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Fossil Energy Program Progress Report for July 1980

L. E. McNeese

Fossil Energy Program

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DEPARTMENT OF ENERGY

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FOSSIL ENERGY PROGRAM PROGRESS REPORT FOR JULY 1980

L. E. McNeese
Program Director

Date Published - October 1980

OAK RIDGE NATIONAL LABORATORY
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FOSSIL ENERGY PROGRAM REPORT FOR JULY 1980

ABSTRACT

This report - the seventy-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, chemical research and development, materials technology, component development and process evaluation, technical support to major liquefaction projects, process and program analysis, fossil energy environmental analysis, coal preparation and waste utilization, coal preparation plant automation, atmospheric fluidized bed coal combustor for cogeneration, technical support to the TVA fluidized bed combustion demonstration plant program, fossil energy applications assessments, performance assurance system support for fossil energy projects, international assessment of atmospheric fluidized bed combustion technology, and PFBC systems analysis.

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1. Summary

L. E. McNeese

Coal conversion development — Rheological characterization measurements were performed on an H-Coal reactor effluent sample from PDU run 130-88. Shear stress versus shear rate measurements were made at conditions (724 K and 18.2 MPa) which closely approximate the H-Coal reactor conditions at the time the sample was taken. The data is well described by a power law model over the shear rate investigated (200-700 s^{-1}). Apparent viscosity was 2.1 mPa·s at 300 s^{-1} shear rate. Values for the velocity in the pipeline viscometer are based on extrapolated values of density for 35 wt % Illinois No. 6 coal slurry. Preparations are underway to measure the density of the H-Coal sample at 724 K and 18.2 MPa using the gamma radiation absorption density instrument.

High conversions of coal to pyridine soluble products have been obtained using multihydroxy benzenes. Some colloidal material has been identified but conversions are still higher than with phenol.

Recoveries of products from the Deno oxidation of Wyodak coal have been greatly facilitated by the discovery that up to 40% by weight of the original coal can be recovered by exhaustive extraction of the filtered solids. The material recovered appears to be composed of aliphatic groups with longer chains than was previously reported in the filtrate.

Chemical research and development - The formation of the new aryl-aryl bond during thermolysis of 2-naphthol appears to occur largely in an unsymmetrical fashion between C-1 and C-3'. This will be a powerful tool in further elucidation of mechanisms. Further data from thermolysis of 1,3-diphenylpropane suggest that both radical addition and β-scission reactions are important. The homologation of 1-butene to C_5 products over a Fe Fischer-Tropsch catalyst is a sensitive function of both the preexposure to and the simultaneous presence of CO.

Materials technology - The study of the effect of coal conversion environments on the fracture toughness of pressure vessel steel was continued. Charpy-V specimens from commercially prepared heats and weldments of 2 1/4 Cr-1 Mo steel are being prepared for testing. Metallographic examination and Gleeble studies to simulate various heat-affected zones of the weldment are also under way. Efforts in the study of corrosion of AFBC heat exchanger materials continued with work concentrated on the preparation of a final topical report on the 4500-h exposure test in the FluiDyne AFBC. In the failure prevention and analysis task, tubing from the light ends column reboiler tube bundle of the Fort Lewis SRC Pilot Plant was analyzed and confirmed to be Incoloy 825. Metallographic examination showed the tube outer surface had large, randomly spaced pits and shallow intergranular attack in the pitted areas. The investigation of materials performance in liquefaction systems continued. These studies include general corrosion and stress-corrosion cracking in specimens exposed in operating pilot plants in laboratory simulations using liquids from the pilot plants and the testing of candidate materials for the $ZnCl_2$ regeneration system of the Conoco Zinc Chloride Hydrocracking Process. In the task for development of modified 9 Cr-1 Mo steel, the fabrication of two large heats into final product form such as plate, bar, and tubing continued. Mechanical property characterization and weldability studies on this alloy are also under way. In the ceramic recuperator task, examination of specimens continued to determine the mechanism for the observed increase in helium permeability resulting from exposure to the products of combustion of No. 6 fuel oil in CRAF Test 1. Pre-exposure characterization of specimens to be exposed to the products of combustion of coal-oil-mixture in CRAF Test 2 is under way.

Component development and process evaluation - An inhouse report outlining the most pertinent and available information on wet grinding of coal is currently being written. A test run was completed of the computer modeling program for the packed bed let-down system using assured SRC-II parameters.

Technical support to major liquefaction projects - Support is provided by Oak Ridge National Laboratory and Union Carbide Nuclear Division Engineering for the major liquefaction projects being managed by DOE Oak Ridge Operations--SRC-I and SRC-II Demonstration Plants and H-Coal Pilot Plant Projects. Activities are reported in seven areas--engineering and design review, technology overview, design data validation, components, materials, environmental and health, and general technical support. Highlights during July include a review of the data base supporting design of the Kerr-McGee Critical Solvent Deashing process, calibration of the coal slurry mixing apparatus, modeling of a packed bed pressure letdown system, analysis of corroding and non-corroding fractionator fluids, and release of the Draft Environmental Inpact Statement for the SRC-II project.

Process and program analysis — The potential cost of providing environmental controls for eight conceptual low-Btu coal gasification plants has been examined in order to illustrate the relative economic impact of alternate pollution abatement technologies. Results of the study are reported in Cost and Technical Characteristics of Environmental Control Processes for Low-Btu Coal Gasification Plants (ORNL-5425), which was published and distributed this month. The evaluations show that environmental controls can be significant contributors to the clean fuel gas cost, particularly for smaller capacity plants, and that greater attention should be focused on wastewater treating processes.

Fossil energy environmental analysis - In the Fossil Energy Environmental Project soil samples were collected from the proposed site of the SRC-II project. Attenuation properties of these soils will be measured to determine potential impacts of solid waste leachates. Photoready copy of the MLGW Draft EIS was delivered on schedule to DOE/Chicago Operations Office.

Primary focus of the Fuel Use Act Program for the month was directed towards finalization of definitive scoping for necessary engineering analyses associated with the proposed powerplant conversions. A task order was received to initiate work on Salem Harbor, the fourth powerplant under this study.

In the Fossil Energy Environmental Impact Work the third document for the NEPA energy projects was completed. This covers solar, geothermal, and small hydroelectric demonstration projects. Drafts of the Environmental Compliance Program Handbooks for the states of Ohio, West Virginia and Tennessee were delivered to DOE on schedule.

Coal preparation and waste utilization - Further testing of both HGMS and OGMS systems was conducted in late July with our superconducting magnet. Samples are currently being analyzed. A double-cone, heavy-media, separatory device is being fabricated. Representatives of the CVI Corporation visited our laboratory.

Coal preparation plant automation - The prototype hardware correlator circuitry was tested and performed satisfactorily using sonic flowmeters installed in a laboratory flow loop as signal sources. Initial testing on the oscillating-sphere viscometer indicates the instrument is sensitive to mechanical shock. Laboratory testing was initiated to determine the relationship between the density and ash content of a particular blend of coal; the goal is to evaluate the possibilities of using an ash versus density correlation as the basis for a simple and relatively inexpensive on-line ash measurement method. Work progressed on the coal preparation plant automation state-of-the-art report. Dynamic models for the froth flotation cells and filtration process have been completed using the Continuous Systems Modeling Program (CSMP). A listing of the coal preparation and instrumentation documents in the project files, arranged by category and containing abstracts and indexes, was generated. One hundred fifty-nine requests for documents, searches, and information were processed. Thirty-nine articles, reports, and books were ordered. Documentation on a commercially available proprietary data acquisition and control software package was obtained on loan and reviewed for potential use in on-site testing at coal preparation plants. Project personnel visited five local coal preparation plants.

Atmospheric Fluidized Bed Coal Combustor for Cogeneration - The subcontract package was completed, signed by UCC-ND, and sent July 29 to Westinghouse for their signature. A meeting was held at ORNL on July 17 to review the status and plans for work on the CCC Program under the Letter of Intent.

Tennessee Valley Authority (TVA) Fluidized Bed Combustion (FBC) Demonstration Plant Program Technical Support - In the AFBC Modeling and Simulation task, the sulfur capture subcode was added to the combined code. This involved incorporating the pore plugging grain model into a fluidized bed. A method for characterizing the active sorbent in the bed has been developed and incorporated into the combined code. Preliminary sulfur capture results from this combined model are given and are currently being analyzed. Work also continued on the freeboard modeling effort. Modifications have been made to the gas phase subcode to decrease the computer run time.

The AFBC bench scale facility is presently being refitted to incorporate recycle. The system includes a new cyclone separator in the fluidized bed exhaust line and a screw feeder to modulate the flow of cyclone solids back into the bed. Installation of the recycle system was about two-thirds complete at the end of July. Work is expected to be finished by mid-August.

In the coal feed tests task, the following additional conclusions have been reached:

- Coal-limestone mixtures begin to salt out in the horizontal line when conveying air velocity approaches 16.8 m/s (55 ft/s).
- A saltation-like phenomenon also occurs in the vertical 90° long radius bend and straight vertical run at about 16.8 m/s.
- When there is no saltation, the pressure drop ratio is only a function of the solids loading.

Further coal limestone tests have been planned.

For the materials evaluation and testing task - muffle furnace tests, metallographic examination of samples from the first three experiments in the gas-metal reactor muffle furnace is continuing and is reported. The first 200-h in-bed test of candidate structural and heat exchanger materials in the FluiDyne AFBC was completed during the month. For this test, the oxygen level in the flue was held at 1%, a condition that was thought to be marginally unsafe from a corrosion standpoint. Since no tubes had obviously failed during the test, it was decided that uncooled tubes would first be removed for inspection. The tubes appeared to be in good condition with moderately thin calcium sulfate deposits ranging from tan to olive-brown over the in-bed portions.

Fossil fuel applications assessments - Dry limestone injection has been included in the investigation of industrial boiler options. Candidate architect-engineering firms have been approached to discuss development of industrial boiler costs.

Performance assurance system support for fossil energy projects - A status report for current performance assurance activities was prepared. A draft report of a failure modes and effects analysis for a generic slurry preheater has been prepared for internal review.

International energy technology assessment - The Oak Ridge National Laboratory is supporting the Lawrence Livermore Laboratory in a broad program funded by the DOE Office of International Affairs. During the month of July effort has been focused on gathering information on direct liquefaction processes and gasifier developments. Compilation of available information by country has been initiated in regard to coal liquefaction materials, and arrangements are being made to extend the efforts of Gilbert/Commonwealth to provide assistance in the materials assessment area as well as the process areas. A literature search is under way to identify and describe development work and application of AFBC systems in foreign countries. Information is now being requested from selected organizations relating to past and current R&D projects in specific AFBC problem areas.

PFBC systems analysis - An engineering systems analysis of PFBC power systems has been initiated to provide data, analysis, and supporting logic for the expanding DOE PFBC program. This is the first reporting period for this task. A detailed heat/mass balance model for the PFBC furnace has been completed. Data has been received from the Elliot Company on the turbo-expander which they see as suitable for PFBC power plant.

2. COAL CONVERSION DEVELOPMENT

J. R. Hightower, Jr.

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

2.1 Physical Properties of Coal Liquids

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

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

Results of rheological characterization measurements on the H-Coal PDU reactor effluent sample are presented.

2.1.1 Work accomplished

Rheological characterization measurements were performed on the H-Coal reactor effluent sample. The pipeline viscometer (PLV) was operated with variable slurry mass flow rate at constant temperature and pressure, 724 K (843°F) and 18.2 MPa (2625 psig). These conditions closely approximate the H-Coal PDU reactor conditions at which the sample was taken, 726 K and 18.2 MPa. Figure 2.1 is the flow curve (logarithmic plot of wall shear stress, τ_w vs the Rabinowitsch-Mooney flow parameter, 8V/D) produced from the measurements. The data correlates well with a straight line fit ($r^2 = 0.993$); so the rheological behavior of the slurry over the range of shear rates investigated (200-700 s^{-1}) is well described by the equation

$$\tau = 7.63\ (\dot{S})^{0.772}$$

where

τ = shear stress, mN/m^2

$\dot{S}$ = shear rate, sec^{-1}.

ORNL DWG 80-1177

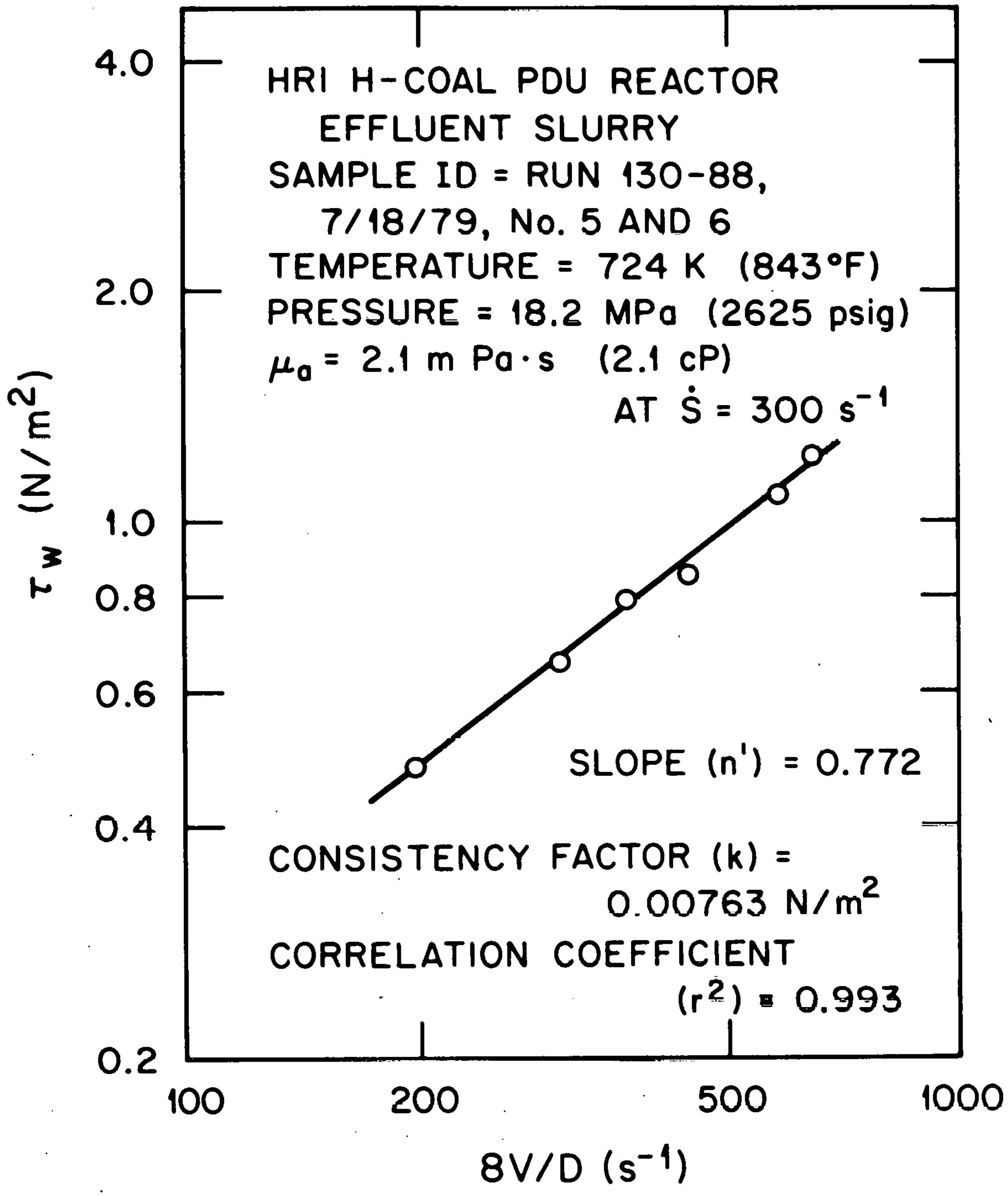


Fig. 2.1. Flow curve for H-Coal PDU reactor effluent slurry at 724 K and 18.2 MPa.

These measurements indicate the slurry to be slightly pseudoplastic. Apparent viscosity was 2.1 mPa·s at 300 s^{-1} shear rate.

The 8V/D values for each data point in Figure 2.1 were calculated using density data (0.80 g/cm^3 at 724 K) from earlier measurements[1] on 35 wt % Illinois No. 6 coal in Indiana No. 5 Wilsonville recycle solvent. In the near future density measurements will be made on the H-Coal PDU reactor effluent slurry, and if there is significant variation from the value used in these calculations, corrections will be made to the flow curve. A change in density will cause a uniform horizontal shift of the flow curve. This shift would not affect the slope of the flow curve; the only changes would be in the horizontal position of the curve and a corresponding shift in the value of the power law model consistency factor.

In preparation for these measurements, the slurry was removed from the two sample bombs (7 liter capacity each) by first melting the slurry via heating the surface of the bomb to ∿435 K. Them helium was bubbled up through the bomb for 0.5 minutes to resuspend any settled solids. The slurry was discharged from the bombs directly into the feed tank by applying helium overpressure. A total of 4 kg was recovered; so the bombs were only partially filled during the sampling operation. The material was placed in a special stirred and heated feed tank. The slurry mass feed rate to the system was determined by continuously monitoring feed tank weight with an electronic load cell. Feed tank temperature was controlled at 450 K. To maintain slurry suspension in the lines between the feed tank and the positive displacement feed pump, the slurry was constantly circulated past the suction port of the feed pump at 0.5 ℓ/min rate. The feed pump head and its discharge line were heat traced at 450 K to maintain fluidity of the slurry as it flowed to the preheater inlet. The preheater was operated with constant heat flux along its length; heat input was controlled such that the slurry just reached the temperature of the viscometer measurement at the preheater exit. Thus, slurry residence time at the measurement temperature before it entered the viscometer was zero. The viscometer was maintained at the measurement temperature by a independent trace heat system. Viscometer differential pressure, inlet and outlet temperatures, and the slurry mass flow rate were recorded by the on-line digital computer data acquisition and analysis system. The slurry exiting the viscometer was collected in a sample bomb piped into the system at the viscometer discharge. A total of 3 kg of slurry was fed to the system while taking the six data points; total time of slurry feed was about one hour. There was no evidence of additional slurry liquefaction reactions as these measurements were being made. The on-line gas chromatograph monitoring the system gas effluent stream did not detect any hydrocarbons or carbon oxides evolution during the run; in comparison, when raw coal slurry is processed at high temperature there is generous gas evolution. Experimental data are summarized in Table 2.1; sample identification and H-Coal PDU run conditions are presented in Table 2.2.

Table 2.1. Rheological characterization data for H-Coal PDU reactor effluent sample
sample ID - Run 130-88, 7/18/79, Nos. 5 and 6
system pressure during measurements - 18.2 MPa

Time (7/22/80)	Feed rate (g/s)	PLV ΔP Range (kPa)	PLV ΔP Ave. (kPa)	PLV temps. In (K)	PLV temps. Out (K)	$8V/D$[a] (s^{-1})	τ_W (N/m^2)	Viscosity (mPa·s)
1240	0.507	0.49-0.63	0.573	722	717	302.2	0.656	----
1247	0.744	0.69-0.81	0.822	724	722	445.4	0.854	----
1254	0.973	0.87-1.04	0.971	724	723	582.9	1.090	----
1306	0.327	0.37-0.46	0.423	724	722	195.7	0.478	----
1313	1.076	1.02-1.13	1.071	724	725	644.8	1.226	----
1320	0.614	0.60-0.75	0.697	728	727	369.2	0.798	----
PLV calibration with Kentucky No. 9 Wilsonville recycle solvent pressure - 13.9 MPa								
0913	0.453	---	0.814	338	338	233.4	1.000	4.28
0927	0.662	---	1.245	338	338	342.3	1.413	4.13
0936	0.884	---	1.721	339	338	456.3	1.953	4.28
1525	0.614	---	1.190	338	338	318.4	1.351	4.24
1540	0.480	---	0.911	339	340	248.9	1.034	4.15
1550	0.862	---	1.718	338	338	447.0	1.949	4.36

[a]Calculated using 35 wt % Illinois No. 6 coal slurry density.

Table 2.2. Data for PDU liquid samples

Date		7/18/79	7/18/79
Time		1730	1800
Sample No.		5 (1)	6 (2)
PDU Run No.		130-88	130-88
PDU Period No.		13A	13A
Data			
Catalyst Bed Expansion		150%	150%
Feed Rate			
Coal	Avg.	(323)	(323)
	Instant	341 lbs/hr	341 lbs/hr
Liquid		(655) lbs/hr	(655) lbs/hr
Gas		6152 SCFH	6152 SCFH
Coal Type		Illinois No. 6	Illinois No. 6
Coal Concentration			
Conversion	Toluene Extraction	92.5	92.5
	DMF Filtration	(88.9)	(88.9)
Catalyst Type		HDS-1442A------------------------------►	
Reactor Temperature		848°F	848°F
Reactor Pressure		2623	2623
		Oak Ridge 6" Bomb	Oak Ridge 6" Bomb

The viscometer was calibrated before and after the run using Kentucky No. 9 Wilsonville recycle solvent. These data are included in Table 2.1. Pre- and post-run calibrations agree within 2%; so no appreciable calibration shift occurred during the run. The noise in the viscometer differential pressure signal (see Table 2.1 heading PLV ΔP range) was caused by erratic slurry feed rate. The seals on the slurry circulation pump allowed some air to enter the circulation stream. The air reduced the efficiency of the positive displacement feed pump causing the variation in slurry feed rate. Since the data logging computer averages slurry feed rate and viscometer differential pressure over a five minute period for each data point, the effects of these variations are minimized. Modifications are in progress to correct the air leakage problem. Chemical analyses on the H-Coal slurry will be reported next month.

2.1.2 Future work

The density of the H-Coal PDU reactor effluent material will be measured at 724 K and 18.2 MPa using the gamma radiation absorption liquid density instrument. If necessary, the flow curve for this material will be corrected based on this information. Additional pipeline viscometer rheological characterization measurements will be made concurrently with the density measurements.

2.2 New Liquefaction Techniques

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

The purpose of these research studies is to provide a better understanding of the chemical processes involved in the liquefaction of coal based on recent advances in knowledge of the structure of coal. The technical approach includes exploitation of the chemistry advances to develop new process concepts based on rapid conversion without the addition of external hydrogen.

Present research is aimed at exploring the conversion of subbituminous and bituminous coals by the use of supercritical phenol, including the mechanisms of hydrogen transfer and structural studies of the converted products. Production of phenol from coal is also being explored since this is the necessary step to utilization of the above reaction in a process scheme.

2.2.1 Hydrogen transfer mechanisms

While phenol is instrumental to the conversion of coal by the process discussed previously, it is not known whether its action is due to the vapor or the liquid. During heat-up phenol is a liquid,

*Chemistry Division.

but at reaction temperatures (460°C) it is above its critical temperature (421.1°C) and exists as a dense gas. If its action is through the gas phase, the density of this phase should effect conversion. Preliminary results reported previously were quite encouraging because of the potential for reducing the amount of phenol required for the conversion. By changing the volume, 2/1 phenol/Wyodak runs were made where the density was held the same as for a 10/1 phenol/Wyodak run. The initial result was a 55% MAF conversion of Wyodak coal to pyridine soluble products in only 15 minutes at 454°C. A repeat gave a 57% MAF conversion.

Densities were back-calculated for key runs from the past two years and a trend of higher conversions with increasing density was noted. Also, a temperature effect on conversion at certain densities indicated that a 2/1 density mixture would give around 70% conversion at 482°C. This run has been made and results will be available next month.

2.2.2 Phenols from coal

During production of phenol from coal, a number of multihydroxy benzenes will also be produced. Hydroquinone (1,4-dihydroxy Benzene) is expected to be present in significant quantities. A run with Wyodak coal at a ratio of 10 parts hydroquinone to one part coal, 454°C, and 15 minutes apparently gave complete solubility in ethanol on an MAF basis. Solubility was determined by filtration from a stirred solution of 30 parts ethanol to one part reacted hydroquinone and coal. Thus, the filtrate contained only soluble coal and hydroquinone or colloidal material. A 10,000 g centrifugation did not produce colloidal material and a 30,000 g centrifugation only produced an amount too small to weigh. However, at 105,000 g for three hours an amount equivalent to 13% of the hydroquinone plus coal was recovered.

It is not known whether the above material was hydroquinone or unreacted coal or both. Filtering the ethanol soluble material, after boiling with water to remove hydroquinone, followed by pyridine extraction of the collected material recovered all the converted product plus some hydroquinone. This indicates that some hydroquinone is present in the ethanol soluble material as very fine colloids. Also, calculations show that around 19% of the collected product is hydroquinone. A repeat gave 11% of the product as hydroquinone. This represents a hydroquinone loss to product of from 1 to 2% of the starting material.

A hydroquinone/Wyodak run under the same conditions as above, but without the ethanol extraction, gave 84% conversion of the collected solids to pyridine soluble products. However, the weight gain of the solids over the starting coal, 58%, indicates that a large amount of the hydroquinone was not removed by the boiling water. These results indicate that if a significant amount of multihydroxy benzenes are produced during the production of phenol from coal, they will result in even more conversion than the phenols themselves. However, incorporation into product may be a problem.

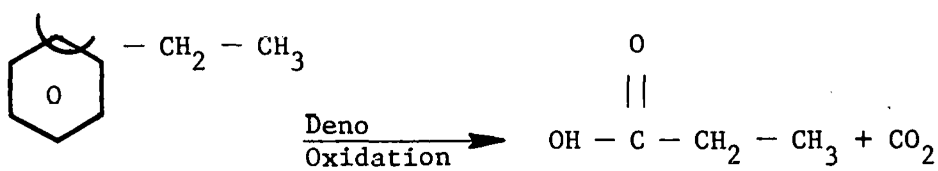
2.2.3 Structural studies

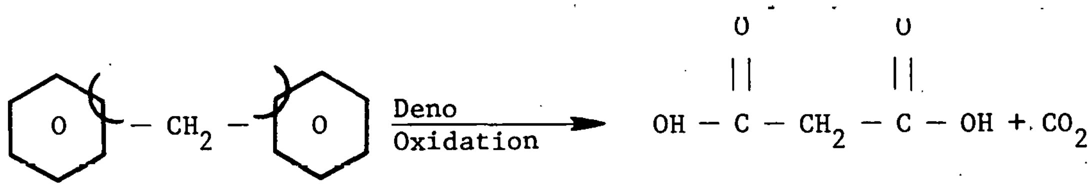
Nitric acid oxidation studies, previously reported, considerably lowered the reactivity of coal with phenol. This month, simple air oxidation of Wyodak coal for 96 hours at 60°C in pyridine decreased the amount of coal converted in the coal-phenol reaction to 48% (from 69% without oxidation). This is similar to the result obtained after HNO_3 oxidation, and is clearly unsatisfactory as a method of increasing conversion in the reaction, or solubility in solvents for subsequent nmr analyses. It is possible that air oxidation at higher temperatures could effect reactivity, but in light of oxidation results thus far, this effect will not be examined.

In the Deno oxidations reported previously, only about one half the coal was recovered. In addition, only about 30% of the recovered material could be analyzed due to limited solubility in the nmr solvent $CDCl_3$. In the Deno procedure a mixture of trifluroacetic acid (TFA), peroxide (H_2O_2) and sulfuric acid (H_2SO_4) are stirred for four hours while refluxing to produce the strong oxidant TF peroxy acid shown below

$$F_3C - \overset{\overset{\displaystyle O}{\|}}{C} - O - OH \ .$$

This material is then added to the coal and heated. To remove the hazardous H_2O_2, 10% platinum on graphite is stirred into the above mixture converting the H_2O_2 to water and platinum oxide. The insoluble PtO and unconverted coal are filtered. Theoretically, the Deno procedure removes aliphatic groups intact from aromatic rings and oxidizes the remainder of the ring to CO_2. A couple of examples are shown below.





To facilitate gc and nmr analyses, the OH groups are esterified as follows,

$$\mathrm{OH-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-OH \xrightarrow[\substack{14\%\ BF_3 \\ 60^\circ C}]{MeOH} CH_3-O-\overset{\overset{\displaystyle O}{\|}}{C}-CH_2-\overset{\overset{\displaystyle O}{\|}}{C}-O-CH_3}\ .$$

It is the chloroform soluble portion of this esterified product that is subsequently analyzed.

It was realized that analyzing only 15% of the product (30% chloroform soluble portion of 50% recovery) may not be representative. Searching for the lost material, the filter cake from the PtO/insoluble coal filtration was refluxed in $CHCl_3$ (56°C) for 24 hours. Twenty to forty percent of the original weight of the coal was recovered from the filter cake. Initial nmr analyses reveal that longer chain aliphatic groups are present in this material when compared to the aliphatic material in the filtrate. The nmr will be rerun after esterification to determine if the material came from an aromatic ring or was otherwise bound in the coal.

2.2.4 Future plans

Reactions of coal with multihydroxy benzenes will continue. Pyridine solubility of reaction products will be determined as will the multihydroxy uptake into converted products. Production of colloidal material in the Hydroquinone/Wyodak reaction will be determined.

Structural studies will continue to emphasize nmr since the results of current studies of silylated products are encouraging. The aliphatic material recovered from the filter will be esterified and compared to the nmr spectra already obtained on that material. The Deno oxidation will be run for longer times to see if a clear solution can be obtained. Deno initially reported that he obtained clear solutions in four hours, but has recently reported times near 18 hours. Unclear solutions may indicate incomplete reactions. Products from Bruceton/phenol runs will also be oxidized by Deno's procedure.

The distribution of multihydroxy benzenes produced from coal is needed to determine their relative importance to the phenol/coal reaction. This will be determined as resources permit.

2.3 References

1. L. E. McNeese (ed.), Fossil Energy Program Quarterly Progress Report for the Period Ending December 31, 1979, ORNL-5630, Oak Ridge National Laboratory, Oak Ridge, Tennessee (April 1980).

3. CHEMICAL RESEARCH AND DEVELOPMENT

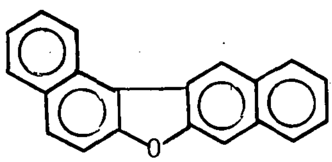
M. L. Poutsma

3.1 Chemistry and Structure of Coal

M. L. Poutsma and C. L. Wolf

Several initial observations made this month concerning thermolysis of both α,ω-diphenylalkanes and naphthols will be reported here, although all of these require further confirmation and quantification.

(1) The *major* thermal condensation product from 2-naphthol is not identical with that from 1,1'-binaphthalene-2,2'-diol. Combining this result with hints in existing old literature, we tentatively conclude that the product from 2-naphthol is dinaphtho[2,1-b;2',3'-d]furan (1) rather than the "anticipated" 2,1-b;1';2'-d isomer 2. This specific



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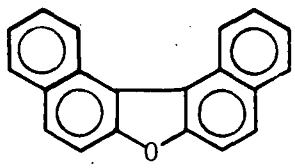

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formation of the new C-C bond between C-1 and C-3' of two 2-naphthol molecules places strong additional constraints on the mechanisms to be considered.

(2) The major *secondary* product from thermolysis of 1,3-diphenylpropane (toluene and styrene are the initial products) has the composition $(C_6H_5)_3C_5H_9$ by glpc-ms analysis, i.e., an adduct of styrene with the starting material. Hence it may be at 365°C that, whereas the primary chemistry is dominated by a radical β-scission process:

$$Ph\dot{C}HCH_2CH_2Ph \longrightarrow PhCH{=}CH_2 + PhCH_2\cdot \ ,$$

the secondary chemistry involves a radical addition:

$$Ph\dot{C}HCH_2CH_2Ph + PhCH{=}CH_2\cdot \longrightarrow Ph\dot{C}HCH_2CHPhCH_2CH_2Ph \ .$$

(3) Thermolysis of 1,4-diphenylbutane at 365°C gives both toluene and allylbenzene as well as ethylbenzene and styrene in amounts dependent on the pressure. The predicted thermochemistry suggests that, whereas the radical $PhCH_2\dot{C}HCH_2CH_2Ph$ is of course less stable than $Ph\dot{C}HCH_2CH_2CH_2Ph$ by some 10 kcal/mole, the transition states for β-scission for the two radicals might be of comparable energy.

3.2 Indirect Liquefaction Chemical Research

R. A. Strehlow and E. C. Douglas

We have previously observed that chain lengthening of butene-1 to pentene or pentane over a carburized Fe-based Fischer-Tropsch catalyst occurred at low space velocities and pressures when the temperature was ∿300°C. We have now studied this chain lengthening process on a freshly reduced iron catalyst never exposed to carbon monoxide. We found that chain lengthening of butene-1 in the presence of hydrogen to pentene and pentane occurred to an extent similar to that observed earlier. The reaction was accompanied by the formation of methane, which showed both hydrogenolysis and carbon deposition on the surface of the catalyst to be occurring. The conversion to the higher hydrocarbons was not however a dominant reaction pathway in comparison with the simple hydrogenation of the butene-1.

Injection of aliquots of carbon monoxide both with test olefins and prior to their injection showed evidence of the well-known fact that, as the CO reacts with the iron catalyst, the ability of the catalyst to hydrogenate the test olefin is impaired; somewhat larger amounts of higher hydrocarbon were produced than in the absence of CO. This is in distinction to our earlier finding that for an injection of a test olefin into a CO/H_2 mixture no evidence of chain lengthening was obtained. The differences between these two situations may be due to the difference between "freshly deposited" and "old" carbon on the catalyst surface and will be explored as we extend the temperature and pressure ranges in this study of chain lengthening of olefins at Fischer-Tropsch catalyst surfaces.

4. MATERIALS TECHNOLOGY

R. A. Bradley

This section describes the research and development performed by the Metals and Ceramics Division on the Fossil Energy Materials Program supported by the Department of Energy's Office of Advanced Research and Technology. It includes tasks on pressure vessels and piping materials, welding and cladding development, corrosion of AFBC materials, failure prevention and analysis and materials research for liquefaction systems, development of modified 9 Cr-1 Mo alloy, and materials for ceramic heat exchangers.

4.1 Pressure Vessel and Piping Materials

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

The purpose of this task is to investigate the fracture toughness and hydrogen attack of pressure vessel steels. We are continuing to characterize the toughness properties of the 286-mm-thick (11 1/4-in.) SA-387 grade 22 class 2 (2 1/4 Cr-1 Mo) weldment from Chicago Bridge and Iron Company. Charpy-V specimens from the base plate are being stress relieved for 7, 28, and 42 h at 691°C (1275°F) to evaluate the effect of time on stress relief temperature. Charpy-V specimens of weld metal and heat-affected zone (HAZ) have been received and are being tested.

The programmed cooling of the 12-mm-square bars from the two Lukens Steel Company heats of SA-387 grade 22 (2 1/4 Cr-1 Mo) have been completed and the tempering [6 h at 663°C (1225°F)] has begun. After tempering, the bars will be divided into three groups. One group will remain as controls, the second will receive a 24-h stress relief at 691°C, and the third will receive a 48-h stress relief at 691°C.

Surface and quarter-thickness Charpy-V specimens have been received, which came from the base plates of submerged-arc welds made in 152-mm-thick (6-in.) SA-204 grade B and 156-mm-thick (6 1/8-in.) SA-516 grade 70 steel plates. Both welds were made by Chicago Bridge and Iron Company. Testing of the specimens is under way.

4.2 Welding and Cladding Development

D. P. Edmonds and G. M. Goodwin

The purpose of this task is to develop techniques for weld overlay cladding of components for coal conversion systems and to characterize weldments in thick-section steels. Evaluation is underway for the 25-cm-thick 2 1/4 Cr-1 Mo steel weldment obtained from Chicago Bridge and

Iron. A metallographic evaluation is ongoing for samples cut from the base metal (surfaces, 1/4 T, and 1/2 T locations), weld metal and HAZ. Early results have shown some small cracks transverse to the weld fusion line. In addition, Gleeble studies to simulate various HAZ structures have begun. Specimens will be subjected to single, double, and triple thermal cycles to simulate multipass welds, and different post-weld heat treatments will be performed. Impact and tensile specimens will then be machined from the thermal treated blanks. Results from this testing will be compared to the properties obtained for the actual HAZ.

4.3 Corrosion of AFBC Heat Exchanger Materials

T. G. Godfrey and J. H. DeVan

Preparation of the draft report on the 4500-h materials test in the FluiDyne AFBC is continuing with completion expected soon. Other activities involving AFBC materials testing are discussed in Section 12 of this report.

4.4 Failure Prevention and Analysis

R. W. Swindeman

4.4.1 Examination of reboiler tube from Fort Lewis SRC Pilot Plant - J. R. Keiser and M. D. Allen

Two pieces of tubing from the Fort Lewis light ends column reboiler tube bundle were sent to ORNL for examination. The tubes had experienced severe surface attack. Although the material had been supplied as Incoloy 825, Fort Lewis personnel questioned the identification since the tubes had experienced corrosion more severe than that found with type 316 stainless steel tubes in the same location. A sample of the tube has undergone chemical analysis and other pieces have been examined metallographically. Results of the chemical analysis, shown in Table 4.1, indicate the material had the composition of Incoloy 825.

The metallographic analysis showed the tube outer surface had large, randomly spaced pits and shallow intergranular attack in the unpitted areas. We cannot determine the cause of the pitting, but we did observe similar, but not as severe, pitting of Hastelloy G and type 317 stainless steel tubes from the wash solvent column reboiler bundle. In the latter case, the pitting seemed to originate at scratches and other surface defects.

Table 4.1. Results of chemical analysis of tube from Fort Lewis light ends column reboiler bundle

Element	Measured Composition (%)	Limiting composition of Incoloy 825 (%)
Al	0.02	0.2 max
Cr	20.0	19.5–23.5
Cu	2.0	1.5–3.0
Fe	26.3	22.0 min
Mn	0.3	1.0 max
Mo	2.6	2.5–3.5
Ni	Major	Balance
Si	0.2	0.5 max
Ti	0.96	0.6–1.2
C	0.019	0.05 max

4.5 Materials Research for Liquefaction Systems

R. W. Swindeman

4.5.1 Materials to resist stress-corrosion cracking in coal liquefaction pilot plants - J. R. Keiser and V. B. Baylor

This work is being performed to assess the resistance of various materials to stress-corrosion cracking in coal liquefaction plants. Efforts this month were directed toward metallographic examination of U-bend specimens which had been exposed at the Wilsonville or the Fort Lewis Pilot Plant.

Three racks of U-bend specimens have been assembled and will be shipped to Fort Lewis to be installed in the separator vessels before resuming SRC-II mode of operation.

4.5.2 Studies of general corrosion in coal liquefaction plants - J. R. Keiser, R. S. Crouse, M. Howell, and J. F. Newsome

The purpose of this work is to determine the potential for general corrosion in coal liquefaction plants. The corrosivity of the fluids is measured by exposing corrosion coupons in a number of vessels in the Fort Lewis, Wilsonville, and Catlettsburg plants. During the past month we have performed electron microprobe examinations of coupons exposed in the fractionation column of the Wilsonville SRC Pilot Plant. These examinations were performed to learn if there is a variation in the composition of corrosion scale as a function of the corrosivity of the oils in the column. These coupons were exposed to low and moderately corrosive oil, and the scale contained a significant amount of iron as well as nickel. Coupons exposed to very corrosive conditions at Fort Lewis are being prepared for examination.

Racks of coupons to be exposed in the Fort Lewis light ends and wash solvent columns are being assembled and should be shipped soon. These samples will be installed before the plant resumes SRC-II mode of operation.

Additional studies on corrosion in the fractionation area of SRC plants are described in Section 6.5.4.

4.5.2 Materials for the Zinc Chloride Hydrocracking Process – V. B. Baylor, J. R. Keiser, and E. H. Lee

The purpose of this work is to evaluate materials for possible use in the regeneration system of the zinc chloride coal liquefaction process. Corrosion coupons are being exposed in a quartz experimental loop to an environment containing HCl, dry air, and $ZnCl_2$ at temperatures ranging from 500 to 1000°C. During the past month new heaters were received (behind schedule) and the experiment was relocated from the Chemistry Division's Molten Salt Reaction Media laboratory to facilities in the Metals and Ceramics Division.

The analyses of the loop deposits and corrosion scales were completed. The solidified material in the loop was determined to be primarily metallic, rich in zinc, with some evidence of chloride. The corrosion scales are suspected to be oxides of nickel, cobalt, chromium, and iron. Zinc was also found to be a major element in a number of the corrosion products. Molybdenum showed less tendency toward oxide formation. The deposits were assumed to be oxides because most deposits showed no evidence of chlorides (implying that metallic salts did not form adherent corrosion products). Selected samples will be submitted for a more definitive analyses.

4.6 Development of Modified 9 Cr-1 Mo Structural Steel

V. K. Sikka

Large heat fabrication, mechanical property characterization, and weldability studies continued during the last month.

Industrial fabrication of two 14-Mg (15-ton) heats of modified alloy to plate and bar was completed during June 1980. One size of bar (9 1/8 in. diam) product made during June was made into tube hollows during the last month. These hollows will be tube reduced to several different sizes at a later date. Some of the sizes will be made for installation in different power plants. Tubes will also be made for product form characterization study. The other size of bar (3 3/4 in. diam) will be used to make tubing by rotary piercing process during the first week of August 1980.

The plate and bar products of the two commercial heats have already arrived at ORNL. These products are being cut for thermal aging studies and machining specimens for Charpy, tensile, and creep testing.

One 14-Mg heat of modified 9 Cr-1 Mo alloy was melted by the argon-oxygen-decarburization (AOD) process at Electralloy during the last month. The vendor chemistry showed that all elements met our specification range. Ingots of this heat are expected at ORNL during the next month.

Twenty machines are currently employed in the creep testing of this alloy. Several of the tests have reached 10,000-h duration.

As part of the new strategy to obtain an earlier ASME Code Case approval of modified 9 Cr-1 Mo, mechanical property testing was started on the tube heats. Tubes from the heat used in making the Tennessee Valley Authority tubing were the first of these heats to be tested. Tensile tests on this heat were completed in February. Three creep tests on this heat are currently in progress. Additional tube heats from Combustion Engineering (Chattanooga, Tennessee) were received during the month of June. Several of these tubes have been heat treated and testing is expected to begin within the next two months.

4.7 Ceramic Heat Exchangers

V. J. Tennery, G. C. Wei, and P. F. Becher

The objective of this task is to evaluate the behavior of candidate structural ceramic materials for use as recuperators or heat exchangers in fossil fuel combustion environments. In this period, the draft of a topical report on the results of the Ceramic Recuperator Analysis Facility (CRAF) Test 1 was reviewed and approved in preparation for issue as an ORNL report.

Additional thin specimens of post-test sintered-α SiC from CRAF Test 1 were prepared for transmission electron microscopy analysis of the microstructure. The objective is to identify the mechanisms for the observed large increases in helium permeability and observed grain growth of sintered-α SiC during the high-temperature, long-term exposure to the combustion products of No. 6 fuel oil in CRAF Test 1.

Tubes of KT SiC, sintered-α SiC, AD-998 alumina, CVD SiC, and Sialon for CRAF Test 2 using coal-oil mixture (COM) fuel were subjected to pretest characterizations including dimensional and weight measurement, x-radiography, and helium permeability measurement. X-radiography showed one longitudinal crack in one as-received AD-998 alumina tube but no defects were observed in all other tubes to be employed in this forthcoming test. This particular AD-998 alumina tube was excluded as a specimen for CRAF Test 2. The helium permeabilities of as-received KT SiC, sintered-α SiC, CVD SiC, AD-998 alumina, and Sialon at room temperature were determined to be near the detection limit of the helium leak detector (1.0E-15 m^3/s) for a ΔP up to 517 KPa (75 psi). Specimens from archive tubes are being prepared for chemical analysis, x-ray diffraction, SEM, optical microscopy, and electron microprobe analysis.

Flexure bars of several type structural ceramics including silicon carbide, silicon nitride, and Sialon were characterized preparatory to their being exposed in the hot duct of the CRAF during Test 2. The bars will be supported in the hot gas stream using siliconized silicon carbide support tubes. Fixtures were designed for determination of fracture strength of these bars in four point flexure in order to determine changes in fracture strength due to the high temperature combustion exposure. X-ray diffraction, electron microprobe, SEM, and optical microscopy are being used to characterize these materials in addition to transmission and analytical electron microscopy.

As reported last month, combustion stability of the COM in the CRAF combustor has been demonstrated for furnace temperatures up to 1400°C. A total quantity of 36 m^3 (9500 gal) of the COM fuel has been ordered for CRAF Test 2. The shipment of this COM fuel is expected in early August. Necessary plumbing, electric, and construction work for fuel storage, preheating, and transferring to the CRAF system is in progress. The CRAF Test 2 will be started soon after receiving the shipment of the COM fuel.

5. COMPONENT DEVELOPMENT AND PROCESS EVALUATION

D. M. Eissenberg

The objective of component development and process evaluation activities is to ensure that coal conversion (liquefaction, gasification, pyrolysis) processes, subsystems, and components have satisfactory functional performance, lifetime, reliability, and safety for their intended applications, and that sufficient component and subsystem performance data are available to permit process design optimizations. Activities to be carried out include performance and cost analyses; assessments of operating plants; field tests; operation of test loops; and the development of advanced processes, subsystems, and components.

Present activities are primarily those carried out as part of the technical support to large liquefaction projects. In addition, studies are being initiated aimed at the development of processes, subsystems, and components for more generic coal conversion applications.

5.1 Technical Support to Large Liquefaction Projects

P. K. Carlson, W. A. McAuley, L. F. Parsly, and A. N. Smith

Activities in this area are in support of the H-coal and SRC Demonstration Projects, and are described in more detail in Chapter 6.

A proposed methodology for evaluating the effect of extending the H-coal reactor lifetime from two to five years was prepared and submitted to DOE/ORO for their consideration. The draft report of a failure modes and effects analysis of a typical coal-oil slurry preheater was circulated internally for review.

We propose to do a failure modes and effects analysis of a typical slurry let-down system as the next task in the performance assurance program.

An inhouse report outlining the most pertinent and available information on wet grinding of coal is currently being written.

A test run was completed of the computer modeling program for the packed bed let-down system using assured SRC-II parameters. The experimental packed bed loop was run using water and water-air mixtures and the results compared with predictions using the computer modeling program.

5.2 Component Test Facilities

D. M. Eissenberg

Objective - Large, dedicated component test facilities are being considered by DOE-FE Office of Engineering Support (OES) to be used to test components being developed for use in liquefaction and gasification demonstration plants. Those being considered include a coal slurry systems testing facility, a dry coal feeder system test facility, and a synfuel ash letdown and solid waste disposal test facility. Assistance will be provided as requested in the planning and implementation of those facilities.

Status summary - Work on the test facilities planning is being deferred while OES submits budget requests.

5.3 New Initiatives in Coal Conversion

D. M. Eissenberg, W. A. McAuley, and H. L. Falkenberry

As part of the Engineering Technology Division strategic planning activities, assessments are being carried out to identify and propose new initiatives in coal conversion. Current activities include an assessment of coal pyrolysis technology and the analysis of a novel slurry feed/letdown system.

5.3.1 Coal pyrolysis

Objective - A review and assessment of coal pyrolysis technology and economics is being carred out by a TVA guest engineer assigned to ORNL to determine the feasibility of utilizing pyrolysis plants in conjunction with utility coal fired power plants to produce useful liquids from the feed coal, with the utility burning the solid residue (char) as a substitute boiler fuel and either selling the coal liquids as syncrude or utilizing them as gas turbine or oil-fired boiler plant fuel.

Status summary - A preliminary cost analysis is being prepared. Technical discussions were held with TVA, Southern Company, Utah Power and Light Company, and EPRI. EPRI plans to sponsor a two-day workshop on pyrolysis technology with ORNL providing technical direction.

5.3.2 Slurry feed/letdown system

Objective - A novel slurry feed/letdown system has been proposed for application to coal liquefaction plants. This system would replace both the conventional high head slurry feed pumps and the conventional slurry letdown valves with a system consisting of multiple flow - work exchangers operated in a batchwise continuous mode.

Status summary - A seed money proposal is under preparation. The proposal will consist initially of a techno-economic assessment of the use of the slurry feed/letdown system in an SRC-II demonstration plant. Plans for a feasibility test are being prepared for submission to DOE/FE.

6. TECHNICAL SUPPORT TO MAJOR LIQUEFACTION PROJECTS

H. D. Cochran

Support is provided by Oak Ridge National Laboratory and Union Carbide Nuclear Division Engineering for the major liquefaction projects being managed by DOE Oak Ridge Operations--SRC I and SRC II Demonstration Plants and H-Coal Pilot Plant Projects. Activities under twenty-four specific substaks are reported in seven broad categories--engineering and design review, technology overview, design data validation, components, materials, environmental and health, and general technical support.

6.1 Engineering and Design Review

This section reports on three subtasks whose objectives are focused on review of engineering and design of the SRC-I and SRC-II demonstration plants and the H-Coal pilot plant: engineering design review, SRC/H-Coal process and design review, and solid-liquid separation design review.

6.1.1 Engineering design review - J. J. Kurtz

Objective - This activity consists of providing technical assistance to the DOE-ORO SRC 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 detail design phase of the SRC-I project is cost-shared by the U. S. Government and the International Coal Refining Company (ICRC). The SRC-II detail design phase is cost-shared by the U. S. Government with the Pittsburg and Midway Coal Mining Company (P&M) and the governments of Germany and Japan.

The principal purpose of the SRC projects design review is to provide objective assessments and evaluations of the contractors' technical progress, identification of potential problems, and critiques of project deliverables.

Status Summary - The SRC-I Project Technical Status Review meeting in Allentown was monitored by UCC-ND/ORNL. Highlights included a presentation of the fired slurry heater tradeoff study, a discussion on negotations and future technical project dialogue with Koppers-Totzek (Germany), and subcontractors' progress and activities.

The SRC-II Project Technical Status Review meeting in Denver was monitored. Highlights included a plan for earlier access by DOE-ORO to PFD issues, critical data needs for process design, and a review of Badger Engineering and Stearns-Roger progress and activities.

Technical support activities for the SRC-I project included comment reviews of the R. M. Parsons Co. Design Basis Memorandum (DBM) for the SRC-I Gas Systems Area-Rev. 1, and for the SRC-I Process Design Criteria, Rev. 2. Comments were transmitted to the DOE-ORO SRC Projects Office. A memorandum was also transmitted to the SRC Projects Office addressing stability analyses of series configuration for dissolver reactors over the range of demo plant operating conditions.

Internal activities requested by the ORO SRC Projects Office included an initial review of the UCC-ND Subtask 18 (Engineering Design Review) to develop a revision, if required, which includes support review and evaluation efforts on quality assurance, safety, and specific components.

6.1.2 SRC-H-Coal process and design review — A. R. Irvine, J. F. Fisher, W. R. Gambill, H. F. Soard

Objective — The objective of this activity is to provide review and analysis of key process areas of the SRC demonstration plants and those aspects of the H-Coal pilot plant that will provide information useful in the design and evaluation of the SRC-I and SRC-II demonstration plants.

Status summary — During July the Design Basis Memorandum (DBM) for the Gas System Section of the 6000 TPD SRC-I Demonstration Plant (Doc. No. 0001-01-003 Rev. 1, 6-20-80) was reviewed. This issue of the DBM shows significant improvement in its quality over the previous issue (Rev. 0) of the same DBM. There are, however, still ambiguities and shortcomings in some portions of the technical descriptions and specifications in the DBM which require further clarification and improvement.

6.1.3 Solid liquid separations design review — B. R. Rodgers and J. R. Hightower

Objective - The objective of this project is to provide technical support to DOE-ORO in the area of solids/liquid separations.

Status summary - At the request of EPRI, a work plan was formulated to examine Kerr-McGee process solvent losses using radioactive tagged solvent B. This will be a follw-on to the work completed on the solvent A, reported in May. This work could begin by the middle of August and will take approximately three months to complete.

At the request of DOE-ORO, an effort was initiated to examine the data base which supports the Kerr-McGee critical solvent deashing process. The results are reported below.

The Wilsonville pilot plant produces a CSD feed which should be much less tractable than the demonstration plant, even for the same dissolver conditions, because of the large residence times at relatively high temperatures between the dissolver and the CSD unit at Wilsonville. It is known that coal liquids will repolymerize if held too long at reactive conditions. The Wilsonville hold-ups (in minutes) for their hot flash mode are compared with those projected for the demonstration plant in the table below.

	Pilot plant		Projected for demo plant	
	Time min	Temp °F	Time min	Temp °F
High pressure flash tank	20-25	800-815	2-3	800-840
Low pressure flash tank	15-20	∿700	2-3	675-775
Vacuum tower bottom	25-30	560-570	small	∿600
TOTAL (avg)	67.5	681	5	773

Hold-up times greater than one hour at temperatures near 700°F should produce more material classified as "preasphaltenes" than ∿5 min above 770°F. The hold-up times given above are for the "hot flash" mode. The so-called "normal mode" involves cooling the dissolver effluent so that the high pressure separator temperature is reduced from ∿800°F to ∿700°F. Thus, the coal liquid-plus-solid is held at a lower temperature and this should result in a lower preasphaltene content. However, a vacuum tower recycle is included in the latter mode which holds up the material for ∿2 hr at ∿570°F. The lower temperature, even for the longer residence time, would not be expected to produce preasphaltenes as rapidly as shorter times at higher temperatures. This could be easily verified in a laboratory.

The design value for SRC recovery of 82.7% is strongly based on the run using demonstration plant conditions at Wilsonville (No. 162) in April of 1979. In the year and a quarter since that run some significant progress has been made which bears directly on the recovery question. In particular two more runs under demo conditions have recently been completed on two other Kentucky No. 9 coals, Dotiki and Fies (run No. 162 used Pyro coal). Also, the use of solvent B has been tested at the Kerr-McGee bench-scale unit at Oklahoma City and a test is currently in progress at Wilsonville.

(a) Two runs under proposed demonstration plant conditions were made in June of 1980. The first run (No. 209) was a 6-day run with the dissolver conditions set at 840°F, 2100 psig, and a space rate of 38 lbs/hr ft^3. The second run (No. 210) was at the same conditions except it was run under "hot flash" conditions for nine days. There was apparently no shutdown or other disruption between the runs. During run No. 209 the high pressure separator temperature averaged 709°F due to use of the E102 cooler on the dissolver effluent before the HP flash. At the end of this run the hot flash mode was started by bypassing the E102 cooler, resulting in an increase in average temperature in the HP flash to 793°F over a period of four days. The insulation on the line between the dissolver and the HP flash unit was then stripped and water sprayed on the line to lower the average temperature to 732°F for four days.

These runs are important because they provide some key evidence to support the speculation that the long residence times in the lines before the CSD unit contribute to preasphaltene production and subsequent lower recoveries than would be expected in the demonstration plant. In this series, the temperature was changed from 709°F to 793°F and back to 732°F, the latter achieved without the cooler. Some change in recoveries should have followed these changes and, in fact, this did occur. The average recoveries during these periods changed from 80% to 76% and back to 80%, respectively, lending some support to expectation of higher recoveries in the demonstration plant CSD unit.

(b) The case for solvent B is strong but needs further verification at Wilsonville. Kerr-McGee has provided data that show that for a low solubility CSD feed from a Wilsonville run in their bench-scale unit at Oklahoma City the soluble coal recovery is increased as much as 20% by use of solvent B. Thus, a poor feed in the demonstration plant, for whatever reason, could be processed by the CSD and still maintain the design recovery. This adds considerable flexibility to the demonstration plant operation, and the option to use solvent B there should be pursued with vigor.

On July 13, run No. 211 at Wilsonville was run under "lined-out" material balance conditions. This run was on Fies (Kentucky No. 9) coal at 38 space velocity, 1700 psi, 825°F, and normal flash mode. This provided a low severity feed to the CSD and a good test of recovery ability. The material balance recovery value for the single CSD solvent was 75.2%. With everything else unchanged. Solvent B was started on July 14 (run No. 212). By July 21, the recovery had reached 87.7% when the first stage let-down valve plugged. This certainly supports the use of solvent B, but a number of problems developed during this run that complicated clear interpretation, and the run needs to be repeated.

Areas that need to be better defined before acceptance of solvent B are:

(1) Loss of solvent B to products, and in general, maintenance of the desired solvent composition. ORNL will examine loss due to reaction with products.

(2) Recovery of solvent B in the process.

(3) Wilsonville has shown a tendency to plug the first stage letdown valve when the SRC recoveries are much over 85%. This may very well not be a problem in the large valves in the demonstration plant.

There seems to be an effect of coal-type even within a given kind of coal. For example, run No. 162, Lafayette (Kentucky No. 9), gave recoveries of 83% under demo conditions while Fies (Kentucky No. 9) only gave 80% under similar conditions. This needs further delineation.

It is important to understand the variability of the data at Wilsonville and its effect on interpretation of results. Using averaging techniques on recovery values from the last 11 days of the demo run (No. 162) at Wilsonville gives an average of 83.0% recovery and a standard deviation of 1.33%. Thus, in actual operation, about 95% of the time the values would fall in a range between 80.0 and 86.0%. For 99% of the time they would fall in a range of 78.8 to 87.2%. With this kind of variability one should express design values to only two significant figures (83% vs 82.7%). Also, the value 83% should not be viewed as exact but as the range of values 80-86%. When comparing 83% to 79% the overlap of ranges should be considered as follows:

76	77	78	79	80	81	82				
				80	81	82	83	84	85	86

The value 79% is outside the 95% confidence level of the value 83% and thus is probably significant. However, comparing 80, 81, or 82 to 83 is probably not significant and we should not assign much value to a change in recovery of these magnitudes simply because it could be due to process variability not related to the CSD unit.

During August an event important to the recovery question is scheduled to occur at Wilsonville: a month-long, steady-state run is planned under demonstration plant conditions. The data discussed herein show that the recovery should be somewhere between 80-83%.

This run should settle the question of the range boundaries and the most probable value for Wilsonville operation. Then, if these numbers are used in the demonstration plant design, the design would be conservative. Obviously, the operation should be monitored closely during this period.

Future plans - An independent assessment will be performed of the design base for the Kerr-McGee critical solvent deashing process with appropriate recommendations to DOE-ORO.

6.2 Technology Overview

This section reports on five subtasks whose objectives are to provide a broad overview of direct liquefaction technology — Direct Liquefaction Technology Overview and four technical field representation tasks.

6.2.1 Direct liquefaction technology overview — R. W. Glass, K. H. Lin, A. R. Irvine, J. P. Belk, J. F. Fisher, G. C. Frazier, J. R. Horton, J. K. Huffstetler, B. Niemann, W. R. Reed, and B. T. Thompson

Objectives — The objectives of this task are:

1. To keep abreast of significant developments in coal conversion R&D activities, to monitor progress in coal liquefaction facilities, and to derive and document technical data of importance to design and operation of pilot, demonstration, and commercial plants. This will also assist in preventing duplication of efforts at various facilities.

2. To prepare a source book of data base and technical information related to direct coal liquefaction processes.

3. To conduct short- to intermediate-term studies on subjects which could have major impact on coal liquefaction technology and economics.

Scope — The role of this subtask is an overview of a wide range of activities relevant to coal liquefaction technology. The major effort will be directed toward the following areas of activities and types of information:

1. R&D activities relevant to (a) modification and improvement of key unit processes and associated equipment, (b) physical and chemical properties of major process streams and products, and other process data base, and (c) processes for upgrading of liquefaction products.

2. Plant experience data from pilot plants and PDUs that are crucial to the design and operations, including (a) significant operation and maintenance experiences, and (b) technical problems encountered due to deficiency in the design or to abnormal process conditions, and specific solutions to the problems.

Status summary — Compilation of the background material for the overview report (or digest) was completed. The background material was based primarily on a comprehensive review of progress reports from the Ft. Lewis and Wilsonville Pilot Plants, the Harmarville PDU (P-99), International Coal Refining Co. (ICRC), and Exxon (EDS) facilities. Preparation of the first issue of the draft overview report is under way to present an assessment of the progress at these facilities based on the technical information contained in the progress reports as well as highlights of the supporting data.

In the activity dealing with ad hoc studies, review of the report by Econergy Associates on upgrading of coal liquids has been completed, and evaluation of pertinent syncrude upgrading reports by UOP and Chevron is in progress. These reviews and evaluations constitute the scoping work in connection with the development of a general processing layout for syncrude upgrading. The immediate aim is to construct the broad outlines of an upgrading process which can be used to estimate how downstream processing can impact upon the demonstration plant design. The extent of the upgrading to be accomplished and the product slate will determine the requirements in areas such as the hydrogen supply and recovery facilities, the hydrodesulfurization process, the refining processes, and utilities. All of these factors have to be taken into account in the design of the SRC demonstration plant.

Preparation of the direct coal liquefaction source book is on schedule. In response to the suggestion of DOE-ORO at the July Monthly Status Review Meeting (see below), a change from the current process-oriented structure of the source book to an equipment-oriented structure will be taken into account in the 1980 issue. Because of the approaching end of FY 1980, however, full implementation of this change will not be possible until FY 1981. The process-oriented structure was adopted when the source book covered only the SRC-I and SRC-II processes. Expansion in the present scope of the source book to also include the EDS and H-Coal processes has made the equipment-oriented structure more appropriate.

6.2.2 Technical representation at field sites — R. W. Glass and S. P. N. Singh

Objective — The objectives is to place a UCC-ND technical representative at each of the major development sites — H-Coal, Exxon Coal Liquefaction Plant, Harmarville, Ft. Lewis, and Wilsonville. The purpose is to facilitate the flow of information between the above-mentioned sites, DOE, and ORNL.

Status summary — Limited progress has been achieved in defining the technical representative's function at the H-Coal pilot plant. A draft position charter was prepared and will soon be forwarded to DOE/ORO and ASFI for their consideration.

A meeting was held on July 1, 1980 with ASFI staff to determine the requirements for establishing the Health and Environmental Monitoring (H&EM) program at the H-Coal pilot plant. ASFI will provide cost estimates for hooking up and providing services to the H&EM trailer and for obtaining the samples called for in the revised list of samples discussed with and given to ASFI.

A Perkin-Elmer gas chromatograph (for on-site gas sample analyses) has been ordered and is expected to be delivered to ORNL by August 15, 1980 for installation in the H&EM trailer.

6.3 Design Data Validation

This section reports on three subtasks whose objectives are aimed at providing experimental measurements to answer questions which have arisen in designing the SRC demonstration plants. These subtasks are: Coal Slurry Mixing Tests, Wet Grinding for SRC Processes, and Vacuum Bottoms Viscosity Measurement.

6.3.1 Coal slurry mixing tests — E. L. Youngblood, L. S. Dickerson, and J. R. Hightower

Objective - The objective of this project is to study the changes that occur in physical properties (particularly viscosity) in coal slurries during mixing at temperatures up to 533 K (500°F). The system includes a small scale mix tank with an agitator and slurry circulation system of the type used for feed makeup in the SRC processes. Continuous viscosity measurements will be made with an on-line pipeline viscometer. The ultimate objective of the study is to establish conditions that will permit the slurry preparation system in the SRC demonstration plants to be operated at increased temperature thereby improving the overall process thermal efficiency and cost.

Status summary - During the month installation of the pipeline viscometers for the slurry mixing system was completed and the viscometer were calibrated using mineral oil, 90 wt gear oil, and glycerin. Three different viscometers are being operated in series to give the desired viscosity and shear rate ranges and also to provide a check for slip at the viscometer wall. The dimensions of the viscometers are 5.138 mm ID x 0.914 m long, 3.607 mm ID x 0.914 m long, and 3.020 mm ID x 0.610 m long. The inside diameter of the tubes was measured with a dial bore gage accurate to ±0.005 mm.

To check the reproducibility of the pipeline viscometers and metering pump several measurements were made at 100% and 50% pumping rates using mineral oil. The results shown in Table 6.1 indicates that good reproducibility can be achieved. The viscosity measurements obtained using the pipeline viscometers of 67 to 72 cp for mineral oil at 24°C is in agreement with a value of 71 cp measured with a Cannon-Fenske viscometer. Measurements were made with mineral oil, 90 wt gear oil, and glycerin to check the operation of the metering pump, and viscometers with fluids

Table 6.1 Calibration of pipeline viscometers with mineral oil

Pumping rate cm³/min	PLV-1[a] viscosity cp	PLV-2[b] viscosity cp	PLV-3[c] viscosity cp
	Pump stroke length 58.8 mm		
375.1	71.1	71.8	69.6
376.3	70.6	70.7	69.0
375.1	72.9	70.5	69.0
374.9	73.5	70.0	68.5
373.4	74.1	70.7	69.1
375.0[d]	72.4[d]	70.7[d]	69.0[d]
1.0[e]	1.5[e]	0.7[e]	0.4[e]
	Pump stroke length 28.7 mm		
182.7	62.6	70.3	71.3
182.7	61.3	70.9	69.9
182.7	69.3	70.5	70.1
182.4	70.0	70.6	69.9
183.7	68.9	70.1	69.7
183.0	67.3	70.1	69.7
182.9[d]	66.6[d]	70.4[d]	70.1[d]
0.5[e]	3.7[e]	0.3[e]	0.6[e]

[a]Pipeline viscometer 5.138 mm ID x 0.914 m long.

[b]Pipeline viscometer 3.607 mm ID x 0.914 m long.

[c]Pipeline viscometer 3.020 mm ID x 0.610 m long.

[d]Average.

[e]Standard deviation.

in the viscosity range of 70 to 900 cp. The metering pump performed satisfactorily although there is a slight decrease in pumping rate with higher viscosity fluids. A typical rheogram for the test fluids is shown in Figure 6.1.

An alternate slurry circulation pump has been obtained for temporary use until the unit which has been ordered arrives. Also the line heaters have been delivered. During the next month installation of the circulation pump and line heat will be started in preparation for introducing feed slurry into the system.

6.3.2 Wet Grinding for the SRC II Process - D. M. Eissenberg and W. A. McAuley

Objective - This study will investigate the feasibility of incorporating a wet grinding process into the SRC II Demonstration Plant. The presently proposed dry grinding/mixing system has encountered problems such as coal swelling and gel formation.

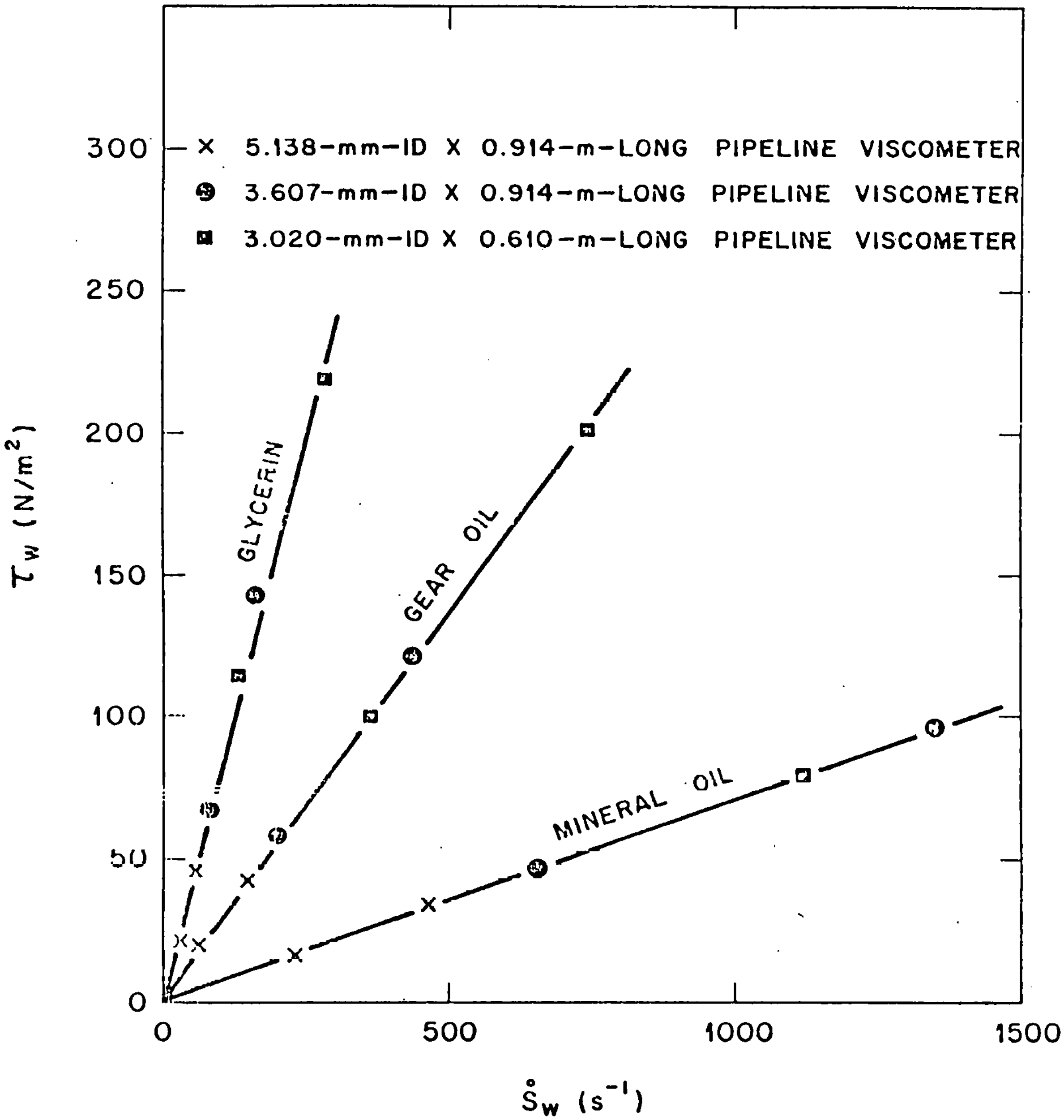
Status summary - An in-house report outlining the most pertinent and available information on the grinding of coal in a solvent is currently being written. Since no one has attempted to grind coal in a medium similar to the recycle slurry in the SRC II Process, the only information available is that primarily from studies on coal-oil mixture utilization and will be reflected. To the extent that information is available the German experience in wet grinding and mixing of coal with distillate solvent and catalyst will also be reviewed. This in-house report, however, will allow ORNL to make a more critical and effective evaluation of the SRC-II wet grinding feasibility study currently being done by Battelle Memorial Institute.

6.3.3 Vacuum bottoms viscosity measurement - J. H. Wilson, B. R. Rodgers, and J. R. Hightower

Objective - The objective of this project is to provide a tested and calibrated instrument for installation at the Ft. Lewis SRC pilot plant or other suitable site which is capable of providing on-line viscosity measurement of residuals obtained from the vacuum still of the SRC-I and II processes. This type instrument is necessary to provide indication of the onset of irreversible polymerization or coking problems which would interfere with controlled feeding of vacuum still bottoms to a gasifier.

Status summary - The flowsheet for the VSB (vacuum still bottoms) viscometer has been modified by piping changes that minimize the number of high temperature valves required. This will simplify the operation as well as reduce the cost of the system. The flowsheet, as it now stands, is shown in Figure 6.1. As in a previous report[1], the equipment necessary for laboratory testing and calibration is shown within the dotted lines.

ORNL DWG 80-1216



RHEOGRAMS FROM PIPELINE VISCOMETER TESTS

Fig. 6.1. Rheograms from pipeline viscometer tests.

ORNL-DWG 80-921R

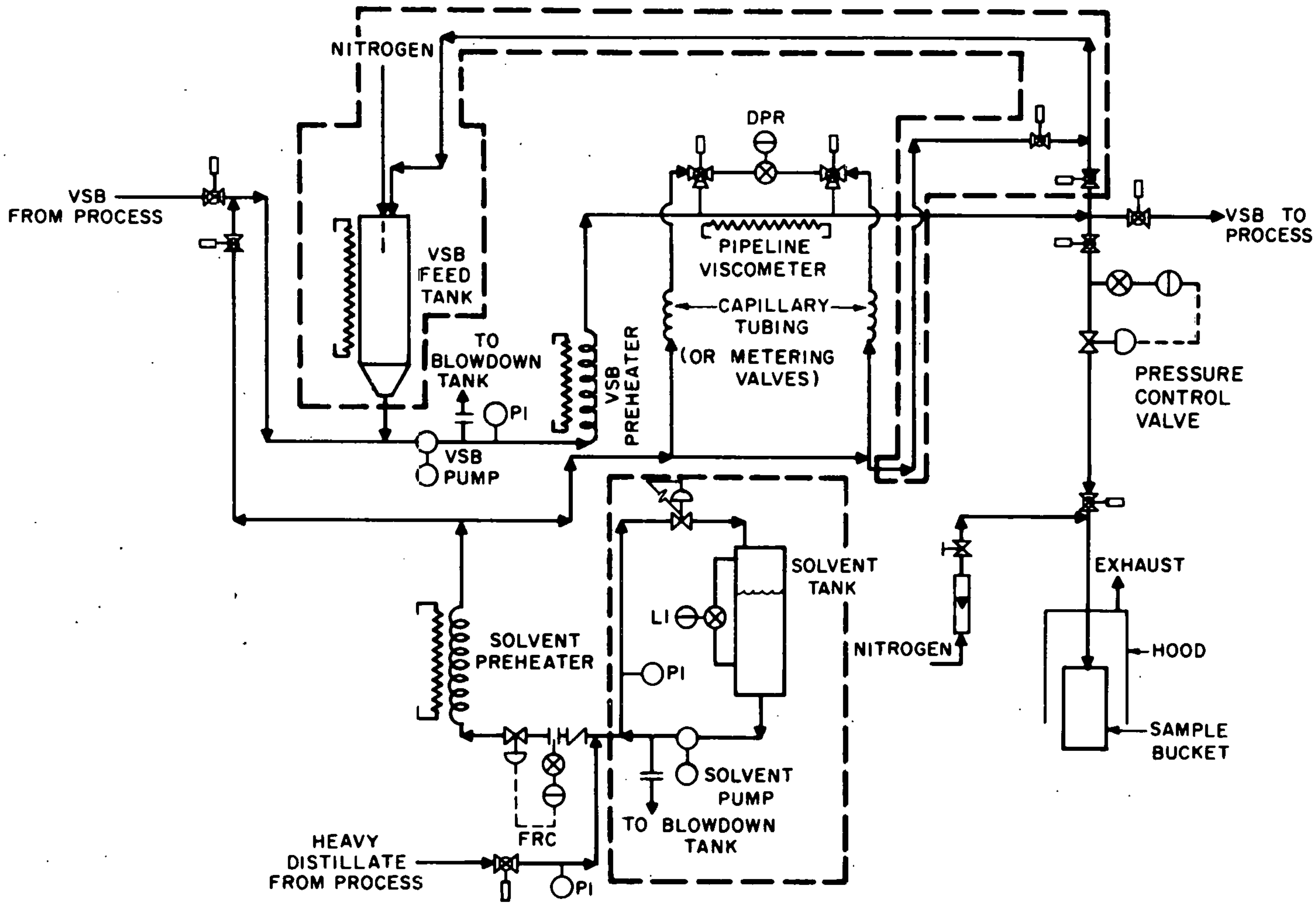


Fig. 6.2. Schematic flow diagram of VSB viscometer.

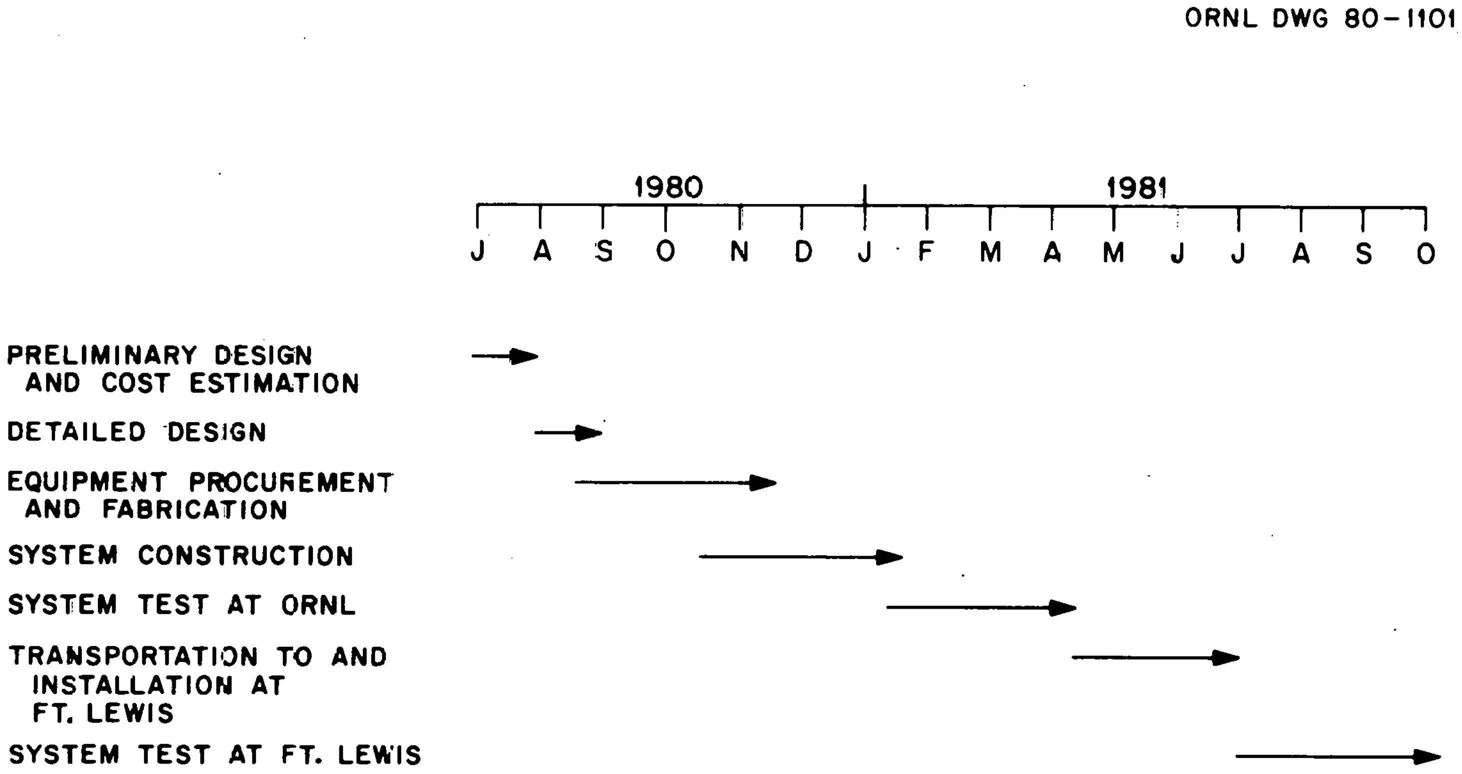


Fig. 6.3. Projected schedule for VSB viscometer project.

UCC Engineering has estimated the costs for design and fabrication of the VSB viscometer. ORNL's Instrumentation and Controls Division has estimated the cost of the instrumentation and control system which includes a field-mounted "slave" computer and a "master" computer to be located in the control room. These estimates are now being reviewed.

An order will be placed within the next few weeks for the "slave" and the "master" computers. The delivery times for the former and the latter units are 90 and 60 days, respectively. Also, a decision will be made on the type of high temperature ball valve to be used for the VSB service and an order will be placed. The computers and the high temperature valves are the critical delivery items.

A projected schedule for the project is shown in Figure 6.3. Construction of the viscometer is to begin in October and the completion data is estimated to be January 1981. Because of an unexpected delay in the completion of the pump-around loop on the Ft. Lewis vacuum still, the viscometer will be installed there later in 1981 or during the first part of 1982. This should allow time for more extensive testing of the viscometer at ORNL, which may include evaluation of alternative viscometers.

6.4 Components

This section reports on three subtasks focused on the components and equipment critical to the successful operation of large, direct liquefaction plants--a Components and Technology Workshop, SRC Components Design Review, and a Packed Bed Pressure Letdown Study.

6.4.1 Components and technology workshop - M. Siman-Tov

At DOE request we have suspended effort on the workshop focused on direct liquefaction projects and are participating in similar workshops being planned by DOE Headquarters.

6.4.2 Component design review - D. M. Eissenberg and T. A. Dahl

Objective - The objective of the component design review is to identify critical components in the SRC-I and SRC-II Demonstration Plants and to provide assessments as to their expected performance based on Phase 1 design specifications and analysis of similar components utilized in pilot plants or other comparable service. Where appropriate, recommendations will be proposed for alternate specifications, alternate component selection or development and testing programs which would lead to improved components.

Status summary - During the month, process design criteria, design basis memoranda, technical support requirements, and technical and project status reports were reviewed and recommendations forwarded as requested.

6.4.3 Packed bed pressure letdown study - D. M. Eissenberg and P. K. Carlson

Objective - The objective of this study is to develop an improved slurry pressure letdown system for possible application to the SRC-I and II Demonstration Plants. The improved system utilizes a packed bed for pressure drop, with flow control provided by addition of clean liquid which volatilizes at the temperature/pressure conditions within the packed bed.

Modeling studies - The modeling procedure consists of two separate programs, one to design a packed bed for a given "design" flow of high pressure separator bottoms and another to determine the flow of condensate required to bring about given reductions in a slurry flow. The bed is first "built" by calculating vapor and slurry rates at pressure intervals; applying a two-phase pressure drop formula to get the quantity $\Delta P/\Delta L$ (pressure drop per unit length) at each pressure interval; and finally by numerically integrating the inverse of this quantity over the entire pressure range to get total length and bed diameter vs length. The results of a typical calculation is given in Table 6.2.

As indicated in Table 6.2, the program increases the bed diameter when $\Delta P/\Delta L$ exceeds a predetermined value. Designing the bed in this fashion yields lower and more uniform velocities, while keeping overall length acceptably short. Conical transitions are used to join constant diameter pipe sections. These transition pieces are 2.54 cm (1") long with a 2.54 cm (1") diameter increase. Packing diameter for the calculations was set at 3.18 cm, and flowrates, compositions, and conditions are approximately those of one 50% letdown train of the SRC II demonstration plant. This is one possible way to design such a device, not necessarily the best. Modifications to the design program can enable the use of other criteria for determining diameter and length of the packed bed.

The abbreviations used in Table 6.2 are defined in the following way:

L = cumulative length

P = pressure

DIA = diameter of bed

T = temperature

V = mole fraction of starting liquid mixture existing as vapor

After fixing the dimensions of the bed using the procedure described, they are used as inputs to a second program which combines varying fractions of a mixture comparable in composition and temperature to the condensate, with the high pressure separator slurry. The program then iterates to the correct condensate flow required to affect a given reduction in slurry flow. In Table 6.3 the results of these calculations are given. The abbreviations are defined as follows:

VLOSS = given reduction in H.P. separator flow

VGAIN = flow of condensate which must be injected into the bed to result in the reduction in a slurry flow

T = final mixture temperature

VZ = final mole fraction in vapor phase

RSUM = length of bed at final iteration (this must be less than the total length given as an input to the program).

Slurry Test Loop - Data taken to date has been limited because of operational difficulties with a turbine-type flowmeter which is used to measure liquid flow. Nevertheless, pressure drop taken with plain water flowing at rates of 1.26×10^{-4} to 1.89×10^{-4} m^3/s (2-3 GPM) seems to agree well with packed bed predictions of Ergun. All the single phase data taken so far falls within a $\pm$ 13% error band of the predicted value. Two phase pressure drops seem to begin very close to the predicted value at low gas rates, and approach a maximum deviation of about 18% as the gas rate is increased. In Table 6.4, some of this data is presented and the predicted two phase drops are given for comparison.

6.5 Materials

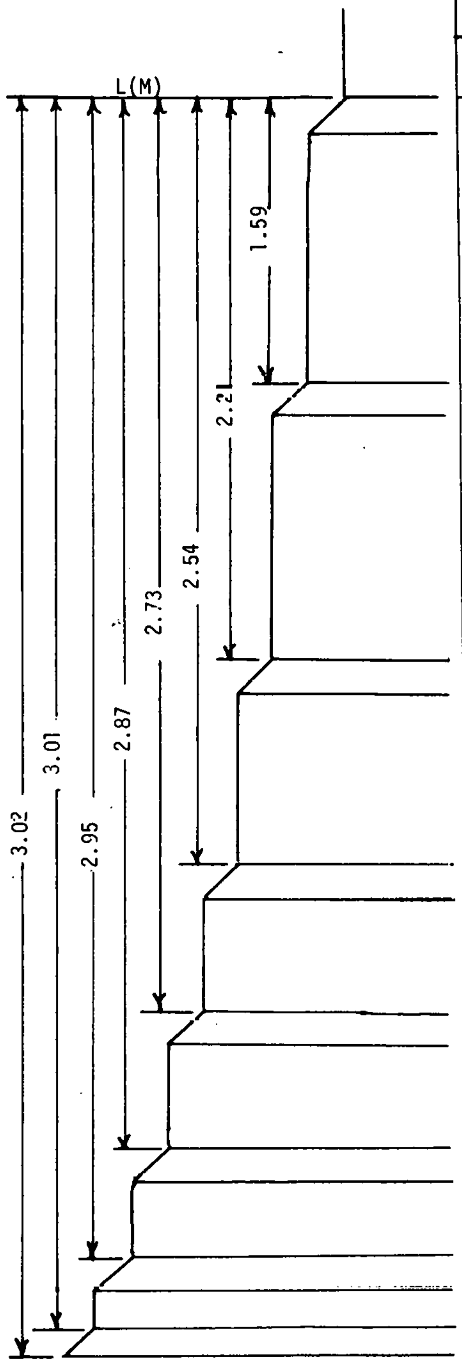
This section reports on four subtasks related to materials of construction for direct liquefaction plants--materials design review and coordination of materials R&D for SRC projects, quality assurance support for H-Coal pilot plant welding, H-Coal materials testing and failure analysis, and investigation of corrosion in fractionation areas of liquefaction plants.

6.5.1 Materials design review and coordination of materials R&D for SRC projects - R. R. Judkins and A. R. Olsen

Objective - The objectives of this task are to assist in the review of contractor documents for materials selection, to review and provide input to materials testing and failure analysis plans, and to coordinate materials research and development for SRC projects.

Status summary - Several design documents (design basis memoranda and process design criteria) for SRC-I were received and reviewed. Materials information in these documents have been minimal to date, however.

Table 6.2. Packed bed letdown valve design calculation results - SRC-II case



DIA[M,(IN.)]	P[MPa,(PSIA)]	T (°C)	V
.152 (6")	13.68(1990)	454.4	.0005
.178 (7")	7.06(1025)	453.7	.1039
.203 (8")	4.44(645)	451.3	.2661
.229 (9")	3.00(435)	448.1	.3924
.254 (10")	2.10(305)	444.7	.4971
.279 (11")	1.45(210)	440.8	.5927
.305 (12")	1.00(145)	437.1	.6712
.330 (13")	.72(105)	434.2	.7259

Table 6.3. Turndown as a function of condensate addition

VLOSS (kg/s)	VGAIN (kg/s)	T (^oC)	VZ	RSUM (m)	TURNDOWN (%) OF DESIGN MASS FLOWRATE
1.95	.350	433.9	.736	3.018	2
3.90	.692	433.7	.746	3.020	4
5.85	1.03	433.4	.756	3.018	6
7.80	1.35	433.2	.764	3.021	8
9.75	1.68	432.9	.773	3.012	10
11.70	1.99	432.7	.781	3.013	12
13.65	2.29	432.4	.789	3.018	14
15.60	2.59	432.2	.797	3.012	16
17.55	2.89	432.0	.804	3.018	18
19.50	3.21	431.8	.811	3.016	20

Table 6.4. Preliminary pressure drop data through test packed bed compared with prediction

ΔP PREDICTED MPa (PSI)	GAS FLOW g/s (SCFM)	LIQUID FLOW M^3/S (GPM)	DOWNSTREAM BED PRES. (GAGE) MPa (PSI)	ΔP MPa (PSI)
.23 (33)	0	$1.58X10^{-4}$(2.5)	.04 (6)	.23 (33)
.34 (49)	.28 (.5)	"	.06 (8)	.34 (50)
.37 (54)	.55 (1.0)	"	.06 (9)	.42 (61)
.41 (59)	.83 (1.5)	"	.08 (11)	.46 (67)
.43 (63)	1.10 (2.0)	"	.08 (12)	.51 (74)
.47 (68)	1.38 (2.5)	"	.09 (13)	.55 (80)
.50 (72)	1.65 (3.0)	"	.10 (14)	.59 (85)
.52 (76)	1.93 (3.5)	"	.10 (15)	.61 (89)

We are presently reviewing SRC-I Phase 0 mechanical specifications for materials selections and plan to issue a report to DOE/ORO on this review by August 15, 1980.

6.5.2 Quality assurance support for H-Coal pilot plant welding - K. K. Klindt

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

Status Summary - No support was needed during the month of July 1980.

6.5.3 H-Coal materials testing and failure analysis - A. R. Olsen J. R. Keiser, and R. W. Swindeman

Objective - The objective of this task is to provide assistance to the Ashland Synthetic Fuels, Inc. (ASFI) in developing and implementing a materials testing, surveillance, and failure analysis plan for the H-Coal Pilot Plant at Catlettsburg, Kentucky. The scope of work involves the review of the materials of construction, participation in the materials testing effort, the preparation of a failure analysis plan acceptable to the participants of the H-Coal Project, and the provision of failure analysis service to the H-Coal Pilot Plant on request.

Status summary - The materials testing activity in support of H-Coal has been inactive, pending the delivery of the coupons now being exposed in the plant at Catlettsburg. In regard to failure analysis services, we have completed our efforts to find a better high grease for packing of block valves.

6.5.4 Investigation of corrosion in fractionation areas of liquefaction plants - J. R. Keiser, D. C. Canada, M. Howell, and R. W. Swindeman

Objective - Severe corrosion has been observed in the fractionation area of the SRC pilot plants. A concentrated effort is being made at ORNL to discover both the corrosion mechanism and a means to control the corrosion.

Status summary - During the past month, our efforts have been directed toward analyses of liquids from the pilot plants and operations of laboratory experiments.

Last month, we reported on the analysis of a set of samples collected at the Fort Lewis SRC Pilot Plant. These samples were collected from 15 different locations in the plant and were intended to permit us to determine the Cl, N, O, and S content of various streams. This set of samples was collected on April 23 while the plant was operating in the SRC-II mode. A second set of samples collected on April 24 during SRC-II mode of operation and a third set collected on July 2 during SRC-I operations are being analyzed. We are also evaluating two sets of samples from the Wilsonville SRC Pilot Plant fractionation area. One set was collected June 5 when the corrosion rate was low, and a second set was collected July 22 when the corrosion rate was appreciably higher. Results of these analyses will be reported as soon as they are available.

Our previously reported chlorine numbers have frequently shown a discrepancy between total and water-soluble chlorine with the total being the smaller of the two numbers. Neutron activation analysis has been used for total chlorine measurement while water-soluble chlorine has been measured by potentiometric titration. We are performing additional cross checks to resolve this apparent conflict.

Last month's report included a description of an experiment in which we were able to greatly reduce the corrosivity of Fort Lewis middle distillate (wash solvent column overhead product) by water washing the oil. Extensive analyses have been performed on the as-received oil, the water-washed oil, and the water used for washing in order to identify the compounds removed from the oil by the water wash. As discussed in our previous report, in two experiments, corrosion rates of carbon steel and type 304 stainless steel were calculated to be 3.92 and 8.80 mm/year in as-received Fort Lewis middle distillate. Water washing of the middle distillate produced an oil which was essentially noncorrosive. In order to determine what constituents were removed from the oil by the water wash, we have thoroughly analyzed the oil and the wash water and performed a gas chromatographic mass spectrometric analysis of the acid and basic fractions of the water. Results of the chemical analyses are given in Table 6.5. These results show that the as-received pretest oils were fairly acidic and had chlorine contents of 400 ppm or greater. The most significant changes to the oil as a result of the water wash were major reductions of the acidity and the chlorine contents. Very little sulfur was removed by the wash, but a significant amount of nitrogen was in the wash water. The atomic percent nitrogen in the wash water aws the same order of magnitude as the atomic percent chlorine. This would support the possibility of anilinium chloride or pyridinium chloride existing in the oils and their removal by the water wash. Hydrolysis of these salts would result in the formation of an acidic solution. The neutralization numbers measured in the wash water can be largely accounted for if all the chlorine present is in the form of hydrochloric acid.

In order to identify the organic constituents removed from the oil by the water wash, a gas chromatographic mass spectrometric (GCMS) analysis was performed on acid and base fractions prepared from the wash water. A relatively simple GC was found in both fractions. All major GC peaks were identified by their mass spectra (refer to Table 6.6). Some minor constituents have not been identified. The majority of the organic material was found in in the acid fraction and phenol was, by far, the most prevalent species detected, followed by cresols. The basic fraction contained aniline and methyl aniline as the major components. Measurable amounts of pyridine homologues were noted.

Since certain aniline homologues and pyridine homologues have nearly identical mass spectral characteristics, that is, aniline and methyl pyridine, in order to identify the larger peaks in the basic fraction, the fraction was derivatized and compared to the underivatized fraction. A GC retention time shift was noted for the peaks in question, and the derivatized form of aniline was confirmed by MS identification.

The acid fraction revealed only two cresols but upon derivatization three GC peaks were identified as cresols.

Since no accumulation of an iron-rich corrosion product has been observed in the wash solvent column, a major unanswered question is how iron, which has reacted with some component of the oil, is then carried away by the oil. One proposed mechanism for removal of the iron is complexation of iron by the phenols. These complexes have been observed for the ferric state, but, to the best of our knowledge, ferrous complexes with phenol have not been identified. Analysis of the as-received post-corrosion test oil showed the iron present was in the 2+ state. Only one test has been performed and additional measurements should be made before the possibility of phenol complexing is ruled out. For iron in the 2+ state it is worth noting that many other complexes are possible, examples being thiocyanate and pyridine-chloride complexes.

As a result of the information gained from this water washing experiment, we have performed two follow-up experiments that have produced some valuable results. Additional samples of water-washed middle distillate have been prepared and the corrosivity of these samples was shown to be very low. For one experiment, anilinium hydrochloride was added to the washed oil in an amount which gave 500 wt ppm chlorine in the oil. The calculated corrosion rates were 1.30 mm/year (51 mils/year) for type 304 stainless steel and 6.28 mm/year (247 mils/year) for carbon steel. In a second experiment the organic constituents which we had identified in the wash water (see Table 6.2) were added to the water-washed middle distillate. We measured negligible corrosion for both carbon steel and type 304 stainless steel which were exposed in a mixture of washed middle distillate, phenol, cresol, aniline, pyridine, and methyl aniline.

Table 6.5. Chemical analyses results of oil and water used in corrosion tests

Liquid	Neutralization number (mg KOH/g)	Concentration, wt ppm				H_2O (%)	Fe^{++}/Fe^{+++}
		Total Cl	Water-soluble Cl	Total N	Total S		
		First Experiment					
As-received pretest oil	0.81	417	507	8100	2990		
Water after washing oil	1.21	310		327	23		<0.1/<0.1
		Second Experiment					
As-received pretest oil	1.24	727	432				
As-received post-test oil	1.10	799	427	8000		0.14	11.7/<0.1
Oil after water wash	0.10	5		5750	2400	0.90	
Water after washing oil	1.45	492		3000	19		

Table 6.6. Major organic components of wash water identified by GCMS analysis listed in order of decreasing abundance

Acid fraction	Basic fraction
Phenol	Aniline
o-Cresol	Methyl aniline
m-Cresol	Methyl pyridine
p-Cresol	C_2-pyridine
C_2-phenol	C_3-pyridine
C_2-phenol	C_4-pyridine
C_3-phenol	1-naphthaleneamine

6.6 Environmental and Health

The objectives of this task are: (1) to assist DOE in the preparation of the NEPA-required Environmental Impact Statements for the SRC-I and SRC-II demonstration plants: (2) to provide environmental technical assistance to DOE in support of these projects; (3) to assist DOE in the review of plans for landfilling of solid wastes from H-coal operations; (4) to provide support to DOE in the accumulation, synthesis, and interpretation of environmental and health data related to direct coal liquefaction technologies, especially SRC and H-Coal processes.

6.6.1 SRC I and SRC II environmental impact statements - C. R. Boston and S. G. DeCicco

SRC-I demonstration project Although the Preliminary Draft EIS was issued in May, DOE and ICRC comments continued to come in throughout June and July. A meeting took place at DOE-HQ to discuss comments from the Office of NEPA Affairs and the Office of General Council. Understandings were reached in most areas but not in the critical areas of health effects, commercialization, floodplain/wetlands and alternative sites. Clear guidance in these areas is still essential. At the close of the month, a draft EIS was being compiled which is to be sent to DOE in August for further review and comment. During the week of July 21, the rare and endangered Indiana Bat was found at the site.

SRC-II demonstration project - The Draft EIS for the SRC-II project was released to the public in May. The public comment period closed on July 30. During the comment period the principle ORNL activity was in upgrading the socioeconomic and archeological/historical analyses. On July 30, ORNL was informed that the EPA had filed 17 pages of comments critical of the document, and the National Resources Defense Council and the National Wildlife Federation had filed 104 pages of comments critical of the DRAFT EIS. Virtually all of the comments attacked DOE's effort to conduct a NEPA review of the project before the completion of the final design. Commentors believed that without the final design, the Draft EIS lacked analytical substance necessary for an adequate environmental review. It should be noted, however, that Federal regulations do not permit completion of design until a final EIS has been issued. Other criticism was based on an inadequate understanding of the technology's health effects and references to documents unavailable during review of the Draft EIS (e. g., the safety analysis report, the report from the Water Resources Council, the traffic study by the West Virginia Dept. of Transportation, the Region VI Development Council's housing study, and the determination report by the State Historic Preservation Officer).

6.6.2 Critical Review of Mutagenesis and Coal Liquefaction Technology - R. F. Kimball and N. B. Munro

The computer file of pertinent compounds with CAS registry numbers started last month is being expanded. It has been used along with other lists to search the Environmental Mutagen Information Center's files for pertinent records on a number of polycyclic compounds of interest. Hard copies have been obtained of a selected group of these documents and have been used to write the section on type compounds. This section is nearly complete except for the bringing together of an appendix showing lists of compounds that have been identified by chemical analysis with information on their mutagenicity. The introductory section has been reviewed by several people, and some revisions are in progress.

The modified document organization and the status of each section follows:

I. Introduction (Completed)

II. Sources of Products and Byproducts (Nearly complete)

III. Mutagenesis Test Protocols (Completed)

IV. Type Compounds (Essentially complete)

V. Specific Test Results with Coal Liquefaction Materials, Including Comparisons with Petroleum and Oil Shale (In progress)

VI. Identification of Research Requirements (Work will start shortly)

VII. Conclusions and Recommendations

6.7 General Technical Support

General technical support is provided for the SRC I and SRC II projects and for the H-Coal project on an as requested basis.

6.7.1 SRC I and SRC II general technical assistance - H. D. Cochran

There is no current activity in this area.

6.7.2 H-Coal pilot plant general technical assistance - H. D. Cochran

The following activity on H-Coal reactor safety assessment (headed by H. A. Mitchell) is in progress in this area.

Objectives - The purpose of the reactor safety assessment is to determine the adequacy of the vessel and to identify any significant failures which would affect the reactor operation and to determine the adequacy of the systems to limit or control those effects. The safety assessment encompasses the major reactor components and subsystems, the instrumentation directly associated with the reactor and normal, upset, and emergency procedures.

Status Summary - The questions concerning the ability of the H-Coal reactor to operate for 5 years instead of the initially proposed 2 year test program were evaluated. An approach to assess the adequacy of the vessel for the 5 year test program was developed and presented to the H-Coal Management Advisory Committee (MAC) on July 24, 1980. The discussion of the potential vessel limitations resulted in several follow-up tasks for UCC-ND being identified. The reevaluation of the creep-fatigue life of the vessel for the 5 year test program will not be initiated until the H-Coal project participants have evaluated the proposed test program and agreed upon the specific test modes. If, at that time, the test program would cause the vessel operation to exceed the 1000 cycle limitation per the ASME Code, then UCC-ND could perform the creep-fatigue analysis. The revised analysis would be based on a revised loading histogram that would be developed from the 5 year test program with the past several months experience of the pilot plant being incorporated and used as a guide for the remainder of the test program.

6.8 References for Section 6

1. L. E. McNeese (ed.), Fossil Energy Program Monthly Progress Report for the Period Ending May 31, 1980, ORNL/TM-7414, Oak Ridge National Laboratory, Oak Ridge, Tennessee (in process).

7. PROCESS ANALYSIS AND ENGINEERING EVALUATIONS

R. W. Glass

Process analysis and engineering evaluations studies are being conducted for DOE/FE to provide on a consistent basis, technical and economic assessments and evaluations of processes and systems for coal conversion and utilization.

7.1 Liquefaction Technology Assessment (LTAS)

R. C. Forrester III, R. Salmon, S. P. N. Singh, J. F. Fisher, R. M. Wham, W. C. Ulrich, and P. J. Johnson

7.1.1 Objective

The objective of the Liquefaction Technology Assessment is to provide technical information, cost information, and economic evaluations needed by the Department of Energy (DOE) to compare, on a consistent basis, coal liquefaction processes. The assessment will be carried out in several phases, starting with processes employing available technology and progressing to those which are in earlier stages of development. Technical and cost information will be provided by Fluor Engineers and Constructors through a contractual agreement with the Oak Ridge National Laboratory (ORNL). ORNL will provide the process design bases, conceptual design philosophy guidance, and economic evaluations based on the cost information provided by Fluor.

7.1.2 Status summary

Revision of the Phase 0 draft report is complete and the manuscript has been submitted for final editing. Publication has been delayed slightly but is expected during the next quarter.

Comments from DOE and proponents on the Phase I draft final report have been received and are being incorporated into the Phase I report. The report is expected to be ready for editing by the end of August or in early September.

Subcontract negotiations with Fluor on LTAS have continued with preliminary approval of the subcontract by UCC-ND, Fluor, and DOE. The contract is expected to be signed by UCC-ND and Fluor in late August then sent to DOE for formal approval. Work on Phase II will begin following approval of the subcontract by DOE/ORO.

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

After work begins on Phase II, ORNL will begin discussions with DOE and Fluor concerning Phase III. The objectives of these discussions will be to come up with a basic flow diagram so that Fluor can begin design work for Phase III. Phase III will examine state-of-the-art Fischer-Tropsch synthesis using commercially available gasifiers.

7.2 Direct Combustion

E. C. Fox and T. D. Anderson

7.2.1 Objective

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

1. Identify and quantify the important factors restricting the use of coal in the sectors of interest.

2. Evaluate potential technological and institutional solutions to the problems identified in (1) above.

3. Make recommendations to DOE/FE relative to the most promising approaches to increasing the near-term use of coal.

7.2.2 Status summary

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

7.3 Advanced Power Conversion Systems

J. E. Jones Jr. and A. P. Fraas[a]

7.3.1 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.

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[a]Consultant

7.3.2 Status summary

A total of eleven systems or components of systems were evaluated. Draft reports covering all of these topics, an overall summary report, and an executive summary report have been completed and are undergoing final review. The reports entitled "Summary of the Research and Development Effort on Open-Cycle Coal-Fired Gas Turbines," ORNL/TM-6253, and "Summary of Research and Development Effort on Air and Water Cooling of Gas Turbine Blades," ORNL/TM-6254, have now been published.

7.4 Process Modeling

R. Salmon, P. J. Johnson, and W. C. Ulrich

7.4.1 Objective

The objective is to assist DOE/FE in its plan for computer analysis and computer support of coal conversion studies. Past work included assistance to Purdue and Lehigh Universities in the development of computer programs for this plan. Physical property data were collected and computerized primarily by Purdue and will be used in support of future process modeling efforts. Purdue's general design program was aimed at material and energy balances, equipment sizing and costing, plant capacity, and general economics. Lehigh's dynamic simulation programs addressed plant design primarily from the standpoint of process performance during transient operations, but can also be used for steady-state conditions. Current work includes process modeling and systems engineering support to Morgantown Energy Technology Center (METC). This comprises implementation of codes delivered by Purdue and Lehigh Universities onto the computer system at METC and development, testing, implementation, and use of new process models.

7.4.2 Status summary

Evaluation of Physical Property Package PPROP

The draft report on the evaluation of the physical property package PPROP is being revised to include the results of several additional examples run during the past month. These include ideal gas enthalpies for 19 pure species over the temperature range 110°F to 1100°F. Agreement with published enthalpy data was good in almost all cases. An error was found in one of the heat capacity constants for propene. Several additional test examples were run involving density, enthalpy, and flash calculations. Some anomalous results were obtained; for example, negative densities for propane and butane were found. An effort is being made to determine the source of the error.

Addition of Solids Handling Capabilities to PPROP

Work continued on the coding of routines for temperature and composition dependence of physical properties of various solids. These routines will be tested on typical coal, char, limestone, and dolomite compositions. Recoding of PPROP subroutines to use the solids data library will begin next month.

Evaluation of Rajan-Wen-Krishnan FBC Computer Program

Additional example problems were run on the fluid bed combustor program in an effort to determine why a material balance was not being achieved. In four examples, the carbon balance failed to close. In one case, the amount of carbon leaving the system was twice the amount entering. The convergence routine gave widely different values for the carbon content of the bed depending on the initial trial value used. Investigation into the reasons for these anomalies is continuing.

7.5 Coal Liquefaction Advanced Research Digest

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

7.5.1 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.

7.5.2 Status summary

An external review of the article "Chemical Reaction Kinetics of Coal Liquefaction" was returned, and an internal review of the article "Chemical Reactions of Coal Liquefaction" was completed.

Researching and writing for the article "Chemical Characterization of Coal-Derived Liquids" and "Free-Radical Chemistry of Coal Liquefaction" have continued.

7.6 Environmental Control Costs for an Indirect Coal Liquefaction Process

P. J. Johnson, R. C. Forrester, S. P. N. Singh, R. M. Wham, and J. F. Fisher

7.6.1 Objective

The objective of this study is to examine the effect of varying degrees of stringency of environmental regulations on the economics of an indirect liquefaction process at several plant capacities. The work is being carried out for the DOE Assistant Secretary for the Environment's Office of Environmental Assessments (OEA) [formerly Office of Technology Impacts (OTI)]. Technical and cost information will be provided by Fluor Engineers and Constructors through a contractual agreement with the Oak Ridge National Laboratory (ORNL). ORNL will provide guidance in the development of environmental regulations and economic evaluations based on cost information provided by Fluor.

7.6.2 Status summary

A monthly review meeting was held with Fluor personnel in Houston to discuss their progress. Fluor presented the results of the work they have performed in three areas: a proposed table of contents for the final report, the proposed environmental regulations for the "Degree B" (current environmental regulations) and "Degree C" (stringent environmental regulations) studies, and a list of specific emissions (compounds) to be considered in the study.

Fluor and ORNL personnel then met with DOE/ASEV representatives in Washington. The results of Fluor's work were discussed, along with a discussion of the options to be considered in the "Degree D" (commercially available environmental technology in the next 10-15 years) study.

Agreement between DOE/ASEV, Fluor and ORNL on the above aspects of the project should be established within the next month.

7.7 Environmental Controls for Low-Btu Gasification

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

7.7.1 Objective

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

7.7.2 Status summary

The project was completed during July with issuance of the final report Costs and Technical Characteristics of Environmental Control Processes for Low-Btu Coal Gasification Plants (ORNL-5425). The abstract is printed on the following page:

*Retired.

ABSTRACT

Technical characteristics and costs of 25 individual environmental control processes that can be used for treating low-Btu coal gas are given. These processes are chosen from a much larger array of potential environmental control processes because of their likely applicability to low-Btu coal gasification operations and because of the limited scope of this study. The selected processes cover gas treating, by-product recovery, wastewater treating, and particulate recovery operations that are expected to be encountered in coal gasification operations. Although the existence of the Resource Conservation and Recovery Act of 1976 is recognized, no treatment schemes for solid wastes are evaluated because of the paucity of information in this area.

The potential costs of emission controls (by using eight integrated combinations of these 25 environmental control processes) in conceptual low-Btu coal gasification plants are given in an adjunct report titled *Evaluation of Eight Environmental Control Systems for Low-Btu Coal Gasification Plants*, ORNL-5481.

The adjunct report, Evaluation of Eight Environmental Control Systems for Low-Btu Coal Gasification Plants (ORNL-5481), was published in March of this year.

8. FOSSIL ENERGY ENVIRONMENTAL ANALYSIS

C. R. Boston, T. H. Row

Environmental support is provided to DOE/Fossil Energy and DOE/ Economic Regulatory Administration. The effort includes: (1) preparation of NEPA-required assessments and statements related to synfuels demonstration programs and fuel conversion implementation; (2) programmatic environmental studies that are critical to the early realization of advanced fossil technologies and minimization of the use of petroleum and natural gas; and (3) general environmental technical assistance.

8.1 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.

8.1.1 Stored solids study - W. J. Boegly, Jr., F. S. Brinkley, E. C. Davis, C. W. Francis and H. W. Wilson, Jr.

An interim draft of the conceptual landfill design study was completed and transmitted to DOE on July 14. Preparation of a report summarizing the studies on sulfates released from gasifier ash continued with an anticipated completion date of early August 1980.

On July 8 and 9, 1980 a trip was made to Morgantown, West Virginia by ORNL personnel for the purpose of collecting soil samples from the site of the solid waste disposal area of the proposed SRC-II demonstration plant. Assistance was provided by Ed Talbott, area U.S. Soil Conservation Service agent and Ron Taylor, area SCS soil scientist, as well as Steve Osborn of D'Appolonia, Inc., consulting engineers for geotechnical work at the site.

The demonstration phase waste disposal area is located on a bluff above the river valley that has previously been used for agricultural purposes. The soils in the area are comprised of Dormont and Westmoreland silt loams, of which Dormont predominates. It is a weathered-in-place series which is medium to strongly acid in pH. The subsoil is a firm, gray silty clay loam and extends to a depth of approximately 1.53 m (60 inches) before hitting shale bedrock. Permeability is classed at moderately slow to slow for this soil. Approximately 400 lbs of subsoil were returned to ORNL for chemical and physical analysis and for use is lysimeter studies.

8.1.2 Coal conversion demonstration projects

Liquefaction projects - S. G. DeCicco

This activity is reported in Chapter 6.

Gasification projects - A. J. Witten

MLGW - The DES mats were sent to DOE on July 14. Ten copies were scheduled to be transmitted to EPA on July 18 and the Notice of Availability was to appear on July 25. However, due to delays in the review by OGC and NEPA Affairs the DES has not been released.

ICGG - Jim Malcolm was at ORNL on July 29, 30, and 31 to discuss comments on the most recent PDES. Work is underway on a revised draft and this should be completed on August 15. This document will then go to NEPA Affairs for comment.

Conoco - A meeting was held at ORNL on July 16 and 17 with representatives of DOE and UOP to discuss comments on the most recent version of the PDES. HDR is working on a revised document, however, it is uncertain when this will be completed since we are awaiting further information required as a result of new emissions given in Conoco's application for a Permit to Install.

8.1.3 Communications

a. Boston and Boegly met with Herschel Jones in Germantown on July July 14 to discuss the Stored Solids Study.

b. Boston and DeCicco met with DOE and EPA in Washington on July 15 to discuss EPA's preliminary comments on the SRC-II DES.

c. DeCicco attended a meeting with International Coal Refining in Allentown on July 16 to discuss the SRC-I project.

d. A meeting was held in Oak Ridge on July 16 and 17 with DOE and UOP to discuss comments on the most recent version of the CONOCO preliminary DES.

e. DeCicco met with the Office of NEPA Affairs in Washington on July 17 to discuss their comments on SRC-I.

f. Jim Malcolm was at ORNL on July 29, 30 and 31 to discuss comments on the most recent PDES for ICGG.

8.2 Economic Regulatory Administration Support Project

R. C. Martin

The purpose of this project is to provide technical assistance to the Economic Regulatory Administration (ERA) of the Department of Energy in its implementation of the Powerplant and Industrial Fuel Use Act of 1978 (FUA). This act has as a general purpose the minimization of the use of petroleum and natural gas as a primary energy source in a manner consistent with applicable environmental requirements. The scope of FUA includes both new and existing electric powerplants and new and existing major fuel burning installations. Within ERA the Office of Fuels Conversion (OFC) is responsible for implementing FUA and meeting the requirements of the National Environmental Policy Act. The Fuels Conversion Analysis Division supplies the technical support for OFC.

Technical activity underway relates to the conversion of three existing powerplants from oil as the primary fuel to coal or other alternate fuel. These powerplants are Arthur Kill and Ravenswood, located in the New York City area, and Northport, located on Long Island. Additional analyses underway support the development of a generic assessment of conversion impacts to the Northeast Region.

The task order to initiate work on the Salem Harbor powerplant in Massachusetts was received at the end of July.

D. J. Wilkes attended a multi-agency meeting on EIS compliance review with Council on Environmental Quality Regulations in New York City on July 2.

8.2.1 Environmental analysis section - N. E. Hinkle

The EIS Implementation Plans for the fuel conversion at the Arthur Kill and Ravenswood powerplants were modified slightly by ERA and forwarded to interested Federal, State, and local agencies in the New York City area. Eventually, appropriate comments from the independent agencies and the ERA modifications will be used to prepare final Implementation Plans for the public record.

The report on fuel supply and transportation for both powerplants has been received from TERA and distributed as needed. The engineering report for the Arthur Kill site has been reviewed by the management team and should be available in final form shortly. The environmental source term report for Arthur Kill has been received from UE&C and distributed to the environmental analysis team.

A noise analysis report was received from UE&C and provided to the socioeconomics analyst for development of the community impact assessment. Instructions have been provided to UE&C for inclusion of final modifications to the noise analysis report.

Development of the environmental impact report is proceeding. Current emphasis is on discussion of the fuel and emission control strategies, description of plant modifications and environmental effects source terms, and summarizing the existing environment at the powerplant sites. Analysis of the environmental impacts has been initiated, but progress is still limited by absence of other studies such as the Con Ed Transportation and Solid Waste disposal study, the New York State Public Service Commission report on solid waste disposal sites for the Con Ed fuel conversion, and task reports for the Northeast Regional EIS. These studies may become available in August.

A. Watson has had additional general discussions with Con Ed officials about the in-plant noise levels, employee exposure to noise, and hearing protection measures for the employees. However, Con Ed officials continue to refuse to provide detailed noise level data or employee exposure to noise data for their powerplants. They did indicate that no reports are prepared for OSHA in the categories of occupational injuries or noise exposure.

Ms. Watson spent two days with the TVA Industrial Hygiene Branch at Muscle Shoals, Alabama, discussing methodology and data bases for performing site-specific occupational health and safety assessments. The TVA staff was able to identify specific noise and accident hazards from the equipment list for coal conversion prepared by UE&C. Access was also provided to monitoring results for noise, asbestos, and coal dust exposures near work stations at TVA powerplants.

A tour of the Colbert Steam Plant was taken. Noise emissions were monitored during this tour. Noise levels exceeding 100 dBA were observed at work stations near ball mills and duct work in the basement levels. Individual hearing protection devices were in use. Heat stress was also identified by TVA as a major problem recently.

The TVA information files and research for these personnel hazards are the only data bases found so far for coal-fired plants. No similar data base for oil-fired plants has been found, but the TVA staff did provide potential industry contacts for further search.

As a result of the visit to the TVA facilities, the occupational hazard assessment for the coal fired plant is nearing completion. However, the lack of site-specific data for the Con Ed plants and for oil-fired plants in general, limits the analysis to a generic citation of the additional occupational hazards likely to be found after conversion to coal combustion.

8.2.2 Air quality analysis section - F. C. Kornegay

As subcontractor to assist with the site-specific air quality modeling, David Kellermeyer of Henningson, Durham and Richardson (HDR)-Santa Barbara has been at ORNL. Air quality projections have been produced for the Arthur Kill and Ravenswood conversions through use of the identified fuels scenario from the Engineering Analysis Section, receptor locations specified by the Environmental and Health analysts, and the CRSTER single-source dispersion model. All fuel scenarios, including base case, have been run. The PASNY plant is presently being run. HDR's analysis will continue with complete results and documentation provided to ORNL soon.

8.2.3 Engineering analysis section - W. L. Greenstreet

Significant progress towards negotiating definitive bases under which to proceed with the engineering analyses was made in July.

Definitive scope and instructions for the Arthur Kill and Ravenswood engineering reports were finalized. Report preparation will now commence since these data and TERA's coal seam identifications are available to be coupled.

Meetings were held on July 10 with ERA to discuss engineering tasks and schedules and on July 28 and 29 ORNL met with United Engineers and Constructors (UE&C) in Philadelphia to conduct a preliminary review of the Arthur Kill Engineering Analysis Technical Report.

Copies of the following reports in support of environmental studies have been received and are in review for final acceptance by ORNL:

1. "Noise Impact Assessment for Arthur Kill Powerplant, New York, New York", UE&C, June 1980.

2. "Determination of Stack Emissions and Solid and Liquid Waste Discharges for Arthur Kill Powerplant", UE&C, July 1980.

3. "Occupational Hazards Evaluation for Arthur Kill and Ravenswood Power Plants", UE&C, July 1980.

Concurrently, the subcontractor is preparing versions of the first two which will be applicable to the Ravenswood plant.

Discussions were held with UE&C to initiate work supportive of the Northport Task Order. A draft Fuel Scenario Identification Report was written and transmitted to ERA. In addition, a follow-up meeting on this report was held with ERA; the conclusion was that all fuel options given in the Fuels Scoping letter (from M. E. Carosella to T. Row, dated June 20, 1980, should be considered in further studies.

Arrangements were made for the Northport engineering site visit and material related to this visit was prepared. This includes a list of engineering aspects of interest for inspection and discussion and a list of questions for transmittal to the utility.

An outline for the engineering analysis technical report was drafted and submitted to ERA for comment. Comments were received, and the outline was revised accordingly.

Continuing activities include investigations of factors influencing derating, such as is projected for the Northport units, and identification of coal supply issues. Work on the paper which deals with factors that influence selection of coals for fuels in reconverted power plants is continuing. A seminar on this topic was presented to members of the ORNL ERA Support Project team. Literature reviews were initiated on coal-oil-mixture handling and firing and on use of refuse derived fuel (RDF) in electrical power plants.

8.2.4 Fuel supply and waste disposal analysis section - A. S. Loebl

TERA delivered its final report on Port Reading (Task 8) in July with additional response to all comments made on the draft. TERA's June 30 report on Transportation Costs and Constraints (Tasks 5,6,9 and

10) was reviewed by ORNL and comments transmitted to TERA. A final report will be issued within two weeks of receipt of ERA's comments. Work is proceeding on the Generic Study of Commercial Uses for Sludge and Ash (Task 7).

8.2.5 Northeast Regional Analysis

R. C. Martin and D. J. Wilkes participated in the public scoping meeting for the Northeast Regional EIS held in New York City on July 14 and Martin on July 15 for the Boston meeting.

Air quality - F. C. Kornegay

Air quality analyses for the Northeast Regional EIS are approaching completion. Preliminary results were presented to DOE and others in Washington on July 9. Following the meeting at which potential problem areas were identified, various scenarios to address the problem areas were developed by ANL, ORNL, and DOE. On July 18, another meeting was held in Washington to agree upon final scenarios. All attendees agreed upon the scenarios. Work to analyze the new emissions is underway at ANL and ORNL. Emission information on all facilities for all scenarios has been developed and has been transmitted to ANL for inclusion in the ASTRAP modeling effort.

Health effects - P. J. Walsh

Completion of the health effects sections of the NE Regional EIS has been given top priority. Work is underway to complete draft input on potential health effects associated with extraction, transportation, preparation, combustion and waste disposal aspects of coal use. The generic technical document on health effects of air pollution from combustion, perhaps the area of most public concern, will provide a detailed backup for the EIS. Work on the technical document is continuing but there may be some delay in completion due to the priority given the EIS and its treatment of other parts of the fuel cycle.

Meetings were held with ERA and ANL personnel July 3 to scope these activities.

8.2.6 Electric utility dispatch analysis - C. R. Hudson

Simulations of the New York and New England Power Pools, both with and without units converted to coal, were made during the month using the PRODCOST code. The results of these simulations were delivered to ERA on July 22. Similar to the REUOM code simulation of New York Power Pool (NYPP), capacity factors for lower cost base loaded units (primarily coal-fired units) were inordinately high. This appears to be due to the implicit assumption in the model of infinite capacity transmission lines. Two approaches are being taken to correct for this. In the REUOM code, Long Island Lighting Company will be separated from the remainder of New York state and transmission line limitations will be introduced. In PRODCOST, which does not have multiarea capability, capacity deratings provided by NYPP will be incorporated. These actions should more accurately model NYPP.

A meeting was held on July 21 with PJM representatives to urge them to provide ERA and ORNL with unit specific data. The final outcome of this is still uncertain.

With ERA approval, the original task schedule as developed in the work proposal has been abandoned. Due to uncertainties regarding data availability, the task will continue into the next fiscal year and documentation of the various regions under study will take place on an as-completed basis.

ORNL has been authorized to develop and document a computerized methodology that will assist in examining the financial impact of fuel conversion. Based on user input of costs, rates of return, lifetimes, etc., the code will calculate the annual revenue necessary to balance all the costs, returns, and taxes for that year. Various tax and capitalization options will be built-in to the code to allow the user to model a wide range of utility/PUC policies.

Work this month consisted of code development. A meeting with ERA staff was held on July 22 to further define needs in this area. ERA is to provide additional information regarding the types of problems to be solved by the code.

8.2.7 Milestones

The following dates have been established for delivery of the first draft of the indicated reports to ERA. Unless otherwise noted, work on these reports is on schedule.

Arthur Kill Powerplant		
Fuel Scenario Evaluation	March 20, 1980	delivered
Environmental Regulations Technical Report	March 25, 1980	delivered
Fuel and Waste Technical Report	May 31, 1980	parts delivered parts delayed
Engineering Analysis Technical Report	August 15, 1980	
Environmental Impact Report	November 1, 1980	
Ravenswood Powerplant		
Fuel Scenario Evaluation	March 20, 1980	delivered
Environmental Regulations Technical Report	March 25, 1980	delivered
Fuel and Waste Technical Report	May 31, 1980	parts delivered parts delayed
Engineering Analysis Technical Report	September 1, 1980	
Environmental Impact Report	December 1, 1980	
Northeast Regional Study		
Air Quality Technical Report	September 15, 1980	
Health Effects Report	September 1, 1980	
Electric Utility Dispatch Study		
New York Power Pool	April 14, 1980	delivered
New England Power Pool	June 1, 1980	delayed
PA-MD-NJ Interconnection	June 1, 1980	delayed
Annual Reports Preparation		
Draft FUA Annual Report	January 28, 1980	delivered
Final FUA Annual Report	February 29, 1980	delivered
Draft Federal Facilities Annual Report	March 15, 1980	delivered
Final Federal Facilities Annual Report	May 15, 1980	delivered
Small Utilities Study		
Draft Report	July 31, 1980	delivered

8.3 Fossil Energy Program Support

C. R. Boston, T. H. Row

This program was initiated with a series of visits to the Energy Technology Centers (ETC) and various Operations Offices to discuss the environmental requirements and projects of Fossil Energy Programs. These discussions resulted in a consistent set of suggested activities designed to provide the environmental effort necessary to assure commercialization of the major coal conversion programs. The ideas generated from these contacts coupled with the defined responsibilities of the Environmental Activities Branch resulted in five specific work areas:

Research planning - Provides for ongoing review of projects coupled with close project interaction to provide the insight needed to assure that all necessary environmental work is initiated.

Critical issues - Provides a detailed critical review of identified environmental problem areas with documentation of findings.

NEPA coordination - Provides assistance in scheduling required NEPA activities in support of major programs or projects.

Regulatory and legislative reviews - Provides a continuing review of all regulatory and legislative items, present and planned, and their effects on fossil energy programs.

Consultation assistance - Provides for identification of a team of experts in the environmental field available to respond rapidly to requests for assistance from the Environmental Activities Branch.

During the month the third document in the NEPA Energy Series was delivered to Washington, DC, and is currently being distributed. Eight copies of the Tenn., W. Va., and Ohio volumes of the Environmental Program Compliance Handbooks were delivered on Schedule. The IH/OM Workshop was rescheduled for November 6-7 in Washington DC.

8.3.1 NEPA compliance coordination - W. W. Goolsby

During this report period the third document for the NEPA energy projects was delivered to Robert Stern, NEPA Affairs Division, Washington, DC. This document entitled "NEPA Energy Projects - Solar, Geothermal, and Small Hydroelectric," dated June 1980, is now being distributed to project personnel, project managers, and other interested DOE and ORNL personnel, locally and throughout the country. Projects included in this document involved the following technologies: Solar Energy Systems - wind, ocean, photovoltaic, solar thermal, and biomass; Geothermal - geopressure, hot dry rock, and geothermal; and Small Hydroelectric Demonstrations.

The project data sheets provide basic information such as project title, project location, estimated project cost, technology involved, and names and location of responsible project personnel. The schedules define project milestones with respect to conceptual design, detailed design, procurement, and construction. The environmental schedule depicts NEPA activities past, present and future. The information provides an inventory and data base of energy research and development projects in operation, under proposal for funding, or funded in part or whole by DOE. The inventory includes projects large enough for process development, pilot demonstration, or commercial application which require(d) environmental assessments and/or environmental impact statements. Verification and documentation of project data and schedules were confirmed through numerous reference and source documents and by personal contact, phone conversation, and visits to DOE Headquarters. DOE Energy Technology Centers, and other involved agencies and personnel.

Also, during this report period a fourth document is being developed on other nonfossil energy projects funded in part or whole by DOE with potential NEPA requirements. The technologies involved include Conversion Facilities, Conservation, Energy Storage, Waste Energy, Energy Transmission, Power Marketing, RA and ERA. At this point it is uncertain the total number of projects that will be included. A computerized data base has been established for all NEPA projects for updating and reporting utilizing the 1022 Data Base Management System and RECON. This will provide quick and efficient access to all project data with numerous options for selecting particular information, data by individual project and/or total project retrieval. Presently, all fossil energy and nonfossil energy projects are being included in the computer data base.

8.3.2 Regulatory and legislative review - J. K. Huffstetler and C. J. Oen

Draft volumes of the Environmental Compliance Program Handbook for the states of Ohio, West Virginia and Tennessee were transmitted to Washington on schedule. Work on the five priority states of Illinois, Kentucky, Ohio, West Virginia, and Tennessee is now complete. Publication of the final versions for these states is expected within the next two months.

Abstracting and indexing of the federal regulations concerning hazardous waste disposal is underway. Publication of the draft volumes of federal regulations covering air quality, water quality, and waste disposal is also expected within the next two months.

Preliminary contact has been made with officials in the states of Indiana, Alabama, Texas, Louisiana, and Pennsylvania. Relevant documents have been requested and have begun to arrive.

8.3.3 Industrial Hygiene/Occupational Medicine Workshop - T. H. Row

All speakers and panel participants for the workshop were contacted and advised of the change in schedule and location for the workshop. Two new speakers for the program were confirmed.

The preliminary selection of the Sheraton Inn in Reston, Virginia reported last month required changing due to a conflict of the Oct. 23-24 date with another conference. Due to the necessity of our rescheduling to Nov. 6-7, another site was chosen. At this time we are in the process of contracting with the Twin Bridge Marriott in Washington, DC.

All planning and materials are being revised for this change in date and location.

9. COAL PREPARATION AND WASTE UTILIZATION

E. C. Hise

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

9.1 High-Gradient Magnetic Separation

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

Initial testing of high-gradient magnetic separation with our superconducting magnet was performed with a -595 + 150 μm size fraction of a Kentucky seam #9 coal. The magnet was used with a canister containing R-type expanded metal mesh and 45 mil spacers in random alignment. Two basic parameters were explored: 1) effect of current and 2) effect of sample size. Figures 9.1 and 9.2 show the data obtained under the above parameters. Chemical analysis will be available in late August.

This experiment was delayed a week by a vacuum leak in the magnet cryostat. Mr. Howard Coffey of American Magnetics was able to locate and repair the fault, avoiding the necessity to return the cryostat to its manufacturer.

9.2 Open-Gradient Magnetic Separation

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

The initial circular feed test series was performed with our superconducting magnet operating in the cusp mode. The sample of Kentucky seam #9 coal used for this test series was rescreened and scalped twice. All samples have been submitted for chemical analyses. A report of this test series will be given when chemical analysis becomes available.

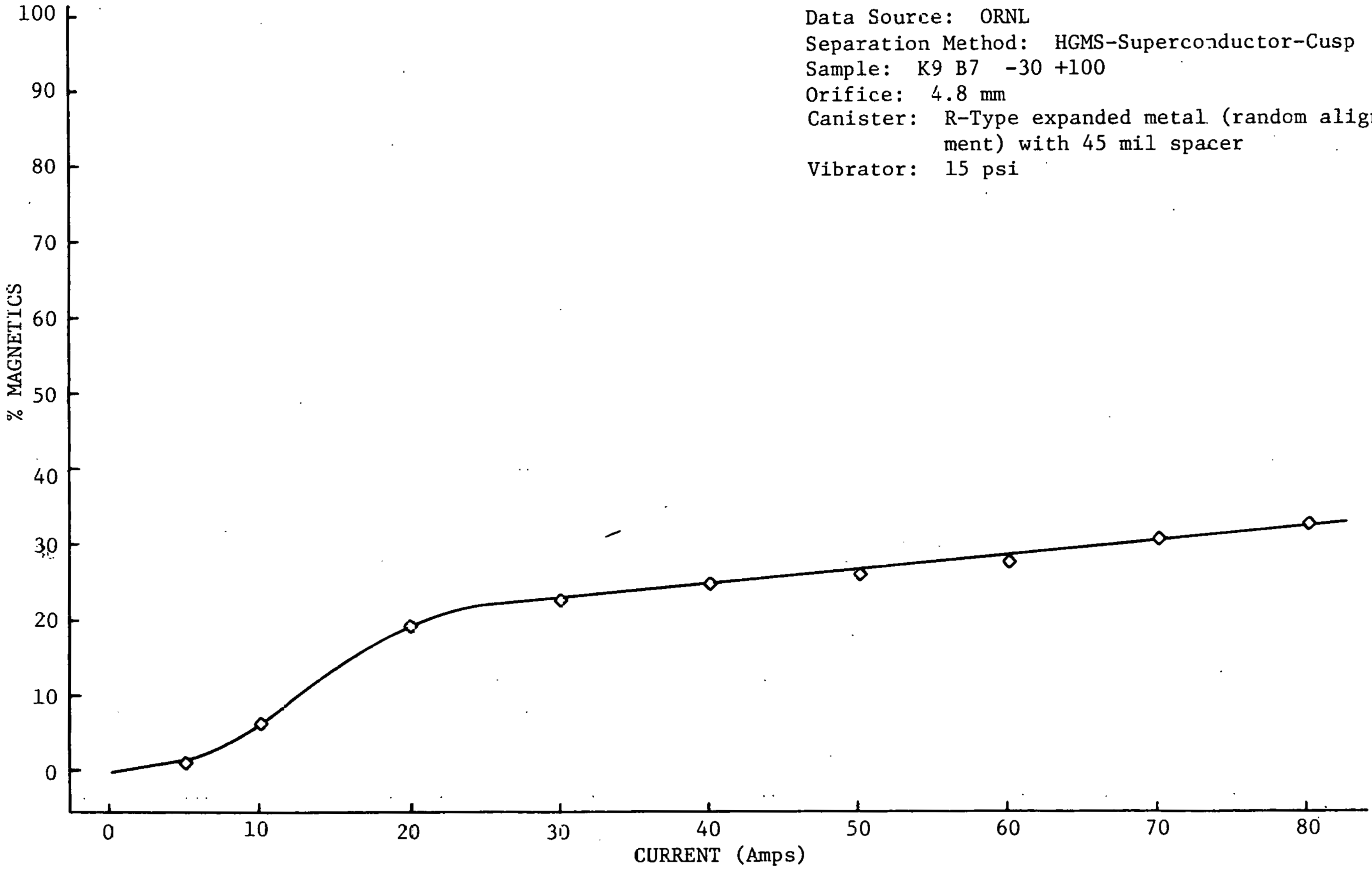

Fig. 9.1 Graph of percent magnetics as a function of current.

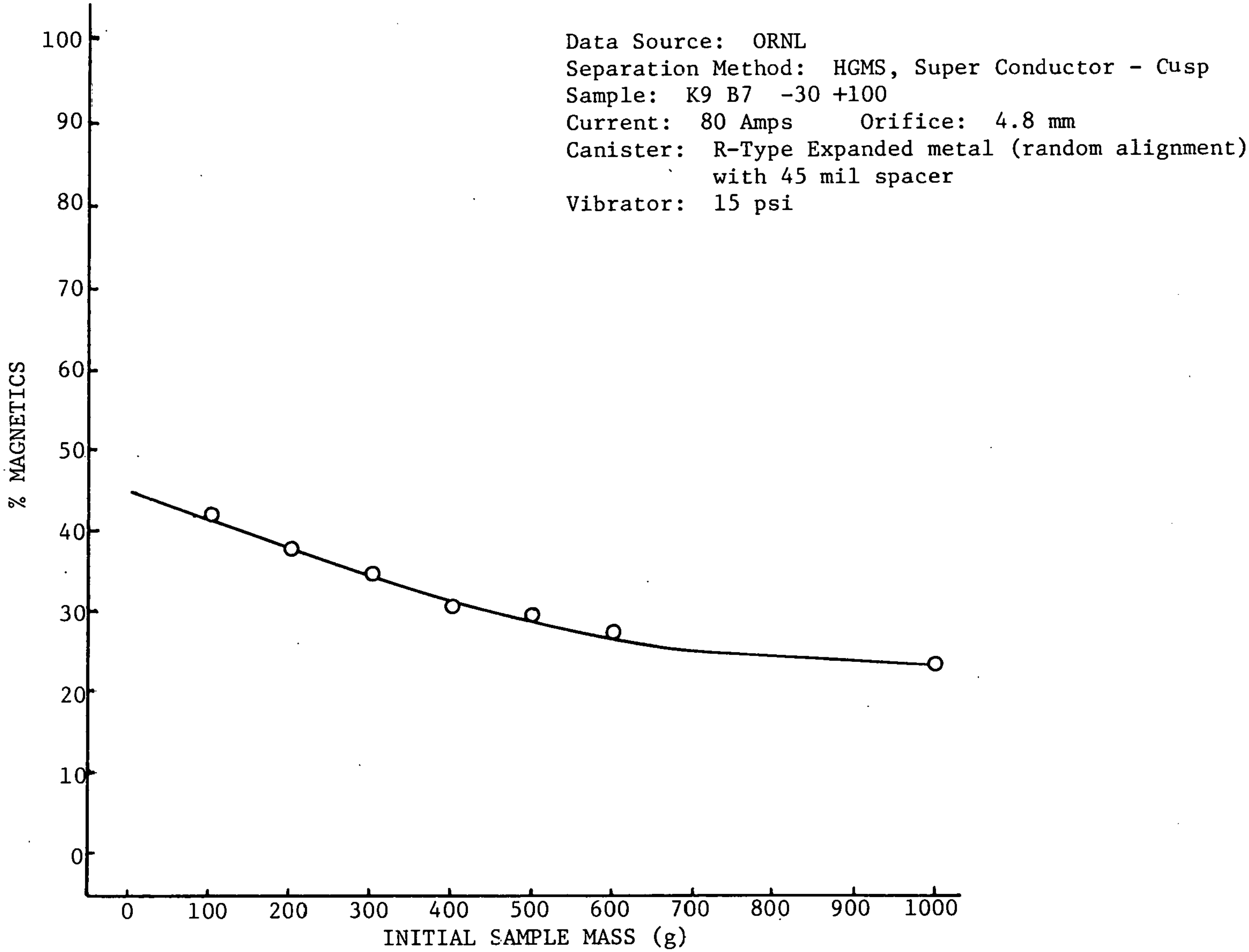

Fig. 9.2 Graph of percent magnetics as a function of initial sample size.

9.3 Industrial Contacts and Cooperation

In cooperation with TVA, a double-cone, heavy-media, separatory device has been drawn and plans submitted for fabrication. This unit was originally designed by Republic Steel Research. Fabrication should be complete by late August.

Messrs. Tom Hickey, Charles B. Hood, and William H. Jaeger of CVI Corporation, a Pennwalt subsidiary, visited our laboratory July 31. They were desirous of learning in detail of the performance of and potential application for the open-gradient magnetic separator and are specifically interested in commercializing this machine.

10. COAL PREPARATION PLANT AUTOMATION

K. R. Carr

The Coal Preparation Plant Automation Program is being conducted at Oak Ridge National Laboratory for the DOE Pittsburgh Mining Technology Center (PMTC). The objectives of this program are to develop instrumentation for the automatic control of coal preparation processes and to demonstrate overall plant automation in a typical coal cleaning plant.

10.1 Physical Measurements

R. L. Anderson and W. H. Andrews

10.1.1 Objectives

The objectives of this work area are to define deficiencies of existing on-line and laboratory instrumentation for physical measurements and to develop instruments needed to accomplish the physical measurements required for automation of coal preparation plants. Physical measurements include all measurements in the plant except those in the analytical instruments category described below. Examples of plant physical measurements are particle size, mass flow, viscosity, and density.

10.1.2 Status Summary

The prototype hardware correlator circuitry was tested and performed satisfactorily using sonic flowmeters installed in a laboratory flow loop as signal sources. The only work now required before on-site testing of this system at a coal preparation plant is to install the circuitry in a suitable waterproof enclosure. As a further refinement in the possible application of the hardware correlator, we plan to study the possibilities of using a small, low cost (a few thousand dollars) microcomputer system such as the Analog Devices Macsym to process the signals from several hardware correlators. Such a system could then provide measurements of mass flow at several locations in a plant.

Testing was started on the oscillating-sphere viscometer. In a bench-top test arrangement the reading of the instrument appears to be sensitive to mechanical shock. A disadvantage of the system is that the reading is given in units of centipoise X g/cm^3, and therefore requires a density measurement and calculation to determine viscosity.

10.2 Analytical Instruments

L. H. Thacker, L. N. Klatt, D. D. McCue, and D. S. Walia[a]

10.2.1 Objectives

The objectives of this work area are to define deficiencies of existing on-line and laboratory analytical instrumentation and to develop instruments needed to accomplish the analytical measurements required for automation of coal preparation plants. Analytical instruments are defined as those instruments that provide information on the chemical constituents of the coal or have a principle of operation based on nuclear methods; examples of analytical instruments are ash monitors, sulfur monitors, and nuclear density gages.

10.2.2 Status Summary

Laboratory testing was initiated to determine the relationship between the density and ash content of a particular blend of coal. As reported last month, the goal of this work is to evaluate the possibilities of using an ash versus density correlation as the basis for a simple and relatively inexpensive on-line ash measurement method. Coal samples for testing were collected by D. S. Walia from 13 locations in the United Coal Company's Wellmore No. 7 coal preparation plant at Big Rock, Virginia. These samples have ash content ranging from 6 to 75%. Also, we are studying the results of other ash versus density investigations either completed or in progress; the extent of our laboratory investigation is expected to be only a few weeks duration.

Work progressed in defining the content and organization of the sections of the state-of-the-art report in the area of analytical instruments.

10.3 Systems Application

R. L. Moore, L. E. Ottinger, and G. R. Wetherington, Jr.

10.3.1 Objectives

The objectives of this work area are to acquire and maintain an in-depth knowledge of the features of the coal preparation plant environment and overall operation which affect the selection and application of instrumentation and controls, to evaluate the suitability of commercial and developmental devices for installation in coal preparation plants, and to provide the coordination to ensure compatibility and proper interfacing of the various systems and devices to be installed for demonstration in operating coal preparation plants.

[a]Oak Ridge Associated Universities

10.3.2 Status Summary

The activity during July consisted mainly of compiling and organizing information for the State-Of-The-Art Assessment report. L. E. Ottinger participated in some of the visits to local coal preparation plants (see section 10.7.2).

10.4 Mathematical Methods

W. R. Hamel, G. O. Allgood, C. H. Brown, and G. S. Canright

10.4.1 Objectives

The objectives of this work area are to utilize mathematical analysis as a tool to study processes, develop control models, and evaluate the technical and economic merit of existing and potential instrumentation devices and systems in the coal preparation plant application. This work area includes the evaluation of existing computer models of coal preparation plants, modification of existing computer programs as required for use, and development of programs and techniques needed to support the coal preparation plant automation effort.

10.4.2 Status Summary

Dynamic models for the froth flotation cells and filtration process have been completed and implemented on the remote PDP-10 computer system using the Continuous Systems Modeling Program (CSMP). Froth cells were developed as five continous stirred tank reactors in cascade. A system response to a step increase in solids feed rate yielded results expected from five cascaded first-order lags. The filter was developed as a continuous stirred tank reactor also. A typical operating cycle was implemented using process variables calculated from existing data. The cycle consisted of filter rotation through the slurry and cake formation, with the drying process omitted. The system was run under normal operating conditions for a one segment disc. Preliminary results indicate a relatively good model representing the filtration process.

10.5 Information and Reports

G. M. Caton and E. R. Rohrer

10.5.1 Objectives

The objectives of this work area are to compile information related to coal preparation plant design and operation, to develop a system for making information readily available to members of the project team, and to assist in the preparation of reports describing work in progress, technical developments, and milestone achievements.

10.5.2 Status Summary

Work was continued on building the computer data base on coal preparation and instrumentation documents. The data base is in two parts. Part 1 consists of 558 references and Part 2 has 278 references from continuing computer searches. A listing of the coal preparation and instrumentation documents in the project files, arranged by category and containing abstracts and indexes, was generated and circulated.

Information acquisition and dissemination activities included the following:

1. One hundred fifty-nine requests for documents, searches, and information were processed.

2. Thirty-nine articles, reports, and books were ordered.

3. Nine current contents routings and fifteen selective routings of the coal preparation search, journals' table of contents, and articles were circulated to team members.

4. A subscription to Coal Age has started and this periodical will be routinely circulated.

10.6 Data Acquisition

J. M. Jansen, Jr., and J. T. Hutton

10.6.1 Objectives

The objectives of this work area are to determine, select, and apply the appropriate data acquisition and processing equipment consistent with the needs for automation and compatible with the physical environment of coal preparation plants. Support activities leading to the implementation of the full-scale demonstration of an automated plant will include assistance in the selection of data acquisition equipment and techniques for use at coal plants and ORNL in the study of processes, the evaluation of installed instruments, and the development of control methods.

10.6.2 Status Summary

Documentation was received from Staff Computer Technology, Inc., on their "PRO" software package. This documentation was provided by the vendor as proprietary information and must be returned in a few weeks. Our review of this software indicates it would be suitable for use with the hardware we have proposed (but not yet ordered) for on-site testing, provided some modifications were made. Necessary modifications to the software package for use with the proposed remote multiplexer system were discussed with the software vendor.

10.7 Visitors and Plant Visits

10.7.1 Visitors

A meeting was held at ORNL with V. J. Orphan of Science Applications, Inc. (SAI), who was at ORNL principally in connection with other programs. We discussed the projects that SAI has in progress or planned with possible application in coal preparation:

(1) The Continuous On-Line Nuclear Analyzer of Coal (CONAC) installation for Detroit Edison at Monroe, Michigan.

(2) The CONAC installation at the Kingston Steam Plant of the Tennessee Valley Authority.

(3) A CONAC/electrical conductivity hybrid system for coal slurry measurements in the steel industry.

(4) A CONAC demonstration unit for the Electric Power Research Institute and the Tennessee Valley Authority.

(5) A copper ore rapid response unit based on sophisticated gamma analysis and utilizing a Digital Equipment Corp., LSI-11 computer.

(6) A system being provided for the Pittsburgh Mining Technology Center to determine the mass fractions of coal, refuse, and water in the hydraulic haulage of coal.

10.7.2 Plant visits

N. C. Bradley, R. P. Migun[b], L. E. Ottinger, and G.V. Seaver[c], made visits a total of to five local preparation plants during July. Following is a list of the plants and their process features.

1. Beech Grove Coal Company at Lake City, Tennessee. The plant throughput is 250T/hr using heavy media washers and cyclones for separation. Instrumentation consisted of truck scales for plant input, belt scales on the product, and pH control for the static thickener.

2. Pioneer Coal Processing Company located at Pioneer, Tennessee. The plant throughput is 300T/hr using heavy media washers, heavy media cyclones, and hydrocyclones. Instrumentation systems installed in this plant are four belt scales, (one each on run-of-mine coal, refuse, product, and train loadout), and pH control of the static thickener.

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[b]Purchasing Division
[c]Roane State Community College

3. Industrial Processing Company at Devonia, Tennessee. The plant throughput is 500 T/hr using a Baum-type jig with electronic control, wet concentrating tables, and hydrocyclones. Instrumentation in use includes an electronic jig bed sensor with variable control of pulse and refuse removal, methane gas detectors in storage silos, pH control of the static thickener, and belt scales on run-of-mine coal and product coal.

4. Tennessee Consolidated Coal Company, located at Whitwell, Tennessee. The plant throughput is 450 T/hr using a heavy media washer (Bravos of Holland), heavy media cyclones, and froth flotation. Instrumentation in use provides control of the heavy media specific gravity, sump levels, and thermal dryer temperature.

5. Ryans Creek Coal Company, Inc., plant located in Whitley County, Kentucky. The plant has a throughput of 250 T/hr using a jig, wet concentrating tables, and cyclones. There is no instrumentation installed in this plant.

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

R. S. Holcomb

11.1 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 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.

11.2 Status Summary

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

The subcontract package was completed and signed by UCC-ND. It was sent on July 29 to Westinghouse for their signature. It is anticipated that it will be signed and returned within one or two weeks. At that time, it will be submitted to ORO for approval.

A meeting was held at ORNL on July 17 to review the status and plans for work on the CCC Program under the Letter of Intent. The meeting was attended by program personnel of Westinghouse, Babcock and Wilcox, Stone and Webster, representatives of DOE-ORO, and ORNL and UCC-ND Engineering Division. An overview of the program and general status report was given by Holcomb of ORNL. This was followed by a presentation of the program status for the contractor team given by Paul Berman of Westinghouse. The original schedule given in the proposal appears to be correct for the time required for performing the contract work. The Reference Plant Design should be completed in about eighteen months and the Test Unit construction in about twenty-six months. The Reference Plant cycle diagram and conceptual layout drawing were presented. The Reference Plant will be based on a cycle where the combustion air is supplied by a forced-draft fan. The combustion air flow was originally selected for 30% excess air, but this will probably be reduced to 20% to achieve an acceptable NO_x emission level. The indication thus far is that there will be no major changes in the Reference Plant conceptual design as presented in the Westinghouse proposal.

The status and plans for the work at Stone and Webster was presented by Neil Schilmoeller and Janis Ossmann. They have sent out questionnaires to 24 industrial firms to obtain information about their electrical and thermal energy needs. They believe that they will have enough information to recommend the electrical and thermal load design conditions and a reference site area for the Reference Plant design in about two months.

The program work at Babcock and Wilcox was reviewed by Ron Gorrell. B&W has received from Westinghouse the turbine air flow and design conditions for the Reference Plant. B&W has adopted design conditions for the combustor that are revised slightly from those in the proposal:

	Original	New
Fluidizing velocity, ft/sec	3.5	3.2
Excess air, %	30.0	20.0
Combustion efficiency, %	98.0	98.0
Ca/S mole ratio	2.6	2.2

They expect the design of the fluid bed combustor will be changed but very little from the conceptual design in the proposal. A Fuller-Kinyon pump coal feed system will be used in the Reference Plant design.

Westinghouse has given B&W the turbine air flow and design conditions for the test unit:

Air flow rate, lb/hr	22,032
Air inlet temperature, °F	661
Air inlet pressure, psia	114

The present turbine air flow rate is 10% higher than the flow rate used in the proposal, at the request of ORNL. B&W will determine whether or not this will result in an increase in the surface area required for the in-bed tube bundle and a decision will be made within three weeks on the flow rate to be adopted for the Test Unit design. Other revised design conditions for the test combustor have been adopted:

	Original	New
Fluidizing velocity, ft/sec	3.5	3.2-3.5
Excess air, %	30.0	20.0
Combustion efficiency, %	98.0	98.0
Ca/S mole ratio	2.6	2.5

Following the general program meeting, a meeting was held to discuss engineering planning for the Test Unit design.

Design of the test unit can proceed smoothly as soon as the decision is made on the turbine air flow rate, which will be settled about August 8. B&W will have a test system design schedule by about August 15.

The preliminary engineering work on facility and test system design and planning by UCC-ND Engineering was presented by Bill Hartman. Drawings of Building 9401-1 have been updated. Availability of head room has been studied, and there is 54 feed available from the floor to the crane hook in the high bay area where it is planned to locate the combustor. The overall height of the test combustor design submitted in the proposal is 65 feet. The possibility of digging a pit below the combustor was discussed, but its width would be limited by large existing footings beneath the floor. It was generally agreed that it would be preferable to reduce the height of the combustor. This appears to be feasible by using a folded design for the convection tube bundle, and B&W was requested to use this design approach and inform Westinghouse and ORNL if serious design problems arise.

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

E. C. Fox

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

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

12.1 AFBC Technology Support - Task 2

M. Siman-Tov and E. C. Fox

12.1.1 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.

12.1.2 Status summary

There was no activity under this task during this month.

12.2 4 × 4 Cold Flow Model - Task 3

M. E. Lackey and R. S. Holcomb

12.2.1 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 × 4 cold flow model for slumping and refluidization tests and conducting bed slumping tests.

12.2.2 Status summary

The 1/4 scale test report by M. E. Lackey, entitled "Cold Slumping Characteristics of a Fluidized Bed," has been approved by TVA and is being prepared for publication.

12.3 AFBC Modeling and Simulation - Task 4a

J. W. Wells, M. H. Culver, A. A. Khan, and R. P. Krishnan

12.3.1 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.

12.3.2 Status summary

The sulfur capture subcode was added to the combined code. This involved incorporating the pore plugging grain model into a fluidized bed. A method for characterizing the active sorbent in the bed has been developed and incorporated into the combined code. This was necessary to avoid excessive run times. Preliminary sulfur capture results from this combined model are given and are currently being analyzed.

Work also continued on the freeboard modeling effort. Modifications have been made to the gas phase subcode to decrease the computer run time. Successful runs have been made and preliminary results are being analyzed.

In the upcoming month, sulfur capture will be incorporated into the freeboard model. At that point the freeboard model will be combined with the overall AFBC code.

Also during this month, separate meetings were held with C. Y. Wen of West Virginia University and M. Horio of Nagoya University (Japan). In these meetings freeboard modeling methods were discussed. The information obtained in these meetings will be very useful in the current freeboard modeling effort.

A meeting was held with TVA management on July 30. The status of the modeling project was presented and proposals for CY 1981 were presented and discussed.

Combined Model

During this month, the SO_2 capture subcode was added to the combined code. This involved incorporating the pore plugging grain model (see monthly report for May 1980) into a fluidized bed. The ability of a sorbent particle to capture limestone depends on the particle size, particle surface properties, time of exposure and concentration of SO_2 in the gas. In a fluidized bed a wide distribution of sorbent particle sizes exists with a wide residence time distribution for each particle size exposed to a spacial distribution of SO_2 concentration in the bed. If a computer code were developed to consider all of these factors, the running time of such a code would be excessive.

In order to develop a more reasonable code for SO_2 capture in a fluidized bed, a method for characterizing the active sorbent in the bed has been developed. This method is based on the following assumptions. First, it is assumed that the plugging time (tp) of a limestone particle can be approximated from the surface properties of the sorbent and average SO_2 surface concentration. Second, the assumption is made that a sorbent particle entering the bed can capture SO_2 only as long as the residence time is less than the pore plugging time. When the surface pores of a sorbent particle plugs, the surface porosity approaches zero. Third, the SO_2 is assumed to be released uniformly in the emulsion phase of the bed. Fourth, attrition in the bed is assumed not to affect the particles' ability to capture SO_2. Fifth, it is assumed that the dust formed by attrition is fully sulfated. Sixth, the active sorbent fraction is assumed to be characterized by a surface mean particle distribution and an average residence time. And seventh, since the solids in the bed are perfectly mixed (back-mix) and gas is in plug flow, the surface SO_2 concentration which the particle has been exposed to during its presence in the bed is the mean SO_2 concentration in the bed.

Based on these assumptions, equations were developed to characterize SO_2 capture in a fluidized bed. From the equation for local porosity (see monthly report for May 1980) the conversion of CaO at the surface can be found as,

$$X_{R_p} = \left(\frac{\varepsilon_c}{1 - \varepsilon_c}\right) \Bigg/ \left(Y\frac{V_{CASO_4}}{V_{CAO}} - 1\right) , \qquad (1)$$

where

X_{R_p} = conversion of calcium oxide to calcium sulfate at the particle surface (R_p), unitless,

ε_c = porosity of calcined limestone, unitless,

V_{CASO_4} = molar volume of pure calcium sulfate, 52.2 cm^3/gmole,

$V_{C\ O}$ = molar volume of pure calcium oxide, 16.9 cm^3/gmole,

Y = weight fraction of calcium oxide in calcine, unitless.

Based on this conversion, the reaction interface within a spherical grain can be found as

$$r_p^3 = [r_g\ (1 - X_{R_p})]^{1/3}\ , \tag{2}$$

where

r_p = radius of grain reaction interface at pore plugging, cm,
r_g = grain radius, cm.

From this the plugging time (tp) can be found by integrating the rate equation for the change of the grain reaction interface.

$$\frac{\partial r_p}{\partial_t} = -KV_{CAO}\ \frac{D_s C_{SO_2}^{sur}}{D_s + Kr(1 - r_p/r_g)}. \tag{3}$$

The final expression for the plugging time is

$$tp = \frac{\left[\frac{K}{D_s}\left(\frac{r_p^3 - r_g^3}{3r_g} - \frac{r_p^2 - r_g^2}{2}\right) - (r_p - r_g)\right]}{KC_{SO_2}^{sur}\ V_{CAO}}\ , \tag{4}$$

where

tp = plugging time, s,
$C_{SO_2}^{sur}$ = SO_2 concentration at radius R_p, gmole/cm^3,
K = chemical rate constant, cm/s,
D_s = diffusion coefficient through the calcium sulfate product layer, cm^2/s,
r_p = reaction interface radius within spherical grain, cm,
r_g = grain radius, cm.

This calculation is independent of particle radius (R_p) and, therefore, applies to all particles.

The above approximate plugging time can be used to calculate the fraction of the total bed inventory which was present in the bed for shorter time than the plugging time (active sorbent fraction). The assumption has been made that a feed sorbent particle entering the bed can capture SO_2 only as long as the particle's residence time is less than the approximate plugging time (tp). Based on the assumption of a back-mixed bed, the weight of active sorbent (W_{SB}^{ACT}) in the bed can be found as

$$W_{SB}^{ACT} = W_{LS} \sum_{R_{max}}^{R_{min}} p_B(R)\Delta R[1 - e^{tp/\tau(R)}] , \tag{5}$$

where

W_{LS} = total weight of sorbent in bed, grams,
$p_B(R)$ = sorbent bed particle size distribution for particle of radius R, cm^{-1} ,
t(R) = average residence time for a particle of radius R, s,
R_{min}, R_{max} = minimum and maximum particle radius in the bed, cm.

In the above expression, $p_B(R)$ and $\tau(R)$ were determined by the limestone-ash elutriation and attrition subcode.

The characteristic radius of the active sorbent fraction is found by evaluating the surface mean radius (R_{SB}^{ACT}) of the active fraction.

$$R_{SB}^{ACT} = \left\{ \sum_{R_{max}}^{Rmin} [x(R)/R] \right\}^{-1} , \tag{6}$$

where

x(R) = weight fraction of radius R particles in the active sorbent fraction and is given by

$$x(R) = p_B(R)\Delta R[1 - e^{-tp/\tau(R)}](W_{LS}/W_{SB}^{ACT}). \tag{7}$$

The active sorbent, described by the W_{SB}^{ACT} and R_{SB}^{ACT}, is distributed uniformly throughout the bed. The residence time distribution of the particles in the active sorbent fraction can be calculated as

$$E_{SB}^{ACT}(t) = (W_{LS}/W_{SB}^{ACT}) \left(\frac{1}{\tau_{LS}} e^{-t/\tau_{LS}}\right), \tag{8}$$

where τ_{LS} is the average overall sorbent residence time defined as

$$\tau_{LS} = W_{LS}/F_{LS} , \tag{9}$$

where

W_{LS} = weight of the sorbent, grams
F_{LS} = feed rate of sorbent, g/s,

The above equation represents a normalized distribution of the particle residence times in the active sorbent.

At this point a code could be developed to do a plug flow analysis of the gas side but again the computation time required would be excessive. In order to avoid this problem the average residence time of the average particle in the active fraction of the bed (t_{SB}^{ACT}) can be found as

$$\tau_{SB}^{ACT} = \int_{o}^{tp} tE_{SB}^{ACT}(t)dt \; . \tag{10}$$

Upon integration, this equation becomes

$$\tau_{SB}^{ACT} = \tau_{LS}(W_{LS}/W_{SB}^{ACT}) \left[1 - e^{-tp/\tau_{LS}} \left(1 + \frac{tp}{\tau_{LS}}\right)\right] . \tag{11}$$

Based on the active sorbent's average particle size and residence time, the average molar flux of SO_2 to an active sorbent particle can be found as

$$N_{SO2}^{AV} = D_e \left. \frac{dC_{SO2}}{dR} \right|_{R = R_{SB}^{ACT}} , \tag{12}$$

where

N_{SO2}^{AV} = average molar flux of SO_2 per particle of radius R_{SB}^{ACT}, gmole/s-cm^2,

D_e = effective diffusivity, cm^2/s,

$\frac{dC_{SO2}}{dR}$ = rate of change of concentration of SO_2 with respect to sorbent particle radius.

This quantity can be used to define an approximate overall reaction rate constant (k) as

$$k = \frac{N_{SO2}}{C_{SO_2}^{EMUL(AV)}} , \tag{13}$$

where

$C_{SO_2}^{EMUL}(AV)$ = average concentration, gmole/cm^3, through the bed,

and k is in units of cm/s.

Since the gas passing through the bed is in plug flow, the SO_2 concentration will vary through the bed. If the concentration profile of SO_2 is relatively flat over the majority of the bed height, then the local molar SO_2 flux to an active particle (N_{SO_2}) can be expressed as a function of height by

$$N_{SO_2} = kC_{SO_2}^{EMUL} , \quad (14)$$

where

k has been defined by Eq. 13,

$C_{SO_2}^{EMUL}$ = local SO_2 concentration in the emulsion phase, gmole cm^3.

The equations above have been used to develop a plug flow analysis of SO_2 capture in the bed (differential balances and flow diagrams will be given next month). The code initially assumes an SO_2 bulk concentration and calculates the characteristics of the active sorbent in the bed (tp, W_{SB}^{ACT}, R_{SB}^{ACT}, t_{SB}^{ACT}, $N_{SO_2}^{AV}$, and K) via Eqs. 4, 5, 6, 10, 12, and 13. The overall reaction rate constant, k, is then used to perform a differential plug from analysis of the gas passing through the bed. This results in an SO_2 concentration profile through the bed. The average of this profile is calculated as compared to the original average SO_2 concentration. If the change is significant, the characteristics of the active sorbent are calculated for the new bulk SO_2 concentration. This process is repeated until a specified tolerance is met. Typical input to the sulfur balance portion of the combined code is given in Table 12.1. Preliminary results from the code are given in Table 12.2. These results are currently being checked and analyzed.

During next month, the combined code will be tested at various conditions.

12.4 Analytical Support and Alternative Design Concepts Evaluation - Task 4b

C. S. Daw, W. K. Kahl, and E. C. Fox

12.4.1 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.

Table 12.1 Typical input parameters for the sulfur capture subcode in the combined code

Temperature, K	1117
Molar volume of $CaSO_4$, cm^3/gmole	52.2
Molar volume of CaO, cm^3/gmole	16.9
Pore diffusion coefficient, cm^2/s	0.075
Constriction factor	0.8
Tortuosity	1.5
Pososity of limestone	0.0
Porosity of calcined stone	0.52
Diffusion coefficient through product on grain, cm^2/s	4.0×10^{-9}
Grain radius, cm	1.0×10^{-5}
Surface reaction rate coefficient, cm/s	0.05

Table 12.2 Preliminary SO_2 capture results from the combined code

Weight of active fraction, g	341,737.1
Weight percent of bed	10.4
Surface mean radius of active sorbent, μm	602
Surface mean radius of sorbent in bed (active + inactive), μm	719
Sorbent plugging time, s (h)	4530 (1.26)
Average residence time of active fraction, s (h)	2580 (0.72)
Percent of sulfur in feed coal captued in bed	68.0
Concentration of SO_2 in gas leaving bed, ppm[a]	800
Bulk SO_2 concentration in bed, gmole/cm^3	7.447×10^{-9}

[a]Volume

12.4.2 Status summary

The draft report detailing the tradeoffs in design parameters and evaluating the economics of various design options is being prepared.

12.5 AFBC Bench Scale Facility - Task 5

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

12.5.1 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.

12.5.2 Status Summary

Activity during the month of July centered on fabrication and installation of the recycle system. The system includes a new cyclone separator in the fluidized bed exhaust line and a screw feeder to modulate the flow of cyclone solids back into the bed. A schematic diagram of the system is shown in Fig. 12.1.

Installation of the recycle system was about two-thirds complete at the end of July. Work is expected to be finished by mid-August; shakedown testing will begin at that time. The recycle solids feedrate will be calibrated as a function of screw feeder speed. The return leg of the recycle cyclone will not be insulated initially. This will allow the feeding of "cold" recycle solids back into the bed as Part I of the recycle test program.

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

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

12.6.1 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.

12.6.2 Status summary

The final report for Task 6, "State-of-the-Art of Pressurized Fluidized Bed Combustion Systems," is in the process of being published as an ORNL Technical Memorandum.

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[a]Consultant.

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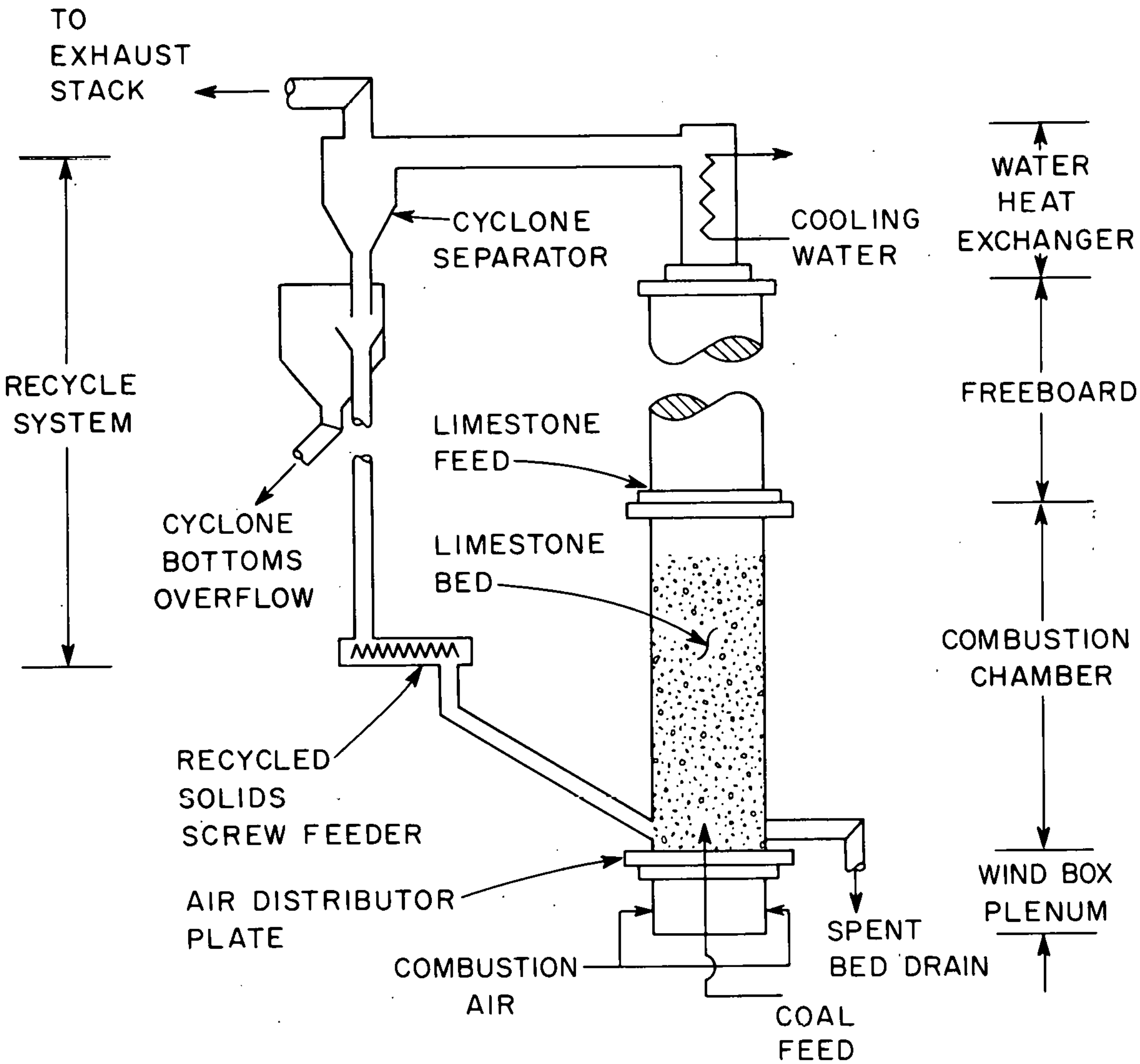

Fig. 12.1. AFBC bench scale combustor with recycle capability.

12.7 Materials Support for TVA Pilot and Demonstration AFBC Plants — Task 9

T. G. Godfrey, P. L. Rittenhouse, J. H. DeVan,
M. D. Allen, and R. A. Bradley

12.7.1 Contract objective

The objective of this task is to provide TVA technical assistance in the materials area as needed. The principal focus of the work is the area of in-bed heat exchanger tubes and hangers, air distributors, side walls, coal feed lines and nozzles, spent bed removal hardware, and cyclones for separating elutriated materials. Two areas of this task have been and/or continue to be active. The first is the review of recommendations for the materials of construction for the pilot and demonstration plants as made to TVA in proposals, contracts, and vendor designs. The second area involves the metallographic analysis of an array of alloys exposed in an AFBC located in Leatherhead, England, and is part of a joint TVA-EPRI materials program.

12.7.2 Status summary

Reviewer comments are being incorporated into the draft version of the technical assessment of issues related to candidate structural alloys for AFBC.

The TVA project manager made no requests for special design or document reviews during this reporting period.

Only minor effort was devoted to the examination of samples from the two TVA-EPRI Leatherhead 1000-h tests.

12.8 Coal Feed Tests - Task 11

C. S. Daw, J. F. Thomas, and V. R. Brantley

12.8.1 Objective

The objective of this task is to investigate experimentally 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.

12.8.2 Status summary

After discussing our current test results with TVA, we have decided not to run the low feedrate conditions in the coal-limestone test series. Instead, we will begin testing with pre-mixed coal and limestone as soon as we receive official authorization from TVA.

The plan for pre-mixed testing is shown in Table 12.3. The objectives are:

- to find the minimum limestone content which will prevent impact plugging of coal with >8% surface moisture (the minimum limestone-coal ratio tested so far has been 1/4);
- to determine the improvement in handling properties (e.g., reduction in bin bridging, etc.) resulting from pre-mixing dry limestone with wet coal;
- to observe the conveying differences between pre-mixed and in-line mixed coal and limestone.

Based on qualitative observations made during the previous tests, we expect wet coal-limestone mixtures to be considerably easier to handle than wet coal by itself. If pre-mixing reduces the need for coal drying, the benefits to TVA could be substantial.

After analyzing the coal-limestone pressure drop data collected in the last series, we have reached these additional conclusions:

- Coal-limestone mixtures begin to salt out in the horizontal line when conveying air velocity approaches 16.8 m/s (55 ft/s).
- A saltation-like phenomenon also occurs in the vertical 90° long radius bend and straight vertical run at about 16.8 m/s.
- When there is no saltation, the pressure drop ratio (i.e., the pressure drop when conveying coal and limestone divided by the air only pressure drop) is only a function of the solids loading (the total solids flow rate divided by the air flow rate). The relationship is linear and appears to be the same as it is for coal only flow.

Applying the last conclusion above, we will probably be able to develop a "universal" correlation for predicting pressure drop in conveying coal, limestone, or coal-limestone mixtures. This should be a useful design tool.

Table 12.3 Coal feed testing — phase II

Proposed pre-mixed coal-limestone tests[a]

Coal surface moisture (%)	Limestone size	Limestone/coal ratio
10	3 mesh x 0	0.05
		0.15
		0.25
10	3 mesh x 11 mesh	0.05
		0.15
		0.25
12	3 mesh x 0	0.05
		0.15
		0.25
12	3 mesh x 11 mesh	0.05
		0.15
		0.25
Saturated	3 mesh x 0	0.05
		0.15
		0.25
Saturated	3 mesh x 11 mesh	0.05
		0.15
		0.25

[a]Coal = 3 mesh × 0 Kentucky No. 9, limestone — 3 mesh × 0, 3 mesh x 11 mesh Fredonia, mixture feedrate — 450 kg/hr, air velocity — 31 m/s.

12.9 Materials Evaluation and Testing — Task 12

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

12.9.1 Contract objective

The objective of this task is to determine experimentally the envelope of operating conditions which will result in safe and reliable performance of in-bed materials. This goal is to be met with a three-phased program. The first phase involves thermodynamics calculations including all likely reactants and products from combinations of selected candidate alloys and in-bed environmental conditions. The second phase includes exposures of candidate materials in carefully controlled environments simulating the range of possible AFBC environments that could be envisioned in normal and off-normal operation. The third phase will be made up of eight 200-h exposures of materials in an actual fluidized bed. Operating conditions for these runs will progressively vary from normal to off-normal.

12.9.2 Status summary

To ensure that materials information generated by this activity is provided to TVA in a manner that will have a meaningful impact on the operation of the pilot plant facility, an accelerated schedule for all three subtasks has been adopted. As a result of this accelerated schedule, some aspects of all three subtasks are being carried out concurrently. A summary of the progress on each of the three subtasks follows.

Subtask I — Thermodynamic Calculations — This activity remains dormant pending accumulation of sufficient results of the other tasks to direct or suggest additional calculations.

Subtask II — Muffle Furnace Tests — Metallographic examination of samples from the first three experiments in the gas-metal reactor muffle furnace is continuing. Run conditions at a furnace temperature of 850°C were:

Run	Time (h)	P_{O_2} Pa	P_{O_2} Atm	P_{S_2} Pa	P_{S_2} Atm
1	150	10^{-6}	10^{-11}	5×10^{-7}	5×10^{-12}
2	150	10^{-11}	16^{-16}	0.5	5×10^{-5}
3	100	10^{-16}	10^{-21}	~ 10	$\sim 10^{-4}$

Observations thus far indicate that Run 2 was the most damaging, especially to the alloy 600 samples. Run 3 (very low oxygen, high sulfur) yielded a rather surprising result in that the alloy 600 samples were not totally destroyed. Significant amounts of subsurface sulfides, both chromium as grain-boundary inclusions and nickel as near-surface liquid, were present together with globular sulfides on the surface.

Depth of attack was about 250 μm for the sample exposed in the as-received "new" condition (mill-finish), but only about 25 μm for the AFBC-exposed sample with the sulfate deposit. Thus, it would appear that the oxide scale on the "used" sample was protective in this experiment whereas the oxygen activity in the gas was too low to develop significant oxide on the "new" alloy.

For the type 304 stainless steel samples in Run 3, sulfidation attack was less pronounced on both types of samples, but the "used" one appeared to be less affected than the "new" one, again showing that some protection is offered by preoxidation.

Sections of samples from Run 3 were subsequently air-oxidized at 850°C for 96 h in a muffle furnace to determine if a sulfidation-oxidation reaction would occur to yield deeper attack. This appeared to be the case for alloy 600 in both the "used" and "new" conditions where complex corrosion scales with high porosity were developed. For type 304 stainless steel, the air-oxidation effect was less pronounced since the extent of sulfidation was much less after Run 3 exposure.

Examination of all specimens from the muffle furnace experiments is continuing and electron microprobe analyses are being initiated to further identify the corrosion products. Subsequent test conditions will be determined after these examinations are completed.

Subtask III — In-Bed Tests — The first 200-h test of candidate structural and heat exchanger materials in the FluiDyne AFBC was completed during the month. For this test, the oxygen level in the flue was held at 1%, a condition that was thought to be marginally unsafe from a corrosion standpoint.

W. D. Goins (TVA) and T. G. Godfrey (ORNL) visited the site to observe the AFBC facility and to examine the tube samples upon their removal. Since no tubes had failed obviously during the test, it was decided that uncooled tubes would be removed first for inspection. Accordingly, Tubes C-8, C-6, B-7 (types 304 and 310 stainless steel and alloy 800, respectively), which are near neighbors, were removed along with A-9, another type 304 stainless steel. The tubes appeared to be in good condition with moderately thin calcium sulfate deposits ranging from tan to olive-brown over the in-bed portions. By use of a tubing bender, a 90° bend of about 4 cm radius was made near the middle of each 12-mm-diam tube to check for gross intergranular attack. No transverse cracks were detected on the tension side under low magnification observations or by dye-penetrant tests. Since these tube samples showed no evidence of damage, it was decided to leave the other tubes in place and to replace these four in kind for the next 200-h test. The four removed from the test will be sectioned and examined metallographically at ORNL.

The second 200-h test will be at an oxygen level of 1/2%, which, with the constant Ca/S of about 2, will produce a SO_2 level of about 3000 ppm in the flue gas. Since this second test should be under more aggressive conditions, the entire array of cooled and uncooled specimen tubes will be removed upon its termination and returned to ORNL for examination.

13. FOSSIL FUEL APPLICATIONS ASSESSMENTS

13.1 Coal Cogeneration/District Heating Plant Assessment

M. A. Karnitz and R. L. Graves

13.1.1 Contract objective

The objective of this work is to provide the Office of Coal Utilization 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 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.

13.1.2 Status summary

There is no change in status during the month of July. Presentations on the results of the assessment are scheduled for August. One presentation is to be made to NSP and one to DOE.

13.2 Fossil Fuel Applications Assessment

H. I. Bowers

13.2.1 Contract objective

The purpose of this task is to assess the technical and economic factors related to modifying the design of new power plants to provide thermal energy for district heating by using the cogeneration process. Most of the work will be accomplished under a subcontract with Burns and Roe.

13.2.2 Status summary

A proposal has been received and evaluated, and all necessary approvals required by UCCND Purchasing have been obtained. The subcontract papers have been sent to Burns and Roe, and we expect to receive the signed subcontract in early August.

13.3 Comparative Assessment of Options for New Industrial Boilers Relative to Air Emission Regulations for the Morgantown Energy Technology Center

O. H. Klepper

13.3.1 Contract objective

The purpose of this work is to define the technologies required to meet the range of allowable emissions for new industrial boilers, the relative merits of these technologies, and to identify needed research and development. Industrial boiler capital costs developed in this program will be incorporated in the CONCEPT computer program for use in this and in future studies.

13.3.2 Status summary

Subtask A - Selection of emission standards and associated boiler criteria. The range of boiler emission levels that is to be investigated was revised to reflect comments received from METC as well as information obtained at the meeting of the National Air Pollution Control Technologies Advisory Committee, July 9 and 10.

Subtask B - Steam supply system characterization. In accordance with METC comments, dry limestone injection has been included in the investigation as one of the SO_2 control options for industrial boilers.

Subtask C - Engineering and economic evaluation. Cost information on industrial steam supply systems is being assembled from seven independent sources in order to develop consistent baseline capital and O/M costs. A revision of an existing regional industrial coal cost data base (including projections of future coal transport costs) was begun in order to develop fuel costs needed for later economic analyses.

General - Candidate Architect-Engineer firms have been approached to discuss a contract for developing industrial steam supply designs and costs needed to characterize alternative steam supply systems.

14. PERFORMANCE ASSURANCE SYSTEM SUPPORT FOR FOSSIL ENERGY PROJECTS

T. W. Pickel, H. A. Mitchell, B. R. Everman,
H. A. Nelms, L. Parsly, A. N. Smith

Performance assurance support is being provided for major DOE-Fossil Energy projects. This support covers the areas of reliability, system safety, and quality assurance. Current activities include support for the liquefaction projects being managed by DOE and a failure modes and effects analysis.

14.1 Objective

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

14.2 Status Summary

A status report of performance assurance activities was prepared at the request of DOE Headquarters. Status of current tasks, proposed tasks, and budgets were discussed. The current effort includes assistance to DOE-Fossil Energy, to DOE-ORO in major liquefaction projects, and in performance of a generic failure modes and effects analysis (FMEA).

Work on the FMEA has been completed, and a draft report was circulated internally for comments during the month. The final draft will be transmitted to DOE-Fossil Energy during the next reporting period.

Several proposed tasks were discussed including additional failure modes analysis, data collection and analysis, development of systems logic diagrams, and trade-off studies to assist in demonstration plant decisions.

15. INTERNATIONAL ENERGY TECHNOLOGY ASSESSMENT

The Oak Ridge National Laboratory is supporting the Lawrence Livermore Laboratory in a broad program funded by the DOE Office of International Affairs. The program is designed to alert DOE management to foreign energy-related technologies of potential interest to the United States.

ORNL has responsibility for the following three areas of work: coal liquefaction including gasifier development status, coal liquefaction materials, and atmospheric fluidized bed combustion. These efforts are closely coordinated with similar activities underway at Argonne National Laboratory in the areas of pressurized fluidized bed combustion and coal gasification materials.

15.1 Liquefaction Technology (Including Gasifier Development Status)

W. C. Ulrich

15.1.1 Objective

Broad objectives of the IETA program are to report foreign technology developments of current interest and to identify and assess those developments of significance to U.S. programs. Detailed assessments in selected areas will also be provided. A specific objective of the ORNL effort is to provide a substantive technical review of the status of foreign technology for the liquefaction of coal, including gasifier development status.

15.1.2 Status summary

Work continued on gathering information concerning foreign coal liquefaction technology. Emphasis is currently focused on direct liquefaction processes and gasifier developments.

Dr. John M. Holmes, who is on assignment from ORNL to the International Energy Agency/Economic Assessment Service in London, England was interviewed during a visit he made to ORNL on July 25. Dr. Holmes recently completed a trip to the Federal Republic of Germany where he visited several sites at which coal gasification projects are being carried out. These included Hamburg-Harburg (Shell-Koppers), Oberhausen-Holten (Texaco), and Saarbrucken (Saarberg-Otto). Copies of Dr. Holmes' trip reports containing information describing project objectives, process conditions, current states of development, future plans, projected economics, etc. were reviewed and discussed.

15.2 Coal Liquefaction Materials

A. R. Olsen and G. M. Caton

15.2.1 Objectives

The objectives of this phase of the assessment program are to identify materials research and development programs in foreign countries in support of liquefaction processes and to assess the programs and findings in terms of their status, applicability to U.S. coal liquefaction development and commercialization programs, and the potential value of possible cooperative agreements.

15.2.2 Status summary

Compilation of available information by country has been started even though information gathering is continuing. In an effort to expand the limited available information on foreign efforts to define appropriate materials for coal liquefaction processes and to correlate all available information with the process development activities, arrangements are being made to obtain the assistance of Gilbert/Commonwealth. Information exchange has been initiated with Argonne National Laboratory as well. Detailed information on materials research and development and operational experience is very difficult to obtain. Although some information is being gleaned from very recent literature and trip reports, in general it appears that such information is often considered as proprietary by the process developers.

15.3 International Survey of Atmospheric Fluidized Bed Combustion Technology

R. P. Krishnan, E. C. Fox, and K. O. Johnsson

15.3.1 Objective

The objective of this program is to provide an international assessment of the status of atmospheric fluidized bed combustion (AFBC) The assessment will describe the applications, critical problem areas, and the current developmental projects that address these problem areas in AFBC technology in foreign countries.

15.3.2 Scope

This assessment is part of a broader program designed by the DOE Office of International Affairs (IA) to alert DOE management to foreign energy-related technologies of potential value to the United States. ORNL and Argonne National Laboratory (ANL) have been assigned the area of fluidized bed combustion. ORNL will survey AFBC, and ANL will survey pressurized fluidized bed combustion (PFBC).

15.3.3 Status Summary

The organizations involved in AFBC development in foreign countries were identified and listed in the April-June 1980 quarterly report. The list includes a description of the facilities and the objectives and current status of the programs. The responses thus far to the questionnaires do not contain detailed information relating to R&D programs in specific problem areas, and therefore information is being requested about these programs from organizations most active in AFBC. The possible problem areas of major concern are:

- in-bed and above bed heat transfer characteristics
- load following and control
- solids handling
- materials (corrosion/erosion data)
- particulate collection

Engineering and operating data in these areas are, in the opinion of U. S. boiler manufacturers, the key to the successful design of commercial-scale AFBC plants. Thus far, we have not been able to obtain detailed information in these areas. In addition to the letter requests for information mentioned above, literature searching is being continued and personal contacts are being made both here and abroad.

16. PFBC SYSTEMS ANALYSIS

R. L. Graves

16.1 Objectives

The engineering systems analysis of PFBC power systems is intended to provide data, analysis, and supporting logic for the expanding PFBC program in DOE in order to achieve rapid commercialization of this technology. The analyses will be useful in evaluating the "evolutionary" approach to PFBC development as well as the "advanced" versions under consideration by DOE. Studies quantifying the trade-offs between cost, emission control, and plant efficiency are to be performed for various levels of PFBC development. Conceptual designs performed under subcontract will provide cost data for sensitivity studies.

16.2 Status summary

This is the first reporting period for this task. A fundamental tool to be used throughout the study, the heat/mass balance model for the PFBC furnace, has been completed. The model is quite detailed and can account for pneumatic transport air requirements, coal drying, cyclone secondary air flows, gas turbine, and compressor. Refinements to the model will include the incorporation of sulfur capture, NO_x release, and combustor efficiency correlations. The combustor-gas turbine model is currently being coupled to a steam power plant model. The basic steam model was provided by TVA and is patterned after an existing fossil power plant in their system. The cycle is subcritical at 2400 psi with one reheat. The steam model is also very detailed and incorporates valve stem and seal losses, pressure drops, and boiler feed pump drive steam turbines.

The overall model will be used to predict performance and emissions, and to determine requirements for heat exchangers for PFBCs of different operating pressures and temperatures.

Data has been received from the Elliot Company on the turbo-expander which they recommend for use in a PFBC system. The turbo expanders are designed to operate on particle laden gases more reliably than conventional gas turbines, but sacrifice efficiency for the sake of durability. The pressure ratio for the expander was recommended as 5 for the two-stage machine. The machine can handle about 440 lb/s of gas which means that 4-5 turbine strings would be needed for an 800 MW(e) plant. This is about the same gas handling capability as a 40 MW(e) industrial gas turbine.

A survey of specific costs ($\$/ft^2$) of heat exchangers has been finished. Air-preheater, economizer, and boiler surface area costs were obtained from various plant designs and industrial contacts. These costs will be used in evaluating how changes in combustor conditions effect equipment costs.

Paul Bauer and Win Bezella of Argonne National Laboratory visited ORNL to discuss how the results of the ORNL program could be used in the ANL study of various advanced power plants. The ANL approach to sensitivities studies for the PFBC is similar to the ORNL program. The ORNL results can apparently be utilized in the market acceptance and penetration studies which are part of the ANL program.

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