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

MASTER

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 FEBRUARY 1977

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Oak Ridge, Tennessee 37830
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COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR FEBRUARY 1977

ABSTRACT

This report - the thirty-first of a series - is a compendium of monthly progress reports for the ORNL research and development programs that are in support of the increased utilization of coal as a source of clean energy. The projects reported this month include those for coal conversion process development, materials engineering, alkali metal vapor topping cycles, a critical components test facility, engineering and support studies, process and program assistance, environmental assessment studies, and coal-fueled MIUS.

1. SUMMARY

J. P. Nichols

Highlights of our progress in February are as follows:

- Two hydrocarbonization runs were performed during February, HC-12 and HC-13. Run HC-12 was a very smooth run and no problems were experienced. In run HC-13 there were minor problems with controlling reactor temperature and coal feeding.
- During the month of February the modifications to the atmospheric carbonizer were completed. Residue carbonization experiments were terminated under instructions from ERDA/FE in order to utilize the carbonizer for work with Illinois No. 6 coal. Tests in the 1-in.-diam agglomeration test reactor were restarted with Illinois No. 6 coal.
- Two-dimensional pyrolysis studies have continued using Eastern bituminous coal typical of that to be gasified by Morgantown Energy Research Center during their UCG field test. Unusual char formations (associated with the swelling nature of the material) have been observed, though tar and gas production per gram is not greatly different from that observed with Western subbituminous coals.
- In the coal-solvent-hydrogen mixing work, preparations are in progress to make pulse test experiments in the packed column with cocurrent upflow of air and a slurry of coal and water. Preliminary measurements show that with no gas flowing, 10-20% of the column volume is occupied by coal which has settled on the bed.
- Installation and pressure review of the equipment for pressurized carbonization has been completed. Minor modifications to instrumentation have been required.

- Materials engineering support activities continued with work on properties of thick sections of steel, development of methods for nondestructive testing of coatings, cladding of low-alloy steels, fireside corrosion in fluidized bed boilers, failure analysis, and publication of a draft report on the use of prestressed concrete pressure vessels.
- Design and construction work continued in preparation for operation of our gas-fired boiler with potassium.
- We continued reference design studies of a coal-fired alkali metal vapor power system.
- Engineering studies and technical support continued with work on process modeling, the process research digest, a survey of industrial equipment capabilities, and a study of large air separation plants.
- Process and program analysis studies continued with work on low Btu gasification, direct combustion, advanced power systems, liquefaction, in situ gasification, and beneficiation of coal.
- In our fossil energy environmental project we completed a preliminary draft of a landfill information assessment, continued the preparation of an environmental monitoring handbook, and developed a plan for preparing a programmatic assessment of plants for production of substitute natural gas.
- In our coal-fueled MIUS project, we completed a 1000-hr endurance run of the coal feed system and began analysis of corrosion specimens that were exposed in a fluidized bed combustor.

2. COAL CONVERSION PROCESS DEVELOPMENT

J. R. Hightower, 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

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

2.1.1 Bench Scale System

Design and Review. There was no effort to be reported in this area during February.

Fabrication and Installation. There was no effort to be reported in this area during February.

Operation. Two runs were made during February -- HC-12 and HC-13. Preliminary material balances, effluent gas analyses, and run conditions are given for Run HC-12 in Tables 2.1, 2.2, and 2.3. This information for Run HC-13 will be presented in the March monthly report.

Run HC-12 was performed very smoothly; coal was fed to the reactor at a feed rate of 10.2 lb/hr for 10 hr 32 min and the steady state reactor bed temperature was 1030°F. The light and heavy oil phases deposited in the scrubber during HC-12 have been filtered through a double layer of Whatman #42 filter paper to remove entrained solids. The filtered oils will be submitted for analyses such as specific gravity, viscosity, boiling point range and solvent fractionation. Results from these analyses will be reported when they are received.

Run HC-13 was performed with an average coal feed rate of 11.1 lb/hr for a total feed time of 10 hr 17 min. After 4 hr 33 min of operation, coal feed was interrupted for no apparent reason. At this point, the coal feeder valve and transport line were disassembled and inspected for signs of plugging. No reason was found for the cessation of feed and after reassembly the experiment was restarted and feed was maintained for 5 hr 44 min until the coal supply was exhausted. During both periods of operation, the desired bed temperature of 905°F was maintained for ~ 1 hr 45 min at which point the bed temperature rapidly decreased to ~ 900°F. A satisfactory explanation for this behavior has not yet been found.

Table 2.1. Preliminary material balance for Experiment HC-12

Average bed temperature: 1030°F

Coal feed rate

Total pressure: 300 psig

As-received: 10.2 lb/hr

H₂ feed rate: 74.6 std ft³/lb maf coal

Moisture-and-ash-free: 9.0 lb/hr

	Mass (g)	Carbon fraction	Ash fraction	Sulfur fraction	Percent of carbon fed	Percent of ash fed	Percent of sulfur fed
<u>Input</u>							
1. Coal	48740	0.6452	0.0633	0.0041	100.0	100.0	100.0
2. Scrubber water	21790 ^a	0	0	0	0	0	0
<u>Output</u>							
3. Char recovered	22385	0.8130	0.1192	0.0023	57.9	86.5	25.5
4. Scrubber top phase	1070	0.5951	0.0290	0.0025	0.21	1.0	1.5
5. Scrubber middle (aqueous) phase	27964 ^a	0.0110	--	--	1.0	--	--
6. Scrubber bottom phase	6980	0.658	0.0143	0.0024	14.6	3.2	8.5
7. Cold trap top phase	0	0	0	0	0	0	0
8. Cold trap middle (aqueous) phase	286	0.00833	--	--	<0.1	--	--
9. Cold trap bottom phase	507	0.6098	0.00064	0.00061	1.0	<0.1	0.2
10. Gases	5000	0.795	--	0.025	12.6	--	62.1 ^c
<u>Rinses</u>							
12. Scrubber - water	29675	0.000518	--	--	<0.1	--	--
13. Scrubber and cold trap - perchloroethylene	41360 ^b	0.0195	0.000623	0.000106	2.6	0.8	2.2
Overall balance	92.2				91.8	91.5	100.0

^aIncludes influx of water through scrubber pump seal^b4.07% residue^cBy difference from 100%

Table 2.2. HC-12 steady state effluent gas composition

Component	Effluent rate (scfm)	Composition (%)	H ₂ and N ₂ -free composition (%)
CH ₄	0.176	1.74	47.1
C ₂	0.046	0.45	12.3
C ₃	0.014	0.14	3.7
CO	0.079	0.78	21.1
CO ₂	0.031	0.31	8.3
H ₂ S	0.028	0.28	7.5
H ₂	9.58	94.53	--
N ₂	0.179	1.77	--
	<u>10.133</u>		

Table 2.3. Summary of Experiment HC-12 conditions
and preliminary material balances

Experiment	HC-12
Average bed temperature, °F	1030
Reactor pressure, psig	300
Solids residence time in the reactor, min ¹	65
Period at steady state, min	565
Feed coal moisture content, wt %	5.12
Gas flowrates, scfm	
Total hydrogen feed	10.8
Coal transport tube	2.6
Draft tube ²	1.8
Downcomer ²	6.4
H ₂ /Coal mass feed ratio	0.36
Carbon balance (% of carbon fed)	
Char	61.4
Liquids	17.8
Gases	12.6
Overall	91.8
Overall ash balance	91.5
Sulfur balance	
Char	27.0
Liquids	10.5
Gases	62.5 ³
Overall mass balance	92.2
Oil yield (wt % of maf coal)	18.1

¹Time to clear overflow in the reactor

²Assuming no gas bypassing

³By difference from 100%

Work Forecast. Routine experimentation will continue in February with a recirculating fluidized-bed run HC-14 at 300 psig and approximately 1150°F.

2.2 Residue Carbonization

J. B. Gibson, F. H. Wilson, and L. S. Dickerson

This project for supporting research and development on residue carbonization is supported by the Division of Coal Conversion and Utilization of ERDA. The work which began November 1, 1975, consists of three tasks: (1) a review and evaluation of experience with the low-temperature carbonizer in the Cresap, West Virginia, pilot plant, (2) modification of an existing reactor to permit continuous feed of solids-laden residues, and (3) operation of the reactor with three feedstocks (vacuum distillation bottoms from the H-Coal process and solvent extraction underflows from SRC and CSF product liquids) at three temperatures up to 1200°F.

Work Accomplished

Task 1: Review and Evaluation (completed)

Task 2: Reactor Modification (completed)

Task 3: Operation

The atmospheric carbonizer was undergoing modifications during February and no residue carbonization experiments were performed. These modifications were completed near the end of the month. Instructions have been received from ERDA/FE to terminate the residue carbonization runs and the carbonizer is being converted to use with Illinois No. 6 coal. Table 2.4 is a summary table of the pertinent data on the residue carbonization runs. A complete summary report will be included in the March, 1977, quarterly.

Six agglomeration tests were performed in the one inch agglomeration test reactor with Illinois No. 6 coal. Severe agglomeration was encountered when pure Illinois No. 6 was used. Mixtures of Illinois No. 6 and Wyodak char are being used to investigate regions of non-agglomeration.

Work Forecast

Runs with mixtures of Illinois No. 6 coal and Wyodak char will be used in carbonization tests in both the atmospheric carbonizer and the agglomeration test apparatus. Methods to prevent caking with a pure Illinois No. 6 coal feed will be investigated.

Table 2.4. Summary of residue carbonization experiments

Note: All runs made in 4 in. reactor with 1 in. draft tube unless otherwise noted

Run No.	Bed Starter	Feed Composition	Total Feed Time	Total Feed Input	Argon Flow Rate*		Reactor Temp	Scrubber Liquid	System configuration changes since last run	Results
					Draft tube (SLPM)	Downcomer (SLPM)				
RC-1	2000 gm crushed firebrick	Pure Residue	60 min.	--	5.4	3.6	1150°F	Water	Curved feed tube 1/2" into draft tube	Feed tube plugged.
RC-2	Same bed as RC-1	Pure Residue	35 min.	--	6.0	3.6	1150°F	Water	No change	Feed tube plugged, draft tube plugged, many hard agglomerates as large as 1-3/4" in reactor.
RC-3	1400gm firebrick	Pure Residue	160 min.	340	15.0	3.6	1200°F	Water	No change	Feed line plugged. Draft tube plugged. 1 to 2" deep plug on top of entire distributor plate.
RC-4	1600 gm firebrick	Pure Residue	15 min.	--	15.2	3.8	1200°F	Water	Straight feed tube, flush with distributor plate, glass beads in scrubber	Scrubber exit plugged. Reactor-scrubber line plugged. Reactor not checked until after RC-5.
RC-5	Same bed as RC-4	Pure Residue	200 min.	530 (RC-4&5)	15.2	3.8	1200°F	Water	Heating tape on reactor-to-scrubber line. Screen lid over glass wool in scrubber	Draft tube plugged. Layer of solidified residue on top of distributor plate. Tar gummed-up on top of glass beads in scrubber.
RC-6	1700 gm Wyodak Char	Pure Residue	120 min.	0	15.4	4.6	1150°F	Methyl-Naphthalene	Draft tube out, used reactor as a spouted bed	Feed line plugged--no feed in.
RC-7	1700 gm Wyodak Char	Pure Residue	150 min.	400 gm	12.4	3.6	1200°F	Methyl Naphthalene	No change	Reactor-scrubber line plugged 3" deep, hard plug formed over distributor plate. Scrubber worked well.
RC-8	1700 gm Wyodak Char	Pure Residue	100 min.	200 gm	12.4	12	975°F	Methyl Naphthalene	Draft tube back in, feed nozzle 5 in. into draft tube	Feed line plugged. Draft tube plugged. Large agglomerate formed in downcomer near bottom of draft tube.
RC-9	1500 gm Wyodak Char	4:1 Char: Residue	100 min.	--	13.5 - 15.5	12-9	975°F	Methyl Naphthalene	Feed tube 5 in. up draft tube -- changed to feed line flush with distributor plate	Hard plug in reactor-scrubber line. Soft plug in draft tube. Soft 6 in. stalactite hanging from deflector cup.
RC-10	1500 gm Wyodak Char	4:1 char: Residue	90 min.	--	15.5	17.2	1200°F	Methyl Naphthalene	No change	Reactor-scrubber line plugged. No agglomeration in reactor or draft tube. Cyclone line plugged.

Table 2.4 (continued)

RC-11	1500 gm Wyodak Char	4:1 Char: Residue	0	No feed	11.5	17.2	1200°F	Methyl Naphthalene	No change	Reactor-scrubber line plugged from previous run.
RC-12	1500 gm Wyodak Char	4:1 Char: Residue	60 min.	1700 gm	11.5	17.2	1200°F	Methyl Naphthalene	No change	Reactor-scrubber line plugged. Cyclone catch-pot full. No agglomeration in reactor.
RC-13	1500 gm Wyodak Char	4:1 Char: Residue	60 min.	1500 gm	8.0	11.8	1200°F	Methyl Naphthalene	No change	Cyclone line plugged.
RC-14	1500 gm Wyodak Char	2:1 Char: Residue	30 min.	520 gm	11.5 - 13.5	17.2	1000°F	Water	8 in. expanded head over reactor, cyclone inside reactor. Straight reactor-scrubber lines replace U-shaped line.	Feed line plugged. Reactor-scrubber line plugged. Char and residue blew over to scrubber.
RC-15	1500 gm Wyodak Char	4:1 Char: Residue	70 min.	2000 gm	10.5 - 5.5	17.2	1100°F	Water	New feeder valve Extra heating tape added to reactor-scrubber line during run.	Reactor-scrubber line plugged initially. Draft tube plugged. Tar build-up on glass beads in scrubber held up water spray. Feed line plugged several times during run.
RC-16	1500 gm Wyodak Char	4:1 Char: Residue	60 min.	1100 gm	5.5	8.6	1100°F	Water	Internal cyclone removed	Feed line plugged. No plug in draft tube.
RC-17	1500 gm Wyodak Char	4:1 Char: Residue	45 min.	--	5.5	8.6	1100°F	Water	Cyclone back in	Feed line plugged. Cyclone plugged. Tar plug formed downstream of scrubber. 1/4" agglomerates in reactor.
RC-18	1500 gm Wyodak Char	4:1 Char: Residue	60 min.	--	6.7	8.6	950°F	Water	Cyclone removed Draft tube removed - spouted bed sheath around feed tube below dist. plate with cooling argon.	Feed line plugged. Reactor-scrubber line plugged.
RC-19	1500 gm Wyodak Char	4:1 Char: Residue	35 min.	900 gm	6.1 - 8.6	8.6	1100°F	Water	Insulated sheath for feed nozzle cooling gas.	Feed line plugged. String filter downstream of scrubber plugged.
RC-20	1500 gm Wyodak Char	4:1 Char: Residue	90 min.	4500 gm	5.8	8.6	1100°F	Water	Draft tube in	Feed nozzle plugged. Draft Tube plugged. Reactor-scrubber line partially plugged.
RC-21	1500 gm Wyodak Char	4:1 Char: Residue	135 min.	4760 gm	9.8	17.2	1150°F	Water	Ramrod installed to clear feed-nozzle during run.	Reactor-scrubber line plugged. Feed line sight glass cracked.
RC-22	1500 gm Wyodak Char	4:1 Char: Residue	140 min.	4770 gm	8.6 - 9.8	8.6 - 17.2	1150°F	Methyl Naphthalene	Reactor-scrubber line cut flush with scrubber wall.	Reactor-scrubber line plugged. No large agglomerates in reactor.

2.3 Experimental Engineering Support of an In Situ Gasification Process

R. C. Forrester III, G. D. Owen, and S. M. Gibson

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.

The coal was machined into 15-cm right circular cylinders, then drilled to accept 1.2-mm thermocouples for internal temperature measurement. The first specimen was heated to 1000°C at 0.3 C°/min.

This month, a higher heating rate was utilized (3.0 C°/min.) to maximum temperatures of 800°C and 1000°C.

In each case, gas evolution could be detected audibly as pyrolysis gases actually bubbled from the swelling, fluid-like material in the reactor. Upon cooling to room temperature, the remaining char was observed to be non-pyrophoric and quite dense. The considerable mechanical strength of the char made recovery of thermocouples difficult and, in some cases, impossible. Porosity variations from the surface of the char block to its center are qualitatively observed to pass through a minimum, though no reasonable mechanism has been proposed to explain this phenomena. Detailed analyses of product gases are forthcoming.

2.4 Coal-Solvent-Hydrogen Mixing

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

Pulse test measurements have been completed in a 1-in. ID column packed with 4.6 mm diam beads with co-current upflow of gas and clear water. Gas and liquid flow rates were in the range of 0-289 cm³/sec (actual volumetric flow rates) and 1-4 cm³/sec, respectively. Calculations to extract axial dispersion coefficients and liquid hold-up from the recorded pulses are continuing. Preparations are now being made to make similar measurements with co-current upflow of air and a slurry of coal (37 wt %) in water flowing at the same volumetric rates as in the experiments with clear water. Replacement stators are being ordered for a Moyno pump which will be used for pumping the slurry. The anthracite coal which has a large fraction of -60+80 mesh solids will be replaced with Wyodak coal pulverized so that all of it will pass through a 140 mesh screen. A size analysis of this coal is being made. Very preliminary tests with the anthracite coal slurry shows that for slurry flow rates in the range of 4.7 - 6.7 cm³/sec and no gas flow, about 10 - 20% of the column volume is occupied by coal which has settled out on the packing (the packing itself occupies 58% of the column volume).

2.5 Pressurized Carbonization of Consol Synthetic Fuel Solid Residues

R. E. Barker, S. M. Gibson, and J. R. Hightower, Jr.

During the early part of February, installation of all equipment and instrumentation was completed. At this point some minor modifications were made to correct "bugs" in the instrumentation. A system pressure check was accomplished at 625 psig and design temperature as final completion of the pressure vessel review. All pressure vessel review and safety requirements have been met and the system is approved for operation.

A simulated experimental run using methyl-napthalene in place of residue will be made during the first week of March. Any problems encountered during this simulated run will be corrected, and it is anticipated that the first residue carbonization experiment will be attempted in March.

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

Materials research and development activities are in progress in several areas:

(1) The tensile properties of SA-387, Class 1 steel have been evaluated as a function of austenitizing temperature. Heat treatment to simulate thick plate behavior was started. Sectioning of a 25-cm (10-in.)-thick plate of A 543, Class 1 steel is in progress.

(2) Several tasks are in progress to develop nondestructive test methods for coatings. Computer-assisted literature searches on diffusion coatings, vapor-deposited coatings, and general coating inspection methods were completed. Project Planning (189) forms for the FY-1979 budget cycle were drafted. Additional specimens of cermets and alloys are being fabricated. Our new x-ray fluorescence measuring system has been delivered. Transmission radiography is now being used to help find cracks in specimens for surface method and high-voltage work.

Thermal camera images of an unbond flaw between a ceramic coating and Alloy 800 substrate have been obtained using both induction and gas torch heat sources. Calibration work on our eddy current lift-off/conductivity instrument continues. Considerable effort has gone into making additional crack specimens for surface inspection work. We have found the ZrO_2 coatings to be surprisingly tough and resistant to various stresses. Electrified particle testing was tried and found unsuitable for surface crack detection on plasma-sprayed ceramics.

Experiments are in progress to test contact-coupled angle-beam ultrasonic methods for missing coating areas and coating thickness measurement. We have made a hand-held probe for electrochemical capacitance testing. A new high-resolution electrode for high voltage testing was made and tested satisfactorily.

(3) No work is in progress on iron and nickel carbonyl formation and prevention.

(4) The welding parameters leading to several different modes of metal transfer in the cladding of low-alloy steel with type 320 steel

were determined. This information is applicable to minimizing under-bead cracking problems.

(5) A draft report on the potential use of prestressed concrete pressure vessels for coal conversion plants has been transmitted to ERDA-FE.

(6) Nondestructive methods (eddy currents) for determining remaining wall thickness and oxide thickness on fluidized bed heat exchanger tubing were developed and standard calibration data were obtained. Metallographic sectioning of tubes was initiated.

(7) Several analyses of failures and surveillance analyses are in progress under the Failure Analysis and Prevention in Coal Liquefaction Plants task.

3.1 Pressure Vessel and Piping and Technology Assessment

D. A. Canonico

The DATA TRAK has been used to simulate the thermal history of SA 387, Grade 22, Class 1 steel plate. This heat treatment was initially selected because there is a large volume of mechanical property data available at ORNL for commercial heats of this specification. Tensile tests at room temperature and 482°C (900°F) have been completed with specimens which were austenitized at 899, 927, and 954°C (1650, 1700, and 1750°F).

We have begun the heat treatment of specimens to simulate the 1/4 thickness location in water quenched thick [203 mm (>8 in.)] steel plates. The cooling rate selected was 0.33 K/sec (0.6°F/sec). Tensile specimens are being machined from the DATA TRAK steel blanks.

The 254-mm (10-in.)-thick quenched and tempered A 543, Class 1 steel plate is being sectioned to provide tensile, Charpy-V, precracked Charpy-V and compact tension specimens from the surface, 1/4 thickness and mid thickness locations. In addition, specimen blanks will be obtained and heat treated in the DATA TRAK. This will permit a correlation of the commercial and laboratory heat treatments.

Also, we are pursuing the possibility of obtaining additional heats of SA 387, Grade 22 in both thin [~25 mm (1 in.)] and thick [~203 mm (8 in.)] plate section sizes.

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 completed a computer-assisted search of post-1968 Metals Abstracts for information on diffusion and vapor-deposition metal coating methods. This search will be repeated for inspection methods and physical properties of coatings.

We have received the hard-copy output from a computer-assisted search for inspection methods for all types of metal coatings, excluding organics, conducted by the Nondestructive Testing Information Analysis Center at Southwest Research Institute. Individual references from this listing are being checked now.

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

A number of specimens are being fabricated by the Welding and Brazing Laboratory. These include tensile-crack and ultrasonic specimens similar to earlier designs, but incorporating bond coats and full layers of cermets and alloys. We have designed two new specimens, a thermal-defect type, and a stepped-thickness type for ultrasonic work. We are also making a cermet electrochemical specimen.

3.2.3 Penetrating Radiation (G. W. Scott and B. E. Foster)

ORNL representatives visited Ortec, Inc. and conducted final acceptance testing of our new x-ray fluorescence measuring system. The system was delivered February 23; shakedown and personnel training on the system are underway.

We have commenced routine transmission and backscatter radiography of tensile-crack specimens at various stages of the cracking process. Transmission radiographs have shown a few very small cracks which were not visible at the surface of the specimen; these cracks may be precursors of open surface cracks. Both types of radiographs were taken with Kodak Type R film placed with the emulsion side against the coating of the specimen.

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

We have succeeded in obtaining the correct heat input rate and viewing time combination for detecting the intentional non-bond in a zirconium oxide coated sample. An induction source was used for heating the specimens, and a scanning infrared camera provided the thermal display. A high-contrast image of the non-bond was obtained which indicated that

the thermal anomaly associated with the flaw is elongated rather than circular, as was intended. Close visual inspection of the coating with oblique lighting revealed a slight surface irregularity which resembles the thermal image.

Having easily detected the non-bond using induction heating, we next switched to a hot gas torch and again succeeded in imaging the flaw. The thermal contrast was not as great in this case, however, because the heat input rate of the torch is less than that of the induction source, and hence diffusion tends to reduce the thermal contrast.

3.2.5 Eddy Current Testing (C. V. Dodd)

We are continuing to work on the self-calibration micro-computer program for the lift-off/conductivity instrument. Least squares computer calculations are being run to determine the best instrument settings. A passive RLC calibrator circuit is being matched with a new reflection-type coil to insure that the instrument settings can be easily repeated.

3.2.6 Surface Inspection Materials (S. D. Snyder)

In the past we have tried to produce cracks in the ZrO_2 coatings by subjecting specimens to tensile stress, but only one specimen out of three cracked. The remaining two specimens spalled at the edges and did not crack. The cracked specimen had a coating thickness of about 0.45 mm (0.018 in.) while those that spalled had coating thicknesses of about 0.25 mm (0.010 in.).

Two other methods to produce cracked coatings have been tried — thermal shock and bending. For the thermal shock trial, the coated side of a specimen that had been previously subjected to tensile stress was heated to a cherry red appearance ($\sim 800^\circ\text{C}$) and then quenched in water at 20°C . No cracks were observed in the coating; it was when viewed at $100\times$ magnification with a microscope. This specimen was then subjected to a bending stress in a crude 3-point bend rig (the center roller was a 1 1/4-in.-diam bar) until cracks in the coatings became visible. This occurred when the specimen was deflected about 2.5 mm (3/32 in.).

A new specimen, No. TC-3 with a 0.25-mm (0.010-in.)-thick coating, was subjected to a bending stress similar to that described above, but no cracks were observed when the specimen was deflected about 3 mm (1/8 in.). While the specimen was held under this bending stress, the coating was heated to cherry red and quenched with cold water. This did not produce any cracks either. Following the bending and the thermal shock the specimen was bent back to nearly flat and then given a tensile stress to 16 kN (3500 lb). Again, no cracks were observed after the tensile stressing.

We finally produced cracking by bending again, but not until the specimen had deflected about 4.7 mm (3/16 in.). The cracks were not visible to the naked eye, but could be seen at 10× magnification. Thus, we have a specimen with smaller cracks than those produced in the first specimen described above.

We have tried the electrified particle test on these cracked specimens. This test does not show any promise of usefulness because the porous coating allows the positively charged calcium carbonate powder to cling in such a diffuse mass that cracks cannot be differentiated.

3.2.7 Ultrasonics (K. V. Cook)

An important problem in the fossil energy program involves measuring, from the outer surface, the presence or absence of inner surface coatings on pipe, tubing, or vessels. These coatings are usually thin, compared with the base material to which they are supposed to be bonded. Additionally, some of the ceramic coatings have high attenuation coefficients for ultrasonic energy.

Pulse-echo commercial thickness gages may be directly applicable for measuring certain coatings and configurations; however, an attempt to measure a 0.25 mm (0.010 in.) ceramic coating sprayed onto a 3.18 mm (0.125 in.) I-800 base material was not successful. The interface signal at the metal-ceramic bond-line was apparently too large to allow resolution of the coating thickness signals.

In an attempt to maximize ultrasonic response to small thickness changes and allow resolution of small time changes in signal detection, we have initiated studies with a transmit-receive contact angle beam probe unit. We fabricated a double wedge contact probe unit which uses two 5 Mhz mini-transducers. One mini-transducer introduces an ultrasonic shear wave into the base material and the second detects the reflected energy from the metal-coating interface at positions predicted by geometrical analysis of multiple reflections. If a coating is adequately bonded to the inner surface, part of the ultrasound is transmitted into the coatings. Because of the different velocities in the media, the waves propagate at a larger angle than those in the base material. Thus, the signal which passes through the coating layer should be offset in position from the interface signal and occur at a sufficiently later time to be resolved. Preliminary studies with this approach have shown promise, although the results are not yet conclusive. We are presently having various coated specimens prepared for future studies.

3.2.8 Electrochemical Testing (G. W. Scott)

We have designed and fabricated a prototype hand-held inspection probe for differential capacitance testing. Experiments to characterize its operation are in progress. It is being tested on Alloy 800 specimens covered with mylar. The sensing area of the probe is approximately 3.2 cm² (0.5 in.²).

3.2.9 High Voltage Testing (G. W. Scott)

We have fabricated and tested our most successful probe electrode. It was machined from a 1.27 mm (0.050 in.) tungsten rod by grinding a taper with a 30-degree included angle to a tip with 0.05–0.08 mm (.002–.003 in.) radius. Experiments with this tip show excellent crack resolution. The gradual change to a larger cross-section reduces ohmic heating and increases tip life.

3.3 Iron and Nickel Carbonyl Formation and Prevention

J. H. DeVan, H. Inouye, and J. Brynestad

Program terminated December 31, 1976. Efforts to obtain added support are still in progress.

3.4 Development of Techniques for Welding and Cladding Cr-Mo and Low-Alloy Pressure Vessel Steels

D. P. Edmonds

During this reporting period we have concentrated on gas metal-arc (GMA) cladding of low-alloy steel with type 320 (AWS designation for Alloy 20) stainless steel. We have obtained 1.59 mm (0.063 in.) diameter type 320 wire from Arcos. Approximate conditions have been determined for cladding in the short-circuiting transfer, the drop transfer, and the spray transfer modes using a 98% Ar-2% O₂ shield gas. Samples are now being prepared for determination of effects of these various cladding conditions on dilution and tendency for hot cracking/microfissuring.

3.5 Prestressed Concrete Pressure Vessel Studies

W. L. Greenstreet

All studies have been completed. The draft report has been transmitted to ERDA-FE, Washington, D.C.

3.6 Fluidized Bed Combustion

C. V. Dodd, R. H. Cooper, and J. H. DeVan

The calibration measurements on tubing samples, which are representative of tubing given a 500 hr exposure to a Fluidized Bed Coal Combustor environment, have been completed. The standard tubes were machined to

provide tubular sections having three thicknesses; the as-machined thicknesses and material resistivity are listed in Table 3.1. The magnitudes and phases of the reflected voltage at 100 and 500 khz, using a R60G reflection coil were measured with the coil flush on the tube and with the coil lifted off the tube 0.005 in. (simulating an oxide layer). The measured values were then compared to calculated values. A least squares computation was performed to fit the measured values to the calculated values, using an offset and slope correction on each measured phase and magnitude. The "corrected" readings are then transformed into physical properties using 12 coefficients for various nonlinear combinations of the phase and magnitude at each frequency. The coefficients are determined from calculated data using least squares fits and then applied to the "corrected" instrument readings.

Metallographic sections of selected tubes have been mounted for polishing, etching, and examination.

Table 3.1. Properties of Standard Tubes

Tube Material	Resistivity ($\mu \Omega \text{ cm}$)	Thickness (in.) of Machined Tube		
		Section 1	Section 2	Section 3
I 800 (Short Tube)	110.8	0.0635	0.0695	0.0730
I 800 (Long Tube)	103.0	0.0360	0.0410	0.0475
I 600	113.5	0.0600	0.0640	0.0680
310 SS	91.20	0.0545	0.0580	0.0620
304 SS	72.98	0.0540	0.0575	0.0630

3.7 Failure Analysis and Prevention in Coal Liquefaction Systems

3.7.1 MHD Combustor Tubing (R. H. Cooper)

The final report on unfailed surveillance combustor tubes removed from a PERC boiler that operated for 1000 hr on an oil-coal slurry has been sent to PERC. Discussion with PERC representatives to correlate PERC data with the ORNL results is in progress.

3.7.2 Pressure Letdown Valve (D. P. Edmonds and D. A. Canonico)

A final report, *Failure Analysis of a Pressure Letdown Valve from the Synthoil Process Development Unit*, ORNL-TM-5742, by D. P. Edmonds, D. A. Canonico, and B. C. Leslie was issued and distributed.

3.7.3 Examination of Fluidized Bed Tubing from MERC (R. J. Gray)

A letter report to M. Zulkoski of MERC from R. J. Gray describes the condition of type 310 stainless steel tubing that was operated in a MERC fluidized bed at 1400-1700°F. Relatively rapid attack was observed at the fusion line of the seam-welded tubes. The data were transmitted to W. T. Bakker, Fossil Energy Headquarters, Washington, D.C.

3.7.4 Visit to SRC Plant, Tacoma, Washington (R. T. King and R. H. Cooper)

The authors visited the solvent-refined coal plant at Tacoma, Washington on February 10 and 11 to determine possible interactions with the Failure Analysis Program. The initial findings are described in a letter report dated February 16, 1977, with copies to W. T. Bakker, Fossil Energy Headquarters, Washington, D.C.

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 local natural gas supply situation eased sufficiently so that a limited amount of gas was available. This made it possible to conduct the vapor separator test and thus complete the water test program. Excellent results were found in the vapor separator test with a vapor exit quality greater than 99.9% being obtained over a range of burner power output from 1.7 to 3×10^6 Btu/hr.

2. Tests were run with argon as a tracer gas to obtain a check on the magnitude of the air leak across the sliding seal around the burner. The results indicated no significant change in the seal leakage.

3. The design of the propane supply system was completed. The contractor has installed the three 1000-gal tanks and work has started on the pipe line to the test system.

4. Design work completed this month includes four drawings of the potassium condensate return piping, two drawings of the sample box, three drawings of the vapor separator modifications for potassium, one drawing of the potassium drain line, and four instrument and control drawings.

5. Fabrication work completed includes finishing the drain tank, additional work on the sample box, and installation of the electric heater power supply cabinets in the control room.

6. Rust Engineering construction personnel began work on installation of the potassium system components and extension of the equipment tower.

7. Plans for Next Month. Construction on the tower and installation of potassium components will be continued; the propane supply system installation will be completed; design work will be continued on the electrical system and instruments and controls; fabrication of the sample box will be completed.

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 detailed preliminary design of a fluidized bed furnace. This will be accomplished by preparing designs for both potassium and cesium vapor cycle systems and making a comparison of these designs. The results will be analyzed and potassium or cesium will be chosen as the cycle fluid and one of the designs will be selected as the reference system. The reference system will be used for the preparation of a detailed preliminary design of a fluidized bed furnace-boiler.

The program will consist of two phases. The first phase will compare several systems using both potassium and cesium as the working fluid. The scope of work for this phase of the program will include the following major tasks:

1. Parametric cycle analyses for cesium and potassium power systems.
2. Furnace boiler conceptual designs for furnace pressures of 1 to 10 atm.
3. Condenser-steam generator conceptual designs for cesium and potassium at several condenser temperatures.
4. Metal vapor turbine design and analysis.
5. Survey of cesium availability and cost.
6. Conceptual designs and layouts of selected systems.

The results of these tasks will provide a variety of conceptual designs for both cesium and potassium. A detailed comparison will be made of the relative merits of the various concepts from which a reference design using either potassium or cesium will be selected. This system will be used to prepare a detailed preliminary design of a fluidized bed furnace-boiler.

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. This analysis gave a total of 972 combinations of which 810 influence the plant efficiency and 162 influence component heat loads and design conditions. The results of this analysis were reported in the January 1977 monthly report.

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. The results of this analysis were reported in the December 1976 and January 1977 monthly reports.

3. Work on the fluidized bed furnace-alkali metal boiler is continuing. Many of the fluidized bed design parameters have been chosen. The atmospheric pressure furnace is not very attractive for an alkali metal system.

4. Work on the alkali metal condenser-steam boiler was continued. The initial effort is directed toward units using reentry type tubes. A computer code has been written to analyze this unit and the code is currently being checked against prior hand calculations of similar units.

5. A meeting was held with ERDA-FE in Oak Ridge on February 8, 1977, to review reporting procedures for the program.

5. CRITICAL COMPONENTS TEST FACILITY

R. E. MacPherson

Internal review of the report draft, X-OE-40, entitled "Critical Component Test Facility Advance Planning for Test Modules," has been completed. Draft copies were submitted to ERDA-ORO and subsequently to ERDA-FE for review and comment. Editing of the document is underway prior to release for publication.

6. ENGINEERING STUDIES AND TECHNICAL SUPPORT

J. R. McWherter

6.1 Process Modeling Support

R. Salmon and D. M. Lister

Contract Objective

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

Status Summary

1. Progress was made on the proposed acquisition of the Flowtran program by ERDA. Advice was given to FE/MFPM on the terms of a proposed agreement under which MIT, Purdue, Lehigh, and ORNL would obtain the program from Monsanto. Our understanding is that negotiations to conclude such an agreement are in progress.

2. Work continued on a computer program for the estimation of the costs of process piping systems. The program is now operational, but additional refinement is needed in the cost data inputs. The results of example runs are being discussed with industrial firms and practicing cost estimators.

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 based on the ICGG flowsheet.

6.2 Process Research Digest

Two of the articles proposed for the first issue of the Digest are being edited and will be sent to ERDA soon for review. A third article is in preparation. The fourth article, "Catalytic Coal Gasification," will be started soon.

6.3 Survey of Industrial Coal Conversion Equipment Capabilities

J. M. Holmes

6.3.1 Rotating Components

W. F. Boudreau, J. R. Horton, M. Siman-Tov, and W. R. Williams

Objective

The objective of this survey, which is being conducted for the Major Facilities Project Management Division (MFPM) of ERDA/Fossil Energy, is twofold:

1. to determine the present capability of the United States' industry to supply the equipment needed for future demonstration and commercial coal conversion plants; and

2. to determine research and development needs, including lead time requirements, for producing equipment of advanced design.

This section of the report deals with rotating components (compressors, pumps, turbines and expanders).

Status

During February, a questionnaire on pumps was prepared by J. R. Horton and W. R. Williams. This questionnaire has been reviewed by a number of UCC-ND personnel who regularly deal with pumps and is almost ready to be sent to industry. The basic format of the questionnaire will also be used in obtaining information on the other items of rotating equipment.

Final pump lists, including both liquid and slurry pumps, are nearly complete. Pumps are categorized primarily by outlet pressure and pressure head. Final compressor lists will be prepared during the first week of March; these lists will be arranged by outlet pressure and pressure ratio as outlined by W. F. Boudreau. Expander and turbine lists must also be finalized.

It is planned that the questionnaires and corresponding equipment lists will be mailed to industry by the end of the second week of March. Responses are expected by the first week of April.

By the end of February, sixteen companies and organizations had responded to the Commerce Business Daily letter which appeared on January 28 and expressed interest in the project.

Problem Areas

The preparation phase is 90% completed; however, the project is approximately four weeks behind schedule. Most of this time will be made up during March since responses to the questionnaire being sent to industry must be returned within three to four weeks of mailing instead of the scheduled seven weeks.

6.3.2 Valves

W. A. Bush, E. C. Slade, and J. P. Wisner

A trip was arranged to Morgantown, West Virginia, to attend the presentation of the "MERC Report on Valve Study for Coal Conversion Process".

Detailed valve study work is in progress in conformance with the established schedule. Seven processes are presently being analyzed for valve uses and calculations are being made. Determinations are in

progress of each valve size, process conditions, stream flow, the function of the valve, operating conditions and materials of construction. An accumulation is in progress of catalog library material.

6.3.3 Hot Gas Cleanup Devices J. P. Meyer and M. S. Edwards

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

- Questionnaires have been drafted and submitted to a number of major designer - constructors (D-C), A-E firms and individuals knowledgeable in hot gas cleanup techniques. These lists were culled from the Engineering News Record's compendium of the top 500 D-C and 1000 A-E firms in 1975, the Power Engineering construction guide and Chemical Engineering's list of major engineering construction companies. Approximately 60 questionnaires were submitted.
- Using the Thomas Register and Chemical Engineering's Guide to Pollution Control Equipment, the major vendors of pollution control devices have been identified.
- A number of gasifier effluent streams have been characterized as to particulate loading, temperature, pressure, and in several cases, flow rate. This data is found in Table 1.
- In the absence of any additional information, the particulate size distribution from gasifiers and PFBC has been assumed to be log normal:

$$F = f[\ln(d_p)] = \frac{1}{\sqrt{2\pi}\sigma} \exp \left\{ - \left[\frac{\ln(d_p) - \ln(\mu)}{\sqrt{2\sigma}} \right]^2 \right\}$$

where

F = probability density function

d_p = particle diameter (μ)

μ = mean particle diameter (μ)

σ = variance

with variance (σ) of 2.28 and mean diameter of 132 microns. National Coal Board data on PFBCs was used to determine both the variance (σ) and the mean particle diameter (μ).

Table 6.1. Characterization of gasifier effluent streams

	Temperature (°R)	Pressure (atm)	Flow Rate (scfh)	Particulate (lb/scf)
BCR	2100	80	39.6×10^6	2.10×10^{-2}
Combustion of Coal				1.5×10^{-4}
CO ₂ Acceptor	2100	10 - 20		$1.6 \times 10^{-3}^{**}$
Hydrocarbonization	1300	8	118.73×10^6	1.5×10^{-3}
Ignifluid	2460 - 2860	1 - 5		$3.6 \times 10^{-2}^{**}$
Koppers-Totzek	3210	1		$1.1 \times 10^{-2}^{**}$
Synthoil	2060	18	52.9×10^6	3.6×10^{-3}
USMB Stirred Bed	1460	20		$2.3 \times 10^{-4}^{**}$
Winkler Stirred Bed	1960 - 2310	1		$1.3 \times 10^{-4}^{**}$
Lunen Combined Cycle				$1.5 \times 10^{-6}^*$
GE Gas Turbine				$2.8 \times 10^{-6}^*$
UA Gas Turbine				$1.1 \times 10^{-6}^*$
Westinghouse Fluid Bed	1860 - 2260	10 - 16		4.3×10^{-3}
ANL Fluid Bed	1910 - 2110	10		5.5×10^{-3}
NSPS				3.0×10^{-5}

* Based on 300 Btu/scf Gas.

** Based on effluent heating value.

6.3.4 Heat Recovery Equipment Survey W. R. Gambill

The objective of this survey is to evaluate equipment potentially suitable for the recovery and utilization of heat in process streams (gas, liquid, solid, and mixed phase) from primary exothermic coal-conversion process steps. Such process steps may include direct hydrogasification, solution hydrocracking, shift conversion, methanation, methanol synthesis, and Fischer-Tropsch synthesis. Extraction of heat from primary process steps will not be included since this area is quite different regarding both goals and criteria. The approximate range of hot-stream temperatures will be 300-2700°F. Information will be collected and evaluated regarding descriptions, sizes, costs, and commercial applicability of regenerators, fluid bed contactors, heat pipes, related equipment, and, to a limited degree, conventional heat exchangers.

Status Summary

Additional information concerning the shell-and-tube exchanger used to preheat the coal/water slurry at the Mohave generating station before it enters the centrifuges was obtained from M. I. Dina, Plant Engineer at Mohave. The unit is horizontal with two tube passes, and the slurry in the tubes (2.465 in. ID) is heated by second-point extraction steam at ~ 150 psia in the shell. A test conducted in late 1975, during which a 47 wt. % coal slurry flowing at 8.8 fps was heated from ~ 80 to 135°F, gave an overall heat-transfer coefficient of 144.4 Btu/hr ft² °F. If it is assumed that the film coefficient for the condensing steam was 1500 Btu/hr ft² °F and that the thermal conductivity of the stainless steel tubes was 10 Btu/hr ft² °F, the slurry film coefficient was 220 Btu/hr ft² °F, or 15% of the value for water at the same velocity, bulk temperature, and tube ID. The mean Reynolds modulus, for $\mu_b = 20$ cp., was 9815. Though no fouling has occurred, tube inlet erosion has been severe. Stainless steel ferrules at the tube inlets have worn out within three months, and hard rubber inserts are being tried.

A survey of costs for large heat exchangers compiled from manufacturer's estimates and quotes obtained in early 1975 was located in an Appendix of a recent book (S. L. Milora and J. W. Tester, "Geothermal Energy as a Source of Electric Power", the MIT Press, Cambridge, Mass., 1976). All costs are in 1976 dollars. For shell-and-tube units, carbon steel construction, surface areas of 20,000 to 30,000 ft², tube-side pressures of 200 to 2000 psia, shell-side pressures of 100 to 4000 psia, and with 3/4 to 1 in. OD tubes 30 to 40 ft long arranged with a pitch/diameter ratio of 1.25, and 1 pass tube and shell sides, the average costs varied from \$7/ft² to \$50/ft². For induced-draft air-cooled units with Al fins and tube pressures of 100 to 4000 psia (other parameters the same as above), the average cost range was from \$15/ft² to \$19/ft² for carbon steel construction and from \$22/ft² to \$30/ft² for 304 stainless steel (costs based on bare tube area).

Literature was received from several vendor companies. Several papers concerning the potential application of heat pipes to fluid-bed coal gasification were located. Preliminary information was obtained on the Hughes "Heatbank" heat exchanger which uses an array of heat pipes.

6.4 Large Air Separation Plant Study

W. R. Gambill

Status Summary

The large plant study was discussed with A. Perkins and J. T. Hugill of Liquid Air, Inc. (San Francisco), an American affiliate of Air Liquide of France. Their operating plants include one with a capacity of 1800 TPD in Hamilton, Ontario, and a 2200 TP D unit in Antwerp, Belgium, where the plant feeds a 900 mile long merchant pipeline operating at 600 psi. Air Liquide will supply six trains of 2200 TPD each for the SASOL II plant in South Africa, where portions of the O₂ plant will be field fabricated. Hugill stated that the use of semi-permeable membranes for initial enrichment of the air feed would be quite inefficient as well as excessively expensive.

A summary of the information obtained at ORNL through February will be presented at a meeting to be held in Oak Ridge on March 9 with the ERDA/FE/MFPM Project Manager.

7. PROCESS AND PROGRAM ANALYSIS

J. R. McWherter and R. Salmon

7.1 Low Btu Coal Gasification

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

Summary

Activities in February 1977 involved completion of a tentative process selection list, completion of a proposed report example and acquisition of additional process data. Activities forecast for March 1977 include work on the preliminary report contents and acquisition of additional process data.

Process Selection

Twenty processes were tentatively selected for more detailed comparison and evaluation. The selection procedure considered the degree of commercialization, technical aspects, gasifier capacity and availability of information. The screening and selection method will be revised as additional process data are obtained and comparisons/evaluations are completed. Other factors that will be used in comparing processes include environmental aspects, regional considerations such as fuel availability and product use, plant investment and product cost.

Process Data

An example was completed containing the type of data that may be included for each process; the example describes the Lurgi fixed bed, dry ash process. Additional data were obtained for a slagging ash version of the Lurgi gasifier - for both the ERDA Grand Forks Energy Research Center and the British Gas Corporation programs. Work continued on obtaining data for (1) the Westinghouse fluidized bed process, which is intended for use in a combined cycle electric power generating project and (2) the Combustion Engineering entrained flow gasifier process. Work began to obtain data for other processes selected for detailed comparisons. These processes include the following.

Fixed Bed Gasifiers: Wellman Galusha/ERDA-MERC
Woodall Duckham/Gas Integrale

Fluidized Bed Gasifiers U-Gas (IGT)
Winkler

Entrained Flow Gasifiers: Texaco
Koppers-Totzek

Additional processes have been scheduled. Processes normally associated with the ERDA sponsored high Btu gasification program are also tentatively scheduled for the process data section.

Report Planning

An example was prepared which includes excerpts from a proposed preliminary project report. The example was intended to illustrate the type of information that may be included. Sample material was presented for the survey and data sections using information collected for the Lurgi fixed bed, dry ash process. Approximately 50 processes will be described briefly in the survey section. About 20 processes will be described in more detail in the Process Data Section. The preliminary report will contain the process survey section plus process data that have been collected at the time the report is prepared. The initial emphasis is on collecting the technical data. Balance of plant data, economic evaluations, detailed process comparisons and recommendations of processes for specific purposes might be added as needed and as time and manpower permit. The final report will contain all the collected information plus the comparisons and evaluations that are made.

Work Forecast

The specific work done in March 1977 will be influenced by the requirements of Dr. L. M. Joseph and other sponsoring ERDA-FE-OPPA personnel. Discussion of the work is scheduled for March 1, 1977, in Washington, DC, and a list of topics was suggested for this meeting. Additional work is planned on the preliminary report; the contents of the process survey section will be reviewed. The process data collection schedule will be modified if needed and work will continue on acquiring additional information. Some work will be done on a generic comparison of gasifier types; this work can ultimately be used as background for specific process comparisons. Preparation and inclusion of balance of plant/economic considerations will be reviewed and plans will be made after this review.

7.2 Direct Combustion

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

Direct Combustion Study

The Scope of Work for the direct combustion subtask has been revised and submitted to Dr. B. Baratz, FE/OPPA, for review. Additionally, a summary of work accomplished in evaluating the state of the art of direct combustion was transmitted to Dr. Baratz in the form of a letter report on February 10, 1977.

Power Plant Reliability Study

The analysis of the FEA data base was completed; capacity factors, availability factors and forced outage rates were analyzed in a linear least-squares fit to each life-year of data, specific years' data and yearly cumulative averages. A 220 page report was issued.

The critique of the CEP analysis of nuclear and coal unit capacity factors and economics was completed and issued in draft form. The draft is being reviewed prior to release as a Technical Memorandum. R. Simard was invited to discuss the critique at the Institute for Energy Analysis of Oak Ridge.

7.3 Advanced Power Conversion Systems

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

The report on oil- and gas-fired open cycle gas turbine development has been completed and submitted for review together with a comparison report on coal-fired gas turbines. The report on ceramic gas turbines is nearly complete and should be finished by about March 18.

The difficult task of ferreting out data on the developmental costs and the operating time of experimental units is largely completed for most of the ten advanced energy conversion systems being studied. Figure 7.1 gives a preliminary plot of the cases for which a fairly complete set of data is available. The amount of running time on fuel cells obtained so far is fragmentary, hence is not yet plotted. Note that some systems have succeeded in getting a large amount of running time with the budgets available whereas others have not. Perhaps even more important, some of the systems have little or no running time at the conditions required for commercially attractive plants. This is a subtle aspect of the business, and it is difficult to obtain the vital data and organize it in a form that conveys the picture reasonably well in terms that can be understood by those not intimately conversant with the technology.

7.4 Liquefaction

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

Process Review

Twelve coal liquefaction processes have been reviewed. The information and references on these processes have been prepared in a standardized data format.

* Consultant

ORNL DWG. 77-535

Fig. 7.1. Total investment in R&D and total operating time for advanced power operations.

Technical Evaluation Ranking System

A preliminary technical evaluation ranking system has been prepared.

Meeting

A meeting was held on January 28, 1977 at Parsons' offices in Pasadena, California between representatives of ERDA's Office of Program Planning and Assessment (OPPA), Union Carbide Corporation, Nuclear Division, Oak Ridge, Tennessee (ORNL), and Parsons. The purpose of the meeting was to discuss a possible reorientation of the order of certain tasks to provide early assessments of technical and economic merits of three or four high potential processes; this effort would receive a high priority and displace certain of the near-term objectives defined in the Work Statement. This change is still under consideration.

7.5 High Btu Gas

A subcontract for this subprogram is being negotiated.

7.6 In Situ Coal Gasification

W. C. Ulrich and G. J. MacKenzie

Several sections of a draft report, "Evaluation of In Situ Coal Gasification Processes on a Regional Basis," were completed. These include the introduction, the basis for comparison of the processes, descriptions of the candidate processes, and a comparison of the processes for the eastern region of the United States. This portion of the report was reviewed with representatives of the Office of Program Planning and Analysis and the Office of Oil, Gas and Shale Technology in Washington on February 23, 1977, and Morgantown Energy Research Center on February 24, 1977 in Morgantown. The work was also discussed with a member of the Laramie Energy Research Center at a meeting in Oak Ridge on February 10, 1977. Draft versions of summary data source sheets were also presented at these meetings. Plans are to complete the draft report and summary data source sheets in March. They will be submitted to OPPA and other interested parties for review and comment.

7.7 Coal Beneficiation

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

The following items have been completed:

1. The ORNL computer program PRP has been successfully used to perform the economic analyses for the various coal beneficiation processes.

2. Economic analysis of the TRW-Meyers (TRW) coal beneficiation process for conceptual plants designed to produce 1,500 and 15,000 TPD MAF product coal from Pennsylvania coal. Pennsylvania coal is bituminous coal from the Lower Kittanning coal bed located in Pennsylvania.

3. Process descriptions for the TRW fine and coarse coal processing schemes.

4. Process design for the 1,500 TPD MAF product coal plant using the Battelle Hydrothermal Coal Process (BHCP).

5. Process descriptions of the mechanical beneficiation and the froth flotation processes.

6. Description of the equipment used in the mechanical beneficiation processes.

The following items are currently being developed:

1. Economic analysis for the mild and deep cleaning modes of the wet beneficiation process for plants producing 1,500 and 15,000 TPD MAF coal using Pennsylvania, Western Kentucky, and Illinois coals. Western Kentucky coal is bituminous coal from Coal bed 6 located in Western Kentucky while Illinois coal is bituminous coal from Coal bed 6 located in Illinois.

2. Process descriptions for the Ledgemont Oxygen Leaching Process (LOL), the SURC Chemical Comminution Process (SURC) and the High Gradient-High Intensity Magnetic Beneficiation Process.

3. Process descriptions for the BHCP and the Pittsburgh Energy Research Center beneficiation process.

The following diagrams and plots were completed:

1. Block flow diagrams for the TRW (fine and coarse coal processing schemes), the SURC and the LOL processes.

2. Plots of the results of the economic analyses for the conceptual beneficiation plants producing 1,500 and 15,000 TPD MAF product coal from Pennsylvania coal using the TRW process.

3. Process flow diagrams for the 15,000 TPD MAF product coal plants for the wet beneficiation-deep cleaning of Western Kentucky coal and the wet beneficiation - mild cleaning of Pennsylvania coal.

7.8 Gas Cleanup

M. S. Edwards

Contacts with low temperature gas cleanup process vendors were completed; additional information was supplied by Allied Chemical Corporation

on the Selexol process, Union Carbide on molecular sieves, Dow Chemical on the use of methyldiethanolamine, Shell Development on the Sulfinol process, and Davy Powergas for the Alkazid "DIK" process. Letters were sent to Eickmeyer & Associates, American Lurgi, and Peabody Engineered Systems for information on the Catacarb, Rectisol, and Stretford processes respectively. No other low temperature process vendor contacts are expected. Process vendors already contacted will be further queried if additional questions arise.

High temperature gas cleanup process developers will be contacted in March.

Based on the information available, the processes compiled were screened using various technical criteria. This screening reduced the number of processes under consideration to fifteen. Starting in March, these processes will be further evaluated to limit the number of candidate processes to less than ten. Detailed technical descriptions of these candidates will be provided, along with process economics culled from the literature search and vendor contacts.

7.9 Coal Prices and Volumes

O. L. Culberson*

Work continued on the correlation of mine-mouth costs of Western U.S. coals as a function of heating value, sulfur content, ash content and contract quantity. This correlation and a comparable one for Eastern U.S. coals hopefully will be completed during March.

7.10 Energy Transportation Costs

O. L. Culberson*

No progress was made on the costs of transporting low-Btu and high-Btu gases. All available manpower was applied to the correlation of coal prices.

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).

Task 1, the survey of primary feedstocks for chemical production was completed.

* Consultant

Task 2, the identification of the impediments to the utilization of chemical feedstocks from coal and oil shale is underway. The open literature is being searched in order to find what factors have historically caused feedstock changes. The production history and thus feedstock change information is more complete for the chemicals: Ammonia, Ethylene, Acetic Acid, Phenol. This list contains chemicals that are both aromatic and aliphatic and for which feedstocks vary from synthesis gas to heavier oil fractions. Broadly, the feedstock change factors appear to be feedstock price and availability, by-product value and manufacturing-type costs. Technical advances often caused chemical demands and manufacturing costs to change.

Preliminary screening of the various coal conversion processes had begun. The PARAHO oil shale project will probably be the only oil shale process to be studied.

8. FOSSIL ENERGY ENVIRONMENTAL PROJECT

C. R. Boston

8.1 Landfill Storage of Coal Conversion Solid Wastes/Information Assessment

H. M. Braunstein

A preliminary draft of the landfill information assessment was completed on February 9, 1977, and reviewed by ERDA on February 18, 1977. The remainder of the month was devoted to modifying the document (in response to comments) and scientific editing. Production of the printed, clean draft by the Technical Publications Department is expected by March 11, 1977.

The experimental phase of this task which will be a joint undertaking of Environmental Sciences Division and Energy Division was initiated.

8.2 Environmental Monitoring Handbook

M. S. Salk

Preparation of Part I of the Handbook (preconstruction monitoring) is underway. A qualitative list of effluents from coal conversion facilities was prepared. Relevant literature was reviewed and analyzed. Writing commenced on the general introduction to the handbook and to the introduction, scope, and purpose sections of the individual subsections.

8.3 Programmatic Assessment/Pipeline Gas

L. H. Stinton

During the month of February an outline was developed, section responsibilities were assigned, and target dates for submitting sections were set. Three sites representing three major coal provinces in the United States have been identified and information pertaining to these sites is being collected. Team members are working on effluent identification and site descriptions which should be completed in March.

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 feed system on automatic operation was completed without interruption this month. The system will be opened for inspection of components and the pressure drop and leakage flow across the feed components will be checked.

9.2 Supplemental Studies

The final report from FluidDyne on the corrosion test operating history was received this month. The report indicates that the temperature distribution on the specimen tubes was fairly uniform for all of the 16 locations and that there was only one short excursion where the SO_2 concentration in the flue gas went significantly higher than about 400 ppm.

Four of the specimen tubes have been selected for metallographic examination and the tubes have been sectioned. The microscope samples are being polished for examination next month.

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