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**Fossil Energy Program
Progress Report for November 1979**

L. E. McNeese

**OPERATED BY
UNION CARBIDE CORPORATION
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*Fossil
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**FOSSIL ENERGY PROGRAM
PROGRESS REPORT FOR NOVEMBER 1979**

**L. E. McNeese
Program Director**

Date Published - January 1980

**OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY**

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FOSSIL ENERGY PROGRAM REPORT FOR NOVEMBER 1979

ABSTRACT

This report - the sixty-fourth of a series - is a compendium of monthly progress reports for the ORNL research and development programs that are in support of the increased utilization of coal and other fossil fuel alternatives to oil and gas as sources of clean energy. The projects reported this month include those for coal conversion development, materials engineering, a coal equipment test program, an atmospheric fluid bed combustor for cogeneration, engineering studies and technical support, process and program analysis, environmental assessment studies, magnetic beneficiation of dry pulverized coal, technical support to the TVA fluid bed combustion program, coal cogeneration/district heating plant assessment, chemical research and development, and technical support to major liquefaction projects.

1. Summary

L. E. McNeese

Highlights of our progress in November are as follows:

Coal Conversion Development - Density measurements were made on 35 wt % Illinois No. 6 coal/Wilsonville recycle solvent slurry and on recycle solvent alone using the gamma radiation absorption density instrument on the CLFS preheater discharge stream. Structural studies of soluble products from coal-phenol reactions continued.

Chemical Research and Development - Based on additional results concerning the thermolysis of 1-naphthol, we have proposed a tentative mechanism as a focus for further investigation. Rather than proceeding through free radicals, the reaction may involve a molecular ene reaction followed by dehydration and hydrogen transfer to form dinaphtho[1,2-b;-2',1'-d]furan. Hydrogen transfer to 1-naphthol would then generate the second major initial product, 1-tetralone. Remodeling and shakedown of laboratory facilities for study of Fischer-Tropsch catalysts has proceeded on schedule. Initial analytical results from a simulated coal liquefaction run with added 1-¹⁴C-tetralin in the Coal Liquids Flow System show a small but real incorporation of tetralin fragments into the polar liquefaction products.

Materials Engineering - The study of the effect of coal conversion environments on the mechanical properties of pressure vessel steel was continued. Specimens from the 17-d autoclave run at 10.3 MPa (1500 psi) and 490°C all showed some decarburization but the exposure time was too short to cause a detectable volume increase in all but one of the specimens. In the task to develop weld overlay cladding techniques with type 320 Cb stainless steel, Sandvik, Inc., is preparing strip clad weld samples and nearly all will be completed by the end of the calendar year. The type 320 Cb alloy has been melted and is being made into strip electrode. Efforts in the study of fireside corrosion of AFBC heat exchanger materials included repolishing the complete set of samples from the 4500-h Fluidyne AFBC exposure, metallographic examination of these specimens and measurements of scale thickness, corrosion penetration, depth of any sulfide inclusion, and tube-wall metals thickness. In the failure prevention and analysis task, metallographic, chemical, electron microprobe, and X-ray studies were made of the 316 SS wall and a Hastelloy G tray from the wash solvent column of the Ft. Lewis SRC plant. The scale composition was determined and a mechanism for the corrosion process was proposed. Corrosion studies in the quartz test loop for the ZnCl_2 liquefaction process continued with a successful run of 20 h exposure of 18 coupons. U-bend stress-corrosion cracking specimens that were exposed in the Ft. Lewis dissolver and separator vessels are being cleaned for examination. In the task for development of advanced 9 Cr-1 Mo steel, impact and creep tests have been run on specimens from a 4 in. x 4 in. test ingot. Data to date indicate that the creep strength of the plate exceeds the ASME code case minimum values for type 304 SS. Combustion Engineering, Inc., is preparing the 9 Cr-1 Mo tubes for insertion in TVA boilers. In the ceramic recuperator task, ceramic tubes from the first Ceramic Recuperator Analysis Facility test were visually inspected. The AD 998 alumina tube appeared to perform best. A high-pressure SiC heat exchanger was tested for 48 h in a coal-oil-mixture-fired forge furnace at 1095°C and 0.52 MPa. A detailed failure analysis report for this test is being prepared. Management responsibility for a portion of the AR&TD Fossil Energy Materials Program was transferred from DOE-HQ to ORO/ORNL and some funding was placed in the ORNL financial plan. The management plan was reviewed and approved, the program plan was completed and reviewed, and the materials needs assessment was completed except for the executive summary.

Component and Process Evaluation Studies - The final report for the Survey of Industrial Capability for Coal Handling (ORNL/TM-6929) has been completed in draft form and is awaiting approval by DOE. Working drawings for piping and instrumentation are under preparation for a bench scale system to investigate pressure letdown of slurry product from coal liquefaction plant dissolvers. The H-Coal Materials and Technology Task Force has completed a preliminary assessment of critical areas in the H-Coal Pilot Plant. A review of this assessment with Ashland Synthetic Fuels, Inc., is planned for December. A project in support of the Economic Regulatory Administration is in progress. Task descriptions are being

developed concerning conversion of two Consolidated Edison power plants from oil to coal in accordance with the Fuel Use Act. In the Performance Assurance Study, a generic Failure Modes and Effects Analysis is being developed for slurry preheaters in coal liquefaction plants.

Process and Program Analysis - The Liquefaction Technology Assessment (LTAS) project is nearing completion of its initial milestone, an interim report of the processing costs for indirect synthesis of (1) turbine-grade methanol, (2) methanol for gasoline blending, and (3) gasoline (using the Mobil MTG process). Conceptual process plant designs, capital and operating cost estimates, and other support information prepared by Fluor Engineers and Constructors will be used in the development of the detailed economics early in December.

Fossil Energy Environmental Project - In the Stored Solids Study, attempts are underway to obtain representative soil samples from the ash storage area at the proposed SRC-II site. Results from lysimeter measurements are being analyzed.

Work is underway on EIS preparation for all six demonstration projects. Preliminary draft EISs for MLGW, Grace, and ICGG should be ready for DOE internal review in early January.

Coal Preparation and Waste Utilization - Shakedown testing of the one ton per hour continuous separation system has begun at Sala Magnetics. The analytical modeling of magnetic fields may have revealed what we believe to be a unique and very practical configuration for an open-gradient separation magnet.

Atmospheric Fluidized Bed Coal Combustor for Cogeneration (AFBCCC) - The program subcontract was sent to Westinghouse on November 8. They signed it and returned it to the Purchasing Division on November 28. It will be sent to DOE/ORO by December 5 for their review and approval.

Tennessee Valley Authority (TVA) Fluidized Bed Combustion (FBC) Demonstration Plant Program Technical Support - At the end of last month, the 4 x 4 cold flow bed was filled with limestone that has a particle size of approximately 1000 μm . This material was added to the bed to determine the effects of particle size upon the slumping characteristics. The system was shaken down after the limestone addition and the fluidizing characteristic of the stone was determined. The minimum fluidizing velocity was found to be 0.49 m/s (1.6 ft/sec).

Preparation of the annual report for the AFBC modeling and simulation task was initiated. Rough drafts describing the bubble growth subcode, the elutriation-attrition subcode, and the system code have been prepared.

In the AFBC bench scale facility, testing of the Three Rivers limestone was continued and almost 30 hours of burning with Kentucky number nine coal was completed during the month. The limestone was successfully calcined and sulfated and preliminary sulfur capture data has been obtained for a fluidizing velocity of 1.2 m/sec (4 ft/sec) and a bed temperature of 830°C (1525°F). A cursory examination of raw data taken at these conditions indicates that the Three Rivers limestone achieves 85% sulfur capture at a calcium-to-sulfur mole ratio near 3 to 1 and 90% at a ratio near 4 to 1.

The initial results for the analytical support and alternative design concepts evaluation indicate that the costs are not a strong function of design superficial velocity, but are more dependent on the static bed depth chosen. From these preliminary results, it appears that expanded bed depths as deep as 4.6 to 5.5 m could be justified.

In the AFBC Technical source book and R&D evaluation, an effort has been made to lay down the basis for design parameters concerned with combustion efficiency. This month the effort has been restricted to summarizing the kinetics related to the combustion process.

In the Dynamic Modeling task, SO₂ control was added to the system. Proportional plus integral action operates on the flue gas SO₂ error signal and the calcium-to-sulfur ratio is varied to null the set point error. The large heat capacity of the bed limestone may significantly affect the controllability of the plant. The tendency of this heat capacity, combined with the relatively weak heat transfer coefficients between the bed and the pressure parts, is to introduce a resistance-capacitance time delay between steam pressure error and coal feed.

Construction of the basic coal feed test facility has been completed, including two long radius bend pipe sections (K/D = 12) and a 100 mm x 100 mm rotary feeder. The first test configuration has been installed, and this will be used for test series 1 and 2. General system shakedown testing has been completed. Testing with nominal 2% moisture is nearing completion. No plugging has occurred in the conveying line, but there have been some problems with feeding 2% moisture coal due to the small feed line.

Coal Cogeneration/District Heating Plant Assessment - The coal/cogeneration power plant study with NSP and UE&C produced a major result on the steam turbine cycle. UE&C presented an economic comparison which showed that the cogeneration unit should have full condensing capability due to the fact that NSP is a summer peaking electric utility. Refinements to the design and operating modes of the closed-cycle gas turbine cogeneration plant have been made.

Technical support to major liquefaction projects - Efforts have continued in November to define and scope the technical support to be provided by ORNL and UCC-ND Engineering in FY 1980 for the major liquefaction projects. Design review activities have been confined to monitoring of the contractor's technical status meetings. The Direct Liquefaction R&D Review Project has been successfully completed ahead of schedule, and a draft report has been widely distributed. Work has continued on the preliminary draft environmental impact statements for SRC-I and SRC-II, but progress has been constrained by inadequate starting materials. The H-Coal materials and technology review has been given major emphasis in November. A preliminary assessment report has been prepared with limited distribution for review. Performance assurance support has continued in the areas of reliability, safety, and quality assurance.

2. COAL CONVERSION DEVELOPMENT

J. R. Hightower, Jr.

Coal conversion development activities are carried out in the Chemical Technology Division. This section discusses two projects conducted for the Division of Fossil Fuel Processing -- Physical Properties of Coal Liquids and New Liquefaction Techniques.

2.1 Physical Properties of Coal Liquids

G. E. Oswald, E. L. Youngblood, M. R. Gibson,
L. S. Dickerson, and R. L. Andrews

The objective of this project is to measure and correlate physical properties (viscosity, density, thermal conductivity, and heat capacity) of various coal-solvent slurries and solids-free, coal-derived liquids at typical processing conditions, up to 31 MPa (4500 psig) hydrogen pressure and 810 K (1000°F) in a bench-scale, continuous flow system. This system includes a slurry preheater and a hydrogenation reactor to simulate processing conditions prior to physical property measurement. Immediately after physical property measurement, the test fluids will be quenched and sampled for chemical characterization. Physical properties will be correlated ultimately with chemical characteristics of the test liquid to provide information useful to designers.

The initial results of density measurements for Wilsonville recycle solvent and 35 wt % Illinois No. 6 coal/Wilsonville recycle solvent are presented in this section.

2.1.1 Work accomplished

Density measurements were made on 35 wt % Illinois No. 6 coal/Wilsonville recycle solvent slurry and on recycle solvent alone using the gamma radiation absorption density instrument on the CLFS preheater discharge stream. Slurry exhibits an unusual decrease in density between 560 and 650 K (550 and 711°F). This temperature span corresponds to the gelation region observed during earlier pipeline viscometer measurements.¹

For measurement, the test liquid was heated to temperature in the preheater and passed directly through the density instruments pressure vessel. The vessel was maintained at temperature by electrical resistance surface heaters. An internal thermocouple monitored the actual test liquid temperature in the density measurement chamber. System pressure was 13.9 MPa (2000 psig). Measurements were made from room temperature to ~700 K (800°F); preheater discharge temperature and measurement vessel temperature were increased in unison. Results are

presented in Figure 2.1. As temperature is increased, slurry density exhibits an essentially linear decrease, similar to that observed for solvent, up to ~560 K (550°F). As temperature is increased beyond 560 K, slurry density drops sharply, departing substantially from the trend established by the measurements at lower temperatures. The sharp drop in density is probably the result of coal swelling during the depolymerization process. Maximum deviation from the lower temperature trend, 0.04 specific gravity units, was at ~650 K (710°F). As temperature is increased beyond 650 K, density increases joining the low temperature trend line at 680 K (765°F). This increase most likely results from a decrease in depolymerization activity as coal conversion proceeds. All measurements were made at a constant liquid feed rate of 2.5 kg/hr. Preheater residence time was 1.8 minutes; residence time in the density instrument vessel was 3.7 minutes. These data are the first density measurements with this system and replicate measurements will be necessary to confirm this behavior.

2.1.2 Future work

Replicate density measurements will be made on coal/solvent slurry.

2.2 New Liquefaction Techniques

J. W. Larsen,* T. L. Sams, R. K. Hessley,* and B. R. Rodgers

Oxidative degradation of the pyridine soluble product from the reaction of Wyodak coal in phenol has been completed and work has begun on the residue. Structural studies of the soluble material using ^1H and ^{13}C nmr have also been initiated.

Studies of both Wyodak coal and Bruceton coal at temperatures below 482°C have been completed and preparation of a paper describing this work is in progress. Studies using a partially oxidized coal are underway as are studies using solvents other than phenol.

2.3 References

1. L. E. McNeese (ed.), Fossil Energy Program Progress Report for May 1979, ORNL/TM-6928, Oak Ridge National Laboratory, Oak Ridge, Tennessee (July 1979).

*Chemistry Division

Fig. 2.1. Liquid density vs temperature.

3. CHEMICAL RESEARCH AND DEVELOPMENT

M. L. Poutsma

3.1 Chemistry and Structure of Coal

M. L. Poutsma and C. L. Wolf

Studies of the thermolysis of 1-naphthol in sealed tubes at 400°C have continued, both to identify products and to determine their variation with reaction time and pressure. Because of a continuing quantitative glpc problem (now hopefully cured), our results still lack the precision desired. However, general trends are now apparent. The initial products are dinaphtho[1,2-b; 2',1'-d]furan (1) and 1-tetralone (2) (and presumably water). Whereas condensation product 1 continues to increase with increasing conversion of 1-naphthol, reduction product 2 appears to go through a maximum and to be gradually replaced by naphthalene (3). Especially in liquid-phase runs, two additional significant products are tetralin (4) and a material $C_{20}H_{14}O$ which, by mass spectroscopy, may be a naphthyl-naphthol. Hence the product composition is clearly complex and strongly dependent on reaction conditions.

A sampling of results as a function of reaction time, 1-naphthol pressure, and tube material are shown in Table 3.1. We stress that these are preliminary and subject to further analytical improvement. Entries 1-4 (1 atm pressure in untreated Pyrex tubes), entries 5-7 (1 atm pressure in chromic acid-washed Pyrex tubes), and entries 15 and 16 (50-60% liquid in washed Pyrex tubes) show the effects of increasing reaction time. Conversion increases somewhat smoothly but product distributions vary in as yet not understood fashion. Entries 5 and 10-15 constitute a pressure variation study at constant time in the washed Pyrex tubes. Although there appears to be a general trend of increasing conversion level with increasing pressure, the trend is not smooth. Entries 2, 6, 8, 9 represent an attempt to evaluate the effect of tubing material. Some indication of acceleration in the metal tube might be indicated, but this is not confirmed by entries 16 and 17.

Clearly there are presently uncontrolled factors which lead to lack of precise reproducibility in this reaction, and we are actively pursuing their definition. However, we will present a possible mechanism only as a working hypothesis. Remembering that formation of specific isomer 1 occurs without formation of 1,1'-binaphthalene-4,4'-diol, the major expected free-radical coupling product, we propose a molecular rather than free-radical pathway: an ene reaction with 1-naphthol serving as both the ene and the enophile. Intramolecular hemiketal formation in initial intermediate 5 would give 6, a hydrated, dihydroform of product 1. Facile loss of water would not be surprising. Loss of "hydrogen" occurs by transfer to 1-naphthol, probably in several steps, to generate 1-tetralone (2). If 5 enolizes before cyclization, a route to naphthyl-naphthol becomes possible.

Table 3.1

Thermolysis of 1-Naphthol-Preliminary Results at 400°C

Entry	Tube Material	P(atm)	t(hr)	Conv.(%)	Molar Ratio		
					<u>3</u>	:	<u>2</u> : <u>1</u>
1	Pyrex-unwashed	1	3	0.4	0.04	:	0.57 : 0.39
2	Pyrex-unwashed	1	8	1.4	0.02	:	0.26 : 0.72
3	Pyrex-unwashed	1	16	1.7	0.06	:	0.38 : 0.56
4	Pyrex-unwashed	1	40	6.2	0.08	:	0.03 : 0.89
5	Pyrex-washed	0.85	0.5	0.1	0.07	:	0.31 : 0.62
6	Pyrex-washed	1	8	2.2	0.03	:	0.41 : 0.55
7	Pyrex-washed	1.05	17.3	4.1	nd	:	0.11 : 0.89
8	Quartz	1	8	1.4	0.04	:	0.39 : 0.57
9	Stainless Steel	1	8	9.8	0.02	:	0.12 : 0.86 ^a
10	Pyrex washed	0.24	0.5	0.3	nd	:	nd : major
11	Pyrex washed	2.84	0.5	0.2	0.04	:	0.32 : 0.64 ^b
12	Pyrex-washed	7.75	0.5	2.4	0.03	:	0.35 : 0.59 ^c
13	Pyrex-washed	14% liq.	0.5	0.2	0.02	:	0.47 : 0.54 ^b
14	Pyrex-washed	50% liq.	0.5	12.5	0.03	:	0.25 : 0.66 ^{b,d}
15	Pyrex-washed	67% liq.	0.5	10.1	0.02	:	0.33 : 0.61 ^e
16	Pyrex-washed	56% liq.	17.3	65	0.23	:	nd : 0.77 ^f
17	Stainless Steel	93% liq.	25.7	70-90	0.30	:	nd : 0.70

^aAn additional product appeared with retention time between 3 and 2.^bAn additional product appeared with retention time just before 1.^cAlso 0.04 4. ^dAlso 0.06 4. ^eAlso 0.03 4. ^fAlso includes a little 4.

3.2 Indirect Liquefaction Chemical Research

R. A. Strehlow and E. C. Douglas

A pulsed microreactor system with a dedicated mass spectrometer is being modified for use in the study of Fischer-Tropsch and closely related catalysts. The objective of the present activity is to determine the range of control of product distribution which may be available for the reaction. During the month a cold trap was installed, the mass spectrometer was tested, and an initial preparation of catalyst (ferric hydroxide on kieselguhr) was made. The immediate goal will be to assess the amount of information which the system can generate and to design the detailed experiments to be performed later.

3.3 In-Process Tracer Studies of Liquefaction*

M. L. Poutsma and T. L. Sams**

A simulated SRC-I coal liquefaction run was carried out by the Chemical Technology Division personnel in the Coal Liquids Flow System in which a 33% slurry of Illinois #6 coal in Wilsonville recycle solvent was doped with 1.2 wt % (based on solvent) 1-¹⁴C-tetralin (850 μ Ci/g). Product analysis is now in progress. A center cut of product slurry (collected from the high pressure vapor-liquid separator) was solvent fractionated into oils, asphaltenes, and preasphaltenes-plus-residue; 0.8% of the total label present in the total slurry was found in the asphaltenes and 0.4% in the preasphaltenes-plus-resins. Hence a small but real portion of tetralin fragments has become bound to the polar liquefaction products.

*Supported by the ORNL Exploratory Studies Program.

**Chemical Technology Division.

4. MATERIALS ENGINEERING

R. A. Bradley

The materials engineering and associated technology reported here are in support of activities directed or coordinated by the Materials Section, Office of Planning and Technology Assessment, Fossil Energy. Other related work funded by the Office of Fossil Fuel Utilization and the Office of Fossil Fuel Processing is also included.

4.1 Pressure Vessel and Piping Materials

W. J. Stelzman, R. O. Williams, and D. A. Canonico

The program is concerned with the influence of an operating environment on the in-service reliability and safety of large pressure vessels for use in second-generation coal conversion systems. The candidate steels from which these vessels will be constructed are subject to an environmentally induced embrittlement at the currently projected operating condition of these units. Of prime concern is the effect of the coal conversion environment, in particular hydrogen, on both low and high-temperature properties of these steels.

We have completed a 17-d autoclave run in which 12 specimens of SA 335, grade P11 low-alloy steel pipe were exposed to hydrogen at 10.3 MPa (1500 psi) and 490°C. The specimens had received different process heat treatments. No hydrogen leakage was detected during the run and the problem with the strain gage lead wire breakage appears to have been solved; however, loss of signal from some of the strain gages, apparently caused by shorting of the lead wires at the strain gage, caused an early termination of the run. Some degree of decarburization was found in each specimen but the exposure time was too short to cause a detectable volume increase in all but one of the specimens. The volume increase of this specimen will be determined in a metallographic examination.

Additional specimens are being assembled in the test facility and should be ready for the next run soon.

4.2 Fossil Energy Welding and Cladding Development

J. F. King and G. M. Goodwin

Sandvik, Inc., has reported that our strip clad weld deposits are being made and nearly all will be completed by the end of this calendar year. They will be shipped around the first of next year. The type 320 Cb alloy has been melted and is currently being made into strip electrode. This material will require longer to develop cladding procedures and will be the last we receive.

4.3 Fireside Corrosion of AFBC Heat Exchanger Materials

T. G. Godfrey and J. H. DeVan

The complete set of samples from the 4500-h test in the FluidDyne 18-in. AFBC was repolished for metallographic examination. This was necessary since some of the specimens, originally prepared in late 1976, had degraded with time, and we felt that it was necessary to make a thorough and consistent examination of the entire specimen array under uniform conditions.

Metallographic examination of these specimens has been essentially completed, and measurements of scale thickness, corrosion penetration, depth of sulfide inclusions (if present), and tube-wall metal thickness have been made. What remains is the correlation of all these results with pre-test measurements and experimental conditions throughout the time segments of the test. This work is now in progress.

4.4 Failure Prevention and Analysis

R. W. Swindeman

4.4.1 Examination of Materials from Fractionation Area of SRC Plants (J. R. Keiser and V. B. Baylor)

The most serious corrosion problem observed in the SRC pilot plants occurs in the fractionation area. A concentrated, interdisciplinary effort is being made at ORNL to determine the cause of this corrosion problem.

A metallographic, chemical, electron microprobe, and X-ray study has been made on a section of the 316 SS wall and a Hastelloy G tray from the wash solvent column at the Ft. Lewis SRC plant. The metallographic analysis of the wall shows that the scale formed appears to be identical to that formed on the 316 SS trays of the Wilsonville fractionation column. (Scale from the fractionation column tray was examined previously.) Chemical analysis studies show the scale from 316 SS exposed in either of these vessels contains 25-28 wt % Ni, 28-32% S, 8-12% Cr, 4-6% Mo, and 4-5% Fe. Electron microprobe studies of the scale indicate only Ni and S on the outer surface with increasing amounts of chromium with increasing depth into the scale. X-ray analysis detects two phases; both of the M_3S_4 type where M is Ni, Fe, Cr and Mo.

Analysis of the Hastelloy G tray shows the scale contains 45 wt % Ni, 34% S and 7% Mo with negligible amounts of Fe and Cr. X-ray analysis indicates the presence of NiS along with a minor phase which probably contains Mo.

As a result of these examinations, we feel the corrosion in the Ft. Lewis wash solvent column is essentially the same as that in the Wilsonville fractionation column and likely occurs through formation of a sulfide scale and removal of all the iron (and perhaps some of the chromium) in some soluble form. Future efforts will be devoted to proving or disproving this hypothesis.

Samples of the liquid from the 1st, 9th and 15th trays of the Wilsonville fractionation column have been received and submitted for chemical analysis.

On November 29, a meeting was held at ORNL to discuss the fractionation area corrosion problem. The meeting had 32 attendees including representatives from Ft. Lewis, Wilsonville, five oil companies and several other organizations. Another meeting will be held in 3-6 months.

4.5 Materials for Zinc Chloride Liquefaction Process

V. B. Baylor and J. R. Keiser

This task is intended to permit evaluation of materials proposed for use in the regeneration and condenser vessels of the Zinc Chloride Liquefaction Process. Corrosion coupons are being exposed in a quartz test loop to an environment similar to that of the regeneration and condenser vessels. The first successful run consisted of a 20 h exposure of 18 coupons. The temperature range over which the coupons were exposed was 855 to 969°C and the environment consisted of HCl, dry air, and ZnCl₂ vapor. Weight loss measurements indicate Inconel 617 had the lowest corrosion rate while Haynes 25 and Haynes 188 were among the worst. A relatively non-adherent scale was formed on most specimens, and this scale, which was removed before weighing, is being analyzed.

Because one of the specimen holding racks broke during insertion into the quartz loop, not as much data were obtained during this run as we normally expect to obtain. Furthermore, the broken rack damaged the loop to the extent that it may have to be replaced.

4.6 Materials to Resist Stress-Corrosion Cracking in Coal Liquefaction Pilot Plants

J. R. Keiser and V. B. Baylor

U-bend specimens which have been exposed in the Ft. Lewis dissolver and separator vessels are being cleaned in preparation for dye penetrant and metallographic examination. Several of the specimens were severely attacked; two Inconel 600 specimens disappeared and two unidentified specimens were cracked completely apart.

New racks of U-bend specimens are being assembled for shipment to Ft. Lewis for an anticipated December shutdown.

Assembly of our laboratory facility is complete except for installation and check-out of a data logger which besides data collection will be used to perform some alarm functions. Availability of this instrument and approval of the High Pressure Experiment Review Committee will be necessary before high pressure hydrogen experiments can be started.

4.7 Development of Advanced 9 Cr-1 Mo Structural Steel

V. K. Sikka

Large heat fabrication, mechanical property characterization, weldability, and steam-corrosion studies continued during the last month. Several accomplishments made during the last month are as follows:

1. Quotations for the fabrication of ingots from the two 15-ton heats were received. Details of placing the order for this job are still being worked out. We expect to place the order by the end of December.
2. The plate from the 4 in. x 4 in. test ingot from the argon-oxygen-decarburization (AOD) of heat No. 1 of the two 15 ton heats was machined into impact and creep specimens. The impact tests have been completed in both the transverse and longitudinal direction of this plate. The 50 ft-lb transition temperature for this plate was +4°C in the transverse direction and -37°C in the rolling direction. This anisotropy was expected because the plate was not subjected to cross-rolling.
3. Six creep rupture tests have failed thus far on this plate. Four of these tests were at 649°C and one each at 538 and 539°C, respectively. Data are showing that this plate has creep strength which exceeds the ASME code case minimum values for type 304 at all three test temperatures. Furthermore, the reduction of area values for tests ruptured thus far exceed 73%. Several additional creep tests are continuing on specimens from this plate.
4. Creep testing also continued on several experimental heats with intentional variations in Si and N.
5. A meeting was held at TVA Chattanooga to discuss more details of inserting the modified 9 Cr-1 Mo tubes in their boilers. At this meeting, TVA agreed to insert 8 tubes of ~8' length each in their Kingston plant. The tube size is 2 in. OD x 0.321 in. wall. Tubes will contain bends and welds. These tubes will be made from experimental heats. The composition of the two 15 ton heats will be duplicated for these tubes. The tubes have to be delivered to TVA by the second week of January. To meet this tight schedule, this work has been subcontracted to Combustion Engineering. They have assured us and TVA that they can meet the TVA schedule.

TVA has also indicated that we will have the opportunity to replace some of the tubes made from experimental heats by tubes made from the 15-ton heats at subsequent shutdowns, which will occur at 18-month intervals from March 1980.

4.8 Ceramic Recuperators (Heat Exchangers)

V. J. Tennery, G. C. Wei, and G. W. Brassell

The CRAF test No. 1 was successfully completed on October 31. After the CRAF and RTF were cooled down to ambient temperature, the 14 ceramic tubes were disassembled from the test chamber and were subjected to visual inspection. The results of visual inspection of all the ceramic tubes indicated that AD 998 alumina tube had the best performance. Mullite, Corderite, and Zirmul tubes had longitudinal and circumferential cracks while KT SiC, NC430 SiC, Refel SiC, Sintered α -SiC, CVD SiC, CVD SiC on SiC, Carbofrax A SiC, Carbofrax M SiC, Refrax 20 SiC had bumps or blisters on the OD of the leading side of the tubes. Post-test analysis including metallography, chemical, microstructure, and structural analyses, and permeability, thermal expansion coefficient, and mechanical strength measurements of the tubes will be performed as soon as photographing of the post-test tubes is completed.

A high-pressure SiC heat exchanger (HX) module designed, and fabricated by Hague International was tested for 48 h in a coal-oil-mixture (COM) fired forge furnace at 1095°C (2000°F) and 0.52 MPa (60 psig). The test which was initially intended to run for a 200-h time period was terminated after 48 h due to excessive air leakage at the SiC HX tube/header joint. Disassembly and inspection of the HX module revealed that one SiC (sintered α) insertable seal had failed catastrophically and two others were slightly cracked. Preliminary results of fracture analysis conducted on the system indicate that a faulty air driven bellows system did not properly allow for expansion of the SiC tubes, thus resulting in extremely high stress levels at the joint. A detailed failure analysis report is presently being prepared. Three of the SiC tubes from this test will be sent to ORNL within the next three weeks. Final report preparation is underway at Hague International.

4.9 AR&TD Fossil Energy Materials Program Management

R. A. Bradley

The transfer of management responsibility of part of the AR&TD Fossil Energy Materials Program from DOE-HQ to ORNL was accomplished and the management plan for the ORO/ORNL-managed portion of the program was approved by DOE. Some funds for this program were placed in the ORNL Financial Plan. Subcontracts (interagency agreements, memorandum purchase orders, and subcontracts) are now being placed.

The AR&TD Fossil Energy Materials Program Plan was reviewed by DOE, and DOE comments have been incorporated. The plan is to be issued as an ORNL/TM.

The Fossil Energy Materials Needs Assessment was completed except for the executive summary.

5. COMPONENT AND PROCESS EVALUATION STUDIES

J. M. Holmes

Component and Process Evaluation Studies in progress in the Engineering Technology Division Fossil Energy Program include the following.

- Survey of Industrial Capability for Coal Handling Equipment
- Slurry Pressure Letdown Studies
- Support for the H-Coal Project
- Engineering for the Economic Regulatory Administration Project
- Fossil Energy Performance Assurance Support

5.1 Coal Handling/Preparation and Ash/Slag Removal Equipment Survey

D. A. Dyslin, F. C. Zapp, O. W. Thomas
M. D. Silverman, and J. M. Holmes

The final report has been completed in draft form and is awaiting approval by DOE. It is entitled "Survey and Conceptual Flow Sheets for Coal Conversion Plant Handling - Preparation and Ash/Slag Removal Operations," ORNL/TM-6929. The report covers the preparation of conceptual flow sheets, including major equipment lists, and a survey of equipment availability for future coal conversion plant handling-preparation and ash/slag removal operations.

5.2 Slurry Pressure Letdown Studies

P. K. Carlson and J. M. Holmes

Work on the Slurry Pressure Letdown System is proceeding. ORNL Engineering is preparing working drawings of the test loop and device, which can then be used by fabrication personnel. Instrumentation needs are being handled by Instrumentation and Controls Division (I&C) with slurry metering and layout of the gas injection and metering system as prime concerns. A number of high pressure fittings, which would have had to be ordered, were located within the ORNL system and so some savings in time and cost may be realized as a result. A safety review of the system is planned during December.

5.3 Support for the H-Coal Project

L. F. Parsly and P. K. Carlson

The H-Coal Materials and Technology Task Force completed a preliminary assessment of the DOE-Ashland Synthetic Fuels, Inc. project during the month. According to the charter of the task force, this assessment was based on a review of H-Coal flow and engineering diagrams, operations manuals, related pilot plant quarterlies, and information obtained from visits to HRI-Trenton, C. E. Lummus, SRC-Ft. Lewis, and SRC-Wilsonville. The report includes recommendations and conclusions on the design of the soon-to-be-completed pilot plant covering the areas of materials of construction, engineering, equipment reliability, and incident reporting.

ETD is concerned with the component reliability aspects of the assessment. Overall, the equipment choices for the plant appear to be based on sound judgment and the latest related experience. However, certain critical areas were examined in detail to examine potential operating and safety problems. These areas included:

- Slurry Letdown valves
- Centrifugal slurry pumps
- Ebullating bed reactor pump
- Lummus de-ashing system
- Slurry mixing
- Slurry preheaters
- High pressure vapor system
- Catalyst addition and withdrawal
- Hydroclone system

A review meeting on preliminary conclusions of the Task Force effort was held to inform members of the SRC Project Office at DOE/ORO of our status and preliminary results. A draft of the preliminary report to be issued to DOE/ORO and ASFI for review and comment is being prepared for issue by December 7. We hope to review this with ASFI the week of December 16.

5.4 Engineering for the Economic Regulatory Administration Project

W. L. Greenstreet and M. L. Myers

During the past month, subcontracting activities (including RFP drafting and distribution, meetings with candidate subcontractors, proposal review, and subcontractor selection) were carried out. Organizational meetings were held and interfaces between task groups were identified. Overall ERA Project task descriptions were drafted, responsibilities were identified roughly, and project scheduling initiated. Task details and schedules continued under active negotiation between ORNL and the sponsor.

5.5 Fossil Energy Performance Assurance Support

L. F. Parsly and A. N. Smith

We are preparing a generic Failure Modes and Effects Analysis (FMEA) for a slurry preheater, using one of the H-Coal slurry preheaters as a typical example. This should be issued to DOE/FE for comment by December 31.

6. ENGINEERING STUDIES AND TECHNICAL SUPPORT

R. W. Glass

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

6.1 Process Modeling

R. Salmon, D. M. Lioter, O. L. Culberson,
D. G. Ball, K. W. Childs, and W. C. Ulrich

6.1.1 Contract Objective

The objective is to assist DOE/FE in its plan for computer analysis and computer support for coal conversion studies. This includes assistance to Purdue and Lehigh Universities in the development of computer programs for this plan. Physical property data are being collected and computerized primarily by Purdue and will be used in support of programs prepared by both universities. Purdue's general design program will aim at material and energy balances, equipment size and costing, plant capacity, and general economics. Lehigh's dynamic simulation programs will address plant design primarily from the standpoint of process performance during transient operations, but can also be used for steady-state conditions. A single flowsheet will be selected to assess the operability and complementary utility of both design programs.

6.1.2 Status Summary

Lehigh Programs

Installation of the latest versions of DSS/2 and the Dynamic Coal Gasification Models was completed during the reporting period. Additionally, the automatic double precision feature of the Fortran H extended compiler was used to obtain double precision load modules. The results of executing the models in both single and double precision are summarized in Table 6.1.

The Gasifier Model would not execute successfully in single precision because it requires an IMSL subroutine called ZSYSTEM which we only have available in double precision.

The differences observed between the IBM and CDC results in the Pyrolysis Model are being investigated.

Detailed descriptions of all routines in the Double-Precision Converter Program were prepared. No testing or development work on this program was performed during the reporting period.

Purdue Programs

Arrangements were made for delivery of the following Purdue codes:

1. Physical properties Package (PPROP)
2. Mass Balance Program — Version 3 (MBP-3)
3. PCOST
4. PYROLYSIS Model
5. Large Scale Simulation Program
6. Equipment Library (which contains):
 - a. Hydrogen Plant Model
 - b. Hydrotreating Model
 - c. Methanation Model
 - d. Utilities Model
 - e. Vapor Recovery Model

The above codes, including test case data, were dumped on tape and dispatched with documentation to ORNL.

Codes due for delivery at the end of December are:

1. Gasification and Combustion Model
2. Energy Balance Program — Version 3 (EBP-3)

Work on a document containing brief descriptions of the codes and documentation available from Purdue and Lehigh Universities resulting from their process modeling contracts was initiated and is about 85% complete.

Process Modeling Support Work for METC

The purpose of this work is to provide process modeling and systems engineering support to Morgantown Energy Technology Center (METC), including implementation of codes delivered by Purdue and Lehigh Universities onto the computer system at Morgantown and development, testing, implementation, and use of process models for METC.

A meeting of ORNL and METC representatives to discuss the process modeling support work was held in Morgantown on November 9. A list of specific tasks was agreed upon for submission to ORNL management for approval, resource assignment, and costing. A detailed statement of work for carrying out these tasks is being prepared for inclusion in the pertinent field task proposal/agreement.

Table 6.1. Computer execution results for Lehigh models
in single and double precision

Name	Description	Performance	
		Single	Double
COMP1	Dynamic Compressor Model	4	5
DCO2	Dynamic Carbon Dioxide Removal Model	-1	-1
DHP1	Dynamic Hydrogen Plant Model - 1	4	5
DHP2	Dynamic Hydrogen Plant Model - 2	-1	-1
GAS1	Dynamic Gasifier Model	0	5
METH1	RMP-Bulk Methanation Model - 1	3	5
METH2	RMP-Bulk Methanation Model - 2	-1	-1
PHYSP	Ideal Gas Physical Properties Package	5	5
PYRO1	Dynamic Pyrolysis Unit Model	-2	-2
SSHP1	Steady State Hydrogen Plant Model	5	5

Key:

- 2 IBM single and double precision versions almost identical but differ from CDC results.
- 1 No results from Lehigh to compare with. IBM single and double precision results almost identical.
- 0 Would not successfully execute.
- 3 Fair agreement with Lehigh results.
- 4 Good agreement with Lehigh results.
- 5 Excellent agreement with Lehigh results.

6.2 Coal Liquefaction Advanced Research Digest

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

6.2.1 Contract Objective

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

6.2.2 Status Summary

Acquisition and review of the literature on the "Chemical Reaction Kinetics of Coal Liquefaction" were begun for the second article of the upcoming Digest issue.

A search of the RECON data base was conducted to identify published literature on the subject "Characterization of Coal-Derived Liquids." The results of this search are currently being evaluated.

7. PROCESS AND PROGRAM ANALYSIS

R. W. Glass

Process and program analysis studies are being conducted for the DOE Fossil Energy Division of Planning and Systems Engineering. The program objective is to provide on a consistent basis, technical and economic evaluations of competing processes and systems for coal conversion and utilization.

7.1 Liquefaction Technology Assessment (LTAS)

R. C. Forrester III, R. Salmon, A. R. Irvine, S. P. N. Singh,
J. F. Fisher, R. M. Wham, and S. L. LeStrange

7.1.1 Contract Objective

The objective of this study is to provide a comparative assessment of the technical feasibility, economic competitiveness, and environmental acceptability of selected coal liquefaction processes representing different process classes on a uniform, consistent, and impartial basis.

The assessment encompasses four phases of work, identified as Phase 0, Phase I, Phase II, and Phase III. Each phase includes development of process designs, capital and operating cost estimates, process economic analysis, sensitivity studies, and assessment of technical feasibility and risk on as consistent a basis as possible. Existing process designs and cost estimates will be used whenever possible, with modification as necessary.

7.1.2 Status Summary

Revision of the Phase 0 draft report is continuing, with particular attention directed toward developing a set of process contingency factors for the processes examined which might reflect differences in development status. Numerous reviewer comments have been received from DOE and these are also being incorporated in the revised draft report which will be made available for limited proponent review near the end of the year. Final changes to the report will then be made and the publication process will begin early next year.

Phase I of the project has continued to proceed with preparation by Fluor Engineers and Constructors, Houston Division, of detailed process designs for the indirect synthesis plants of interest:

1. ICI methanol synthesis, followed by drying to turbine specifications, drying to gasoline blending specifications, and gasoline synthesis via the Mobil MTG process.
2. ICI methanol synthesis, followed by gasoline synthesis via Mobil MTG, but with coproduction of SNG allowed.

All designs incorporate Lurgi dry-bottom gasifiers with a Western sub-bituminous coal feed.

An interim report describing the completed capital and operating cost estimates will be delivered to ORNL in December and ORNL will begin examination of process economics under various financial assumptions. Due to the unavailability of a definitive design for the direct liquefaction processes of interest, examination of a representative of that class will be deferred until later in the fiscal year.

A work statement for Phase II of LTAS was prepared and delivered to DOE for approval. Preliminary indications are that Phase II will involve evaluation of alternative gasification systems in the process designs developed for Phase I. Specifically, process designs for methanol synthesis followed by gasoline production via Mobil MTG (coproduction of SNG allowed) would be developed using two different gasification systems: Texaco and Koppers-Totzek. Designs for both Eastern and Western coals will be prepared for each gasification system.

7.2 Direct Combustion

E. C. Fox and T. D. Anderson

7.2.1 Contract objective

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

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

7.2.2 Status summary

The main report "Conversion to Direct Coal Combustion in the Industrial and Commercial/Residential Sectors - A Study of the Barriers to Implementation in the Near Term," ORNL/TM-6139, is being prepared for final publication.

7.3 Advanced Power Conversion Systems

J. E. Jones Jr. and A. P. Fraas^a

7.3.1 Contract objective

The objectives of this project are to review selected major advanced power conversion systems and to assess these systems with respect to their basic R&D status.

7.3.2 Status summary

A total of eleven systems or components of systems were evaluated. Draft reports covering all of these topics, an overall summary report, and an executive summary report have been completed and are undergoing final review. The report entitled "Summary of the Research and Development Effort on Open-Cycle Coal-Fired Gas Turbines," ORNL/TM-6253, has been completed and is being prepared for final publication. Other reports are being corrected for final publication.

^aConsultant

8. FOSSIL ENERGY ENVIRONMENTAL PROJECT

C. R. Boston

The Fossil Energy Environmental Project provides DOE with program assistance in the performance of environmental assessment functions related to the expansion of fossil energy conversion technologies, performs assigned technical assistance tasks, and conducts programmatic environmental investigations that are critical to the early realization of advanced fossil energy technologies.

8.1 Stored Solids Study

W. J. Boegly, Jr., E. C. Davis, C. W. Francis, S. K. Hall
S. Y. Lee, and H. W. Wilson, Jr.

Activities continued to obtain site soil from the proposed SRC-II demonstration plant location in West Virginia. Uncertainties in the final location of the ash disposal area have complicated the problem of obtaining representative soils. We have been told that the final site location has now been fixed and soil sampling can be initiated. Requests have also been made to ORO for significant quantities of gasified vacuum bottoms from the Texaco gasifier from the current extended run on material produced from Kentucky 9/14 coal. We also understand that a run will be made using the Texaco gasifier on vacuum bottoms resulting from liquefaction of Powhatan coal, and samples of this material have also been requested since this is planned to be the feed coal for the demonstration plant. Samples of SRC-I gasified mineral ash residue have also been requested, but no firm indication of their availability has been determined.

Hydraulic conductivity measurements have been initiated on one of the 22-in.-diameter ash/soil lysimeters to determine residence times prior to removing the ash and the soil for detailed analysis. The drum being "deconstructed" was loaded with Waste E and soils obtained from the demonstration plant site. Specific increments of ash and soils will be removed and analyzed for trace elements. Results of these analyses will be compared with a one-dimensional computer model prediction of trace element movement.

8.2 Coal Conversion Demonstration Projects

8.2.1 Liquefaction projects - S. G. DeCicco

This activity is reported in Chapter 13.

8.2.2 Gasification projects - A. J. Witten

A reconnaissance tour of potential alternative sites for MLGW, Grace, ICGG, CONOCO, SRC-I, and SRC-II occurred on November 5-8. A team coordinated by R. A. Conley included R. Ketelle, R. Cushman, and G. Suter. The visited sites were Rivergate in Memphis, TN.; Moro Island in Illinois; Equality, KY.; North Pt. Pleasant and Ravenswood in W. VA., and two sites in Noble County, Ohio.

MLGW - Work is proceeding on PDEIS preparation. The document is approximately 80% complete. A significant activity during this month was interaction with Foster Wheeler to obtain more process information, particularly in the area of design alternatives.

Grace - Work is proceeding on PDEIS preparation. The document is approximately 70% complete. A meeting has been scheduled for December 5 in Lexington, Ky. to discuss traffic on Rt. 60 with state representatives.

ICGG - Work is proceeding on PDEIS preparation. The document is approximately 80% complete. Information requested from Dravo in early October and promised for mid-October was received in mid-November.

CONOCO - The CONOCO Environmental Scoping Meeting is scheduled for December 4 in Caldwell, Ohio. A dry run was held at the CONOCO offices in Washington, D.C. on November 14. Assuming receipt of the Final ER on February 1, the PDEIS will be completed on May 1. EIA has agreed to submit draft ER material, by section, beginning in December.

8.3 Communications

a. Conley, Cushman, Ketelle, and Suter visited potential alternative sites for the six synfuels demo projects on November 5 to 8.

b. Witten attended the Grace monthly project review meeting in Memphis on November 7, 8.

c. Conley and Witten met with Roy F. Weston, Inc., in West Chester, PA. on November 9, to discuss the status of their EIS support efforts on alternatives.

d. Boston attended the MLGW monthly project review meeting in Memphis on November 13, 14.

e. Witten participated in a "dry run" of the CONOCO scoping meeting, held in CONOCO's offices in Washington, D. C., on November 13.

8.4 Milestones

Preliminary draft environmental statements (PDES's) will be completed three months after receipt of acceptable, final environmental reports (FER's) from the industrial partners. Current schedules, contingent on delivery of FER's, call for PDES's, as follows: Grace, 1/2/80; SRC-I, 3/7/80; SRC-II, 2/8/80; ICGG, 1/2/80; MLGW, 1/2/80; CONOCO, 4/30/80.

9. COAL PREPARATION AND WASTE UTILIZATION

E. C. Hise

The objectives of this program are: to develop, demonstrate, and bring to commercial viability, processes and equipment for the removal of pyrite and ash-forming minerals from dry crushed coal by either or both processes of high-gradient magnetic separation (HGMS) and open-gradient magnetic separation (OGMS); to integrate the magnetic process into the coal preparation system to achieve the most effective and economic preparation of the raw coal; and to develop processes to minimize the refuse disposal by efficiently utilizing the heating value and concentrated mineral resources in that refuse.

9.1 High-Gradient Magnetic Separation

E. C. Hise, M. T. McFee, and D. L. Mailen

Initial testing and shakedown of the one ton per hour continuous separation demonstration system has begun at Sala Magnetics. The feeding and distribution of the coal to the matrix and the collection of the several streams leaving the matrix are being measured and regulated. Tests with the magnet energized will begin in December. Samples of the same batch of coal are being separated in the laboratory solenoid for correlation with the continuous separation machine at Sala Magnetics.

A contract change request has been submitted to add a wet magnetic circuit to the coal preparation plant design study now being performed by Powell Construction Company. A coal sample has been sent to Rich Hucko, of DOE, Pittsburgh, who has offered to perform the wet magnetic separation tests to define the process characteristics. Mr. Hucko has also offered to perform a computer analysis of the conventional coal preparation circuits shown in the Powell design study.

During shakedown testing of the superconducting laboratory magnet, it became apparent that the bore of the cryostat had become distorted so that the magnetic coil was binding during insertion and removal. The coil and cryostat were returned to the fabricator to be corrected.

9.2 Open-Gradient Magnetic Separation

A. S. Holman, M. T. McFee, and D. L. Mailen

Dr. Fritz Friedlander of Purdue University has been working with ORNL primarily on the modeling of OGMS. He has studied our solenoid simulations and has concurred that they appear correct. Work is now underway to incorporate the solenoid models into our existing trajectory computer model.

An extremely interesting discovery was made during the month which may have significant impact on OGMS. Until now, we and others have attempted to generate fields which have the correct shape and magnitude to perform the desired separations within the bore of the solenoid. However, it appears that the field at each end of the solenoid is already shaped in a suitable manner. Therefore, by processing just outside the end of the windings, at right angles to the bore of the magnet, the desired separations are viable. We are currently studying this configuration to learn what, if any, physical limitations this mode might have.

A device has been designed for the superconducting magnet which will allow us to position an orifice inside the center bore of the cryostat at the top of the magnet. It will enable us to change the size of the orifice as well as its position anywhere from the center of the bore to within 8 mm of the inside wall. Fabrication should be completed by late December.

Further modifications have been completed on the Frantz magnetic separator. We are now able to obtain consistent, reproducible data, with a loss of less than four tenths percent per sample run due to random scattering.

9.3 ORNL/TVA Chemical Comminution Project

S. R. Smith^a

In recent months, TVA and ORNL have cooperated in a program to study the liberation of inorganic mineral contaminants from coal. Washability analysis of four run-of-mine coal samples from western Kentucky and southern Illinois has been completed, including float-sink analysis of coal that has been treated by the chemical comminution process and mechanical crushing. The Electric Power Research Institute is preparing to sponsor process development tests at Hazen Research in Golden, Colorado, in conjunction with Catalytic, Inc., who is licensed to develop the chemical comminution process. TVA will select two coals of interest for these tests at Hazen based on the results of the washability tests performed at ORNL.

Laboratory studies indicate that chemical comminution liberates more inorganic material from coal than mechanical crushing to the same size consist (range). Coal particles tend to reduce to about the 12 x 50 mesh range, with only a slight increase in material finer than 100 mesh.

Laboratory washability experiments on samples from the Illinois No. 6 seam showed significant advantages for chemical comminution over mechanical crushing. These float-sink tests demonstrated that, at the same product recovery, the cumulative sulfur content of the float product was much lower for the chemically comminuted product than for coals crushed to a comparable size. Furthermore, at the same sulfur content

^aTVA Guest Engineer

level, product recovery by the chemical comminution process was greater than by the mechanical grinding method. These results can be seen in Table 9.1.

9.4 Conferences and Trips

E. C. Hise, A. S. Holman, and J. F. Thomas

Messrs. William Thomas and Steve Smith, TVA guest engineers, worked at Sala Magnetics for a week performing a series of tests of screening coal at different moisture levels to obtain design information of throughput and efficiency for dry coal screening. They also observed the preparations and shakedown testing of the one ton per hour continuous separation demonstration.

Mr. Alv Orheim of the Norwegian Coal Company visited our laboratory to discuss and observe magnetic separations of dry crushed coal.

John Thomas attended the Coal Technology '79 conference held in Houston, Texas, November 6-8. Several papers were presented concerning coal beneficiation. Copies were obtained of all available papers presented at the conference.

Table 9.1. Illinois No. 6

Comminuted	Individual Fractions				Cumulative Floats			
	Wt. Frac.	% Ash	% Sulfur	Btu/lb	Wt. Frac.	% Ash	% Sulfur	%Btu Recovery
F 1.35	.30	8.6	2.7	12,706	.30	8.6	2.7	36
1.60	.35	21.8	3.7	10,532	.65	15.7	3.2	80
1.80	.15	40.5	4.9	8,101	.80	20.4	3.5	91
1.80 S	.06	53.4	12.0	5,828	.86	22.7	4.1	94
-30 mesh fines	.14	14.6	4.3	11,730				
Crushed	Wt. Frac.	% Ash	% Sulfur	Btu/lb	Wt. Frac.	% Ash	% Sulfur	%Btu Recovery
F 1.35	.30	9.5	2.8	12,656	.30	9.6	2.8	36
1.60	.39	21.2	4.1	10,904	.69	16.2	3.5	76
1.80	.13	42.6	4.3	7,785	.82	20.3	3.7	86
1.80 S	.07	59.7	13.4	4,756	.89	23.4	4.4	89
-30 mesh fines	.11	21.6	4.4	10,856				

10. ATMOSPHERIC FLUIDIZED BED COAL COMBUSTOR FOR COGENERATION (AFBCCC)

R. S. Holcomb

10.1 Objective

The Coal Combustor for Cogeneration (CCC) Program is directed at the development of a fluidized bed coal combustion system heating air inside tubes to provide high temperature clean air to drive a gas turbine to generate electricity. The heat in the air leaving the turbine exhaust would be recovered to supply industrial process heat. The gas turbine is very well suited for cogeneration since the ratio of thermal to electrical energy is about 3 to 1 for the gas turbine cycle as compared to a ratio of about 5 to 1 for a back-pressure steam turbine, and the exhaust heat from the gas turbine is available at a higher temperature. The scope of the program includes the study of industrial cogeneration plants in the size range from 5 to 50 MW(e) and the construction and testing of a 0.3 MW(e) technology test unit.

10.2 Status Summary

R. S. Holcomb, R. H. Guymon, N. W. Durfee, and W. A. Hartman

The program subcontract was sent to Westinghouse on November 8. They signed it and returned it to the UCCND Purchasing Division on November 28. It will be sent to DOE/ORO by December 5 for their review and approval.

The Request for Modification of the project directive has been prepared and will be submitted to ORO early in December for approval. This request is for partial authorization to proceed with UCC engineering design work and procurement of the combustor test unit under the subcontract at an estimated cost of \$990,000.

Engineering planning for Task 2 - Test Unit Design and Construction was initiated and has proceeded well during November. The first draft of the Work Breakdown Structure and the Work Breakdown Responsibility Table was completed. These are under review and revisions should be completed next month.

11. TENNESSEE VALLEY AUTHORITY (TVA) FLUIDIZED BED
COMBUSTION (FBC) DEMONSTRATION PLANT PROGRAM
TECHNICAL SUPPORT

E. C. Fox

Tennessee Valley Authority has assumed a lead role in the demonstration of FBC technology for application in large utility boilers. ORNL will provide technical support and services to TVA in FBC systems. This work is to support TVA's objective to develop FBC systems for utility electric power generation which will burn high-sulfur coal and meet environmental emission standards.

TVA will be the lead agency in this work and will reimburse DOE for the work to be performed by ORNL. This work is to be conducted by ORNL under the terms and conditions of the Interagency Agreement between TVA, DOE, and ORNL regarding support for FBC research (reference: Agreement TV-48296A, Subagreement 5).

11.1 AFBC Technology Support - Task 2

M. Siman-Tov and E. C. Fox

11.1.1 Contract objective

The objective of this program is to provide technical support of a general nature in FBC systems and respond to specific requests from TVA personnel. Such requests may include reviews, assessments, participation in TVA tasks, and similar activities.

11.1.2 Status summary

No activity under this task during this month.

11.2 4 x 4 Cold Flow Model - Task 3

M. E. Lackey and R. S. Holcomb

11.2.1 Contract objective

The objective of this task is to experimentally investigate slumping of a portion of a fluidized bed using a sub-scale cold flow model. The scope of work includes design and minor modification of the 4 x 4 cold flow model for slumping and refluidization tests and conducting bed slumping tests.

11.2.2 Status summary

The determination of the slumping characteristics of a 1/4 scale factor model of the TVA pilot plant have been completed. These tests were conducted with approximately 400 μm limestone at a superficial velocity of 0.3 to 0.6 m/s and a bed depth of approximately 0.5 m.

In order to establish the validity of the model, additional testing with the 4 x 4 bed will be conducted with 1000 μm limestone at superficial velocities up to 1.5 m/s.

A draft of the report for the 1/4 scale factor tests was completed and submitted to TVA for review and comments.

The limestone that was used in the 1/4 scale factor test was drained from the 4 x 4 bed and the bed was filled with approximately 1000 μm limestone. This material was added to the bed to determine the effects of the particle size upon the slumping characteristics. The system was shaken down after the limestone addition and the fluidizing characteristics of the stone was determined. The minimum fluidizing velocity was found to be 0.49 m/s.

11.3 AFBC Modeling and Simulation - Task 4

J. W. Wells, R. P. Krishnan, and M. Siman-Tov

11.3.1 Contract objective

The objectives of this program are to develop a simple steady-state model for conceptual design of the main cell and carbon burnup cell and to incorporate in this model the ability to predict trends in bed performance under various feed and operating parameters.

11.3.2 Status summary

Preparation of the annual report for calendar year 1979 was initiated. Rough drafts describing the bubble growth subcode, the elutriation-attrition subcode, and the system code have been prepared. Next month the combustion subcode will be described, and a final rough draft of the annual report will be submitted.

Also during this month, Babcock and Wilcox (B&W) report LR:79:4775:04 was received. This document includes a description of the Oregon State University's (OSU) AFBC simulation. The OSU simulation assumes instantaneous devolatilization. In the ORNL model, the volatiles are assumed to be released uniformly through the bed. Neither assumption is accurate and recent information given below may establish a better understanding of the devolatilization process in fluid beds. Recently, B&W has reported corrosion problems in the submerged tube bundle.¹ Reducing zones have been observed directly above the coal feed points. These problems may be due to excessive devolatilization in the region above the feed point. The B&W report gives data which show that devolatilization time of a coal particle is a function of particle diameter and is not instantaneous.² Specifically, experimental measurements show that a 200 μm coal particle requires less than a second to devolatilize and a 3000 μm particle requires as much as 6 to 10 seconds to devolatilize. This implies that fines (<500 μm diameter) in the feed are devolatilized rapidly, while large particles require longer periods of time. B&W also gives the mixing time of a fluid bed as around 15 seconds. This implies that the coal feed particles are uniformly distributed through the bed at the end of 15 seconds. Highley and Merrick found a fluid bed required between 10 and 40 seconds to become well mixed.³ Solids mixing in a fluidized bed is due to the passage of gas bubbles upward through the bed. This induces both lateral and vertical mixing. Kunii and Levenspiel show experimental evidence that vertical mixing is about an order of magnitude greater than the lateral mixing.⁴ Data presented by Highley and Merrick for a 1.5-m (5-ft) diameter coal ash bed show that particles entering the bottom of the bed make their way rapidly (about 2 seconds) to the surface of the bed.³ This implies that coal fed at the bottom of the bed is carried rapidly to the surface of the bed. During this rise, the finer particles are completely devolatilized, while the larger particles are only partially devolatilized. Once these particles reach the surface, two things occur. The smaller particles are elutriated and larger particles are returned back to the bed. The larger particles remaining in the bed have been displaced laterally and continue the devolatilization process. As stated previously, the devolatilization time is a function of particle diameter. If large amounts of fines are fed to the bed, a large amount of volatile gas will be rapidly released in the region above the feed point. Therefore, a large amount of oxygen will be consumed and the possibility exists that reducing conditions will be present in the region above the feed point. As was pointed out earlier (see ORNL/TM-7057), the B&W feed system may cause excessive fines to be formed. The more friable coal is especially prone to attrition. Therefore, it is possible that a large amount of coal fines are entering the bed. These fines will devolatilize completely as they rise to the surface of the bed. This may cause the reducing condition which has been observed above the feed point.

11.4 AFBC Bench Scale Facility - Task 5

G. P. Zimmerman, R. H. Guymon, and R. S. Holcomb

11.4.1 Contract objective

The objective of this task is to experimentally investigate heat transfer, sulfur capture, carbon loss, and combustion of recycle carbon using the ORNL AFBC bench scale combustor.

11.4.2 Status summary

Test facility description - The combustor is 0.25 m ID and about 4.6 m tall. The combustor is designed for burning 5 to 14 kg/hr of coal and is equipped for limestone addition. The system is designed to operate with a bed fluidizing velocity in the range of 1.2 to 3 m/s and bed temperatures up to 870°C. The bed is cooled by compressed air flowing through 12.7 mm OD tubes immersed in the bed.

Scope - The scope of work includes tests to determine sulfur capture and carbon loss over a range of fluidizing velocities of about 1.2 to 3 m/s, combustion of recycle carbon over a velocity range of 1.2 to 2.4 m/s, and bed temperatures of 790 to 900°C. Several combinations of coal and sorbent of interest to TVA will be tested at several values of Ca/S. Carbon loss will be measured for each coal and several values of fluidizing velocity. Recycle carbon will be fed to the combustor to study its combustion.

Progress to date - Testing of the Three Rivers limestone was continued and almost 30 hours of burning with Kentucky number nine coal was completed during the month. The limestone was successfully calcined and sulfated and preliminary sulfur capture data has been obtained for a fluidizing velocity of 1.2 m/s and a bed temperature of 830°C (1525°F).

A cursory examination of raw data taken at these conditions indicates that the Three Rivers limestone achieves 85% sulfur capture at a calcium-to-sulfur mole ratio near 3 to 1 and 90% at a ratio near 4 to 1. These early results are subject to further testing, as well as a more complete chemical analysis of both coal and limestone. The Kentucky number nine coal being used in this test series contains 4% sulfur.

The new stack gas analyzer appears to be working well after checkout and shakedown testing earlier in the month. Carbon monoxide (CO) readings of 2000 to 3000 ppm have been obtained during the test series. The up-scale calibration gas for the NO_x meter has not yet been received; hence no NO_x data has been obtained.

Combustion tests during the month were interrupted twice due to mechanical failure of the limestone feeder. The mechanical connector between the drive motor and the auger screw was to blame on both occasions.

Upon closer examination, it was discovered that the large percentage of fines in the as-fed limestone were being compacted and placing a high torque load on the limestone feeder. A periodic air purge of the feeder screw is made in order to eliminate this problem.

Problems also arose when the flue gas exhaust line plugged. The plugging occurred on a cold, rainy day in lines outside the building. Apparently condensate from the products of combustion combined with the fly ash and plugged two elbow joints where horizontal and vertical sections of pipe meet. When the plugs were removed, the elbows were replaced with joints which slope and eliminate all right-angle bends.

The other three TVA limestones were crushed late in the month in anticipation of future sulfur capture tests. The preparation of these limestones for use as bed and feed material should now proceed smoothly.

Testing during the month of December will be oriented toward verification of results for the Three Rivers limestone. The repeatability of test conditions will be the criteria for "good data." A superficial velocity of 2.4 m/sec (8 ft/sec) will be the next condition tested.

11.5 Assessment of the State-of-the-Art of PFBC Systems - Task 6

R. L. Graves, M. E. Lackey, and A. P. Fraas^a

11.5.1 Contract objective

The purpose of this program is to provide TVA with an assessment and overview of the state-of-the-art for PFBC systems and their associated components.

11.5.2 Status summary

The final report on the state-of-the-art of PFBC systems is to be submitted for typing during the week of December 3. Draft copies will be sent to TVA shortly thereafter.

The gas turbine cascade tests at Leatherhead are nearing completion with only about 150h out of the goal of 1000h remaining to be run as of November 27, 1979. The preliminary indication is that both the General Electric and American Electric Power gas cleanup systems are operating sufficiently well to eliminate serious erosion on the blade samples.

11.6 Analytical Support and Alternative Design Concepts Evaluation - Task 7

E. C. Fox, C. S. Daw, and R. P. Krishnan

11.6.1 Contract objective

The objectives of this task are to assist TVA in determining the design parameters which are critical to an effective AFBC system from the standpoints of efficiency and cost and to provide direction as to better design options.

11.6.2 Status summary

The work this month has been focused on equating the AFBC performance in terms of cost. For this analysis, the economic ground rules listed in Table 11.1 were used. The cost comparison was made by calculating the revenue required over the lifetime of the project and comparing this to a base case arbitrarily selected as Case 1 (see the September monthly report for a detailed description of each case). By using this method the relative merit of each design condition can be examined. One important design tradeoff is choosing the design fluidizing velocity and bed depth.

The initial results indicate that the costs are not a strong function of design superficial velocity, but are more dependent on the static bed depth chosen. Table 11.2 presents results for cases in which only bed depth and fluidizing velocity were varied. From those results it appears that expanded bed depths as deep as 4.6 to 5.5 m could be justified. This is because the cost of fan power and boiler strengthening is offset by the improved sulfur capture and combustion efficiency. It should be noted that these results depend on the validity of correlations that were derived from much shallower beds. What it does indicate is a need for data from deeper beds to determine the validity of the correlations.

Table 11.1. Economic Assumptions

Fixed Charge Rate	10.6%
Escalation Coal	6.2%/year
Other	6.0%/year
Plant Life	30 years
Plant Capacity	70%
Discount Rate	10%
Coal Cost	\$30/ton
Limestone Cost	\$10/ton
Disposal Cost	\$5/ton

Table 11.2. Economic Comparison

Case	Superficial Velocity	Static Depth	Expanded Depth	Incremental Revenue Required
1	8 ft/sec	4 ft	7.2 ft	0
4	8 ft/sec	6 ft	10.8 ft	-\$85.6 x 10 ⁶
20	8 ft/sec	10 ft	18 ft	-\$81.3 x 10 ⁶
41	4 ft/sec	3 ft	3.8 ft	+\$72.5 x 10 ⁶
3	4 ft/sec	4 ft	5.1 ft	-\$15.2 x 10 ⁶
6	4 ft/sec	6 ft	7.6 ft	-\$48.9 x 10 ⁶
42	4 ft/sec	10 ft	12.7 ft	+\$20.7 x 10 ⁶

11.7 AFBC Technical Source Book and R&D Evaluation - Task 8

M. Siman-Tov and A. A. Khan

11.7.1 Contract objective

The objectives of this program are: 1) to develop a single comprehensive source book of technical data for design procedures and evaluation of AFBC facilities and programs, 2) to review and evaluate existing and proposed AFBC facilities to perform research and development for TVA, and 3) to interpret and translate results of test studies performed for TVA and further the knowledge in AFBC research and development activities.

11.7.2 Status summary

An effort has been made to lay down the basis for design parameters concerned with combustion efficiency. This month the effort has been restricted to summarizing the kinetics related to the combustion process. The following items were covered.

1. Devolatilization - Once coal is fed into the combustor, it is heated suddenly and it undergoes a thermal decomposition which produces solid char and gaseous volatile matter.

The char usually accounts for 30 to 70% by weight of the original coal. The fraction of volatile material is not fixed and depends on the decomposition conditions. Unfortunately, the models that predict devolatilization are crude because of the extremely complex nature of the phenomenon. The simplest model so far is that developed by Anthony and Howard⁵ to predict fractional volatile release.

$$V^* - V = \frac{V^*}{\sigma(2\pi)^{1/2}} \int_{-\infty}^{\infty} \left\{ \exp[-k_0 \int_0^t \exp(E/RT) dt] \exp\left(\frac{E - E_0}{2\sigma^2}\right) \right\} dE,$$

where

- V^* = ultimate total volatile yield at $t = \infty$, wt %,
- V = cumulative total volatile yield at time T , wt %,
- σ, E_0 = distributional constants, kcal/gmole,
- k_0 = preexponential factor, sec^{-1} ,
- E = activation energy, kcal/gmole,
- T = temperature, K,
- R = universal gas constant, kcal/gmole-K,
- t = time, sec.

To use the expression, it is necessary not only to have the constant V^* , σ , E_0 , and k_0 , but also the temperature and residence time t . The appropriate kinetic constants for Montana lignite and Pittsburgh bituminous coals are presented in Table 11.3.

For devolatilization of individual chemical constituents for Illinois No. 6 coal, a model has been derived by Reklaites, et al.⁶, at Purdue as follows.

$$V_i = V_i^* F(a_i T - b_i),$$

where

- V_i^* = ultimate yield of product i , wt %,
 $\bar{V}_i$ = cumulative yield of product i up to temperature T , wt %,
 F = cumulative normal Gaussian distribution function,
 a_i, b_i = constants for product i , K, dimensionless,
 T = temperature, K.

The parameters V_i^* , a_i , b_i are given in Table 11.4.

2. Reactivity of Char Particle - The overall chemical reactivity of a char particle depends on the type and concentration of active sites and the pore structure. This determines the concentration profile of oxygen or other gaseous reactants.
3. Surface Mechanisms for Char Combustion - Table 11.5⁷ lists the significant global reactions occurring during char combustion. The carbon-hydrogen reaction is too slow for most practical purposes. The kinetics of each of these have been briefly examined.

The global surface reaction rate for this is given by:

$$R = \frac{k C_{CO_2}}{1 + a C_{CO} + b C_{CO_2}},$$

where

- R = g/m²s,
 k, a, b = empirical constants,
 C_{CO_2}, C_{CO} = concentration of CO_2 and CO in gas, gmol/l.

Table 11.3. Experimental Parameters of Multiple-Reaction Model
and Standard Deviations of Data and Correlation

Parameters and Standard Deviations	Lignite (All Pressures)	Bituminous Coal (69 atm)
Frequency factor (k_o), sec^{-1}	1.07×10^{10}	2.91×10^9
Mean activation energy (E_o), kcal/mole	48.72	36.89
Std. dev. of act. E. (σ), kcal/mole	9.38	4.18
Ultimate yield (V^*), wt % of orig. coal	40.63	37.18
Std. dev. of data (S), wt % of orig. coal	± 1.73	± 1.85
Std. dev. of correlation (S'), wt % of orig. coal	± 0.25	± 0.42

Table 11.4. Kinetic Parameters for Illinois No. 6 Pyrolysis

Product	$a_i (K^{-1})$	$-b_i$	V_i^* (wt % dry coal)
H ₂	0.013293	11.831	1.22
H ₂ O	0.011488	7.898	6.05
CO	0.037222	30.801	4.07
CO ₂	0.054738	43.921	2.22
CH ₄	0.058159	46.236	3.88
C ₂ H ₄	0.023264	17.448	1.54
Oil	0.011632	8.317	18.52
Total			37.50

Table 11.5. Carbon Gasification and Combustion:
Four Major Reactions

Reaction	ΔH_{298} (kcal/gmol)	Temperature Range for which $K_p > 1$	Relative rate at 800 K and 0.1 atm
$C + CO_2 \rightarrow 2CO$	41.2	$T > 950 \text{ K}$	1
$C + H_2O \rightarrow CO + H_2$	31.4	$T > 950 \text{ K}$	3
$C + 2H_2 \rightarrow CH_4$	-17.9	$T < 820 \text{ K}$	3×10^{-3}
$C + O_2 \rightarrow CO_2$	-94.1	$T < 5000 \text{ K}$	10^3

The expression for global reaction rate for this reaction is given by:

$$R = \frac{kC_{H_2O}}{1 + aC_{H_2} + bC_{H_2O}},$$

where

$$R = \text{g/m}^2\text{S},$$

$k, a, b = \text{empirical constants},$

$C_{H_2O}, C_{H_2} = \text{concentrations in gaseous phase of } H_2O \text{ and } H_2, \text{ gmol/l.}$

Few kinetic studies are available for C/H_2 reaction. Most studies report the global intrinsic rate has a first-order dependence on hydrogen concentration.

$$R = kC_{H_2},$$

where

$$R = \text{g/m}^2\text{S},$$

$C_{H_2} = \text{gas phase concentration of } H_2, \text{ gmol/l.}$

Despite extensive investigation, the mechanism of C/O_2 reaction is probably the least understood of the four reactions. The reason is complications caused by (1) mass transfer effects, (2) pore structure changes, and (3) swelling and cenosphere formation.

Of primary importance is CO/CO_2 ratio, since both CO and CO_2 are formed. This is given by:

$$CO/CO_2 = Ae^{-E/RT},$$

where

$$A = 10^{2.5},$$

$E = 6-9 \text{ kcal/mol at low pressures.}$

The global intrinsic reaction rate for this reaction can be either:

$$R = m_c k C_{O_2}$$

or

$$R = m_c k C_{O_2}^{1/2},$$

where

m_c = mass of char particle,
 R = g/m^2s ,
 k = experimental constant,
 C_{O_2} = concentration of oxygen in gas phase, $gmol/l$.

11.8 Materials Support for TVA Pilot and Demonstration AFBC Plants - Task 9

R. H. Cooper, T. G. Godfrey, J. H. DeVan,
and R. A. Bradley

11.8.1 Contract objective

ORNL proposed to assist TVA technically in the materials area. The unique part of an AFBC is the fluidized bed combustor and its associated hardware, since the balance of the plant closely resembles a conventional pulverized-coal supply system. The principal areas of concern are the in-bed heat-exchanger tubes and hangers, the air distributor, side walls, coal feed lines and nozzles, spent-bed removal hardware, and cyclones for separating elutriated material.

11.8.2 Status summary

Discussions have been held with W. D. Goins, TVA project engineer, regarding selection of in-bed materials for the AFBC Pilot Plant. Areas of concern are the selection of welding alloys for in-bed use, possible inclusion of chromized Cr-Mo steel in the superheater, and the choice of the particular austenitic stainless steel for the finishing superheater. A meeting is to be held at the Babcock & Wilcox (B&W) Alliance Research Center in December with the interested parties to establish a final recommendation on these items.

Plans are being made with the TVA project engineer for the metallographic examination of the tubes, coupons, and marker rods from the second 1000-h test in the CURL/Leatherhead AFBC. Since this is a very large specimen set, we believe that a limited number of samples must be carefully selected for the most detailed metallographic examination and the remainder, subjected to a more routine analysis.

11.9 Dynamic Modeling of the TVA Fluidized Bed Combustion Pilot Plant - Task 10

O. L. Smith

11.9.1 Contract objective

The objective of this task is to provide dynamic modeling and transient systems analysis directly applicable to the TVA pilot plant. As an important benefit, the information obtainable from a dynamic model would help in the specification of such features as function, range, and type of instrumentation required to provide the desired plant operating characteristics.

11.9.2 Status summary

In addition to the controllers previously reported, SO₂ control was added to the system. Proportional plus integral action operates on the flue gas SO₂ error signal (departure from set point), and the calcium-to-sulfur ratio (limestone feed rate) is varied to null the set point error. Deadtime of the SO₂ detector is not explicitly represented in the present controller, i.e., boiler transients are assumed long compared with detector deadtime. This assumption may be removed in the future.

The large heat capacity of the bed limestone may significantly affect the controllability of the plant. The tendency of this heat capacity, combined with the relatively weak heat transfer coefficients between the bed and the pressure parts, is to introduce a resistance-capacitance time delay between steam pressure error and coal feed. Such a lag may increase system sluggishness and deteriorate load following ability. The use of derivative (phase lead) action in the coal feed controller can reduce the delay between pressure error and coal feed response. In order to study the desirability of derivative action, it has been added to the coal feed controller in such a way that it can be turned on and off as desired.

Closed loop (controls operating) calculations with the model have been and are being performed. Various graphical and tabular results have been delayed in graphic arts preparation, and it will be necessary to postpone presentation until next month.

11.10 Coal Feed Tests - Task 11

J. A. Stevens, C. S. Daw, and V. R. Brantley

11.10.1 Contract objective

The objective of this task is to experimentally investigate feeding techniques and equipment for AFBC application. Fundamental tests will be conducted in order to establish the key operating variables over which reliable coal and limestone pneumatic feeding can be achieved.

11.10.2 Status summary

Construction of the basic test facility has been completed, including two long radius bend pipe sections ($R/D = 12$) and a 100 mm x 100 mm rotary feeder. The first test configuration has been installed, and this will be used for test series 1 and 2. For test 3, the line size from the feed hopper to the coal pickup tee will be increased to the maximum allowable size of four inches.

Coal feeder calibration tests have been run in order to determine coal flow rate versus regulator setting (shaft speed) for coal with various surface moisture levels. The larger feed line will allow feeding of wetter coal due to the decreased probability of hopper bridging.

General system shakedown testing has been completed. Testing with nominal 2% moisture is nearing completion. So far, all equipment has worked adequately. No plugging has occurred in the conveying line, but there have been some problems with feeding 2% moisture coal due to the small feed line. These should be eliminated by the larger feed line. No other significant problems have been encountered. Summary reports for each test series will be issued in the near future.

11.11 Materials Evaluation and Testing - Task 12

R. H. Cooper, T. G. Godfrey, J. H. DeVan,
and R. A. Bradley11.11.1 Contract objective

The objective of this task is to experimentally determine the envelope of operating conditions which will result in safe and reliable performance of in-bed materials. The experimental work is to be initially guided by thermodynamic calculations involving all likely reactants and products for selected alloy and environment combinations.

11.11.2 Status summary

This is a new task that is yet to be formally approved and funded through ORO to ORNL. However, preliminary calculations are being made to check the new data incorporated into the existing computer code.

11.12 References for Section 11

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12. COAL COGENERATION/DISTRICT HEATING PLANT ASSESSMENT

M. A. Karnitz and R. L. Graves

12.1 Objective

The objective of this work is to provide the Fossil Fuel Utilization Division of DOE with an evaluation of the coal-fired closed-cycle gas turbine as a cogeneration power plant specifically for district heating in the Minneapolis-St. Paul area. This entails a preliminary design study, including a cost estimate. The design study is a cooperative effort between ORNL, United Engineers and Constructors (UE&C), and Northern States Power (NSP). Design of an extraction steam system for the same application is being carried out simultaneously by UE&C and will allow a comparative evaluation of both cogeneration plants. These design studies are part of a considerably larger program involving other divisions of DOE with the objective of evaluating district heating in Minneapolis-St. Paul.

12.2 Status Summary

The UCCND contract with the St. Paul District Heating Development Co. (SPDHDC) was approved by the SPDHDC board representative and sent to DOE-ORO for approval. The project is being replanned as a result of a preliminary analysis of thermal energy costs performed in October. Emphasis has been placed on initiating construction of the first transmission line from the NSP 3rd Street plant to the state capital complex, possibly by December, 1980. Therefore, developing financing sources for this first phase has been initiated with the state, local bond underwriting firms, and the HUD-UDAG office. State backing for government obligation bonds is being negotiated with the state legislature and executive office. Contacts with St. Paul commercial building owners is underway; also a sub-contract is being negotiated with the local firm and a Swedish consultant on building conversion costs and engineering.

Tom Row and Mike Karnitz traveled to EPA Region 5 in Chicago for a District Heating Exchange meeting on November 15, 1979. Also in attendance were staff from the SPDHDC, Minnesota Pollution Control Agency, NSP, and the Cincinnati EPA Laboratory. The Region 5 people in attendance included the Air Enforcement Branch and the Air Programs Division. We presented an overview of the Twin Cities district heating work and this was followed by an informal discussion on the St. Paul Demonstration Project. The Air Enforcement Group expressed concern on whether district heating would provide a total emission offset. There is to be a follow-up meeting in either December or January between the Region 5 people and the Twin Cities participants for further discussions on the St. Paul Demonstration Project.

Bill Mixon and Mike Karnitz attended a DOE District Heating Task Force meeting on November 27, 1979, in Washington, D.C. At the meeting there was a review of a draft document on a national district heating strategy. Allen Rubin, chairman of the task force, will incorporate the comments suggested at this meeting and submit the plan on November 30, 1979. The plan calls for a large scale district heating implementation program.

The coal/cogeneration power plant study with NSP and UE&C produced a major result on the turbine cycle. At a meeting attended by Mike Karnitz and Ron Graves in Minneapolis on November 1, 1979, UE&C presented an economic comparison which showed that the cogeneration unit should have full condensing capability. This is mainly due to the fact that NSP is a summer peaking electric utility. This recommendation was accepted by the staff of NSP. Also presented at this meeting were diagrams of the plant layout. The only significant additional space requirement was the area used for the district heating condenser. The next progress meeting is scheduled for December 11, 1979, in Minneapolis.

Refinements to the design and operating modes of the closed-cycle gas turbine cogeneration plant have been made. By specifying a design point with some recuperator bypass, the desired 400 MW(e) and 700 MW(t) output can be obtained. This design gives the closed-cycle turbine plant a maximum power output of about 520 MW(e). These operating characteristics are very similar to those of the extraction steam system being studied, hence the comparison between the systems will emphasize differences in efficiency and capital cost.

Analysis of control via compressor inlet temperature has been studied briefly. This is certainly a legitimate control method, but appears to offer no significant improvements in design and only minor improvement in efficiency over recuperator bypass and inventory control in the range of heat and power loads required in the district heating application. A low pressure ratio design appears to be more suitable with the selected control method.

13. TECHNICAL SUPPORT TO MAJOR LIQUEFACTION PROJECTS

T. W. Pickel

Technical support is being provided for the major liquefaction projects being managed by the Oak Ridge Operations Office of DOE. Current activities are related to the Solvent Refined Coal Demonstration Plant Projects, SRC-I and SRC-II, and the H-Coal Pilot Plant Project. Major parts of the current effort are concerned with SRC environmental support and H-Coal materials and technology review. Support is being provided in the areas of reliability, safety, and quality assurance.

13.1 SRC Demonstration Plants Design Review

J. J. Kurtz

13.1.1 Contract objective

This activity consists of providing technical assistance to the DOE-ORO Solvent Refined Coal Projects Office on the SRC-I and SRC-II projects. The SRC-I project involves the design, construction, and operation of a coal liquefaction plant for the production of a clean solid boiler fuel. The SRC-II project is for the production of a clean liquid boiler fuel. The government-funded preliminary design of the SRC-I project is contracted with the Southern Company Services, Inc. (SCS), and the SRC-II project contract is with the Pittsburgh and Midway Coal Mining Company (P&M).

The principal purposes of the SRC projects review and evaluation activities are to provide objective assessments of the contractors' technical progress, identification of potential problems, and critiques of project deliverables.

13.1.2 Status summary

The SRC-II monthly technical status review meeting on November 29 was monitored. A major area of concern raised at the meeting was the P&M projection that the formal base-line design with an estimate would not be available until January 21, 1981. This represents an approximate 12-month slip from a target date of December 1979/January 1980 at the completion of Phase 0.

Preceding the technical status review meeting, a meeting was attended on November 28 with P&M and GMRC to review the Phase-0 deliverables comments by UCC-ND/ORNL. The P&M responses to the comments can be categorized into the following generic groupings: design has changed; need confirming R&D data or experience; not resolved pending

impact of other system parameters; comment misinterprets intent. However, P&M indicated an awareness of the issues raised by the comments.

A preliminary draft by the joint venture of the Phase-1 work statement for the SRC-I project was reviewed and commented at the request of the ORO SRC Projects Office. Most of the comments addressed the unilateral responsibilities for the joint venture group and the incomplete definition of the activities implied in the work statement. The comments were transmitted formally to the ORO SRC Projects Office on November 20.

A preliminary draft of the UCC-ND Engineering plan for support of coal liquefaction projects in FY 1980 was reviewed internally and a copy transmitted informally to the ORO SRC Projects Office. Mutual accord on the plan is still open.

The following documents were issued.

Letter: "SRC-I Technical Status Review Meeting - October 24," M. Bender to J. F. Pearson, Jr., November 19, 1979. o

Attachment: Comments on Draft Work Statement for SRC-I Phase-1 Design, L. E. McNeese to Marvin Rogers, November 21, 1979.

Letter: "Agenda Items for SRC-I Technical Status Review on December 11, 1979," J. J. Kurtz to Marvin Rogers, November 21, 1979.

13.2 Direct Liquefaction R&D Review

B. R. Rodgers, C. H. Brown, W. R. Cambill

13.2.1 Contract objective

This project is an intensive, short-term assessment of current research and development activities of importance to the SRC demonstration projects. The assessment includes acquisition and review of published information, discussions with R&D personnel involved in relevant activities, visits to sites of important R&D activities, monitoring of critical R&D operations, accessing, to the extent possible, the proprietary information of importance to the project, and cross-matching R&D activities to the technical data needs of the industrial partners in the demonstration project. Based on the assessment of R&D activities against the data needs of the SRC demonstration projects, recommendations will be formulated, including: priority of activities; adequacy of the R&D program; the need for possible acceleration, extension, or redirection of current activities; and possible new activities required beyond the current program.

13.2.2 Status summary

The draft report, ORNL/TM-6952, "Technical Support of the SRC Demonstration Project: Assessment of Current Research and Development," was widely distributed, particularly to those institutions whose activities in coal conversion research are described within the report. Comments and updates have been incorporated into the final report which is in publication. It will be issued as ORNL/TM-6952 within the next few months.

13.3 SRC Source Data Book

J. P. Belk, M. H. Culver, J. R. Horton, M. R. Lambert,
H. A. Mitchell, B. Niemann, W. R. Reed, J. R. Tate,
B. T. Thompson, W. T. Thompson

13.3.1 Contract objective

The objective of this project is to develop and to make available in one package an independent source of technical information and data base as an aid to DOE program management and other participants in the DOE program to design, construct, and operate SRC demonstration plants.

13.3.2 Status summary

An activity description for the source book has been prepared, approved, and entered in project files. Information in the activity description reflects the content of the current work statement, which was prepared for FY 1979. An updated activity description will be prepared when the FY 1980 work statement is submitted and approved. Work breakdown structure and milestones for the FY 1980 work statement for the SRC source data book are being prepared for peer review, management approval, and submission to DOE-ORO.

13.4 SRC Environmental Support

S. G. DeCicco

13.4.1 Contract objective

The objective of this project is to provide DOE with program assistance in the performance of environmental assessment functions related to the SRC projects. Assessment functions include review of environmental monitoring programs and results, guidance to DOE's industrial partners in their environmental impact analyses, review of environmental permits and licensing requirements, review of SRC contract deliverables, and providing the lead role in fulfilling DOE's responsibilities under the National Environmental Policy Act (NEPA).

13.4.2 Status summary

Progress on the preliminary draft environmental impact statements (PDES) for the SRC-I and SRC-II projects has been constrained by inadequate starting materials. Pittsburgh and Midway Coal Mining Company (SRC-II) submitted their environmental analysis report in October. The report was to provide ORNL with plant design information, environmental monitoring data, and analyses of impacts, all of which had been carefully delineated by ORNL. The report had too many important omissions for ORNL to begin writing the PDES. Pittsburgh and Midway Coal Mining Company and Stearns-Roger (A/E and environmental subcontractor) used the month of November to prepare the remaining portions of the report. During the entire week of November 26-30, a meeting was held in Denver to secure this information; ORNL was represented.

Earlier in the month (November 15, 1979) a meeting was held at ORNL at DOE's request. A representative of DOE's Office of NEPA Affairs used the opportunity to meet ORNL's EIS team and discuss the plans for the EISs. A new SRC-II EIS schedule was proposed that took into account the late arrival of the complete information package. This schedule shows an ORNL EIS status report to DOE on January 1, 1980; followed by a PDES to DOE on February 8, 1980; and a draft EIS (DES) on March 28, 1980. DOE hopes to issue the DES on April 24, 1980.

The SRC-I project is over a month behind the SRC-II project due to a long and continuing succession of problems that Air Products, Rust Engineering, and Dames & Moore have had in preparing their environmental analysis report. Draft sections of the report have been dribbling into ORNL for review over the last two months and by the end of November the draft report was complete with the exception of plant design alternatives. The ORNL staff is preparing comments on the draft report. Dames & Moore is expected to issue a final report by late January 1980. Until we can estimate when Dames & Moore will complete their segment of the work enabling ORNL to begin, there is no basis for projecting an EIS schedule for the projects.

Also during November, Texaco cleared all data from the slag leaching experiments for use in the EISs.

13.5 H-Coal Materials and Technology Review

R. A. Bradley, K. H. Lin, P. Carlson, V. Guthrie, J. R. Horton,
H. A. Mitchell, B. Niemann, L. Parsly, W. R. Reed,
R. W. Swindeman

13.5.1 Contract objective and scope

Overall objective - Evaluation of the materials of construction and the coal liquefaction technologies and equipment to be used in the H-Coal

pilot plant relative to the available data and experiences. The evaluation will attempt to ensure the maximum utilization of the existing information and experiences from other liquefaction pilot plants and process demonstration units (PDUs), and to provide the bases for efficient and reliable operation of the plant.

Scope - The project activities will cover the following five subjects pertaining to the H-Coal pilot plant:

1. materials of construction and potential materials-related problems in the plant;
2. reliability of critical components in the pilot plant design;
3. potential problems associated with the plant equipment and accessories due to deficiencies in the engineering design;
4. significant operating and maintenance experiences from other liquefaction pilot plants, which will be useful to the H-Coal pilot plant, and
5. an "incident report" system to distribute information on technical problems.

13.5.2 Status summary

H-Coal data review and analysis of information from other coal liquefaction facilities - Review of the operation and design data for the H-Coal pilot plant is continuing. Also being reviewed is the information acquired during visits of the Task Force members to the SRC-Ft. Lewis Pilot Plant, the HRI-Trenton PDU and the C-E Lummus Company to extract data of importance to the H-Coal plant. The results of these reviews served as the primary basis for preparation of the preliminary assessment report for the H-Coal plant.

Visit to coal liquefaction facility - A site visit was made by the Task Force representatives to the SRC-I process demonstration unit at Wilsonville, Alabama, on November 27, 1979. Highlights of the visit follow.

Meeting Participants: Catalytic, Inc. (4), DOE (1), Task Force (5)

Major Subjects of Discussion: (a) brief background information on SRC-I process at Wilsonville, (b) experiences with critical systems and components [e.g., slurry recirculation pumps, filtration system (Fonda and U.S.), letdown valves (Fischer and Consolidated), pre-heaters, vacuum column, and solvent wash column], (c) corrosion and erosion problems (corrosion mainly in low temperature area, e.g., vacuum and solvent wash columns; erosion in filter, letdown valves, and pumps), (d) decoking procedure, and (e) tour of PDU.

Preparation of preliminary assessment report - The preliminary assessment report entitled "Preliminary Assessment of H-Coal Pilot Plant, Catlettsburg, Kentucky" was completed, and was distributed among a limited number of persons within the DOE-ORO and UCC-ND/ORNL. A copy was also sent to ASFI for their review prior to a meeting between ASFI and Task Force members during the week of December 17, 1979.

The report presents the preliminary results of the work being carried out by the H-Coal Materials and Technology Task Force whose task is to provide DOE-ORO with an independent assessment of materials of construction, process technology, and equipment to be used in the H-Coal pilot plant. The emphasis is placed on (a) identification of potential problems associated with the materials of construction, equipment and engineering design, and (b) assessment of the adequacy of the operating procedure and plans for corrective actions to deal with the problems.

13.6 Materials Testing and Failure Analysis

R. W. Swindeman, V. B. Baylor, J. R. Keiser

13.6.1 Contract objective

The objective of this activity is to provide technical assistance to the H-Coal pilot plant project in the areas of materials testing and failure analysis.

13.6.2 Status summary

Personnel involved in the H-Coal project attended a meeting at ORNL on corrosion problems in fractionation columns. Represented were Hydrocarbon Research, Inc. (Trenton), Ashland Synthetic Fuels, Inc. (Catlettsburg), Ashland Oil Research (Ashland), Kentucky Center for Energy Research (Lexington), and American Oil Company (Naperville). Corrosion problems in the fractionation columns of SRC plants were discussed, and techniques of monitoring and inhibiting the corrosion rate were examined.

A draft of the H-Coal failure analysis and materials evaluation plan was sent to several H-Coal project participants. The failure analysis reporting scheme was discussed with NBS personnel.

13.7 H-Coal Quality Assurance Assistance

K. K. Klindt

13.7.1 Contract objective

The objective of this task is to provide technical support to DOE SRC in the resolution of weld quality problems in the piping system at the H-Coal pilot plant.

13.7.2 Status summary

Trips have been made to H-Coal pilot plant, Catlettsburg, Kentucky, on November 5-9, 14-16, and 27-30, 1979, to determine the action to be taken on ultrasonic indications found in welds during the base-line inspection for later in-service inspection. These inspections are on both stainless steel and carbon steel double extra heavy pipe systems.

During the initial trip on November 5-9, it was found that with about 75% of the applicable welds ultrasonically inspected, 140 out of 706 contained indications. The attempts to confirm the UT indications with the use of radiography were only partially successful; however, sufficient small X-ray indications were found to create concern as to the possibility of starting a rather large repair program. Radiography was being performed using special techniques and very fine grain film in the effort to find the reason for the UT indications. All the radiographs were reviewed, including the special technique shots. It was agreed that some evidence of minor imperfections could be seen in some film. With one exception these were so minor that it was debatable as to whether a repair might be more detrimental than the presence of imperfection. It was suggested that the determination as to the need for repair should be by a nonconformance review board and not by the inspectors. This suggestion was followed and plans were made to select the review board and meet on November 15.

On November 14-16, a trip was made to assure that the necessary information was available for the review board meeting. Assistance in interpretation was provided during the nonconformance review.

On November 27-30, a trip was made to interpret all field radiographs of the applicable welds made during the construction and also new radiographs of the Gulf and Western shop welds. The radiographs for 100 welds were interpreted.

13.8 Performance Assurance System Support

H. A. Mitchell, V. H. Guthrie, L. F. Parsly, A. N. Smith

13.8.1 Contract objective

The ORNL Performance Assurance System Support Office is responsible for acquiring, generating, and disseminating information relating to performance assurance (PA). The Support Office will provide performance assurance related technical support services to those Fossil Energy programs under the decentralized management control of the Oak Ridge Operations Office and to programs under the direct management control of the Washington Headquarters Office. The Support Office will, as required, design and develop appropriate procedures, tools, and methodology necessary to provide the PA support services indicated.

Two specific tasks have been initiated at the request of Fossil Energy Headquarters Office: (1) preparation of generic failure modes and effects analyses and (2) assistance to SRC projects to review contracts and deliverables.

13.8.2 Status summary

An action plan was developed during the previous reporting period describing the preparation of a generic failure mode and effects analysis (FMEA) for Task 1. Based on that action plan, a review of systems and components in the SRC-I, SRC-II, and H-Coal projects was performed to identify components common to all systems. As a result, a generic FMEA of a slurry preheater is being prepared.

A failure modes and effects analysis (FMEA) work sheet and an explanation to be used in the preparation of the FMEA were developed. First drafts of the FMEA for selected items which make up the preheater have been completed and detailed information from pilot plant experience has been incorporated. It is expected that a preliminary draft of the work sheet and system description of the preheater will be available during the next reporting period.

As part of Task 2, the performance assurance support group assisted in the preparation of rough drafts of standard requirements for safety, reliability, and quality assurance at the request of Fossil Energy Headquarters Office. The scope of the standards includes minimum management and technical requirements necessary to provide an adequate performance assurance program.

A meeting was held on November 2, 1979, at Oak Ridge Operations Office with DOE-HQ and DOE-ORO personnel. The purpose of the meeting was to discuss, with representatives of the ORO SRC Projects Office and ORO safety and quality assurance (QA) organizations, the policy and procedures for the incorporation of performance assurance requirements and activities in Fossil Energy programs. These requirements and activities are primarily based on the rough drafts of standard requirements for safety, reliability, and quality assurance described above. In summary, major comments were discussed and the response was judged acceptable.

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