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

MASTER

OAK RIDGE NATIONAL LABORATORY
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COAL TECHNOLOGY PROGRAM
PROGRESS REPORT FOR NOVEMBER 1977

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COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR NOVEMBER 1977

ABSTRACT

This report — the fortieth of a series — is a compendium of monthly progress reports for the ORNL research and development programs that are in support of the increased utilization of coal as a source of clean energy. The projects reported this month include those for coal conversion process development, materials engineering, alkali metal vapor topping cycles, a coal equipment test program, an AFB coal combustor for cogeneration (CCC), engineering and support studies, process and program assistance, and environmental assessment studies.

1. SUMMARY

L. E. McNeese

Highlights of our progress in November are as follows:

- Hydrocarbonization run HC-24 was completed using Illinois No. 6 coal (pretreated with aqueous sodium carbonate at 300°C) at 1060°F and 300 psig. Reactor operation proceeded very smoothly during the 7.7-hr run. The hydrocarbonization system is being prepared for run HC-25 which will be made using Wyodak coal at a hydrogen pressure of 150 psig.
- A block of Pittsburgh seam bituminous coal and a block of Wyodak subbituminous coal were pyrolyzed under reducing gas in support of in situ gasification. Information from previously completed block pyrolysis of bituminous coal under an argon atmosphere show that differences in evolved gas result from differences in heating rates. Compared to block pyrolysis at 0.3 C°/min, block pyrolysis at 3 C°/min produces less gas but gas with a higher heating value, yielding a higher overall pyrolysis gas efficiency in recovering coal heating value.
- Experimental work on the fracture toughness and tensile properties of steels that may be used for piping and pressure vessels in very large gasification systems continued. The toughness of quenched 2 1/4 Cr-1 Mo steel simulating the surface of a 254 to 305 mm-thick plate was measured, and the differences in toughness and tensile properties following two temperature treatments were determined. Post-weld heat treatment effects were also characterized. All properties remained within the range for ASME SA 387, Grade 22, Class 2 material.
- Work on inspection techniques for ceramic and cermet coatings is being closed out by completing and updating reports in various draft stages. Procurement of CoCrAlY coating material was delayed slightly by required bidding procedures. Test radiography on various thicknesses of Incoloy Alloy 800 was initiated.

- Correlations between the amount of dilution during weld clad overlaying with Alloy 20 and the tendency for microfissuring are being developed for the gas metal-arc and submerged arc processes. Buttering the workpiece with Inconel 82 reduces the tendency for cracking during welding.

- Examination of heat exchanger tubes that have been exposed in the atmospheric fluidized bed combustor at FluidDyne Corporation for up to 1500 hr is in progress. Tubing for a 3000-hr experiment will be delivered to FluidDyne Corporation during December.

- Failure analysis activities have included examination of samples exposed in the solar erosion-corrosion experiment, assistance with the Wilsonville, Alabama, Solvent Refined Coal Plant for nondestructive examination of plant components, and examination of type 310 stainless steel air distributor plates from the Rivesville atmospheric fluidized bed combustor and the Alexandria, Virginia bed. Sigma phase formation was observed in the distributor plates from both beds and mechanical properties testing to assess the effects of this phase on ductility is in progress.

- In our gas-fired potassium boiler project, problems with blocking of the vent lines were resolved satisfactorily. The system was started up and a 50-min duration run was completed at a power level of 1.9×10^6 Btu/hr which is about 50% of the design power level. Two operating problems were encountered: (1) A leak occurred at a point where the liquid level indicator lines exit from the potassium liquid return line. A small amount of potassium leaked into the indicator lead sheaths and caused corrosion and subsequent breakage of the lead wires. This will be corrected by installing two argon bubbler lines in the boiler drum and welding a cap over the indicator sheath tubes to seal the area where the leak occurred. (2) The bypassing of combustion air across a leaking seal in the air supply system represents a potential problem in that if the fraction of the incoming air lost by leakage increases significantly at high air flow rates, the design power level of 4×10^6 Btu/hr for the potassium tests may not be reached.

- Work continued for development of detailed process information to be used by TRW in developing the critical components test plan.

- Work is underway to establish a program for testing coal feeders under development by DOE/FE. Jet Propulsion Laboratory has recommended five feeders for testing. Contact was made with the Energy Research Division of TVA to determine whether a cooperative feeder testing program could be arranged.

- The performance specifications for our AFB coal combustor for cogeneration (CCC) project and the request for proposal (RFP) were revised and reviewed in a meeting with DOE/FE staff. Four changes were requested: (1) the distributor plate specification should allow designs different from the ORNL design, (2) coal feed nozzle spacing should allow for each feed point to serve up to 36 ft^2 of bed cross-section,

(3) viewing port windows in the combustor should have a minimum area of 30 in.² and (4) a conference will be held after issuance of the RFP to provide information and answer questions. A coal feed splitter to handle the coal for the CCC was fabricated and tested. This type of splitter appears to have promise for a more compact feed system for large coal combustors.

- In our project for landfill storage of solid wastes, word was received that a 55-gal drum of Bigas solid waste and a drum of feed coal will be provided. We have requested larger quantities of waste from COGAS and from slagging Lurgi operation in England and Scotland. Design of the field-scale lysimeters was completed and procurement is being examined.

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, and studies of residue carbonization in a pressurized carbonizer.

2.1 Hydrocarbonization Research

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

Work accomplished. -- In November hydrocarbonization run HC-24 was made using Illinois No. 6 coal that had been pretreated with aqueous sodium carbonate at 300°C in an autoclave. The run duration was 7.7 hr during which time 73 lb of coal was fed. The run proceeded very smoothly with no interruptions of feed or other difficulties during the entire run. The fluid-bed temperature was uniform at 1060°F and the temperature at the top of the draft tube was 1035°F indicating that there was good fluidization and char recirculation through the draft tube. The reactor pressure was 300 psig. Nominal hydrogen flow rates to the reactor were 14 scfm to the downcomer; 5 scfm coal transport gas, and 1 scfm to the draft tube nozzle.

The system has been drained and cleaned for liquid yield determination but analytical results are not yet available, and material balance determinations have not yet been made. The system appeared to be in good condition following the run. There were no indications of caking or agglomeration when the char was removed from the reactor. The smooth operation of the system and the small quantity of fines in the feed material (14% -140 mesh) appeared to have resulted in a low carryover of char with the oil collected in the scrubber. It is expected that a clean oil product will be obtained for determining the physical properties. More detailed information concerning the run will be given in later progress reports.

Additional gas composition data for run HC-21 which was made using Wyodak coal in a uniformly fluidized bed and for run HC-23 which used Illinois No. 6 coal that had been pretreated with CaO-NaOH are shown in Fig. 2.1 through 2.4. The composition of CH₄, CO, CO₂, and C₂ and C₃ compounds (on an H₂- and N₂-free basis) are shown plotted as a function of temperature along with gas compositions from previous runs using Wyodak coal. The gas composition from the uniformly fluidized bed in run HC-21 and from the treated Illinois No. 6 coal in run HC-23 fit well into the trend established by the previous runs using Wyodak coal and a recirculated fluidized bed. As shown in these figures the concentration of CH₄ and CO increased with increasing temperature while the concentration of CO₂ decreased. The concentration of the C₂ and C₃ compounds remained relatively constant as a function of temperature.

Fig. 2.1. Concentration of methane in the off-gas from the bench-scale hydrocarbonization system.

Fig. 2.2. Concentration of carbon monoxide in the off-gas from the bench-scale hydrocarbonization system.

Fig. 2.3. Composition of carbon dioxide in the off-gas from the bench-scale hydrocarbonization system.

ORNL-DWG 77-826 RI

Fig. 2.4. Composition of C₂ and C₃ compounds in the off-gas from the bench-scale hydrocarbonization system.

Work forecast. -- The hydrocarbonization system will be cleaned, and material balance calculations will be made for run HC-24. Preparations will begin for run HC-25 which will be made using Wyodak coal at a lower hydrogen pressure (150 psig). This run is scheduled to be made about the first of February.

2.2 Experimental Engineering Support of In Situ Gasification Processes

P. R. Westmoreland, L. S. Dickerson, and R. L. Andrews

Pyrolysis is an important reaction step in all coal conversion and combustion processes, and appropriate data are needed for modeling of in situ gasification (underground coal gasification). Earlier data described the pyrolysis of powder samples, generally at high heating rates. By contrast, in situ gasification may react a broad seam cross-section, or may react large blocks formed by roof collapse or seam fracturing. Because of coal size, heat and mass transfer resistances can affect yields from block pyrolysis as compared to powder pyrolysis.

In experiments which began at ORNL in 1975, 6-in.-diam (16 cm) right circular cylinders of subbituminous and bituminous coal have been pyrolyzed by heating the blocks at 0.3-14 C°/min (surface temperature) from ambient temperature to maximum temperatures of 500-1000°C. Using an argon or hydrogen purge gas, gas and vapor-phase reaction products are continuously swept from the reactor. Water, oils, and tars are collected in a water-cooled condenser and by filters, and the remaining noncondensable gases are metered and periodically sampled. In many of the experiments, block temperature profiles have been measured by internal thermocouples. These tests are designed to support modeling of field in situ gasification experiments at Laramie Energy Research Center, Lawrence Livermore Laboratory, and Morgantown Energy Research Center (MERC).

Effects of heat and mass transfer resistances have been observed in both subbituminous and bituminous coal block pyrolysis. Pyrolysis at 3 C°/min of naturally moist subbituminous blocks produced more gas (especially H₂ and CO) than pyrolysis of powders, dried blocks, or blocks heated at 0.3 C°/min. This increase evidently is caused by self-gasification of the blocks' hot outer surface as H₂O from the damp, shrinking core diffuses outward. In bituminous coal, swelling is decreased and more light hydrocarbons are produced from blocks pyrolyzed at 3 C°/min as compared to 0.3 C°/min pyrolysis. Such differences may result from differences in plasticity distributions within the block.

2.2.1 Recent Experiments

Experiments since August, 1977 have tested the effects of increased H₂ partial pressure on coal block pyrolysis by using an H₂ reactor purge gas. Some shifts in gas composition may be produced, but H₂ effects on amounts and characteristics of the tar are of special interest. Conditions of these experiments with hydrogen, BP2-33 through BP2-40, are

summarized in Table 2.1. The last two experiments, PB2-39 and BP2-40, were conducted in November.

Experiment BP2-39 was the first bituminous coal block pyrolysis test to be conducted under an H_2 cover gas at $0.3\text{ }^\circ\text{C}/\text{min}$ to a maximum block temperature of 925°C . As described earlier,¹ swelling has been more pronounced in $0.3\text{ }^\circ\text{C}/\text{min}$ experiments than in tests at higher heating rates. In BP2-39, the 5-7/8-in.-diam, 8-7/8-in.-high coal block swelled outward to fill the 8-in.-internal diameter of the reactor. The top of the block sagged about 2 in. at the center, but around the outer diameter a 1- to 2-in.-thick rim swelled about 4 in. above the original surface, the combined effects producing a 6-in.-deep crater in a 13-in.-high cylinder of char.

Hydrogen was used to purge a subbituminous coal block pyrolysis experiment for the first time in BP2-40. The block surface was heated at $3\text{ }^\circ\text{C}/\text{min}$ until it reached 825°C ; that temperature was maintained until gas evolution stopped, as in previous experiments. To compare condensible hydrocarbons produced in this hydrolysis to material in earlier subbituminous pyrolysis experiments, simulated distillation curves for the liquids will be determined.

Gas evolution from BP2-39 and BP2-40 was calculated from wet test meter flow measurements and from compositions measured by a process gas chromatograph (GC). Analyzed components are H_2 , CH_4 , C_2H_4 , and C_2H_6 , C_3H_6 , and C_3H_8 , CO , CO_2 , H_2S , and Ar or N_2 , and the instrument is recalibrated with standard mixtures of these gases before each experiment. Although GC cycle time may be reduced to 550 sec, cycle time is adjusted to 10 min in $3\text{ }^\circ\text{C}/\text{min}$ experiments and to 15 min for $0.3\text{ }^\circ\text{C}/\text{min}$ experiments. By using these data, flowrates and composition of the evolved gases are calculated with a programmable calculator during the progress of the experiment. Gas evolution data for experiments BP2-39 and BP2-40 are summarized in Tables 2.2 and 2.3 respectively.

2.2.2 Bituminous coal pyrolysis gas evolution - argon purge gas

In experiments BP2-23 through BP2-32, cylinders of bituminous coal were pyrolyzed in argon purge gas to produce a test matrix of experiments at 0.3 and $3\text{ }^\circ\text{C}/\text{min}$ with maximum temperatures of 600 , 800 , and 1000°C . Gas evolution from these experiments, normalized as standard liters (0°C , 1 atm) per kg of moisture-and-ash-free coal is summarized in Table 2.4.

Bituminous coal powders have been pyrolyzed at similar conditions by other researchers. Van Krevelen² cited gas evolution data describing the pyrolysis of vitrinites from a coking coal with a heating rate of $1.8\text{ }^\circ\text{C}/\text{min}$ to a final temperature of 700°C . In those data H_2 evolution was observed to increase steadily with temperature; CH_4 evolution was continuing but nearly complete at 700°C ; no additional hydrocarbons containing more than 2 carbon atoms per molecule were evolved above 600°C ; and small amounts of CO were produced, rates slowly increasing with temperature. Approximately 195 std l/kg coal maf of total gases were produced during heating to 700°C , including 85 std l/kg coal maf each of H_2 and CH_4 .

Table 2.1. Summary of experimental conditions for pyrolysis experiments using a hydrogen cover gas

Run number	Date of run	Heating rate (C°/min)	Maximum temperature (°C)	Cover gas		Coal rank	Coal block			
				Type	Flow rate (Std. liter/min)		Dimensions (cm)		Weight	
							Height	Diameter	(kg)	(kg maf)
BP2-33	8/13/77	3	600 (640)	H ₂	2.90	Bituminous ^a	24.0	15.7	6.133	5.811
BP2-34	8/31/77	3	1000	H ₂	2.95	Bituminous	17.8	15.2	4.564	4.323
BP2-35	9/21/77	3	800	H ₂	2.95	Bituminous	21.9	15.2	5.384	5.100
BP2-37	10/17/77	3	900 (880)	H ₂	3.08	Bituminous	18.4	15.1	4.217	3.995
BP2-38	10/31/77	14	900 (890)	H ₂	2.90	Bituminous	19.7	15.4	4.658	4.413
BP2-39	11/14/77	0.3	900 (925)	H ₂	3.00	Bituminous	22.5	14.9	5.000	4.737
BP2-40	11/30/77	3	800 (825)	H ₂	3.14	Subbituminous ^b	21.9	15.2	4.993	3.313

^aBituminous coal blocks were all from the Pittsburgh seam which will be gasified in Morgantown Energy Research Center field tests.

^bSubbituminous coal block was from the Roland-Smith seams, Wyodak Mine, resembling coal used in the field tests of Laramie Energy Research Center and Lawrence Livermore Laboratory.

Table 2.2. Summary of gas evolution data from experiment BP2-39
(bituminous coal block pyrolysis to 925°C at 0.3 C°/min, H₂ purge gas)

	Total	H ₂	CH ₄	C ₂ 's	C ₃ 's	CO	CO ₂	H ₂ S
Gas evolution								
Volumetric (std. liters)	718.4	273.3	284.3	25.1	10.89	34.5	11.75	68.3
Normalized (std. l/kg maf coal)	149.5	57.7	60.0	5.30	2.30	7.28	2.48	14.41
Mass (g)	470.8	24.6	203.6	33.2	21.1	43.2	23.1	103.9
Normalized (g/kg maf)	99.4	5.19	43.0	7.01	4.45	9.12	4.88	21.9
Average composition of evolved gas (Vol %)	--	38.0	39.6	3.49	1.52	4.80	1.64	9.51
Elemental composition (g)								
Carbon	221.6							
Hydrogen	91.8							
Sulfur	97.8							
Oxygen	41.5							
Gas higher heating value (MJ)								
	21.17							
(Btu)	20080							
(Btu/scf)	735							
Gas efficiency (Btu in gas/Btu in coal)								
	12.5%							

Table 2.3. Summary of gas evolution data from experiment BP2-40
(subbituminous coal block pyrolysis to 825°C at 0.3 C°/min, H₂ purge gas)

	Total	H ₂	CH ₄	C ₂	C ₃	CO	CO ₂	H ₂ S
Gas evolution								
Volumetric (std. liters)	1428.9	491.8	332.5	126.2	29.7	226.7	210.5	11.48
Normalized (std. l/kg maf coal)	431.3	148.5	100.4	38.1	8.96	68.4	63.5	3.47
Mass (g)	1222.2	44.26	238.1	167.8	57.5	283.5	413.6	17.47
Normalized (g/kg maf)	368.9	13.36	71.9	50.6	17.4	68.4	124.8	5.27
Average composition of evolved gas (Vol %)	--	34.4	23.3	8.83	2.08	15.86	14.72	0.80
Elemental composition (g)								
Carbon	596.7							
Hydrogen	149.6							
Sulfur	16.4							
Oxygen	462.6							
Gas higher heating value (MJ)	36.67							
(Btu)	34790							
(Btu/scf)	640							
Gas efficiency (Btu in gas/Btu in coal)	37.7%							

Table 2.4. Comparison of total gas evolution from Pittsburgh seam bituminous coal — block pyrolysis with argon purge gas

Experiment	Rate of reactor temperature increase (C°/min)	Maximum temperature (°C)	Gas evolution (std. l/kg coal maf)							
			H ₂	CH ₄	C ₂	C ₃	CO	CO ₂	H ₂ S	Total
BP2-38	0.3	600	46.2	46.7	8.12	4.30	6.75	3.42	2.54	118.0
BP2-31	0.3	800	127.3	56.4	8.22	3.62	43.6 ^a	4.01	2.84	246.1
BP2-23	0.3	1000	197.7	68.7	9.68	5.38	17.02	6.46	0.69	305.5
BP2-26	0.3	1000	169.0	66.3	7.63	8.61	20.0	3.81	3.81	279.2
BP2-30	0.3	1000	a	a	a	a	a	a	a	a
BP2-27	3	600	49.3	63.9	14.96	9.29	6.75	4.50	2.15	148.8
BP2-29	3 ^b	600	71.9	71.9	11.83	5.67	12.62	4.40	0.0	178.3
BP2-25	3	800	126.1	73.8	14.87	3.13	12.62	4.50	5.38	240.3
BP2-24	3	1000	150.5	80.3	15.26	4.40	13.99	4.69	0.39	269.6
BP2-32	3	1000	a	a	a	a	a	a	a	a

^aBeing recalculated — sample bottles contained air leakage.

^bRan 85 min at 6.1 C°/min, then 90 min at 1.9 C°/min.

Similar trends were observed in gases from block pyrolysis at 0.3 or 3 C°/min. For H₂, CH₄, and CO, the total evolution increased from maximum block temperature from 600 to 800 to 1000°C. C₂ and C₃ gas evolution remained relatively constant at all three temperatures, indicating that little cracking or production of these light hydrocarbons had occurred. Evolution data for CO₂ and H₂S are also relatively constant, which suggests that nearly all evolution of these gases is complete at 600°C and that little char-CO₂ self-gasification occurs in block pyrolysis at these conditions.

However, as shown in these data and in an earlier report,³ differences in evolved gas result from the differences in heating rates. Compared to block pyrolysis at 0.3 C°/min, block pyrolysis at 3 C°/min produces less gas but with a higher heating value, yielding a higher overall pyrolysis gas efficiency in recovering coal heating value.

2.2.3 Department of Energy Underground Coal Gasification Program

P. R. Westmoreland and H. D. Cochran met on November 17 in Washington, D.C. with A. P. Sikri, S. Zukor, E. L. Burwell, and P. R. Wieber of the DOE Division of Oil, Gas, Shale, and In Situ Technology to present recent data and for general program discussions. In order to speed transfer of useful information from this project to other DOE UCG program participants, letter copies of these reports will be forwarded to appropriate participants.

A. P. Sikri requested ORNL preparation and presentation of a UCG status review paper based on a previously accepted abstract. The paper, "In Situ Gasification: Recovery of Otherwise Inaccessible Coal Reserves," by P. R. Westmoreland, R. C. Forrester, and A. P. Sikri, will be presented at the Miami (Fla.) International Conference on Alternative Energy Sources on December 5-7, 1977.

J. W. Martin of MERC visited ORNL on November 23 to see the block pyrolysis apparatus and to discuss recent bituminous coal block pyrolysis data. To support the planned MERC field tests, characterizations of block swelling and of pyrolysis tars are particularly useful. Martin also expressed interest in data from the planned ORNL pressurized block pyrolysis tests, since their reverse combustion linkage will be performed at 550 to 650 psig and since pressure may be required to maintain forward combustion.

2.2.4 Plans for December

During December bituminous coal block pyrolysis will resume using coal supplied during November by MERC. One experiment, BP2-41, is planned for maximum temperature of 600°C reached at 0.3 C°/min. Analysis and evaluation of oil and gas production will continue.

2.3 Pressurized Carbonization of Coal Liquefaction Residue

R. E. Barker

Experimentation has been completed on this task and a final report is in preparation.

2.4 References for Section 2

1. J. P. Nichols (ed.), *Coal Technology Program Progress Report for October 1977*, ORNL/TM-6137 (December 1977).
2. D. W. Van Krevelen, *Coal*, Amsterdam: Elsevier Publishing Company (1961), p. 268-269.
3. J. P. Nichols (ed.), *Coal Technology Program Progress Report for August 1977*, ORNL/TM-6066 (October 1977).

3. MATERIALS ENGINEERING

R. T. King

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

Summary

Experimental work on the fracture toughness and tensile properties of the steels that may be used to construct very large gasification systems continued. The toughness of quenched 2 1/4 Cr-1 Mo steel simulating the surface of a 254- to 305-mm-thick plate was determined, and the differences in toughness and tensile properties following two tempering treatments were determined. Post-weld heat treatment effects were also characterized. All properties remained within the range for ASME SA 387, Grade 22, Class 2 material.

Work on ceramic and cermet coatings is being closed out by completing and updating reports in various draft stages. Procurement of CoCrAlY coating material was delayed slightly by required bidding procedures. We initiated some test radiography on various thicknesses of Incoloy Alloy 800.

Correlations between the amount of dilution during weld clad overlaying with Alloy 20 and the tendency for microfissuring are being developed for the gas metal-arc and submerged arc processes. Buttering the workpiece with Inconel 82 reduces the tendency for cracking during welding.

Examination of heat exchanger tubes that have been exposed in the atmospheric fluidized bed combustor at Fluidyne Corporation for up to 1500 hr is in progress. Tubing for a 3000 hr experiment will be delivered to Fluidyne Corporation during December.

Erosion-corrosion samples exposed to a prototypic gasifier environment at Solar, Incorporated are being examined. Nondestructive examination of parts from the Solvent Refined Coal Plant at Wilsonville, Alabama, is in progress. Examination of the type 310 stainless steel air distributor plates from the Rivesville atmospheric fluidized bed combustor and the Alexandria, Virginia bed is in progress; sigma phase formation was observed in distributor plates from both beds, and mechanical properties testing to assess the effects of this phase on ductility is in progress.

3.1 Pressure Vessel and Piping Materials

D. A. Canonico, T. N. Jones, and C. E. Hudson

The discussions held between ORNL, ERDA, and the Ralph M. Parsons Company personnel in August 1977 have been considered in the revisions that have been made to the document on assessment of materials technology for second generation commercial gasifiers and reactors for coal conversion systems. These revisions were completed in November and the document is being prepared for formal distribution as an ORNL Report (ORNL-5238).

During November we completed the Charpy V-notch (C_V) and tensile tests of 2 1/4 Cr-1 Mo steel that was heat treated in our DATA TRAK to simulate the surface of 254 to 305 mm (10 to 12 in.) thick plate that was quenched during processing. The cooling rate employed was nominally 3K/sec (5R/sec). Two austenitizing temperatures, 1038 and 927°C (1900 and 1700°F) were employed. Tensile and C_V tests were conducted on the materials in the "as-quenched" condition. The C_V results for the two austenitizing temperatures are nearly identical; both had upper shelf energy values of nearly 68 joules (50 ft-lb), the onset of upper shelf occurs at near 93°C (200°F) and the 41 joule (30 ft-lb) temperature is near room temperature [~27-32°C (80-90°F)]. The tensile properties for the "as-quenched" steel are given in Table 3.1.

Some specimens that were austenitized at 927°C were tempered [1 hr at 704°C (1300°F)] and post-weld heat treated [40 hr at 677°C (1250°F)]. This heat treatment is representative of that which the surface of a thick walled 2 1/4 Cr-1 Mo steel pressure vessel may be exposed during fabrication. The effect of this heat treatment on tensile properties is also given in Table 3.1.

Increasing the austenitizing temperature from 927 to 1038°C has a minimal effect on the tensile properties; the yield and ultimate tensile strengths are slightly higher at the lower austenitizing temperature. Imposing a thermal history similar to that which occurs during fabrication decreases the tensile and yield strength; however, the levels are well within the required values for the ASME SA 387 Grade 22 Class 2 specification. (These values in Table 3.1 represent surface material and the Code requires that acceptance tests be conducted on material from the 1/4 thickness depth location. The cooling rate at this location is slower. Studies using the DATA TRAK to simulate the properties at the 1/4 thickness location are underway.)

The thermal history representing a fabrication heat treatment significantly improved the C_V toughness. The upper shelf (for the 2 1/4 Cr-1 Mo steel austenitized at 927°C) was increased to ~115 (95 ft-lb), the onset of upper shelf was decreased to near 10°C (50°F) and the 41 joule (30 ft-lb) temperature was decreased to near -46°C (-50°F).

Table 3.1. Tensile properties^a for 2 1/4 Cr-1 Mo steel

Heat treatment temperature °C (°F) and time	DATA TRAK cooling rate from austenitizing temperature deg/sec K (R)	Test temperature °C (°F)	Strength — MPa (ksi)		Ductility — %	
			Yield 0.2% offset	Ultimate	Total elongation	Reduction in area
Austenitize 1038 (1900) 1 hr	2.5 (4.5)	24 (75)	759 (110)	980 (142)	11.5	57.9
		343 (650)	869 (126)	1064 (154)	11.0	50.2
Austenitize 927 (1700) 1 hr	2.7 (4.8)	24 (75)	779 (113)	1007 (146)	11.5	57.2
		343 (650)	879 (127)	1090 (158)	11.2	49.8
Austenitize 927 (1700) 1 hr						
Temper 704 (1300) 1 hr	2.7 (4.8)	24 (75)	455 (66)	566 (88)	17.1	72.2
		343 (650)	421 (61)	538 (78)	12.3	66.0
PWHT 677 (1250) 40 hr						

^a Average of two tests.

3.2 Inspection Techniques for Wear- and Process-Resistant Coatings

R. W. McClung and G. W. Scott

3.2.1 Review and Evaluation (G. W. Scott)

We have elected to revise the comprehensive report on nondestructive inspection of coatings drafted some months ago. The revised report will cover all project work on ceramic and cermet coatings. Work on metallic coatings will be reported together with work done on CoCrAlY coatings at the end of FY 1978. Revision will be completed December 1.

The topical report on arc-discharge testing received final editorial corrections this month. A submission for the Fossil Energy Annual Report was prepared.

3.2.2 Specimens and Standards (D. P. Edmonds and G. W. Scott)

The procurement of CoCrAlY powder has been delayed slightly by the bidding procedure required whenever the government-funded division of Union Carbide Corporation (UCC-ND) buys from a private-enterprise division of the company. Delivery was scheduled for November 29, but the material has not arrived.

3.2.3 Penetrating Radiation (G. W. Scott)

We have made test radiographs to determine the optimum exposure conditions for 3.2, 6.4, and 9.5 mm (.12, .25, and .38 in.) thickness of Incoloy Alloy 800 (I800). Those radiographs will be evaluated to determine sensitivity.

3.2.4 Eddy Current Testing (G. W. Scott)

We are assembling the results of work performed during the period June through August of 1977 into a report on the application of a commercial instrument to the measurement of nonconductive coating thicknesses. This effort will conclude eddy-current work on ceramic and cermet coatings.

3.3 Fossil Energy Welding and Cladding Program

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

We are investigating the effects of welding conditions on the soundness and corrosion properties of type 320-Cb stainless steel cladding deposits. Chemical analyses have been performed on gas metal-arc (GMA) and submerged-arc (SA) clad deposits made with different welding conditions on carbon-steel base metals. As the percentage of base metal dilution in the SA and GMA deposits increases, the contents of P, Si, Ni, Cr, Mo, Nb, Co, and Cu were found to decrease. The contents of Fe and C increase while the Mn, S, and other residual elements were virtually unaffected. The use of an intermediate layer of Inconel

82 for GMA deposits significantly decreased the fissuring susceptibility of the material. This is associated with significant increases in Mn, Ni, Cr, Nb, Ti, and Cu, and with decreases in Fe, C, Si, and Mo contents. The Inconel 82 layer also provides a buffer zone that absorbs strain and slows carbon diffusion to the austenitic material. The type 320-Cb SA deposits have been previously reported to have lower susceptibility to fissuring than comparable GMA deposits. When compared to the GMA deposits, the SA deposits generally have higher concentrations of C, Mn, P, S, and Si with lower Ni, Cr, Mo, V, Cb, Co, and Cu contents. For the SA cladding, deposits that cracked contained significantly less nitrogen than comparable deposits that did not crack.

3.4 Fireside Corrosion of Atmospheric Fluidized Bed Combustor Tubes

T. G. Godfrey and J. H. DeVan

3.4.1 Experimental Exposure of Surveillance Tubes at the FluidDyne Combustor

Metallographic preparation of three of the specimen tubes from the 1500-hr test at FluidDyne has begun. The tubes selected were:

<u>POSITION</u>	<u>TUBE MATERIAL</u>
3-B	316 SS
5-D	800-800 Alonized-800
6-B	310 SS-310 Alonized-310 SS

The tubes were first sectioned at one-inch distances into the bed from each end. Tube 3-B was sectioned at the two one-third points while 5-D and 6-B were sectioned on each side of the welds at the one-third points. Three other tubes which have experienced 1000 hr in the AFBC (310 SS, 316 SS, and Alloy 800) were selected for examination also, but have not yet been sectioned. The remaining two tubes (310 SS) removed from the experiment will not be examined since they were non-pedigreed replacements for the failed 1-600 tubes and experienced only 900 hr exposure.

In the upcoming 3000-hr experiments in the AFBC, composite 2 1/4 Cr-1 Mo steel/304 SS tubes will be tested with a 950°F limit set on the Croloy section. To improve the quality of the temperature measurement, we plan to weld-braze the sheathed type-K thermocouples in the tube wall. An 82 Au-18 Ni weld-braze alloy was tested for 100 hr at 1100°F in a 3-5% O₂ atmosphere in contact with alkali-alkaline-earth-carbonate-sulfate and pure Na₂SO₄ to simulate bed conditions. Metallographic examination revealed only a very minor surface attack had occurred. We are, therefore, confident that this alloy will be suitable for the weld-braze.

The 2 1/4 Cr-1 Mo/304 SS and the high temperature tubes are being fabricated and should be delivered to FluidDyne in December. FluidDyne

will use two of the new low-temperature tubes during a shake-down run to evaluate the new thermocouple integrity. The eight remaining old tubes and the eight new tubes will then be installed in the bed for the start of the 3000 hr test, together with a new set of low-temperature tubes.

3.4.2 Measurement of Wall Thickness in Test Bed Tubes (G. W. Scott)

We evaluated two parallel efforts underway at ORNL Inspection Engineering. Tube walls will be inspected using one of two methods: (1) a commercial ultrasonic caliper with digital readout; or (2) timing measurements on multiple tube wall reflections displayed on a oscilloscope. Method (1) requires machining and checkout of a special coupling shoe for small-diameter tubing. Method (2) requires retrieval and reassembly of equipment used for earlier work on other projects. The ends of the tube sections will be checked by mechanical measurement with a tube-wall micrometer to verify and, if necessary, provide calibration corrections to the ultrasonic measurements.

3.5 Failure Analysis and Prevention

R. T. King

3.5.1 Solar* Erosion/Corrosion Coupons (T. G. Godfrey)

Examination of the subject samples has continued. Results will be reported when they are more complete.

3.5.2 Inspection Assistance to the Solvent Refined Coal Plant, Wilsonville, Alabama (G. W. Scott)

We radiographed a 5.1 cm (2 in.) thick section cut from the forged 347 stainless steel ring (SRC dissolver tank lower head) as a metallographic specimen. Radiographs made looking in the circumferential direction (tangent to the ring's circumference) showed a crack indication extending the full length [20.3 cm (8 in.)] of the ring. The location and appearance of this indication suggests that it is caused by a lamellar flaw in the ring wall, roughly parallel to the inside (ID) and outside (OD) surfaces of the ring. Flaws of this type would make the ring unsuitable for fabrication of ultrasonic standards. The ring was intended for use in the plant but rejected when the defects were found by Wilson Industries, Houston, Texas.

We received the lower (cap) section from the Wilsonville, Alabama SRC dissolver tank. Plant personnel asked us to make calibration blocks for ultrasonic thickness measurement of the tank wall from this section.

* Division of International Harvester Company.

We have scribed orientation markings on the part and made up a radiographic shooting sketch. We plan to radiograph the cylindrical wall section, which is cast 310 stainless steel (25-20), approximately 21.6 cm (8.5 in.) long and is 6.4 cm (2.5 in.) thick. The radiographs will also contain the end-cap weld, which is between forged 310 stainless steel and cast 310 stainless steel (weld metal and method unknown). While evaluating the suitability of the material for use in calibration blocks, we will also determine whether any significant degradation occurred in the tank section prior to its removal from the plant.

3.5.2 Examination of the Air Distributor Plates from Atmospheric Fluidized Bed Combustors

The air distributor plates at the Rivesville, Virginia, and Alexandria, Virginia, fluidized bed combustors are said to be from the same batch of wrought type 310 stainless steel plate. Distortion and serious cracking of the Rivesville distributor plates from "D" cell was observed, and cracking of the "C" cell plate has been reported. We find sigma phase present at the grain boundaries of plates from both plants after service. However, only minor indications of cracking were found in the plates from the Alexandria bed. Differences in thermal and stress cycling are likely to be involved in resolving why the air distributor plate at Rivesville cracked extensively while that at Alexandria did not.

4. ALKALI METAL VAPOR TOPPING CYCLES

R. S. Holcomb

4.1 Gas-Fired Potassium Boiler

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

4.1.1 Contract Objective

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

4.1.2 Status Summary

1. The problems with the blocking of the vent lines were resolved satisfactorily with increased cooling on the drain tank vent line and a liquid potassium trap on the condenser vent line.

2. The system was started up again and heated to boiling for a 50-min period at a power level of 1.9×10^6 Btu/hr.

3. A leak occurred at a point where the liquid level indicator lines exit from the potassium liquid return line. A small amount of potassium leaked into the indicator lead sheaths and caused corrosion and subsequent breakage of the lead wires. It was decided to install two argon bubbler tubes in the boiler drum to provide an alternate method of obtaining the potassium liquid level.

4. The bypassing of combustion air across a leaking seal in the air supply system represents a potential problem in that if the fraction of the incoming air lost by leakage increases significantly at high air flow rates, the design 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.

4.1.3 Plans for Next Month

The two argon bubbler lines will be installed in the boiler drum, and a cap will be welded over the indicator sheath tubes to seal the area where the leak occurred.

5. COAL EQUIPMENT TEST PROGRAM

J. M. Holmes and R. W. MacPherson

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

- Critical Equipment for Demonstration Plants (TRW Study)
- Coal Feeder Test Program

Progress on these topics during November, 1977 is summarized in the following sections.

5.1 Critical Equipment for Demonstration Plants (TRW Study)

TRW Energy Systems continued work on their Critical Components Test and Evaluation Program under subcontract to ORNL. However, progress is constrained because the essential proprietary information on two demonstration plant processes is not yet available. Negotiations with the Illinois Coal Gasification Group (ICGG) and six of their subcontractors are currently underway to obtain nondisclosure agreements on the COGAS process. It is anticipated that these negotiations will be completed by the end of December, 1977. Contact has been made with the Memphis Gas Light and Water Co. (MGLW) to obtain detailed information on their U-Gas Demonstration Plant, and a presentation by ORNL and TRW of the purpose, scope and merit of the Critical Components Test Program has been proposed for the third week in December, 1977.

In the absence of detailed process information from the demonstration plant contractors, flowsheets are under development at ORNL and TRW to provide preliminary data for the study. ORNL is preparing a set of COGAS flow sheets developed from information available in the literature. The flowsheets will identify the major equipment and piping, process conditions and instrumentation, and will also include a preliminary material balance. These flowsheets will be completed by the middle of December, 1977. TRW has developed a preliminary flowsheet for the U-Gas process based on "best estimate" equipment requirements, process conditions and a material balance. These preliminary process flowsheets will be used to identify areas and individual components believed to be critical to the operation of the plants. Confirmation of this preliminary list of critical components will be pursued as soon as the non-disclosure agreements with the demonstration plant contractors have been completed.

TRW is developing a set of questionnaires concerning critical components to be used in interviewing component vendors and plant contractors. The questionnaires will include equipment such as valves, heat exchangers, feeders, instrumentation, etc. Completion of the questionnaires is dependent upon receipt of detailed information from the process developers which will not be available until the non-disclosure

agreements have been completed. National Bureau of Standards failure analysis reports on DOE pilot plants and PDU's have been reviewed to identify specific problem areas encountered to date in coal conversion pilot plants.

5.2 Coal Feeder Test Program

Work is underway at ORNL to establish a program for testing coal feeders under development by DOE/FE. Jet Propulsion Laboratory (JPL), the coordinator for DOE feeder development, has recommended five feeders for testing. The initial feeder considered for testing is a linear pocket feeder developed by Foster Miller Associates (FMA). Other feeders to be considered include FMA's centrifugal feeder, Ingersoll Rand's screw feeder and Lockheed's ejector and kinetic extruder. A preliminary specification is being prepared for the FMA linear pocket feeder which will include the recommendations provided by JPL. Additional specifications required for the conceptual design of a test facility will be identified and requested from FMA and JPL. A site visit to FMA was made during November to examine their small-scale equipment and obtain information for the preliminary specification.

Process requirements for a number of promising coal conversion systems have been developed by ORNL Engineering. This information will be utilized to define potential areas of application for the five feeders specified by JPL.

A contact has been made with TVA's Energy Research Division to determine whether a cooperative feeder testing program at one of the TVA coal-fired stations can be arranged. Specifications for the initial feeder test will be forwarded to TVA as soon as they become available and will serve as the basis for discussion at a meeting with TVA early in January, 1978.

6. AFB COAL COMBUSTOR FOR COGENERATION (CCC)

R. S. Holcomb

The performance specifications were revised to incorporate the comments of the Engineering Division and the changes agreed upon in an October 14 meeting with DOE/FE. The request for proposal (RFP) was drafted, reviewed by the Engineering Division and revised.

A meeting was held with DOE/FE in Washington on November 28 to review the RFP and specifications. It was attended by Steve Freedman, Wayne McCurdy and Walt Saunders of DOE/FE, Bob Chronowski and Jack Branam of Mitre Corporation and R. S. Holcomb of ORNL. Four changes were recommended by Mitre and requested by Steve Freedman: (1) the specification for the distributor plate should be made more general to allow designs different from the ORNL design, should include provisions for insulating the top of the distributor plate, and should be removable so that the ORNL distributor or other designs might be installed for testing in the future; (2) the requirements for the coal feed nozzles should include provisions for nozzle spacing so that feeding tests can be run with each feed point serving an area up to 36 ft²; (3) the viewing ports in the combustor should have a minimum window area of 30 in.²; (4) a conference should be held after the RFP is sent out in order that all interested vendors can be further informed and have an opportunity to ask questions and offer comments. In addition to these changes, a number of helpful suggestions were made to improve the content and organization of the RFP and the specifications. The material will be revised to incorporate these changes and submitted for review.

Work has been nearly completed on an abbreviated assessment study to serve as a market survey to be included as an appendix to the RFP for the combustor. Some revisions of the text of the general energy survey and preparation of a few more examples of process applications remain to be done.

The request for a Memorandum Directive was approved by DOE-ORO, and the Memorandum Directive is in effect. The Preliminary Proposal for the formal project directive will be completed by the middle of next month and will be submitted for ORNL-UCND and DOE-ORO approval.

Layout studies for the system in Building 9731 are in progress and are about 50% complete.

6.1 Supplemental Studies

An alternate design for a splitter for dividing the coal feed into four streams has been investigated. The riffle system for dividing the coal flow has been demonstrated to work well for splitting the feed into four streams in a two-stage divider. The riffle has one disadvantage in that each riffle will split the flow into only two streams so that the

number of riffle boxes or stages gets rather large as the size of the combustor increases and in turn requires many coal feed points for good distribution. The alternate splitter design consists of feeding the coal (suspended in an air stream) into a vertical capped pipe where it exits through four horizontal holes, and each of the four streams enters a line through which it passes to the combustor. A splitter to handle the coal feed rate for the CCC combustor was fabricated and tested. The first tests yielded an uneven split of the coal among the four outlets, but modifications improved the performance. A configuration was found that gave a variation in the coal feed rate of $\pm 8\%$ or less from the average for the four streams. This type of splitter appears to have promise for a more compact coal feed system for large combustors for industrial applications.

Both the riffle divider and the capped-pipe splitter will be evaluated during the coal feed system tests with the fluidized bed cold-flow model. The drawings for the installation of the coal feed test system in the fluidized bed model are complete, and installation work will begin next month.

Metallographic examination of samples from the tubes exposed during the 1000-hr corrosion test is in progress. The preliminary results indicate that there was no significant corrosion of the tubes.

7. ENGINEERING STUDIES AND TECHNICAL SUPPORT

J. R. McWherter

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

7.1 Process Modeling

R. Salmon, D. M. Lister, and D. Sellinger

7.1.1 Contract Objective

The objective is to assist DOE/FE in its plan for computer analysis and computer support for coal conversion studies. This includes assistance to Purdue and Lehigh Universities in the development of computer programs for this plan.

Physical property data are being collected and computerized primarily by Purdue and will be used in support of programs prepared by both universities. Purdue's general design program will aim at material and energy balances, equipment size and costing, plant capacity, and general economics. Lehigh's dynamic simulation programs will address plant design primarily from the standpoint of process performance during transient operations, but can also be used for steady-state conditions. A single flowsheet will be selected to assess the operability and complementary utility of both design programs.

7.1.2 Status Summary

- a. Physical properties and material balance routines received from Purdue are being edited to remove Fortran incompatibilities with the IBM-360 system. An ORNL editing routine is being used. It is expected that editing and production of revised routines will be completed early in January. Example problems will then be run to test the operation of the programs.
- b. Work continued on the heat exchanger design and cost program HDC. Current efforts are directed at (1) improving the flange design subroutine, (2) expanding the data library on materials costs and properties, and (3) making comparative tests to determine how the overall costs produced by the program compare with those estimated by other methods.

7.2 Synthetic Fuels Process Research Digest

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

7.2.1 Contract Objective

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

7.2.2 Status Summary

- a. The first issue of the digest was distributed. Topics presented in the issue are as follows:
 - (1) Coal Gasification with Chemically Incorporated Catalysts,
 - (2) Flash Hydrolysis of Coal,
 - (3) Zinc Chloride Hydrocracking of Coal and Coal Extracts,
 - (4) Conversion of Methanol to High-Octane Gasoline.
- b. Topics selected for the second issue of the digest are:
 - (1) Consol Low-Pressure Hydrogen-Donor Process,
 - (2) SRC-II,
 - (3) Low to Intermediate Btu Gasification, and
 - (4) Fischer-Tropsch Process.

Article 1 for the second issue has been drafted and is now in review. Material for articles 2, 3, and 4 has been collected, and draft outlines are being prepared.

7.3 Survey of Industrial Coal Conversion Equipment Capabilities

R. W. Glass, J. M. Holmes, J. R. Horton, M. Siman-Tov,
W. R. Williams, W. A. Bush, E. C. Slade, J. P. Meyer,
M. S. Edwards, W. R. Gambill, and W. R. Reed

7.3.1 Contract Objective

The general objective of this project is to conduct surveys of industrial coal conversion equipment capabilities that will identify the present ability 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 DOE/FE programs.

- During FY-77 equipment survey areas of principle concern were
- (1) rotating components, (2) valves, (3) heat recovery equipment, and
 - (4) hot gas cleanup devices.

7.3.2 Status Summary

A draft work statement was prepared and reviewed with DOE/FE during November for the proposed survey work in FY 1978 on this project. Several additional tasks were requested and priorities were shifted. These changes will be incorporated into the work statement.

A presentation of the FY 1977 survey project results was made on November 29 to DOE/FE personnel in Washington, D.C.

Project personnel participated in the "Workshop on Valves for Solids Handling Service in Coal Conversion Processes" in Morgantown, WV, on November 14-16, 1977, and a paper entitled "Determination of Parameters and Design Suggestions for Valves in Critical Locations of Fossil Energy Conversion Plants" was presented. An overview of the FY 1977 work on valves was presented.

Information has been collected on the status of coal conversion pilot plants and demonstration projects being sponsored by DOE. Information was requested and received from the National Bureau of Standards Data Base on reported failure incidents for pumps, compressors and valves; although requested, no incidents involving hydraulic turbines or gas expanders were reported. Information collected and received to date will be utilized in studying equipment operating experience in coal conversion pilot plants. Demonstration projects presently under contract with DOE will provide information for determining equipment requirements on which to base studies of available equipment prices and development programs for unavailable equipment.

Review of three of the four FY 1977 survey reports has been completed by DOE/FE and review of the fourth is expected shortly. After the comments have been incorporated into the various reports, they will be edited and published.

7.4 Flash Hydrolysis

S.P.N. Singh

7.4.1 Contract Objective

The objectives are to perform a preliminary technical and economic assessment of the Cities Service and the Schroeder flash hydrolysis processes and to determine whether a more detailed engineering evaluation of one of these processes is justified.

7.4.2 Status Summary

- a. A draft of the final report was completed in September and forwarded to DOE for review.

- b. DOE/FE comments on the draft report were received, and appropriate revisions have been made. The revised report is being circulated for internal review and comment.

7.5 Hot Gas Purification Processes

M. S. Edwards and J. P. Meyer

7.5.1 Contract Objective

The objective of this project is to investigate the present state-of-the-art hot gas cleanup processes. The application of most interest is the removal of contaminants (i.e., particulates, sulfurous gases, alkali metals, etc.) from coal-derived fuel gas prior to its use in firing combined cycle turbines.

7.5.2 Status Summary

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

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

W. R. Gambill

7.6.1 Contract Objective

The objective of this review is to survey, appraise, and catalog the processes for heat recovery which industry offers or plans to offer or may logically be expected to offer. These processes will be applicable to the recovery of heat in process streams from primary exothermic coal conversion and combustion process steps. Simple unaugmented application of conventional heat transfer equipment will not be included. The review will distinguish between presently installable technology, near term developable technology, and future prospects. Consideration will be given to possible transfer of technology from other industries.

7.6.2 Status Summary

- a. Additional descriptive material was evaluated. Items included high-temperature waste heat boilers and transfer line exchangers, quench coolers, and fluid-bed driers and coolers.

- b. Preparation of the final draft report was begun. This report describes our survey and appraisal of current and anticipated heat-recovery processes and associated equipment which should be applicable to the recovery of heat in process streams from primary exothermic coal conversion and combustion process steps.

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

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

7.7.1 Contract Objective

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

7.7.2 Status Summary

- a. A general review of the project was held on November 11 at ORNL with R. H. Lamb (project consultant) and project staff members in attendance, however Dr. T. Simpson, DOE/FE Project Manager was unable to attend. Comments on the draft report have been received from all reviewers (including DOE/FE).
- b. Draft report comments have been incorporated, and the final draft is in editorial review.

The assessment considers two basic hot gas treatment systems, with each system specifically addressing both sulfur and particulate removal. The reference system incorporates a panel filter for dust removal and fixed bed adsorber/regenerator units. The project system incorporates a moving bed filter/adsorber unit, with fluid bed regeneration of the recycled filter/adsorber media. Both systems produce high pressure steam (waste heat boiler) from the regeneration off-gases. The assessment includes simple equipment flowsheets and material balances for both systems, and comparative economics are developed.

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

R. W. Glass and L. Seglin*

7.8.1 Contract Objective

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

*Consultant.

7.8.2 Status Summary

- a. A progress review meeting was held November 11 at ORNL. L. Seglin (project consultant) and ORNL staff members attended, however, Dr. T. Simpson (DOE/FE) was unable to attend. Minutes and results of the meeting were transmitted to DOE/FE (Simpson) by letter on November 14.
- b. The summary subcontract draft report (L. Seglin) is nearing completion and is expected early in December.

The project considers specifically the comparison of the subject process (a molten-iron/steam concept) to the more conventional concepts employed in the Koppers-Totzek and Bigas processes. All three processes are considered as part of an overall integrated SRC-II system. Process flowsheets, system costs, and product distributions are described for each case and comparative economics are developed. A development program for bringing the molten-iron process to the state of commercial availability is discussed.

7.8.3 Changes

The scope of Task 7 was expanded to include a comparison with the Bigas process, and to evaluate the subject process by comparing costs for each hydrogen process option, integrated with the SRC-II process.

7.8.4 Supporting Data

These data are going through a final check, and will be included in the draft report. The main conclusion of that report is that the subject process does not possess a significant advantage over alternates considered to justify recommending developing it further. This results from its low thermal efficiency and high capital cost.

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

J. Fisher and G. R. Peterson

7.9.1 Contract Objective

The objective of this project is to provide a technical and economic comparison of processes available for the control of gaseous hydrocarbon (HC) and carbon monoxide (CO) emissions. The Lurgi gasification process is considered as a reference source system, and comparisons of control technologies will consider incineration as the reference control system.

7.9.2 Status Summary

The information obtained to date has been evaluated. Preparation of a summary topical report is in progress.

7.10 Environmental Controls for Low-Btu Gasification

S.P.N. Singh, M. S. Edwards, and G. R. Peterson

7.10.1 Contract Objective

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

7.10.2 Status Summary

- a. As required under Task 1 of the project, a detailed work plan was completed and transmitted to DOE/FE. Tasks 2, 3, and 4 were also completed in accordance with the schedule shown in the work plan. Task 2 was the preparation of a list of the environmental control processes to be evaluated; Task 3 was the preparation of a list of gasifiers and their characteristics; Task 4 was the selection of four representative gasification processes for use in the detailed evaluation of environmental control alternatives.
- b. Results of these tasks were transmitted to DOE/FE by letter dated November 30. An oral presentation of these results will be made to DOE/FE representatives next month.

7.11 Support of the Office of Initial Operations (OIO)

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

7.11.1 Objectives

The objectives of this project are:

- a. to perform rapid, 14-day-turnaround reviews and analyses of documents provided by the Office of Initial Operations of DOE/FE on coal conversion demonstration plant projects with appropriate follow-up as requested.
- b. to conduct requested evaluations in areas which include considerations of startup, safety, environmental protection, maintainability, and reliability.

- c. to develop guidelines for the preparation of safety, operation and maintenance manuals.

7.11.2 Status Summary

A team of four people will be involved on this assignment on a permanent basis. The initial effort of the team is to establish the methodology for the rapid reviews and analyses. This effort primarily consists of team member familiarization with the four contracted demonstration plants, literature searches, identification of and consultation with present operating group reviewers and resident specialists within the Coal Technology Program, establishment of a comprehensive rapid review team directory of personnel with alternates in case of unavailability, and the preparation of appropriate checklists.

During November, DOE requested the review of two documents consisting of the Grace and Ebasco Management Plans for their demonstration plant to produce synthesis gas from coal to be used as feedstock for an ammonia plant. The two documents also contained a Technical Support Plan which produced the most salient comments.

A two day effort was requested, and the results were transmitted on time by telephone to DOE with a follow-up written response dated November 15, 1977.

8. PROCESS AND PROGRAM ANALYSIS

J. R. McWherter

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

8.1 Low Btu Coal Gasification

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

8.1.1 Objective

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

8.1.2 Status Summary

Comments on the draft report were received during the month and reviewed. A second report draft will be prepared when all comments are received. The second draft will be issued for review, modified as needed, and used as the basis for the final report. Procedures to prepare and publish the final report were discussed with ORNL Technical Publications personnel.

A majority of the 21 process data subsection comments were received from the process proponents — both the DOE program managers and industrial sponsors. These valuable reviews will update and make the process descriptive material more accurate.

A number of processes are briefly described in the draft report in addition to the 21 processes described in more detail. Contacts were made during the month with representatives of fourteen (briefly described) processes and reviews requested of the one-page summaries. Several reviews have been received. Remaining reviews and comments, when received, will be used to modify the first draft and prepare the second draft.

8.2 Direct Combustion

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

8.2.1 Objectives

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

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

8.2.2 Status Summary

The interim report covering the first phase of the study has been transmitted to DOE in draft form. Work on the alternatives to on-site direct combustion has begun. The two principal systems to be investigated are central steam generation with a pipeline distribution system to multiple industrial users and the area coal depot concept. The coal depot would provide multiple fuel products (i.e., stoker coal, pulverized coal, and coal sized for fluid beds and limestone) for dispersed industrial users. The depot would act as the unloading, storage, and coal processing system for many users. A number of distribution systems will be investigated. These will include rail, truck and pipeline transport. In addition to the technical requirements for these systems, capital and operating cost data are being compiled for use in the economic analysis.

8.3 Advanced Power Conversion Systems

Drafts of all twelve reports covering this work were completed and submitted to DOE/FE for review before September. No additional work was done in November on this project.

8.4 Liquefaction

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

8.4.1 Task 1. Survey Liquefaction Processes

Parsons completed the preliminary report (Data Source Book) for internal review prior to publication. This report summarizes the characteristics of 32 liquefaction processes reviewed during the screening survey.

8.4.2 Task 2. Detailed Review of High Potential Liquefaction Processes

Parsons completed the fixed capital investment estimates for four of the five high potential processes. The only process to be completed is the CSF process.

The Fischer-Tropsch process cost estimate was revised to reflect a condition of no power import/export to the system.

Economic analyses were performed for the H-Coal and M-Gasoline processes and the revised Fischer-Tropsch process.

Process flow diagrams were prepared for four of the five processes. The CSF process flow diagram is being prepared.

8.5 High Btu Gas

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

8.5.1 Contract Objective

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

8.5.2 Status Summary

The final report on "Evaluation of the Battelle Agglomerating Ash Burner High Btu Coal Gasification Process" was issued.

8.6 In Situ Coal Gasification

W. C. Ulrich

8.6.1 Contract Objective

The objective of this program is to provide technical and economic evaluations of candidate processes for the in situ conversion of coal to fluid products presently of interest.

During FY 1977, technical and economic evaluations of the linked-vertical-well process as applied to subbituminous coal were addressed. Three alternative end product configurations were considered - electricity, SNG, and syngas.

8.6.2 Status Summary

FY-1977 Work

Draft copies of the final report, "Process Designs and Economic Evaluations for the Linked Vertical Well In Situ Coal Gasification Process," ORNL-5341, were submitted to DOE/FE on September 30, 1977 for review. We are awaiting comments and guidance regarding the publication of this report.

FY-1978 Work

- a. Members of the project evaluation team met with DOE/FE representatives in Washington on November 22 to discuss the FY 1978 project work statement. DOE/FE representatives requested that the work statement be revised to include a detailed design based on one major end product (gasoline), rather than a broader-range coverage of three end products. A revised work statement is being prepared accordingly.
- b. A preliminary study of the market potential for various products from in situ coal gasification facilities located in Wyoming was prepared and presented at the above-mentioned meeting.

8.6.3 Open Items

External review of the draft evaluation report, "Process Designs and Economic Evaluations for the Linked Vertical Well In Situ Coal Gasification Process," is continuing. Comments from in situ project members at Morgantown Energy Research Center were received.

8.7 Coal Beneficiation

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

8.7.1 Contract Objective

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

8.7.2 Status Summary

Comments received from DOE on the draft of the final report on coal beneficiation are being reviewed. A meeting with DOE representatives will be arranged to consider these comments in preparation for final publication of the report.

8.8 Gas Cleanup Studies

M. S. Edwards

8.8.1 Contract Objective

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

8.8.2 Status Summary

We are awaiting comments from DOE on the draft report ORNL/TM-6077, transmitted to DOE on September 30, 1977. The report provides detailed process descriptions and cost data for 7 methods of removing H₂S from a low-Btu, coal-derived gas. The processes include: MDEA, Benfield, Selexol, Sulfinol, Stretford, MERC Iron Oxide, and Molecular Sieve.

8.9 The Potential of the Synthesis of Chemicals from Coal as a DOE Research Program

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

The final draft report was completed and submitted for review.

8.10 HYGAS Modeling

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

8.10.1 Contract Objective

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

8.10.2 Status Summary

- a. A preliminary work statement for the project was prepared and discussed with DOE/FE representatives at Washington on November 22. A number of changes were requested by DOE, and a revised work statement is being prepared accordingly.
- b. A letter was sent to DOE indicating the kinds of data needed from Scientific Design.
- c. A literature search and evaluation for gasifier modeling techniques and HYGAS descriptive material is in progress.

9. FOSSIL ENERGY ENVIRONMENTAL PROJECT

C. R. Boston

9.1 Stored Solids Study

W. J. Boegly, Jr.

A 55-gallon drum of Bigas solid waste and a 55-gallon drum of feed coal are to be sent to ORNL during the week of November 21-25, 1977. Olin Collitti (DOE) has been asked to obtain larger quantities of Cogas and Slagging Lurgi waste from England and Scotland. We requested 36 each, 55-gallon drums of waste from each plant. We probably will not be able to obtain feed coal since the Cogas run will be made using char from the New Jersey COED pilot plant.

Design has been completed on the field-scale lysimeters. We are now checking to see who might bid the units, to obtain approximate costs, and to estimate delivery times. The lysimeters will be made of reinforced fiberglass.

Laboratory leaching tests of solid waste samples continue. Some analytical results have been received. Additional leachate samples have been sent to the Environmental Sciences Division analytical laboratory.

A draft of the literature review on runoff from coal storage piles has been prepared, and is currently undergoing editorial review. It is anticipated that this document will be delivered by December 30, 1977.

9.2 Environmental Monitoring Handbook

S. G. DeCicco

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

During the month of November revisions to all but two sections of the Handbook were completed and submitted to technical editing. Close contact was maintained with Radian Corporation who are under contract to DOE/FE. Radian projects that their first draft will be delivered to Hershel Jones on December 15. After DOE/FE review, we will immediately receive Radian's text. If no revisions are requested by DOE/FE, the material will constitute the final draft of the Handbook. If significant revisions are required, a delay of 4-6 weeks may occur. The completion date for the Handbook is solely contingent on the date of arrival of

Radian's section, and the ease with which it can be incorporated into Chapter 4. As a best estimate, the projected completion data has been delayed to January 31, 1978 to allow for integration of the document.

9.3 Technical Assistance

9.3.1 Interaction with Demonstration Plant Contractors (S. G. DeCicco)

On November 7, we received the revised scope of work from the Westinghouse Environmental Studies Department for the entire monitoring program for the Conoco demonstration plant. This work plan was reviewed by the Fossil Energy Environmental Project team.

On November 10, Boston and DeCicco attended a meeting at DOE/FE Headquarters with Al Lloyd, Hershel Jones, Bob Verner, Bernie Baratz and Dave Jones to discuss the cost of the new monitoring program and environmental report, and ramifications of delaying the program.

On November 22, Bill Watson (Conoco) visited ORNL to discuss the need for the various areas of the monitoring program, and the effects of reducing the intensity of the monitoring.

9.3.2 Other Activities

Work was initiated on finalizing the first document prepared by the Fossil Energy Environmental Project, "Environmental Inclusions in Requests for Proposals (RFP's)," Draft, December, 1976. DOE would like to reference this document in Program Opportunity Notices as well as Requests for Proposals and, therefore, would like to see it finalized and assigned an ORNL document number. Since only minor change are necessary, the final document should be completed in January.

9.4 Carryover Activities from FY 1977

9.4.1 Environmental and Health Aspects of Disposal of Solid Wastes from Coal Conversion: An Information Assessment (H. M. Braunstein)

This document is receiving final in-house review and is now scheduled to go to the printer on January 15, 1978. The original target date of December 1 was missed because the required in-depth review was not completed on schedule.

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