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

L. E. McNeese

MASTER

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FOSSIL ENERGY PROGRAM
PROGRESS REPORT FOR SEPTEMBER 1979

L. E. McNeese
Program Director

Date Published - November 1979

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
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FOSSIL ENERGY PROGRAM REPORT FOR SEPTEMBER 1979

ABSTRACT

This report - the sixty-second of a series - is a compendium of monthly progress reports for the ORNL research and development programs that are in support of the increased utilization of coal 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 September are as follows:

Coal Conversion Development - The gamma radiation absorption liquid density instrument was calibrated using a variety of solids-free organic liquids and coal-solvent slurries at room temperature and atmospheric pressure. Maximum deviation from a least squares fit to these data was 0.021 specific gravity units. The least squares fit will be the instrument calibration for future measurements on slurries at processing conditions. Two experiments were performed in the Coal Liquids Flow System during the month but operating difficulties prevented long-term operation. Corrections have been made for these problems that are expected to significantly improve the operation of the system. A paper entitled "Rheological Characterization of Coal Liquefaction Preheater Slurries" has been prepared for publication. The chemical oxidizing system, $\text{CF}_3\text{COOH}/\text{H}_2\text{O}_2/\text{C}_2\text{SO}_4$, developed by Deno and co-workers, preferentially attacks aromatic structures and preserves most of the aliphatic structures. This oxidation has been performed on products from the reaction of phenol with Wyodak coal to aid in elucidating the hydrogen transfer mechanism. The products were examined by ^1H NMR, gas chromatography and mass spectrometry. Fabrication of the field testing units of the portable fluorometric spotter continued during September.

Chemical research and development - Unexpected thermolysis reactions of 1-naphthol at 400°C have been discovered. The major product results from condensation of two naphthol molecules to give a dinaphthofuran. Minor products are still being identified.

Materials Engineering - The study of the effect of coal conversion environment on the mechanical properties of pressure vessel steel was continued. The 400-h autoclave run in which specimens with different microstructures resulting from various heat treatments were exposed to hydrogen at 1500 psi and 490°C was completed. In the task to develop techniques for weld overlay cladding with type 320Cb stainless steel, a subcontract was placed with Sandvik, Inc. to produce strip clad weld samples for evaluation. The study of fireside corrosion of AFBC heat exchanger materials continued. Metallographic examination and scale thickness measurements on samples from the 4500-h test in the Fluidyne AFBC are in progress, but results are not yet available. In the Failure Prevention and Analysis task, corrosion in the fractionation column at the Wilsonville SRC pilot plant and in the wash solvent column of the Ft. Lewis SRC pilot plant was investigated. The identity of the corrosive is still unknown. The assembly of the apparatus to evaluate materials for the zinc chloride regeneration system in the zinc chloride liquefaction process was completed and determination of thermal gradients was begun. In the study of stress corrosion cracking in coal liquefaction environments, the exposure of U-bend specimens in the Wilsonville and Ft. Lewis SRC pilot plants continued. A significant milestone was achieved in the development of advanced 9 Cr-1 Mo structural steel with the melting of two 15-ton heats by Carpenter Technology Corporation. Chemical analyses indicated that both heats met our specified chemistry. In the ceramic recuperator task, the first 500-h test of candidate structural ceramics was initiated in the Ceramic Recuperator Analysis Facility.

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 for submission to DOE. The major conclusion is that equipment for the projected requirements for coal handling and preparation and ash/slag removal is currently available or can be readily scaled up from existing equipment. Recommendations are made for future study on individual components and approaches for achieving high plant operating reliability of coal and ash handling equipment. Work has been started on a bench scale system designed to simulate pressure letdown of a coal liquefaction plant slurry product from the dissolvers. Support for the H-coal materials and Technology Task Force continued and was concerned with an evaluation of operating conversion plant component failure data.

Engineering Studies and Technical Support — Final revision of one of the last three reports related to the Survey of Industrial Coal Conversion Equipment Capabilities: Equipment Operating Experience, Prices, and Development Programs (ORNL/TM-6587) is complete and distribution is expected in November. The report discusses equipment operating experience in pilot plants supported by the Department of Energy; presents equipment price correlations, based on vendor estimates and suitable for initial conceptual design cost estimating; and reviews the scheduling and economics of equipment development programs.

Process and Program Analysis — Monitoring of the IGT HYGAS pilot plant operations by Scientific Design Company (SD) was discontinued this summer and a final report describing results of their evaluation is nearly complete. A consultant, Fred A. Zenz, has been asked to assess the problems of clinker formation and fluid bed system scale-up, about which SD and IGT have differing viewpoints.

Fossil Energy Environmental Project — In the Stored Solids Study, soil samples were obtained from the proposed site for the SRC-I project. Studies using continuous flow leaching columns have been initiated. In the Resource Recovery work, three gasifier wastes have been subjected to direct leach with refluxing 6 N hydrochloric acid to determine the feasibility of removing hazardous trace elements leaving a more inert residue for disposal.

Work is underway on EIS preparation for all six demonstration projects. Draft Environmental Reports or their equivalent have been received from the industrial partners for four of the projects.

Magnetic Preparation of Dry Crushed Coal — The general mathematical model for calculating the fields and gradient of solenoids is now operational and being verified for accuracy. Preliminary calculations indicate that our present laboratory solenoid may generate adequate force to accomplish open-gradient separations.

The new laboratory space has been prepared in Building 9201-3, the equipment has been moved from the 9204-1 laboratory, and the superconducting magnet is being installed and prepared for operation.

The TVA guest engineers have completed the bulk of the chemical comminution tests and have samples ready for chemical analysis.

Atmospheric Fluidized Bed Coal Combustor for Cogeneration (AFBCCC) — The work statement for the subcontract was prepared by ORNL and submitted to Westinghouse at a meeting on September 13. It has been revised at their request and submitted for their acceptance. It is projected that the subcontract package will be sent to Westinghouse about October 10 for their acceptance and signature.

TVA FBC Demonstration Plant Program - In AFBC technology support, the review and evaluation of the proposals submitted by Babcock and Wilcox (B&W) and Combustion Engineering to TVA for designing and building an AFBC pilot plant have been completed. A letter report, summarizing the team's integrated comments and specific discussions, was delivered to TVA. During the past month, ORNL started an additional related activity in support of TVA's effort to clarify issues of concern and modify B&W's design as necessary until a final acceptable design is achieved.

Cold Flow model slumping tests have been conducted over a range of fluidizing velocities from 1 to 2 ft/sec and bed depths from 1 to 1.5 ft to represent scale studies of values four times as large. These tests completed the testing of the 1/4 scale factor slumping tests. The data are being analyzed and a report is in preparation.

For the AFBC Modeling effort, during the month an abstract for a paper on attrition in fluid beds was prepared and submitted to the Powder and Bulk Solids Conference in Chicago, Illinois. Work on the attrition-elutriation model continued. Specifically, the coal ash section was added. During this process, the difference between the nature of the coal ash and limestone feed size distributions were noted. Coal ash size distribution is best fit by a semi-log plot, while limestone is fit by log-log plot. Numerical problems have been encountered in the ash attrition-elutriation code. These are currently being analyzed. Morgantown Energy Technology Center data were analyzed. Because of the operating conditions and geometry, these data may not be applicable to utility AFBC's.

In the AFBC Bench Scale Facility, four combustion runs totaling 12-1/2 hours were completed during September. A superficial velocity of 6 ft/sec and a bed temperature of 1470°F were maintained in order to study the effects of lower bed temperature on sulfur capture. During the period of September testing, the bed particles had a harmonic mean size of 875 μm (based on the size-weight distribution) and a median (50 percent) size of 1020 μm . Particle densities averaged 71 lb/cu. ft. The bulk of activity during September was oriented toward preparation of coal and limestone for the TVA materials tests. The 100 drums of coal contained about ten percent moisture when received; therefore, it was necessary to dry the coal prior to any attempt at crushing and/or screening. Two drums of the first limestone to be tested have been dried, crushed, and screened.

Work on the final report on the PFBC state-of-the-art is continuing. Development facilities are being contacted by phone in order to obtain the most recent status on ongoing development programs.

In the Analytical Support Task, performance analyses have been completed for 38 cases. Thus far we have investigated the following parameters: velocity, bed height, excess air, above bed combustion, coal and limestone size, bed ash size, operation without a CBC and without recycle, operation without a CBC but with recycle, coal reactivity, and bed particle density.

In the AFBC Source Book, an addition was made to the heat transfer section to include estimation of heat transfer coefficients for a fluidized bed in turbulent flow regime. A draft of the fluidization section has been prepared. For a selected representative subsection (chosen as the formula for bed expansion ratio), the following are being included:

1. Graphical representation of results of calculation;
2. A programmable calculator program for doing the calculation; and
3. If possible, a nomogram will also be included.

In Materials Support, the review of the proposals submitted to TVA by Babcock & Wilcox and Combustion Engineering for the AFBC Pilot Plant was completed and comments relevant to materials considerations were forwarded to project management. In addition, discussions were held with TVA personnel regarding changes in the original proposal by B&W involving deletion of the carbon burn-up cell together with a number of other modifications.

In Dynamic Modeling, a sulfur capture submodel was added to the simulation of the pilot plant. A calculation was made with the model to explore the sensitivity of SO_2 capture to change in load. A 1% reduction in firing rate was made at constant C/S ratio, and the changes in equilibrium values of selected variables evaluated. A part of the month was spent in further review and evaluation of the pilot plant proposals.

Coal Cogeneration/District Heating Plant Assessment - The St. Paul District Heating Development Company is developing preliminary cost estimates for the first segment of a 200-MW hot water district heating system.

On the Coal/Cogeneration Power Plant study, Northern States Power and United Engineers and Constructors reevaluated the temperature criteria and concluded that the maximum temperature of 270°F is more appropriate for hot water district heating in the Twin Cities.

Technical support to major liquefaction projects - The level of support effort for the SRC projects was reduced this month after completion in August of the review and evaluation of Phase 0 deliverables. SRC environmental support continued. A Notice of Intent to prepare an EIS was written for each SRC project and sent to DOE-HQ for publication in the Federal Register. Although DOE held a public scoping meeting for each project, it has been decided that additional meetings should be held and announced nationally via the Federal Register.

2. COAL CONVERSION DEVELOPMENT

J. R. Hightower, Jr.

Coal conversion development activities are carried out in the Chemical Technology Division. This section discusses four projects conducted for the Division of Fossil Fuel Processing -- Physical Properties of Coal Liquids, Coal Slurry Preheaters, New Liquefaction Techniques, and In-Plant Environmental Monitors.

2.1 Physical Properties of Coal Liquids

G. E. Oswald and E. L. Youngblood

Physical properties (viscosity, density, thermal conductivity, and heat capacity) of both coal-solvent slurries and solids-free, coal-derived liquids will be measured at typical processing conditions, up to 31 MPa (4500 psig) hydrogen pressure and 810 K (1000°F) in a bench-scale, continuous flow system, the system includes a slurry preheater section 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 with chemical characteristics of the test liquid.

Calibration and theory of operation for the gamma radiation absorption liquid density instrument are discussed in this section.

2.1.1 Work accomplished

The gamma radiation absorption liquid density instrument, Figure 2.1, was calibrated using a variety of solids free organic liquids and coal-solvent slurries. Test liquids were circulated, at 2 liter/min rate, through the 2.95 cm ID flow section at room temperature and atmospheric pressure. Results are presented in Figure 2.2. The abscissa is arbitrary units representing the linearized output of the ion chamber detector in response to incident radiation which has passed through the test liquid. Hydrometers were used to measure test liquid density. Calibration data is presented in Table 2.1. Maximum deviation from a least squares fit to these data was 0.021 specific gravity units (SGU) for acetone (0.755 by gamma attenuation, 0.776 by hydrometer). Maximum deviation for the three slurries measured was 0.016 SGU. The least squares fit will be the instrument calibration for future measurements on slurries at processing conditions. The accuracy of density measurements is not affected by the pressure or temperature of the process liquid so accuracy within 0.02 SGU is expected for on-line measurements at processing conditions. Measurements are subject to variations in the atomic composition of the test liquids as explained below. These effects cause the slight scatter in the calibration measurements.

GAMMA ABSORPTION LIQUID DENSITY GAUGE

Fig. 2.1. Gamma absorption liquid density gauge.

ORNL DWG 79-1601

Fig. 2.2. Gamma radiation absorption density instrument calibration liquid density (g/cm³) vs linearized detector output.

Table 2.1. Gamma radiation absorption density
instrument calibration data

Test liquid	Temperature (k)	Density (g/cm ³) ^a	Linearized detector output
Hexane	297	0.663	968.0
Acetone	301	0.776	965.2
30% Coal-Hexane Slurry	302	0.793	963.5
Ethanol	302	0.821	963.0
Ethanol	292	0.832	962.6
Recycle Solvent (Wilsonville)	297	0.990	957.5
H ₂ O	301	1.000	957.0
30% Coal-Mobil Solvent Slurry	301	1.053	956.0
35% Coal-Recycle Solvent Slurry	302	1.086	954.2

^aBy hydrometer.

Gamma Radiation Absorption Theory — As gamma radiation passes through matter it undergoes absorption by interacting with atoms of the absorbing material. The decrease in the energy of an incident beam of gamma radiation is exponential in form, as expressed by Lambert's law:

$$I = I_0 e^{-\mu \rho x} \quad (1)$$

where

I_0 = radiation at the detector with no process liquid in pipe

I = radiation at the detector with process liquid in the pipe

μ = mass absorption coefficient (cm^2/g)

ρ = density of process liquid (g/cm^3)

x = internal diameter of the pipe (cm)

The internal diameter of the pipe is constant, and the mass absorption coefficient is nearly constant for the variation in atomic composition expected for coal-solvent slurries. Therefore, the resultant radiation, I , is only a function of process liquid density, and the linearized detector output, logarithm of I , is directly proportional to changes in process liquid density.

Table 2.2 lists the mass absorption coefficients for the major atomic constituents of coal and process solvents. These values are at the 662 keV energy level emitted by the Cs 137 gamma radiation source used in the instrument. Mass absorption coefficients for slurries or solvents can be calculated by equation 2 independent of state-solid or liquid:

$$\mu_{TOT} = \sum_i \mu_i m_i \quad (2)$$

where

μ_{TOT} = mass absorption coefficient for process liquid

μ_i = mass absorption coefficient for each constituent i

m_i = mass fraction of constituent i

The mass absorption coefficient for hydrogen is about double that for the other elements; so absorption will be somewhat sensitive to process liquid hydrogen content. In CLFS experiments to date, the hydrogen content of product slurry has been about 8.5% and for feed slurry about 7%. This would result in an absorbance variation of 3% or 0.03 SGU at a nominal specific gravity of 1.0. So this effect is small and will not mask density changes resulting from thermal and absolute pressure effects.

Table 2.2. Mass absorption coefficients - $(\text{cm}^2/\text{g})^a$
at 662 keV photon energy - Cs 137

Element	μ
C	0.0777
H	0.1540
N	0.0775
O	0.0777
S	0.0779
Si	0.0777
Al	0.0750
Fe	0.0738

^aPhoton cross sections, attenuation coefficients, and energy absorption coefficients from 10 keV to 100 GeV, (NSRDS-NBS 29) 1969.

Although small, corrections will be made on density measurements for the effects of pipe thermal expansion. The decrease in pipe wall density and hence decreased radiation absorbance with increasing temperature will be determined by measuring the amount of radiation passing through the empty pipe over the span of measurement temperatures. Also, a correction will be made for the small increase in pipe internal diameter with increasing temperature. This results in a slight increase in the radiation beam path through the test liquid.

2.1.2 Future work

The density instrument will be installed at the preheater discharge, and measurements will be made on 35 wt % slurry from 450 K (350°F) to 700 K (800°F) at 13.9 MPa (2000 psig) pressure. The slurry will be sampled for chemical characterization.

2.2 Coal Slurry Preheaters

E. L. Youngblood and J. R. Thurgood

This preheater project is principally concerned with thermal and rheological characterizations of slurry flow in preheaters at preheating conditions (pressures up to 31 MPa and temperatures to 810 K). Experiments are made in conjunction with a companion project, Physical Properties of Coal Liquids.

2.2.1 Work accomplished

Work continued to improve the operability of the Coal Liquids Flow System and to prepare a paper for publication in the open literature describing the rheological studies done thus far. Two experiments were performed during the month, but operating difficulties prevented long term operation. During the first experiment, the pumping rate of the slurry feed pump was very erratic. It was determined that the seals on the slurry circulating pump were allowing air to be drawn into the slurry ahead of the feed pump suction. After the seals were replaced and the air inleakage was stopped, operation of the feed pump was very stable. The second experiment was terminated when a blockage occurred near the inlet of the reactor. The blockage appeared to have resulted either from incompletely cleaned out of the equipment prior to the experiment or from a cold spot in the slurry line near a block valve. Correction of these problems is expected to significantly improve the operation of the system. The ventilation system for the facility has been improved by installing an exhaust duct directly above the equipment.

A paper entitled, "Rheological Characterization of Coal Liquefaction Preheater Slurries," has been prepared along with R. W. Hanks* who is a consultant for ORNL. The paper presents a correlation of the rheological data obtained thus far and will be submitted for publication in the near future.

2.2.2 Work forecast

Additional rheological measurements will be made using Illinois No. 6 coal and Wilsonville recycle solvent to expand and also determine the reproducibility of the rheological data obtained thus far with Illinois No. 6 coal and Wilsonville recycle solvent.

*Chairman, Chemical Engineering Department, Brigham Young University, Provo, Utah.

2.3 New Liquefaction Techniques

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

There are a variety of chemical oxidants which have been used to elucidate the structure of coals. Such common oxidants as O_2 , HNO_3 , $Mn(VII)$, and CrO_3 have all provided useful information in this regard, but are less than ideal principally because they destroy much of the aliphatic structure¹ in coal, but do not degrade the more complex aromatic structure.

Deno and co-workers have developed an oxidative technique which uses $CF_3COOH/H_2O_2/H_2SO_4$ as the oxidizing species.² They report that this reagent is unique in that it preferentially attacks aromatic structures, but preserves most of the aliphatic moieties.^{3,4} Further, they have demonstrated that when coal is subjected to trifluoroacetic acid (CF_3COOH) oxidation, benzene polycarboxylic acids are formed only from polyaromatic clusters.²⁻⁴ Such a process provides a means both of elucidating the highly informative aliphatic character of coal and also revealing, indirectly, the aromatic structure. The technique also has the advantages of being relatively uncomplicated and rapid.

Our process, coal liquefaction using phenol and heat, has shown that a hydrogen shuffling process occurs within the coal and results in the formation of a high yield of lower molecular weight, pyridine-soluble products. It is believed that determining the aliphatic (hydrogen) structure in the parent coal, in the soluble products, and in the insoluble residue will provide the most valuable information about the origin and fate of the hydrogen which participates in the shuffling process. Initially, we investigated Wyodak coal. Our liquefaction technique was highly successful with the initial subbituminous coal, Wyodak. Deno and co-workers have also investigated the structure of Wyodak coal.⁵ We will apply the method to the analysis of the soluble extract and insoluble residue of Wyodak coal after liquefaction, and also to a bituminous coal, Bruceton, during the next month.

We examined the methyl esters of the carboxylic acid product by ¹HNMR and by gas chromatography, and compared the results with selected standard reference compounds. Subsequently, the product and reference esters were analyzed in greater detail by gas chromatographic separation followed by mass spectral analysis. The methyl esters were separated on a 6-ft stainless steel column packed with three percent SE-30 on NAW Chromosorb W. A temperature program from 130°C to 260°C at 80/min was used. Nitrogen at 30 cc/min was the carrier gas. Each separated component was subjected to electron-impact mass spectroscopy at 70 eV.

Table 2.3 summarizes the results of the gc/ms analysis of Wyodak coal. It agrees substantially with Deno and co-workers⁵ but there are some significant variances. Deno et al. found that acetic, malonic, and succinic acid are the predominant aliphatic products, and from the

Table 2.3. A summary of the analysis of Wyodak coal
after oxidation and esterification

Retention time (min)	Molecular weight	Compound
1.5	132	$\text{CH}_3\text{OOCCH}_2\text{COOCH}_3^a$
2.0	146	$\text{CH}_3\text{OOCCH}_2\text{CH}_2\text{COOCH}_3^a$
2.5	160	$\text{CH}_3\text{OOC}(\text{CH}_2)_3\text{COOCH}_3^b$
3.4	204	$\text{C}_2\text{H}_3(\text{COOCH}_3)_3^c$
3.8	218 ^a	$\text{C}_3\text{H}_5(\text{COOCH}_3)_3^c$
5.0	218 ^b	$\text{C}_3\text{H}_5(\text{COOCH}_3)_3^c$
6.5	262	$\text{C}_2\text{H}(\text{COOCH}_3)_4^c$
7.8	276	$\text{C}_3\text{H}_4(\text{COOCH}_3)_4^c$
10.3	252	$\phi(\text{COOCH}_3)_3^d$
13.8	310	$\phi(\text{COOCH}_3)_4^d$
16.5	368	$\phi(\text{COOCH}_3)_5^c$
19.4	(404) ^e	
22.2	(404)	
26.2	(404)	

^a Sample data corresponds to data from reference compound and with spectra in: A. Cornu and R. Massot, "Compilation of Mass Spectral Data," Heyden, London, 1975; E. Stenhagen, S. Abrahamsson, and F. McLafferty, (eds.), "Registry of Mass Spectral Data," John Wiley, New York, 1974.

^b Sample data corresponds to spectra in literature cited in a above. No reference compound analyzed.

^c A postulated formula ϕ = benzene.

^d Sample data corresponds to spectra of reference compounds. Literature data not available ϕ = benzene.

^e 373 + 31.

relative peak height found the quantities to be in the order malonic > succinic >> acetic acid. The amount of acetic acid recovered is related to the amount of sulfuric acid used in the oxidation reaction.⁵ In repeated samples analyzed by FT-¹HNMR we have failed to observe any acetic acid. There is a discrepancy in our ¹HNMR and gas chromatographic analysis of the relative quality of amloric, succinic, and glutaric acid. The resolution of this is incomplete.

The peak in the gas chromatographic trace at retention time 2.5 is prominent in our data. The mass spectrum corresponds to dimethyl glutarate (Table 2.3). Deno et al. reports the complete absence of this compound in their investigation.⁵ In addition, two other aliphatic products were observed in our analyses. The compound with molecular weight 204 shows a large, sharp gas chromatographic peak, and the 218 species is the most prominent in the chromatogram.

The identity of dimethyl malonate and dimethyl succinate is unequivocal. Based on chemical ionization analyses, Deno et al. have assigned the structure $(\text{CH}_3\text{O}_2\text{C})_2\text{CHCH}_2\text{CH}_2\text{CO}_2\text{CH}_3$ to the 218 species. He does not postulate the structure of the 204 compound.⁵ The formula $\text{C}_2\text{H}_2(\text{CO}_2\text{CH}_3)_3$ is reasonable because it accounts for the difference of 14 in the mass compared to the 218 species. The compounds 262 and 276 have not been confirmed. Table 2.4 shows that the relative intensities of the characteristic mass spectral peaks are similar to those of 204 and 218, respectively. The differences in the mass values suggest the loss of COOCH_3 , CO_2 , or CH_2 from the larger homologue (Table 2.4). The assignment of $\emptyset (\text{COOCH}_3)_3$ as the structure at retention time 10.3 (ms 252), and $\emptyset (\text{COOCH}_3)_4$ at retention time 13.8 (mw 310) was made by comparison to

Table 2.4. Relative intensities of characteristic mass spectral ion fragments

Retention time (min)	Molecular weight	P-31	P-30	P-59	59
3.4	204	.7	--	1.5	100
3.8	218 ^a	.1	--	.2	56
6.5	262	1.7	--	3.3	100
5.0	218 ^b	13	.9	19	100
7.8	276	6	.6	2	100

reference compounds. From the mass spectrum, the structure ϕ (COOCH₃)₅ can be assigned to the compound with the retention time 16.5 (mw 368). The mass spectra for the series of peaks which follow at 19.4, 22.2, and 26.2 minutes are unresolved. It is possible that these species are isomers. The relative intensity of many of the ion fragments also correspond to those on the spectrum at 16.5 minutes. Table 2.5 summarizes the intensity at mass values which appear to be the most important. The parent molecular ion is uncertain. The intensity at mass 373 is prominent in all three species. The apparent loss of a molecule of water (-18) to produce the fragment at mass 355 is striking, and suggests the presence of adjacent H and OH moieties. If 373 represents the P-31 fragment, the molecular weight of all three species is 404. One possible formula is (CH₃COO)₅C₆H₆ - CH₂OH. Chemical ionization mass spectroscopy is being carried out to determine the molecular weight of these fractions unambiguously.

2.4 In-Plant Environmental Monitors

D. D. Schuresko and M. S. Blair*

Fabrication of the portable fluorometric spotters for field testing continued during September. Several design changes have been incorporated into these units during their fabrication. One such change has been relocation of much of the uv lamp ignition circuitry from the electronics module to the optics head. Thus the problem of having to use lamp supply cables which can handle 6 amps of steady current and which are insulated to 5 kilovolts is resolved with the use of separate current supply and lamp ignition lines. The 600 VDC, 0.33 MFD capacitor and the silicon controlled rectifier (SCR) which discharges this capacitor through the ignition pulse transformer have also been relocated to the optics head so that the ignition lines in the umbilical cable connecting the optics and electronics units carry the charging voltage and not the fast SCR discharge. Laboratory testing and check-out of the field evaluation units should begin shortly.

*Instrument and Controls Division.

Table 2.5. Relative intensity of characteristic mass spectral fragments
for high molecular weight products in Wyodak coal after oxidation

Retention time (min)	Molecular weight	399	373	369	355	341	339	338	337	335	309	59
16.5	368	---	---	.4	3	1.4	3.5	17	100	3	2.4	13
19.4	(404)	5.1	24	11	80	29	7	--	9.7	39	6.5	52
22.2	(404)	---	23	10	80	32	6	--	---	7	---	24
26.2	(404)	2.6	19	9	75	30	5	--	---	--	---	11

2.5 References

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3. CHEMICAL RESEARCH AND DEVELOPMENT

M. L. Poutsma

3.1 Chemistry and Structure of Coal

M. L. Poutsma

Our exploratory studies over the last few months concerning the co-thermolysis of bibenzyl and 1-naphthol were based on the tacit assumption that any chemistry of 1-naphthol would be induced only by radicals produced by homolysis of bibenzyl. We have now discovered this hypothesis to be wrong. In spite of having no weak covalent bonds, compared with bibenzyl, 1-naphthol shows a complex thermolysis chemistry at 400°C. The major product is dinaphtho[1,2-b; 2',1'-d]furan; four other organic products are formed whose identity remains to be conclusively demonstrated; the stoichiometry of furan formation implies production of water but this has not yet been verified.

Ten exploratory runs have been performed at varying pressures and reaction times. Not only the product distribution but also the conversion level (in contrast with the behavior of bibenzyl) is strongly dependent on 1-naphthol pressure, suggestive of a kinetic order greater than one. However, major scatter among the individual results suggests that some reaction variable is still eluding our grasp.

We plan to examine this reaction of 1-naphthol further because of its relevance to pyrolytic chemistry of the phenolic groups in coal. The furan-forming condensation reaction and probable release of water, which are quite rapid even at 400°C, have obvious implications as possible modes of oxygen removal and residue formation during coal processing.

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, Division of Planning and Systems Engineering, Fossil Energy. Other related work funded by the Division of Fossil Fuel Utilization and the Division 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 the 400-h autoclave run in which specimens with different microstructures resulting from various heat treatments were exposed to hydrogen at 1500 psi and 490°C. Following disassembly, it was determined that the loss of strain gage signals was due to separation of the copper lead wires. The cause of the separation was not apparent; however, in future assemblies the lead wires will be reinforced.

The facility is also being upgraded in preparation for the next run.

4.2 Fossil Energy Welding and Cladding Development

J. F. King and G. M. Goodwin

A contract has been established with Sandvik, Inc. to develop strip cladding techniques for depositing type 320Cb stainless steel and other materials of interest on 2 1/4 Cr-1 Mo steel. We will receive clad plates 305 mm x 610 mm x 24.5 mm with single layer clad deposits for our evaluation. The nominal compositions of clad material to be received from this program are listed in Table 4.1. Two of these compositions will be obtained from wire rather than strip electrode due to the availability of this product form.

We are scheduled to begin receiving clad plates in approximately two months and have all the material in hand by four months. Comparative testing will be initiated as the materials are available.

Table 4.1. Filler Metal Compositions^a

Strip	C	Si	Mn	Cr	Ni	Mo	Cu	Cb
320	0.02	0.2	3	20	35	2.5	3.5	0.8
2RK65	0.02	0.4	1.8	20	25	4.5	1.5	-
2RM69	0.02	0.2	4.5	25	22	2.1	-	-
(310LMo)								
3RE14	0.025	0.3	1.8	24	13	-	-	-
(309)								
NiCrMo-3	0.05	0.2	0.2	21.5	6.1	9.0	-	3.6
Wire:								
Sanicro 28	0.02	0.2	1.8	27	31	3.5	1.0	-
Sanicro 41	0.03	0.4	0.4	21	41	3.3	-	-

^aTypical, wt %.

4.3 Fireside Corrosion of AFBC Heat Exchanger Materials

T. G. Godfrey and J. H. DeVan

Metallographic examination of all tube samples from the 4500-h test in the FluidDyne AFBC has resumed. Because a number of these metallographic samples were originally prepared in 1976, after the first 500-h exposure, it was necessary to repolish them to restore a viewable surface. The sulfate deposit, oxide scale, and subsurface sulfides deteriorate upon exposure to the atmosphere for long times. For the sake of consistency, it was decided to repolish all specimens so they would be in the same condition.

Measurements of scale thickness, intergranular corrosion and depth of subsurface sulfide inclusions (if present) have begun, but results are too incomplete to report at this time. It may be noted, however, that all high temperature tube samples examined thus far display subsurface sulfides (of the supposedly innocuous manganese type) that extend about 20 μm beyond the general corrosion front. It is not known whether these sulfide inclusions are the cause or the effect of the slight general corrosion.

4.4 Failure Prevention and Analysis

R. W. Swindeman

4.4.1 Examination of corrosion coupons from SRC plants - (V. B. Baylor and J. R. Keiser)

After two months exposure in the T105 fractionation column at the Wilsonville SRC plant, coupons were removed and examined, and then reinserted to accrue further exposure time. Three coupons, 26-15, 18-2, and NYBY MONIT, were considered failures, removed from further testing, and sent to ORNL for analysis. They were replaced with coupons of other alloys. This round of testing confirmed previous results of the relative corrosion resistance with Hastelloy C-276 as the most resistant and the ferritic stainless steels and carbon steel the least resistant.

4.4.2 Examination of the wash solvent column at the Ft. Lewis SRC plant - (V. B. Baylor, B. C. Leslie, M. D. Allen, J. R. Keiser, and R. W. Swindeman)

Oak Ridge personnel visited the Ft. Lewis SRC plant on September 13 and 14 for the purpose of examining the wash solvent column which was severely corroded after several months of operation. The 316 stainless steel vessel lost about 0.1 in. of the 0.25 in. thickness in the mid-section of the 100 ft column. Examination of replicas of metallurgically prepared surfaces of the column revealed that the material was fine-grained and in a solution-annealed condition. There was no evidence of sensitization or microcracking. Trays made of Hastelloy G were also corroded in the mid-section of the column. The attack consisted of a heavy scale plus thinning near the slots where bubble caps were attached. The features of this attack were discussed with a group of corrosion engineers who specialize in the petrochemical industry and it was the consensus that such attack is not typical of naphthenic acid but could be due to the presence of an organic acid in combination with a chlorine or ammonia-bearing substance.

4.5 Materials for Zinc Chloride Liquefaction Process

V. B. Baylor and J. R. Keiser

The purpose of this task is to evaluate materials for use in the zinc chloride regeneration system of the Zinc Chloride Liquefaction Process. Assembly of the testing apparatus was completed. Determination of thermal gradients in the loop has begun.

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

J. R. Keiser and V. B. Baylor

Stress corrosion cracking U-bend specimens are still in place in both the Wilsonville and Ft. Lewis SRC plants. Some specimens were removed from the T105 fractionation column at Wilsonville and examined visually and reinserted. Cracking was noted on the E-Brite 26-1 specimen after three months exposure. Sites for U-bend specimens at the H-Coal Pilot Plant were determined.

Assembly of laboratory equipment is almost complete, and laboratory testing should begin next month.

4.7 Development of Advanced 9 Cr-1 Mo Structural Steel

V. K. Sikka

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

Both 15-ton heats funded by DOE Fossil Energy were melted by Carpenter Technology Corporation during the first two weeks of September. The heat No. 1 was argon-oxygen-carburization (AOD) melted and cast into electrodes. The electrodes were electroslag-remelted (ESR) to make one each of 22 and 30-in.-diam ingots. Each ingot was 120 in. long. Heat No. 2 was AOD melted and split into two 19-in.-square ingots and electrodes for the ESR process. The electrodes were electroslag-remelted into 22-in.-diam ingots.

For the second heat, a small 4 by 4-in. test ingot was cast from the AOD part of the metal. After receiving the ingot at ORNL, it was hot-extruded and cold-rolled to produce $5/8 \times 3 \times 32$ in. plate stock. This plate will be subjected to Charpy-impact and creep-rupture testing during the next few months.

Coupons received from ingots of both heats were subjected to check chemical analysis. The check analysis was compared with the vendor analysis and the specified analysis. Based on this comparison, it was concluded that both of the large heats met our specified chemistry and thus should be accepted.

We have planned the fabrication flow diagrams for each of the ingots and are currently preparing to place orders to make the tube, bar, and plate products. The tubing will be used for insertion in the TVA super and reheaters, whereas bar and plate products will be used for testing and evaluation.

4.8 Ceramic Recuperator (Heat Exchangers)

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

Work on Subtask A has been completed except for preparation of two sections of a report summarizing results of the three subcontracts completed on the economic application and design of ceramic recuperators plus availability of materials for such units by about 1984.

In Subtask B, assembly of the Ceramic Recuperator Analysis Facility (CRAF) was completed and tube test specimens of 14 refractory structural ceramic materials were inserted and instrumented with minimal difficulty. The materials include NC 430 SiC, KT SiC, α -SiC, CVD SiC, CVD SiC on Cordierite, MAS 8400 Cordierite, Zirmul Z-1000, AD-998 Al_2O_3 , and Mullite ($\sim 3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_3$). The tubes are mounted between refractory header blocks with secondary air flowing through the tubes supplied by an auxiliary fan such that they operate as heat exchanger elements in a cross flow mode.

CRAF Test No. 1 started on September 17 using a high vanadium No. 6 oil. Thermocouples are cemented onto the outer diameter and in the inner diameter of the tubes at the mid-span in the flue gas duct. Temperatures (maximum) measured at the outer diameter of the ceramic tubes are about 1225°C with the burner delivering on the order of 3×10^6 Btu/h. The tube wall thicknesses range from 1.6 mm to 9.5 mm depending upon the material, and the measured temperature gradients across the walls vary from about 5 to 20°C , respectively. Appreciable heating of the secondary air occurs.

The test plan includes 500 h of combustion exposure and as of September 28, a total exposure of 160 h had been accumulated on the test samples.

On September 20, V. J. Tennery made a program review presentation at the Pittsburgh Energy Technology Center (PETC) which will be managing the heat exchanger technology program starting in FY 1980. As of October 1, we have not received notification of program continuation for FY 1980 from PETC; if notification is not received by October 19, the combustor will be closed down.

Visual observation of the tubes through an observation viewport in the side of the CRAF has revealed the formation of bumps or blisters on the outer diameter of some of the SiC tubes after 50 h at $T_{\text{max}} = 1225^\circ\text{C}$.

Characterization of the as-received structural ceramics continued with completion of the metallography, electron microprobe, and x-ray diffraction measurements. Chemical analyses, scanning electron microscopy, thermal expansion, and helium permeability measurements continued.

Start of the 200 h 50/50 coal-oil-mixture (COM) test of pressurized SiC/ Al_2O_3 heat exchanger tubes with SiC mechanical compression seals has been delayed until October 22 due to equipment problems at Hague International.

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

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 will be submitted to DOE for approval in October. 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.

Two equipment surveys were conducted - one before the flow sheets were developed and the other after initial flow sheets were completed. The first survey, based on preliminary information, covered pulverizers, thermal dryers, and ash/slag grinders. Questionnaires for all three equipment areas were prepared and sent to all known U.S. manufacturers of this type of equipment. Because of poor response to the initial questionnaires, changes in coal size consist requirements, and additional information gained through flow sheet design studies, a new set of questionnaires was prepared. Equipment areas for this survey were selected from the reference flow sheets developed under subcontract by Bechtel National, Inc. Specifically, the survey included cage mills, rod mills, ball mills, ball tube mills, bowl pulverizers, fluidized-bed driers, screens, and air separators. This second survey was conducted by extensive phone conversations followed by detailed written information forms from the manufacturers as a confirmation to the initial information.

The bases and approach used in flow sheet development are presented for coal preparation operations including breaking, coarse-coal cleaning, coarse-coal crushing, fine-coal cleaning, live storage-blending, dead storage, fine crushing, and grinding. A total of 50,000 short tons/day having a nominal total moisture content of 8.0 wt. % was assumed to be used as feed material to the coal conversion plant complex, including its atmospheric pressure fluidized-bed power/steam plant. Eighty-five percent of the coal is utilized in the reactors for the conversion process and fifteen percent is fed to the power/steam plant.

Two major bituminous coal seams were specified as possible conversion plant sources: Pittsburgh seam coal as represented by coal from Monongalia County, West Virginia, and Kentucky No. 9 seam coal as represented by coal from Hopkins County, Kentucky.

Selection of the nine coal conversion processes for the flow sheet development was based on projects of interest to the Department of Energy (DOE). The nine are: U-GAS, COGAS, HYGAS, Texaco Partial Oxidation, Exxon Donor Solvent, Exxon Catalytic Gasification, SRC-I, SRC-II, and H-Coal. Two conceptual flow sheets for ash/slag removal were developed for the handling of solid waste streams. One is for the transport of combined solid wastes as a dry material and the other is for water slurry transport and recycle of water from the solid waste disposal site.

The major conclusions resulting from this study include:

1. In general, equipment that meets the projected requirements for coal handling and preparation and ash/slag removal by future commercial coal conversion plants is currently available. Present capacity limits of some commercially used equipment can probably be overcome by a scale-up of existing equipment.
2. Improved coal handling and preparation and ash/slag removal equipment is anticipated for future conversion plants because of development of new construction materials, higher equipment reliability requirements, and improved fabrication methods.
3. Because of the large investment that will be required for coal conversion plants, substantial investment in high-reliability coal handling and preparation facilities would be fully justified.
4. Research into the best design approaches for achieving high plant operating reliability in large-capacity coal handling and preparation facilities could result in improved coal conversion economics. In this regard, evaluation of the performance of existing large-capacity materials handling and preparation operations, such as power plant coal operations, could provide useful information.
5. In addition to the best approach(es) to achieving high plant operating reliability, areas where development and demonstration is required include:
 - a. scale-up of coal pulverizers,
 - b. solvent-coal slurry grinding,
 - c. scale-up of gravimetric feeders,
 - d. coal collection and baghouse explosion prevention system,
 - e. pulverized and ultrafine coal transport equipment, and
 - f. pressurized ash and slag crushers.

6. Development of data to improve the predictability of the performance of fine-crushing equipment would be useful in engineering demonstration and commercial coal conversion plants. (Eight of the nine coal conversion processes may require fine-coal feed - minus 1/4" but with some particles greater than 20 mesh). Therefore, the need for a coal fine-crushing program similar to DOE's coal pulverizing and grinding program should be evaluated.
7. Development of new or improved large capacity fine-particulate classification equipment could solve the problem of removal of ultrafines (defined as -100 mesh coal) from fine coal before conversion, when such removal is required or economically justified.
8. The most economical method for obtaining the large quantities of hot gas required for simultaneous coal drying and pulverizing, or for coal fluidized-bed drying, is from a power plant steam/gas generator. This approach has two advantages over direct coal firing: it is more efficient and, at least in the case of fluidized-bed steam/gas generators, the need for flue gas desulfurization following coal pulverizing or drying is eliminated.
9. Coal feed requirements for coal conversion processes should be based on the largest coal size consist and highest allowable moisture, ash, and sulfur content compatible with the overall process. This approach will minimize the number of units and types of equipment required and will result in lower overall costs. Fine, dry pulverizing of coal presents one of the highest cost alternatives - system capital costs in the two-hundred-million-dollar range.
10. Consideration should be given to implementing additional R&D programs on impact type comminution equipment, such as cage mills. The feasibility of using such equipment for producing large quantities of coal of size consists compatible with Texaco Partial Oxidation and H-Coal conversion processes should be investigated.
11. Fabrication of high-reliability equipment may not be economically feasible. Labor-intensive societies tend to design and build equipment economically, but the amount of maintenance necessary to achieve a certain degree of reliability is high. On the other hand, equipment designed to operate longer under minimum maintenance conditions tends to be more expensive. Such economic trade-offs must be investigated for specific equipment and operations.

12. Considering the time it will take to develop the equipment required for the conversion process itself, ample lead time will be available to fabricate and test equipment required in the coal handling and preparation and ash/slag removal operations investigated in this survey.

5.2 Slurry Pressure Letdown Studies

A slurry test loop, which has been constructed using surplus equipment, is being retrofitted for high pressure test runs. Establishment of pressure vs. flow rate capability of the test rig is necessary in order to determine what test conditions are possible. Initial testing will be done on a packed bed for pressure letdown. It is estimated that 3 to 4 gpm of clean liquid at 1500 psig or better can be demonstrated with the Moyno pump. Flow rates for slurries will be somewhat less due to the flow characteristics of the pump. Provision is being made to introduce metered compressed gas into the bed along with the slurry in order to simulate flashing of the dissolved gases during pressure letdown in a liquefaction plant. Tests will be run to determine the pressure differential as a function of slurry flow, gas flow, solids size consist, solids concentration and packing dimensions. The packed bed to be investigated initially is a one-inch schedule 80 pipe, 6-ft long bed containing 1/8-inch diameter spheres.

5.3 Support for the H-Coal Project

L. F. Parsly and P. K. Carlson

Evaluation of component failure data continues under the H-Coal Materials and Technology Task Force. A number of critical areas have been identified in comparing H-Coal design information with operating experience at other locations, principally SRC II. Most of the components in the SRC II process have counterparts in H-Coal, thus the effort relies primarily on information contained in monthly, quarterly, and annual reports from the SRC projects spanning the past five years. Trips to relevant locations are also planned as a means of gathering information. ORNL work related to coal liquefaction, and trip reports resulting from other tasks, especially SRC R&D assessment work, is being reviewed for valuable information.

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. Lister, O. L. Culberson,
D. G. Ball, and K. W. Childs

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 Models

Checkout of the single precision results obtained from running the Lehigh models continued. The following paragraphs summarize the findings.

- Carbon Dioxide Removal (DCO2) - Subroutine ZBENTY was acquired locally, converted to single precision and linked into the model, which was successfully executed. Unfortunately we do not have any results from Lehigh University for this model so no comparison could be made to determine the accuracy of the results obtained here at Oak Ridge.
- Dynamic Hydrogen Plant Version 1 (DHP1) - The problems in subroutine PRINT were resolved, although not ideally. The results obtained were in very good agreement with those obtained from Lehigh.

- Gasifier Model (GAS1) - Subroutine ZSYSTEM was acquired locally, converted to single precision and linked into the model which was successfully executed. The results were in excellent agreement with those obtained from Lehigh.
- Methanation Plant Version 2 (METH2) - This model executed successfully. Unfortunately we do not have any results from Lehigh University for this model so no comparison could be made to determine the accuracy of our calculations.
- Dynamic Pyrolyses Model (PYR01) - Work on this model has been postponed pending a reply from Lehigh regarding a number of errors which have been identified.

Delivery of Remaining Models

- Lehigh - In a recent telephone conversation with Dr. Schiesser, ORNL was promised delivery of the latest versions of all Lehigh models by the end of September 1979.
- Purdue - In a recent telephone conversation with Dr. Sood at Purdue, we were told not to expect anything further before the end of November 1979.
- Conversion to Double Precision - The reordering of COMMON areas was completed and all subroutines successfully compiled. The remainder of the conversion process has been halted pending the arrival of the latest version of the code from Lehigh.
- Documentation of Storage System of Lehigh Models - A memo is being prepared outlining the storage system used to house the Lehigh codes. A draft preliminary copy has been sent to Dr. Schiesser, who will attempt to emulate our system on the CDC computer at Lehigh.
- Double Precision Converter Program - The latest modifications to the MARK1 edition of the code have been implemented in the CDC version. These modifications are currently being tested. When successful test runs have been obtained a copy of the source code will be forwarded to Dr. Schiesser.

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

The draft of the article "Depolymerization of Coal" was revised to incorporate suggestions of the initial reviewers and was subsequently distributed for final internal and external review.

Reviewer comments on the first draft of a second article, "Chemical Reaction Mechanisms of Coal Liquefaction," have been received and revision of the manuscript to incorporate suggested changes is in progress.

6.3 Survey of Industrial Coal Conversion Equipment Capabilities

W. R. Williams and D. W. Hatcher

6.3.1 Contract Objective

The objective of this project is to conduct surveys of industrial equipment capabilities that will identify the present capability of industry to supply the equipment needed. The project will also determine research and development needs, including lead time requirements, for producing equipment of advanced design for the various unit operations of critical importance to the Division of Fossil Fuel Processing.

6.3.2 Status Summary

The last three reports related to the survey of industrial coal conversion equipment capabilities are being edited by Technical Publications. These include a report on letdown valves (ORNL/TM-6585), a report on equipment operating experience, prices, and development programs (ORNL/TM-6587), and a report providing an executive summary of all work done on survey of industrial coal conversion equipment capabilities (ORNL/TM-6810). Distribution of all three reports is expected to be complete by mid-December.

6.4 Environmental Controls for Low-Btu Gasification

S. P. N. Singh, M. S. Edwards, J. F. Fisher,
G. R. Peterson, and R. Salmon

6.4.1 Contract Objective

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

The project is divided into two phases: Phase I consists of Tasks 1 through 5 of the work statement and covers the preparation of a detailed work plan and the selection of gasification and environmental

control processes for use in the study. Phase II consists of Tasks 6 through 8 and covers the collection and analysis of technical and economic data on the various environmental control processes and the preparation and analysis of flowsheets showing overall systems of environmental control processes used with various gasifiers.

6.4.2 Status Summary

DOE/Fossil Energy approval on the two draft reports titled Costs of Environmental Control Processes for Low-Btu Coal Gasification Plants (ORNL-5425) and Evaluation of Eight Environmental Control Systems for Low-Btu Coal Gasification Plants (ORNL-5481) has been received.

Proponent review of both reports was completed in June, followed by incorporation of reviewer comments and suggestions in early July. Delays in final technical editing have forced a revision of the anticipated distribution date to December 1979.

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 In Situ Coal Gasification

M. S. Edwards and W. C. Ulrich

7.1.1 Contract Objective

The objective of this project has been to provide technical and economic evaluations of candidate processes for the conversion of coal in situ to fluid products presently of interest. During FY 1977, technical and economic evaluations of the linked vertical well process applied to subbituminous coal were addressed. Three alternative end product configurations were considered - electricity, SNG, and syngas. In FY 1978, an evaluation was conducted of an in situ facility for producing gasoline from methanol via the Mobil-M process.

7.1.2 Status Summary

The final report of our 1977 technical evaluation of in situ coal gasification, Process Designs and Economic Evaluations for the Linked Vertical Well In Situ Coal Gasification Process (ORNL-5341), was published and distributed on August 22. This report detailed three conceptual process designs and cost estimates which illustrated several potential applications of underground coal gasification.

The 1978 report, Evaluation of an In Situ Coal Gasification Facility for Producing M-Gasoline via Methanol (ORNL-5439), is complete with publication now expected in mid-November.

The site of the Hoe Creek #3 underground coal gasification (UCG) experiment near Gillette, Wyoming was visited in mid-September. The latest experiment was initiated August 14 by Lawrence Livermore Laboratory under DOE funding and is providing significant insight into several aspects of UCG: use of steam/oxygen injection to produce high quality gas; advantages of directional drilling to link production and injection wells; procedure for transferring the gasification zone to the next set in a series of production and injection wells; etc.

The data obtained from this experiment would be very suitable for improving the design basis assumed by ORNL for the UCG portion of the M-Gasoline production facility. Usable data on oxygen-blown UCG operations were very limited when the report (ORNL-5439) was developed and predicted operation from computer models based on air-blown UCG experience was used. This approach introduced concerns about the validity of our economic results which could be resolved by examining actual data from oxygen operations in comparison with model predictions of such operations.

7.2 HYGAS Modeling

J. P. Meyer, G. C. Frazier, J. W. Wells, J. P. Belk, and R. M. Wham

7.2.1 Contract Objective

The limited objective of this contract was to develop a simplified model of the HYGAS pilot plant gasifier, using operating conditions and yield information obtainable from the open literature.

7.2.2 Status Summary

The final draft report Mathematical Model of the HYGAS Pilot Plant Reactor (ORNL-5475) has been reviewed and approved for issue by DOE-FE/DPST. Proponent reviews by IGT and others have been completed and final revisions have begun. Publication and distribution are expected to be complete in December.

7.3 High Btu Gas

A. R. Irvine

7.3.1 Contract Objective

This subprogram is being analyzed under subcontract by the Scientific Design Company, Incorporated (SD) with A. S. West as Project Manager. The present work is divided into three phases as follows:

1. The objective of Phase I is to provide technical and economic evaluations of competing processes, concepts, and systems for the production of high Btu gas from coal.
2. The objective of Phase II is to monitor and analyze data from the HYGAS Pilot Plant.
3. The objective of Phase III is to perform a technical and economic evaluation of the Battelle Agglomerating Ash Burner Process for the production of medium Btu fuel gas, synthesis gas, and hydrogen from coal.

7.3.2 Status Summary

As mentioned in previous progress reports, Phase I activities in this project have resulted in the issue of a final report, Battelle Agglomerating Ash Burner Process for High-Btu Gas Applications (ORNL/Sub-7240/1. Further evaluation of the Battelle process for medium-Btu gas applications (Phase III) has been completed and issue of the final report (ORNL/Sub-7240/4) occurred in July.

Monitoring of IGT's HYGAS Pilot Plant by SD engineers was discontinued during the month of July. Effort is currently directed toward preparation of a final report on this activity. This report is to provide a synopsis of operations observed and a discussion of problems associated with pilot plant operations, their causes, and probable solutions. A consultant, Fred A. Zenz, is assessing the problems of clinker formation and the relative performance of a pilot scale fluid bed system vis-a-vis a commercial scale unit, about which SD and IGT have differing viewpoints. A draft of the final report is expected to be completed in October.

7.4 Direct Combustion

E. C. Fox and T. D. Anderson

7.4.1 Contract objectives

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

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

7.4.2 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.

7.5 Advanced Power Conversion Systems

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

7.5.1 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.

7.5.2 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.

7.6 Fuel-Grade Methanol Synthesis Technology Assessment

R. Salmon, M. S. Edwards, and R. M. Wham

7.6.1 Contract Objective

The objective of this work is to review and assess the present state-of-the-art of indirect liquid fuels synthesis, with particular emphasis placed upon those processes which produce methanol suitable for use as fuel as the principal product.

7.6.2 Status Summary

Initial comments on the draft final report for this project, Production of Methanol and Methanol-Related Fuels from Coal, ORNL-5564, have been received and final revisions to the report began in August. The revised draft was completed this month and is now being given final review before beginning the publication process.

^aConsultant

7.7 Liquefaction Technology Assessment (LTAS)

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

7.7.1 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.

7.7.2 Status Summary

While the Phase 0 draft report is being given technical review by members of the DOE LTAS Steering Committee, intensive in-house revisions have been prepared and are being incorporated in a revised report to be completed in October. Following receipt of DOE comments, the report will be made available for limited proponent review and final changes will be incorporated shortly thereafter. The publication process is expected to begin in late November.

A Phase I "kick-off meeting" with Fluor Engineers and Constructors was held in Houston on September 4 and scope details, work schedules, and project management plans were negotiated. The ICI methanol synthesis process using Lurgi dry-bottom gasification for conversion of coal to synthesis gas was chosen as the indirect liquefaction process to be examined. The SRC-II process will be used as representative of direct liquefaction processes.

Both plants will be designed so as to place them on a realistic basis for a first plant rather than an Nth plant.

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.

Soil samples were collected at the SRC-I site in Newman, Kentucky during the month of September. Two soils predominate at this site: the Elk and the Melvin. Both bulk and core samples were obtained for each of these soil types for analysis at ORNL. Assistance in obtaining the core and bulk samples was provided by the local U. S. Soil Conservation Service (Charles Loyal and Frank Cox). Arrangements have been made to sample the SRC-II and CONOCO sites in the near future as soon as the exact location of the ash disposal areas have been delineated. Soils from the MLGW site will also be collected when it has been decided how the ash disposal area will be prepared, and whether it will be located on fill material dredged from the Mississippi River.

Continuous-flow leaching columns have been assembled and leaching studies initiated using Waste H to obtain additional data on trace elements leached from the waste during the initial applications of water.

An experiment has been designed to investigate the possibility that the low leaching rates observed in the high temperature ash/slugs that are water quenched are due to the presence of a hard-glassy outer layer. With time this hard layer might erode exposing a material which might be more leachable. Waste C has been selected for this study. A fairly large sample of this waste has been sieved to give various particle size fractions. The proposed RCRA extraction procedure (EP) will be used on each of these fractions, and the particle surface areas will be measured. The larger particles will then be ground and sieved to provide similar smaller size fractions observed in the "as received" waste. EP's will be run on these size fractions and compared to the original waste. Completion of this experiment should provide information on effect of particle size (surface area) on leaching and some indication of the distribution and leachability of trace elements in the inner core of the particles.

8.2 Processing of Coal Conversion Wastes for Disposal and Resource Recovery

R. M. Canon, G. Jones, Jr., and J. S. Watson

Three gasifier wastes have been subjected to direct leach with 6 N hydrochloric acid at ambient temperature for a period of 16 hours. This acid was chosen because it proved to be the most effective in treating these wastes at reflux temperatures (as previously reported). These tests were intended to determine the feasibility of such a leach for removal of the leachable hazardous trace elements, leaving a solid more inert than the original. However, as shown in Table 8.1 for gasifier waste 3, such a treatment can result in recovery of a considerable amount of aluminum and iron. During these experiments, the GA3 leach temperature rose spontaneously at 45°C, probably because of a high CaO concentration. It should also be noted that the GA4 run was extremely slow to filter. Samples of these liquors will also be analyzed for the trace metals by ICP (Inductively Coupled Plasma Spectrometry). Though complete removal of hazardous metals is not expected, it may be possible to remove the leachable portion of these elements quickly and easily in a simple ambient leach. Further investigations are planned in this area.

Table 8.1. Metals Recovery from Gasification Ash by Leaching with 6 N HCl at Ambient Temperature for 16 Hours

Ash	% Recovery		Run No.
	Al	Fe	
GA2	46	7	043
GA3	81	80	044
GA4	36	69	045

8.3 Coal Conversion Demonstration Projects

8.3.1 Liquefaction projects - S. G. DeCicco

This activity is reported in Chapter 13.

8.3.2 Gasification projects - A. J. Witten

Grace - Responses to the ORNL comments promised on September 1 were received on September 7. Responses to remaining comments will be incorporated in the FER due October 1.

The only unresolved issue is traffic. It is the opinion of ORNL that the additional traffic imposed on Rt. 60 by the plant will result in an impractical delay for both worker traffic and existing traffic. Mitigating measures seem necessary, however, insufficient information exists for making detailed recommendations. We have proposed to DOE that a survey of road conditions by link be performed for Rt. 60. This has not yet been implemented.

Work has begun on writing the PDES. The document is approximately 15% complete.

ORNL was represented at the Monthly Review Meeting in Memphis, TN. on September 13 and 14.

MLGW - The complete Draft ER was received on September 25. The PDES schedule was based upon a delivery date of September 14, therefore, the PDES delivery date is expected to slip by two weeks. A meeting has been scheduled with Energy Impact Associates (EIA) in Pittsburgh on October 3 to discuss team comments on the ER. This meeting is tentative and contingent upon team need.

Work has begun on writing the PDES. The document is approximately 5% complete.

ORNL was represented at the Monthly Review Meeting on September 26 and 27. The EIS outline was reviewed and the commenting process was discussed.

ICGG - The Final ER, due during the third week of September, had not arrived by the end of the month. PDES preparation is continuing in its absence. The document is approximately 10% complete. A meeting has been scheduled for October 5 with Dravo in Pittsburgh to discuss process description and plant design.

CONOCO - No ER material has arrived. A meeting has been scheduled for October 4 at EIA in Pittsburgh. The purpose of this meeting is to brief ORNL and DOE on the current status of the ER preparation and to discuss the possibility of ORNL review of the draft ER by section.

8.4 TVA Gasification Project

S. G. DeCicco

On September 25 ORNL was invited to make a presentation to TVA on our coal conversion-environmental capabilities. McNeese, Row, Craig, Cooper, and DeCicco attended from ORNL. TVA was receptive to our presentation and is now reviewing their internal capabilities to determine where ORNL assistance is needed. A typical work plan showing the areas of ORNL expertise was left with TVA. These areas include: project management guidance, specifying required site and plant design information, preparing a Notice of Intent, holding a Public Scoping Meeting, identifying environmental permits, licenses and approvals, preparing and defending the EIS, and post EIS monitoring.

8.5 Communications

- a. Witten attended the Grace Monthly Review Meetings on September 13, 14 in Memphis, TN.
- b. Ketelle and Wilson visited the SRC-I site on September 18 and 19 and recovered soil samples for use in the Stored Solids Study.
- c. DeCicco, Craig, and Row attended a meeting at TVA in Chattanooga, TN. on September 25 to discuss the Gasifier Project.
- d. Witten attended the ICGG Monthly Review Meetings in Newark, N.J. on September 26, 27.

8.6 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, 1-2-80; SRC-II, 1-2-80; ICGG, 12-15-79; MLGW, 12-15-79; CONOCO, 2-1-80.

9. MAGNETIC PREPARATION OF DRY CRUSHED COAL

E. C. Hise and A. S. Holman

9.1 Objective

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.

9.2 Status Summary

The laboratory space in Building 9201-3 has been prepared and all laboratory equipment has been moved from Building 9204-1. A nonmagnetic stand and work platform has been constructed and installed in Room 193A, and the superconducting magnet is being set up for initial testing. The Frantz magnetic separator and the petrographic equipment are in Room 193B. The gravimetric separation laboratory and the laboratory office are in Room 193. The jaw crusher and the Gilson screen are located in the shared space for crushing and classifying in Room 196. Room 197 contains the coal chemistry equipment and the chemical comminution experiment being conducted by the TVA guest engineers.

A third analytical tool for modeling magnet configurations is now operational and is being verified for accuracy. The first model was for the Frantz Isodynamic separator, and its particle trajectory calculations have been experimentally verified. The second model is for the field formed by a current wall or infinite radius solenoid. This was written to provide a relatively simple tool to explore trends. The third is capable of modeling a solenoid of any radius and length, made up of any number of magnets aiding or opposing, and can present in tabular or graphic form the total field, the axial component, the radial component, and the radial gradient along an axial line at any radius. The remaining task is to integrate the particle trajectory routine with the field calculation.

This model has calculated several cases for our superconducting laboratory solenoid which has a winding inside diameter of 10 cm, an outside diameter of 15.2 cm, a warm bore diameter of 9 cm, and a total length of 30.5 cm. The winding is split so the two coils can be operated either aiding or opposing. Fig. 9.1 is a plot of the field as a radius of 3.5 cm with the coils aiding. The magnet exhibits the nearly uniform total field over the central 15 cm of length that is desired for HGMS. Fig. 9.2 is a plot of the field at a radius of 3.5 cm with the coils opposing to generate a radial gradient as desired for OGMS. The radial force exerted on a particle in such a field is proportional to the product of the total field and

Figure 9.1. Calculated field of laboratory superconducting magnet coils in aiding mode plot at radius of 3.5 cm.

Magnet Simulation

Figure 9.2. Calculated field of laboratory superconducting solenoid coils in opposing (cusp) mode plot at radius of 3.5 cm

the gradient. As opposed to the nearly uniform force in the isodynamic magnet, the force in the solenoid ranges from well below to well above that of the isodynamic but appears to be adequate to permit experimental correlation of a calculated particle trajectory and perhaps to perform useful operation.

9.3 Status Summary - ORNL/TVA Chemical Comminution Project

S. R. Smith and W. A. Thomas^a

In recent months, TVA and ORNL have cooperated in a program to study the liberation of inorganic mineral contaminants from coal. A chemical comminution process is being compared to a mechanical crushing process as a means of liberating more of the ash and sulfur from raw coal. Washability analysis of four run-of-mine coal samples from western Kentucky and southern Illinois have been completed, including float-sink analysis of coal that has been treated by the chemical comminution process. At this time, over 150 coal fractions from the four samples are being analyzed at X-10 and Y-12 analytical chemistry laboratories for ash, sulfur, and Btu content. These analyses, when combined with the corresponding weight recovery data from the raw coal samples, will allow qualitative evaluation of the samples to determine which is the best candidate for further process development tests. 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.

Chemical comminution is a process that involves exposure of the coal to ammonia or other low-molecular weight chemicals that are inexpensive and recoverable. The chemical disrupts the natural bonding forces acting across the internal boundaries of the coal structure where the majority of the ash and pyritic sulfur deposits are located. Breakage occurs along these boundaries, thus exposing the ash and pyrite for follow-on separation by either specific gravity difference or other separation processes, such as magnetic separation. No significant dissolution of the coal occurs, and 99 percent of the ammonia can be recovered and reused. Since no mechanical force is applied, the size distribution of the fractured coal is governed by the internal fault system, the chemical employed, the process operating parameters of NH_3 pressure (about 100 psi), temperature (ambient), and residence time (about three hours).

^aTVA Guest Engineers

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

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

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

The work statement for the subcontract was prepared by ORNL. It is based on the Westinghouse proposal as submitted with a limited number of amendments specifying the requirements for the design and fabrication of the test system components and equipment. These requirements include those for engineering drawings, calculations, fabrication schedule, quality assurance, shipment, and performance specifications.

A meeting was held at Westinghouse on September 13 to discuss the proposed work statement with ORNL, UCC Purchasing, Babcock and Wilcox, and Stone and Webster representatives present. The work statement was accepted by the Westinghouse team with a few revisions in the language of the statement.

A new draft of the work statement incorporating the requested revisions was prepared by ORNL a few days later, and this was sent to Westinghouse and Babcock and Wilcox for final acceptance.

Most of the negotiations on the legal terms have been resolved. Westinghouse and Babcock and Wilcox have agreed to negotiate the subcontract and accept it in the near future, and settle any unresolved legal terms separately at a later date.

It is currently projected that the subcontract package will be completed by UCC Purchasing Division by about October 10 and sent at that time to Westinghouse for their acceptance and signature. When the signed subcontract is received from Westinghouse, it will be submitted to DOE-ORO for approval.

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

J. E. Jones Jr.

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 J. E. Jones Jr.

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

The review and evaluation of the proposals submitted by Babcock and Wilcox (B&W) and Combustion Engineering (CE) to TVA for designing and building an AFBC pilot plant have been completed. A letter report, summarizing the team's integrated comments and specific discussions, was delivered to TVA. B&W was selected by TVA and awarded the contract on September 20.

During the last month, ORNL started an additional related activity in support of TVA's effort to clarify issues of concern and modify B&W's design as necessary until a final acceptable design is achieved. TVA has prepared a list of questions and possible modifications to the design. ORNL has reviewed this list and discussed various suggestions and additions in a meeting with Jerry Fourroux and Mark Hill from TVA on September 28, 1979. This was followed by a draft letter summarizing ORNL's input. Meetings with B&W personnel to discuss these issues are planned for the first week of October.

11.2 4 x 4 Cold Flow Model - Task 3

R. S. Holcomb and M. E. Lackey

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

Design and Modifications - The fluidizing-air plenum has been re-designed so that the air can be shut off to a portion of the 4 x 4 bed with the air flow continuing to the other portion. A new simulated tube bundle has been designed for the slumping tests. The design is based on a 1/4 scale factor - i.e., the tube diameter, bed depth, and fluidizing velocity will be 1/4 that of the full-scale FBC boiler. The cold flow model has been modified to incorporate the design changes.

Testing - Tests were conducted to investigate the effects of slumping a portion of the bed and continuing operation of the remainder. Observations were made to study mixing between the active and slumped portions, fluidizing air bypass through the slumped section, elutriation from the fluidized section and deposit in the slumped section, and maximum buildup of the slumped bed. The fluidizing air was then turned on to the slumped portion, and the action of the two sections was studied during refluidization. Cold flow model slumping tests have been conducted over a range of fluidizing velocities from 1 to 2 ft/sec and bed depths from 1 to 1.5 ft to represent scale studies of values four times as large. Other operating data were obtained incidental to these tests.

Progress to Date - Slumping tests were conducted with a superficial velocity of 2 ft/sec in the fluidized section of the bed and a nominal velocity of 0.46 ft/sec and 0.55 ft/sec in the slumped section of the bed. The static contour of the bed after an operating time of two hours is shown in Figures 11.1 and 11.2. As can be seen from inspection of the bed contours, a slip plane zone exists in the slumped bed in addition to the downflow zone reported for the case of no air supplied to the slumped zone. Also, the contours indicate that the size and location of solids peak height in the slumped zone is a function of air supplied to the slumped section of the bed.

These tests completed the testing of the 1/4 scale factor slumping tests. The data are being analyzed and a report is in preparation.

A motion picture sequence was taken of the slumping test and presented to TVA personnel. The flow patterns observed in the movies clearly indicate the bypassing of the fluidized portion of the bed by the fluidizing

Figure 11.1. Solids distribution after operation for two hours with a superficial velocity of 2 ft/sec in the fluidized side and 0.46 ft/sec in the slumped side.

Figure 11.2. Solids distribution after operation for two hours with a superficial velocity of 2 ft/sec in the fluidized side and 0.55 ft/sec in the slumped side.

air indicating a potential problem associated with a reducing condition at the interface of the fluidized and slumped section of the bed.

To determine the effects of particle size upon an amount of material that is removed from the fluidized bed and deposited in the slumped bed when operating in the slumped mode, an additional test with a limestone that has a particle size of approximately 1000 μm was proposed to TVA. The cost of this additional test is estimated to be \$25,000.

11.3 AFBC Modeling and Simulation - Task 4

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

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

During this month, an abstract for a paper describing attrition in fluid beds was prepared. This abstract was sent to the Powder and Bulk Solids Conference in Chicago, Illinois.

Also during this month, the coal ash elutriation and attrition section was added to the present code. Coal ash is the material left after all of the volatiles and char of the coal have been burned. The equations used to describe elutriation and attrition are given by Highley and Merrick.¹ The procedure is the same as given in previous reports (see July monthly). The size distribution for the coal ash as feed to bed with coal was estimated from data for a 1/8 in. x 0 coal ash also given by Highley and Merrick and is shown in Fig. 11.3. As can be seen, the size distribution of the ash can be satisfactorily fit by a straight line on semi-log paper. This type of plot is fit by an equation of the following form.

$$R = Ae^{By},$$

where

y = weight fraction passing through the screen,
A, B = constants,
R = radius of the particle.

This form is different from that used to fit the size distribution of the limestone.² The limestone size distribution is also shown in Fig. 11.3 and cannot be fit by a straight line on semi-log paper. Fig. 11.4 shows the limestone and ash size distributions plotted in log-log paper.

As can be seen, a straight line can be drawn through the limestone points, but not the ash. Thus, for limestone feed particle size distribution, the best fit can be obtained from the following form:

$$Y = AR^B,$$

where

Y = weight fraction passing through the screen,
A, B = constants
R = particle radius.

At present, some numerical problems are being encountered in the ash code. This problem is still being investigated. It seems that the solution to the differential particle balance (see July monthly) becomes unstable when the rate of elutriation exceeds the rate of attrition at a certain size of radius R. This instability could also be caused by the attrition and elutriation rate exceeding the feed rate to the bed of this size fraction. Hand calculations are now under way to establish the exact nature of this problem.

The analysis of attrition and elutriation data of the Morgantown Energy Technology Center³ was also started. The applicability of these data to utility fluid beds may be limited because of the operating conditions and the size and geometry of the bed. Preliminary analysis did show a much smaller particle size leaving the bed ($\sim 150 \mu\text{m}$).

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Figure 11.3. Semi-log plot of size distribution of coal ash and limestone feed to the bed.

Figure 11.4. Log-log plot of size distribution of coal ash and limestone feed to the bed.

11.4 AFBC Bench Scale Facility - Task 5

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

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 10 in. ID and about 15-ft. tall. The combustor is designed for burning 10 to 30 lb/hr of coal and is equipped for limestone addition. The system is designed to operate with a bed fluidizing velocity in the range of 4 to 10 ft/sec and bed temperatures up to 1600°F. The bed is cooled by compressed air flowing through 0.5 in. OD tubes immersed in the bed.

Test program - Heat transfer tests will be done for 1000 and 1900 μm mean size limestone over the fluidizing velocity range of 4 to 10 ft/sec at bed temperatures of 1400 to 1600°F. Sulfur capture and carbon loss tests will be run for selected coals and limestones of interest to TVA for several values of Ca/S over a fluidizing velocity and temperature range similar to that for heat transfer. Tests to investigate the combustion of recycle char removed by the cyclone separator will be run for various operating conditions.

Progress to date - Four combustion runs totaling 12-1/2 hours were completed during September. A superficial velocity of 6 ft/sec and a bed temperature of 1470°F were maintained in order to study the effects of lower bed temperature on sulfur capture; the test results appear in Table 11.1. The observed sulfur capture at 1470°F appears to be slightly better than the sulfur capture results at 1550°F as tabulated in a previous report. The last two items in Table 11.1 indicate low sulfur capture at relatively high calcium to sulfur ratios, but this is believed to be directly related to lower bed depths.

With respect to these results, it is now believed that the lower sulfur capture obtained at 4 ft/sec and 1470°F, as reported last month, must be attributed to poor mixing at the lower velocity and not the effects of lower bed temperatures. If time permits, this phenomenon will be more thoroughly studied prior to the start of the TVA materials tests next month.

During the period of September testing, the bed particles had a harmonic mean size of 875 μm (based on the size-weight distribution) and a median (fifty percent) size of 1020 μm . Particle densities averaged 71 lb/cu. ft.

Table 11.1. AFBC sulfur capture results for September.

Date Time	9-6-79 14:37	9-6-79 15:47	9-10-79 13:07	9-10-79 14:02	9-10-79 14:50	9-12-79 13:31	9-12-79 14:38
Bed temperature, °F	1479	1476	1472	1474	1470	1466	1467
Superficial velocity, ft/sec	5.7	5.7	6.0	6.1	6.1	6.0	6.0
Static bed depth, inches	30	30	32	33	34	26	29
Coal feed rate, lb/hr	24.6	24.6	26.0	25.6	25.6	28.4	28.4
Limestone feed rate, lb/hr	4.1	4.9	5.0	5.6	6.5	7.2	9.3
Calcium/Sulfur, mole ratio	2.0	2.4	2.3	2.7	3.1	3.1	4.0
Combustion air flow, lb/hr	225	225	240	242	241	240	240
O ₂ in flue gas, percent	3.55	3.2	3.6	3.4	3.65	3.8	3.45
Indicated excess air, percent	19.8	17.6	20.2	18.9	20.6	21.6	19.3
Carbon utilization, percent burned	77.3	77.3	81.3	81.3	81.3	74.5	74.5
SO ₂ in flue gas, ppm	830	660	590	530	450	775	630
Sulfur Capture (weight percent removed):							
As-fed coal	60.6	69.2	71.9	75.0	78.4	62.6	70.1
As-burned coal	63.4	74.9	77.5	79.2	82.4	73.0	78.0

Limestone size: 12 x 30 mesh

Coal analysis: C 67.66%
H₂ 4.66
O₂ 5.79
N₂ 1.33
H₂O 2.33
S 2.53
Ash 15.7

The new flue gas sampling and analysis system has arrived and it will be connected as soon as possible. Tests with TVA materials will be begun with the current flue gas sampling system, if necessary, because of any delay in placing the new system in operation. The bulk of activity during September was oriented toward preparation of coal and limestone for the TVA materials tests. The 100 drums of coal contained about ten percent moisture when received; therefore, it was necessary to dry the coal prior to any attempt at crushing and/or screening. Approximately one-fifth of the coal has been dried and is awaiting further processing.

Two drums of the first limestone to be tested have been dried, crushed, and screened. This is a sufficient quantity for completion of the first series of TVA materials testing. One drum of each of the remaining three limestones have been sampled and will be prepared as needed for future testing.

An attempted data run at the very end of September was terminated due to a leak at the flange which connects the combustion region to the free-board. The gasket-type of seal had failed, and bed material as well as flue gases were escaping near the top of the fluidized region. This situation was corrected with a leak-tight weld around the flange.

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

Work on the final report on the PFBC state-of-the-art is continuing. Development facilities are being contacted by phone in order to obtain the most recent status of ongoing development programs. NASA-Lewis has recently completed a series of small turbine tests using their 23-cm PFBC. Initial tests with a single Perodyne cyclone led to catastrophic loss of turbine blading in as little as 13 hours on some runs. Modification of the particle collector eventually resulted in a 400-hr run with minimal erosion on the blades. Dust loading was reported to be about 0.02 gr/SCF. The turbine inlet temperature was about 690 to 780°C (1274 to 1436°F) for the various runs which were made.

Table 11.2. AFBC with carbon burnup cell.

Main Bed						CBC			
	T	V	Ho	E.A.	α	T	V	Ho	E.A.
1	1550°F	8 ft/sec	4 ft	20%	.85	1800°F	8 ft/sec	4 ft	20%
2	1550°F	6 ft/sec	4 ft	20%	.85	1800°F	8 ft/sec	4 ft	20%
3	1550°F	4 ft/sec	4 ft	20%	.85	1800°F	8 ft/sec	4 ft	20%
4	1550°F	8 ft/sec	6 ft	20%	.85	1800°F	8 ft/sec	4 ft	20%
5	1550°F	6 ft/sec	6 ft	20%	.85	1800°F	8 ft/sec	4 ft	20%
6	1550°F	4 ft/sec	6 ft	20%	.85	1800°F	8 ft/sec	4 ft	20%
7	1550°F	6 ft/sec	3 ft	20%	.85	1800°F	8 ft/sec	4 ft	20%
8	1550°F	4 ft/sec	4 ft	10%	.85	1800°F	8 ft/sec	4 ft	20%
9	1550°F	4 ft/sec	4 ft	3%	.85	1800°F	8 ft/sec	4 ft	20%
10	1550°F	4 ft/sec	4 ft	20%	.85	1650°F	8 ft/sec	4 ft	20%
11	1550°F	4 ft/sec	4 ft	20%	.85	1800°F	4 ft/sec	4 ft	20%
1A	Case 1 conditions with $\alpha = 1.0$								
1B	Case 1 conditions with $\alpha = 0.95$								
1C	Case 1 conditions with $\alpha = 0.90$								
1D	Case 1 conditions with $\alpha = 0.80$								
1E	Case 1 conditions with $\alpha = 0.75$								
12	Case 1 conditions with no CBC and no recycle								
13	Case 2 conditions with no CBC and no recycle								
14	Case 3 conditions with no CBC and no recycle								
15	Case 9 conditions with no CBC and no recycle								
16	Case 1 conditions with no CBC but with recycle, $\beta = 0.50$, $\eta = 0.95$								
17	Case 2 conditions with no CBC but with recycle, $\beta = 0.50$, $\eta = 0.95$								
18	Case 3 conditions with no CBC but with recycle, $\beta = 0.50$, $\eta = 0.95$								
19	Case 9 conditions with no CBC but with recycle, $\beta = 0.50$, $\eta = 0.95$								
20	Case 4 conditions with 10 ft static bed height								
21	Case 1 conditions with larger limestone size								
22	Case 1 conditions with larger bed ash size								
23	Case 1 conditions with larger bed ash (> case 22)								
24	Case 1 conditions with larger coal size distribution								
25	Case 1 conditions with $R = 10$ in main bed, $R = 0.1$ in CBC								
26	Case 1 conditions with $R = 0.1$ in main bed, $R = 0.1$ in CBC								
27	Case 1 conditions with recycle and $\beta = 0.90$, $\eta = 0.95$								
28	Case 1 conditions with recycle and $\beta = 0.10$, $\eta = 0.95$								
29	Case 1 conditions with recycle and $\eta = 0.50$, $\beta = 0.50$								
30	Case 1 conditions with recycle and $\eta = 0.80$, $\beta = 0.50$								
31	Case 1 conditions with ρ bed ash = 205								
32	Case 1 conditions with ρ bed ash = 150								
33	Case 1 conditions with C increased to 3.5								

 α = Fraction of combustion occurring in the bed

T = Bed temperature

V = Superficial gas velocity

Ho = Static bed height

 β = Fraction of recycle char which burns in each pass η = Fraction of elutriated solids which are recycled

Table 11.3. Results of AFBC Performance Analysis

Case	Superheater Surface (ft ²)	Reheater Surface (ft ²)	Evaporator Surface (ft ²)	Waterwall Surface (ft ²)	Economizer Surface (ft ²)	Coal Flow (lbm/hr)	Limestone Flow (lbm/hr)	Waste Flow (lbm/hr)	Main Bed Air Flow (lbm/hr)	Main Bed & Grid ΔP (in/H ₂ O)	CBC Air Flow (lbm/hr)	CBC Bed & Grid ΔP (in/H ₂ O)	Total Bed Plan Area (ft ²)
1	1.050 × 10 ⁵	1.660 × 10 ⁵	2.973 × 10 ⁴	8.175 × 10 ⁴	2.997 × 10 ⁵	7.198 × 10 ⁵	2.876 × 10 ⁵	3.244 × 10 ⁵	7.968 × 10 ⁶	89.2	3.840 × 10 ⁵	89.2	1.480 × 10 ⁴
2	9.280 × 10 ⁴	1.671 × 10 ⁵	2.759 × 10 ⁴	9.015 × 10 ⁴	2.994 × 10 ⁵	7.198 × 10 ⁵	2.325 × 10 ⁵	3.215 × 10 ⁵	7.968 × 10 ⁶	89.2	4.694 × 10 ⁵	89.2	1.965 × 10 ⁴
3	8.720 × 10 ⁴	1.543 × 10 ⁵	1.802 × 10 ⁴	1.097 × 10 ⁵	2.994 × 10 ⁵	7.178 × 10 ⁵	2.605 × 10 ⁵	3.092 × 10 ⁵	7.946 × 10 ⁶	89.2	4.112 × 10 ⁵	89.2	2.882 × 10 ⁴
4	1.052 × 10 ⁵	1.649 × 10 ⁵	2.343 × 10 ⁴	8.318 × 10 ⁴	2.984 × 10 ⁵	7.146 × 10 ⁵	2.324 × 10 ⁵	2.927 × 10 ⁵	7.910 × 10 ⁶	138.8	2.169 × 10 ⁵	89.2	1.437 × 10 ⁴
5	9.312 × 10 ⁴	1.657 × 10 ⁵	2.073 × 10 ⁴	9.312 × 10 ⁴	2.976 × 10 ⁵	7.150 × 10 ⁵	2.307 × 10 ⁵	2.917 × 10 ⁵	7.915 × 10 ⁶	138.8	3.400 × 10 ⁵	89.2	1.927 × 10 ⁴
6	1.040 × 10 ⁵	1.735 × 10 ⁵	1.568 × 10 ⁴	1.146 × 10 ⁵	2.971 × 10 ⁵	7.142 × 10 ⁵	2.197 × 10 ⁵	2.857 × 10 ⁵	7.906 × 10 ⁶	138.8	3.637 × 10 ⁵	89.2	2.859 × 10 ⁴
7	9.292 × 10 ⁴	1.685 × 10 ⁵	3.104 × 10 ⁴	8.987 × 10 ⁴	3.012 × 10 ⁵	7.247 × 10 ⁵	3.375 × 10 ⁵	3.531 × 10 ⁵	8.022 × 10 ⁶	64.4	5.529 × 10 ⁵	89.2	1.994 × 10 ⁴
8	8.720 × 10 ⁴	6.064 × 10 ⁴	2.290 × 10 ⁴	1.034 × 10 ⁵	2.852 × 10 ⁵	7.150 × 10 ⁵	2.614 × 10 ⁵	3.088 × 10 ⁵	7.255 × 10 ⁶	89.2	4.468 × 10 ⁵	89.2	2.646 × 10 ⁴
9	8.720 × 10 ⁴	1.116 × 10 ⁵	2.745 × 10 ⁴	9.505 × 10 ⁴	2.753 × 10 ⁵	7.131 × 10 ⁵	2.624 × 10 ⁵	3.088 × 10 ⁵	6.776 × 10 ⁶	89.2	4.769 × 10 ⁵	89.2	2.483 × 10 ⁴
10	8.720 × 10 ⁴	1.568 × 10 ⁵	2.100 × 10 ⁴	1.040 × 10 ⁵	2.987 × 10 ⁵	7.186 × 10 ⁵	2.611 × 10 ⁵	3.100 × 10 ⁵	7.955 × 10 ⁶	89.2	4.122 × 10 ⁵	89.2	2.880 × 10 ⁴
11	8.720 × 10 ⁴	1.568 × 10 ⁵	1.849 × 10 ⁴	1.060 × 10 ⁵	2.987 × 10 ⁵	7.178 × 10 ⁵	2.605 × 10 ⁵	3.092 × 10 ⁵	7.955 × 10 ⁶	89.2	4.122 × 10 ⁵	89.2	2.955 × 10 ⁴
1A	9.452 × 10 ⁴	7.137 × 10 ⁴	3.403 × 10 ⁴	8.175 × 10 ⁴	2.997 × 10 ⁵	7.198 × 10 ⁵	2.876 × 10 ⁵	3.244 × 10 ⁵	7.968 × 10 ⁶	89.2	3.840 × 10 ⁵	89.2	1.480 × 10 ⁴
1B	9.452 × 10 ⁴	1.111 × 10 ⁵	3.260 × 10 ⁴	8.175 × 10 ⁴	2.997 × 10 ⁵	7.198 × 10 ⁵	2.876 × 10 ⁵	3.244 × 10 ⁵	7.968 × 10 ⁶	89.2	3.840 × 10 ⁵	89.2	1.480 × 10 ⁴
1C	9.452 × 10 ⁴	1.480 × 10 ⁵	3.116 × 10 ⁴	8.175 × 10 ⁴	2.997 × 10 ⁵	7.198 × 10 ⁵	2.876 × 10 ⁵	3.244 × 10 ⁵	7.968 × 10 ⁶	89.2	3.840 × 10 ⁵	89.2	1.480 × 10 ⁴
1D	1.275 × 10 ⁵	1.637 × 10 ⁵	2.829 × 10 ⁴	8.175 × 10 ⁴	2.997 × 10 ⁵	7.198 × 10 ⁵	2.876 × 10 ⁵	3.244 × 10 ⁵	7.968 × 10 ⁶	89.2	3.840 × 10 ⁵	89.2	1.480 × 10 ⁴
1E	1.467 × 10 ⁵	1.620 × 10 ⁵	2.686 × 10 ⁴	8.175 × 10 ⁴	2.997 × 10 ⁵	7.198 × 10 ⁵	2.876 × 10 ⁵	3.244 × 10 ⁵	7.968 × 10 ⁶	89.2	3.840 × 10 ⁵	89.2	1.480 × 10 ⁴
12	1.229 × 10 ⁵	1.762 × 10 ⁵	2.495 × 10 ⁴	7.958 × 10 ⁴	3.093 × 10 ⁵	7.582 × 10 ⁵	3.030 × 10 ⁵	3.669 × 10 ⁵	8.393 × 10 ⁶	89.2	-	-	1.479 × 10 ⁴
13	1.090 × 10 ⁵	1.786 × 10 ⁵	1.844 × 10 ⁴	9.363 × 10 ⁴	3.102 × 10 ⁵	7.651 × 10 ⁵	2.762 × 10 ⁵	3.595 × 10 ⁵	8.470 × 10 ⁶	89.2	-	-	1.990 × 10 ⁴
14	8.722 × 10 ⁴	1.775 × 10 ⁵	1.082 × 10 ⁴	1.137 × 10 ⁵	3.081 × 10 ⁵	7.574 × 10 ⁵	2.569 × 10 ⁵	3.431 × 10 ⁵	8.384 × 10 ⁶	89.2	-	-	2.955 × 10 ⁴
15	8.720 × 10 ⁴	1.429 × 10 ⁵	1.534 × 10 ⁴	9.551 × 10 ⁴	2.857 × 10 ⁵	7.590 × 10 ⁵	2.572 × 10 ⁵	3.481 × 10 ⁵	7.212 × 10 ⁶	89.2	-	-	2.542 × 10 ⁴
16	2.327 × 10 ⁵	2.138 × 10 ⁵	2.548 × 10 ⁴	8.078 × 10 ⁴	3.288 × 10 ⁵	7.220 × 10 ⁵	2.713 × 10 ⁵	3.184 × 10 ⁵	8.359 × 10 ⁶	89.2	-	-	1.473 × 10 ⁴
17	2.133 × 10 ⁵	2.119 × 10 ⁵	1.932 × 10 ⁴	9.323 × 10 ⁴	3.264 × 10 ⁵	7.225 × 10 ⁵	2.628 × 10 ⁵	3.143 × 10 ⁵	8.444 × 10 ⁶	89.2	-	-	1.984 × 10 ⁴
18	1.878 × 10 ⁵	2.085 × 10 ⁵	1.150 × 10 ⁴	1.133 × 10 ⁵	3.202 × 10 ⁵	7.203 × 10 ⁵	2.460 × 10 ⁵	3.041 × 10 ⁵	8.365 × 10 ⁶	89.2	-	-	2.949 × 10 ⁴
19	1.563 × 10 ⁵	1.846 × 10 ⁵	1.389 × 10 ⁴	1.019 × 10 ⁵	2.984 × 10 ⁵	7.160 × 10 ⁵	2.445 × 10 ⁵	3.028 × 10 ⁵	7.258 × 10 ⁶	89.2	-	-	2.654 × 10 ⁴
20	1.071 × 10 ⁵	1.640 × 10 ⁵	1.286 × 10 ⁴	8.956 × 10 ⁴	2.968 × 10 ⁵	7.108 × 10 ⁵	1.931 × 10 ⁵	2.701 × 10 ⁵	7.868 × 10 ⁶	238.0	7.015 × 10 ⁴	89.2	1.401 × 10 ⁴
21	1.043 × 10 ⁵	1.641 × 10 ⁵	2.851 × 10 ⁴	8.043 × 10 ⁴	2.980 × 10 ⁵	7.174 × 10 ⁵	2.501 × 10 ⁵	3.037 × 10 ⁵	7.941 × 10 ⁶	89.2	3.375 × 10 ⁵	89.2	1.466 × 10 ⁴
22	1.039 × 10 ⁵	1.668 × 10 ⁵	3.014 × 10 ⁴	8.276 × 10 ⁴	3.001 × 10 ⁵	7.214 × 10 ⁵	2.942 × 10 ⁵	3.283 × 10 ⁵	7.986 × 10 ⁶	89.2	4.259 × 10 ⁵	89.2	1.492 × 10 ⁴
23	9.949 × 10 ⁴	1.722 × 10 ⁵	2.962 × 10 ⁴	1.262 × 10 ⁵	3.050 × 10 ⁵	7.336 × 10 ⁵	4.318 × 10 ⁵	4.072 × 10 ⁵	8.121 × 10 ⁶	89.2	6.341 × 10 ⁵	89.2	1.556 × 10 ⁴
24	1.075 × 10 ⁵	1.665 × 10 ⁵	2.771 × 10 ⁴	7.977 × 10 ⁴	3.000 × 10 ⁵	7.192 × 10 ⁵	2.795 × 10 ⁵	3.293 × 10 ⁵	7.961 × 10 ⁶	89.2	2.162 × 10 ⁵	89.2	1.446 × 10 ⁴
25	1.094 × 10 ⁵	1.661 × 10 ⁵	2.448 × 10 ⁴	7.762 × 10 ⁴	2.997 × 10 ⁵	7.175 × 10 ⁵	2.695 × 10 ⁵	3.138 × 10 ⁵	7.942 × 10 ⁶	89.2	-	-	1.400 × 10 ⁴
26	1.103 × 10 ⁵	1.773 × 10 ⁵	3.844 × 10 ⁴	6.775 × 10 ⁴	3.015 × 10 ⁵	7.274 × 10 ⁵	3.344 × 10 ⁵	3.519 × 10 ⁵	8.052 × 10 ⁶	89.2	1.018 × 10 ⁶	89.2	1.620 × 10 ⁴
27	2.304 × 10 ⁵	2.128 × 10 ⁵	2.557 × 10 ⁴	8.038 × 10 ⁴	3.281 × 10 ⁵	7.205 × 10 ⁵	2.707 × 10 ⁵	3.167 × 10 ⁵	8.341 × 10 ⁶	89.2	-	-	1.470 × 10 ⁴
28	2.463 × 10 ⁵	2.209 × 10 ⁵	2.557 × 10 ⁴	8.137 × 10 ⁴	3.342 × 10 ⁵	7.317 × 10 ⁵	2.745 × 10 ⁵	3.290 × 10 ⁵	8.471 × 10 ⁶	89.2	-	-	1.493 × 10 ⁴
29	1.227 × 10 ⁵	1.778 × 10 ⁵	2.459 × 10 ⁴	8.099 × 10 ⁴	3.111 × 10 ⁵	7.438 × 10 ⁵	2.794 × 10 ⁵	3.209 × 10 ⁵	8.432 × 10 ⁶	89.2	-	-	1.486 × 10 ⁴
30	1.380 × 10 ⁵	1.835 × 10 ⁵	2.473 × 10 ⁴	8.087 × 10 ⁴	3.132 × 10 ⁵	7.311 × 10 ⁵	2.746 × 10 ⁵	3.176 × 10 ⁵	8.405 × 10 ⁶	89.2	-	-	1.481 × 10 ⁴
31	1.043 × 10 ⁵	1.671 × 10 ⁵	2.880 × 10 ⁴	8.226 × 10 ⁴	3.004 × 10 ⁵	7.213 × 10 ⁵	2.941 × 10 ⁵	3.283 × 10 ⁵	7.984 × 10 ⁶	89.2	3.992 × 10 ⁵	89.2	1.486 × 10 ⁴
32	1.139 × 10 ⁵	1.657 × 10 ⁵	2.964 × 10 ⁴	7.882 × 10 ⁴	2.992 × 10 ⁵	7.179 × 10 ⁵	2.582 × 10 ⁵	3.076 × 10 ⁵	7.947 × 10 ⁶	89.2	3.013 × 10 ⁵	89.2	1.460 × 10 ⁴
33	1.077 × 10 ⁵	1.690 × 10 ⁵	3.067 × 10 ⁴	8.217 × 10 ⁴	3.031 × 10 ⁵	7.276 × 10 ⁵	3.721 × 10 ⁵	3.728 × 10 ⁵	8.054 × 10 ⁶	89.2	3.880 × 10 ⁵	89.2	1.496 × 10 ⁴

Table 11.4. Results of AFBC performance analysis.

Case	Void fraction in no tube zone	Void fraction in tube zone	Expanded bed height (ft)	Transport disengaging height (ft)	Fraction of limestone elutriated	Main bed combustion efficiency	Ca/S ratio	Overall combustion efficiency	Overall boiler efficiency
1	0.695	0.745	7.15	10.20	0.203	0.952	2.73	0.999	0.870
2	0.637	0.682	6.06	8.37	0.167	0.941	2.68	0.999	0.870
3	0.567	0.604	5.11	6.41	0.132	0.948	2.49	0.999	0.873
4	0.695	0.745	10.80	10.20	0.203	0.973	2.23	0.999	0.877
5	0.638	0.682	9.10	8.36	0.167	0.957	2.21	0.999	0.876
6	0.567	0.604	7.65	6.41	0.132	0.954	2.11	0.999	0.877
7	0.638	0.682	4.54	8.36	0.167	0.931	3.18	0.999	0.864
8	0.567	0.604	5.11	6.41	0.132	0.944	2.50	0.999	0.876
9	0.567	0.604	5.11	6.41	0.132	0.940	2.50	0.999	0.878
10	0.567	0.604	5.11	6.41	0.132	0.948	2.49	0.998	0.872
11	0.567	0.604	5.11	6.41	0.132	0.948	2.49	0.999	0.873
1A	0.695	0.745	7.15	10.20	0.203	0.952	2.73	0.999	0.870
1B	0.695	0.745	7.15	10.20	0.203	0.952	2.73	0.999	0.870
1C	0.695	0.745	7.15	10.20	0.203	0.952	2.73	0.999	0.870
1D	0.695	0.745	7.15	10.20	0.203	0.952	2.73	0.999	0.870
1E	0.695	0.745	7.15	10.20	0.203	0.952	2.73	0.999	0.870
12	0.695	0.745	7.15	10.20	0.203	0.952	2.55	0.952	0.826
13	0.637	0.682	6.06	8.37	0.167	0.941	2.47	0.941	0.819
14	0.567	0.604	5.11	6.41	0.132	0.948	2.32	0.948	0.827
15	0.567	0.604	5.11	6.41	0.132	0.940	2.32	0.940	0.825
16	0.695	0.745	7.15	10.20	0.203	0.995	2.57	0.995	0.867
17	0.637	0.682	6.06	8.37	0.167	0.994	2.49	0.994	0.867
18	0.567	0.604	5.11	6.41	0.132	0.995	3.34	0.995	0.870
19	0.567	0.604	5.11	6.41	0.132	0.994	2.34	0.999	0.875
20	0.695	0.745	18.0	10.20	0.203	0.991	1.86	0.999	0.881
21	0.717	0.767	7.69	9.03	0.041	0.957	2.39	0.999	0.873
22	0.674	0.725	6.73	11.30	0.155	0.947	2.79	0.999	0.860
23	0.517	0.640	5.00	6.70	0.203	0.922	4.03	0.999	0.854
24	0.695	0.745	7.15	10.20	0.203	0.973	2.66	0.999	0.871
25	0.695	0.745	7.15	10.20	0.203	0.999	2.57	0.999	0.873
26	0.695	0.745	7.15	10.20	0.203	0.874	3.15	0.999	0.861
27	0.695	0.745	7.15	10.20	0.203	0.997	2.57	0.997	0.869
28	0.695	0.745	7.15	10.20	0.203	0.983	2.57	0.983	0.856
29	0.695	0.745	7.15	10.20	0.203	0.968	2.57	0.968	0.842
30	0.695	0.745	7.15	10.20	0.203	0.984	2.57	0.984	0.857
31	0.687	0.737	6.98	10.70	0.203	0.950	2.79	0.999	0.868
32	0.736	0.788	8.22	8.08	0.203	0.962	2.46	0.999	0.872
33	0.695	0.745	7.15	10.20	0.203	0.952	3.30	0.999	0.861

11.6 Analytical Support and Alternate 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

Performance analyses have been completed for 38 cases. Case conditions and results are summarized in Tables 11.2, 11.3, and 11.4. Thus far we have investigated the following parameters; velocity, bed height, excess air, above bed combustion, coal and limestone size, bed ash size, operation without a CBC and without recycle, operation without a CBC but with recycle, coal reactivity, and bed particle density. In addition to the conclusions given in the August monthly, we have determined the following:

- Recycle of elutriated fines to the main bed produces an effect similar to above bed combustion - i.e. recycled fines tend to pull more heat out of the bed, resulting in more heat transfer in the convection bundles and less in the bed. Overall heat transfer surface is increased because convected heat transfer coefficients are lower than bed heat transfer coefficients.
- Recycle of elutriated fines in place of a CBC reduces the required Ca/S ratio, because elutriated S is not subsequently burned at high temperature where capture is inefficient.
- Typical recycle conditions can produce extremely high solids loadings in the convection bundles. Recycle solids flow rates may get 4 to 5 times the inlet limestone feed rate.
- Operating beds about 4-ft deep with no CBC and no recycle substantially reduces overall boiler efficiency.
- Gas residence time in the bed (and thus combustion efficiency and S capture) tends to be increased by bed ash particles of smaller size and lower density.
- Reducing fines in the coal feed improves the combustion efficiency and reduces Ca/S ratio. According to B&W, the fines most likely to reduce combustion efficiency are those between the elutriable cut size and 270 mesh.

^a Consultant

- Operating beds with static depths as deep as 10 ft may eliminate the need for either recycle or a CBC. The penalty paid in power cost is offset by savings in equipment, coal, and limestone usage.

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 addition was made to the heat transfer section to include estimation of heat transfer coefficients for a fluidized bed in turbulent flow regime. This formulation was developed by F. W. Staub⁴. It is suspected that some of the AFBC test facilities are running close to turbulent conditions. It should be noted, however, that the criterion for transition from a bubbling bed to a turbulent bed is still under investigation. The heat transfer coefficient may be calculated from,

$$N_u / N_{ug} = [1 + (150/d_p)^{0.73} (\rho_s \bar{U}_{sd} / \rho_g \bar{U}_{sd})]^{0.45}$$

for $20 \mu\text{m} < d_p < 1000 \mu\text{m}$ if $1000 < d_p < 3000 \mu\text{m}$, then put $d_p = 1000 \mu\text{m}$ (d_p is in μm);

where;

d_p = average size of particles, μm ,
 U_{sd} = superficial solids velocity based on total bed cross section.

$$U_{sd} = 0.42(1 - \alpha_{av}) \Delta 2m^{0.4} (\text{m/sec}),$$

where;

$\Delta 2m$ = the mixing length and is estimated to be equal to length of spacing between the tubes, cm,

α_{av} = the overall void fraction approximated by

$$\alpha_{av} = 1 - (H/H_{mf})(1 - \epsilon_{mf}),$$

where;

H/H_{mf} = the height expansion ratio,

H_{mf} = height at minimum fluidization velocity and is approximately equal to height of stationary bed,

ϵ_{mf} = the voidage at minimum fluidization and is equal to voidage of loosely packed material,

ρ_s, ρ_g = solids and gas densities, respectively,

Nu = the outside Nusselt number

$$Nu = hD_T/kg,$$

where;

h = outside heat transfer coefficient,

D_T = outside tube diameter,

kg = conductivity of gases at mean film temperature.

Nu_g is Nusselt number based on heat transfer coefficient to tube banks with only gas flowing at same superficial velocity. It can be estimated from McAdams (p. 228) and Grimson's equation.

A draft of the fluidization section has been prepared. For a selected representative subsection (chosen as the formula for bed expansion ratio), the following are being included:

1. Graphical representation of results of calculation.
2. A programmable calculator program for doing the calculation.
3. If possible, a nomogram will also be included.

The formula of bed expansion ratio is:

$$H_f/H_{mf} = 1 + \frac{10.978(U - U_{mf})^{0.738} d_p^{1.006} \rho_s^{0.376}}{U_{mf}^{0.937} \rho_g^{0.126}} \pm 12\%,$$

where;

H_f = expanded height, ft,

H_{mf} = height at minimum fluidization, ft,

U = superficial velocity of gas, ft/sec,

U_{mf} = minimum fluidization velocity, ft/sec (given by Wen and Yu's equation) expressed as

$$U_{mf} = (\mu_g / d_p \rho_g) \left(\sqrt{\frac{33.7^2 + 0.0408 \frac{(\rho_s - \rho_g)g}{\rho_g^2}}{\rho_g^2}} - 33.7 \right),$$

where;

μ_g = gas viscosity at bed conditions,

ρ_s, ρ_g = solid and gas densities,

d_p = average particle size,

g = acceleration of gravity.

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

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

11.8.1 Contract objective

ORNL proposes 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

The review of the proposals submitted to TVA by Babcock & Wilcox (B&W) and Combustion Engineering (CE) for the AFBC Pilot Plant was completed, and comments relevant to materials considerations were forwarded to project management. In addition, discussions were held with TVA personnel regarding changes in the original proposal by B&W involving deletion of the carbon burn-up cell together with a number of other modifications. A list of questions and comments regarding the B&W design is being prepared.

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

A sulfur capture submodel was added to the simulation of the pilot plant. Because virtually all available data fit the type of formalism used by Babcock and Wilcox, the approach used here is similar. SO_2 capture in the bed was treated in two parts: capture in the bubble phase with which elutriated limestone was associated and capture in the emulsion phase with which the remaining limestone was associated. Capture in the freeboard was treated as a third zone. Reaction between SO_2 and limestone was approximated as proportional to the available molar quantities of the two. After mathematical integration of the differential equations over the reaction time, the formulas expressed fractional capture as a function of calcium-to-sulfur ratio, gas or bubble residence time, fractional elutriation, and temperature. A single parameter in the formulas for the three zones was evaluated by fitting to the experimental data available from the Alliance 6 x 6 facility. At bed height of 4 ft, freeboard height of 34 ft, and superficial velocity of 4 ft/sec anticipated for the pilot plant, the model gives 60% capture in the bed and 25% in the freeboard (85% total) when using high reactivity limestone, a C/S ratio of 1.61, and 35% elutriation.

A calculation was made with the model to explore the sensitivity of SO_2 capture to change in load. A 1% reduction in firing rate was made at constant C/S ratio, and the changes in equilibrium values of selected variables are shown in Table 11.5.

Table 11.5. Sensitivity of SO_2 capture to load change of -1%.

Bed temperature (°F)	Superficial velocity (ft/sec)	Bubble velocity (ft/sec)	Bed capture (fraction)	Freeboard capture (fraction)	Total capture (fraction)
-5.7 (-0.37%)	-0.035 (-0.88%)	-0.105 (-1.25%)	0.00518 (0.61%)	-0.003 (-0.36%)	0.0022 (0.25%)

Bed temperature decreased (-0.37%) and tended to decrease SO_2 sorption. Superficial and bubble velocities decreased, increasing residence time, and tended to increase sorption. These opposing trends resulted in a new increase in SO_2 sorption of 0.25%. Increased capture in the bed (0.61% of total capture) had the effect of reducing capture in the freeboard (-0.36% of total capture) because reduced SO_2 input to the freeboard more than offset increased residence time in the freeboard. Any variation in elutriation was neglected.

A change was made in the pilot plant model to reflect the status of contract negotiations between TVA and B&W. Since it appears that the feedwater heating system will be deleted from the design, it has accordingly been deleted from the model.

Details of the carbon burnup bed have been suppressed in the model up to now. With the deletion of the carbon burnup bed from the design specification, this approximation in the model disappeared.

A part of the month was spent in further review and evaluation of the pilot plant proposals.

11.10 Coal Feed Tests - Task 11

J. A. Stevens 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

The basic test configuration for the first test series has been designed and will make use of an existing rotary feeder, coal pickup tee, feed hopper and catch tank. A rolling blade air lock valve will replace the rotary feeder when it is received from the manufacturer. This type of feeder will permit test parameters to be varied over the full range of conditions specified in the project proposal. Design considerations were taken into account to allow for system modifications needed for future test series requirements.

Procurement of both two-inch-nominal carbon steel and pyrex pipe sections and instrumentation has been initiated. An unused, large capacity dust filter was located in-house along with a solids blender. The dust filter will be connected to the exit tank for fine particulate removal. The solids blender will be used to ensure both a uniform particle size distribution and uniform moisture content.

Cleanup operations within the coal lab have been completed and arrangements have been made for craft labor assistance during facility construction. Coal preparation procedures have been determined and will be initiated in the near future in order to meet the requirements for the first test series. The basic facility is scheduled to be built and operating by early November.

A preliminary schedule for the first test series will be sent in the near future to the TVA project manager for approval. The basic test parameters are estimated to be OX1/4-in. coal with surface moisture levels set at 2, 4, and 6%; mass flow rates set at 500, 1000, and 2000 lbs/hr; and saturated air with velocities set consecutively at 100, 75, and 50 ft/sec. The limiting values of both coal moisture level and flow rate will have to be determined during initial testing due to the restricted capability of the coal feed system as designed for the first test series. This system will be modified for future tests to allow for operation over the full parameter range. These initial tests will also be necessary for general system checkout and calibration purposes.

11.11 References

1. D. Merrick and J. Highley, AICHE Symposium Series, No. 137, Vol. 70, p. 366, 1974.
2. "B&W Quarterly Technical Progress Report for the Period of January through March 1979," LR:79:4775:01, 1979.
3. J. S. Mei, et al., "Fluidized Bed Combustion of High Sulfur Coals," METC/RI-79/4.
4. ASME Journal of Heat Transfer, Vol. 101, p. 391, August, 1979.

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 St. Paul District Heating Development Company is developing some preliminary cost estimates for the first segment of the 200-MW hot water district heating system. They are investigating the feasibility of running a line from the Third Street Boiler Plant to the Capitol Complex. The contract with the St. Paul District Heating Development Company will not be completed until early November. However, the contract will be back dated so that work can begin on October 1.

M. A. Karnitz attended a DOE District Heating Task Force Meeting on September 12, 1979, in Washington, D.C. In response to a request, we put together some background information on district heating. It is anticipated that this material will be used in the initial draft of a National District Heating Program.

Editorial work was completed on the full Studsvik report, a District Heating Net Energy report, and the District Heating/Cogeneration Symposium Proceedings. Editorial work is continuing on the Building Conversion and the Power Plant Retrofit studies. The District Heating Institutional Issues study is in the final review process.

On the Coal/Cogeneration Power Plant study, Northern States Power and United Engineers & Constructors reevaluated the temperature criteria. They concluded that the maximum temperature of 270°F was more appropriate for hot water district heating in the Twin Cities. The lowering of the temperature from 300°F would mean an increase in cost due to increase piping size; however, this would be offset by the reduction of electricity sacrificed in the cogeneration process.

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. The level of effort was reduced this month after completion of the review and evaluation of Phase 0 deliverables for the SRC projects. Major parts of the current effort are concerned with SRC environmental support and H-Coal materials and technology review.

13.1 SRC Demonstration Plants Design Review

J. J. Kurtz, J. M. Holmes, A. R. Irvine,
W. R. Williams, W. R. Winsbro

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

At the request of the ORO Solvent Refined Coal Projects Office, the management plan for the SRC-I project, presented by the Southern Company Services (SCS) in their "Definitization Plan for Phases I, II, and III" (Task 5 deliverable for Phase 0), was reviewed. The primary object of the review was to determine the adequacy of the contained work statement for Phase 1 activities, relative to the project status at the end of Phase 0.

Concerns were raised regarding the contractor's concept of project schedule, project objective, R&D interface with design evaluation, and contractor/DOE management relationships. These concerns were transmitted to the ORO Solvent Refined Coal Projects Office as assistance in the negotiations for a Phase-1 agreement.

13.2 Direct Liquefaction R&D Review

M. S. Edwards, B. R. Rodgers, C. H. Brown, W. R. Gambill

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," has been widely distributed, particularly to those institutions whose activities in coal conversion research are described within the report. Comments and updates will be incorporated into the report prior to publication.

The industrial groups primarily responsible for proposing R&D to support SRC demonstration projects were visited (Air Products & Chemicals, Inc., SRC-I; Gulf Mineral Resources Company, SRC-II) for discussions of such R&D plans. Interactions and potential overlaps with developmental R&D at the various SRC pilot plants and laboratories were identified. Both groups are now expected to submit more definitive plans to DOE-ORO keyed closely to the R&D needs of the SRC demonstration plants.

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

The first deliverable item for the SRC source book project has been delivered to the DOE-ORO Assistant Manager for SRC Projects for review and comment. The draft document is also being reviewed by ORNL Fossil Energy Program managers, UCC-ND Engineering managers for the source data book project, and project team members. Distribution of the document was limited due to the preliminary nature of the material contained in this initial draft.

Further work in FY 1980 is anticipated. The source book is intended to be a "living document" which will be further developed by additions and revisions of material to better meet the contract objective.

13.4 SRC Environmental Support

S. G. DeCicco

13.4.1 Contract objectives

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

SRC-I and SRC-II demonstration projects - During the month of September, several steps were taken to comply with the EIS procedures set forth by the Council on Environmental Quality (CEQ), the National Environmental Policy Act (NEPA), and DOE's Division of NEPA Affairs. As required, a Notice of Intent to prepare an EIS was written for each SRC project and sent to DOE-HQ for publication in the Federal Register. The notices describe the proposed actions, alternatives to the actions, the structure of the team preparing the EIS, the industrial partners, the significant environmental issues, and announce the date and location of the public scoping meetings.

Although DOE held a public scoping meeting for each project, DOE's Office of General Council decided that additional meetings should be held and announced nationally via the Federal Register. For the SRC-I project, scoping meetings are to be held in Owensboro on October 24 and Louisville on October 25. For the SRC-II project, scoping meetings will be held in Morgantown on October 22 and Pittsburgh on October 23. ORNL will be represented on the panel at each meeting.

Draft EIS Implementation Plans were also prepared this month for each project. They are similar in content to the Notices of Intent but go into more depth. They are required by CEQ regulations and are used as an internal means to assure that DOE is following the NEPA procedures.

ORNL's schedules for delivering the SRC EISs hinge on the dates that Dames & Moore (SRC-I) and Stearns-Roger (SRC-II) deliver their EIS support material to us and on the quality and state of completion of the material delivered. Stearns-Roger should be on schedule with a delivery on October 1. Dames & Moore should be about three weeks off with a delivery on October 19. The ability of the projects' design groups to estimate plant effluents has been a stumbling block in terms of schedule and the anticipated thoroughness of the EISs. Current estimates for the preliminary draft EISs (PDEIS) are: January 7 for SRC-I and December 14 for SRC-II.

At a meeting with Stearns-Roger on September 20 and 21, ORNL reviewed and commented on draft EIS support material. A similar meeting for Dames & Moore is being set up for October 15.

13.5 SRC Net Energy Analysis

W. P. Huxtable, K. F. Wu

13.5.1 Contract objective

The objective of this project is to evaluate the overall energy efficiency of solvent refined coal (SRC) processes from coal mining to electricity production and delivery. Analysis will consider not only plant efficiency but will also encompass energy requirements of raw material acquisition, product distribution, plant construction, and other factors.

13.5.2 Status summary

The draft report of the study was completed except for editing and final review. The study has gradually been revised to include most of the latest information supplied by the recent Phase 0 documents on the SRC-I and SRC-II commercial plants.

Our most recent results indicate that for each 30,000 tons of coal processed about 94,000-98,000 barrels of crude oil consumption can be displaced in the eastern United States. The chief difference in the two commercial SRC plants is the amount of electricity which each consumes. When proper credit is given for the energy resources necessary to generate this electricity, the SRC-I and SRC-II commercial processes have nearly the same thermal efficiency.

The draft report summarizing these and other results should be available this coming month.

13.6 H-Coal Materials and Technology Review

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

13.6.1 Contract objective and scope

Overall objective - The materials of construction and the coal liquefaction technologies planned for use in the H-Coal pilot plant relative to the available data and experiences will be evaluated. The evaluation will attempt to ensure the maximum utilization of the existing information and experiences from other liquefaction pilot plants and 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;
5. an "incident report" system to distribute information on technical problems.

13.6.2 Status summary

Review of technical data on H-Coal pilot plant - A more comprehensive study of the design and operation of the pilot plant is in progress through review of the following documents which were acquired recently.

1. Operations Manuals for Sections 100 (Coal Preparation), 200 (Hydrogenation), 400 (Waste Water Treatment and Utilities), 500 (Deashing), and 600 (Waste Oil Recovery), in conjunction with the process flow and engineering drawings.
2. Selected portion (five books) of the proprietary final design report. The detailed review is being carried out to identify any shortcomings and potential problems in the plant. The review will also provide the basis for determining the types of data from other liquefaction pilot plants that will be useful to the H-Coal plant.

Visit to H-Coal pilot plant - The visit to the H-Coal pilot plant, Catlettsburg, Kentucky, was made by K. H. Lin to: (a) consult with the DOE site representative and ASFI regarding additional technical information for the plant and (b) to select from among the available information the

pertinent data which will be utilized immediately. Major portion of the day was devoted to review and selection of the information provided by Dick Santore (DOE).

The information consisted of the proprietary final design report (four volumes, 42 books total) and Operations Manuals for Sections 500 and 600. Based on the pertinence of the data to the work of the Task Force, five books of the final design report and all of the operations manuals were selected for use by the Task Force members.

A meeting was held afterward with Dick Santore (DOE) and Ray Schutter (ASFI) to discuss availability of 12 items of information requested by the Task Force members. Most of the requested information are available, although many of the items are either incomplete or not in the form of official, written documents. Some are so voluminous that it is impractical to attempt to go through in detail or to reproduce completely.

Trips to coal liquefaction pilot plants - Arrangements are under way to visit selected coal liquefaction pilot plants and related facilities. The tentative selected list of plants includes the SRC Ft. Lewis and SRC Wilsonville plants, the HRI Trenton facility, the C. E. Lummus Company (New Jersey) and the CSF Cresap plant. Most of the plant trips are planned for the month of October.

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