steam-Iron commercial plant design which includes untested expanders. These expanders will face particulate-laden streams of 1100°F (high pressure expander) and 2000°F (low pressure expander). We plan to discuss this system with Braun and Bechtel.

3. Expansion Joints. Pilot plant experience has been very good with external dynamic balance pressure expansion joints. Bellows or packing gland type joints will be used in a commercial plant where expansion joints are inside pressure vessels.

4. Mechanical Connectors. Grayloc connectors are preferred for connections which must be broken repeatedly. Both Grayloc connectors and ring joint flanges have been used with no major problems, even for the most severe services.

5. Heat Recovery. Heat recovery is not attempted in the pilot plants; instead, hot effluent streams are quenched. Commercial facilities will incorporate heat recovery. Difficulties have resulted from dirty cooling water (taken from a nearby canal) and excessive solids concentrations. Refractory linings have been a problem, partly because of unusual installation procedures required by the small size piping in the plant; this left some refractory material in tension.

Richard Field of the Inspector General's Office of DOE requested prices of multiple unit, state-of-the-art slurry pump systems versus a single unit, "advanced" design pump. Preliminary information is being obtained and forwarded to Field. More detailed information is forthcoming in July as a part of this survey.

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 draft final report titled Scoping Study on Two Flash Hydro-pyrolysis Processes (ORNL/TM-6265) has been typed on photomasters and should be ready for publication shortly.

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.

In this work, a survey of the available and developmental processes for the removal at high temperature of various contaminant materials (particulate, sulfur, nitrogen, and alkali metal compounds) has been conducted. Based on the data obtained in this work, from a variety of sources, an analysis has been performed to evaluate the performance of a number of potential cleanup processes in light of the overall system needs.

7.5.2 Status Summary

The final report, ORNL/TM-6178, A Survey of Processes for High Temperature - High Pressure Gas Purification, which includes a review of the available systems for the removal of particulates and sulfur and nitrogen compounds to levels compatible with high temperature - high pressure turbine operation has been revised to address final comments. The report is now in publication.

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

W. R. Gambill and W. R. Reed

The objective of this review has been to survey, appraise, and catalog the processes for heat recovery which industry offers or plans to offer or may logically be expected to offer. These processes are applicable to the recovery of heat in process streams from primary exothermic coal conversion and combustion process steps. Simple unaugmented application of conventional heat transfer equipment are not included. The review distinguishes between presently installable technology, near term developable technology, and future prospects. Consideration is given to possible transfer of technology from other industries. The final report for this work, State-of-the-Art Review of Heat Recovery Processes, ORNL/TM-6222 is now in publication and will be issued soon.

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

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

The objective is to assess the feasibility of a proposed moving bed system for removal of sulfur and particulates from raw gasifier gas. The assessment considers two basic hot gas treatment systems, with each system specifically addressing sulfur and particulate removal. The reference system incorporates a panel filter for dust removal and fixed bed adsorber/regenerator units. The project system incorporates a moving bed filter/adsorber unit, with fluid bed regeneration of the recycled filter/adsorber media. Both systems produce high pressure steam (waste heat boiler) from the regeneration off-gases. The assessment includes simple equipment flowsheets and material balances for both systems, and comparative economics are developed. Final typing and review of the study report has been concluded and the draft forwarded to editing and publication.

* Consultant.

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 draft report was completed and reviewed by the DOE Project Manager. Comments are being considered and discussion on revisions to the report are in progress.

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

J. F. Fisher and C. 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.

* Consultant.

7.9.2 Status Summary

Processes examined for decontaminating the tail gases included recovery and recycle methods as well as those that convert the contaminants to harmless products. The most recent proposed EPA emission standards for carbon monoxide and nonmethane hydrocarbons were used as upper limits for the residual contaminants in the treated effluent. Limited assessments of the technical and economic feasibility of ten processes were made. Of the processes studied, the two most promising were found to be incineration in a coal-fired boiler and catalytic incineration. Neither of these methods has been employed commercially under the projected operating conditions, although both are employed in other industries to carry out the basic reactions involved. Total capital and operating costs on a 20-year discounted cash flow basis with 100% equity financing and 12% annual after-tax return on investment were estimated to be 4¢/MMBtu of SNG for the coal-fired boiler and 5¢/MMBtu for the catalytic case. However, the uncertainties in the costs are greater than the indicated cost differentials. The cost of incineration in a gas-fired boiler using sulfur-free medium-Btu gas was estimated to be 11¢/MMBtu of SNG. All other routes examined were several times more expensive than this.

The final draft report titled Control of Hydrocarbon and Carbon Monoxide Emissions in the Tail Gases from Coal Gasification Facilities (ORNL/TM-6229) is being revised as requested by F. E. Witmer of DOE. Technical editing of the report is in progress.

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

Consistent with Tasks 6 and 7 objectives, draft write-ups on the technical characteristics of the 25 selected environmental control processes have been completed and are being internally reviewed. Draft write-ups on the capital and operating costs of the above-mentioned 25 processes are at various stages of development. These are expected to be completed shortly.

Since no established sequence of processes exists for the treatment of the anticipated water effluent from the coal gasifiers, educated guesses have been made to arrive at the contaminant concentrations, responses to particular treatment processes, and the attendant waste water treatment costs.

Written approval to proceed with Phase II of the study was received from DOE/FE-DET on May 5, 1978.

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

A Generic Design Checklist, made up of a number of diverse checklists, primarily aimed at in-house reviewers, has been distributed internally to appropriate personnel. These checklists are intended to be the means to generate more specific checklists by process area or equipment and serve to jog the memory of a reviewer confronted with the task of evaluating a provided document. The checklists distributed comprise procedural review emphasis, design discipline Q.A. emphasis, and functional emphasis (start-up, operability, environmental, safety reliability, maintainability).

Work continues on developing specific design checklists strictly applicable to the specific process areas of coal conversion plants.

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, D. E. Reagan, 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

Work was completed on the second draft of the report entitled "Low Btu Coal Gasification Processes." Volume 2, "Selected Process Descriptions," was prepared for reproduction; distribution to Department of Energy and ORNL reviewers will follow. This second volume provides a detailed description of 21 coal gasification processes. The previously distributed Vol. 1 described the approach and results of selecting processes for detailed study and provided summaries of 58 coal gasification processes. Each process description in Vol. 2 includes a summary plus information on status, description, operating conditions, reactants, utilities, products, efficiency, test results, process considerations, and references. The process descriptions in Vol. 2 included changes in the original draft material that were suggested by reviewers from the U.S. Department of Energy and/or industrial firms responsible for the process. Comments from the reviewers of Vols. 1 and 2 will be used to prepare the report for final publication.

8.2 Direct Combustion

E. C. Fox and T. D. Anderson

8.2.1 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.

8.2.2 Status Summary

The industrial review meeting held in Oak Ridge on May 23 indicated that the draft report was acceptable and should be published as soon as possible. The industrial representatives indicated complete agreement with all of the major conclusions and recommendations. It was also decided that the report should have a summary edition that is much briefer than the main report, but presents all the major results, conclusions, and recommendations. This summary is in the final stages of preparation and will be published before the main report.

8.3 Advanced Power Conversion Systems

J. E. Jones Jr. and A. P. Fraas*

8.3.1 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.

8.3.2 Status Summary

A total of eleven systems or components of systems were evaluated. Draft reports covering all of these topics (see tabulation below), an overall summary report, and an executive summary report have been completed and have received extensive reviews by persons especially knowl-

* Consultant

edgeable of the various technologies involved. Seven reports are now on mats, and the remaining six are undergoing typing, editing, or makeup.

- 1) Summary of the Development of Steam Power Plants for Central Stations
- 2) R&D Experience and Current Status of Development of Open Cycle Gas Turbines
- 3) Summary of the Development of Open Cycle Gas Turbine-Steam Combined Cycles
- 4) Summary of the R&D Effort on Open Cycle Coal-Fired Gas Turbines
- 5) Summary of the R&D Effort on Air and Water Cooling of Gas Turbine Blades
- 6) Summary of the R&D Effort on Ceramic Gas Turbines
- 7) Summary of the R&D Effort on Closed Cycle Gas Turbines
- 8) Summary of the Work on the Supercritical CO₂ Cycle
- 9) Summary of the R&D Effort on Alkali Metal Vapor Cycles
- 10) Summary of the R&D Effort on Open Cycle MHD Systems
- 11) Summary of the R&D Effort on Fuel Cells
- 12) Comparison of Advanced Energy Conversion Systems on the Basis of R&D Experience
- 13) Comparison of Advanced Energy Conversion Systems on the Basis of R&D Experience. Executive Summary Report.

8.4 In Situ Coal Gasification

W. C. Ulrich and M. S. Edwards

8.4.1 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.

8.4.2 Status Summary

Process flowsheets were completed for all major plant units, including proprietary plant sections, of the in situ syngas-to-gasoline facility.

Material and heat balances for the M-gasoline plant were revised to better define equipment duties and specifications. Revisions based on information provided by the Badger Company were also made to the catalyst regeneration system which is included in this plant.

The contract with Davy Powergas for supplying design and cost data for the methanol synthesis plant was finalized. Under the terms of the contract, we transmitted to Davy an initial information package containing gas analyses, temperatures, pressures, and estimated methanol production rate based on our preliminary process flowsheets and material balance calculations.

8.4.3 Open Items

Publication of the FY-77 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.

8.5 Coal Beneficiation

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

8.5.1 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.

8.5.2 Status Summary

Publication of the project final report is pending resolution of comments with DOE/FE.

8.6 Gas Cleanup Studies

M. S. Edwards

8.6.1 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.

8.6.2 Status Summary

The draft report ORNL/TM-6077, Selection of Candidate H₂S-Removal Processes Applied to Low-Btu Coal Gas, was sent to the Department of Energy on October 3, 1977. The report gives detailed process descriptions and cost data for seven methods of removing H₂S from a low-Btu coal-derived gas: MDEA, Benfield, Sclexol, Sulfinol, Stretford, MERC Iron Oxide, and Molecular Sieve. Each of these processes was selected as representing a particular category of gas treating.

Final DOE comments have been resolved and the final draft report has been cleared for technical editing prior to publication.

8.7 HYGAS Modeling

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

8.7.1 Contract Objective

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

8.7.2 Status Summary

During the reporting interval, work on the HYGAS project has focused on the areas of devolatilization, the characterization and thermal cracking behavior of coal derived liquids, model definition and the development of a multiple bed simulation program. In addition, an analysis of the available material balance data for runs 28 through 67 has been completed.

In the area of devolatilization, the models of Suuberg et al¹ for Montana lignite and Reklaitis² for Illinois No. 6 coal have been programmed. The results are presented in Fig. 1 and 2 in terms of the yield of a particular product versus temperature.

Fig. 8.1. Devolatilization products of dry Montana lignite versus temperature

Fig. 8.2. Devolatilization products of dry Illinois #6 versus temperature

Because Illinois No. 6 yields approximately 20% liquid products by weight, it is critical that both the liquid itself and its thermal cracking products be characterized. To a lesser extent, this is true of Montana lignite since its liquid yield accounts for no more than 5% of its total weight. In the case of Illinois No. 6 coal, the empirical formula of the liquid product was computed by using a material balance (ultimate analysis of coal less known weight of carbon, hydrogen, and oxygen (CHO) associated with other devolatilization products) to determine the elemental amounts of CHO associated with it. For the case of Montana lignite, Suuberg et al¹ have indicated that the liquid contains 90% carbon and 10% hydrogen by weight. These known weight ratios were reduced to a molar basis.

In order to account for the cracking products of these coal derived liquids, a rough split based on the work of Hesp and Waters³ has been made. The breakdown of the various thermal cracking products for each coal is presented in Tables 1 and 2.

Table 1. Cracking products of Illinois No. 6 coal derived liquid

Empirical formula:

Product	Yield (lb/lb liquid)
CH ₄	.0815
H ₂	.0065
C ₂ H ₄	.0535
C ₄ H ₆	.0383
CO	.0357
H ₂ O	.0120
C ₇ H ₈	.2000
C	.5723

Table 2. Cracking products of Montana lignite
coal derived liquid

Empirical formula:

Product	Yield (lb/lb liquid)
CH ₄	.1785
H ₂	.0112
C ₂ H ₄	.0934
C ₂ H ₆	.0669
C ₇ H ₈	.2000
C	.4500

An analysis of the IGT fluidized model indicates that it is predicated on the assumption of plug flow with respect to the solids phase and backmix with respect to the gas phase. It is a common practice in the petroleum industry to assume that the opposite case (solids in backmix, gas in plug flow) is a more accurate description of actual fluidized bed behavior. At this time, it is unclear as to exactly why IGT has selected the solids-plug flow and gas-backmix model as an a priori assumption. This is particularly true in light of the fact that the physical construction of the HYGAS pilot plant precludes such a choice simply from a consideration of gravitational forces. It can be inferred from the work of Prycioch et al⁴ that the IGT model may be based on the experimental observation that when both solids and gases are in countercurrent plug flow (moving bed) it is possible to produce 900 Btu/scf gas from partially devolatilized coal.

In order to explore the effects associated with a different fluid mechanical regimes, ORNL is developing two simulation programs. The first of these is simply a direct application of IGT fluidized bed model as indicated in the IGT Data Preparation Handbook and in compliance with our work statement. The second model will be based on the assumption that both the solids and gas will be perfectly backmixed. Our reason for assuming this configuration, rather than the preferred solids-backmix and gas-plug flow model is based on the fact that the algorithms for devolatilization and rapid rate methane formation are not adaptable to such a configuration. Both of the programs will be multiple bed in design.

Work has been completed on the linked two bed model (steam-oxygen gasifier and high temperature reactor) and efforts are now underway to develop multiple bed algorithms for both of the previously described mixing schemes.

8.7.3 Problem Areas

Difficulties in numerical convergence may arise as the multiple bed system is developed. This is particularly true in cases where either a large amount of steam or oxygen is supplied to the gasifier rendering it impossible to satisfy the water gas shift equilibrium condition.

8.8 Liquefaction

R. W. Glass

8.8.1 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.

8.8.2 Status Summary

The information package for the H-Coal process was completed. The package contains, among other items, a block flow diagram with heat and material balance, dissolver elemental balance, high potential process evaluation data, manpower requirements, purchased utilities, water supply and effluent treatment, procedures for environmental control of air effluents, sulfur balance, and catalysts and chemicals cost. The information package for the CSF case was also completed; this contains the same items listed above for the H-Coal case. The description of the H-Coal case, including data sources, constructed cost bases, and process description sections, has been revised.

Fixed capital cost estimates and profitability analyses for the SRC-II, CSF and H-Coal processes are in progress. In addition, a draft of the task report for internal review is being prepared.

8.9 High Btu Gas

R. W. Glass

8.9.1 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.

8.9.2 Status Summary

Phase I of the project is essentially completed. Preparations for transmitting to NTIS the final report "Evaluation of the Battelle Agglomerating Ash Burner High Btu Coal Gasification Process" are in the final days.

Monitoring of the HYGAS Pilot Plant by SD personnel continues. Test Run No. 72 achieved self-sustained operation at 2000 hours on May 20, 1978. On May 22, 1978 problems with the coal handling and pretreatment sections caused a temporary stoppage of the char feed to the gasifier. Current operating conditions are:

Pressure	500 psia
Char feed	2 TPH
Oxygen	700 lbs/hr
Total Steam	5050 lbs/hr
Char Conversion	80%

The overall operation is smooth and except for the cycling of one of the sparger level thermocouples all equipment seems to be operating satisfactorily.

Finally, project work on Phase III is progressing and a draft report is being organized.

8.10 Comparative Cost Estimates of Five Coal Utilization Processes

R. W. Glass

8.10.1 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 entrainment 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.

8.10.2 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.

8.11 References for Section 8

1. E. H. Suuberg, W. A. Peters, and J. B. Howard, "Product Composition and Kinetics of Lignite Pyrolysis," Paper presented at 173rd National Meeting of ACS Division of Fuel Chemistry, Vol. 22, No. 1, March 21-25, 1977, New Orleans, La.
2. G. V. Reklaitis, Purdue University, West Lafayette, Ind., personal communication.
3. W. R. Hesp and P. L. Waters, "Thermal Cracking of Tars and Volatile Matter from Coal Carbonization," Ind Eng Chem Prod Res Develop 9(2), 1970, pp. 194-202.
4. E. J. Prycioch, H. L. Feldkircher, C. L. Tsaros, J. L. Johnson, W. G. Bair, B. S. Lee, F. C. Schora, J. Huebler, and H. R. Linden, Production of Pipeline Gas by Hydrogasification of Coal, Vol. 1, 1954-64, Research Bulletin No. 39, Institute of Gas Technology, Chicago, Ill. (December 1972).

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.

The 34 drums of Cogas Waste have now been received at ORNL and are undergoing analysis to assure consistency with the initial barrel shipped earlier. O. A. Colitti (DOE/FE) has obtained samples of bottom and fly ash resulting from combustion of SRC-I product in a utility boiler. These materials do not represent solid wastes expected from demonstration or commercial SRC-I plants. The latter may be difficult to obtain but we are pursuing several possibilities.

Redesign of smaller lysimeters continues. As currently envisioned, samples of each waste type will be loaded into three, 2 1/2 ft. diameter lysimeters containing three different soil types, representative of various regions of the U. S. Cogas will be the first waste type tested to be followed by Slagging Lurgi, Hygas, SRC-I, and SRC-II when sufficient amounts are obtained. When only small amounts of waste are available it may be necessary to leach the waste and pass portions of the leachate through individual soil columns of close to laboratory size.

9.2 Environmental Monitoring Handbook

S. G. DeCicco

The Handbook was released in final printed form on May 9. This timely completion permitted us to use and distribute it at the kick-off meeting for the Grace/Ebasco demonstration project.

9.3 Technical Assistance

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

Grace/Ebasco Demo Project - On May 12 we hosted a meeting which initiated our involvement in the Grace/Ebasco demonstration project. The following groups were represented: DOE/ORO, W. R. Grace & Co., DOE/Coal Conversion Division, DOE - Chicago Operations Office, Mound Laboratory, Ebasco Services, Inc., Dames & Moore, and the FEEP team.

The agenda for the meeting included a general review of the demo project, an outline of procedures for interaction among parties, a more detailed description of the process and the site, a description of the environmental monitoring program, and the schedule for ER and EIS preparation.

MLGW Demo Project - On May 5 we received a copy of Energy Impact Associates' proposed leaching study of U-Gas waste. We have been asked to comment on this study which seeks to characterize the leachate from the waste and generate data needed for a landfill design.

ICCG Demo Project - On May 12, FEEP representatives were asked to attend a DOE meeting in New York to discuss potential cost overruns associated with the environmental task. The meeting was also attended by representatives of ICCG and Gibbs & Hill. FEEP representatives responded to technical questions on the monitoring program.

CONOCO Demo Project - On May 30, FEEP was asked by DOE to review a contract modification regarding the environmental task. The contract modification was the first formal change in scope since the original (inadequate) environmental work statement. This modification appears to have corrected only a few of the inadequacies.

9.4 Atmospheric Fluidized Bed Combustion Assessment

S. G. DeCicco

This represents a new activity for FEEP and is supported by DOE/Power Systems Division (John Belding). An effort of about 3 PM's will be used to develop an environmental assessment of several AFBC designs being considered for a demonstration plant. A meeting was held on May 24 to discuss progress of the project. The primary emphasis will be on assessing potential effluents - both gaseous and solid.

10. MAGNETIC BENEFICIATION OF DRY PULVERIZED COAL

D. M. Eissenberg and 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

A 4 in-diameter by 40 in-long column has been placed in operation as a fluidized bed to air classify crushed or pulverized coals. Qualitative tests have been performed to remove the agglomerating fines and to separate the coals into various size fractions for magnetic processing. The column elutriates the fines with a fair degree of selectivity, and, as is to be expected, the amount of fines that must be removed for the remainder to process properly is a function of the degree of crushing or pulverizing.

Coal origin	Pulverizing process	% 400 mesh measured by seiving	% Removal required for magnetic processing
Upper Freeport seam	Laboratory hammer mill	25	8-10
Y-12 steam plant	Power plant hammer mill	39	10-12
Bull Run steam plant	Power plant bowl mill	55	35-45

The degree of pulverization of coal is an important parameter to both the combustion and the magnetic processing. While it is not essential that the magnetic processing be performed on coal that is ready for firing, the entire process will be simpler if that is possible. In an informal conversation, Mr. John Harvey of Babcock & Wilcox expressed an industry interest in the magnetic processing of dry pulverized coal as well as the opinion that the industry may now be over-pulverizing. The opportunity to work directly with the boiler manufacturers as well as the boiler-using utilities is now being pursued.

11. ATMOSPHERIC FLUIDIZED BED COMBUSTION DEMONSTRATION PLANT

C. B. Smith and J. E. Jones, Jr.

11.1 Engineering Support

No engineering support activities were performed during May.

11.2 Technology Assessment

M. Siman-Tov, S. G. DeCicco, E. C. Fox,
T. G. Godfrey, R. E. Kuhlmann, and M. E. Lackey

11.2.1 Task objectives

DOE/Fossil Energy has proposed to design and construct a 200 MWe demonstration power plant using an atmospheric fluidized bed combustion (AFBC) process. To insure the success of the proposed project, the data base required must be available in a compatible way with both the scale and the schedule proposed. The objectives of this task were set in order to achieve that purpose and they are as follows:

1. To assess the AFBC technology and determine the existing data base as applicable to the proposed 200 MWe AFBC demonstration plant.
2. To identify the most critical problem areas and R&D needs for the plant.
3. To recommend priorities and schedule for the required R&D activities.

11.2.2 Status summary

During May the task force made progress in the following areas.

1. Completed reviews of the three boiler manufacturers' designs and cost estimates for the demo plant.
2. Completed the parameter analysis matrix and defined major problem areas of the AFBC process.
3. Developed the revised table of contents for the final report.
4. Finalized visit schedule to agencies, private firms, and facilities involved in pertinent AFBC development.

The reviews have highlighted some of the problem areas of each design which may be cause for concern. A combined final review will be completed shortly.

The parameter analysis matrix provides a point-by-point comparison of the three designs. This has been included as an attachment in last month's report.

The table of contents for the final report will act as a general outline guide in fully developing the text of the assessment. Revisions to the topics of discussion will be incorporated as input is made from the members of the team.

Visits to the various facilities, agencies, and private companies are being undertaken. During the upcoming month, visits will be made to EPRI, MERC, Battelle Columbus Laboratories, EPA, and possibly to the two A-E firms (Stone & Webster and Burns & Roe). Trip reports will be published after each visit and the information gained incorporated into the final report. All trips will hopefully be completed by early July.

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