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# Coal Technology Program Progress Report for March 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 MARCH 1977

Date Published - May 1977

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OAK RIDGE NATIONAL LABORATORY  
Oak Ridge, Tennessee 37830  
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ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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COAL TECHNOLOGY PROGRAM PROGRESS REPORT FOR MARCH 1977

## ABSTRACT

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

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## 1. SUMMARY

J. P. Nichols

Highlights of our progress in March are as follows:

- In the final hydrocarbonization experiment with Wyodak subbituminous coal, the coal was hydrocarbonized at 1100°F and 300 psig in the recirculating fluidized bed. Preparations which began for hydrocarbonizing char-diluted Illinois No. 6 included a renewed emphasis on the ambient mock-up and 1200°F char devolatilization in the atmospheric carbonizer.
- The work on residue carbonization has been terminated by mutual agreement between ERDA/FE and ORNL. Future work with the atmospheric carbonizer will be in support of hydrocarbonization research.
- Two-dimensional pyrolysis behavior of an eastern bituminous coal (Pittsburgh seam) continues to be examined in the laboratory. Results to date indicate that swelling is significantly more pronounced at very low heating rates.
- Axial dispersion and liquid hold-up measurements have continued in the column packed with glass spheres with cocurrent upflow of a coal-water slurry and air. Plans are being prepared to replace the water with an organic fluid in our continuing studies of coal-solvent-hydrogen mixing.
- In our pressurized carbonization work, three runs were made using methyl-naphthalene to simulate CSF residue with a material balance closure of 79.5% of the run which analytical results had been obtained. In addition, several small modifications of the product recovery system were made.
- We are continuing to use the DATA TRAK to simulate the microstructure at various depth locations in thick sections of 2 1/4 Cr-1 Mo steel. Testing of the specimens from the A543 Class 1 steel plate is underway.

- Several activities are in progress that are related to inspection techniques for wear- and process-resistant coatings.

- Deposition of Alloy 320 cladding on ferritic stainless steels by the gas metal-arc method has been attempted with several shielding gases. Equipment for simulation of shop cladding methods was developed.

- Experimental investigations of fireside corrosion on tubing from a fluidized bed combustor have proceeded with metallographic examination and analyses of the scale formed during the test exposure. Methods for nondestructively determining remaining tube wall thickness and scale thickness were developed.

- Failure prevention and analysis work was aimed at several parts from the Solvent Refined Coal Plant in Ft. Lewis, Washington.

- The mechanical design of the gas-fired potassium boiler system was completed with the issue of the last four drawings this month. One electrical and five instrument and control drawings were completed. Fabrication work completed includes attaching heaters and thermocouples on the drain tank and insulating it, welding of piping and fittings on the sample box, and initial work on the main control panels. The installation of the propane tanks and piping was completed. The potassium condenser, condenser enclosure, inlet air duct, and inlet air plenum were installed on the equipment tower.

- Conceptual design and layout work for the overall coal-fired alkali metal system was initiated this month. However, this was directed toward the use of three pressurized furnaces and is thus being stopped. This task will be delayed until a new concept of the atmospheric pressure furnace arrangement is prepared.

- One of the four articles to be included in the first issue of the Process Research Digest was sent to ERDA for review. The subject of this article is "Conversion of Methanol to High Octane Gasoline." A second article, "Flash Hydrolysis of Coal," was edited and will be sent to ERDA for review in April.

- Surveys of industrial coal conversion capabilities continued with emphasis on rotating components, valves, hot gas cleanup devices, and heat recovery equipment.

- Process and program analysis research studies continued with work on low-Btu gasification, direct combustion, advanced power conversion, liquefaction, high-Btu gasification, in situ gasification, and beneficiation.

- In the fossil energy environmental project, a first draft of a landfill assessment report was issued for review and work continued on the Environmental Monitoring Handbook and Pipeline Gas Programmatic Assessment.

## 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, J. B. Gibson, L. S. Dickerson, C. H. Brown, Jr.  
F. H. Wilson, G. W. Oswald, J. Beams, and J. C. Rose

#### 2.1.1 Experimental Development

Work Accomplished. Recirculating fluidized bed research in plastic models resumed during March. Solids feeding and withdrawal, an alternative distributor plate, a larger diameter (1 in.) draft tube, and various draft tube-distributor plate spacings are to be studied in the existing 4-in. diam Lucite mock-up.<sup>1</sup> Since operation of the bench-scale hydrocarbonizer with agglomerating coal depends on good internal circulation, increased emphasis is being placed on understanding recirculating fluidized beds by using cold models.

The atmospheric pressure carbonizer which has been used for residue carbonization studies has been reconverted to support of the coal hydrocarbonization research. The atmospheric pressure carbonizer will provide two services: (1) production of devolatilized char for experiments in the 20 atm hydrocarbonizer and (2) evaluation of methods to prevent caking in runs with undiluted Illinois No. 6 coal.

During March five runs were made on the agglomeration test reactor and two runs on the atmospheric carbonizer. The agglomeration tests indicated char/coal mixtures of 4/1 or 5/1 should be sufficient to prevent agglomeration. Two runs on the atmospheric carbonizer with a 4/1 char/coal ratio produced essentially the same results. Each run was 1-1/2 hours long at a feed rate of approximately 10 lb/hr. Considering the small quantity of fresh coal (3 lb) fed to the reactor, extensive amounts of tar were formed, which plugged the char overflow line. Each run was concluded when the reactor began filling with char. During clean-up of each run, a very loose, friable agglomerate was found in the draft tube. Based on these results, char and coal in the ratio 5/1 will be used in the first bench-scale hydrocarbonization experiment on Illinois No. 6 coal.

Work Forecast. Testing will begin in the 4-in. diam mock-up to evaluate a larger draft tube (1-in. diam vs. 3/4-in.), an alternative distributor plate, and solids feeding and withdrawal.

A 100 lb batch of char will be devolatilized in the atmospheric carbonizer at 1200°F for the char/coal run in the hydrocarbonization facility. Following this, changes will be made in the reactor and a run will be made with undiluted Illinois No. 6 coal to test caking tendencies.

### 2.1.2 Bench-scale Hydrocarbonization System

Work Accomplished. Routine experimentation continued in March with HC-14, recirculating fluidized bed hydrocarbonization of Wyodak subbituminous coal (9.2 lb/hr for 6.0 hr) at 300 psig. As in HC-13, after a long period of stability (3.3 hr at 1100°F), bed temperatures began to drop stepwise (1.1 hr at 1050-1075°F, then 1.5 hr at 1010°F). Currently, because instability is thought to result from unsatisfactory understanding and operation of the recirculating fluidized bed, emphasis is being placed on improving the accuracy of gas flow measurement and analyzing the ambient mock-up. Nevertheless, useful data from the upper range of hydrocarbonization temperatures should result.

Experiment HC-13 run conditions and preliminary material balances are summarized in Table 2.1. Bed temperature during HC-13 decreased from 950°F to 900°F, rather than 905°F to 900°F as reported in February.<sup>2</sup>

Work Forecast. A coal preheater will be designed, reviewed, built, and installed during the next two months. The coal dilute-phase transport line will be coiled and pass through a 450°F Dowtherm bath, electrically heated.

During April, experiment HC-15 will hydrocarbonize Illinois No. 6 coal, diluted to 17% by Wyodak char.

## 2.2 Residue Carbonization

J. B. Gibson 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

Table 2.1. Summary of Experiment HC-13 conditions and preliminary material balances

Experiment	HC-13
Bed temperature, °F	950/900
Reactor pressure, psig	300
Estimated solids residence time in the reactor, min <sup>a</sup>	60
Period at steady state, hr	5.3/3.0
Coal Feed	
Moisture content, wt. %	6.52
As-received feedrate, lb/hr	11.1
Moisture-and-ash-free feedrate, lb/hr	9.7
Time of feeding, hr	10.3
Hydrogen flowrates, scfm	
Total hydrogen feed	10.8
Coal transport tube	2.7
Draft tube nozzle	4.4
Through distribution plate	3.7
H <sub>2</sub> /Coal feed ratio	
lb H <sub>2</sub> /lb coal	0.38
scf H <sub>2</sub> /lb coal (maf)	67
Carbon balance (% of carbon fed)	
Char	70.3
Liquids	12.5
Gases	10.4
Overall	94.0
Overall ash balance (% of ash fed)	89.7
Sulfur balance (% of sulfur fed)	
Char	40.5
Liquids	7.3
Gases	52 <sup>b</sup>
Overall mass balance (% of mass charged)	94.5
Oil yield (wt % of maf coal)	15.4

<sup>a</sup>Time to char overflow in the reactor

<sup>b</sup>By difference from 100%

The work on residue carbonization has been terminated by mutual agreement between ERDA/FE and ORNL. A summary report of this work will be included in the March, 1977, quarterly. Future work with the atmospheric carbonizer will be in support of the hydrocarbonization research and will be reported under that heading.

### 2.3 Experimental Engineering Support of an In Situ Gasification Process

R. C. Forrester III and G. D. Owen

#### 2.3.1 Large-Block Pyrolysis Experiments

As described in previous reports, samples of Eastern bituminous coal (Pittsburg seam) 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. Several of these specimens have been heated at rates of 0.3 and 3.0°C/min to temperatures ranging from 600 to 1000°C.

In each experiment, gas evolution can be audibly detected as pyrolysis gases bubble from the swelling, fluid-like material in the reactor. After cooling to room temperature, the remaining char is observed to be non-pyrophoric and quite dense, having considerable mechanical strength. It is interesting to note that the characteristics of chars produced from blocks of Western subbituminous coals are precisely opposite these, such chars being pyrophoric, porous, and extremely friable.

Details of gas production rates and composition for all experiments will be included in the second quarterly progress report.

#### 2.3.2 ERDA's UCG Program

Recent results of pyrolysis experiments conducted at ORNL were presented on March 15 at the combined meeting of UCG Working Groups on Modeling and Laboratory Research. All ERDA-funded activities in UCG development were summarized and discussed by meeting attendees, following which Dr. P. R. Wieber (ERDA-HQ) presented recent perspectives from Washington, D. C. The meeting was held in Morgantown, West Virginia at MERC.

## 2.4 Coal-Solvent-Hydrogen Mixing

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

Studies of liquid mixing in coal-solvent hydrogenation reactors have continued. The anthracite coal which had a large fraction of -60 +80 mesh solids has been replaced with Wyodak coal, all of which passes through a 100 mesh screen; 95% passes 140 mesh, and 90% passes through a 200 mesh screen. This coal, slurried in water (35 wt. % coal), has an apparent viscosity and density at 20°C and 1 atm of 110 cP and 1.125 g/cm<sup>3</sup> using a Brookfield Viscometer and hydrometer, respectively. The slurry has been successfully pumped with a Moyno pump and 26 pulse test measurements have been completed in the 1-in.-ID column packed with 4.6-mm-diam glass beads. Slurry flow rates were in the range of 6.5 - 12.8 cm<sup>3</sup>/sec with no gas flow and 3.6 - 5.9 cm<sup>3</sup>/sec with air flow rates of 82.9 - 227 cm<sup>3</sup>/sec (S.C.). Slurry flow rates are being measured by diverting the column effluent to a 1-ft section of 3-in.-diam glass pipe and timing a known volume.

Calculations to extract axial dispersion coefficients and liquid holdup values from the recorded pulses obtained to date are continuing. Coordinate points on the recorded pulses are now being automatically picked off through access to a Graphic Data Digitizer from Elographics, Inc. The data is then fed via paper tape directly into a computer program where it is analyzed in two ways: (1) by the standard analysis by moments, and (2) using a pulse transfer function. The second method is designed to reduce the influence of tailing of the pulses on the calculated values of the axial dispersion coefficient and the liquid holdup.

Preparations are now being made to conduct similar experiments with co-current upflow of air and slurry of coal (35 wt. %) in an organic liquid. Several organic liquids are being considered, including mineral oil and vegetable oil. However, since the KCl tracer will not be useable in the organic fluid, an alternative tracer technique must be used. Two possibilities are presently being studied: (1) using a gamma-emitting radioactive tracer in the liquid phase with appropriate electronic detection instrumentation, and (2) using an organic phase conductivity improvement agent with extremely sensitive conductivity meters.

## 2.5 Pressurized Carbonization of Consol Synthetic Fuel Solid Residue

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

During March three runs were made using methyl-naphthalene to simulate CSF residue. These runs have shown the product recovery system to be inadequate. The addition of a cyclone separator and an activated carbon bed downstream of the condenser appear to have solved the product recovery problems. These preliminary runs have also revealed difficulties in

achieving steady liquid feed to the reactor; however, a procedure has been developed that results in a steady liquid flow to the reactor. In the first preliminary run no attempt was made to make a material balance, and analytical results are not available for the third preliminary run. However, material balance calculations have been completed for the second preliminary run and are summarized in Table 2.2.

In April one final preliminary run using methyl-naphthalene as simulated CSF residue will be made. If this run reveals no new problems, the experimental program using CSF residue will be started immediately.

Table 2.2. Results of simulated CSF residue carbonization

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Feed	200 g methyl-naphthalene
Fluidizing gas	Argon
Temperature	900°F
Pressure	50 psig
Total recovery	156.7 g (78.3%)
Gas evolution	1.7 g (0.87% total feed)

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#### 2.6 References for Section 2

1. "Coal Technology Program Progress Report for July 1974," ORNL/TM-5037 (October 1975).
2. "Coal Technology Program Progress Report for February 1977," ORNL/TM-5858 (April 1977).

### 3. MATERIALS ENGINEERING

R. T. King

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

#### Summary

We are continuing to use the DATA TRAK to simulate the microstructure at various depth locations in thick sections of 2 1/4 Cr-1 Mo steel. Testing of the specimens from the A543 Class 1 steel plate is underway.

Several activities are in progress that are related to inspection techniques for wear- and process-resistant coatings.

Our revised work statement for FY-1977 was submitted and approved by ERDA/FE. An outline list of potential defect conditions for diffusion coatings has been assembled. Fabrication of plasma-sprayed specimens continues. We have requested a standard "alonized" carbon steel specimen from Alon Processing, Inc. Characterization methods are being prepared for this specimen. Preparatory work on equipment and specimens for x-ray fluorescence experiments continues. Thermal imaging experiments continue; we are setting up a new line-scanning IR camera to replace our area imaging camera in order to improve the transient-recording capability. Attempts to adapt a commercial dimensional capacitance gage to controlled-standoff coating thickness measurement were unsuccessful, but will be repeated with modified fixtures. A unique agent for liquid penetrant examination of ceramics was discovered - green food dye. Various ultrasonic experiments to measure coating thickness continue. Operation of a hand-held electrochemical capacitance probe was demonstrated; some linearizing modification is needed.

Deposition of Alloy 320 cladding on ferritic stainless steels by the gas metal-arc method has been attempted with several shielding gases. Equipment for simulation of shop cladding methods was developed. An RFQ for thick section welds was reviewed.

Experimental investigations of fireside corrosion on tubing from a fluidized bed combustor have proceeded with metallographic examination and analyses of the scale formed during the test exposure. Methods for nondestructively determining remaining tube wall thickness and scale thickness were developed.

Failure prevention and analysis work was aimed at several parts from the Solvent Refined Coal Plant in Ft. Lewis, Washington.

### 3.1 Pressure Vessel and Piping and Technology Assessment

D. A. Canonico

We are continuing to use the DATA TRAK controller system coupled with a fast-response furnace and quench apparatus to simulate industrial heat treatment thermal cycling at various depths in thick sections of 2 1/4 Cr-1 Mo steel. The cycling is representative of surface, 1/4 T, and 1/2T locations in approximately 12-in. thick plate subjected to an austenitizing treatment followed by either quenching air cooling or furnace cooling. Charpy impact specimens made from thermally cycled bar stock are being tested now to assess their fracture toughness from about room temperature to the upper shelf. The data are not yet sufficient to yield trend information.

### 3.2 Inspection Techniques for Wear- and Process-Resistant Coatings

R. W. McClung and G. W. Scott

Work is continuing in several areas that appear promising for non-destructive examination of coating materials. The work is reported separately below.

#### 3.2.1 Review and Evaluation (G. W. Scott)

From our literature review, we have accumulated sufficient information to define some potential flaw conditions for diffusion aluminum alloy coatings. The following is a rough outline:

- A. Inadequate diffusion by the alloying species, e.g., aluminum
  - 1. Insufficient depth of penetration
  - 2. Incorrect alloy concentration
- B. Mechanical damage to the diffused alloy layer
  - 1. Erosion by process exposure
  - 2. Isolated cracks or holes exposing un-alloyed substrate material
- C. Microstructural damage to the diffused layer
  - 1. Corrosion, internal or external
  - 2. Diffusion zones for contaminants
  - 3. Grain structure changes from thermal or mechanical stress cycles

This list, when completed, can be compared against information developed by the coating method/material screening programs to identify those conditions which we should try to detect with NDT methods.

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

Several specimens are being prepared by the Welding and Brazing Laboratory. A tensile specimen has been prepared with a .254 mm (.010 in.) thick cermet coating of 50% ZrO<sub>2</sub>/50% NiCrAl. We are also preparing ultrasonic and thermal specimens using ceramic and cermet coatings.

We contacted Alon Processing again on March 24 and learned that they have available a standard sample specimen, 2 × 2 × 1/8 in., of alonized carbon steel. They agreed to send us one.

We are designing a characterization scheme for the 2 × 2 "alonized" specimen. Thus far, the examinations proposed include NDT and analytical techniques to study the external surface, the surface alloy layer (by external methods), and a cross-section (after cutting) of the specimen.

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

Installation, shakedown, training, and calibration work continue on our x-ray fluorescence system. We have made transmission radiographs of specimens planned for use in x-ray fluorescence experiments.

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

We continued our experimental investigations of the thermal detection of nonbonds in ZrO<sub>2</sub> coating. We have been able to image the intentional nonbond in our standard sample under a fairly wide range of variations in the heat input conditions. As expected, the time window in which the defect could be seen remained quite small and essentially independent of heat input parameters. A number of additional nonbond specimens has been ordered and should be available soon.

A line-scanning infrared camera has been obtained and will soon replace the imaging camera now being used. The former unit has the advantage of interrogating any point of the scan 60 times per second instead of 16 times per second, as is the case with the imaging camera.

### 3.2.5 Capacitance Testing (G. W. Scott)

Controlled standoff experiments on our ZrO<sub>2</sub> standards were attempted using a polyethylene sleeve mounted over the probe panel and held by

set screws. Preliminary trials produced unstable readouts from the instrument which were apparently due to continuous deformation of the plastic barrel. The experiment will be repeated, possibly with a modification to ensure constant pressure on the probe as it is pressed against the specimen surface.

### 3.2.6 Surface Inspection Materials (S. D. Snyder)

We have observed that all of the penetrants used to inspect the ZrO<sub>2</sub> ceramic coatings operate in reverse to the normal penetrant behavior; i.e., the penetrant washes from the cracks and is held by the porous coating. Even though this reversal persists, all of the crack indicating materials are valuable as a qualitative test to show the presence or absence of cracks. Certainly, they do not provide any quantitative information that can be related to crack size other than in general terms, such as coarse or fine cracks.

Since the inspection materials are rather sophisticated dye formulations, we decided to try a very simple product, green food dye. The food dye was diluted in a 1:1 ratio with water and a trace of Photo-Flo 200 solution<sup>1</sup> was added as a wetting agent. This penetrant was applied from a medicine dropper in an amount necessary to have an even spread over the entire coating surface. After a dwell time of about 5 min, the coating was washed with water for 15 sec from a spray head of the type found on most kitchen sinks, and dried with forced air. The coarse cracks became evident as the food dye penetrant was removed from them. Another 15 sec water spray wash and forced air drying brought out the finer cracks while smearing the evidence of the coarser cracks by the overwash. Of all the products we have tried, this simple, inexpensive, and non-toxic penetrant has produced the best results for detection of cracks in the ZrO<sub>2</sub> ceramic coating and provides a determination of relative crack sizes by preferential washing.

### 3.2.7 Ultrasonic Methods (K. V. Cook)

An important problem in the fossil energy program involves measuring, from the outer surface, the presence 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.

A commercial pulse-echo thickness gage was used, during a vendor demonstration, in an attempt to measure a 0.25-mm (0.010-in.) ceramic

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<sup>1</sup>Eastman Kodak Company, Rochester, N.Y.

coating sprayed onto a 3.18 mm (0.125 in.) I-800 base material. The test was not successful, as was the case with ORNL's existing thickness gage. Lower frequency transducers for our unit will be tried when new coated specimens become available.

A second double wedge contact probe unit which uses two 5-Mhz mini-transducers has been fabricated. The second wedge introduces 45° longitudinal waves; whereas, the first wedge introduces 45° shear waves as the interrogation energy. Preliminary testing with these units indicate that for 3.18 mm (0.125 in.) or thicker substrates, a 45° wave can be propagated; however, thin materials generate multi-mode energy which is difficult to interpret and will require further study. Pending receipt of the various coated specimens, a study of these units will be continued.

### 3.2.8 Electrochemical Testing (G. W. Scott)

The hand-held differential capacitance probe was tested on a specimen consisting of an IN-800 plate covered with mylar tape and containing "defects" made by cutting holes of known areas in the tape. The response of the probe is not a linear function of the exposed metal area, but does increase with increasing area. We are examining new probe designs with a view toward producing a more uniform distribution of the reference electrode material (platinum wire) to see if the response can be smoothed out.

## 3.3 Welding and Cladding

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

During this reporting period we have concentrated on gas metal-arc (GMA) and submerged-arc (SA) cladding of low-alloy steel with type 320 stainless steel. For the GMA cladding we have experimented with several mixed shielding gases, including 98% Ar-2% O<sub>2</sub>, 95% Ar-5% O<sub>2</sub>, 75% Ar-25% He, and 25% Ar-75% He. Best results were obtained using 75% Ar-25% He mixture and we are in the process of preparing samples for metallography using this gas mixture. We have modified existing equipment for welding by submerged-arc with alternating current (ac) and for lateral torch oscillations. This will allow us to clad using techniques more prototypic of actual heavy section fabrication shop practices. In addition we have reviewed an RFQ concerning development of automated field welding techniques for heavy section low-alloy and Cr-Mo steels in the horizontal and vertical welding positions.

### 3.4 Fireside Corrosion

R. H. Cooper and J. H. DeVan

The analysis of Alloy 800H, Alloy 600, types 304, 316, and 310 stainless steel, and Alonized Alloy 800H and type 310 stainless steel tubing from a fluidized bed combustion experiment is in progress. The tubing was exposed to gas temperatures of about 900°C for a 500 hr trial burning Illinois No. 6 coal, with 250 to 450 ppm average SO<sub>2</sub> contents and 2 to 3% excess oxygen. Initial examination of the tubes suggests that CaSO<sub>4</sub> deposits may have protected the tubes from erosion. Measurements of scale thickness, by metallographic methods, and development of eddy current techniques for nondestructively measuring remaining wall thickness and scale thickness are in progress.

### 3.5 Failure Prevention and Analysis

R. T. King

Examination of components from the Solvent Refined Coal Plant at Ft. Lewis, Washington, and related development work is in progress. Specific activities include:

- (a) Development of ultrasonic testing methods to determine the presence of coked solids in process lines.
- (b) Preparation of guidelines for determining the presence of coked solids in process lines by radiographic examination with an iridium source.
- (c) Petrography to determine the extent of coking of material in an elbow in the process stream just ahead of the dissolver.
- (d) Development of high temperature brazing materials for joining tungsten carbide valve stem tips to the stem.
- (e) Examination of a flapper valve from the wash solvent distillation tower for corrosion/erosion mechanism.

#### 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. 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

A test was run to determine if the empty boiler tube bundle could be heated with the burner prior to filling with potassium and hold the temperature distribution uniform enough to avoid excessive thermal stresses. Runs with the main burner at its minimum stable power level and with the pilot flame operating at maximum power both resulted in excessive temperature differences. It was concluded that an external air preheater will be required for filling with potassium.

The mechanical design of the system was completed with the issue of the last four drawings this month. One electrical and five instrument and control drawings were completed.

Fabrication work completed includes attaching heaters and thermocouples on the drain tank and insulating it, welding of piping and fittings on the sample box, and initial work on the main control panels.

The installation of the propane tanks and piping was completed. The potassium condenser, condenser enclosure, inlet air duct, and inlet air plenum were installed on the equipment tower. Work was started on erecting the structural steel for the tower extension.

Plans for Next Month. Fabrication of the sample box piping will be completed; design work will be continued on the electrical systems and instruments and controls; fabrication of the main control panels will continue; construction on the tower will be completed and installation of the potassium components will be continued.

## 4.2 Coal-Fired Alkali Metal

G. Samuels

### 4.2.1 Contract Objective

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

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

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

#### 4.2.2 Status Summary

The first phase of the cycle analysis has been completed. This was a parametric analysis of the three basic systems of the plant, i.e., atmospheric, intermediate, and high pressure fluidized bed combustion systems. The results of this analysis were reported in the January 1977 monthly report.

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.

The work on the fluidized bed furnace during the first six months of the project was concentrated on a vertical tube boiler arrangement for a pressurized furnace and is thus invalidated by the change in direction of the program. The atmospheric furnace will require a different concept and this work is just getting started.

Work on the alkali metal condenser-steam generator was continued. A computer code has been prepared to analyze a reentry tube type unit for this application. The code has now been checked against previous hand calculations and is in good agreement with the prior results.

Conceptual design and layout work for the overall system was initiated this month. However, this was directed toward the use of three pressurized furnaces and is thus being stopped. This task will be delayed until a new concept of the furnace arrangement is prepared.

### 5. CRITICAL COMPONENTS TEST FACILITY

R. E. MacPherson

The report, X-OE-40, entitled "Critical Components Test Facility Advance Planning for Test Modules," has been edited and is now in the process of being reproduced for publication.

No further progress on the Critical Components Test Facility work is expected until results of the survey by another contractor are available.

## 6. ENGINEERING STUDIES AND TECHNICAL SUPPORT

J. R. McWherter

### 6.1 Process Modeling

R. Salmon and D. M. Lister

#### 6.1.1 Contract Objective

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

#### 6.1.2 Status Summary

1. The final report on the computer program PRP was issued (ORNL-5251). PRP is a discounted cash flow program for calculating the manufacturing cost of a product when the investments and operating expenses are known. The program is being made available through Argonne Code Center.

2. Work continued on the development of the process piping cost estimation program PPL. New cost data were obtained from manufacturers of valves, insulation, and pipe supports. The routines for estimating installation costs were improved. An example problem containing 25 process equipment items and 20 process lines was run. The output cost tabulations were discussed with ITT-Grinnell and Rust Engineering. Work was started on a report describing the program.

3. Development of the heat exchanger design and cost estimation program HDC continued. Tube count data were obtained from Nooter Corporation and were found to check quite well with the tube count routine in the program. Costs of tubing were obtained from Allied Tube Company. Information on flange design and prices of flange forgings were obtained from Taylor Forge. The calculation routine for tubesheet thickness is being improved to include checking the perimetral shear stress as required by TEMA.

4. The DSS program for solving large sets of differential equations was received from Lehigh University. The package included 16 example problems. Work was started on adapting DSS for installation on the ORNL computing system. It is expected that the first test runs will be made by the first week of April.

#### 6.1.3 Problem Areas

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

## 6.2 Synthetic Fuels Process Research Digest

J. R. McWherter and Alan Spiewak

One of the four articles to be included in the first issue of the Digest was sent to ERDA for review. The subject of this article is "Conversion of Methanol to High Octane Gasoline." A second article, "Flash Hydrolysis of Coal," was edited and will be sent to ERDA for review in April. The other two articles are being prepared by a technical writer, F. J. O'Hara, under subcontract.

## 6.3 Survey of Industrial Coal Conversion Equipment Capabilities

J. M. Holmes

### 6.3.1 Contract Objective

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

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

During March, the lists of process conditions for both pumps and compressors were completed. Questionnaires for both categories, which were prepared by J. R. Horton and W. R. Williams, were finalized after extensive review by Union Carbide Corporation--Nuclear Division (UCC-ND) personnel. The pump questionnaire and corresponding equipment lists were mailed to industry on March 31. Compressor information should be sent out on April 1.

A visit was made to TVA's Bull Run Steam Plant on March 11 by J. R. Horton and W. R. Williams to discuss the capabilities of pumps in service at that location. Information obtained indicated that several high-pressure pumps (over 4000 psi pressure head), as well as some high-flow (over 100,000 gpm), low-pressure pumps should definitely be within the present capability of industry.

A meeting was held with T. K. Lau of MFPM of ERDA/FE on March 29 at ORNL. The status of this and several related studies being conducted at ORNL was reviewed.

Expander and turbine lists and questionnaires are now being finalized. This material should be ready for mailing by mid-April.

Industry responses to the questionnaire on pumps will be received during April. Compressor information will be received late in April and during early May as will expander and turbine data. As these responses are received, analysis of the present capability of industry to provide rotating equipment for coal conversion plants will begin. Areas requiring research and development will be identified; these areas include both development of new equipment and investigation of methods for improving pump reliability and performance.

6.3.3 Valves and Other Pressure Let-Down Devices  
(W. A. Bush, E. C. Slade, and J. D. Wisner)

Valve sizes were calculated and process conditions determined including pressure, temperature, and flow mediums from studies of seven different concepts (Hygas, Bigas, Synthoil, Coalcon, Lurgi, Hydrocarbonization, and Fischer-Tropsch).

These values are being summarized and will be used as the parameters for directing "availability questionnaires" to industry and manufacturers.

Lists of manufacturers have been compiled and exploratory letters are being prepared.

6.3.4 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 the major vendors of pollution control devices as identified in the Thomas Register and Chemical Engineering's "Guide to Pollution Control Equipment."
- In concert with the task of identifying applicable control equipment is the need to quantify existing and projected turbine specifications. To this end, a questionnaire has been prepared and sent to a list of major turbine manufacturers requesting such information.
- A follow-up letter has been drafted to be sent to designer-constructors (D-C) and A-E firms who have been derelict in responding to our initial request for information on hot gas cleanup devices. It has been reviewed and will be posted shortly.
- To date, responses received from A-E and D-C firms complying with our initial request for hot gas cleanup information has yielded little additional data, thus indicating that our original appraisal of available equipment and vendors was fairly complete.

- In terms of performance, data on the particulate removal efficiency of the Aerodyne Tornado and the Donaldson Tanjet in high temperature applications has been obtained. Further work on acquiring similar performance data for other cleanup devices is being pursued.
- A new dimension in this study has been added by considering the question of the availability of instrumentation suitable to high temperature--high pressure particulate measurement. Contact has been made with Nancy O'Fallon at Argonne National Laboratory in ascertaining the state-of-the-art of this technology.

A questionnaire was drafted and sent to individuals and organizations specifically requesting information relating to hydrogen sulfide removal at high temperature.

As additional organizations are identified with information in the area of hot gas hydrogen sulfide removal, they will be sent the questionnaire on H<sub>2</sub>S removal. For example, if responses from persons contacted for particulate removal information indicate that data are also available for gaseous impurity removal at high temperature, they will be recontacted via the H<sub>2</sub>S removal letter for such information.

A meeting with the ERDA Project Manager, T. K. Lau, was held in Oak Ridge on March 29.

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

Heat exchanger tabulations were extracted from the draft report on three coal conversion processes - Synthoil, Fischer-Tropsch, and Hydrocarbonization.

Critical units - i.e., those in the most severe service - are being identified. Detailed information concerning their Organic Rankine Cycle (ORC) units for generating power from waste heat was obtained from the Kinetics Corporation (Sarasota, Florida).

W. R. Gambill attended the A.I.Ch.E. meeting and Petrochemical Exposition in Houston, Texas, from March 19-24, also participating in a short course titled "Process Design for Energy Conservation" and attending a panel discussion on heat exchangers and current energy conservation practices. Discussions were held with J. T. Taborek, Technical Director of Heat Transfer Research, Inc. (Alhambra, California), Anthony Docherty, President of Thermex, Inc. (Houston), and Ed Hansen, President of Engineers and Fabricators Company (Houston) regarding topics relevant to this survey. Catalogs describing the products of 27 heat exchanger fabricators have been received and more are forthcoming.

The information obtained during the Houston visit was summarized at a meeting held for T. K. Lau in Oak Ridge on March 29 and will be outlined in further detail in a trip report to be prepared in April.

### 6.3.6 Changes

A request was made that the availability of instrumentation be considered in the hot gas cleanup study.

### 6.3.7 Problem Areas

#### 1. Rotating Components

The mailing of questionnaires to industry is approximately 6 weeks behind schedule; however, compilation of responses, when completed in mid-May, will be only 2 weeks behind schedule.

#### 2. Valves - None.

#### 3. Hot Gas Cleanup Devices

Because of the diversity of service encountered by the wide ranging differences in the quality of gasifier effluent, it may be necessary to "typify" one or perhaps two gasifier effluent streams. This will enable manufacturers, who build cleanup devices on a specialty basis, to comply with our information requests particularly as regards cost data. If, on the other hand, we desire to consider only those vendors who sell packaged or off-the-shelf items, then this restriction is unnecessary. In making this choice, some flexibility is lost. In any event, a decision must be made.

## 6.4 Large Air Separation Plant Study

W. R. Gambill

A summary of the information obtained at ORNL through February was presented at a meeting held for Dr. T. Simpson, ERDA/FE/MFPM, during his visit to Oak Ridge on March 9. No further work was done on this study during March.

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

W. R. Gambill

### 6.5.1 Contract Objective

The objective of this review is to survey, appraise, and catalog the processes for heat recovery which industry offers or plans to offer or may logically be expected to offer. These processes will be applicable to the recovery of heat in process streams from primary exothermic coal conversion and combustion process steps. Simple unaugmented application of conventional heat transfer equipment will not be included. The review

will distinguish between presently installable technology, near term developable technology, and future prospects. Consideration will be given to possible transfer of technology from other industries.

#### 6.5.2 Status Summary

The early work on this review was described at a meeting held in Oak Ridge on March 9. The work statement was tentatively reworded and the time schedule revised slightly. Papers and reports concerning direct contact cooler-condensers, slurry heat transfer, augmented tubular exchangers, and heat pipe arrays were located, ordered, and received.

The information obtained by W. R. Gambill during a 6-day visit to Houston (see Sect. 6.3.5) will be outlined in some detail in a trip report to be issued in April.

### 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

##### 7.1.1 Summary

Activities in March 1977 involved agreement on work reporting plans and preparation for a March 31 status presentation to UCC-ND personnel. Activities forecast for April 1977 include completion of a draft of the one-page summaries in the process survey section and acquisition/review of additional process data.

##### 7.1.2 Work Reporting Plans

Agreement on the approach to reporting was reached with Dr. L. M. Joseph of ERDA/FE/Office of Program Planning and Analysis at a March 1, 1977, meeting in Washington, D.C. A draft of the process survey section will be prepared and distributed at a convenient date, now planned for April 1977. This section will contain one-page summaries of approximately 53 gasifier processes. A final report will be prepared near the end of the contract period which is September 30, 1977. The final report will contain an introduction and summary, process survey, process data, comparisons, conclusions, and recommendations. Certain sections of the final report might be distributed as interim drafts for information and review. The final report (1) is intended to provide information and additional insight on the processes, and (2) could be used by persons wanting data and a basis for additional evaluation. Gasifiers will be included that produce both low (air feed) and intermediate (oxygen feed) Btu coal derived fuel gas.

### 7.1.3 Status Presentation

Information on the status of the low Btu coal gasification study was presented to UCC-ND personnel on March 31, 1977. The study was described and introductory material included on coal conversion, coal gasification, gas uses, and relative costs. Gasifier types were then described; namely, the fixed bed, fluidized, entrained, and molten. The screening procedure was mentioned and consisted of reviewing 88 processes, summarizing 53 of them, and selecting 21 for detailed evaluation. Outlines of the process summary and detailed process data section were discussed; examples of these sections were shown. Gasifier factors of interest were listed; these factors consisted of status, economics, site related, technical, and social. Technical parameters were described in more detail and then compared for the gasifier types. Criteria for rejecting certain processes were discussed. The criteria included items such as low efficiency, low capacity, and major technical problems. The 21 processes selected for detailed evaluation were listed. Future work was mentioned and the presentation was summarized.

### 7.1.4 Other Work

Additional process information was collected in March. Certain of the information was reviewed in preparing for the March 31 status presentation. The one-page summaries for 53 processes were reviewed. Additional work will be done as part of their preparation for the draft report section.

### 7.1.5 Work Forecast

Work planned for April includes completion of approximately 53 one-page summaries and publication in draft form of the process survey section containing the summaries. Process information will be added to that already included in the process data section. Data collection and review will be emphasized for the following gasifier processes:

Fixed bed: Lurgi-dry ash, ERDA-MERC  
Lurgi-slugging, Woodall-Duckham

Fluidized bed: Westinghouse, BCR Tri-Gas  
U Gas, Winkler

Entrained flow: Texaco, Koppers-Totzek  
Combustion Engineering, Foster Wheeler

## 7.2 Direct Combustion

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

United Engineers and Constructors has begun work on the subcontract. The revised work scope is to include the costing of small industrial/commercial size steam and hot water units firing pulverized and stoker coal. Also, they are to arrive at cost estimates for small industrial size fluidized bed units.

Other work accomplished includes the gathering of data concerning the environmental regulations in the key industrial regions, collection of data concerning the availability of coal fired packaged boilers, and the gathering of technical information from the few vendors that offer these systems. Several industrial contacts have been made. Corporate level contact within 3-M Company has revealed that they are very interested in coal fired units for their industrial operations (50-250  $\times 10^3$  lb/hr steam). Also, the Texas Industrial Commission is interested in this area and each seems agreeable to provide input into our user assessment.

## 7.3 Advanced Power Conversion Systems

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

A draft of the fourth topical report, "Summary of R&D Effort on Ceramic Gas Turbines," was issued during the month. The current effort is primarily on the reports for water-cooled gas turbines, fuel cells, open cycle MHD, and combined cycles. Most of the information on MHD systems has been obtained. This includes some foreign results; however, we will probably not be able to get budgetary data on the cost of the foreign work. At least 24 U.S. organizations have received contracts for work on various aspects of MHD. The project goals, costs, and operating times obtained under these contracts have been accumulated.

## 7.4 Liquefaction

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

### 7.4.1 Activity Summary

#### A. Survey Liquefaction Processes

##### 1. Objectives

To review and evaluate the various coal liquefaction processes available in the world. Determine the most promising technologies for further detailed study.

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\* Consultant.

## 2. Activity Summary

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

- HRI's H-Coal
- Pittsburgh Energy Research Center's Synthoil
- Gulf Oil Corporation's Catalytic Coal Liquids (CCL)
- Exxon Donor Solvent (EDS)
- Arthur D. Little's ADL Extractive Coking
- Brookhaven National Laboratory's Rotating Fluidized Bed
- The Oil Shale Corporation's Toscoal
- U.S. Steel's Clean Coke
- The Coalcon Pyrolysis process
- The Consol Synthetic Fuel (CSF) process

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

### B. Establish Uniform Data Format

#### 1. Objectives

To serve as a check list to assure that pertinent data, as available, is obtained on each process, and (2) to provide a uniform method of presenting data in the Source Data Book.

#### 2. Activity Summary

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

### C. Establish Standard Techniques for Process Evaluation

#### 1. Objectives

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

#### 2. Activity Summary

The preliminary ranking factors were completed. These factors will be used in ranking the various processes soon.

### D. Establish Uniform Economic Comparison Basis

#### 1. Objectives

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

## 2. Activity Summary

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

### 7.5 High Btu Gas

This subprogram is being analyzed under subcontract by the Scientific Design Company, Inc. (A. S. West, Project Manager). A report was prepared as the first part of the effort, "Evaluation of Literature Sources for a Bibliography on Production of High Btu Gas from Coal." Evaluation of one of the processes was initiated.

### 7.6 In Situ Coal Gasification

W. C. Ulrich and G. J. MacKenzie

The draft report, "Evaluation of In Situ Coal Gasification Processes on a Regional Basis," was completed on schedule, and copies were submitted to OPPA and others for comment and review. Also submitted were draft copies of "Summary Data Source Sheets for the In Situ Coal Gasification Evaluation Project."

We started assembling information that will be needed to perform the economic analysis of the regional processes selected in the evaluation report mentioned above. This includes, for example, coal analyses, process data (such as raw gas compositions and yields), and reports on drilling costs. Contacts were also initiated with manufacturers and vendors to obtain cost data and operating information on drilling rigs and associated equipment.

G. J. MacKenzie traveled to Laramie Energy Research Center on March 1, 1977, and to Lawrence Livermore Laboratory on March 2, 1977, to discuss field test programs and plans with representatives of these organizations.

### 7.7 Coal Beneficiation

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

#### 7.7.1 Contract Objective

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

### 7.7.2 Status Summary

The following items have been completed:

1. Economic analysis for the mild and deep cleaning modes of the wet beneficiation process and the Battelle Hydrothermal Coal Process (BHCP) for plants producing 1,500 and 15,000 TPD MAF coal using Pennsylvania coal.
2. Process description for the Ledgemont Oxygen Leaching (LOL), the BHCP and the Pittsburgh Energy Research Center (PERC) coal beneficiation processes.

The following items are currently being developed:

1. Process descriptions for the SURC Chemical Comminution and the High Gradient Magnetic Beneficiation processes.
2. The preliminary report on the coal beneficiation study is expected to be ready for delivery to ERDA/OPPA in April.

## 7.8 Gas Cleanup Studies

M. S. Edwards

Low-temperature gas cleanup processes were under evaluation. Correspondence with Eickmeyer and Associates in regard to the Catacarb process of activated hot carbonate is continuing. Several questions delayed the conceptual costing being provided by Eickmeyer and Associates to aid in evaluating the Catacarb process. The latest design questions were answered by letter on March 29 and should allow completion of the costing of an example Catacarb system. Responses have not been received at this time from American Lurgi, Peabody Engineered Systems or Ford, Bacon and Davis, Texas, regarding their respective licensed systems: Rectisol, Stretford, or Takahax. Follow-up letters and/or telephone contacts are planned in April to get information from these vendors.

Letters were sent to all identified organizations involved with high-temperature gas cleanup process development. All available information on such efforts was requested. Responses are expected in April.

The final screening of processes to reduce the number of candidates to below 10 is incomplete, awaiting the remaining responses detailed above. However, there are several processes, based on presently available data, which appear likely candidates. To avoid undue delay while waiting on a final determination of candidate processes, detailed descriptions of these tentative selections were initiated. As these descriptions are completed and final candidate processes selected, the chosen process vendors will be recontacted for their comments on the detailed descriptions. This will hopefully prevent any obvious technical errors from influencing the results of this study.

## 7.9 Coal Prices and Volumes

O. L. Culberson\*

Correlations were completed for the mine-mouth prices of "eastern" and "western" coals as a function of higher heating value, and sulfur and ash contents.

For

MM\$/T = mine-mouth cost, dollars/short ton

H = higher heating value,  $10^3$  Btu/lb

A = percent ash

S = percent sulfur

N = number of data points from which correlation was derived

$R^2$  = multiple correlation coefficient, the percentage of the variation in MM\$/T explained by the model

the correlations are:

Eastern Coals (east of Mississippi River)

$$\text{MM}\$/\text{T} = -9.919 + 2.206\text{H} - 0.248\text{A} - 0.454\text{S}^2$$

$$\text{N} = 139$$

$$\text{R}^2 = 43.5$$

Western Coals (west of Mississippi River)

$$\text{MM}\$/\text{T} = -2.822 + 1.912\text{H} - 0.334\text{A} - 0.066\text{S}^2$$

$$\text{N} = 75$$

$$\text{R}^2 = 47.9$$

The data points used were June 1976 contract purchases for steam coal reported in the August 30 and September 6, 13, and 20, 1976, issues of Coal Week (McGraw-Hill).

## 7.10 Energy Transportation Costs

O. L. Culberson\*

No progress was made on this project because the limited manpower was concentrated on the project for coal volumes and prices.

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\* Consultant, University of Tennessee.

## 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).

### 7.11.1 Task Status

#### Task 1. Survey of Primary Feedstocks for Chemical Production

Completed.

#### Task 2. Identifications of the Impediments to the Utilization of Chemical Feedstocks from Coal and Oil Shale

The preliminary results for Task 2 have been reported in the Mid-Project Report, which includes technical results through the month of March.

#### Task 3. ERDA Program Considerations

A low-level information gathering effort concerning present ERDA programs has begun. By completing a small part of Task 3 ahead of schedule, Task 2 can be extended slightly, with a minimum of disruption. This will allow completion of any additional Task 2 work that was identified as necessary from the Mid-Project Report.

## 8. FOSSIL ENERGY ENVIRONMENTAL PROJECT

C. R. Boston

8.1 Landfill Storage of Coal Conversion  
Solid Wastes/Information Assessment

H. M. Braunstein

Technical editing of the first draft of the information assessment was completed and copies were delivered on March 14, 1977. The document was also distributed for in-house review with comments due April 15, 1977. Initial comments from ERDA have been quite favorable.

## 8.2 Environmental Monitoring Handbook

M. S. Salk

Work continued on the preparation of Part I, Baseline Monitoring. A slip in schedule of one week from April 15 to April 22, 1977, is now expected for review and finalization of this part of the Handbook. Outlines were prepared for the socioeconomic and aquatic sections of Parts II and III of the Handbook.

## 8.3 Programmatic Assessment/Pipeline Gas

L. H. Stinton

Work continued on the Pipeline Gas Programmatic Assessment through the month of March. A detailed working outline was assembled and sites have been identified on a township level. Process descriptions, effluent identification, and site descriptions are about 50% complete and should be completed by April 8. It now appears that document preparation will not be complete until May 6, 1977, and completion of the draft document will be postponed for 2 weeks allowing delivery on June 1, 1977.

## 9. COAL-FUELED MIUS

R. S. Holcomb and W. R. Nixon

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

### 9.1 Coal Metering and Feed Systems

Following completion of the 1000-hr endurance run, pressure drop and air leakage across feed components were measured and the air leakage across the rotary feeder had increased from 0.75 to 1 cfm.

The system was then disassembled for inspection. No wear was visible on the coal feed nozzles or on the rotating parts or housings of the feed components. The only fault found was in a rear shaft seal of the screw feeder that had been installed for the endurance test. About 4 lb of fine coal dust had leaked through this seal and accumulated within the motor and drive shaft housing. The screw feeder was included to provide a perfectly uniform flow at low feed rates, but endurance test results indicate that the system would be more trouble-free if this feeder is not used.

### 9.2 Supplemental Studies

Metallographic examination of samples cut from the corrosion specimen tubes has been nearly completed. Preliminary findings indicate no evidence of erosion. A surface deposit or scale composed of about 60%  $\text{CaSO}_4$  was present on all tube materials, but the scale was about twice as thick on the Inconel 600 tube. Preliminary measurements show no reduction of wall thickness, but this will be checked further by more exact techniques. The samples with Alonized coatings show separation of the Alonized layer from the base material; thus, Alonizing does not look very promising. The Incoloy 800 specimen shows intergranular corrosion attack for a depth of about 0.0012 in. Further analysis will be done to determine if this is sulfidation or oxidation attack. No intergranular corrosion was observed in 304 and 310 stainless steels and Inconel 600.

The results of the 500-hr exposure are encouraging and warrant continued exposure of the 12 remaining tubes for an additional 500 hr to observe the trend in corrosion rate. Negotiations have been initiated for FluidDyne to run the second corrosion test.

A second heat transfer tube is being prepared at ORNL with tube wall thermocouples installed flush with the outside surface of the tube. A series of 16 data points will be obtained to check the results of the first heat transfer test. The heat transfer tests will be run prior to the second corrosion test under the same subcontract.

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