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

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OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION FOR THE ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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COAL TECHNOLOGY PROGRAM
PROGRESS REPORT FOR MAY 1977

Date Published: July 1977

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COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR MAY 1977

ABSTRACT

This report — the thirty-fourth 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 critical components test facility, engineering and support studies, process and program assistance, environmental assessment studies, and coal-fueled MIUS.

1. SUMMARY

J. P. Nichols

Highlights of our progress in May are as follows:

- In Hydrocarbonization Research two successful operability tests with sustained operation of the bench-scale hydrocarbonizer were achieved with Illinois No. 6 coal diluted with char (5 parts char per part of coal). Experiments with reduced concentrations of char are planned for next month.
- In our project for pressurized carbonization of Consol Synthetic Fuel Residue, the preliminary results of four successful tests indicate that coking of the most valuable <700°F fraction of the residue is small (about 7%) and is insensitive to pressure (50 and 400 psi). Coking of the high boiling fraction is greater and increases with pressure.
- In our studies of piping and pressure vessels sections of 2 1/4 Cr-1 Mo steel have been subjected to heat treatments that simulate the 1/4 thickness locations in 25 to 30 cm (10 to 12 in.) plates that were quenched, tempered, and postweld heat treated during processing. Steel of this section was able to satisfy the minimum tensile requirements for the SA 387 Class 2 material specification.
- Several activities are in progress for the nondestructive testing of coatings. Our first-year review report on plasma-sprayed coating is in technical review. A survey of fossil-energy coating users to determine programmatic NDT needs is in progress. We are still setting up our line scan IR camera; a new heat-transfer code is now on the main ORNL computer system. Eddy current work has been reduced. We have designed and are fabricating a new crack specimen for surface inspection work. A topical report draft on high voltage testing is being written.
- A gas mixture that allows stable spray mode gas-metal-arc (GMA) deposition of Alloy 20 cladding has been found.

- Failure analysis activities included examination of several components from the solvent refined coal plants at Wilsonville, Alabama, and Tacoma, Washington.

- In our gas-fired potassium boiler project, we completed all of the design work except for several of the instrument and control drawings, selected an air preheater for startup, and completed most of the construction work on the equipment tower. In the next month we will complete construction of the equipment tower and begin the installation of connecting piping.

- In our design studies of a coal-fired alkali metal vapor topping cycle, we have completed the first phase of a cycle analysis and the design and analysis of a metal vapor turbine. We continued the design of an atmospheric pressure fluidized bed furnace, the condenser-steam generator, and the layout work for the overall system.

- The report entitled Critical Component Test Facility - Advance Planning for Test Modules was published. This report presents the planning study for the conceptual design of component test modules on a nonsite-specific basis. For the purpose of this study, tests of lock hopper valves, slurry pumps, continuous solids feeders, and hot gas cleanup systems were considered. The Stearns-Roger Engineering Company, of Denver, Colorado, assisted in the study, and their design recommendations and cost estimates are included.

- In our engineering studies and evaluation project we continued work on process modeling; preparation of a Synthetic Fuels Research Digest; a survey of industrial coal conversion equipment capabilities; and studies of fluidized bed hydrothermal liquefaction, rapid hydrogenation, hot gas cleanup, large air separation plants, and processes for heat recovery.

- In our process and program analysis project we continued studies of low-Btu gasification, high-Btu gasification, liquefaction, direct combustion, advanced power conversion, and coal beneficiation.

- In our fossil energy environmental project we received comments and are finalizing our report on the landfill storage of solid wastes from coal conversion; are continuing the planning of an experimental project for landfill storage; and are continuing the preparation of an Environmental Monitoring Handbook, a Programmatic Assessment of Pipeline Gas, and a Programmatic Assessment of Fuel Gas.

- In our coal-fueled MIUS project we completed a series of successful tests of the coal feeding system, and a report on the analysis of 500-hr fire-side corrosion tests in a fluidized bed combustor. Our corrosion specimen tubes were returned to Fluidyne for an additional 500 hr of exposure for corrosion testing.

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

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

2.1.1 Experimental Development

Work Accomplished. Distributor plate and char fluidization tests were carried out in the ambient mockup during May. Three distributor plates were evaluated in the recirculating fluidized bed model: a 54-hole plate with 3/64-in-diam holes (identical to plate in the bench-scale reactor), a 42-hole plate with 0.005-in-diam holes, and a 42-hole plate with 1/64-in holes. Only the plate with 1/64-in holes distributed gas well under realistic conditions using 30-45 cm H₂O pressure drop. Table 2.1 summarizes minimum fluidization data on char from Run HC-12. Experimental and calculated minimum fluidization velocities agree satisfactorily using gases with markedly different properties.

In the atmospheric pressure carbonizer one test was made using pure Illinois No. 6 coal at 1200°F; however, caking occurred early in the run and no data were obtained.

Work Forecast. Experiments will be carried out in the ambient mock-up with the 1-in-diam draft tube in June, evaluating different draft tube elevations above the distributor plate. The atmospheric pressure carbonizer will be used to prepare char for use as an inert diluent for the bench-scale hydrocarbonization system.

2.1.2 Bench-Scale Hydrocarbonization System

Work Accomplished. During May further progress was made toward attaining operability of the bench-scale hydrocarbonization system with caking Illinois No. 6 coal. Two operability tests, Runs HC-16 and HC-17, were completed successfully in which Illinois No. 6 coal,

Table 2.1. Minimum fluidization conditions for HC-12 char

Char density^a: 1.05 g/cm³Char weight-mean diameter: 165 μ m

Temperature: 20-35°C

Pressure: 1.0 atm

Voidage at minimum fluidization: 0.58

Bed pressure drop at minimum fluidization: 0.45 cm H₂O/cm bed

Minimum fluidization velocity (m/sec)		
<u>Gas</u>	<u>Experimental</u>	<u>Calculated</u> ^b
Helium	0.0149	0.00850
Nitrogen	0.0122	0.00969
Argon	0.0073	0.00756

^a Effective particle density for fluidization calculations; determined by mercury pycnometry.

^b Method of Wen and Yu, AIChE Journal, 12, 610 (May 1966).

diluted with char, was fed to the 825°F reactor bed. Several modifications to the system have improved feeding performance and system control.

The following modifications were made to the system prior to Run HC-16:

1. A high pressure purge line was connected to the scrubber pressure tap (PR-50).
2. Hydrogen supply to the draft tube was rerouted to bypass the preheater.
3. The coal feed line was shortened to be flush with the distributor plate.
4. An alumina sheath, 1/4-in. thick, was installed to insulate the feed nozzle as it enters the reactor.

5. The 3/4-in. draft tube was replaced by a 1-in. draft tube.
6. The deflector above the draft tube was raised from 6-in. to 12-in. above the draft tube.
7. Corrosion coupons were removed from the cyclone dipleg.
8. Four segmental baffles were installed inside the cold trap. The sections between baffles were packed with wire mesh, fiberglass, and cotton filter medium respectively.

Run HC-16, the second operability test with Illinois No. 6 coal, was our first successful attempt to sustain feeding of caking coal to the reactor. A mixture of one part Illinois No. 6 coal to five parts char (devolatilized at 1200°F) was fed to the reactor at a rate of 11.4 lb/hr for a period of 1.25 hr. The reactor bed was at 825°F at 300 psi hydrogen pressure. To aid in handling agglomerating coal, the hydrogen feed rate was increased from 10.7 SCFM used in Run HC-15 to 19.0 SCFM in this run. The higher hydrogen supply rate assures recirculation of the bed of char in the reactor.

The initial attempt to start Run HC-16 encountered some difficulties. Shortly after the initiation of coal feed, system pressure control became unstable because some tars that were not knocked down by the scrubber reached the pressure control valve fouling the trim. The system was shut down and the cold trap filter assembly (described above) was installed to entrap this material. Before continuing the run a starter bed of char was loaded directly into the reactor. With these changes coal was fed continuously for 1.25 hours before the coal feed line plugged terminating the run. The hydrogen flow rates in the reactor and superficial velocities, assuming no bypassing, were: downcomer - 11.0 SCFM, 0.29 ft/sec; draft tube - 8 SCFM, 2.6 ft/sec (assuming 450°F average temperature); and coal transport tube - 7 SCFM, 57 ft/sec.

During postrun inspection of the reactor it was discovered that thermal stress had caused the transport tube to break free of the draft tube nozzle screen and slip under it. This restriction was responsible for the feeding difficulties and poor reactor bed circulation.

After run HC-16 a radial spacer was installed at the end of the coal transport tube to hold it rigidly in the center of the draft tube nozzle, and the internal cyclone was removed.

Run HC-17 was the third operability test with Illinois No. 6 coal. A mixture of one part coal to 6 parts char was fed at a rate of 9.6 lb/hr for 7 hours without interruption. The reactor bed was at 825°F and 300 psig hydrogen pressure. A partial blockage in the reactor char overflow line after seven hours of steady operation terminated the run. During the period of steady operation the axially spaced reactor bed

temperature measurements were very uniform indicating good bed recirculation. The hydrogen flow rates were the same as for Run HC-16 and a char starter bed was used as in Run HC-16.

After Run HC-17 there was only a light coat, $\sim 1/16$ " thick, of agglomerate material clinging to the reactor walls. There was little tar in the scrubber and cold trap liquids, but the cold trap filter collected 1.2 lb during the run.

Oil yield, carbon balance, and evolved gas composition data from the 14 Bench Scale Hydrocarbonization experiments with Wyodak subbituminous coal are presented. A summary for each run is in Table 2.2. Figure 2.1 presents oil yield as a function of temperature at 300 psig hydrogen pressure for the five steady-state experiments employing the recirculating fluidized bed reactor. For comparison, oil yield data from two other hydrocarbonization investigations on Wyoming subbituminous C coal are included. A uniformly fluidized bed reactor was used in both of these studies. Also shown in Table 2.2, the composition of gas evolved during hydrocarbonization of Wyodak coal at 300 psi hydrogen pressure showed the following trends as the reactor temperature increased over the range 790°F to 1070°F:

1. CH_4 - increased from 33% to 50%
2. CO - increased from 12% to 23%
3. CO_2 - decreased from 37% to 3%
4. C_2 's and C_3 's - approximately constant at 14%

Table 2.3 lists the specific gravity (ASTM D1298-67) viscosity (ASTM D445-74), and ultimate analysis of typical product oil from Wyodak coal (obtained during Run HC-12). This oil was produced at 1030°F reactor bed temperature and 300 psig hydrogen pressure. Figure 2.2 is the simulated boiling point curve (ASTM DZ807-73) for the oil. Particulate matter was filtered from the oil before the above analysis.

Table 2.3. HC-12 scrubber oil

Specific Gravity	1.074
Viscosity (cs)	
At 100°F	18.4
At 210°F	2.6
Composition (%)	
Moisture ($\leq 105^\circ\text{C}$)	0.68
Ash	< 0.01
Carbon	84.76
Hydrogen	7.35
Nitrogen	1.02
Sulfur	0.28
Oxygen (difference)	6.9

Table 2.2. Summary of hydrocarbonization experiments with Wyoming subbituminous coal.

Hydrocarbonization Run No.	HC-1 ^a	HC-2 ^a	HC-3 ^a	HC-4 ^a	HC-5 ^a	HC-6 ^a	HC-7 ^a	HC-8	HC-9	HC-10	HC-11	HC-12	HC-13	HC-14
Uniformly or recirculating fluidized-bed reactor (UFB or RFB)	UFB	UFB	UFB	UFB	UFB	UFB	RFB	RFB	RFB	RFB	RFB	RFB	RFB	RFB
Bed temperature, °F	1075	1050	910	1000	965	1030	820	790	955	1050	1035	1025	905 ^b	1070 ^c
Reactor pressure, psig	300	300	300	300	300	150	300	300	300	300	300	300	300	300
Coal Feed														
Rate, as-received, lb/hr	1.3	8.5	13.2	14.0	15.5	16.3	14.8	13.6	6.8	4.4	8.9	10.2	11.1	9.2
Elapsed time, hr	9.6	13.2	8.1	7.3	7.7	5.1	6.9	6.2	4.8	10.6	2.3	10.5	10.3	6.0
Hydrogen feed rate, scfm	6.48	4.86	4.42	4.71	4.55	2.28	6.90	10.04	10.34	10.28	10.21	10.21	10.23	10.23
Oil yield, ^d wt% of maf coal	8.7	10.3	11.2 ^e	8.7	6.7	8.0	5.4	6.1	3.1 ^e	15.3	-- ^f	18.1	15.4	21.0
Carbon recovery														
% in char ^d	51.5	51.3	69.9	65.1	63.2	66.2	73.3	71.4	68.6	56.4	-- ^f	61.3	70.3	58.4
% in liquid ^d	11.7	14.3	14.4	12.8	8.4	10.1	6.7	6.0	5.5	15.6	-- ^f	17.8	13.4	18.5
% in gas ^d	29	23.5	13.7	23.4	21.1	19.2	11.5	7.1	10.2	15.6	-- ^f	12.6	10.4	18.4
Overall ^d	92	89.0	98.0	101.2	92.6	95.5	91.5	84.5	84.3	87.6	-- ^f	91.7	94.1	95.3
Steady state gas analyses (H ₂ and N ₂ Free)														
% CH ₄	64.0	49.7	34.7	44.2	43.9	40.8	18.0	40.2	51.0	50.8	44.8	47.1	40.6	50.8
% C ₂	14.0	11.4	12.0	13.4	14.0	12.5	11.4	6.8	8.0	12.7	8.9	12.3	9.5	13.6
% C ₃	7.0	7.7	8.9	7.9	7.1	5.6	8.3	2.1	2.0	2.0	3.2	3.7	7.4	3.8
% CO	14.0	19.3	14.8	19.1	16.6	16.1	15.4	11.7	15.0	20.8	26.7	21.1	14.2	20.5
% CO ₂	0	11.2	28.4	14.9	18.0	24.2	34.7	37.0	23.0	3.0	7.3	8.3	21.0	4.2

^aCoal used in runs HC-1 through HC-7 was exposed to air during grinding and sizing. For subsequent runs, coal has been prepared in an inert atmosphere.

^bTime-average temperature. Operated at 950° for 4.6 hr, lost bed during shutdown, restarted at 950° for 1.8 hr, dropped to 900° for 0.8 hr, then 810° for 3.1 hr.

^cTime-average temperature. Operated at 1100° for 6.0 hr, dropped to ~1065° for 1.1 hr, then 1010°F for 1.5 hr.

^dPreliminary calculations, pending comprehensive evaluation of data.

^eOil yields in HC-3 and HC-9 are questionable because of operational, sampling, and analysis problems.

^fSteady-state period was too short to produce yield data.

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Fig. 2.1. Liquid hydrocarbon yields from hydrocarbonization of subbituminous C coals at 300 psi hydrogen pressure. a. Reported yield includes water (4). b. Corrected for water based on published correlation (3).

Fig. 2.2. Simulated boiling point curve for oil produced during the hydrocarbonization of Wyodak coal.

Work Forecast. Experiment HC-18 will be performed with Illinois No. 6 coal diluted 6/1 with char from Run HC-17 devolatilized at 1200°F in the atmospheric carbonizer. Reactor bed temperature will be raised to 1050°F. Sustained operation at higher bed temperatures and/or lower char/coal dilution ratios are objectives for future experiments.

Further analysis of the results of experiments performed with Wyodak coal will be reported when completed.

2.2 Experimental Engineering Support of an In Situ Gasification Process

J. B. Gibson and L. S. Dickerson

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.

Personnel changes occurred during May, and run BP2-29 was carried out as a training run. In BP2-29, bituminous coal was heated at a rate of 6.1°C/min for the first 85 min; followed by a heating rate of 1.9°C/min for 90 min. A maximum temperature of 700°C was held until devolatilization was complete, approximately 8 hours. The remainder of the month was spent familiarizing the new personnel with the experimental program.

2.3 Coal-Solvent-Hydrogen Mixing

J. M. Begovich, R. C. Lovelace, and J. R. Hightower, Jr.

Studies of liquid mixing in coal-solvent hydrogenation reactors have continued. A total of 124 pulse test measurements have now been completed in the 1-in.-ID x 10-ft-long column packed with 4.6-mm-diam glass beads using air and a 35 wt % coal-water slurry in cocurrent up-flow. At 25°C and 1 atm this coal-water slurry has a density of 1.14 g/cm³ as measured with a hydrometer and a viscosity of 22.4 cP using a reverse flow Cannon-Fenske viscometer. This compares to an apparent viscosity of 90 cP using a Brookfield Synchroelectric viscometer. Flow rates used were in the range of 0-230 cm³/sec and 1.25 - 21.3 cm³/sec for the air and slurry, respectively, and encompass the liquid and gas volumetric flow rates (3 cm³/sec slurry and 100 cm³/sec gas at 4000 psi and 450°C) used in the 1.1-in.-diam Synthoil development reactor at the Pittsburgh Energy Research Center (PERC).

The preliminary information obtained from the first 72 pulse test measurements with the coal-water slurry is summarized in Table 2.4. Calculations for all of the runs have not been completed and conclusions from these results cannot yet be drawn, but some preliminary observations can be made. The liquid holdup with respect to the void volume, R_L , also known as liquid saturation, is plotted vs the slurry flow rate,

Table 2.4. Preliminary results of dispersion and pressure drop experiments in a glass column packed with 4.6-mm-diam glass beads with cocurrent upflow of air and coal slurry

Column Diameter = 2.54 cm
 Column Length = 310 cm
 Bed Porosity = 0.42

Run number	Liquid flow cm ³ /sec	Gas flow cm ³ /sec	Liquid holdup, ϵ_L (fraction of total bed volume)	Liquid saturation, R_L (fraction of void volume)	ΔP psi	Peclet number Pe	Dispersion coefficient, D cm ² /sec	Energy dissipation per unit volume $\frac{v_L \Delta P_f}{L}$ ft. lb _f . ft ⁻³ . sec ⁻¹
140	10.13	0	0.371	0.884	6.1	63.3	26.4	5.6
141	10.41	0	0.371	0.883	6.1	94.8	18.2	5.8
142	10.41	0	0.367	0.874	6.1	78.6	22.2	5.8
143	10.48	0	0.363	0.864	6.1	65.9	26.9	5.8
144	12.75	0	0.380	0.905	7.6	64.4	32.0	8.8
145	12.76	0	0.378	0.900	7.6	104.9	19.8	8.8
146	14.88	0	0.374	0.891	9.1	61.6	39.6	12.3
147	14.88	0	0.363	0.865	9.1	28.5	88.0	12.3
148	14.88	0	0.374	0.891	9.1	63.5	38.4	12.3
149	17.14	0	0.387	0.921	9.8	72.7	37.4	15.3
150	17.00	0	0.368	0.875	9.8	12.2	232.3	15.2
151	17.00	0	0.377	0.897	9.8	21.7	127.6	15.2
152	19.83	0	0.380	0.904	11.5	77.3	41.5	20.8
153	8.15	82.85	0.174	0.414	11.2	9.1	316.4	8.3
154	9.21	83.95	0.200	0.476	11.2	25.2	112.4	9.4
155	9.21	82.85	0.188	0.448	11.2	8.2	367.8	9.4

Table 2.4. (continued)

Run number	Liquid flow cm ³ /sec	Gas flow cm ³ /sec	Liquid holdup, ϵ_L (fraction of total bed volume)	Liquid saturation, E_L (fraction of void volume)	ΔP psi	Peclet number Pe	Dispersion coefficient, D cm ² /sec	Energy dissipation per unit volume
								$\frac{v_L \Delta P_f}{L}$ ft. lb _f . ft ⁻³ . sec ⁻¹
156	6.73	106.03	0.181	0.431	10.4	31.9	71.5	6.4
157	6.73	106.03	0.180	0.429	10.4	23.8	96.4	6.4
158	5.95	137.49	0.171	0.406	11.2	27.7	77.5	6.1
159	6.23	137.49	0.183	0.435	12.8	63.0	33.3	7.3
160	6.73	167.19	0.166	0.394	15.2	21.6	115.4	9.3
161	6.66	168.94	0.155	0.360	14.2	20.8	126.9	9.2
162	6.02	200.5	0.153	0.365	16.0	33.1	72.9	8.8
163	6.09	200.5	0.143	0.340	16.0	17.9	146.1	8.9
164	5.74	227.2	0.142	0.337	18.4	21.3	116.6	9.6
165	5.53	224.9	0.139	0.330	18.4	22.9	106.8	9.3
166	11.7	85.1	0.180	0.428	16.0	9.6	416.9	17.1
167	11.7	85.1	0.191	0.454	16.0	23.9	147.8	17.1
168	11.0	116.3	0.166	0.395	18.8	8.9	455.3	18.9
169	11.2	116.3	0.145	0.372	18.8	7.0	624.2	19.2
170	10.6	147.1	0.152	0.361	20.4	7.6	567.9	19.7
171	10.8	147.1	0.151	0.383	20.4	13.3	311.8	20.1
172	10.3	176.6	0.155	0.369	22.4	12.8	318.8	21.1
173	10.3	176.6	0.144	0.342	22.4	7.9	556.9	21.1
174	9.85	204.8	0.135	0.322	24.4	7.4	602.0	22.0
175	9.70	204.8	0.141	0.335	24.4	10.8	391.4	21.6
176	9.21	230.7	0.139	0.331	26.0	13.7	297.5	21.9
177	9.21	230.7	0.144	0.343	26.0	44.3	71.1	21.9
178	15.6	77.9	0.155	0.392	22.0	3.6	604.8	31.3

Table 2.4. (continued)

Run number	Liquid flow cm ³ /sec	Gas flow cm ³ /sec	Liquid holdup, ϵ_L (fraction of total bed volume)	Liquid saturation, R_L (fraction of void volume)	ΔP psi	Peclet number Pe	Dispersion coefficient, D cm ² /sec	Energy dissipation per unit volume $\frac{v_L \Delta P_f}{L}$ ft. lb _f . ft ⁻³ . sec ⁻¹
179	15.7	77.9	0.196	0.467	22.0	43.2	114.0	31.5
180	15.1	108.4	0.191	0.455	24.8	91.1	53.3	34.2
181	14.8	108.4	0.179	0.426	24.8	27.6	184.0	33.5
182	14.3	136.1	0.175	0.416	26.4	118.4	42.4	34.5
183	14.2	136.1	0.160	0.381	26.4	19.2	285.0	34.2
184	13.7	163.9	0.170	0.404	28.0	116.8	42.6	35.0
185	13.7	163.9	0.157	0.374	28.0	13.1	411.2	35.0
186	13.7	163.9	0.159	0.378	28.0	19.0	279.6	35.0
187	12.9	190.6	0.155	0.369	29.6	39.1	130.6	34.9
188	13.0	190.6	0.137	0.327	29.6	8.9	651.1	35.1
189	12.1	215.5	0.144	0.344	31.2	24.3	212.1	34.5
190	12.0	215.5	0.146	0.347	31.2	94.7	53.6	34.2
191	6.80	0	0.507	1.207	3.2	151.5	5.4	
192	6.70	0	0.360	0.858	3.2	-38.6 ^a	-29.6 ^a	
193	1.96	0	0.194	0.463	3.2	34.7	17.9	
194	6.50	0	0.378	0.901	3.2	-63.5 ^a	-16.6 ^a	
196	5.60	0	0.385	0.917	3.2	380.1	2.3	
197	11.20	0	0.428	1.019	3.2	78.6	20.4	
198	2.30	0	0.236	0.5627	2.4	12.7	47.0	
199	4.50	0	0.366	0.8702	3.2	309.0	2.4	
200	5.70	0	0.398	0.9485	3.2	124.0	7.1	
201	5.70	0	0.394	0.9375	3.2	40.2	22.1	

Table 2.4. (continued)

Run number	Liquid flow cm ³ /sec	Gas flow cm ³ /sec	Liquid holdup, ϵ_L (fraction of total bed volume)	Liquid saturation, R_L (fraction of void volume)	ΔP psi	Peclet number Pe	Dispersion coefficient, D cm ² /sec	Energy dissipation per unit volume $\frac{v_L \Delta P f}{L}$ ft. lb _f . ft ⁻³ . sec ⁻¹
202	10.40	34.1	0.184	0.438	16.8	5.9	538.3	
203	10.00	34.1	0.205	0.490	16.8	32.8	91.0	
204	3.30	102.0	0.153	0.377	4.4	7.9	151.7	
205	8.10	90.3	0.162	0.387	12.8	6.8	447.1	
206	5.00	94.8	0.155	0.370	10.0	7.0	234.4	
207	5.80	94.8	0.170	0.404	9.6	7.6	277.4	
208	5.20	98.2	0.185	0.443	6.8	12.1	142.2	
209	3.77	100.0	0.162	0.386	6.0	7.7	135.5	
210	3.15	103.0	0.195	0.465	4.4	51.3	19.3	
211	2.50	105.2	0.172	0.409	4.0	57.2	15.6	
212	2.50	105.2	0.163	0.400	4.0	16.6	55.1	

^a Negative values of the dispersion coefficient (and, hence, Peclet number) which are physically meaningless result occasionally from errors in the data digitizing technique. The runs will be corrected for these errors.

Q_L , in Fig. 2.3 at various gas flow rates, Q_G . The liquid saturation is the fraction of void volume in the column occupied by the liquid phase. As such, it is related to the liquid holdup, ϵ_L , which is the fraction of total column volume occupied by the liquid phase, through the void volume, or bed porosity. As the gas flow rate is increased, liquid is displaced and hence the liquid saturation appears to have a minimum as the liquid flow rate is increased. It should be noted that the points plotted in Fig. 2.3 are averages of the repeated runs shown in Table 2.4.

The pressure drop due to flow across the packed column is plotted in Fig. 2.4 as the energy dissipation per unit volume, $v_L \Delta P_F / L$, vs the slurry flow rate at various gas flow rates. Energy dissipation per unit volume has been correlated with mass transfer coefficients in the literature.^{1,2} The pressure drop and hence the energy dissipation increase with both increasing liquid and gas flow rates. A detailed comparison has yet to be made with the base line data collected on the packed column using cocurrent upflow of air and water over a similar range of flow rates. Very preliminary observations indicate that the liquid saturation was not significantly affected by the addition of coal to the water phase, but that the pressure drop over the column using the coal slurry was more than double that using clear water.

Similar data will be obtained next on the 1-in.-ID x 5-ft-long Kenics contactor and then on the 1-in.-ID x 10-ft-long column packed with 1/8-in. x 1/8-in. right circular cylinders. The cylinders will simulate the inert glass pellets used for one run at PERC. The Kenics inline static mixers consist of a series of right-hand and left-hand helical elements. For fluids in turbulent flow, this geometry is claimed to cause complete stream inversion, create microscale turbulence, and produce radial mixing. For coal conversion applications, its low restriction of cross-sectional area should be conducive to low erosion rates and plug-free operation.

2.4 Pressurized Carbonization of Consol Synthetic Fuel Residues

R. E. Barker, S. M. Gibson, and G. S. Martin

This project is intended to determine experimentally the degree of coking and liquid degradation to be expected when Consol Synthetic Fuel (CSF) residue is fed to a pressurized carbonizer. The system described in earlier monthly reports has been modified to feed the residue into the side of the reactor with gas atomization. The system as it now stands is shown in Fig. 2.5. This arrangement has operated successfully with CSF residue during the most recent four experiments.

To date, four pressurized carbonization runs have been made using CSF residue as the feed material, all at a fluidized-bed temperature of 900°F. In these four runs two feed materials have been tested at two pressures each; whole CSF residue and the <700°F boiling fraction of CSF residue (obtained earlier this month from CONOCO Coal Development Co.)

Fig. 2.3. Effect of fluid flow rates on the liquid saturation for air and coal slurry in cocurrent upflow through a packed column.

Fig. 2.4. Effect of fluid flow rates on the energy dissipation per unit volume for air and coal slurry in cocurrent upflow through a packed column.

Fig. 2.5. Pressurized carbonization experiment flow diagram.

each were tested at 50 psi and 400 psi. Although material balance calculations are complete for only one of these runs (PRC7), some preliminary coke production data is available for all four runs. These coke production results are summarized in Table 2.5. It appears from these data that pressure has little effect upon the coking of the lighter, 700°F boiling fraction feed. The experiments using whole residue as feed indicate that more coke is formed at higher pressures. Simulated boiling point distribution curves for the residue feed and the liquid product for PRC7 are shown in Figures 2.6 and 2.7 respectively. Note that the product liquid is somewhat lighter, (about 93% compared with about 78% boiling below 700°F) again indicating that it is the heavier fraction in the residue which is contributing to coke formation, and not the lighter more valuable solvent. Preliminary material balance calculations for PRC7 indicate a 30% deficit; however, inefficient liquid recovery procedures are suspected to cause this, and an improved procedure is being developed.

During the next month an effort will be made to analyze more completely the data obtained in the experiments. In addition, more experimental runs will be made at varying conditions including at least one run using char from hydrocarbonization of Wyodak coal as bed material instead of alumina. This run is intended to show that the high-fired alumina does not contribute significantly to the coking results.

Table 2.5. Preliminary Coking Results

T ~ 900°F for all runs

Run	P (psig)	Feed	Feed wt (g)	coke wt (g)	% Feed appearing as coke
PRC-7	400	residue	181	77	42
PRC-8	50	residue	151	45	30
PRC-9	400	solvent*	161	12	7.2
PRC-10	50	solvent*	179	13	7.3

*Solvent is <700°F boiling fraction of residue.

ORNL DWG.77-967

Fig. 2.6. Simulated boiling curve for FRC 6 liquid product (93% <700°F).

ORNL DWG. 77-966

Fig. 2.7. Simulated boiling curve for PRC 6 residue feed (78% <700°F).

2.5 References for Section 2

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3. MATERIALS ENGINEERING

R. T. King

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

Summary

Sections of 2 1/4 Cr-1 Mo steel have been subjected to heat treatments that simulate the 1/4 thickness locations in 25 to 30 cm (10 to 12 in.) plates that were quenched, tempered, and postweld heat treated during processing. Steel of this section was able to satisfy the minimum tensile requirements for the SA 387 Class 2 material specification.

Several activities are in progress for the nondestructive testing of coatings. We have incorporated results of recent budget adjustments into milestone projections. Our first-year review report on plasma-sprayed coating is in technical review. A survey of fossil-energy coating users to determine programmatic NDT needs is in progress. We are still setting up our line scan IR camera; a new heat-transfer code is now on the main ORNL computer system. Eddy current work has been reduced. We have designed and are fabricating a new crack specimen for surface inspection work. A topical report draft on high voltage testing is being written.

A gas mixture that allows stable spray mode gas-metal-arc (GMA) deposition of Alloy 20 cladding has been found.

Failure analysis activities included examination of several components from the solvent refined coal plants at Wilsonville, Alabama and Tacoma, Washington.

3.1 Pressure Vessel and Piping Materials

D. A. Canonico

The simulation of the thermal history of thick walled 2 1/4 Cr-1 Mo steel by the DATA TRAK is continuing. Simulation of the 1/4 thickness depth location of approximately 254 and 305 mm (10 to 12 in.) thick plate quenched from 923°C (1700°F) has been completed. The "as-quenched" yield and ultimate strengths for the 1/4 thickness location are 630 MPa (91.4 ksi) and 886 MPa (128.6 ksi), respectively. Tempering these

specimens at 704°C (1300°F) for 1 hour decreased the yield and ultimate strengths to 516 MPa (74.9 ksi) and 633 MPa (91.9 ksi), respectively. These values are below the minimum yield strength [586 MPa (85 ksi)] and ultimate tensile strength [723 MPa (105 ksi)] required in the SA 542 Class 1 specification. Imposing a representative post weld heat treatment (PWHT) [677°C (1250°F) for 40 hours] reduced the yield and ultimate tensile strengths of 394 MPa (57 ksi) and 543 MPa (79 ksi), respectively. After the PWHT the tensile properties of the 2 1/4 Cr-1 Mo steel heat treated to simulate the metallurgical conditions at the 1/4 thickness depth location in thick plate just barely satisfied the minimum requirements for SA 387 Grade 22 Class 2 steel plate.

The Charpy V-notch (C_V) toughness has been determined for this steel in the same metallurgical conditions. The results of the C_V tests are provided below.

Metallurgical Condition ^a	Charpy V-Notch Energy [j (ft-lb)] at Temperature Indicated				
	°C (°F)	°F (°F)	°C (°F)	°C (°F)	°C (°F)
	-29(-20)	-12(+10)	+24(+75)	66(+150)	+121(+250)
Quenched (923°C cooled at 0.26 K/sec)	-	-	27(20)	46(34)	52(38)
Q and Tempered (1 hr at 704°C)	-	24(17.5)	85(625)	133(97.5)	136(100)
Q & T and Post Weld Heat Treated (40 hr at 677°C)	20(15)	41(30)	129(95)	150(110)	150(110)

^aMetallurgical condition at 1/4 thickness location in 254 and 305 mm thick steel plate simulated by DATA TRAK.

It is evident from the C_V data provided above that the toughness of the SA 387 Grade 22, Class 2 steel plate is quite good. The drop weight nil ductility temperature (NDT) at the 1/4 thickness of the post weld heat treated thick walled vessel should be about -12°C (+10°F). (This assumes a 30 ft-lb C_V correlation with the drop weight NDT.) Further, the upper shelf energy is about 150 joules (110 ft-lbs).

In summary, this study of the tensile and C_V properties of 2 1/4 Cr-1 Mo steel suggests that this steel will not satisfy the requirements of the SA 542 Class 1 specification when processed to 254 and 305 mm thicknesses.

3.2 Inspection Techniques for Wear- and Process-Resistant Coatings

R. W. McClung and G. W. Scott

Work is in progress in several areas to determine suitable methods for nondestructive testing of plasma-sprayed coatings.

3.2.1 Review and Evaluation (G. W. Scott)

We recently completed an evaluation of the impact of the re-distribution of FY-1976 carry-over budget funds. Generally, the effect will be a reduction of effort level which will postpone the dates of projected milestone accomplishments. The details are indicated in the following sections.

The technical report on plasma-sprayed coating inspection is presently in the hands of technical reviewers.

We are making preparations to conduct an information survey of other coating-related activities within the fossil energy program. This survey will be conducted by telephone, insofar as practicable, and it is intended to guide future efforts toward the total needs of the fossil energy program.

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

A thermal line-scanning camera has been obtained and will be used to evaluate our coating nonbond standards. An automatic offset circuit, described last month, is also available but is still being converted to use with the infrared camera. An advanced version of the Heating V Code is now programmed into the ORNL Computer System, and a report detailing access to and use of the code has been obtained.

3.2.3 Eddy Current Testing (G. W. Scott)

Activities on the design demonstration of a dual-frequency cermet coating thickness instrument have been suspended for the remainder of this year (CY-1977). We plan to re-start the work in January 1978, using funding currently projected for that period.

3.2.4 Surface Inspection Materials (S. D. Snyder)

We redesigned the blank for tensile-crack specimens to include a longer-radius curve in the throat area. Recent specimens have tended to spall rather than crack under tensile stress and uneven stress distribution over the throat cross-section appears to be a possible

cause. The longer-radius design will level out the stress distribution across the throat. Blanks have been cut and will be sprayed during June.

3.2.5 High-Voltage Testing (G. W. Scott)

We have completed approximately one half of the draft of a topical report on the arc-discharge detection of cracks in ceramic coatings.

3.3 Welding and Cladding

J. J. Woodhouse, J. D. Hudson, W. C. Oliver, and D. P. Edmonds

We are continuing to investigate the effects of welding conditions on the structure and properties of type 320 Cb stainless steel cladding deposits. During this reporting period we have used several different mixed shielding gases for gas metal-arc (GMA) claddings, in an attempt to obtain metal transfer by the spray mode. Earlier clad samples have been made with drop transfer, using 75% Ar-25% He shielding gas. However, spray transfer is generally more desirable for cladding because of the higher deposition rates that can be obtained. Results from this work indicate that stable spray transfer, with 1.59-mm (0.063-in.)-diam type 320 Cb wire, can be obtained with Ar-2% O₂ shield gas mixtures.

3.4 Fireside Corrosion

R. H. Cooper and J. H. DeVan

During the reporting period the analysis of four surveillance test tubes from the Fluidyne fluidized bed experiment was continued. In addition, a preliminary report summarizing work to date was written and is currently under review. Replacement tubes for the next 1000 hr exposure have been prepared and have been shipped to Fluidyne for insertion into the bed. A set of 2 1/4 Cr-1 Mo tubes for low temperature exposure are included.

3.5 Failure Prevention and Analysis

R. T. King, R. H. Cooper, B. C. Leslie, L. Harris, and R. J. Crouse

A failure analysis team visited the Wilsonville Solvent Refined Coal Plant to determine whether ORNL can provide or recommend inspection

services during a future shutdown. Several items were returned for examination at ORNL:

(1) A surveillance coupon of 410 stainless steel and one of type 316 stainless steel that had an undetermined exposure in the top of the dissolver tank were examined for scale characteristics. Metallographic examination of the scale showed that it was discontinuous in several areas. Microprobe analysis indicated that the scale on the type 316 stainless steel specimen was high in sulfur, and may be a sulfide. The scale on the type 410 stainless steel is probably an oxide.

(2) The inlet orifice of a Worthington pump used to pressurize feedstock slurry for the process was sectioned and analyzed. It is a casting which has a composition similar to Alloy 20.

Some wrap-up work on parts returned from the Tacoma (Washington) SRC plant was completed:

(1) The 4-in. Sch. XX, 5 D type 347 stainless steel elbow from below the dissolver tank was found to have a tightly adherent sulfide scale coating.

(2) The type 347 stainless steel flapper valve from the wash solvent distillation column had an 0.01 mm scale, of which a third was sulfide corrosion product and the balance was probably coke.

(3) Petrographic analysis of the coked plug from the slurry preheater elbow was completed and the results have been sent to the Pittsburgh and Midway Coal Company. We are now in a position to complete a report on the elbow.

4. ALKALI METAL VAPOR TOPPING CYCLES

R. S. Holcomb and G. Samuels

4.1 Potassium Vapor Topping Cycle

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

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. The electrical design work for the potassium system was completed this month with the release of the heater and thermocouple schedule drawing. With the mechanical design work having been completed in March, this finishes all the design work except for some of the instrument and control drawings. Six drawings were revised and two new drawings were completed for the instrument and control system. The electrical and instrument and control drawings are being completed later than was planned in the schedule, but this is not expected to delay final completion of the system since fabrication and installation of the electrical and instruments and controls is being phased in while the design work is being completed.

2. Fabrication work completed includes completion of modification of the vapor separator for installation in the potassium system, installation of heaters and thermocouples on the sample box, and fabrication of control panels 6 and 7 and installation of the metroscope and smoke detectors on panel 5.

3. An electric air preheater for startup has been selected instead of a gas-fired preheater because it will have a lower cost and it can be supplied in about one-third the time required for delivery of a gas-fired unit. Bids for the electric heater have been invited and will be opened on June 16.

4. Construction work on the equipment tower has been completed except for a small part of the metal siding, louvers, and the top. Installation of the metal siding has proceeded much more slowly than had been estimated by the contractor. It is now expected that the construction will be completed by June 15. As a result of this delay, the installation of the piping will be getting started late, but it can be put back on schedule with the use of more personnel.

5. Plans for Next Month. Work will continue on the instrument and control drawings; fabrication of the control panels will continue; construction on the tower will be completed and installation of connecting piping will begin.

4.1.3 Problem Areas

The bypassing of combustion air across the leaking seal represents a potential problem in that if the fraction of the incoming air lost by leakage increases significantly at high air flow rates, the target power level of 4×10^6 Btu/hr for the potassium test may not be reached. It is currently planned to operate to as high a power level as possible with the leaking seal for the potassium test and it is expected that it will be possible to operate to a power level close to 4×10^6 Btu/hr.

4.2 Coal-Fired Alkali Metal

G. Samuels

4.2.1 Contract Objective

The objective of the Coal-Fired Alkali Metal Power System Design 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. Several variations of the cycle arrangement for the atmospheric pressure system were analyzed during the month.

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 concept now being studied is a horizontal forced-circulation unit.

4. Work on the alkali metal condenser-steam generator was continued. A computer code has been prepared to analyze a reentry tube type unit for this application.

5. Conceptual design and layout work for the overall system was limited to those considerations necessary for the furnace design work.

5. COAL EQUIPMENT TEST FACILITY

R. E. MacPherson

The report ORNL/ENG/TM-6, entitled Critical Component Test Facility -- Advance Planning for Test Modules, was published. This report presents the planning study for the conceptual design of component test modules on a nonsite-specific basis, as requested by ERDA-FE. For the purpose of this study, tests of lock hopper valves, slurry pumps, continuous solids feeders, and hot gas cleanup systems were considered. The Stearns-Roger Engineering Company, of Denver, Colorado, assisted in the study, and their design recommendations and cost estimates are included.

Negotiations are now underway on a subcontract for the purpose of planning for the evaluation of potentially critical equipment and components of coal conversion/utilization demonstration/commercial plants.

A schedule 48, covering the construction planning and design (CP&D) funds for the coal equipment test facility, has been processed.

6. ENGINEERING STUDIES AND TECHNICAL SUPPORT

J. R. McWharter

6.1 Process Modeling

R. Salmon and D. M. Lister

6.1.1 Contract Objective

To assist Purdue and Lehigh Universities in the development of computer programs for the simulation of coal-conversion plants.

6.1.2 Status Summary

1. A report describing the process piping cost estimation program PPL was started. The introductory and data preparation sections were completed.

It was learned through contacts on the MIT Aspen advisory board that Fluor Engineers and Constructors are working on a process piping program using an approach similar to that used in PPL. Arrangements were made for a visit to Fluor to discuss the programs. Initial discussions have indicated that Fluor representatives are interested in learning what we are doing and may be willing to exchange some kinds of information, such as engineering standards, construction practices, and nonproprietary cost data.

2. Work continued on the heat exchanger design and cost program HDC. The program now prints out a complete materials and labor summary for a shell and tube exchanger in any of the TEMA categories. Further development of the program now requires calibration of the cost algorithms for the various parts. Information from vendors on the costs of plate, tubing, and forgings is being incorporated in the program as it is received.

It is believed that additional data on the costs of labor operations and overhead can be obtained through visits to manufacturers and suppliers. The general methodology used can also be discussed during such meetings. Arrangements for this are being pursued.

3. The Lehigh programs for solving sets of ordinary and partial differential equations have now been installed and run on the Oak Ridge IBM 360-195 computer system. Some modifications to the programs were necessary to accomplish this. These have been fully discussed with Lehigh and will be described in a report now in preparation.

6.1.3 Problem Areas

Acquisition of process data on the ICGG gasification system remains a problem. The data are needed by Purdue and Lehigh in connection with the development of their simulation models, which are to be used on the ICGG flowsheet.

6.1.4 Supporting Data

Ways of coping with the nonavailability of data on the COGAS process will be discussed at a meeting in Washington, D.C., in June.

6.2 Synthetic Fuels Process Research Digest

R. W. Glass

6.2.1 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.

6.2.2 Status Summary

All of the four articles that constitute the first issue have been written; two have been sent, in draft form, to ERDA/DMER and to the contractors whose work is discussed.

Article 1 (Catalytic Coal Gasification), chronologically the last to be processed, is currently being edited. Article 2 (Flash Hydropyrolysis of Coal) is nearing the end of the draft-review process; comments have been received from the three contractors, and L. M. Kindley of DMER has indicated that his comments will be received soon. Article 3 (Zinc Chloride Hydrocracking of Coal and Coal Extracts) has been edited, and its review draft is being prepared for distribution in early June. Incorporation of the comments received from reviewers of Article 4 (Conversion of Methanol to High-Octane Gasoline) is being delayed to maximize the speed of getting Articles 1 and 3 out for review.

Much of the delay encountered in processing this issue is attributed to problems in "shaking down" the production and review processes. Special attention is being paid to determining the ease with which Article 1 is prepared, as an indication of the extent to which the process has been (or can be) streamlined.

The following topics have been identified for the second issue: (1) the SRC II process, (2) intermediate Btu gasification for process heating, (3) Consol low-pressure hydrogen donor process, and (4) an overview of the Fischer-Tropsch process.

6.3 Survey of Industrial Coal Conversion Equipment Capabilities

R. W. Glass and J. M. Holmes

6.3.1 Contract Objective

The objective of this project is to conduct surveys of industrial equipment capabilities that will identify the present capability of industry to supply the equipment needed. The project will also determine research and development needs, including lead time requirements, for producing equipment of advanced design for the various unit operations of critical importance to the Major Facility Project Management Division's (MFPM) programs.

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

Visits were made to two architect-engineering firms, Stearns-Rogers and R. M. Parsons, and Airco Cryogenics, a manufacturer, on April 27, 28, and 29, respectively.

The last of four questionnaires on the availability of rotating equipment was completed during May. This questionnaire, dealing with hot gas expanders, was mailed to industry on May 13. Sets of two or more questionnaires were sent to those manufacturers having capabilities in several areas of rotating equipment on this date also. It was requested that all questionnaires be completed and returned by June 3. Letters have been received from several firms indicating a need for more time to respond, perhaps as much as three weeks. Analysis of responses to the questionnaires was begun during May and should be near completion by the end of June.

A report, "Results of the Commerce Business Daily Article," was prepared by W. R. Williams. The CBD method of obtaining an indication of industry willingness to supply information does not appear to be very effective; however, it did provide an opportunity for two manufacturers to be included in this study who would otherwise have been overlooked.

On May 27 and 28 visits were made to Union Carbide's Taft, LA, facility (Chemicals and Plastics Division) and Charter Oil and Exxon facilities in Houston and Baytown, Texas.

During visits to A-E firms and users of rotating equipment, their opinion as to who are the best manufacturers for the various types of equipment being studied has been requested. In general, the same basic group of manufacturers has been mentioned. This information will be considered when arranging discussions with manufacturers during June and early July.

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

Seven processes were used to identify critical applications of valves. This information has been used to formulate a letter of inquiry to ball valve manufacturers. The present investigation is being limited to ball valves. The original list of over 1000 suppliers was reduced to 447 possible companies for study. Letters and questionnaires are expected to be mailed to 179 of these. These letters contain design conditions developed over the last several months and a "matrix" for manufacturers response.

On May 4th, a meeting was held in Houston, Texas, with members of the "Valve Manufacturers Association" and A.C.F. Industries representatives. Questions of critical valve conditions, valve availability, and methods of soliciting valve industry response were discussed.

A tour of the W.K.M. Facility was conducted after the meeting. Their capability was impressive and of particular interest was the method of applying stellite No. 6 to carbon and austenitic steels and the large diameter ball valves that were observed. Work is also proceeding on the final report form.

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

A. Particulate Removal

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

- (a) Contact has been made with several manufacturers of particulate measurement equipment potentially suitable for high temperature--high pressure (HTHP) applications. These include:

- Acurex Aerotherm
485 Clyde Avenue
Mountain View, California
- Leeds and Northrup Company
Technical Center
North Wales, Pennsylvania
- Spectron Development Laboratories, Inc.
3303 Harbor Boulevard
Costa Mesa, California
- Environmental Systems Corporation
1212 Pierce Parkway
Knoxville, Tennessee

Each of the instruments, viewed as viable, has been evaluated in a standardized manner as outlined on the enclosed evaluation form. Care has been taken to distinguish between the type of measurement method used, that is whether aerodynamic sizing, based on the Stokes parameter,

$$\varphi = \frac{C \sigma_p D_p^2 V_j}{18 \mu D_j}$$

where:

C = Cunningham slip correction

σ_p = particle density

D_p = particle diameter

V_j = stage jet velocity

μ = gas viscosity

D_j = stage jet diameter

or optical sizing, based on reflective properties, has been employed. The differences that exist between these two techniques, and the data they produce, have been evaluated via a literature review.

- (b) A summary of existing and projected turbine particulate loading tolerances for different turbine units has been culled from germane reports, as well as private correspondence with major turbine manufacturers. This data, contained in Table 6.1, is largely tentative in nature insofar that it represents reasonable estimates based on limited information obtained from existing devices operating successfully under similar conditions. Hence this data, aside from the projections, can be assumed to be generally conservative in scope. In addition to limits associated with particulate loading, there is a general consensus among turbine vendors to limit the maximum allowable particulate size to less than 5 microns in diameter. Such a restriction will assure adequate rotor and stator protection against erosion.
- (c) In order to provide a basis for analysis, data on collection efficiency vs particle size is essential. This data has been obtained and is presented in Fig. 6.1.¹ Although this information is only rigorously accurate for low temperature--low pressure applications, it can, in conjunction with the hypothesized log normal particle size distribution, give a rank ordering of each device or process in terms of its collection ability. This follows, since the work of Rao et al.² has shown that the collection efficiency of a device or process deteriorates as the temperature or pressure is elevated. Hence, an upper bound on performance can be established.

Table 6.1. Turbine particulate loading specifications

Manufacturer	Grain loading (gr/scf)	
	Turbine expansion gas	Low Btu fuel gas ^a
Brown-Boveri	3.2×10^{-4}	2.9×10^{-3}
General Electric	1.7×10^{-4b} (0.3 ppm weight)	1.5×10^{-3}
Ingersoll-Rand Turbo Expanders	7.0×10^{-2} (12.5 ppm weight)	6.3×10^{-1}
United Technologies Pratt & Whitney: Turbo Power & Marine)	2.2×10^{-4} (0.4 ppm weight)	2.0×10^{-3}
Westinghouse	2.0×10^{-4} (0.4 ppm weight)	1.6×10^{-3}
HT ³ Recommendation	2.0×10^{-3} (4 ppm weight)	1.8×10^{-2}
Westinghouse PFBC	$2.0 \times 10^{-4} - 2.0 \times 10^{-3}$	$1.8 \times 10^{-3} - 1.5 \times 10^{-2}$
Projection	(4 - 36 ppm weight)	

^aBased on air/fuel ratio of 8:1 for 225 Btu/scf gas with dust free air at turbine inlet temperature of 1800°F.

^bBased on air/fuel ratio of 40:1 for 1000 Btu/scf gas with dust free air at turbine inlet temperature of 1800°F.

Fig. 6.1. Extrapolated fractional efficiency of particulate removal devices.

B. Hydrogen Sulfide Removal

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

- (a) Letters of inquiry were sent to Babcock & Wilcox, Battelle Pacific Northwest Laboratories, and the Institute of Gas Technology for information on H_2S removal at high temperature.
- (b) The response from Battelle Pacific Northwest indicated that additional information would not be provided on a gratis basis. Some general comments on high-temperature cleanup had been received in April.
- (c) UOP, Inc. will provide information on a licensed process that was developed by Shell Oil for SO_2 removal from flue gas. It is possibly applicable to the removal of H_2S as well.
- (d) Letters were sent to previously contacted H_2S removal process developers where responses have not yet been received. Prompt responses were urged.

6.3.5 Heat Recovery Equipment Survey (W. R. Gambill)

A letter summarizing information on waste heat recovery and process heat exchangers obtained during a 6-day visit to Houston was issued.

An English volume entitled The Coal Tar Data Book (2nd ed., 1965) was received. Data obtained for various types of heat-exchange equipment in six continuous tar distillation plants indicate quite low heat-transfer rates. For ~30 heat exchangers (vapor/tar, oil/tar, pitch/tar, condensers, fired-heater convection tubes, and batch heaters), the range of surface heat flux was from 160 to 3000 Btu/hr ft² and that of overall heat-transfer coefficient from 0.4 to 26 Btu/hr ft²°F.

Two additional vendors of potentially applicable exchangers were identified in "The Directory of Industrial Heating and Combustion Equipment, U.S. Manufacturers, 1977-1978" — viz., The American Schack Co., Inc. (Wexford, Pennsylvania) and Thermal Transfer Corp. (TTC), Monroeville, Pennsylvania.

Additional vendor catalogs and brochures were received and inquiries transmitted. Literature concerning waste-heat-boiler problems and heat-pipe heat exchangers was reviewed. A recently received Westinghouse report (High Temperature Turbine Technology Program) is explicit concerning the ways in which fouling, corrosion, and erosion render present heat recovery system design difficult and uncertain. Problems addressed include tar and ash slag fouling, residual hydrocarbon deposition, carbon laydown, hydrogen and H_2S attack, nitriding, and aqueous and chloride-salt corrosion. See Sect. 6.8 for additional heat-recovery information.

6.4 Engineering Assistance

J. M. Holmes

6.4.1 Contract Objective

To provide engineering assistance to ERDA/Major Facilities Project Management Division.

6.4.2 Status Summary

Preliminary planning was started on the engineering evaluation of a commercial-scale Fluid Bed Hydrothermal Liquefaction (FBHL) process. This process will incorporate pressurized hydrocarbonization of bituminous coal plus pressurized fluid bed gasification and combustion of the char produced by the hydrocarbonization. Work has been started on the development of a computerized mass balance program that will permit the rapid computation of a complete material balance for any combination of hydrocarbonizer operating parameters. This material balance will include all of the major processing units in the process. To obtain information concerning the hydrocarbonization portion of the FBHL flowsheet, a trip was made to Coalcon's Tonawanda Mini-Test Facility on May 26, 1977. Information on the basic proposed flowsheet and material balances for the Coalcon process was obtained. A list of Coalcon reports to be published by July 1977 was also obtained.

6.5 Rapid Hydrogenation

S. P. N. Singh

6.5.1 Contract Objective

To perform a scoping study on two conceptual flash hydrolysis processes to determine if a more detailed engineering evaluation of the flash hydrolysis process is justified.

6.5.2 Status Summary

Preliminary material and energy balances for the two candidate processes have been completed. This is estimated to be about 30% of the project effort. Further information is being sought to perform an economic analysis of the two processes.

6.5.3 Changes

With ERDA/MFPM approval, a more recent version of the Spencer Chemical Company process proposed by W. C. Schroeder in the January 1976 issue of Hydrocarbon Processing will be evaluated instead of the original Spencer Chemical Company version of the process.

6.6 Hot Gas Purification Processes

M. S. Edwards and J. P. Meyer

6.6.1 Contract Objective

The objective of this project is to investigate the present state-of-the-art of 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.

6.6.2 Status Summary

1. Three additional hot gas H_2S removal process developers were contacted for information: Babcock & Wilcox, Battelle Pacific Northwest Laboratories, and the Institute for Gas Technology.
2. R. H. Moore of Battelle Pacific Northwest responded that he could not provide any additional assistance to the study on a no-cost basis, after a brief letter on April 11 listing several general comments.
3. Dr. J. Pohlenz at UOP, Inc. was contacted for information on their license of a Shell Oil process for sulfurous gas removal at high temperature. He will provide some additional information, although the process itself is marketed for flue gas SO_2 removal rather than H_2S removal.
4. Follow-up letters were sent to request a prompt reply from the following H_2S process developers: University of Kentucky; Battelle Columbus Laboratories; Conoco Coal Development Company; City College of New York; Hanna Mining Company; and Air Products and Chemicals, Inc.
5. Contact has been made, as discussed in Sect. 6.3.4, with several manufacturers of particulate measurement equipment potentially suitable for high temperature--high pressure (HTHP) applications.
6. Some information on existing and projected turbine particulate loading tolerances for different turbine units is given in Table 6.1 of Sect. 6.3.4. This information is tentative in nature and is discussed in Sect. 6.3.4.
7. In order to provide a basis for analysis, data on collection efficiency vs particle size is essential. This data has been obtained and is presented in Fig. 6.1 of Sect. 6.3.4.

6.7 Large Air Separation Plant Study

W. R. Gambill

6.7.1 Contract Objective

The primary objectives of this study are to determine if significant economies of scale would be provided by building single-train cryogenic air separation plants with capacities in the range of 2,000 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.

6.7.2 Status Summary

At the direction of MFPM, this study has been reactivated at ORNL. Meetings held with the Engineering Division resulted in identification of personnel to aid with subcontract placement, liaison, and final evaluation. A tentative expanded work plan has been prepared, and initial steps are being taken toward subcontract procurement.

A current article on large O_2/N_2 production plants by Springmann of Linde AG (Hydrocarbon Processing, February 1977) suggests that the specific energy requirement (kWhr/SCF, e.g.) for O_2 production has reached a minimum at a capacity of ~2200 STPD. There is a minimum specific energy consumption at 80 mol % O_2 in the product gas; the value for 99.5 mol % O_2 is ~15% higher. A plot of specific capital costs shows an almost flat curve from 2200 to 3500 STPD. Information from this article could be interpreted to mean there are no economies of scale to be expected at oxygen capacities beyond ~3000 STPD.

6.7.3 Changes

A draft report can probably be provided by May 1978. This date is contingent on the subcontract placement date.

6.7.4 Open Items

Groundrules should be established as to whether N_2 will be a salable coproduct and whether capacity-factor mismatch between the O_2 plant (98%) and the coal-conversion plant (90% to perhaps as low as 60%) should be included in the economic projections.

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

W. R. Gambill

6.8.1 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.

6.8.2 Status Summary

A letter summarizing information on waste heat recovery and process heat exchangers obtained during a six-day visit to Houston was issued. With the thought that a Heat Transfer Salt (HTS) thermal-energy transport system might be used in a coal-conversion plant, a recently issued ORNL report (TM-5862) which surveys the technology for storage of thermal energy in HTS was obtained and is being studied.

Information was obtained regarding thin-wall spiral tubing ("Turbotec" tubing) made by Spiral Tubing Corporation (New Britain, Connecticut). When used in marine keel coolers, this tubing has doubled the heat transfer rate of conventional straight-bore tubing.

An inquiry has been sent to Thermo Electron Corporation (Waltham, Massachusetts) concerning their waste heat recovery and conversion system for generating electrical energy (0.5 to 10 MWe) from process exhaust gases.

A copy of the Proceedings of the Second International Heat Pipe Conference (1976) was received. It contains three relevant papers on heat-pipe heat exchangers:

1. Heat Pipe Thermal Recovery Unit Applications (Q-dot Corp., U.S.A.);
2. Preliminary Design Study of Heat Pipe Heat Exchangers (University of New Mexico, U.S.A.);
3. Study of Heat and Mass Transfer in Heat Pipe-Based Exchangers (Luikov Heat and Mass Transfer Institute, U.S.S.R.).

6.9 Evaluation of Moving Bed System for Heat Recovery and Contaminant Removal from Raw Gasifier Gas

6.9.1 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.

6.9.2 Status Summary

Work on this project has been initiated with a consultant-engineer. Preliminary discussions have resulted in a first-case definition of the gasifier product gas to be treated.

6.10 References for Section 6

1. Clean Power Generation from Coal R&D Report 84, Westinghouse Research and Development Corporation, Pittsburgh, Pa., January 1973, for OCR, Washington, D.C.
2. A. K. Rao et al., Particulate Removal from Hot Gas Streams at High Temperature/High Pressure, Midwest Research Institute, Kansas City, Mo., August 1975, NTIS, PB-245-853.

7. PROCESS AND PROGRAM ANALYSIS

J. R. McWherter and R. Salmon

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.

7.1 Low Btu Coal Gasification

H. F. Hartman, D. E. Reagan, and J. P. Belk

7.1.1 Summary

Activities in May 1977 included issuing the process summary section for review and comment. Work continued on obtaining and summarizing process data. Environmental aspects of low Btu coal gasification processes were reviewed. A presentation on the status of the low Btu study was made to Mr. Robert Johnston of the International Energy Agency - Coal Research group. The conference, "Institute on Scientific Problems Relevant to Coal Utilization," was attended at West Virginia University and the Morgantown Energy Research Center was visited.

Activities forecast for June 1977 include collection of additional process data and preparation of initial drafts. Work is also planned on the process screening/selection section of the project report.

7.1.2 Process Summaries

A draft of the process summary section was issued for review and comment. The section contained 54 one-page summaries of processes that are or have been used to produce low and intermediate Btu gas from coal. Processes were grouped by gasifier type (fixed, fluidized, entrained, molten). An indexed list contained the names of all 85 processes that were mentioned, including 31 additional processes for which summaries were not provided. Information, when available, was provided in each summary for the following categories: name, developer/licensor, gasifier type, status/history, operating conditions, reactants, products, feed methods, ash removal, and (a brief) description. Material provided in this section will be revised and updated as necessary during the preparation of more detailed descriptions of approximately 22 processes.

7.1.3 Process Data

Work continued on collecting, reviewing, and summarizing data for some of the approximately 22 processes that will be described and evaluated in more detail. Topics in the technical data part of this section were reviewed and now consist of the following:

- Title page (name, type)
- Summary (process summary)
- Status (availability, development plans/funding, history)
- Process Description/Diagrams (gasifier, plant)
- Operating Conditions (temperature, pressure, space velocity)
- Reactants (coal, oxidant)
- Utilities (water, electricity)
- Products (gas, by-products, wastes)
- Efficiency
- Test Results
- Critical Areas
- References

Other topics to be added after completion of the technical data part include:

- Environmental and Safety Considerations
- Cost Considerations
- Regional Considerations
- Recommendations

7.1.4 Environmental Considerations

Environmental aspects of low Btu coal gasification processes were reviewed as part of preparation of a draft work statement for a proposed study of environmental control methods. A partial list of effluents and emissions was prepared for the major process systems. Certain of these are listed below:

<u>System</u>	<u>Effluent/Emission</u>
Coal Storage	dust, run-off water
Coal Preparation	wash water, ash
Coal Gasification	gases, heat, ash, slag, char
Raw Gas Treatment	particulates, waste water
Acid Gas Treatment	CO ₂ vent
Sulfur Recovery	sulfur
Tail Gas Treatment	vent stream
Waste Water Treatment	NH ₃ , phenol, sludge
Cooling Tower	vapor, drift
Utility Boiler (steam)	fly ash, SO ₂ , NO _x
Flue Gas Treatment	ash, sludge
Oxygen Plant (if provided)	nitrogen
Waste Storage (ash)	leachable materials (metals, salts)

7.1.5 Presentation/Discussion

A presentation on the purpose, activities, and status of the Low Btu Coal Gasification Study was made on May 12 to Mr. Robert Johnston of International Energy Agency (IEA) - Coal Research, London, England. Mr. Johnson is in the Economic Assessment Service part of IEA. Some of the mutually interesting technical and economic aspects of coal conversion were discussed after the presentation.

7.1.6 Coal Utilization Conference

The "Institute on Scientific Problems Relevant to Coal Utilization" was attended by H. F. Hartman on May 23-25 at West Virginia University in Morgantown, West Virginia. Topics that were discussed included:

- Critical Paths to Coal Utilization (in combustion, pyrolysis, gasification, liquefaction, MHD)
- Coal Properties and Processing Characteristics
- Mining and Preparation
- Materials Problems and Research
- Environmental Assessments
- Coal Utilization Funding (ERDA, EPRI, NSF)

Several projects at the Morgantown Energy Research Center (ERDA-MERC) were visited during a tour of the facilities and included coal gasification (fixed-stirred bed), combustion (fluidized bed), in-situ gasification (pilot plant).

7.1.7 Work Forecast

Additional data will be collected in June for use in the Process Data (Technical) Section. Initial drafts of these sections will be prepared for several of the 22 processes being included for more detailed comparison/evaluation.

Work will be done on the Process Screening/Selection Section. This section will provide reasons for reducing the 85 processes originally considered to the 54 processes for which one-page summaries were prepared. Additional information will also be provided on why 22 specific processes were selected from the 54 that were reviewed.

7.2 Direct Combustion

E. C. Fox, T. D. Anderson, and J. R. Tallackson

7.2.1 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.

7.2.2 Results

About one-fourth of the present work initiated in February has been completed to date. Much of the month has been spent contacting vendors of both large and small coal combustion equipment to discuss the technical details and arrive at cost for the various systems. Many of the residential/commercial coal manufacturers echoed the response that the outlook for the sale of small size-coal combustors for residential and commercial space heating looked very good. For instance, contact with Mr. Robert Prill, owner of Prill Manufacturing, revealed that his sales in April were up about 30% over the previous month. He manufactures a unique type of stoker which is claimed to be smokeless, more reliable, and require less maintenance. Mr. Prill also provided cost information and some literature concerning his combustion systems as have other firms.

T. D. Anderson and E. C. Fox spent a day in Canton, Ohio, discussing with Babcock and Wilcox Marine and Industrial Division the commercial availability of coal combustion equipment for industrial and commercial/residential applications. B&W supplies industrial coal-fired boilers in sizes from 10,000 to over 1 million lb/hr of steam. They offer no package coal-fired units but are thinking about offering a unit of 20,000 lb/hr. They do not believe they can go much larger because of shipping limitations. They claimed that modular construction is better than field erection but

they could not pin down any size breakpoints for either method. Typically, the lead time on an industrial boiler installation is ~3 years with a breakdown as follows:

Planning and negotiations:	6-7 mo.
Equipment delivery:	12-14 mo.
Construction:	12 mo.
Shakedown:	6 mo.

B&W feels that fluidized bed technology is very promising for the industrial sector, but identifies the solid waste and erosion problems as the key technical barriers. They feel that the rate at which industry can convert to coal will be severely constrained by the capacity of the boiler manufacturers. The manufacturers are reticent to gear up for a short-term, one-shot changeover to coal, followed by a diminished production rate.

United Engineers and Constructors have completed the majority of their cost estimates. These estimates, which are to include pulverized, stoker, and fluidized-bed furnaces for the production of steam and hot water, in sizes typical of small industrial and large residential/commercial applications will be used in the economic evaluation. The draft report which summarizes the capital and operating cost, as well as efficiencies and other technical details, will be ready the first part of June. Additionally, they are including in their estimates the cost for a large scale coal handling facility suitable for use in our assessment of the coal depot concept.

The cost of coal transportation and handling is a key element in estimating the economic competitiveness of coal for small users. Numerous coal transportation costs have been compiled to evaluate the economic differential between various types of coal shipments and to establish the projected delivered cost of coal to the selected industrial and residential/commercial sites. The railroad transportation costs have been obtained directly from various railroad contacts. The following is a typical example of the cost comparisons:

Coal Rail Transportation to Houston, Texas

	<u>N. Wyoming</u>	<u>Colorado</u>	<u>S. Wyoming</u>	<u>S. Illinois</u>
Single car (\$/100 ton-mile)		1.40-1.60		1.60
Bulk rate (\$/100 ton-mile)	1.05-1.3	1.30-1.50	1.30-1.75	
Unit train (\$/100 ton-mile)		0.7-0.8	0.8	

In addition to rail transportation, costs for shipment by barge and truck are also being compiled.

The description of the technologies for firing coal in pulverized, stoker, and fluidized bed systems is nearing completion. The summary for the technical feasibility for retrofitting gas- or oil-fired boilers to coal-fired has been made and the analysis of conversion to coal/oil mixtures is in progress. Regardless of the economic incentives, conversion of gas- or oil-fired boilers to coal firing will not be technically feasible if low ash fusion temperature coals are used and questionable if a high ash fusion coal is used with considerable boiler modification and deration.

T. D. Anderson and E. C. Fox are scheduled to meet with Union Carbide Corporation, Celanese Company, Power Systems Engineering Incorporated, The Texas Industrial Commission, and the Texas Governor's Energy Advisory Council the week of June 6-9, 1977. These discussions will be centered around the user and public acceptance elements of the direct combustion study.

7.3 Advanced Power Conversion Systems

A. P. Fraas,^{*} G. Samuels, M. E. Lackey,
W. M. Wells, and S. Thompson

Four reports on advance power conversion systems have been transmitted in draft form to OPPA-FE. These reports covered the alkali metal vapor topping cycle, open cycle coal-fired gas turbines, conventional open cycle gas turbines, and ceramic gas turbines. Five other reports are undergoing internal review or being revised. These include combined gas turbine-steam cycles, closed cycle gas turbines, fuel cells, water-cooled gas turbine, and MHD. It is anticipated that drafts of these reports will be transmitted to OPPA-FE during June. Additional information may become available at the meeting on fuel cells to be held in Boston the latter part of June, and this will be incorporated into the final report.

7.4 Liquefaction

This work is being done under subcontract by the Ralph M. Parsons Company (J. B. O'Hara, Project Manager).

7.4.1 Survey Liquefaction Processes

Activity Summary. Two additional processes, the UOP Extraction and Rockwell International's Direct Hydrogenation, were surveyed during the month. This work essentially completes the initial survey of coal liquefaction processes. A total of thirty-two potential processes have been surveyed. All data and references have been filed according to the type of process.

Parsons continued to compare the strengths and weaknesses of the candidate liquefaction processes.

* Consultant.

7.4.2 Established Uniform Data Format

1. Objectives

- a. To serve as a check list to assure that pertinent data, as available, is obtained on each process.
- b. To provide a uniform method of presenting data in the Source Data Book.

2. Activity Summary

This task has been completed. The uniform data format has been prepared and is in use.

7.4.3 Establish Standard Techniques for Process Evaluation

1. Objectives

To establish standard techniques for process evaluation and ranking of the various processes.

2. Activity Summary

We will continue to use the preliminary ranking factors as transmitted to ORNL with the January period progress report. These ranking factors are being used as a guide to process evaluation and represent one of a number of inputs to the evaluation process.

7.4.4 Establish Uniform Economic Comparison Basis

1. Objectives

To provide techniques and methods for economic comparison of the most viable processes on a uniform basis for the detailed process analyses.

2. Activity Summary

A preliminary procedure has been prepared for the economic comparison of the processes. This procedure is being refined in preparation for transmittal to ORNL for review and discussion.

7.4.5 Detailed Review of High Potential Liquefaction Processes

1. Objectives

To perform detailed process, technological and economic analyses of high potential liquefaction processes. ORNL and Parsons will agree on processes to be reviewed.

2. Activity Summary

The Mobil M Process to produce gasoline from coal is being reviewed.

A meeting was held on April 11 at DuPont's Wilmington offices between Parsons and DuPont personnel to discuss their report entitled "Economic Feasibility Study - Fuel Grade Methanol from Coal." This report was prepared for the Office of Commercialization of ERDA by the Research and Development Division of the Industrial Chemicals Department of DuPont Company. Information contained in this report will serve as a basis for defining the technology and projected costs for producing methanol from coal as an intermediate for production of gasoline from coal.

Process design to produce 50,000 bbl/day of gasoline from coal was continued. The basic process steps include (1) the entrained gasification of coal, shift conversion, and gas cleanup steps to produce a suitable gas for methanol synthesis, (2) methanol synthesis, and (3) conversion of methanol to gasoline.

Methanol synthesis will be accomplished using the proven ICI technology. The crude methanol, containing about 17% water, will be utilized as feed stock to the Mobil M - Gasoline process.

Information contained in Mobil's report, "Development Studies on Conversion of Methanol and Related Oxygenates to Gasoline," published November 1976 under ERDA Contract No. E(49-18)-1775 is being used to develop the design for gasoline production step.

A gas plant to separate the gas from liquid products leaving the Mobil M - Gasoline units is being designed. The unsaturated gases are being reacted in an alkylation unit to produce additional gasoline.

7.5 High Btu Gas

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

7.5.1 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 Summary Status

During the month of May, work was directed in the following areas:

1. A report prepared by Battelle on their Agglomerating Ash Burner Process was reviewed and SD comments were discussed with Larry Joseph of OPPA. Some additional material balance information was provided to ERDA for use by DuPont in their review of the SD process evaluation.

2. Work was initiated on the SD study for the production of hydrogen utilizing the hot char exiting the Hydrane process hydrogasification step. The work is proceeding satisfactorily and SD expects to have process flow-sheets, heat and material balances, and equipment sizes by the end of June.

3. Work has also been initiated on developing a "Generalized Approach to High Btu Coal Gasification Processes." SD is now in the process of establishing the major process parameters which have a significant effect on the capital, operating, and gas costs.

7.6 In Situ Coal Gasification

W. C. Ulrich and G. J. MacKenzie

7.6.1 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.

7.6.2 Status Summary

Revisions were made to the preliminary flowsheet for a 1000 MW(e) combined-cycle generating plant operating on low-Btu gas. These changes were a result of further discussions with experimenters at the Laramie Energy Research Center, and telephone conversations with contacts in other engineering groups who are performing similar energy-oriented economic evaluations and with equipment vendors and manufacturers. Material and energy balance calculations were performed for the revised flowsheet, and equipment sizing calculations were started.

Several alternate in situ field development plans were prepared for study. The plans are based on four approaches to the design of a 1000 MW(e) generating plant which result from considering two unit plant sizes (large and small) and two process concepts (split plant and centralized plant). For a large plant the field development plans, equipment, processing, utilization, etc., are based on operation of large-scale individual units [e.g., one 1000 MW(e) unit]. In a small plant these items are based on operation of a number of parallel units or modules [e.g., four 250 MW(e) modules]. A split plant has equipment such as compressors, cyclones, gas scrubbers, package boilers, etc., in the field. The main gas treating facility and electric generating equipment are at a central location. Scrubbed gas is piped from the field to the central location. In a centralized plant all major equipment is at a central location. Compressed air is piped to the field, and raw gas is piped from the field for treating and use.

Two members of the evaluation group visited the Laramie Energy Research Center on May 12, 1977, for discussions involving the preliminary flowsheet and field development options for the linked vertical well process.

7.7 Coal Beneficiation

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

7.7.1 Contract Objective

To identify and analyze various currently used and potential coal beneficiation techniques.

7.7.2 Status Summary

The preliminary draft of the Coal Beneficiation Study report was reviewed with Dr. L. Joseph of ERDA/OPPA on June 3, 1977.

7.8 Gas Cleanup Studies

M. S. Edwards

7.8.1 Contract Objective

As part of a general study on various coal conversion methods, 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.

7.8.2 Status Summary

1. Shell Development Company provided some additional process data for the ADIP amine gas-scrubbing process.
2. No additional information on high-temperature gas cleanup processes was received in May. Follow-up letters were sent to request prompt responses.
3. The vendors providing conceptual designs and costs for their processes have still not submitted final values; Peabody Engineered Systems (the Stretford process) and Eickmeyer and Associates (the Catacarb process).
4. A draft of the evaluation including the selection of candidate systems was prepared for the ERDA contract manager.
5. Detailed descriptions of the candidate processes is underway. The second process description was initiated.

7.8.3 Changes

As requested by the ERDA program manager, an interim draft report was prepared which includes results of the gas cleanup study through the selection of the fewer than ten candidate systems.

7.9 Coal Prices and Volumes

O. L. Culberson*

The report describing the correlation of coal price to distance shipped, heating value, and sulfur and ash content is nearing completion.

7.10 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 (D. N. Garner, Project Director).

Present ERDA-funded contracts were identified that impact chemical production from coal or oil shale. There are eleven contracts included in the list.

The compilation of information is continuing on projects concerning chemicals from coal and oil shale. Private companies have been the object of recent inquiries trying to identify recently completed and on-going programs of interest. Initial contact has been made with the following companies:

DuPont
Burlington Northern
Hercules
Celanese
Union Carbide

Burlington Northern is the only company with announced plans to utilize coal as a feedstock. The interest these companies have exhibited is encouraging, and efforts will be continuing along these lines.

*Consultant.

8. FOSSIL ENERGY ENVIRONMENTAL PROJECT

C. R. Boston

8.1 Landfill Storage of Coal Conversion Solid Wastes/Information Assessment

H. M. Braunstein

All the external referees have now commented on the landfill document. Written reports are still due from two referees. No major revisions were suggested; however, many useful comments were received. These will be valuable in finalizing the report.

8.2 Landfill Storage of Coal Conversion Solid Wastes/Experimental Phase

W. J. Boegly

Program planning and waste procurement were the major activities during the month. Initially, wastes will be requested from seven pilot plants. These are Hygas, AGA Commercial, CO₂ Acceptor, Walz Mills, Synthane, Battelle Agglomerating Burner, and Bi-Gas. Initial waste quantities requested from each plant are about 3 ft³ of residue, with a further request for future amounts of about 170 ft³. Samples of the coal producing the residue were also requested.

8.3 Environmental Monitoring Handbook

L. H. Stinton

All sections of the first draft of Subtask 5, Document Preparation, Part I (Preconstruction Monitoring) were completed and sent to the editor as a supplement to the first draft. Additional comments will be incorporated when Parts II and III are complete.

Outlines for Parts II and III (Construction and Operation) are being reworked as sections are written by team members. The target date for submitting all rough drafts is June 30. The edited document will be available 4 to 6 weeks later (July 30 to August 15).

8.4 Programmatic Assessment/Pipeline Gas

L. H. Stinton

The pipeline gas programmatic assessment has essentially been completed in rough draft form. The editors should receive the complete document by June 10, 1977. The target date for the edited document is June 30, 1977.

8.5 Programmatic Assessment/Fuel Gas

L. H. Stinton

Information is currently being obtained on the two sites selected as surrogate sites. These are Memphis, Tennessee, in Shelby County and Baskett, Kentucky, in Henderson County. The draft outline will be based on that for the pipeline gas assessment with modifications suggested by the team members. Work will begin on this project in June.

9. COAL-FUELED MIUS

R. S. Holcomb and W. R. Nixon

This project for analysis, design, and demonstration of a concept utilizing a fluidized-bed coal combustion system as a heat source for a gas turbine generator suitable for applications in Modular Integrated utility Systems (MIUS) is carried out under the ORNL-HUD-MIUS Program within the Energy Division. Work is supported by the U.S. Department of Housing and Urban Development under HUD Interagency Agreement No. IAA-H-40-72 and by the Energy Research and Development Administration, Office of Fossil Energy (formerly Office of Coal Research, Department of the Interior), under ERDA Contract No. E(49-18)-1742. The project consists of four phases: I - Conceptual Preliminary Evaluation; II - Conceptual Design; III - Detailed Design and Construction; and IV - Shakedown, Performance, and Endurance Tests.

9.1 Coal Metering and Feed System

A series of coal feeding tests will be conducted in the cold flow model test facility. Visual observations of particle flow will be required as a part of the coal feeding tests. Transparent plastic pipe and fittings were ordered during this period for installation into the coal feed system.

9.2 Supplemental Studies

The report on the analysis of the corrosion specimens has been completed. Draft copies were given to ERDA-FE on May 25, 1977.

The additional cost of the 1000-hr corrosion test has been approved by ERDA-FE. The Fluidyne subcontract was written for the longer test period. Four additional specimen tubes, above the original 16, are now planned to be included in the corrosion test. These four tubes will be composed of low chrome-moly steel and during testing will be cooled to maintain a peak wall temperature of 1000°F. The new tubes have been included to provide data for the ERDA Industrial Demonstration Program, but it is anticipated that the results will be applicable to low temperature zones of the ORNL combustor (TTU) and other fluidized bed combustion applications.

The original 16 corrosion specimen tubes have been shipped to Fluidyne. The four new chrome-moly steel tubes are being prepared and should be shipped very soon.

The new heat transfer tube was completed and shipped to Fluidyne the last week in May. Following shakedown running of the furnace, the heat transfer test is scheduled to begin about June 15, 1977.

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