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Coal Technology Program Progress Report for April 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 APRIL 1977

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
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UNION CARBIDE CORPORATION
for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR APRIL 1977

ABSTRACT

This report - the thirty-third 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.

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1. SUMMARY

J. P. Nichols

Highlights of our progress in April are as follows:

- Several modifications were made in our bench scale hydrocarbonization system in an attempt to develop a procedure for the handling of caking coals.

- We continued experimental work on the pyrolysis of large blocks of coal, pressurized carbonization of residues, and three-phase mixing.

- Impact testing of 10-in.-thick pressure vessel steel has disclosed major gradients in impact properties.

- We continued development of a variety of methods for nondestructive testing of wear- and process-resistant coating.

- We have experienced some success in the development of welding techniques for cladding of carbon steels with Alloy 320 stainless steel.

- A microprobe examination of high alloy steel tubes that had been exposed in a fluidized bed combustor for 500 hr revealed about 0.001-in.-thick scales of predominantly calcium sulfate.

- In our gas-fired potassium boiler project we continued design, fabrication, and installation of equipment that is needed for initial operations with potassium.

- We continued the design study of a coal-fired boiler for an alkali metal vapor topping cycle.

- We continued engineering study and technical support work with activities in process modeling; preparation of the first volume of a Synthetic Fuels Process Research Digest; a survey of industrial coal conversion equipment capabilities; and studies of processes for heat recovery, rapid hydrogenation, and purification of hot gas.

- Process and program assistance work included studies on low-Btu gasification, high-Btu gasification, liquefaction, direct combustion, advanced power conversion, and *in situ* gasification of coal.

- In the fossil energy environmental project, we continued the preparation of a plan for an experimental study of the disposal of solid wastes from coal conversion in landfills, the preparation of an Environmental Monitoring Handbook, and the preparation of an environmental assessment for the pipeline gas program.

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, studies of residue carbonization in an atmospheric pressure carbonizer and in a pressurized carbonizer, engineering support studies for in situ gasification, and studies for identifying and characterizing alternate reactor concepts for coal hydroliquefaction.

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. Experiments were resumed in April after modifications to the ambient mock-up. A 3/16-in. diam transport line for solids feeding was installed inside the 3/8-in. diam draft tube nozzle. Because effects of draft tube diameter and the distance of the draft tube above the distributor plate are of interest, both 3/4-in. and 1-in. diam draft tubes with adjustable legs were fabricated. Two distributor plates will be analyzed for pressure drop and quality of gas distribution. One plate has fifty-four 3/64-in. diam holes and the other plate has forty-two 0.005-in. diam holes.

Experiments began in April with distributor plate evaluation and minimum fluidization velocity tests. Char from run HC-12 was used for the mock-up tests. Its particle size distribution is shown in Table 2.1. Weight mean particle size is 165 microns, with over 89% in the sieve size range -50 +230.

A 100 lb batch of char was devolatilized in the atmospheric carbonizer at 1200°F for use as an inert diluent in the 20-atm bench-scale hydrocarbonization facility. The char will be mixed with Illinois No. 6 coal for use in run HC-15.

Following the char devolatilization run several changes were made in the equipment in preparation for studying the caking tendencies of Illinois No. 6 coal.

The changes are:

1. A cold trap, operated at the temperature of dry ice, was installed downstream of the scrubber to trap any condensible material passing through the scrubber.

2. The position of the draft tube in the reactor which was originally 1 in. above the distributor plate was lowered to 1/2 in. above the distributor plate.

Table 2.1. Particle size analysis of char from Run HC-12

Size range	Mean particle size[a] (microns)	Weight percent
+20	--	0.0
-20 +25	774	0.17
-25 +30	651	0.26
-30 +35	548	0.72
-35 +40	460	0.73
-40 +45	387	1.47
-45 +50	326	1.38
-50 +60	274	2.85
-60 +70	230	16.02
-70 +80	194	10.28
-80 +100	163	13.64
-100 +120	137	22.49
-120 +140	115	7.50
-140 +170	97	9.86
-170 +200	81	5.32
-200 +230	69	4.17
-230 +270	58	2.23
-270 +325	49	0.67
-325 +400	41	0.21
-400	19	0.07

[a]Weight mean particle size = 165 microns.

3. A new char overflow line was installed from the reactor overflow port to the char receiver.

Work Forecast. Experiments will continue on the effect of draft tube diameter and spacing. Gas velocities simulating those in the 20 atm bench-scale hydrocarbonizer will be emphasized. Tests will be performed to determine the caking tendencies of Illinois No. 6 coal.

2.1.2 Bench-Scale Hydrocarbonization System

Work Accomplished. In the period following run HC-14, several changes were made in the experiment. In an effort to more accurately measure the gas flowrates to the equipment, all of the orifice flow meters were recalibrated, and one new orifice plate was installed directly upstream of the gas preheater. The new orifice will enable us to more accurately determine the gas flowrate to the downcomer. Orifice recalibrations indicate that a larger fraction of gas was flowing to the downcomer (rather than to the draft tube) than was desired. As a result, a much smaller gas flow to the draft tube was realized. This imbalance in gas flowrates is the probable cause for temperature instabilities noted during runs HC-13 and 14. The temperature instabilities probably resulted from poor recirculation of solids in the reactor. A differential pressure transmitter was also connected across the reactor; the high pressure side was attached to the downcomer supply line and the low pressure side was connected to the vent pipe which goes from the reactor top flange to the reactor rupture disc. This will enable measurement of the total differential pressure across the reactor without subjecting the pressure taps to plugging with coal particles.

Preliminary material balances and gas compositions for run HC-14 are reported in Tables 2.2 through 2.4.

Run HC-15 was performed during the period April 18-19, 1977. This run was the first attempt at hydrocarbonizing an agglomerating coal. Coal feed for the run was prepared by mixing 20 lb of Illinois No. 6 coal, sized to -50 +150 mesh, with 100 lb of char from Wyodak coal which had been devolatilized at 1200°F in the atmospheric pressure carbonizer. Three attempts at feeding coal were made with coal being fed for 12, 4, and 9 min during each respective attempt. The reactor temperature for each attempt was approximately 1100°F. Gas flowrates to the draft tube, downcomer, and transport tube were 1.8, 6.3, and 2.6 scfm respectively (which should have resulted in gas velocities in the draft tube, downcomer, and transport tube of 4.9, 0.19 and 21.5 ft/sec assuming that only the gas fed to the draft tube entered it). Each attempt at coal flow was terminated by the coal transport tube plugging at the inlet to the reactor.

A total of 4.1 lb of coal-char mixture was fed. After the third attempt at coal feeding, a leak developed in the inner seal on the scrubber pump, and a plug developed between the scrubber and the coal trap. The system was then shut down for inspection and minor revisions.

Table 2.2. Preliminary material balance for Experiment HC-14

Average bed temperature: 1070°F
Total pressure: 300 psig

	Mass (g)	Carbon fraction	Ash fraction	Sulfur fraction	Percent of carbon fed	Percent of ash fed	Percent of sulfur fed
Input							
(1) Coal	25,016	0.6382	0.0628	0.0039	100.	100.	100.
(2) Scrubber water	20,250	0	0	0	0	0	0
Output							
(3) Char recovered	11,083	0.8077	0.1248	0.0028	56.1	88.0	31.6
(4) Scrubber top phase	650	0.6414	0.0223	0.0027	2.6	1.0	1.8
(5) Scrubber middle (aqueous) phase	24,500	0.00874			1.3		
(6) Scrubber bottom phase	1,767	0.736	0.0056	0.0028	8.1	0.6	5.0
(7) Cold trap top phase	0	0	0	0	0	0	0
(8) Cold trap middle (aqueous) phase	250	0.00827			<0.1		
(9) Cold trap bottom phase	237	0.7360	0.0056	0.0028	1.1	0.1	0.7
(10) Miscellaneous tars	0	0	0	0	0	0	0
(11) Solvent residue	2,854	0.4233	0.0101	0.0013	7.6	1.8	3.8
(12) Gases	8,274	0.3541		0.0068	18.4		57.4[a]
Rinses							
(13) Scrubber - water	29,900	0.000468			0.1		
(14) Scrubber and cold trap - trichloroethane	58,840	b					
Overall balances	110				95.3	91.5	100.0

[a]Calculated by difference.

[b]See item 11.

Table 2.3. HC-14 effluent gas composition at steady state--1090°F at 12:16 pm on 3/22/77

Component	Effluent flow rate (scfm)	Composition (%)	H_2 and N_2-free composition (%)
CH_4	0.278	2.243	50.8
C_2	0.075	0.602	13.6
C_3	0.021	0.166	3.8
CO	0.112	0.906	20.5
CO_2	0.023	0.185	4.2
H_2S[a]	0.013	0.102	2.3
H_2	11.84	95.58	--
N_2	0.027	0.214	--
	12.39		

[a]Near low limit of sensitivity; accuracy questionable.

Table 2.4. Summary of Experiment HC-14 conditions and preliminary material balances

Experiment	HC-14
Bed temperature, °F	1100/1065/1010
Reactor pressure, psig	300
Estimated solids residence time in the reactor, min[a]	89
Period at steady state, hr	3.3/1.1/1.5
Coal feed	
Moisture content, wt %	5.37
As-received feed rate, lb/hr	9.2
Moisture-and-ash-free feed rate, lb/hr	8.0
Time of feeding, hr	5.97
Hydrogen flow rates, scfm	
Total hydrogen feed	10.2
Coal transport tube	2.7
Draft tube nozzle	5.4
Through distributor plate	2.1
H_2/coal feed ratio	
lb H_2/lb coal	0.37
scf H_2/lb coal	77
Carbon balance (% of carbon fed)	
Char	58.4
Liquids	18.5
Gases	18.4
Overall	95.3
Overall ash balance (% of ash fed)	91.5
Sulfur balance (% of sulfur fed)	
Char	32.7
Liquids	10.2
Gases	57.1[b]
Overall mass balance (% of mass charged)	110
Oil yield (wt % of maf coal)	21

[a]Time to char overflow in the reactor.

[b]By difference from 100%.

Post-run inspection of the line between the scrubber and the cold trap revealed that the blockage occurred at the entrance to the cold trap and was due to ice formation. Water was probably blown over from the scrubber during depressurization and subsequently froze during a period of low gas flow. The pipe from the scrubber to cold trap was about 50% blocked by an accumulation of tar which was probably deposited during the lifetime of the equipment.

The scrubber pump seals were removed and replaced with new seals. Disassembly of the reactor following run HC-15 revealed the following:

1. The draft tube was plugged in the bottom 8-in. section.

2. The cyclone dip leg was plugged in the bottom 2-in. section.

3. The walls of the reactor were coated with an agglomerated material up to the second overflow port. The thickest coating was opposite the cyclone dipleg.

4. A total of 2.8 lb of agglomerate was retrieved from the reactor.

Work Forecast. Experiment HC-16 will be performed with Illinois No. 6 coal diluted to 0.17% by Wyodak char with the following experimental changes:

1. Gas will be fed cold to the draft tube, and the draft tube nozzle below the distributor plate will be thermally insulated from the hot downcomer gas by a layer of alumina.

2. The 3/4-in.-diam draft tube will be replaced by a 1-in.-diam draft tube.

3. An inert layer of char will be put in the feed hopper so that an inert bed can be created in the reactor prior to feeding agglomerating coal.

4. Higher gas flowrates will be used to promote better recirculation in the reactor.

2.2 Experimental Engineering Support of In Situ Gasification Process

R. C. Forrester III, J. B. Gibson, and G. D. Owen

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, later this year.

During April, low-temperature experiments (600°C maximum) were carried out at both heating rates of interest, 0.3 and 3.0 C°/min. Chars produced in each test were similar to those formed during high-temperature experiments; none was pyrophoric and all possessed considerable crushing strength. A summary of char characteristics from some representative tests is given in Table 2.5. Note that, as expected, hydrogen content of the char decreases as maximum pyrolysis temperature rises. These data also support the observation that increases in char density at radial positions about halfway from center to surface of the residual block are caused by tar cracking and subsequent carbon deposition.[1] Samples from BP2-24, for example, show increased carbon content and reduced heating value at $^r/_R = 0.5$.

We were also able to alleviate an operational problem which had previously made gas production rates at 0.3C°/min somewhat unstable. At this lower heating rate, the specimen was apparently swelling enough to cover the furnace control thermocouple, greatly increasing the response time constant of the control circuit. By moving the thermocouple to a higher position in the reactor, contact with the swelling coal was precluded. This phenomenon was not observed at the higher heating rate, presumably because the degree of swelling was not as great.

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 51 pulse test measurements have 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 upflow. Slurry flow rates were in the range of 10.8 - 21.3 cm^3/sec with no gas flow and 5.9 - 12.5 cm^3/sec with air flow rates of 78 - 230 cm^3/sec.

To encompass the liquid and gas volumetric flow rates (3 cm^3/sec slurry and 100 cm^3/sec gas at 4000 psi and 450°C) used in the 1.1-in.-diam Synthoil process development reactor at the Pittsburgh Energy Research Center (PERC), it will be necessary for part of the pumped slurry to bypass the column and return directly to the feed tank. Slurry flow rates will be measured before and after each pulse test to be certain of a constant flow rate during the test.

The six Kenics mixing elements* ordered in January have been received. These six in-line static mixers will allow a 1-in.-diam by 5-ft-long contactor to be fabricated and will replace the 1-in.-diam by 10-ft-long column filled with glass beads when tests with the packed column have been completed.

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*Kenics Corp., No. Andover, Mass. 01845

Table 2.5. Characteristics of chars produced by two-dimensional pyrolysis of Pittsburg seam coal

Sample number	Maximum pyrolysis temperature (°C)	Heating rate (C°/min)	Radial position ($^r/_R$)[a]	Component weight percent[b]						Heating Value[c] (BTV/lb)
				moisture	ash	carbon	hydrogen	nitrogen	sulfur	
BP2-24F	1000	3.0	1	0.43	8.06	95.95	0.66	1.43	2.02	14,192
BP2-24G	1000	3.0	0.5	<.01	7.47	97.47	0.53	1.31	1.62	13,698
BP2-24H	1000	3.0	0	0.33	8.73	96.82	0.85	1.43	1.96	14,254
BP2-25B	800	3.0	0.5	0.52	7.84	94.62	1.11	1.71	3.39	14,418
BP2-27C	600	3.0	0	0.65	9.25	90.88	2.85	2.06	1.96	15,987
BP2-23C	1000	0.3	0.5	0.15	4.63	96.37	0.63	1.64	1.35	14,207
BP2-26D	1000	0.3	1	0.14	9.95	97.44	0.68	1.07	1.77	13,967

[a]Char samples were taken from three areas of the cylindrical block: at the axis of symmetry ($^r/_R$ = 0), at the surface ($^r/_R$ = 1), and between these extremes ($^r/_R$ = 0.5).

[b]All values are maf except those shown for moisture and ash themselves.

[c]Values shown are maf. Multiply by 2.326 to obtain kJ/kg.

2.4 Pressurized Carbonization of Consol Synthetic Fuel Residue

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

In April an effort was made to carbonize CSF residue, however, the original feed tank arrangement proved to be inadequate for feeding the residue. A packed-plunger positive displacement pump, which was on hand, has been installed and tested using methyl-napthalene to simulate CSF residue. This test showed improvements in feeding over earlier runs using methyl-napthalene and the original feed tank. Pumping the residue has proved difficult, however, because the particles in the residue fouled the check valves in the pump. Some runs using clarified (settled and decanted) residue are planned for May.

2.5 References for Section 2

1. J. P. Nichols (ed.), Coal Technology Program Quarterly Progress Report for the Period Ending March 31, 1977, ORNL-5282, in publication.

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

Impact testing of 25.4 cm (10 in.) thick A543 Class 1 steel plate has disclosed major gradients in properties. The 68 joule (50 ft-lb) temperature for surface specimens can be −62°C, while that for mid-thickness specimens can be +27°C.

Revisions to our summary report on plasma-sprayed coatings are nearly complete. We have made additional plasma-sprayed specimens and received a specimen from Alon Processing, Inc. We have received and radiographed fifty-six specimens from the erosion-corrosion experiments at Solar Corporation.

All installation work on our x-ray fluorescence system is complete; we are calibrating the illumination beams now. We have received our new line-scanning infrared (IR) camera and are installing some auxiliary circuits to adapt it to the measurement method planned for our coating specimens.

We tested liquid penetrant on a cermet specimen and found that its porosity entraps penetrant much the same as ceramic coatings do. We demonstrated the plan-view recorder in our high voltage probe system and have completed all planned experiments on that system.

Deposition of Alloy 320 cladding on carbon steels by the gas metal-arc and submerged arc processes is continuing. Some of the deposits appear to be sound. We are varying welding parameters to determine suitable ranges for obtaining sound cladding deposits.

Measurements of the rate of corrosion on fluidized bed combustor tubes are reported. Much of the scale on the high alloy steels is $CaSO_4$.

Failure analysis activities aimed at Solvent-Refined Coal plants are outlined.

3.1 Pressure Vessel and Piping Materials

D. A. Canonico

We have completed the Charpy V-notch (C_V) testing of the 25.4 cm (10 in.) thick A 543 Class 1 steel plate. The upper shelf energy values of the WR oriented (weak direction) specimens at the mid-thickness and quarter-thickness locations are 92.5 and 106 joules (68 and 78 ft-lb), respectively. The 68 joule (50 ft-lb) temperatures are 27 and −26°C (+80 and −15°F), respectively, for the mid-thickness and quarter-thickness locations. The 68 joule (50 ft-lb) temperature for C_V specimens removed from the surface of the 25.4 cm plate is about −62°C (−80°F).

We are continuing the simulation of the microstructure at various depths of thick plates of 2 1/4 Cr-1 Mo steel. Both surface and quarter thickness locations have been simulated with the DATA TRAK. These specimens were austenitized at 927°C (1700°F) and cooled at the appropriate rate. They have been tempered and given a simulated post weld heat treatment (PWHT). Room temperature and C_V tests have been conducted after austenitizing and cooling (Q), after Q and tempering (Q and T) and after Q and T and PWHT.

3.2 Inspection Techniques for Wear- and Process-Resistant Coatings

R. W. McClung and G. W. Scott

Several nondestructive methods with good potential for inspection of coatings are being explored. The work is reported below by method.

3.2.1 Review and Evaluation (G. W. Scott)

We have nearly completed editing and revising the report of program work for 1976 on plasma-sprayed coatings. Final report preparation will begin during May.

3.2.2 Specimen and Standard Fabrication (J. D. Hudson and D. P. Edmonds)

During this reporting period several types of specimens were prepared by the Welding and Brazing Laboratory. The following tensile specimens have been prepared:

1. bond coat of NiCrAl 0.076 mm (0.003 in.) thick plus cermet coat 50% ZrO_2/50% NiCrAl 0.254 mm (0.010 in.) thick,
2. bond coat of NiCrAl 0.076 mm (0.003 in.) thick plus ceramic coat of ZrO_2 0.254 mm (0.010 in.) thick.

The following ultrasonic specimens have been prepared:

1. bond coat of NiCrAl (0.254 mm (0.010 in.) thick,
2. cermet coat of 50% NiCrAl/50% ZrO_2 0.254 mm (0.010 in.) thick,
3. ceramic coat of ZrO_2 0.254 mm (0.010 in.) thick on type 304 stainless steel block 2.54 × 5.08 × 10.16 cm (1 × 2 × 4 in.).
4. Incoloy 800 plate 0.32 × 5.08 × 10.16 cm (0.125 × 2 × 4 in.) was divided into four equal sections — with one section left as sand-blasted, one section coated with 0.254 mm (0.010 in.) thick ZrO_2, one section with 0.508 mm (0.020 in.) thick ZrO_2 and one section with 0.762 mm (90.030 in.) thick ZrO_2, and
5. the same procedure as 4 was used for bond coating with NiCrAl.

During this reporting period several types of specimens were prepared by the Welding and Brazing Laboratory. Unless we indicate otherwise, the substrate material is low alloy steel. Tensile specimens have been prepared with

(a) bond coat of NiCrAl, 0.076 mm (0.003 in.) thick, plus a 50% ZrO_2/50% NiCrAl cermet coat, 0.254 mm (0.010 in.) thick, and

(b) bond coat of NiCrAl, 0.076 mm (0.003 in.) thick, plus a ceramic coat of ZrO_2, 0.254 mm (0.010 in.) thick.

Ultrasonic specimens have been prepared with the following features:

(a) a bond coat of NiCrAl, 0.254 mm (0.010 in.) thick,

(b) a cermet coat of 50% NiCrAl/50% ZrO_2, 0.254 mm (0.010 in.) thick,

(c) a ceramic coat of ZrO_2, 0.254 mm (0.010 in.) thick, on a 2.54 × 5.08 × 10.16 cm (1 × 2 × 4 in.), type 304 stainless steel block,

(d) an Incoloy 800 plate 0.32 × 5.08 × 10.16 cm (0.125 × 2 × 4 in.) was divided into four equal sections, with one section left as sand-blasted, one section coated with 0.254 mm (0.010 in.) thick ZrO_2, one section with 0.508 mm (0.020 in.) thick ZrO_2, and one section with 0.762 mm (0.030 in.) thick ZrO_2.

(e) The same procedure as (d) was used for bond coating with NiCrAl.

We received the specimen requested from Alon Processing. It is now being circulated for preliminary examination and testing.

3.2.3 <u>Penetrating Radiation</u> (B. E. Foster and G. W. Scott)

We are calibrating the beam from various excitation sources procured for use with our x-ray fluorescence (XRF) systems. We have two ring sources, ^{109}Cd and ^{153}Gd. Because the manufacturers do not distribute the source material uniformly around the rings, the intensity of illumination is not uniform across a circular area seen by the detector and located on the axis of the system. By exposing x-ray films at various distances from the sources, it is possible to find a position where the intensity is uniform. The specimen will be placed at this position for experiments.

We have completed all installation work on the XRF system, including a work platform and liquid nitrogen handling equipment.

We have made transmission radiographs of the specimen from Alon Processing and of 56 specimens received from Solar Corporation erosion-corrosion tests. Interpretation is not complete on the Solar specimens.

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

A line-scanning infrared camera has been obtained and will be used to inspect the coating nonbond standards which we have fabricated. This camera is considerably better-suited than our imaging unit for evaluation of the standards in that the interval between successive interrogations of any given point in the scan is approximately one-fourth that of the imaging camera. In addition, the output is an analog voltage rather than the somewhat subjective thermal image provided by the larger camera.

Previous experience with this type of thermal testing has shown that, in order to keep the analog display on scale during a rapid transient, the sensitivity of the display device must often be reduced to the point where the small variations indicative of flaws are difficult or impossible to see. An alternative to this practice is to increase the sensitivity and to continually adjust the offset control to keep the rapidly changing display on scale. Unfortunately, the offset control rarely has sufficient range to permit this approach, and the degree of operator interaction required is quite large. Accordingly, an automatic offset control was designed and built for an earlier project and is being modified for the present work. This control incorporates a sample-and-hold peak-detecting circuit which is updated during each sweep of the camera. With this unit, the operator can select any desired sensitivity and the control will automatically hold the display on scale. At the termination of testing, the peak value obtained is switched to a measuring circuit where the peak temperature may be determined.

3.2.5 Surface Inspection Materials (S. D. Snyder)

A cermet tensile crack specimen, No. CP72-C01, has been prepared with a 0.30 mm (0.012 in.) thick plasma sprayed coating of 50% ZrO_2 — 50% NiCrAl on a IN-800 substrate. The I.D.E.A. technique with ZL-22A penetrant was used on this yet uncracked specimen to learn something about the degree of difficulty of removal of excess penetrant. Two tests were done, each with four cycles of emulsification-washing-drying. In the first test an emulsification time of 1 min in each cycle was used, and in the second test the emulsification time was changed to 3 min in each cycle. The results of both tests showed that this technique is not applicable to the cermet because of its porosity and resultant ability to hold the penetrant too tightly to be emulsified and washed out. The cermet coating behavior with the ZL-22A penetrant was about the same as that of the ZrO_2 ceramic coating.

3.2.6 <u>High Voltage Probe</u> (G. W. Scott)

We assembled and successfully tested our planview recording system. We made two types of recordings: "positive", in which the recorder writes an ink line over flaw areas, and "negative", in which it writes everywhere except over the flaw areas. The negative mode produces a superior visual image, which compares favorably with photographs of filtered particle indications from the same specimen.

These experiments conclude all work presently planned for the high voltage system. We intend to start preparation of a topical report soon.

3.3 Welding and Cladding

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

We are concentrating on determining the effects of welding conditions on the structure and properties of type 320 stainless steel clad deposits. Clad deposits are being made with the gas metal-arc (GMA) and submerged-arc (SA) processes on carbon-steel base materials.

Gas metal-arc clad deposits have been made using a mixed shielding gas of 75% Ar-25% He; welding at 200 amps, (direct current reverse polarity), 31 volts, 7.6 cm/min travel speed, and 1.6 cm oscillation width. These conditions yield deposits with 25% dilution from the base metal. The deposits have been checked for fissure by metallographic and dye-penetrant examination. No fissures were located metallographically on sections taken transverse to the clad surface. However, dye penetrant examination revealed several fissures on the surface of the deposits. Samples are currently being prepared for side-bend and face-bend testing. In addition, we are evaluating other shielding gases for GMA cladding in an attempt to obtain a more stable arc and to have better control of the mode of metal transfer. Submerged-arc deposits have been made using Arcos S-4 flux with alternating current, welding with 475 A, 40 V, and 15.2 cm/min travel speed. Lateral torch oscillations of 0 cm, 1.3 cm, 1.9 cm, and 3.2 cm have been used. Visual inspection of these deposits has not revealed any large fissures on the clad surface. We are in the process of performing metallographic, dye-penetrant, and bend testing of these deposits.

3.4 Fireside Corrosion

R. H. Cooper and J. H. DeVan

Analysis continues on surveillance tube samples of Alloy 800H, Alloy 600, types 310H, 304 stainless steel, and Alonized 800H and type 310 stainless steel. These materials have received a 500 hr exposure to a fluidized bed coal combustor environment. Thus far, metallographic measurements have revealed a discontinuous scale approximately 0.0012 in. thick on the alloy 800, 310, and 304 surfaces exposed to the fluidized bed environment. A uniform and continuous scale approximately 0.002 in. thick was observed on the Alloy 600 material. In both cases microprobe analysis indicates that most of this scale is composed of $CaSO_4$. A thinner scale (0.0001 in. or less) of Cr_2O_3 was identified between the $CaSO_4$ scale and the base metal in each alloy. Comparison of the tube wall thickness for these materials before and after exposure to the fluidized bed environment revealed no statistically significant metal loss. However, it should be noted that in view of the measurement errors associated with the thickness measurements and the brief environmental exposure, only corrosion progressing at a linear rate greater than 20 to 25 mils/yr could be resolved by these measurements.

Furthermore, metallographic and microprobe analysis of these samples is in progress. In addition, components for four more test tubes are currently being procured for subsequent fabrication. These four tubes plus the original 12 test tubes will be shipped to Fluidyne for reinsertion into the fluidized bed. This group of 16 tubes will be given a 1000 hr exposure in the Fluidyne facility.

3.5 Failure Prevention and Analysis

R. T. King

The several failure analysis activities on components from the Solvent-Refined Coal (SRC) Plant at Tacoma, Washington, are at different stages of development:

(a) Ultrasonic methods for determining the presence of coked solids in process lines have been demonstrated and reported.

(b) An iridium^{192} source has been demonstrated and reported to be suitable for detecting coking in process lines.

(c) The petrographic study of coked material in a process line has revealed a variation in microstructure. Coking experiments with feedstock coal and solvents indicate a strong effect of temperature on the structure of coke formed from these materials. Since coking is a persistent problem in coal liquefaction plants, we suggest that a program aimed at determining conditions under which coking occurs be considered.

(d) Brazing materials thought to be suitable for attaching tungsten carbide valve tips to stems have been purchased.

(e) Examinations of a flapper valve from the wash solvent distillation tower, and a type 347 stainless steel elbow, are nearly complete. Because they are not failures responsible for plant shutdowns, the work was allowed to progress slowly.

A team visit to the Wilsonville SRC plant was made at the request of the plant, to determine useful methods for examining high pressure components during later shutdowns. Surface metallography of accessible areas is proposed for the next shutdown. We encourage support for the development of ultrasonic methods. Other details of the trip are in the report.

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 design work on the potassium system is nearing completion. Electrical drawings issued this month included heater and thermocouple location and tabulation drawings and conduit routing drawings. One instrument and control drawing, the wiring diagram for the No. 5 main control board, was issued.

2. Fabrication work completed includes completion of the sample box and associated piping, work on modification of the vapor separator for installation for potassium operation, assembly of the potassium liquid level indicator elements, and fabrication work of main control boards No. 6 and 7.

3. The drain tank and its enclosure were installed on the equipment tower. Most of the condenser enclosure installation is complete. Installation of the structural steel for the tower extension is nearly complete, and installation of the siding has begun with completion expected by the middle of May.

4. Plans for next month. The final electrical drawing will be completed; work will continue on the control diagram and wiring detail drawings; fabrication of the control panels will continue; construction on the tower will be completed and installation of connecting piping will begin.

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.

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, Advanced Planning for Test Modules, has been renumbered and will be issued as ORNL-ENG-TM-6. Reproduction is in process.

A subcontract is being negotiated with TRW Energy Systems Division for assistance in developing a plan for the testing and evaluation of critical components of coal conversion demonstration plants.

6. ENGINEERING STUDIES AND TECHNICAL SUPPORT

J. R. McWherter

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. Two code packages for solving ordinary and partial differential equations (DSS/ODE and DSS/PDE) have been received from Lehigh University. The programs include a number of example problems and are documented exceptionally well. We are working on the installation of these programs on the Oak Ridge computers. The first package has been checked out and is operational. The second is still in work but is expected to be running early in May.

Data sets were opened on ORNL disk storage modules to house the source and object modules and the test data provided for the example problems.

Problems encountered in the conversion of the programs to the ORNL computers are being solved in collaboration with Lehigh. Thus far there have been no unusual difficulties, and there has been no indication that any will develop.

2. Work continued on the development of the heat exchanger design and cost program HDC. Data were obtained from Elliott Corporation on the labor requirements for the tube-rolling operation. This information has now been incorporated in the program. Several forging manufacturers were contacted for data on the costs of flange forgings and have agreed to send prices on typical sizes.

During the month, the HDC program was enlarged to include a more detailed cost analysis of the heat exchanger in accordance with its TEMA three-letter type designation. The user inputs the TEMA type designation (for example, AES), and the program uses this to determine the appropriate mechanical design features and physical parts required. A detailed materials and labor summary is then calculated and printed.

In May, example problems will be run to compare the results of the program with cost estimates prepared by vendors.

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.

6.2 Synthetic Fuels Process Research Digest

F. J. O'Hara,* S. P. N. Singh, and Alan Spiewak

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

Topics to be included in the first issue are: (1) Catalytic Coal Gasification, (2) Flash Hydropyrolysis of Coal, (3) Zinc Chloride Hydrocracking of Coal and Coal Extracts, and (4) Conversion of Methanol to High Octane Gasoline.

Article 1 was completed and submitted for editing. Article 2 was edited, composed, and is being sent to ERDA for review. Article 3 is being edited and will be sent to ERDA for review in May. Article 4 was reviewed by ERDA and Mobil Research and Development Corporation. The latter sent more recent information on this subject. The comments will be incorporated in the article and the revision sent to ERDA again for review.

6.2.3 Changes

The first issue of the digest will not be made before late June. The time to prepare the articles is taking much longer than anticipated.

6.2.4 Problem areas

The receipt and inclusion of more recent information on Article 4 will result in some delay in completion of this article. The length of time required for composition of test, tables, and illustrations is much more than anticipated.

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*Technical writer working under subcontract.

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)

On April 1, letters were mailed to manufacturers of compressors containing the questionnaire and equipment specifications list which have been developed during the last several months. Some responses to both this mailing and a similar mailing on pumps, which was sent out on March 31, have already been received.

A questionnaire on hydraulic turbines, including a list of process conditions, has been prepared and was mailed to industry on April 26. A meeting was held on April 12 with John Kirkland of TVA in Knoxville to review and discuss this questionnaire and equipment list.

A questionnaire on gas expanders is now being developed. Only a few applications of gas expanders have been identified in the reports which are being used as a basis for this study. In a phone conversation with one manufacturer, it was learned that they too had found only limited information. For this reason this last questionnaire may follow a somewhat different format. A meeting with A. P. Fraas of ORNL to discuss expander technology was held on April 20. The mailing of expander information, as well as questionnaires to manufacturers of several types of rotating equipment, should occur during the first week of May.

On April 5, a meeting was held with Otto Decker, the Vice-President of Business Development for Mechanical Technology, Inc. He discussed several of the projects that MTI, a manufacturing and R&D firm located in Latham, New York, is conducting and indicated his company's interest in responding to the several questionnaires which have been developed.

As of the writing of this report, visits are planned for April 27, 28, and 29 to Stearns-Rogers, R. M. Parsons, and Airco Cryogenics. The first two organizations are architect-engineering firms, located in Denver and Los Angeles, respectively, and the latter a manufacturer in Los Angeles. Information from these meetings will be summarized in the May 1977 monthly report.

6.3.3 Valves and other letdown devices (W. A. Bush and E. C. Slade)

Information that had been obtained by calculating valve sizes during March was summarized into seven sheets (one for each process studied). Letters are in preparation based upon the above, for submission to the valve industry in order that a capability appraisal may be obtained.

An approach has been formulated to the "Valve Manufacturers Association" through ANSI Subcommittee members, whereby the V.M.A. President has indicated that he would like to see the problem of "valves for coal conversion" explained (perhaps unofficially) to the V.M.A. Members General Meeting in late May.

This direction is being pursued through the V.M.A. Technical Coordinating Committee. Expressions of cooperation are very encouraging.

6.3.4 Hot gas clean-up devices (J. P. Meyer and M. S. Edwards)

During the reporting interval, the following work directed toward particulate removal has been completed:

- Follow-up letters have been sent to turbine manufacturers who have not responded to our initial request for information regarding turbine tolerance specifications.

- On-site visits have been made to EPRI, Acurex Aerotherm and Combustion Power Company in California.

  At EPRI, contact was made with Sy Alpert and Al Dolbec and a review of their analysis and perspective on hot gas clean-up was presented. On the whole, they are not optimistic about its potential and prefer to back low-temperature clean-up with regeneration as the most feasible alternative.

  Fred Moreno, together with various members of the Acurex Aerotherm staff, presented an in-depth analysis of the problems associated with high-temperature--high-pressure particulate measurement. Their conclusion was that this technology was still at its infancy and substantial strides would have to be made before reliable results could be obtained. The implication of this analysis is that it is currently impossible to assess gasifier effluent and device efficiency since the equipment needed to produce the data for this analysis is unavailable. The absence of experimental results bears out this observation.

  An optimistic approach appears to underscore Combustion Power Company's dry scrubber concept. They believe that extremely high clean-up efficiencies can be obtained by their unit (99%+) if optimum operating conditions are achieved. Tests at MERC on one of their units will commence this summer.

As a common basis of comparison for each prospective device, a standardized assessment form has been prepared, and is included with this report. The approach used in the layout of this form is that it should contain design data capable of being used directly by a process engineer. In this way, vagrancies in the data can be easily identified.

For every piece of equipment previously identified as applicable to hot gas particulate removal, contact has been made, both by telephone and letter with the manufacturer, to obtain as much specific information as possible.

In order to assess the degree of removal efficiency needed by gas cleaning equipment in high-temperature--high-pressure applications, Tables 6.1-6.3 have been prepared. In the first table, a parametric study is made illustrating the degree of overall removal efficiency required by the process as a function of various inlet grain loadings and turbine tolerances. Table 6.2, on the other hand, considers the removal efficiency required by the final clean-up device assuming that 95% of the inlet material can be removed by some sort of roughing unit such as a cyclone or a multiclone. Finally, Table 6.3 examines the problem of particulate distribution and computes the amount of material removed by considering that some separation device is able to remove all material above a certain micron size. Mathematically, the entries are given by:

$$\text{Efficiency (\%)} = \frac{\int_{x_L}^{\infty} F(x,\mu_d,\sigma)\,dx}{\int_{0}^{\infty} F(x,u_d,\sigma)\,dx}$$

where: $F(x,\mu_d,\sigma)$ = log normal particulate mass distribution function

μ_d = mean particle diameter (μ)

σ^2 = variance (μ)

x_L = threshold cutoff value (μ)

Table 6.1. Overall process clean-up efficiencies (%) needed for acceptable turbine life as a function of gasifier effluent loading and inlet turbine specifications

Effluent loading (gr/scf)	Turbine tolerance (gr/scf)		
	0.05	0.002	0.0001
70	99.93	99.99	99.99
30	99.83	99.99	99.99
10	99.50	99.98	99.99

Table 6.2. Overall clean-up efficiencies (%) required for a final clean-up device as a function of inlet loading and turbine load allowances

Inlet loading (gr/scf)	Turbine tolerance (gr/scf)		
	0.05	0.002	0.0001
3.5	98.57	99.94	99.99
1.5	96.67	99.87	99.99
0.5	90.00	99.60	99.98

Table 6.3. Overall collection efficiencies for a hypothetical device as a function of mean particle diameter ($\bar{\mu}d_p$) and perfect collection efficiency above a given particle diameter

Mean particle diameter (μ)	Diameter (μ) above which total collection occurs	
	5	10
132	92.4	87.1
66	87.1	79.7
33	79.7	70.0

Based on the assumption that the mass distribution is log normal with respect to particle diameter:

$$F[\ln(x)] = \frac{1}{\sqrt{2\P}\ \sigma} \exp \left[- \left\{ \frac{\ln(x) \ -h(dp)}{\sqrt{2}\ \sigma} \right\}^2 \right]$$

where: F[lnx] = particle mass distribution

x = particle diameter (μ)

μ = mean particle diameter (μ)

σ^2 = variance (in this case, taken as 5.20 μ)

The following work directed toward H_2S removal has been addressed this reporting period:

- Response from Westinghouse included a draft of their Phase I report under the High Temperature Turbine Technology Program. This document provides their latest assessment of hot gas cleanup problems and promises.
- Gilbert Associates likewise provided their latest review: Fuel Gas Cleanup Technology for Coal Gasification, FE2220-15, dated March 24, 1977, by B. N. Murthy, M. G. Klett et al.
- Both reports have been reviewed for information pertinent to the hot gas cleanup surveys.
- Kennecott Copper Corporation sent a report, "Hot Gas Desulfurization," dated April 1976, from their Ledgemont Laboratory summarizing the information they developed on the use of a copper-based absorbent.
- No other responses specific to H_2S removal processes have been received this past month.

6.3.5 Heat recovery equipment survey (W. R. Gambill)

Status summary

The information on heat recovery and utilization obtained from various sources during a visit to Houston in late March was organized and a trip report prepared.

Tabulations of heat exchangers taken from draft evaluation reports for three processes — Synthoil, Fischer-Tropsch, and Hydrocarbonization — are being sent to ERDA/FE/MFPM.

Six more descriptive brochures have been received from vendor companies. A discussion was held with Bill Small of Phillips Petroleum Company concerning the rod-baffle exchanger. The literature survey and evaluation of the material on hand are continuing.

6.4 Large Air Separation Plant Study

W. R. Gambill

Status summary

No work was done on this study during April. Further activity on this task is pending direction from ERDA/Fossil Energy.

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

W. R. Gambill

6.5.1 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.

6.5.2 Status summary

The information on heat recovery and utilization obtained from various sources during W. R. Gambill's visit to Houston in late March was organized and a trip report prepared.

During a discussion with J. J. Zimmerman, Vice President of Kinetics Corporation (Sarasota, Florida), he indicated that the actual efficiency of the rotary positive displacement screw-type expanders used in their organic Rankine cycle (ORC) units is 80%. They anticipate a unit cost of ~\$400/kW(e) for a 10 MW(e) ORC system operating with a minimum ΔT (heat source to heat sink) of 100°F. Working fluids have been Freons 11, 12, and 114.

The Hawthorne Leslie Company in England is producing a system for recovering heat from Diesel engines on ships. The exhaust gas is used to boil water, the steam passing to a turbine which drives a high-speed alternator with an output currently to 1.5 MW(e).

Bill Small (Engineering Services) of Phillips Petroleum in Bartlesville, Oklahoma, was contacted concerning the Phillips pebble heat transfer device. This approach, which was oriented to a specific process, was abandoned about 20 years ago following a two-year R&D effort. The device was apparently a sensible heat transporter of the TOSCO type, utilizing a circulating stream of small refractory cubes. The rod-baffle exchanger (RBE) developed by Phillips for high-reliability service on North Sea platforms is being sold by several companies with license rights. In addition to minimizing tube vibration and shell-side fouling, tests conducted with water, air, and oil have shown that the ratio of heat transfer to shellside pressure drop ($U/\Delta P_s$) is ~1.8 times higher for an RBE than for a standard, segmentally baffled shell and tube exchanger.

The literature survey and evaluation of the material on hand are continuing.

6.6 Rapid Hydrogenation

S. P. N. Singh

6.6.1 Contract objective

The objective is to conduct a scoping study of two candidate rapid hydrogenation processes to determine the need for a more detailed process evaluation of the rapid hydrogenation process.

6.6.2 Status summary

Information is currently being gathered on the two candidate processes — namely, the Cities Service Short Residence Time (SRT) Hydropyrolysis process and the Spencer Chemical Company process — to form the basis for the scoping study.

S. P. N. Singh visited Cities Service R&D facilities in Cranbury, New Jersey, to discuss the status of their SRT Hydropyrolysis process development effort and to determine the availability of information regarding their proprietary process.

6.7 Hot Gas Purification Processes

M. S. Edwards and J. P. Meyer

6.7.1 Contract objective

The objective of this project is to investigate the present state-of-the-art of hot gas cleanup processes.

6.7.2 Status summary

Due to the similarity of this project with the one on hot gas cleanup devices, the reader is referred to Sect. 6.3.4 for a more detailed description of the work completed during the reporting period.

To date, the following work has been undertaken on this project:

- A review of the pertinent literature on hot gas purification processes has been completed.
- Inquiries have been forwarded to hot gas cleanup process vendors and/or developers. We are awaiting responses.
- Contacts with industrial firms seeking additional process information, especially the identification of technology in other industrieis that might be applicable to hot gas cleanup, has been completed.

- Identification and characterization of gasifier and PFBC effluent streams is currently being pursued.

- Contacts with major gas turbine developers seeking information on turbine inlet tolerances is in progress.

6.8 Engineering Assistance

J. M. Holmes

ORNL is providing the services of an experienced engineer for such periods of the year as requested to provide technical assistance to ERDA/FE/MFPM.

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

A work statement was prepared and an effort is underway to obtain the services of a consultant for this project.

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

Activities in April 1977 included work on preparation of the process summaries and acquisition/review of additional process data. Activities forecast for May 1977 include publication of the process survey section and preparation of drafts of the technical data sections for some of the 22 processes of most interest. These 22 processes were selected from the consideration of some 50 processes that produce low and intermediate Btu gas from coal. One-page process summaries were reviewed and prepared for typing. Topics included in the summaries were gasifier type, developer/licensor, status/history, operating conditions, reactants, products, coal feed, ash removal and process description.

Technical data were collected and reviewed for some of the following 22 processes which are being compared/evaluated:

Fixed Bed Processes

ERDA-GFERC
ERDA-MERC
Lurgi-dry ash
Lurgi-slagging (British Gas Corp.)
Wellman-Galusha
Woodall-Duckham

Fluidized Bed Processes

Battelle/Union Carbide Agglomerating Burner
BCR Tri-Gas
CO_2 Acceptor
HYGAS (IGT)
Synthane
U Gas (IGT)
Westinghouse
Winkler

Entrained Flow Processes

Babcock and Wilcox
BI-GAS
Combustion Engineering
Foster Wheeler
Koppers-Totzek
Texaco

Molten Bath Gasifiers

Atomics International
Otto-Rummel

Work planned for May includes publication of the process survey section in draft form. This section contains summaries of approximately 50 processes that are being (or have been) used to produce low and intermediate Btu gas from coal.

7.2 Direct Combustion

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

The subcontractor, United Engineers, is completing their estimates for operating and capital costs for industrial/commercial size steam and hot water units. These costs, which will include vendor estimates, will be part of their report to be transmitted the second week in May.

Some environmental concerns were considered. An investigation into the Houston-Galveston industrial region indicates that replacement of the present boilers, which are burning natural gas with coal burning equipment, will probably not cause significant problems as far as NO_x and SO_2 are concerned. However, the increase in particulates will probably raise the ambient level substantially above the primary standards set by EPA.

Further contact has been made with boiler vendors and a trip is planned in early May to meet with representatives of Babcock and Wilcox.

7.3 Advanced Power Conversion Systems

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

Efforts to compile data on operating experience with fuel cells have continued with little success to date. Data have been obtained for the Union Carbide program and for three Pratt and Whitney 12.5-kW modules tested by Public Service of New Jersey. Data on the NASA ground test and flight operation of fuel cells have been promised but have not yet

*Consultant.

been received. Efforts to obtain data on United Technologies (Pratt and Whitney) operating experience (the most significant body of work) have been unsuccessful. Except for these data the draft report on Fuel Cells is virtually completed.

The draft reports on MHD and Combined Gas Turbine-Steam Cycles have been roughed out and are currently being reviewed and revised. These, together with the Fuel Cell report, should be ready for submission to ERDA/FE/Office of Program Planning and Analysis by the latter part of May. It is expected that a substantial amount of additional information will become available at the meeting on Fuel Cells to be held in Boston the latter part of June, and this will be incorporated in the report.

7.4 Liquefaction

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

Seven additional processes were reviewed. The information and references on each process were prepared in a standardized data format. The processes included:

- Pittsburg and Midway Coal Mining Company's Solvent Refined Coal (SRC) process.
- Lummus Company's Clean Fuels from Coal (CFFC) process.
- Conoco Coal Development's Zinc Halide Hydrocracking.
- Cities Service's Short Residence Time (SRT) Hydropyrolysis.
- University of Utah Intermediate Coal Hydrogenation.
- The Schroeder Rapid Hydrogenation process.
- The Brookhaven National Laboratory Flash Hydropyrolysis process.

All data and references have been filed according to the type of process.

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

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.

An effort was initiated on an assessment of the production of gasoline from methanol by the Mobil process. The scope also includes the production of methanol from coal. Target date for completion of a report is mid-June 1977.

Discussions were initiated with organizations on the subject of production of methanol from coal. This included, among others, the du Pont and Davy Powergas Companies. Plans were made to meet with du Pont personnel in Wilmington, Delaware, to discuss this subject.

7.5 High Btu Gas

This subprogram is being analyzed under subcontract by the Scientific Design Company, Inc. (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.

7.5.2 Summary status

During the month of April a very substantial effort was expended on an evaluation of the Battelle Agglomerating Ash Burner process to product high-Btu gas. This evaluation included the preparation of conceptual process flowsheets, heat and material balances, equipment specifications, order of magnitude capital cost and operating cost estimates.

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

Draft copies of a report, Evaluation of In Situ Coal Gasification Processes on a Regional Basis, were submitted to OPPA on April 1, 1977, for review and comment. The report compares four candidate in situ coal gasification processes on the basis of a qualitative assessment of their technical merits and suitability for application to various resource types and configurations in the continental United States. Also submitted were draft copies of "Summary Data Source Sheets for the In Situ Coal Gasification Project."

Work continued on the economic analysis of the four candidate in situ processes which are the subject of the evaluation project. A preliminary flowsheet was prepared for a 1000-MW(e) combined-cycle generating plant operating on low-Btu gas. Field test data obtained by the Laramie Energy Research Center on the linked vertical well (LVW) process with western subbituminous coal were used to calculate a material balance for the plant. Horsepower requirements were determined for the gasification and linking air compressors and for the raw gas compressor. Heat balance calculations for the system were started but are incomplete at this time.

Special emphasis is being placed on obtaining information on costs associated with drilling operations for current in situ coal gasification field tests. Results of initial investigations indicate that oil-well drilling cost data are not directly convertible to in situ coal gasification applications. The main reason for this is the different type of equipment required for drilling oil wells because of the generally much greater depths involved.

A member of the evaluation project staff attended the ANS topical meeting, "Energy and Mineral Recovery Research," at the Colorado School of Mines in Golden, Colorado, on April 11-13, 1977.

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 sent to ERDA/OPPA for their information and comments.

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. Ford, Bacon and Davis, Texas, responded to a request for information on their licensed Takahax process. They provided a copy of the latest paper on the process.

2. American Lurgi Corporation indicated in a telephone conversation that the Rectisol process is not suitable for the conditions expected in low-Btu gasification.

3. Two vendors who are providing conceptual designs and costs for their processes have not yet submitted final values: Peabody Engineered Systems (the Stretford process) and Eickmeyer and Associates (the Catacarb process). Additional inquiry indicated that the two vendors are working on the designs as the press of other business commitments permit. Hopefully, they will finish the estimates in May.

4. There has been only a limited response to the requests for information on high-temperature gas cleanup processes. Kennecott Copper Corporation sent a report which summarized the information they developed on copper-based absorbents. Westinghouse and Gilbert Associates both provided their latest assessments of high-temperature gas cleanup technology.

5. A preliminary report by C. F. Braun on high-Btu gas cleanup was obtained from ERDA. It will be reviewed for pertinent information.

6. The screening of gas cleanup processes is essentially completed. A draft of the evaluation including the selection of candidate systems is being prepared for the ERDA contract manager.

7. Detailed descriptions of the candidate processes is underway. The rough draft of one process description is almost complete.

As requested by the ERDA Program Manager, an interim draft report is being 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*

Preparation began on a report describing the details of the multiple regression analysis used to obtain the correlations of prices of eastern and western U.S. coals which were reported last month.

*Consultant from the University of Tennessee.

7.10 Energy Transportation Costs

O. L. Culberson*

E. C. Fox and J. R. Tallackson have undertaken the acquisition of a working understanding of the parameters, and their relative significance, which affect the costs of shipping coal by truck, rail, and water. Contact has been established with a number of coal companies, railroads, and barge lines, and a meeting was held at Oak Ridge on April 20 with three representatives of the Missouri Pacific Railroad.

7.11 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.

*Consultant from the University of Tennessee.

8. FOSSIL ENERGY ENVIRONMENTAL PROJECT

C. R. Boston

8.1 Landfill Storage of Coal Conversion Solid Wastes/Information Assessment

H. M. Braunstein

Internal comments on the landfill information assessment have been received. External comments have been solicited from individuals at I.I.T. Center/Chicago, University of Notre Dame, Department of Interior, Illinois State Geological Survey, and EPA. To date, both written and verbal comments have been highly favorable.

8.2 Landfill Storage of Coal Conversion Solid Wastes/Experimental Phase

W. J. Boegly

Work was initiated on the planning and design stage of the experimental phase of the landfill study. Bill Boegly was appointed task leader and several planning sessions were held with Hershul Jones (ERDA), J. O. Duguid, C. R. Boston, W. J. Boegly, R. G. S. Rao, and H. M. Braunstein. Additional FY 1977 funding will be needed to get started on laboratory-scale leaching studies. H. Jones is investigating possibilities of obtaining this funding from ERDA Division of Major Facility Project Management. He is also looking into sources of large amounts (several tons) of coal conversion solid wastes from operating pilot plants.

8.3 Environmental Monitoring Handbook

M. S. Salk

Work was essentially completed on Subtask 5, Document Preparation, Part I (Preconstruction Monitoring). The only sections of the document which are not finished are 1.4, Description of Chemical Analysis, and parts of 1.2, Description of Aquatic Environments. These are currently being prepared and will be submitted as a supplement to the first draft during May. The entire document was reviewed by a number of ORNL personnel and their comments and suggestions incorporated into the first draft. The document was delivered to H. T. Jones, ERDA/FE/MFPM, on April 26, 1977.

Outlines were prepared for several of the construction and operational monitoring sections and work was begun on Parts II and III (Construction and Operational Monitoring) of the Handbook.

8.4 Programmatic Assessment/Pipeline Gas

L. H. Stinton

The bulk of Sections 1 and 2 have been submitted as rough drafts. These sections include process requirements, process descriptions, effluents, and site descriptions for the three surrogate sites. The emphasis has shifted to evaluation of construction and operation impacts. A rough draft of the document will be assembled for editing by May 13, 1977.

9. COAL-FUELED MIUS

R. S. Holcomb and W. R. Mixon

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 Systems

The 1000-hr endurance run of the coal metering and feed system, and the subsequent inspection of components, was successfully completed during the last period. Current plans include integration of the feed system in the 4-ft square cold flow model test facility to study various aspects of coal feeding over a range of fluidized bed operating conditions. A layout drawing of the installation was prepared this month.

9.2 Supplemental Studies

Metallographic examination of samples from the four corrosion specimen tubes was completed and a report was initiated. Comparisons of the final and original wall thicknesses at a magnification of 100x showed no measurable reduction in the wall thickness, within the measurement error band of 0.0012 in., for each of the four materials examined: 304 and 310 stainless steel, Inconel 600, and Incoloy 800. The Incoloy 800 was the only material that showed any intergranular attack, showing a band about 0.0012-in. deep beneath the surface. Microprobe analysis of the elemental composition of the material in the intergranular corrosion region showed that no detectable amount of sulfur was present and it was concluded that intergranular attack was due to oxidation.

The low corrosion rates observed from the first 500-hr test suggest strongly that much more meaningful data would be obtained if the second corrosion test period were 1000 hr rather than 500 hr as planned. A request for approval of the longer test was submitted to ERDA.

The second heat transfer tube has been completed except for brazing of the thermocouples in the grooves in the tube wall. It is expected that the tube will be completed and ready to ship to FluiDyne by the third week of May.

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