MASTER

**Coal Technology Program
Progress Report for August 1977**

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Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy \$5.25; Microfiche \$3.00

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Contract No. W-7405-eng-26

COAL TECHNOLOGY PROGRAM
PROGRESS REPORT FOR AUGUST 1977

Date Published: October 1977

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Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
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DEPARTMENT OF ENERGY

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COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR AUGUST 1977

ABSTRACT

This report — the thirty-seventh 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 as a source 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 facility, a fluidized bed combustor technology test unit, engineering and support studies, process and program assistance, and environmental assessment studies.

1. SUMMARY

J. P. Nichols

Highlights of our progress in August are as follows:

- In hydrocarbonization research, material balance results from Run HC-21 confirm earlier tests with Wyodak coal, showing an oil yield of 21% based on MAF coal. A short run, HC-22, with a feed mixture of 3 parts char to 1 part Illinois No. 6 coal, developed problems with agglomeration in the reactor in spite of good char recirculation and good heat transfer to the coal in the draft tube. Preparations are underway for Run HC-23 in which Illinois No. 6 coal will be pretreated with aqueous NaOH/CaO to eliminate agglomerating tendencies.
- In our work for experimental engineering support of an in situ gasification process, the first two tests have been completed in which blocks of coal are pyrolyzed in a reducing (hydrogen) atmosphere. Earlier results are presented in terms of heating value of the gas evolved.
- In our coal-solvent-hydrogen mixing work, experiments were completed with the Kenics mixer reactor and with the packed-bed reactor. A summary report is being prepared.
- With the completion of three additional pressurized carbonization tests using Consol Synthetic Fuel (CSF) residue, effort has shifted to focus on pressurized carbonization of vacuum still bottoms from the H-Coal process. A summary evaluation of the carbonization results with CSF residue is being prepared.
- The fracture toughness characterization of 25.4-cm-thick ASTM A543 Class 1 plate is in progress. Precracked Charpy V-notch samples from the surface, 1/4 thickness, and mid-thickness depth locations, and 0.394T

compact tension specimens from the 1/4-thickness locations have been tested. The data suggest that the transition temperature for material from the 1/4-thickness depth location is below -13°C , whereas the transition temperature for material from the mid-thickness location is closer to -50°C .

- We have initiated preparatory activities for the investigation of inspection methods for plasma-sprayed CoCrAlY coatings on I800 substrates. Other current activities are directed toward the smooth conclusion of work on plasma-sprayed ceramic and cermet coatings.

- We obtained the first successful scans of thermal defects with our line-scanning infrared camera. A trial process using liquid penetrant produced a reversed indication of cracks in a cermet specimen.

- Submerged-arc test deposits of type 320 Cb cladding on carbon steel were made by the submerged-arc method. Most of the weld deposits were fissure-free and did not crack during side bend testing.

- Preparation of several failure analysis reports on components from the Wilsonville and Tacoma Solvent Refined Coal plants is in progress. Planning for the inspection of parts of the Wilsonville plant that will be accessible when the dissolver tank is removed is complete.

- In our gas-fired potassium boiler project, we completed and leak-tested all of the potassium piping for the system and made preparations for loading the drain tank with potassium. Initial operation of the system with potassium is still scheduled for November 1.

- We completed the design work on the fluidized bed alkali metal vapor cycle system and are now preparing the final report for this study.

- In our engineering studies and evaluations project, we continued work on process modeling, the preparation of a Synthetic Fuels Research Digest, a survey of industrial coal conversion equipment capabilities, and studies of flash hydropyrolysis, hot gas purification processes, processes for heat recovery, and hydrogen production by the steam/molten iron process.

- In our process and program analysis studies, we continued studies of low-Btu gasification, direct combustion, advanced power conversion systems, liquefaction, high-Btu gasification, in situ gasification, and coal beneficiation. These initial scoping studies are due to be complete with the issuance of reports by October 1.

- Program funds to continue our AFBC Technology Test Unit were received on August 15. Work was initiated on the application assessment study, on preparation of the performance specifications for obtaining combustor designs from manufacturing firms, and preparation of a request for a Memorandum Directive for the project from ERDA-ORO.

- TRW Energy Systems continued their subcontract activity to develop a comprehensive plan for the Coal Equipment Test Program (CETP). ORNL was requested by ERDA-FE-MFPM to consider facility requirements for testing coal feeders under development by MFPM. Jet Propulsion Laboratory personnel, who have been coordinating this activity for MFPM, will visit ORNL in September to discuss how this activity will be initiated.

- Samples of waste from the Hygas Pilot Plant (IGT) and Agglomerating Burner (Battelle-Columbus) have been shipped to ORNL for experimental studies of the landfill storage of solid wastes.

- Our Environmental Monitoring Handbook is now being used extensively by contractors and their environmental subcontractors in designing monitoring programs for the nation's first fossil demonstration plants (pipeline gas). This has become an extremely important position document in our role as advisors to the contractors in developing the environmental reports and ultimately in our role as authors of the environmental impact statements.

2. COAL CONVERSION PROCESS DEVELOPMENT

H. D. Cochran, Jr.

Coal conversion process development activities are carried out in the Chemical Technology Division. This section discusses hydrocarbonization studies in a 20-atm bench-scale facility, engineering support studies for in situ gasification, studies for identifying and characterizing alternate reactor concepts for coal hydroliquefaction, and studies of residue carbonization in a pressurized carbonizer.

2.1 Hydrocarbonization Research

R. L. Andrews, J. Beams, C. H. Brown, Jr., L. S. Dickerson, J. B. Gibson, G. E. Oswald, J. C. Rose, P. R. Westmoreland, and E. L. Youngblood

2.1.1 Experimental Development

Work Accomplished. Gas flow rates successfully used for Run HC-22 in the bench-scale hydrocarbonizer were chosen from cold model test data described last month. Based on temperature measurements in the draft tube and downcomer during Run HC-22, good recirculation and downcomer fluidization were achieved. These results represent a significant extrapolation from the cold model test conditions of N₂ or He recirculation at 90°F and 1 atm to H₂ recirculation at 1050°F and 21 atm.

An alternative gas distributor plate for the recirculating fluidized bed was evaluated during August. Its purpose is to eliminate bypassing of gas from the downcomer distributor plate into the draft tube, thus insuring good downcomer fluidization. As shown in Fig. 2.1, the distributor plate is elevated above the draft tube entrance leaving a gap for solids flow. Gas from a separate plenum (denoted as 1) can be injected around the axial gas jet to supplement draft tube gas supply, while fluidizing the solids flowing through the draft tube-distributor gap.

Gas requirements must be understood for proper application of this alternative distributor. Char recirculation data with N₂ fluidization using the standard distributor in the cylindrical, three-dimensional mock-up (Table 2.1) and using the alternative distributor in the rectangular, two-dimensional mock-up (Table 2.2) are compared on a common basis in Fig. 2.2. Only data from the sloped-plate alternative distributor are graphically compared since solid circulation rates were significantly higher with the sloped plate than with the flat plate. The alternative distributor required more gas to achieve the same solid circulation rates as the standard distributor, and it appeared to be

ORNL DWG 77-1529

Fig. 2.1. Two-dimensional model of alternative distributor design.

Table 2.1. Circulation data for flat plate distributor, three-dimensional model

Axial jet (slpm)	Nitrogen flow rates		Char circulation rate $\left(\frac{\text{g/sec}}{\text{cm}^2 \text{ draft tube}} \right)$
	Plenum (slpm)	Total $\left(\frac{\text{cm}^3/\text{sec}}{\text{cm}^2 \text{ reactor}} \right)$	
2.35	0.0	0.48	0.0
2.35	6.5	1.83	0.0
2.38	13.2	3.20	4.6
2.38	26.9	6.01	18.6
2.38	41.1	8.95	26.2
5.86	0.0	1.20	0.0
5.89	6.6	2.56	0.5
5.86	13.3	3.94	12.3
5.89	26.8	6.73	22.5
5.97	40.9	9.63	26.2
11.75	0.0	2.41	0.0
11.81	6.5	3.77	3.0
11.86	13.2	5.15	14.9
11.95	26.9	7.98	20.4
12.01	41.3	10.95	29.5
17.6	0.0	3.61	0.0
17.7	6.5	4.98	<0.2
17.8	13.2	6.39	14.9
17.9	26.9	9.21	19.0
18.0	41.4	12.21	23.2
23.6	0.0	4.85	0.0
23.7	6.6	6.23	<0.2
23.8	13.2	7.63	11.6
24.0	27.0	10.48	18.3
24.3	41.5	13.51	21.6

Table 2.2. Circulation data for alternative distributor, two-dimensional model

Distributor plate	Nitrogen flow rates				Char circulation rate $\left(\frac{\text{g/sec}}{\text{cm}^2 \text{ draft tube}}\right)$
	Jet (slpm)	Plenum 1 (slpm)	Plenum 2 (slpm)	Total $\left(\frac{\text{cm}^3/\text{sec}}{\text{cm}^2 \text{ reactor}}\right)$	
Flat	11.6	0.0	13.0	10.0	0.9
Flat	11.6	11.6	13.0	14.7	2.4
Flat	11.6	23.2	13.0	19.4	0.9
Sloped	11.6	0.0	13.0	10.0	3.3
Sloped	11.6	5.8	13.0	12.3	10.7
Sloped	11.6	11.6	13.0	14.7	8.2
Sloped	11.6	17.4	13.0	17.0	11.0
Sloped	11.6	23.2	13.0	19.4	9.2
Sloped	11.6	29.0	13.0	21.7	10.1
Sloped	11.6	35.1	13.0	24.2	10.3
Sloped	11.6	11.6	0.0	12.0	9.2
Sloped	11.6	11.6	6.5	17.3	13.9
Sloped	11.6	11.6	19.5	19.9	6.1
Sloped	11.6	11.6	26.0	10.0	7.4
Sloped	0.0	11.6	13.0	17.0	14.9
Sloped	17.4	11.6	13.0	19.4	11.9
Sloped	23.2	11.6	13.0	9.4	3.8

Fig. 2.2. Comparison of solid circulation rates and gas requirements for currently-used and alternative distributors.

limited to circulation rates below those achievable with the standard distributor. However, the alternative design did permit downcomer fluidization independent of whether the bed was circulating. Further development may decrease its gas requirements.

Work Forecast. Support of the bench-scale hydrocarbonizer will continue as necessary.

2.1.2 Bench-Scale Hydrocarbonization

Work Accomplished

Fabrication and Installation. A coal preheater was fabricated and installed in the transport line to preheat the coal feed stream entering the reactor. The preheater is constructed of 12-in. sched 40 pipe and is filled with Dowtherm G heat transfer fluid. The Dowtherm is heated with a tubular electric heater. Coal passes through the preheater inside a 30-ft-long coil of 3/16-in.-OD tubing.

Other modifications were also made to improve the temperature control of the reactor. The draft tube gas was routed through the preheater. The coal transport line which enters the reactor coaxially with the draft tube supply line was thermally insulated to prevent agglomeration of coal inside the line. A thermocouple was inserted about 1/4 inch inside the draft tube, 2-3/8 inch from the top to measure the temperature of the material flowing through the draft tube.

Shaft seals were replaced in the scrubber pump to eliminate leakage caused by wear and abrasion from char in the scrubber water.

Operation. Additional analytical data have been received for Run HC-21 which was made using Wyodak coal with the reactor operated as a uniformly fluidized bed. A high oil yield (21% based on MAF coal) was obtained. Preliminary material balance, steady state effluent gas analyses, and summary of experimental conditions for this experiment are presented in Tables 2.3, 2.4 and 2.5.

During August one short run (HC-22) was made using a 3/1 ratio of char/Illinois No. 6 coal. The system was then cleaned out in preparation for making a run with Illinois No. 6 coal that had been chemically treated to reduce the caking properties. The Illinois No. 6 coal was treated with an aqueous mixture of lime and caustic in an autoclave.

The main objective of Run HC-22 was to determine if the caking problems in the reactor that had been experienced in previous runs with Illinois No. 6 coal could be eliminated by insuring that the material leaving the draft tube had been heated above 1000°F. To accomplish this all the gas and coal streams entering the reactor were preheated and a thermocouple was installed in the draft tube as described previously. A starter bed of char was added to the reactor before the run

Table 2.3. Preliminary material balance for Experiment HC-21

Average bed temperature: 1035°F
Total pressure: 300 psig/260 psig^c

	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	55958	0.5779	0.0562	0.0032	100.0	100.0	100.0
(2) Scrubber water	51240	0.0	0.0	0.0	0.0	0.0	0.0
<u>Output</u>							
(3) Char recovered	22323	0.8073	0.1213	0.0017	55.7	86.1	21.2
(4) Scrubber top phase	406	0.7374	0.0540	0.0040	0.9	0.7	0.9
(5) Scrubber middle (aqueous) phase	63530	0.009461			1.8		
(6) Scrubber bottom phase	5213	0.6868	0.0176	0.0024	13.2	3.5	8.3
(7) Cold trap top phase	0						
(8) Cold trap middle (aqueous) phase	7062	0.01211			0.3		
(9) Cold trap bottom phase	3535	0.5619	0.0105	0.0017	5.1	1.2	3.4
(10) Charcoal trap light oil	625	0.8155		0.0034	1.6		1.2
(11) Solvent residue	1924	0.5764	0.00056	0.0021	3.4	<0.1	2.3
(12) Gases	7863	0.5706		0.0148 ^a	13.9		65.3 ^a
<u>Rinses</u>							
(13) Scrubber - water	22910	0.0 ^d			0.0		
(14) Scrubber and cold trap - perchlorethylene	68460	b					
Overall balances	103.0				96.9	91.5	100.0

^aCalculated by difference^bSee item 11.^cReactor pressure was at 300 psig for the first 5.9 hours of coal feed and at 260 psig for the remaining 6.3 hours.^dAnalysis not performed.

Table 2.4. HC-21 effluent gas composition at steady state--
300 psig^a, 1035°F at 0500 on 7/19/77

Component	Effluent flow rate (scfm)	Composition (%)	H ₂ and N ₂ -free composition (%)
CH ₄	0.193	1.56	46.6
C ₂	0.045	0.36	10.9
C ₃	0.017	0.14	4.1
CO	0.089	0.72	21.4
CO ₂	0.041	0.33	9.9
H ₂ S ^b	0.029	0.23	7.0
H ₂	11.887	96.39	--
N ₂	0.032	0.26	--

^aSystem pressure was 260 psig for part of the experiment. For this condition steady state effluent gas composition was not appreciably different from the above at 300 psig.

^bNear low limit of sensitivity; accuracy questionable.

Table 2.5. Summary of Experiment HC-21 conditions
and preliminary material balances

Experiment	HC-21
Bed temperature, °F	1035
Reactor pressure, psig	300/260 ^a
Estimated solids residence time in the reactor, min ^b	70
Period at steady state, hr	5.9/6.3 ^a
Coal feed	
Moisture content, wt %	15.2
As-received feed rate, lb/hr	10.1
Moisture-and-ash-free feed rate, lb/hr	8.0
Time of feeding, hr	12.17
Hydrogen flow rates, scfm	
Total hydrogen feed	12.9
Coal transport tube	4.2
Draft tube nozzle	1.2
Through distributor plate	7.5
H ₂ /coal feed ratio	
lb H ₂ /lb coal (maf)	0.51
scf H ₂ /lb coal (maf)	96.7
Carbon balance (% of carbon fed)	
Char	59.2
Liquids	23.8
Gases	13.9
Overall	96.9
Overall ash balance (% of ash fed)	91.5
Sulfur balance (% of sulfur fed)	100.0
Char	21.2
Liquids	13.5
Gases	65.3 ^c
Overall mass balance (% of mass charged)	103.0
Oil yield (wt % of maf coal)	21.3

^aReactor pressure was at 300 psig for the first 5.9 hours of coal feed
and at 260 psig for the remaining 6.3 hours.

^bTime to char overflow in the reactor.

^cBy difference from 100%.

was started. Hydrogen flow rates of 5 scfm to the transport line, 14 scfm to the downcomer and 1 scfm to the draft tube were used. The flow rates were based on conditions that gave good char circulation and fluidization in mockup studies. The initial bed temperature in the reactor was 1075°F. All the temperatures in the fluidized bed were closely grouped, and the temperature of the material flowing through the draft tube was 1045°F indicating that there was good fluidization in the bed and good circulation through the draft tube. The coal pre-heater performed well, heating the feed stream to 385°F before it entered the reactor. Coal feed was started at a relatively slow rate of 2.5 lb/hr. After 5 minutes the rate was increased to 5 lb/hr, and 12 minutes later the rate was increased to 7 lb/hr. During this period the system appeared to perform well, and there was a high gas evolution rate indicating that the coal was being devolatilized. However, after about 20 minutes of operation the temperature of the material passing through the draft tube began to decrease, and the bed temperatures began to diverge, indicating that caking had occurred. Operation was continued until the draft tube became plugged after about 35 minutes of run time.

Post run inspection showed that the downcomer area was caked around the top of the draft tube. Evidently the coal was not sufficiently devolatilized in the draft tube to prevent caking after it was discharged into the downcomer region. After the run the reactor, scrubber, and cold trap were cleaned in preparation for the next run.

Treated coal for Run HC-23 is being prepared by heating a coal-water slurry containing CaO and NaOH in an autoclave to approximately 250°C. The method being used is similar to that developed at Battelle Memorial Institute¹ for desulfurization of coal. The treatment also eliminates the caking tendencies of the coal and in some cases improved the liquid yields from pyrolysis.² The treatment is being carried out in a batch autoclave using the following procedure. A slurry is prepared by mixing 1.81 kg Illinois No. 6 coal (-50 +170 mesh), 0.24 kg CaO, 1.27 kg NaOH, and 7.28 kg of water. The slurry is loaded into a rocking autoclave and heated to 200 - 275°C. Approximately 3 hours is required for heatup. The system is held at temperature for about 1 hour, and the cool down period is about 5 hours. The coal is then removed, washed, filtered and dried in a vacuum drier. Approximately 60 pounds of treated coal has been prepared to date. Measurements made on some of the first batches of treated coal gave a Free Swelling Index of less than 0.5 indicating only a very slight tendency to agglomerate.

2.2 Experimental Engineering Support of an In Situ Gasification Process

J. B. Gibson, L. S. Dickerson, and T. C. Scott

As described in previous reports, samples of Eastern bituminous coal have been obtained from the Morgantown Energy Research Center (MERC)

for use in our large-block pyrolysis studies. The coal is typical of the material which will be burned by MERC in their field test near Pricetown, West Virginia.

During August the first two experiments utilizing a hydrogen purge gas were carried out. In these experiments bituminous coal was heated at a rate of $3\text{ }^{\circ}\text{C}/\text{min}$ in a reducing (hydrogen) atmosphere. The maximum pyrolysis temperature for Runs BP2-33 and BP2-34 were 600°C and 1000°C , respectively.

Minor errors were discovered in the computer program used previously to perform the analysis of the experimental data. These errors were corrected and the data for the first 31 runs were reanalyzed. The results of the reanalysis are summarized in Table 2.6. All of the runs with an inert (argon) purge gas except BP2-32, for which analytical data have not yet been received, are included in this summary table.

The heating value of the evolved gas, total amount of gas produced, and the thermal efficiency of the pyrolysis for both the subbituminous and the bituminous coals are presented graphically in Figures 2.3 through 2.7. (For the purposes of this discussion thermal efficiency is defined as the ratio of total usable energy in the evolved gas to total available energy in the coal.)

In Figure 2.3 it can be seen that gas produced from bituminous coal has a higher heating value which is greater than that of the gas produced from subbituminous coal and that the heating value of the produced gas decreases with increasing temperature. For the bituminous coal the faster heating rate ($3\text{ }^{\circ}\text{C}/\text{min}$) produced gas with the greater heating value while for the subbituminous coal the lower heating rate ($0.3\text{ }^{\circ}\text{C}/\text{min}$) produced the greater heating value. The reasons for this can be best understood by consideration of the mechanisms by which hydrogen, which has a relatively low heating value, is produced from each coal. With bituminous coal hydrogen is produced primarily by the thermal cracking of hydrocarbons. The lower heating rate allows a higher degree of cracking which increases the amount of hydrogen formed and reduces the amount of hydrocarbons. This results in the decreased heating value.

With the subbituminous coal a large fraction of the hydrogen produced is formed by the steam/char reaction. This reaction also produces relatively large amounts of carbon monoxide which, like hydrogen, has a relatively low heating value. (The steam/char reaction occurs in the subbituminous coal because it initially contains approximately 27% moisture and not in the bituminous coal because it contains only about 1% moisture.) More hydrogen and carbon monoxide are formed by the steam/char reaction at the higher heating rates. The steeper internal thermal gradients associated with the faster heating rate causes more water to be trapped in the interior of the coal block when the external surface has reached 600°C . At 600°C the steam/char reaction becomes significant and produces the large amounts of hydrogen and carbon monoxide which lower the heating value of the gas.

Table 2.6. Summary of in situ gasification experiments

Run Number	Date of run	Coal Type	Heating Rate °C/min.		Maximum Temperature °C	Cover Gas (Argon) Flow Rate Std. lit/min.	Coal Block Dimensions cm		Coal Block Weight kg	Coal Block Weight maf kg	Recovered Char Weight kg	Recovered Liquid Data kg				EVOLVED GAS DATA																Thermal Efficiency Btu Gas/Btu Coal	Mass Balance (% Weight Accounted for)				
			Nominal	Actual			Height	Diameter				Oil	Tar	Water	Total	Volume Percent Composition												Volume (liter)		Weight (g)			Liter Gas Evolved per kg Coal maf		Average Btu/cu ft Tie Element	Tie Element Gas	Flow Meter Gas
																H ₂	CH ₄	CO ₂	CO	C ₂	C ₃	C ₄ ⁺	H ₂ S	Benzene	Toluene	N ₂ , H ₂ & Others	Tie Element	Flow Meter	Tie Element	Flow Meter	Tie Element		Flow Meter				
BP2-1	12/22/75	Wyodak Subbituminous	3.00	0.52	919	e	15.2	15.9	3.859	3.573	1.508	c	.120	c	1.259	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
BP2-2	1/22/76	"	3.00	2.79	1044	e	12.6	15.9	3.209	2.971	1.209	c	.125	c	1.136	52	11	11	23	2	.2	0	.01	.1	.02	1	1226	1516	816	985	413	510	416	21	98.5	104	
BP2-3	2/5/76	"	3.00	1.11	500	e	16.5	15.2	3.699	3.424	1.782	c	.082	c	1.478	20	19	31	13	4	3	2	0	.01	.01	8	272	120	312	132	74	33	511	5	96.6	91.7	
BP2-4	2/18/76	"	0.30	0.33	500	e	17.8	15.2	4.496	4.162	2.379	.052	.256	1.491	1.800	13	19	34	14	5	4	4	.3	.05	.02	7	441	224	569	238	98	50	623	8	105.6	98.2	
BP2-5	2/25/76	Hanna No. 1 Subbituminous	3.00	2.96	500	3.05	5.7	6.4	0.227	0.198	0.144	d	.024	d	a	8	17	8	4	5	3	2	0	0	0	53	36	17	38	19	182	86	448	a	d	d	
BP2-6	3/3/76	"	0.30	0.30	500	3.00	5.9	6.4	0.232	0.202	0.145	c	.002	c	0.020	10	22	7	0	7	5	3	0	0	0	46	53	19	50	17	227	82	615	a	92.5	78.3	
BP2-7	3/11/76	Wyodak Subbituminous	0.30	0.35	600	3.04	17.2	14.9	3.866	3.580	1.569	d,c	.164	d	d	23	28	14	24	3	1	.5	0	.08	.05	6	632	591	588	549	163	153	570	12	d	d	
BP2-8	3/18/76	"	3.00	2.97	600	3.06	6.4	6.4	0.253	0.234	0.112	c	.051	c	0.054	22	20	21	11	5	2	2	0	0	0	17	43	22	44	24	171	88	519	11	82.9	75.2	
BP2-9	4/1/76	"	3.00	2.67	700	3.06	6.4	6.4	0.254	0.235	0.104	c	.058	c	0.059	33	17	12	20	2	1	.6	0	0	.2	14	49	33	42	30	194	132	469	12	80.5	76.1	
BP2-10	4/23/76	"	0.30	0.31	700	3.06	14.1	16.2	3.734	3.457	1.635	c	.103	c	1.537	31	18	15	23	2	1	1	.3	.04	.05	9	795	692	699	612	213	186	463	13	103.7	101.3	
BP2-11	5/4/76	"	3.00	2.33	800	3.06	30.2	15.9	6.976	6.459	2.612	c	.108	c	2.181	35	14	15	32	2	.5	.3	.07	.2	.04	1	2449	2670	2185	2376	351	383	450	20	100.0	102.8	
BP2-12	5/14/76	"	3.00	2.53	800	3.08	26.2	15.2	6.147	5.692	2.359	c	c	c	1.875	50	13	12	21	2	.3	.2	.06	.1	.02	1	2534	1799	1757	1249	412	293	431	23	97.5	89.2	
BP2-13	6/9/76	"	0.30	0.32	800	3.21	17.8	15.2	5.553	5.142	2.320	.233	.019	2.078	2.330	40	21	12	18	2	1	.6	.02	.05	.01	5	1067	621	812	499	192	112	512	13	98.4	92.7	
BP2-14	7/7/76	"	0.30	0.28	900	3.10	18.4	15.6	4.258	3.942	1.710	.060	.054	c	1.668	41	18	12	20	2	1	.5	.02	.03	.01	5	946	778	725	591	222	183	482	14	96.4	93.2	
BP2-15	7/27/76	"	3.00	3.33	900	3.10	21.6	15.2	5.041	4.667	1.877	.100	.045	1.356	1.491	50	9	11	27	1	.03	.2	.02	.1	.02	2	1996	2284	1388	1611	396	453	400	21	94.3	98.8	
BP2-16	8/24/76	"	0.30	0.28	1000	3.15	20.7	15.2	4.903	4.540	1.925	c	.034	c	1.870	45	17	12	16	1	1	.5	0	.04	.02	7	1186	1074	843	790	242	219	463	15	94.6	93.5	
BP2-17	9/9/76	"	3.00	3.02	1000	3.05	18.4	15.2	4.380	4.055	1.599	c	.024	c	1.087	54	8	10	25	1	.3	.1	.03	.1	.02	1	1871	2113	1223	1386	461	521	386	21	89.2	93.0	
BP2-18	9/27/76	" ^b	0.30	0.31	900	3.11	25.7	15.9	6.277	5.812	2.587	c	.135	c	2.572	46	16	14	16	1	.6	.3	0	.05	.01	6	1462	1193	1041	871	233	190	434	13	98.8	96.1	
BP2-19	10/18/76	" ^b	3.00	3.08	1000	3.10	18.4	14.9	4.074	3.722	1.659	.029	.054	1.593	1.676	48	16	12	19	2	.6	.4	.02	.1	.04	2	1012	1044	716	758	248	256	465	15	99.4	100.5	
BP2-20	11/12/76	"	3.00	3.00	600	3.01	17.2	15.1	3.901	3.612	1.644	.034	.167	1.260	1.461	30	22	25	11	4	3	2	0	.1	.04	3	566	589	564	590	157	163	580	11	94.1	94.7	
BP2-21	11/22/76	"	3.00	3.07	500	3.27	17.8	15.2	3.959	3.666	1.794	c	.086	c	1.706	12	24	31	15	5	4	2	0	.06	.06	7	323	156	396	189	88	43	608	6	98.4	93.2	
BP2-22	12/9/76	"	0.30	0.30	600	3.06	17.8	15.2	4.014	3.717	1.765	.101	.067	1.535	1.703	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a		
BP2-23	1/26/77	Pittsburgh Seam Bituminous ^b	0.31	0.31	1000	2.99	15.2	15.2	3.550	3.289	2.372	c	.498	0.100	0.598	58	20	2	5	3	2	1	.2	.02	.03	9	1150	1109	545	539	350	337	559	22	99.0	98.8	
BP2-24	2/11/77	Pittsburgh Seam Bituminous	3.00	3.03	1000	3.02	16.5	16.0	4.086	3.786	2.346	.217	c	c	0.543	54	29	2	5	5	2	1	.1	1	.06	1	1088	1413	563	725	266	346	695	22	84.5	88.4	
BP2-25	2/25/77	"	3.00	2.90	800	3.01	22.2	15.2	5.087	4.713	3.335	.080	.341	.331	0.752	50	30	2	5	6	1	.7	2	.5	.08	3	1206	1454	666	812	256	309	709	20	93.4	96.3	
BP2-26	3/15/77	"	0.30	0.28	1000	3.00	19.4	16.7	4.591	4.254	3.235	.503	.114	.140	0.757	54	21	1	6	2	3	1	1	.03	.05	11	1355	1275	698	628	318	300	587	21	102.2	100.6	
BP2-27	3/31/77	"	3.00	2.41	600	3.03	15.2	14.9	3.518	3.260	2.410	.236	.190	.109	0.535	30	39	3	4	9	6	3	1	.2	.1	5	545	565	429	446	167	173	967	18	95.9	96.4	
BP2-28	4/21/77	"	0.30	0.25	600	3.03	18.4	15.2	4.421	4.096	3.183	c	c	c	0.726	34	37	3	5	6	3	3	2	.04	.08	7	565	529	408	393	128	120	842	13	97.7	97.3	
BP2-29	5/31/77	"	0.30	6.1 & 1.9	600	2.94	20.7	15.2	4.814	4.457	3.375	c	c	c	0.686	38	38	2	7	6	3	1	0	.2	.07	5	867	922	570	614	194	207	804	17	96.2	97.1	
BP2-30	6/27/77	"	0.30	0.27	1000	2.93	22.2	15.2	4.857	4.497	3.237	c	c	c	0.823	43	16	6	20	2	2	1	1	.02	.02	9	1676	1375	1190	904	376	309	515	21	100.1	102.2	
BP2-31	7/13/77	"	0.30	0.28	800	2.88	15.9	16.0	4.127	3.821	2.770	c	c	c	0.627	46	20	1	16	3	1	1	1	0	0	11	1076	1039	656	637	282	272	576	18	98.2	97.8	

^aData not available.
^bCoal block dried before heating
^cLiquid fractions would not separate.
^dCondenser water line leaked into liquid product.
^eA flow rate of 3.00 standard liter per minute was assumed for this run.

Fig. 2.3. Higher heating value of gases evolved from large coal blocks as a function of coal type, heating rate, and maximum pyrolysis temperature.

Fig. 2.4. Total gas evolution of large blocks of subbituminous (Wyodak) coal, as a function of heating rate and maximum pyrolysis temperature.

Fig. 2.5. Thermal efficiency of the gasification of large blocks of subbituminous (Wyodak) coal as a function of heating rate and maximum pyrolysis temperature.

Fig. 2.6. Total gas evolution of large blocks of bituminous (Pittsburgh seam) coal as a function of heating rate and maximum pyrolysis temperature.

Fig. 2.7. Thermal efficiency of the gasification of large blocks of bituminous (Pittsburgh seam) coal as a function of heating rate and maximum pyrolysis temperature.

Figures 2.4 and 2.5 show the total amount of gas evolved from pyrolysis of large blocks of subbituminous coal and the thermal efficiency of the pyrolysis process. At about 600°C, the higher heating rate produces significantly greater quantities of gas and a greater thermal efficiency than the lower heating rate. This is due to the previously discussed mechanism of the steam/char reaction.

Figure 2.6 shows the total gas evolved from the pyrolysis of large blocks of bituminous coal. Between 600°C and 800°C there is a relative increase in the amount of gas evolved at the lower heating rate in comparison to the amount evolved at the higher heating rate. This is probably due to the increased cracking of hydrocarbons to form hydrogen.

Figure 2.7 shows that for bituminous coal the faster heating rate has a slightly greater thermal efficiency than the lower heating rate.

For the subbituminous coal the higher heating rate produces greater quantities of gas and at a higher thermal efficiency. Balanced against this, however, is the fact that the gas produced at the higher heating rate has a slightly lower heating value. For the bituminous coal, the higher heating rate produces a gas with a greater heating value and at a higher thermal efficiency. However, slightly smaller quantities of gas are produced.

2.3 Coal-Solvent-Hydrogen Mixing

J. M. Begovich and R. C. Lovelace

Pulse test measurements were completed for the 1-in.-ID x 5-ft-long contactor filled with the Kenics inline static mixers. During August the contactor was operated with cocurrent upflow of air and 35 wt % coal/water slurry using flow rates in the range of 0 - 500 cm³/sec for the air and 22 - 114 cm³/sec for the slurry. A final report will be issued covering the air/water and air/slurry results in both the 1-in.-ID x 10-ft-long packed column and the 1-in.-ID x 5-ft-long Kenics contactor.

A 1/2-in.-ID x 8-ft-long empty glass pipe has been installed for investigation; such a configuration is typical of the preheaters in many coal liquefaction processes. Additional gas and liquid rotameters have been installed which will permit measurement of air and water flow rates in the range 2.8 - 600 cm³/sec and 0.2 - 270 cm³/sec, respectively. A group of graduate students of the Massachusetts Institute of Technology's School of Chemical Engineering Practice (MIT-SCEP) is scheduled to obtain mixing, holdup, and pressure drop data in the empty glass column during September. Similar data may also be obtained in the 1-in.-ID x 10-ft-long column packed with 1/8-in. x 1/8-in. cylindrical packing to determine the effect of particle shape. The results of their investigation will be reported in the monthly reports of the Coal Technology Program and in a separate report issued by the Oak Ridge station of the MIT-SCEP.

2.4 Pressurized Carbonization of Coal Liquefaction Residue

R. E. Barker and S. M. Gibson

This project is intended to determine experimentally the degree of coking and liquid degradation to be expected when coal liquefaction residue is carbonized in a pressurized fluidized bed carbonizer. The experimental apparatus and results of early experiments are described in earlier reports.

During August three runs were completed. These runs completed work on the Consol Synthetic Fuel (CSF) residue feed using hydrocarbonization char as a bed material, although some of these runs may need to be repeated. Material balance calculations are continuing on these and preceding experiments as the analytical results become available. An attempt will be made to present all of these results in a coherent form as soon as possible.

The project is being redirected to use H-Coal vacuum still bottoms (VSB) as feedstock instead of the CSF residue. Since the VSB is a solid material, provisions must be made to feed it to the carbonizer. Initial plans were to slurry the VSB in a relatively inert liquid (benzene) and feed through the existing pump system. Unfortunately, the VSB/benzene mixtures proved intractable except at unreasonably high (about 10:1 weight ratio) benzene dilutions in the existing system. Another method will be tried--pulverized VSB will be fed semi-continuously in a pneumatic manner.

During September a useful method for feeding VSB to the fluidized bed carbonizer will be found and will be used to make at least one run with VSB feed and alumina as bed material. In addition, work on analyzing results of earlier runs will continue.

2.5 References for Section 2

1. E. P. Stambaugh et al., "Environmentally Acceptable Solid Fuels by the Battelle Hydrothermal Coal Process," 2nd Symposium on Coal Utilization, Louisville, Ky, October 1975.
2. E. P. Stambaugh et al., "Novel Concept for Improved Pyrolysis Feedstock Production," ACS meeting, New Orleans, La, March 1977.

3. MATERIALS ENGINEERING

R. T. King

The materials engineering and associated technology reported here are in support of activities directed by the Materials and Power Generation Branch of the Division of Materials and Exploratory Research, ERDA, in the Division of Fossil Energy. Other related work not funded directly by this division of ERDA/FE is included also.

Summary

The fracture toughness characterization of 25.4 cm thick ASTM A543 Class 1 plate is in progress. Precracked Charpy V-notch samples from the surface, 1/4 thickness, and mid-thickness depth locations, and 0.394T compact tension specimens from the 1/4 thickness locations have been tested. The data suggest that the transition temperature for material from the 1/4 thickness depth location is below -73°C , whereas the transition temperature for material from the mid-thickness location is closer to -50°C .

ORNL and ERDA/FE representatives met in Washington, D.C. on August 30 to revise the objectives of the coating inspection project. We have initiated preparatory activities for the investigation of inspection methods for plasma-sprayed CoCrAlY coatings on I800 substrates. Other current activities are directed toward the smooth conclusion of work on plasma-sprayed ceramic and cermet coatings.

We obtained the first successful scans of thermal defects with our line-scanning infrared camera. A trial process using liquid penetrant produced a reversed indication of cracks in a cermet specimen.

Submerged-arc test deposits of type 320 Cb cladding on carbon steel were made by the submerged-arc method. Most of the weld deposits were fissure-free and did not crack during side bend testing.

The testing of heat exchanger tubes in the fluidized bed facility, operated by the Fluidyne Corporation, continued under the conditions described last month.

Preparation of several failure analysis reports on components from the Wilsonville and Tacoma Solvent Refined Coal plants is in progress. Planning for the inspection of parts of the Wilsonville plant that will be accessible when the dissolver tank is removed is complete.

3.1 Pressure Vessel and Piping Materials

D. A. Canonico, W. J. Stelzman, and R. K. Nanstad

We have continued the characterization of the 25.4 cm (10 in.) thick ASTM A543 Class 1 steel plate. Fracture toughness properties have been determined using both precracked Charpy V-notch (PCC_v) and 0.394T Compact Tension (CT) specimens. Previously, we reported PCC_v static fracture toughness data at -18, 38, and 260°C (0, 100, and 500°F). During the past month we have conducted additional tests at 129, -77, and -129°C (350, -100, and -200°F). These data, as well as those previously reported, are provided in Table 1. In addition to the PCC_v tests at the surface, 1/4 thickness and mid-thickness depth locations, we have conducted 0.394T CT tests of material from the 1/4 thickness depth. These data are also provided in Table 3.1. The PCC_v properties were calculated using equivalent energy procedures. The CT results were obtained using both equivalent energy and J-integral calculational procedures. The J-integral was obtained by extrapolating crack opening displacement values from the specimen front face to the load line. For both equivalent energy and J-integral calculations, maximum load was used as the criterion for crack initiation.

The 25.4 cm thick A543 Class 1 steel plate exhibits excellent toughness at the 1/4 thickness depth at temperatures below -101°C (-150°F). Valid (in accordance with the requirements of ASTM E 399) K_{IC} data are not attainable (with 0.394T CT specimens) at -129°C (-200°F). Additional fracture toughness tests are planned with IT CTs at temperatures of -157°C (-250°F).

A correlation between PCC_v and CT specimens can be made with specimens removed from the 1/4 thickness depth location. The similarity in toughness values is noteworthy. Further, the toughness values obtained through K_{ICd} and K(J) calculational methods are also similar. This study with small fracture toughness specimens suggests that the transition temperature for this steel at the 1/4 thickness depth location is extremely low, probably below -73°C (-100°F). The transition temperature for material removed from the mid-thickness location has not been conclusively determined but it is higher in temperature, probably closer to -46°C (-50°F).

3.2 Inspection Techniques for Wear- and Process-Resistant Coatings

R. W. McClung and G. W. Scott

3.2.1 Review and Evaluation (G. W. Scott)

ORNL and ERDA/FE representatives met to formulate revised objectives for the coating inspection project. Emphasis will be shifted to metallic plasma-sprayed overlay coatings, specifically CoCrAlY, 0.005-0.020 in.

Table 3.1. Fracture Toughness Properties of 25.4 cm
(10 in.) Thick ASTM A543 Class 1 Plate

Plate Depth	Test Temperature °C (°F)	PCCV ^a K _{Icd}		0.394 CT ^b	
		K _{Icd}		K(J)	
		MPa $\sqrt{m}$	(ksi $\sqrt{in.}$)	MPa $\sqrt{m}$	(ksi $\sqrt{in.}$)
		RW ^c	WR ^d	WR	
Surface	-129 (-200)	69 (63)	103 (94)		
	-73 (-100)	-	208 (189)		
	-18 (0)	229 (208)	229 (208)		
	38 (100)	-	225 (205)		
	93 (200)	225 (205)	-		
	149 (300)	-	202 (184)		
	260 (500)	203 (185)	192 (175)		
1/4 Thick	-184 (-300)	-	-	38 (35)	38 (35)
	-129 (-200)	90 (82)	110 (100)	103 (94)	104 (95)
	-101 (-150)	-	-	156 (142)	157 (143)
	-73 (-100)	-	202 (184)	166 (151)	169 (154)
	-18 (0)	223 (203)	225 (205)	200 (182)	202 (184)
	38 (100)	-	199 (181)		
	93 (200)	216 (197)	-		
	176 (350)	193 (176)	185 (168)		
	260 (500)	196 (178)	169 (154)		
Mid Thick	-129 (-200)	48 (44)	59 (54)		
	-73 (-100)	-	102 (93)		
	-18 (0)	215 (196)	191 (174)		
	38 (100)	-	185 (168)		
	93 (200)	202 (184)	-		
	176 (350)	199 (181)	-		
	260 (500)	146 (133)	176 (160)		

^aPrecracked Charpy V-notch specimens.

^b1 cm (0.394 in.) thick Compact Tension specimens.

^cRW - Specimen Orientation: Specimen axis in rolling direction (RD); fracture propagation transverse to RD.

^dWR - Specimen Orientation: Specimen axis transverse to RD; fracture propagation in RD.

thick, on I800 substrates. Variables of interest, in priority order, are (1) cracks or other defects which penetrate the coating and allow access to the substrate, (2) thickness of the coating, and (3) unbonds or delamination defects. There is no continuing interest in ceramic or cermet coatings; therefore work in these areas will be closed out.

Actions to revise the direction of ORNL work have already commenced.

3.2.2 Thermal Testing (W. A. Simpson, Jr.)

We have examined nonbond standards with a single line-scan infrared camera. Previously we had evaluated these samples with an imaging (two-dimensional) camera which could locate the nonbonds but made quantitative measurements only with difficulty. The present system allows the absolute temperature to be determined at any instant and eliminates electronic saturation problems inherent in the imaging camera, which is not designed to evaluate transient phenomena.

3.2.3 Surface Inspection Materials (S. D. Snyder)

Cracked cermet specimen CP-72T-C01 has been used exclusively this month for crack detection tests with penetrant materials. Following the unsuccessful tests with the food dye formulation and the ZL-1B water washable penetrant, experiments with ZL-22A post emulsified fluorescent penetrant were conducted. From the first test using the I.D.E.A. technique where the specimen is given a penetrant strip-wash before emulsification, it became obvious that this was a reasonable crack detection method, even though the method produces crack indication by a reversal of the normal image-producing mechanism. Here, penetrant is removed from the cracks while being held in the uncracked porous background. It was determined that the penetrant strip-wash removes more penetrant from the cracks than the emulsification does, but both steps are necessary. Also, the maximum contrast between the fluorescence of the penetrant held in the background porosity and the lack of penetrant in the cracks is observed immediately after the final drying. The penetrant in the uncracked portion of the coating bleeds back into the cracks as time progresses. Application of developer is undesirable because the bleeding is hastened by the absorbent action of the developer. Efforts to optimize the penetrant strip-wash and emulsification times are in progress.

3.3 Fossil Energy Welding and Cladding Program

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

During this reporting period we have concentrated on type 320 Cb stainless steel cladding of carbon steel, using the submerged-arc (SA) welding process. Several experimental SA deposits were made with constant lateral torch oscillation, but with varying current and travel

speeds. Dilution from the base metal varied from 15 to 33%. Dye-penetrant examination of the clad surfaces revealed no fissuring in any of the deposits, except in arc-stop areas. However, side-bend testing of these deposits revealed fissuring in a deposit with 25% base metal dilution. Preliminary results indicate that submerged-arc clad deposits can tolerate more dilution from the base metal without fissuring than comparable gas metal-arc deposits.

3.4 Fireside Corrosion

R. H. Cooper and J. H. DeVan

The testing of heat exchanger tubes in the fluidized bed facility, operated by the Fluidyne Corporation, continued under the conditions described last month.

3.5 Failure Analysis

R. T. King and R. H. Cooper

Failure analyses on several parts and components received from the Wilsonville Solvent Refined Coal Plant are near completion. ORNL staff members have collaborated with plant operation personnel to plan for inspection of some of the areas of the plant that will be successible during a shutdown in September 1977.

4. ALKALI METAL VAPOR TOPPING CYCLES

R. S. Holcomb and G. Samuels

4.1 Gas-Fired Potassium Boiler

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

4.1.1 Contract objective

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

4.1.2 Status summary

1. Design work was completed on the power supply and controls for the combustion air preheater.

2. The potassium piping installation was completed this month. The system was pressure tested to 370 psig and then evacuated and checked for leaks with a helium leak detector. There was no indication of a leak during the test.

3. Modification of the combustion air piping was completed.

4. The combustion air preheater was received and installation was begun.

5. Work was completed on connecting the wiring to the power supplies and instruments in the control room. Most of the thermocouples and electric heaters have been installed. Electrical wiring and instrument wiring have been connected on the experiment except for the thermocouples and heaters which will be connected after insulation of the system is complete.

4.1.3 Plans for next month

Installation of the electrical and instrument systems and checkout of the instruments and controls will be completed. The installation of the air preheater will be completed. The fill-and-drain tank will be filled with potassium. The preliminary operation and checkout procedures for the system will be established.

4.2 Coal-Fired Alkali Metal Power System

G. Samuels

4.2.1 Contract objective

The objective of this study is to establish a reference design for a 200-MW(e) alkali metal vapor/steam Rankine cycle system employing a coal-fired fluidized bed furnace and to prepare a preliminary design of a fluidized bed furnace. This will be accomplished by studying the relative merits of both potassium and cesium vapor cycle systems and making a comparison of these systems. The results will be analyzed and potassium or cesium will be chosen as the cycle fluid and one of the systems will be selected as the reference. The reference system will be used for the preparation of a preliminary design of a fluidized bed furnace-boiler.

The initial scope of this study was curtailed in late March 1977. The program is now limited to a study of an atmospheric fluidized bed system using either cesium or potassium as the working fluid. The new schedule also changed the study from the two-phase approach which was to be completed by December 31, 1977, with an interim report to be issued by August 31, 1977. The work on the atmospheric system will be covered in a single report to be completed by September 30, 1977. The scope of work for the revised program includes the following major tasks:

1. Parametric cycle analysis for cesium and potassium power systems.
2. Conceptual designs for an atmospheric pressure fluidized bed furnace.
3. Condenser-steam generator conceptual designs for cesium and potassium at several condenser temperatures.
4. Metal vapor turbine design and analysis.
5. Conceptual layouts of overall system.
6. Preliminary design of an atmospheric pressure fluidized bed furnace for either a cesium or potassium power system.

4.2.2 Status summary

1. The first phase of the cycle analysis has been completed. This was a parametric analysis of the three basic systems of the plant, i.e., atmospheric, intermediate, and high pressure fluidized bed combustion systems.

2. The first phase of the metal vapor turbine design and analysis has been completed. This effort was restricted to a determination of the number of stages, hub diameter, blade height, and stress and turbine efficiency.

3. The work on the fluidized bed furnace during the first six months of the project was concentrated on a vertical tube boiler arrangement for a pressurized furnace and is thus invalidated by the change in direction of the program. The atmospheric furnace selected for the reference design is a horizontal forced-circulation unit.

4. Work on the alkali metal condenser-steam generator was completed.

5. Conceptual design and layout work for the overall system was limited to those considerations necessary for the furnace design work. This is now being completed except for one drawing.

5. COAL EQUIPMENT TEST PROGRAM

R. E. MacPherson

TRW Energy Systems continued their subcontract activity to develop a comprehensive plan for the Coal Equipment Test Program (CETP). A proposal was received for follow-on activities associated with execution of the plan. Funding was not available during this report period to proceed with processing of the subcontract; however, all activities that could be completed without committing funds were underway.

ORNL and TRW representatives met with ICGG for the second time and agreement was reached on how to proceed with necessary negotiations for secrecy agreements between ICGG and ORNL-TRW. These negotiations are underway.

ORNL was requested by ERDA-FE-MFPM to consider facility requirements for testing coal feeders under development by MFPM. Jet Propulsion Laboratory personnel, who have been coordinating this activity for MFPM, will visit ORNL in September to discuss how this activity will be initiated.

6. FLUIDIZED BED COMBUSTOR TECHNOLOGY TEST UNIT

R. S. Holcomb

Program funds were received on August 15. Work was initiated on the application assessment study, on preparation of the performance specifications for obtaining combustor designs from manufacturing firms, and preparation of a request for a Memorandum Directive for the project from ERDA-ORO.

A tentative outline of the scope of the assessment study was completed. The first major task will be to obtain an accurate survey of the electrical load profile and process heat loads by temperature level in over as wide a range as possible of the major segments of industry, including such industries as chemical, petroleum, paper, rubber, glass, cement, metal treating and finishing, food-grains processing, lumber, ceramics, etc. A literature search is in progress to seek to obtain the results of other studies of industrial energy requirements. These results will be augmented by inquiries to industrial organizations to verify reported data, obtain data where it is lacking, and to gain insight into practical aspects of the methods and forms in which energy can be supplied to particular processes.

The performance specifications for the combustor are being prepared in two parts: specifications for the conceptual design and specifications for the detailed design. Work is in progress on both sections and the first draft of the conceptual design specifications is nearly complete. This section will be reviewed internally and revised while the detailed design specifications are being completed.

The first draft of the request for a Memorandum Directive has been prepared and reviewed. Revisions are being made and the final draft should be ready to submit for approval in about a week. A preliminary proposal for the formal project directive will be submitted to ERDA-ORO upon the completion of a new cost estimate and project schedule.

6.1 Supplemental Studies

The corrosion test was restarted on August 14. After running for about 120 hr, the test was again interrupted by the failure of specimen tubes. Inspection of several tubes revealed that the two Inconel 600 tubes had ruptured from corrosion attack at a point just out of the fluidized bed where the tube passes through a hole in the refractory lining at the end of the tube where the maximum tube wall temperature occurs. The hole in the refractory brick is oversize and bed material filled up the space around the tube. The corrosion apparently occurred here as the result of a low oxygen level and a reducing environment leading to attack by calcium sulfate and possibly by hydrogen sulfide from incomplete combustion of coal particles that may have been present. An upset condition had occurred the night before the tube failure in which the coal feed rate had increased and the bed temperature reached about 1700°F, and

the bed had insufficient air for complete combustion for about 15 min until the bed was brought back into the correct conditions. This upset may have accelerated the corrosion attack at the points where the tubes failed and may have resulted in the failures occurring earlier than would have otherwise been the case. The Inconel 600 tubes and a number of others that were removed for inspection showed a uniform reddish-brown, thin, hard deposit over the length of tube in the fluidized bed with no visible corrosion attack at any place except at the point of failure of each of the Inconel 600 tubes.

It was concluded that the Inconel 600 material is unacceptably susceptible to corrosion attack where reducing conditions are present and that it does not appear to be an attractive candidate for tubing in coal-fired fluidized beds. Accordingly, the Inconel 600 tubes were replaced with 310 stainless steel tubes for continuation of the test.

The furnace controls were modified in that an upper limit was placed on the coal feed rate so that even when the excess air level calls for an increase in the coal feed, it cannot exceed a maximum value fixed by the upper limit. This will prevent a large temperature overshoot in the bed and help ensure that the excess air level is always equal to or greater than the 15% specified for the test.

The corrosion test was resumed on August 30.

7. ENGINEERING STUDIES AND TECHNICAL SUPPORT

J. R. McWherter

7.1 Process Modeling

R. Salmon and D. M. Lister

7.1.1 Contract Objective

The objective is to assist the Fossil Energy Major Facility Project Management Division of ERDA 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.

7.1.2 Status Summary

- a. The contents of a magnetic tape received from Purdue University was processed to a partitioned data set on the IBM 360/195 computer system. A print out of the data set showed that it contained many subroutines, and some data which could be used to test the subroutines. A test plan for the subroutines is being designed and should be put into operation late in September.
- b. The report describing the installation of DSS/2 was published and distributed.
- c. All the DSS Numerical Differentiators have been converted to double precision for operation on the 360/195. An increased accuracy of results was realized.
- d. The effect of scaling the constants used in the DSS/2 eleven point numerical differentiator was investigated. Results of the analysis should be available in September. Plans are being extended to repeat this analysis on other of the available differentiators.
- e. The status of the project was discussed with Mr. D. Falconer, the ERDA/FE Project Manager, during his visit to ORNL on August 17 and 18.

7.2 Synthetic Fuels Process Research Digest

R. W. Glass

7.2.1 Contract Objective

The objective is to provide continuing technical assistance to the Assistant Director for Processes of the Division of Materials and

Exploratory Research (DMER) by preparing digest reviews of current or potential subjects relating to coal conversion technology.

7.2.2 Status Summary

- a. Final reproduction mats for the article "Conversion of Methane to High-Octane Gasoline" and the associated final review have been completed.
- b. Reproduction mats for the article, "Flash Hydroxyolysis of Coal" have been prepared, and copies will be forwarded for final review during the second week of September.
- c. Comments on the article "Zinc Chloride Hydrocracking of Coal and Coal Extract" for inclusion into the final draft have been slow arriving, but are now being incorporated into production mats. Copies for final review will be forwarded soon.
- d. Minor corrections required for reproduction mats of "Catalytic Coal Gasification" have been completed. The article has passed draft review, and will be issued soon for final review.

7.3 Survey of Industrial Coal Conversion Equipment Capabilities

R. W. Glass and J. M. Holmes

7.3.1 Contract Objective

The general 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 Major Facility Project Management Division's (MFFM) programs.

7.3.2 Rotating Components (J. R. Horton, M. Siman-Tov, and W. R. Williams)

- a. A trip was made by J. R. Horton and W. R. Williams to discuss pumps and hydraulic turbines for coal conversion plants during the week of July 25-29. Companies visited were Bingham Willamette (Portland, OR), United (San Jose, CA), Pacific (Los Angeles, CA), Byron Jackson (Los Angeles, CA) and Wilson-Snyder (Dallas, TX). Airco Cryogenics (Irvine, CA), a compressor and expander manufacturer, was also visited before leaving the Los Angeles area. A trip report was prepared.

- b. A trip to discuss compressors was made by W. F. Boudreau on August 2. Discussions were held with American Demag in New York City. A trip report was prepared.
- c. Boudreau, Horton and Williams visited Allis-Chalmers (York, PA) on August 8 to discuss hydraulic turbines. A trip report was prepared.
- d. Otto Decker of Mechanical Technology, Inc., (Latham, NY) met with Boudreau, Horton and Williams in Oak Ridge on August 18. A report of this meeting was prepared.
- e. A draft of the final report is nearing completion and will be reviewed at ORNL during September. A final draft will be sent to MFPM at the end of September.
- f. Discussions with pump manufacturers have revealed that none have a proven multi-stage slurry pump of centrifugal design. Development of such pumps will proceed slowly unless there is a demonstrated market or government funding. For the near term, it appears likely that reciprocating pumps must be used for slurry applications.
- g. Hydraulic turbines are, at the present time, most frequently pumps which are run in reverse and use a different impeller than when run as a pump. Some companies are now developing equipment to be used specifically as hydraulic turbines.

7.3.3 Valves and Other Letdown Devices (W. A. Bush and E. C. Slade)

- a. Preparation of the final report is in progress. The response to the questionnaire sent to valve and actuator manufacturers represents 90% of the dollar volume of the industry.
- b. Valve responses are being categorized in the final report as to product availability for differing process applications, delivery time, materials of construction, and limiting manufacturing factors.
- c. A news item in regard to the ORNL valves for coal conversion study was published in the July and August editions of the Valve Manufacturers Association Monthly Newsletter. The Valve Manufacturers Association (VMA) membership represents 80% of the industrial valve business in the United States.
- d. Most manufacturers who responded to the survey have requested a copy of the final report.

7.3.4 Hot Gas Cleanup Devices (J. P. Meyer and M. S. Edwards)

During the reporting interval, the following work has been completed:

- a. A rough draft of the final report has been submitted to the following individuals for review:

- (1) Carl Jones
Stone & Webster Engineering Corporation
Boston, Massachusetts

Area of specialization - HTHP filtration, process economics.

- (2) Mack Lackey
Oak Ridge National Laboratory

Area of specialization - gas turbine technology.

- (3) Fred Moreno
Acurex Aerotherm
Mountain View, California

Area of specialization - HTHP particulate measurement.

- (4) Seymour Alpert and other personnel
Electric Power Research Institute
Palo Alto, California

Area of specialization - HTHP filtration

- b. Contact with the Jazco Corporation indicates that they have no significant HTHP filtration technology at present.

7.3.5 Heat Recovery Equipment Survey (W. R. Gambill and W. R. Reed)

- a. In early August, a questionnaire concerning their ability to design and fabricate 12 critical heat exchangers taken from three coal-conversion evaluation studies was sent to 23 companies specializing in large, severe-service units. Fluid streams include water/steam, coal/oil, syngas/char, flue gas, air, and various liquid and gaseous mixtures. Temperatures vary from 40° to 1700°F, pressures from 65 to 4280 psia, flow rates from 314×10^3 to 13.3×10^6 lb/hr, and heat loads from 76×10^6 to 2920×10^6 Btu/hr.
- b. Categorization of vendor literature was continued. It was learned that the Q-dot Corp. (Dallas and Los Alamos) will supply heat-pipe arrays made of aluminized steel pipes to operate in gases up to a temperature of 1300°F; one unit has operated in an 1125°F gas stream for about a year. Wyatt Industries, Inc., of Dallas has acquired a numerically controlled gun drill capable of drilling heat exchanger tube-sheets up to 42 in. thick. Large waste heat boilers are available; Kawasaki of Japan, e.g., produces custom made forced-circulation water-tube boilers generating up to 110 TPH of steam; the tube-panel structure reportedly accumulates a minimum of gas-side dust.

- c. Preparation of the draft report was begun.
- d. The heat recovery studies were summarized on August 25 for Mr. Carl Streed of the ORNL Coal Technology Program Advisory Committee.

7.4 Engineering Assistance

J. M. Holmes

7.4.1 Contract Objective

The objective is to provide engineering assistance to the Fossil Energy Major Facilities Project Management Division of ERDA.

7.4.2 Status Summary

The assistance requested to date on this project has been provided and the total costs are now about equal to the budget. Therefore, no further assignments on this project are expected in FY 1977.

7.5 Flash Hydropyrolysis

S. P. N. Singh

7.5.1 Contract Objective

The objectives are to perform a scoping study on two conceptual flash hydropyrolysis processes and to determine if a more detailed engineering evaluation of one of these processes is justified.

7.5.2 Status Summary

- a. The draft report was reviewed internally and certain changes were requested in the economic analyses of the two processes. The requested changes have been completed.
- b. We have requested additional information on the economics of the processes.

7.6 Hot Gas Purification Processes

M. S. Edwards and J. P. Meyer

7.6.1 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 (i.e., particulates, sulfurous gases, alkali metals, etc.) from coal-derived fuel gas prior to firing combined cycle turbines.

7.6.2 Status Summary

During the reporting interval, the following work has been completed:

- a. Information as to the particle size distribution of effluent from pressurized fluidized bed combustors (PFBC) has been obtained from:
 - (1) Acurex Aerotherm Corporation for data acquired at the Exxon Miniplant in Linden, New Jersey.
 - (2) Spectron Development Laboratories, Inc. for data acquired at the Argonne National Laboratory from their PFBC unit.
- b. Contact with developers of HTHP cleanup processes, as applied to coal technology, has revealed that:
 - (1) The R&D program at MERC is undergoing redefinition and is currently being held in abeyance. Information as to its new direction will not be available until late September.
 - (2) Exxon Research and Development Corporation has encountered significant operational problems with its cleanup system which consists of two stages of cycloning followed by a Ducon filter. In September, they will present a summary of their work, to date, at a conference in Washington.
 - (3) The Electric Power Research Institute's development program which involves testing of both Ducon and Brunsmet filters on power plant effluent will not get underway until late 1977.
- c. Contact with U.S.I. Chemical's Technical Director John Giachetto has indicated that he is unaware of any gas cleanup technique used by USIC in their processes for partial oxidation of naphthalene. His only knowledge regarding HTHP filtration used by USIC is in the application of porous metal filters to treat the effluent from a batch reactor system. Further information on this technique is being sought.
- d. After talking with James Hammond and Edward Gordon at Fluor Corporation, they disclosed the following information regarding cleanup techniques downstream of an ethylene cracking furnace:
 - (1) The first method involves the spray cooling of the raw product gas with either water or heavy oil. Both heat exchange and mass transfer occur in the process. In many ways, it is similar to the purification technique used in the Lurgi process and almost identical to the method used in the Lünen, West Germany combined cycle plant. Since it is desired to keep the raw gas at as high a temperature as possible, this technique does not appear applicable in our work.

- (2) A second arrangement is the use of shell and tube heat exchangers to treat the product gas. In this system, steam is generated on the shell side of the unit as the gas is cooled on the tube side. During the cooling, some coke deposit occurs on the tube wall, and it has been indicated that a well-designed system can operate from 60 to 90 days without shutdown. At the end of the exchange, a significant fraction of the particulate matter remains uncollected. Because of considerations regarding heat exchange and particulate removal, this technique does not appear to be a feasible HTHP cleanup alternative.

7.7 Large Air Separation Plant Study

W. R. Reed and W. R. Gambill

7.7.1 Contract Objective

The objective of this study is to determine if significant economies of scale would be provided by building single-train cryogenic air separation plants with capacities in the range of 2000 to 20,000 TPD oxygen production. The oxygen purity is to be 95 vol. % or higher; and the delivery pressure, within the range 1 to 70 atm abs., is to be determined by economics.

7.7.2 Status Summary

- a. The summary of the vendor survey and of other relevant activities was reviewed internally.

7.8 Review of State-of-the-Art of Processes for Heat Recovery

W. R. Gambill

7.8.1 Contract Objective

The objective of this review is 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 will be 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 will not be included. The review will distinguish between presently installable technology, near term developable technology, and future prospects. Consideration will be given to possible transfer of technology from other industries.

7.8.2 Status Summary

- a. Information was received on Rocketdyne's Dual-Medium Thermal Storage System. A 5 MWhr subsystem using 8000 gal of Caloria

HT⁴3 heat transfer fluid and 210 tons of granite rock was successfully tested. The maximum fluid operating temperature was 575°F (302°C). Rocketdyne is also evaluating techniques for storing thermal energy at temperatures up to 1000°F (538°C).

- b. Preparation of the draft report was begun.

7.9 Assessment of a Moving Bed System for Heat Recovery and Contaminant Removal from Raw Gasifier Gas

W. R. Gambill and R. W. Glass

7.9.1 Contract Objective

The objective is to evaluate the feasibility of a proposed moving bed system for recovery of heat and removal of sulfur and particulates from raw gasifier gas.

7.9.2 Status Summary

- a. A meeting of project personnel was held August 3, 1977 at ORNL with MFP representative Dr. T. Simpson. The meeting was to address (1) the process design submitted with the July progress report and concur on the basic design to be used for further evaluation, and (2) to select a gas cleanup system and gas handling capacity to be used as the basis for evaluation.
- b. At the suggestion of Dr. Simpson, and with general consensus of all attendees, the heat removal function of the filter system was eliminated from further substantive project consideration. The heat removal aspect appeared expensive and economically unjustifiable.
- c. The basic system selected for further analysis as a result of the August 3 meeting consists of a single-pass moving bed filter system in which there is no intentional cooling of the raw gas stream. Solids are fed from the filter to a fluidized sulfur oxidizer where sulfur and any carbon are oxidized and dust is elutriated. The oxidizer is fluidized by a recirculating stream of oxidizer off-gas and makeup oxygen. The amount of recirculating gas will be held to the minimum required for proper fluidization and elutriation. The possibility of direct production of elemental sulfur and Claus Unit feed gas in the oxidizer will be considered. The system will be designed for minimum practical heat removal.
- d. In selecting a cleanup system for comparison, reference was made to a 1977 report entitled "Comparative Evaluation of High and Low Temperature Gas Cleaning for Coal Gasification-Combined Cycle Power Systems" prepared by Stone and Webster Engineering

Corporation for the Electric Power Research Institute (EPRI). The report includes energy efficiency and cost estimates for five different coal gasification methods in combination with two gas cleanup systems. One is a conventional ambient temperature system for dust and sulfur removal, and the other is the Morgantown Energy Research Center (MERC) high temperature process using iron oxide as the sulfur sorbent.

Results of the study indicate that the MERC process offers a little better economy for most of the cases studied, and considerably better economy when used in conjunction with Lurgi gasifiers.

Since there are some similarities between the moving bed filter system and the MERC process, it was agreed that the evaluation would be made by comparing the two. In order to evaluate the most promising application, the raw gas conditions, analysis and quantity given in the EPRI report for Lurgi gasification with oxygen was selected for design basis.

- e. A followup meeting was held August 12, 1977 at ORNL to discuss with Dr. Simpson interim progress and further details of the basic system selected for analysis.

Process arrangements were considered for removing dust and sulfur from hot gasifier gas with iron oxide as the sulfur sorbent. Block flow diagrams were presented for arrangements using fixed bed, fluid bed, and moving bed systems for sulfur removal.

A preliminary process flow diagram for the moving bed system was presented. After some discussion, the basic flow scheme was adopted for comparison with the fixed bed system. Due consideration is to be given to heat exchange means for maximizing thermal efficiency.

Phone contact with MERC personnel was indicated for obtaining the latest information on producing elemental sulfur by reaction of FeS with SO_2 .

- f. A tentative date of September 23 was established at the August 12 meeting to review the consultant draft report and plan the last stages of the project.
- g. Information obtained by telephone conversation with MERC relative to their hot gas cleanup processing efforts indicate the following:

No reports have been published since the paper that was presented at an ACS meeting in San Francisco in September 1976.

Some consideration has been given to regeneration of the sulfided sorbent with SO_2 to form elemental sulfur. The idea has been abandoned because the reaction equilibrium is not favorable enough to offer any promise of technical-economic feasibility.

Properly supported iron oxide sorbents can be made strong enough for fluid bed processing. For such use the particles would be made spherical by pelletizing instead of cylindrical by extrusion.

The experimental program for the bench scale (16"Ø gasifier and 12"Ø absorber) has not been carried out. During shakedown runs, there were problems of absorber bed plugging by particulate carry-over from the gasifier. An efficient dust collector is required ahead of the absorber for proper operation of the fixed bed system. The program is being delayed a year or so in order to obtain additional basic information on the process. Meanwhile, MERC is doing development work on the Combustion Power Company moving bed filter and plans to use one for dust collection ahead of the absorber. Alumina pellets are used in the filter for dust collection. MERC plans to try replacing the alumina pellets with sulfur sorbent pellets for simultaneous cleanup of dust and sulfur.

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

R. W. Glass

7.10.1 Contract Objective

The objective is to determine if there is sufficient incentive to develop the subject process for production of hydrogen from coal.

7.10.2 Status Summary

- a. Project personnel met August 12, 1977 at ORNL with ERDA/FE/MFFM representative Dr. T. Simpson to review the final scope of the subject work. Mr. L. Seglin has accepted ORNL's request to assist in the project.
- b. Task 1 of the work is about 70% complete. The task pertains to the preparation of the data base needed for evaluation of technical aspects of the process. No unusual problems have been encountered.
- c. Task 2, development of conceptual flowsheets and estimates of material and energy efficiencies, is about 10% complete. Flowsheets have been prepared for three different systems for conducting the process.

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

J. Fisher, J. M. Holmes, and G. Peterson

7.11.1 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. The Lurgi gasification process and the HCOAL liquefaction process will be considered as reference source systems, and comparisons of control technologies will consider incineration as the reference control system.

7.11.2 Status Summary

- a. Proposed EPA standards, as of November 1977, for the CO₂ rich streams from the Rectisol plant in the Lurgi SNG process are:

nonmethane hydrocarbons less than 100 ppm,
CO less than 200 ppm,
all sulfur as SO₂
non-COS derived sulfur less than 30 ppmv, dry
basis at 2% excess oxygen,
no limit on methane and COS derived sulfur.

These regulations, when applied to processes other than incineration, require 99 plus % removal of nonmethane hydrocarbons, 90 plus % removal of CO, and 99 plus % removal of sulfur compounds.

- b. The representative gas stream under investigation is:

<u>Component</u>	<u>Moles/hr</u>
CO ₂	31,850 mol/h
H ₂ S	3
COS	3
C ₂ 's	384
CO	65
CH ₄	65
H ₂	75 mol/h
Temperature	100°F
Pressure	20 psia

The decontamination processes under investigation are:

Incineration

1. in a coal-fired boiler at 1800°F
2. in a medium-Btu gas-fired boiler at 1800°F
3. over a catalyst bed at 700° to 1000°F.

Absorption

1. decontamination by scrubbing with liquid CO₂ or liquefaction of the CO₂, followed by fractionation to produce a clean CO₂ vent gas and a recycle fuels stream
2. CO₂ absorption in hot carbonate or cold water.

Adsorption

on highly selective molecular sieves at low temperatures.

Diffusion

through porous membranes.

- c. No economic alternates to incineration have been found. While the accuracies of the costs of the alternate routes are in some cases poor, the cost differences between these routes and incineration are so large that the decision in favor of incineration is unquestionable.

The relative economics of the incineration alternates show catalytic oxidation to be the cheaper route, incineration in the coal-fired boiler to be intermediate in cost, and incineration with clean medium-Btu gas to be the most expensive. However, the question of suitable catalysts and their operating life is yet to be resolved. Further, the cost of incineration within a coal-fired boiler is very uncertain. Resolution of this cost may involve a major engineering effort.

Ball park capital and energy related costs are shown in Table 7.1. Capital is based on major equipment sizing from crude heat and material balances. Materials of construction in the low and some high temperature cases need further examination. Carbon steel was assumed for the first pass and may not be adequate.

- d. Adsorption on activated has been ruled out since Calgon Activated Carbon Corporation's analysis shows that the hydrocarbons will not be selectively adsorbed. Adsorption on molecular sieves will only be practical if very selective materials are found. This investigation is continuing. CO adsorption at practical temperatures will be very small.

Incineration of CO to guarantee levels of less than 200 ppm in 2% excess oxygen requires 1800°F according to J. Zink Co.

7.11.3 Problem Areas

The costing of the low-temperature liquid CO₂ processes and the low-temperature adsorption processes beyond very rough ball park

Table 7.1 Decontamination of Rectisol off-gases from
Lurgi SNG Process - CO₂-rich streams
Capital and energy related costs for treatment of
low-sulfur stream combined with Stretford treated
medium-sulfur stream

Process	Capital investment \$MM	Fuel use ^a \$MM/yr	Steam use ^b \$MM/yr
<u>Incineration</u>			
Coal-fired boiler	8	~0	~0
Med. -Btu gas-fired boiler	6	12	< 5 >
Catalytic oxidation	10		<1.8>
<u>Absorption</u>			
Liquid CO ₂ scrubbing	110		>25
CO ₂ condensation	60		~10
Hot carbonate scrubbing	35		19
Cold water scrubbing	110		8
<u>Adsorption</u>			
Refrigerated adsorption of C ₂ 's	50		8
<u>Cupro-ammonium process</u>			
	Incomplete		
<u>Membrane separations</u>			
	Incomplete		

^aCoal priced at \$0.3/MM Btu, med.-Btu gas at \$3.50/MM Btu.

^b900 #/825°F steam at \$1.35/M lb for coal at \$0.3/MM Btu.

estimates will require a great deal of design effort. In view of the indicated incremental capital and energy related costs over incineration, this effort does not appear to be justified.

Accurate comparisons between the alternate incineration routes may require engineering effort beyond the scope of this project. The estimation of the cost of incineration in a coal-fired boiler will probably have to be subcontracted to a boiler manufacturer.

Catalyst manufacturers are being contacted concerning the availability and performance of oxidation catalysts for this service.

8. PROCESS AND PROGRAM ANALYSIS

J. R. McWherter

Process and program analysis studies are being conducted for the ERDA Fossil Energy Office of Program Planning and Analysis. 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

Activities in August 1977 involved work on summarizing the collected process data and on planning the outline and format of the draft report. Work forecast for September 1977 includes completion of the report sections and preparation of the draft report for the project.

8.1.1 Process Data

Technical data subsections for 10 additional processes were prepared for review. Six subsections were prepared in July and the remaining 5 will be completed in early September. Data were assembled and summarized in August for the following processes.

Fixed Bed: Woodall-Duckham

Fluidized Bed: Battelle-Union Carbide Agglomerating Burner
BCR TRI-GAS
HYGAS
Synthane
Winkler

Entrained Flow: BI-GAS
Koppers-Totzek

Molten Bath: Atomics International
Saarberg/Otto (Rummel/Otto)

8.1.2 Process Comparisons

Work continued on the comparison of the 21 processes of most interest. Topics that are being considered for this section of the report include status, capacity, operating conditions, coal type, product characteristics/ composition and efficiency.

8.1.3 Process Considerations

Dr. B. L. Crynes, consultant to the project and professor of Chemical Engineering at the Rose-Hulman Institute of Technology participated in the

work at ORNL on August 22-24. Potential problem areas were listed by him for the 21 gasification processes in the Process Data Section. Some of the potential problem areas have been specifically mentioned in the literature and others were anticipated from comparisons to similar gasifiers and systems. Material based on Dr. Crynes' work will be included in both the Process Data and Process Considerations sections.

8.1.4 Report Planning

A draft report is scheduled for completion on September 30, 1977. The report outline was reviewed and modified. The following major sections are now planned.

1. Introduction and Summary
2. Process Survey Summary
3. Screening and Selection
4. Process Data
5. Process Comparisons
6. Process Considerations
7. Conclusions

The format of the report was established. Typing began on the Process Data Section which will be the longest section of the report. Sections 2 and 3 are complete but will need minor revisions.

8.1.5 Presentations

The status of the low Btu coal gasification study was summarized briefly in two presentations. Dr. C. DiBella and Dr. L. M. Joseph (project manager) of the US ERDA-Fossil Energy-Office of Program Planning and Analysis were provided status information on August 19, 1977, at which time Dr. Joseph suggested additional sources of process data. A second presentation was made on August 25, 1977, to Mr. Carl Streed of the Mobil Research and Development Corporation. Mr. Streed is a member of the ORNL Coal Technology Program Advisory Committee.

8.1.6 Pittsburgh Meeting

H. F. Hartman attended the conference entitled "Coal Gasification, Liquefaction and Conversion to Electricity" that was held at the University of Pittsburgh on August 2-4, 1977. Information was acquired from talks and papers on the status of the following gasification processes: Combustion Engineering, HYGAS, Synthane, Westinghouse, and Winkler. A number of related useful papers were obtained including: a description of the ERDA "Gasifiers in Industry" program, a discussion on fuel gas usage and small gasifier applications, a comparison of estimated costs for central versus on-site gasification plants and a comparison of coal gasification process characteristics.

8.1.7 Work Forecast

September activities will emphasize preparation of the draft report that presents the work completed in the study. The process data and

process comparison sections will be finished. Process considerations and conclusions will be discussed. The summary section will be done and the draft report will be typed, reproduced and distributed.

8.2 Direct Combustion

E. C. Fox, T. D. Anderson, and H. I. Bowers

8.2.1 Objectives

The purpose of this study program is to assist ERDA/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 ERDA/FE relative to the most promising approaches to increasing the near-term use of coal.

8.2.2 Results

E. C. Fox visited Sears Roebuck & Co. in Chicago on August 24, 1977. L. R. Green, Sears' Corporate Energy Resource Planner, discussed Sears' viewpoint on utilizing direct coal combustion for their commercial facilities. Sears had considered coal for their new expansion of the St. Louis distribution center, but discarded that option for a number of reasons.

- The lack of reliable pollution control equipment to allow them to burn high sulfur coal with a reasonable guarantee that emission standards would be met.
- Inability to obtain long term coal contracts.
- Excessive lead times required to meet state and local requirements for permits.
- High rail rates for the low volume shipments.
- High cost of coal combustion equipment and handling facilities.

About 80% of the first task has been completed to date. The environmental, user, and economic assessment of direct coal combustion for the small industrial and residential/commercial users has led to a number of conclusions:

- a. Potential industrial users are wary of converting to coal for several reasons:
 - . The risks associated with coal combustion -- both technical and economic -- are high.
 - . The uncertainties of regulatory policy toward ambient air quality adds to these risks.
 - . The company's competitive position restricts the availability of capital for conversion projects.
- b. From the economic analysis performed during the course of this study, the following conclusions were made;
 - . Small users cannot obtain competitive transportation rates.
 - . Not only is coal quality and source of supply important in the design and costing of a coal fired plant, but small users are unable to secure long-term coal contracts.
 - . Because of the higher coal price and expensive equipment needed, switching to direct coal combustion does not look promising for small industrial users.
 - . Using coal for space heat will not be a viable economic option if alternate fuels are available.
 - . Including escalation in the economic analysis improves the competitive position of coal, as does the proposed investment tax credits and boiler fuel taxes.
 - . Advanced combustion technologies may have the potential to improve the comparative position of direct coal combustion relative to oil and gas slightly, but the key economic barriers will remain unchanged.
- c. Conclusions regarding the environmental effects of converting industry to direct coal combustion include:
 - . There is at present, technology to burn coal to meet present environmental standards.
 - . Any conversion to coal will result in environmental degradation from increased emissions and solid wastes.
 - . Those areas of the country with serious pollution problems at present will have difficulty absorbing new increases.
 - . The areas with high industrial concentrations will be required to offset new emissions.

- . Areas with light industrial concentrations and good ambient air conditions may be able to convert without serious environmental damage.
 - . Even if environmental restrictions for combustion units are successfully met, public concern over some of the impacts may preclude industrial conversion.
- d. For the near term, the logistics needed to convert the industrial sector to coal looks promising.
- . Adequate manufacturers and facilities to produce coal-fired boilers.
 - . Adequate rail and barge transportation systems to haul coal.

These results, along with some details of the economic analysis, were presented to Carl DiBella and Larry Joseph of ERDA's Fossil Energy Division.

8.3 Advanced Power Conversion Systems

A. P. Fraas,* G. Samuels, M. E. Lackey,
W. M. Wells, S. Thompson, and Fred J. Young*

All twelve reports covering this work have been completed. These reports have been sent to experts on the various systems covered in this series for their review and comments. A list of these reports is tabulated below.

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

*Consultant.

12. Comparison of Advanced Energy Conversion Systems on the Basis of R&D Experience

8.4 Liquefaction

The Ralph M. Parsons Company is working under subcontract on this subprogram with J. B. O'Hara as Project Manager.

8.4.1 Survey of Liquefaction Processes

The preliminary report (Data Source Book) summarizing the characteristics of 32 liquefaction processes reviewed during the screening survey has been edited. Draft copies will be submitted to ORNL for review prior to final printing.

8.4.2 Detailed Review of High Potential Liquefaction Processes

Draft copies of Interim Report No. 1 "Coal Liquefaction Processes Research, Mobil M - Gasoline Process," dated June 24, 1977 were transmitted to ERDA and Oak Ridge National Laboratory for review and comment.

This study covered a complex to produce 50,000 barrels per day of gasoline by the use of the Mobil M - Gasoline Process. The grass roots complex includes facilities for:

- a. production of synthesis gas from coal.
- b. conversion of synthesis gas to crude methanol.
- c. production of gasoline by the conversion of crude methanol to gasoline using the Mobil M - Gasoline Process.
- d. ancillaries and off-sites to serve the process plants and the total operation of the complex.

The results of the study indicate that:

- a. the cost of the facility is about \$1.6 billion based on mid-1977 construction costs
- b. economic analysis of the various components contributing to the required plant limit selling price of the gasoline indicate that approximately 75% of the cost is for production of synthesis gas. The conversion of synthesis gas to methanol and the methanol to gasoline conversion each contributed about equally to the remaining 25% of the cost
- c. prime development efforts to reduce cost should be directed to the synthesis gas production unit

8.4.3 Standard Techniques for Process Evaluation

The process evaluation techniques are being reviewed prior to issuance.

8.4.4 Uniform Economic Comparison Basis

The economic comparison procedures are being finalized.

8.5 High Btu Gas

This subprogram is being analyzed under subcontract by the Scientific Design Company, Incorporated (SD) with A. S. West as Project Manager.

8.5.1 Contract Objective

The objective of the work is to provide technical and economic evaluations of competing processes, concepts, and systems for the production of high Btu gas from coal.

8.5.2 Status Summary

During the month of August work was directed in the following areas:

1. The Battelle Agglomerating Ash Burner Process Evaluation has been finalized and will be sent to ORNL for final review and approval prior to issue.
2. All of the variables to be used in "Generalized Approach to High Btu Coal Gasification Economics" have been established and a preliminary report is being prepared.
3. On the Hydrogen Production Study the use of an entrained bed reactor as an alternative to a fluidized bed has been considered.

8.6 In Situ Coal Gasification

W. C. Ulrich

8.6.1 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.

8.6.2 Status Summary

- a. Design of the syngas plant was completed. The plant was designed to produce 386 MMscf/day of a synthesis gas suitable for further chemical conversion.
- b. Capital and operating cost estimates were prepared for both the SNG and syngas plants. These estimates gave product prices ranging about \$1.77 to \$7.23/10⁶ Btu for SNG, and \$1.46 to \$6.36/10⁶ Btu for syngas, depending on cost of coal, type of financing assumed, etc.

- c. Writing of the draft economic evaluation report was started. Sections completed include introduction, process descriptions, basis for design and process assumptions, capital investments, and environmental considerations. Sections remaining to be finished are summary of results, operating costs, and economic analysis.
- d. Oral presentations of the status of the in situ coal gasification evaluation project were made to representatives of OPPA on August 19, 1977 and to the Coal Technology Program Review Committee on August 25, 1977, at ORNL.
- e. A memo which summarized capital and operating cost information developed to date for the three plants being evaluated was submitted to OPPA on August 30, 1977.

8.6.3 Open Items

Review by OPPA (and others) of the draft report, "Evaluation of In Situ Coal Gasification on a Regional Basis," is continuing.

8.7 Coal Beneficiation

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

8.7.1 Contract Objective

The objective of this project is to provide technical and economic evaluations of current beneficiation processes.

8.7.2 Status Summary

- a. The changes in the text of the draft of the interim report that were requested by ERDA/FE-OPPA have been completed.
- b. The economic analyses of conceptual grassroots-type mechanical coal beneficiation facilities and the Battelle Hydrothermal Coal Process for beneficiating the Illinois coal have been completed. The economic analyses are currently being performed for the above mentioned beneficiation of the Western Kentucky coal.

8.7.3 Changes

We were requested by ERDA/FE-OPPA to also perform economic analyses for the case where the beneficiation facilities are treated as battery-limit type plants.

8.8 Gas Cleanup Studies

M. S. Edwards and R. Salmon

8.8.1 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.

8.8.2 Status Summary

- a. Process descriptions have been written for the Benfield, Selexol, Sulfinol, Stretford, and MDEA processes.
- b. Vendors for the Benfield and Selexol processes have reviewed their respective process descriptions. Responses were favorable and no major corrections were required.
- c. Vendors for the remaining processes have not yet responded with comments on their respective process descriptions.

8.9 Coal Prices and Volumes

O. L. Culberson*

Comments on the draft report are arriving late. Comments should be received and incorporated within one to two weeks.

8.10 The Potential of the Synthesis of Chemicals from Coal as an ERDA Research Program

This work is being done under subcontract by the Radian Corporation with D. N. Garner as the Project Director.

The draft final report was completed and submitted to ORNL and ERDA/FE/OPPA for review.

*Consultant.

9. FOSSIL ENERGY ENVIRONMENTAL PROJECT

C. R. Boston

9.1 Landfill Storage of Coal Conversion Solid Wastes/Information Assessment

H. M. Braunstein

Finalization of the document is proceeding with delivery to ERDA expected in September 1977.

9.2 Landfill Storage of Coal Conversion Solid Wastes/Experimental Phase

W. J. Boegly, Jr.

Samples of waste from the Hygas Pilot Plant (IGT) and Agglomerating Burner (Battelle-Columbus) have been shipped to ORNL. Samples of feed coal will also be included with shipment. Materials have not reached ORNL as of August 30, 1977. Staffing of the project has been completed with hiring of a new technician and acceptance of a job offer by a soil chemist. Part-time assignments have also been requested for two other members of the existing ORNL Fossil Energy Environmental Project.

Savannah River has been contacted about design details on the lysimeters used in their radioactive solid waste leaching studies. They currently are fabricating and installing more than 30 each, 6-ft-diam units. We will probably use Fiberglas or concrete tile units.

9.3 Environmental Monitoring Handbook

S. G. DeCicco

The Handbook is now being used extensively by contractors and their environmental subcontractors in designing monitoring programs for the nation's first fossil demonstration plants (pipeline gas).

This has become an extremely important position document in our role as advisors to the contractors in developing the environmental reports and ultimately in our role as authors of the environmental impact statements.

Discussions were held with Hershel Jones (ERDA/FE/MFPM), and Radian Corporation on August 3 and again on August 11 regarding possible additions to the Operation part of the Handbook. It was agreed that Radian would contribute a subsection on process monitoring. This will be incorporated, along with other changes, in Revision 3 of the document.

The intense involvement with contractor interaction will require a delay in delivery of Revision 3 from October 1 to November 1, 1977.

9.4 Programmatic Assessment/Pipeline Gas

S. G. DeCicco

This task has been placed on "hold" at ERDA request (telcon, H. T. Jones, August 8, 1977). No further work is expected this fiscal year.

9.5 Programmatic Assessment/Fuel Gas

S. G. DeCicco

This task has been placed on "hold" at ERDA request (telcon, H. T. Jones, August 8, 1977). No further work is expected this fiscal year.

9.6 Technical Assistance

Considerable team effort went into this task during the month of August, mainly in interaction with contractors in preparing environmental monitoring programs. A number of meetings were held to discuss proposed monitoring plans. Fossil Energy Environmental Project members participated in a site visit to the Illinois Coal Gasification Group (ICGG) demo plant location and in a three-day work session at ORNL to assist the environmental subcontractor (Gibbs & Hill) in developing a detailed monitoring program.

Kickoff meetings with the contractor (CONOCO) and environmental subcontractor (Westinghouse Environmental Systems Department [WESD]) were held at ERDA headquarters to discuss monitoring plans for the Ohio demo plant.

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